Plagues and Players: an environmental and scientific history of Australia's southern locusts

by

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Candidate's declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university. To the best of the author's knowledge, it contains no material previously published or written by another person, except where due reference is made in the text.

Edward Deveson   Date: 30 June 2017

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I thank my employer, the Australian Plague Locust Commission (APLC) and its Director, Chris Adriaansen, who has fully supported my investigations into the history of locust outbreaks. I have had the advantage of ready access to a wealth of scientific publications on locusts and to the valuable historical documents in the APLC library and archive, as well as a long time to consider their content. Other staff members have accepted my reading countless old files and newspaper articles, mostly with good humour. Many current and former staff members, including James Woodman, Rob Graham, Noel Green, Kellie Arnall, John Nolan, Walter Spratt, Peter Spurgin, Ian Wright, Laury McCulloch and Gordon Hooper shared their ideas and institutional recollections.

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This thesis is dedicated to Ken Key, who produced the first historical reconstruction of the regional and seasonal incidence of locust plagues in Australia in 1938. With very limited sources then available, he achieved in his first two years in Australia a detailed and accurate history that I have been able to confirm and extend.

Abstract

This thesis traces the changing course of locust and grasshopper outbreaks in southern Australia and relates them to environmental changes. It also examines the creation and use of scientific knowledge about locusts over more than a century of research. Together, these historical investigations show how the insects' responses to environmental change influenced the course of ecological and agricultural science.

Digitised newspaper records of locust occurrence allow a more complete reconstruction of historic plagues and a new interpretation of the species involved and the environmental correlates of their changing incidence. They also provide a different view of the scientific players who investigated locusts in Australia. These sources are complemented by the writings of many entomologists about locust outbreaks and ecologies from the 1840s to the 1970s. The popular and scientific sources reveal the complexity of ecological ideas, technologies and institutional settings, framed by the common material context of environmental change. This is a history of entomological, ecological and public agricultural science as well as an analysis of the environments in which the outbreaks developed.

European settlers encountered grasshoppers and locusts soon after establishing pastoral and agricultural land use. Swarming populations developed patterns of occurrence that were observed by farmers and naturalists, and there is evidence that their incidence increased during the nineteenth century. Two species, *Austroicetes cruciata* and *Chortoicetes terminifera*, developed frequent outbreak populations on the southern grasslands, making them significant agricultural pests, but they responded differently to changes of climate, landscape and land use. The former swarmed almost annually soon after livestock altered grassland ecosystems within its range, but it declined during the twentieth century. The latter first swarmed across the southern grasslands in the 1870s, but has since maintained irregular outbreak populations through migratory exchanges.

They are taxonomically related native locusts with a similar appearance but distinct ecologies. Untangling their identities was historically marked by scientific confusion. However, the two species can sometimes be distinguished in newspaper reports by diagnostic morphological features, and can often be separated by differences in their seasonal occurrence, abundance, phenology and behaviour.

This thesis argues that the fundamental changes to grassy ecosystems resulting from the rapid expansion of the pastoral industry favoured the development of swarming populations of *both* Australian species. Evidence comes from early Aboriginal comments, thousands of newspaper and official reports, climatic sequences and the nature of landscape changes, as well as the subsequent contraction in outbreak extent and frequency when land use and land cover stabilised in the second half of the twentieth century.

The writings of many investigators reveal overlapping trends in ecological and technological investigations, and place each player within their scientific era. These are examined in the context of international developments and the broader public discourse about locusts and the importance and relevance of science. In this long relationship of feedbacks, the materiality of the insects allowed scientists to discern their ecologies. Science directed government policy on how to respond and governments sponsored *more* science in managing the politics of successive agricultural crises.

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Abbreviations

AAC – Australian Agricultural Council

ALRC – Anti-Locust Research Centre

APLC – Australian Plague Locust Commission

BHC – Benzene hexachloride

COPR – Centre for Overseas Pest Research

CSEC – Commonwealth and States Entomology Committee

CSIR – Council for Scientific and Industrial Research

CSIRO – Commonwealth Scientific and Industrial Research Organisation

DLIS – Desert Locust Forecasting Service (ALRC)

NSW – New South Wales

OC – Organochloride

OP – Organophosphate

PP – Pastures Protection (NSW agricultural extension) Boards

RAAF – Royal Australian Air Force

SCA – Standing Committee on Agriculture

WA – Western Australia

Glossary

adult — a fully winged, mature locust capable of breeding and migrating

band — dense aggregation of nymphs, usually moving forward together

diapause — period of dormancy induced in anticipation of unfavourable environmental conditions

egg bed — an area of soil containing many egg pods (several hundred per square metre)

fledge — final nymphal moult to a soft-bodied adult incapable of long-distance flight

gregarious — behaviour of mutual attraction and coordinated movement

instar — discrete stages of nymphal development each separated by a moult

laying — female locusts depositing clutches of 20–60 eggs into the ground in froth-lined egg pods

nymph — juvenile wingless locust, often referred to as the hopper stage

quiescence — period of dormancy induced directly by environmental conditions

swarm — dense aggregation of adults, milling at the same spot or flying closely together

the grasshopper — *Austroicetes cruciata*

the locust — *Chortoicetes terminifera*

Preface — 'Locust plague: Armageddon, end of days or climate change disaster?'

A swarm of the Australian plague locusts laying eggs at Murrami, near Leeton, New South Wales, December 2008 (photograph, Reg Eade, NSW Local Land Services).

There is always a place for a locust plague in international news. Reports tap a long history of apocalyptic metaphors. In drawing attention to a recent resurgence of locusts in Argentina, described as the worst outbreak for sixty years, the sensational online headline above elicits both deep cultural associations and some new fears for the future.[1] Rural Australia also experiences irregular locust plagues and they generate a level of media hysteria and a particular genre of public statements by agricultural authorities.

During autumn 2010 locusts swarmed throughout the agricultural districts of New South Wales (NSW), South Australia and Victoria. They crowded together at hundreds of locations to lay millions of eggs in tightly packed pods on farm fields, roadways and pastures. This dramatic population

[1] Jess McHugh, *International Business Times*, 26 January 2016 (online), http://www.ibtimes.com/argentina-locust-plague-armageddon-end-days-or-climate-change-disaster-2280092, viewed 1 February 2016.

explosion of the Australian plague locust, *Chortoicetes terminifera* (Walker), followed the familiar cycle of increase over several generations. After widespread heavy inland rainfall during November 2009 – February 2010, a summer generation was established in western Queensland and NSW. The development of an intense La Niña phase of the El Niño-Southern Oscillation in March brought further heavy rainfall, and with it another successful generation of nymphs that, on becoming winged adults, migrated southwards in autumn. The sequence was similar to previous plagues in 1999–2000 and 1973–1974, also significant La Niña periods.

Reports from large horticultural and cereal enterprises of the arriving swarms causing million-dollar losses to emerging crops showed the scale of the damage locusts could cause and raised fears of major agricultural losses when the next generation emerged in spring. The state agriculture departments were understandably anxious about what would happen and, in the climate of tight budgetary constraint, set to convincing their governments that the looming crisis required emergency funding. In June, the South Australian government 'declared war' on the locusts and, with a quarter of its agricultural production estimated to be under threat, committed funds for their control.[2] NSW and Victoria joined the 'battle', also appropriating large budgets for the spring 'campaigns'. Most of the money would be to supply landholders with pesticide, but each state also planned to conduct aerial spraying. The federal agriculture department, through the Australian Plague Locust Commission (APLC), got involved in planning a coordinated response that included both locust control and control of a unified public relations message for the media.

In the lead-up to spring 2010, official statements drew comparisons with previous plagues. For South Australia it was 'the most serious plague threat in forty years', although the last 'plague', where agricultural regions across several states were affected by swarms, had been in 2000. NSW was more seasoned, having had to deal with big infestations in the intervening years 2004 and 2008, but still declared it the 'worst plague locust outbreak for thirty years'.[3] Although swarms had also entered Victoria in 2000, they had not spread so far into its territory for much longer. However, the corporate memory lost sight of the mighty 1970s and 1950s plagues, when swarms had come close to Melbourne. Instead, a parallel was drawn way back to the 1930s, with parts of the state facing their 'worst infestation for some seventy-five years'.[4] Reference to that legendary event made this a 'once-

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[2] *News Release, South Australian Minister for Agriculture, Food and Fisheries, 30 June 2010, '*The South Australian Government has declared war on locusts to combat the most serious plague threat in 40 years … The Government is investing $12.8 million to minimise the impact of locusts'.

[3] *NSW Minister for Primary Industries Media Release, 9 August 2010, '*The worst plague locust outbreak in at least 30 years'.

[4] *Media Release – Federal Minister for Agriculture, Fisheries and Forestry and Victorian Minister for Agriculture*, *21 September 2010*, 'This season could see some areas of Victoria facing their worst locust infestation for some 75 years'.

in-a-lifetime' plague.[5] Historical comparisons provided a dramatic context for the declared agricultural emergency and for justifying government action in this 'worst outbreak in a generation'.[6] The need for agriculture authorities to be seen to prepare and to have the situation under control is part of managing the problem. And the need to draw on memory to imagine what things could be like is one way humans deal with impending natural disasters.

Science played a background role in the locust control response during spring 2010. Those who made the decisions and public statements were informed by the agricultural bureaucracy and its public relations specialists. They were criticised for not being properly trained entomologists, but the response was based on long-accumulated technoscientific knowledge. Farmers, state government extension staff and the APLC carried out the control using insecticides and biopesticides. The war metaphor was taken up by all states and carried by the media. The 'battlelines were drawn' for a 'spring campaign' in the 'locust war' and the many aircraft 'on stand-by' added to the anticipation of 'an epic battle'.[7] The rhetoric and the response was familiar to anyone who had experienced or had read about previous locust plagues.

The appeal was to history to attest to the dire situation, that it was the worst for plague for however-many years. But the documentary history of plagues comes from scientists trying to understand, through their patterns and periodicity, how and why they happened. Such comparisons have always been part of trying to make sense of such irregular and distressing insect phenomena. In reality it didn't matter as there was no objective way to substantiate these dramatic claims made for effect — both convenient and captivating by invoking events 'beyond living memory'. After all, the individual experience and recollection of locust swarms is local, subjective, transitory and, for much of the population, vicarious. As in many past plagues, however, the media also made room for more dispassionate and humorous views of the machinations of official responses.[8]

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[5] Wendy Pugh, *Bloomberg Business*, 11 June 2010 (online), 'The advice of leading scientists indicates the scale of the coming spring's outbreak could be as bad as we experienced in 1973 and 1974 when locusts swarmed through much of Victoria' state premier John Brumby said today in a statement. 'Prior to that, the last outbreak of this scale was in 1934, so we could be facing a once-in-a-lifetime locust plague with locusts swarming right across the state'.

[6] *The Sydney Morning Herald*, 20 September 2010 (online), Ellie Harvey, Locusts munch their way across state's crops in the 'the worst outbreak in a generation'.

[7] *The Australian*, 22 October 2010, 'Epic Battle Looms as Locusts Stir'.

[8] Andrew Marlton, cartoonist 'First Dog on the Moon', appeared in Crikey Online News on 29 September 2010, https://firstdogonthemoon.com.au/cartoons/2010/09/29/grasshoppers-revealed/

Andrew Marlton (*First Dog on the Moon*), 'Grasshoppers Revealed', *Crikey Online News*, 29 September 2010.

Considering this history of locusts in Australia raises many questions. Have all plagues been the same and in the same places? Are they getting worse or were they much worse in the forgotten past? Were they all even caused by the same insect? These questions also have a history and relevance to an uncertain future.

My interest in the history of locust outbreaks grew out of a professional role in the APLC as an interpreter of computer maps of locust distribution, meteorology and habitat information in an attempt to predict likely population developments. When I started to investigate events beyond the better known twentieth-century locust plagues, I knew there had been plagues on and off since the 1840s. I also knew that another species that no longer causes much concern — the small plague grasshopper *Austroicetes cruciata* (Saussure) — had been a serious agricultural pest in the first half of the twentieth century and was considered worse than *C. terminifera* in Western Australia and South Australia.

Estimating where locusts are likely to occur in large numbers necessarily involves looking at records of past events to identify regions that are prone to infestations. The need to find out what was known about their biology led me to read past as well as current scientific publications about them and, in doing so, to find a potted history of locust science. Like other histories of scientific ideas, some ecological constructs went through phases of incredulity, acceptance, orthodoxy, challenge and then replacement. While an idea held currency it seemed to frame further research questions around it, making challenge seem irrelevant. But challenging established ideas is the way that science moves forward, as well as one way that scientists attempt to gain notoriety. The scientific engagement with locusts in Australia has also been populated by generations of entomologists working to accumulate knowledge for a living, for a career and consequently for their employers. The alliance of science and government, like that of farmers and government, has had its ups and downs, but since the late nineteenth century has yielded many utilitarian advantages.

My role in the APLC as a geographer rather than an entomologist placed me as both a scientific insider and marginal to scientific activities in a small institution.[9] In producing forecasts, official reports and map inscriptions of locust events, I have interpreted and represented scientific knowledge about locust ecology and history.[10] Therefore, my analysis of past locust events and locust science, making use of both official and newspaper sources, is what Anna Bramwell has labelled an 'involved history', written by a 'member' within a discipline involved in the creation of that history, which brings an inherent risk of bias and reflective blind spots.[11]

With this acknowledgement then, I tell the stories of two species that were conflated in the term 'locust' and have featured prominently in Australian agricultural history. These are told through the coincident and parallel history of scientific investigations about them. I attempt this on historians' terms of faithful and equitable treatment of sources, and an acceptance that the past was not the same as the present but that its actors were people much like ourselves. Science is a collective, cumulative

[9] I follow Stephen Dovers's broad definition of institutions as formal or informal 'persistent, predictable arrangements, laws, processes or customs serving to structure political, social, cultural or economic transactions or relationships in society, which allow organised collective efforts around common concerns', see S. Dovers, *Environment and Sustainability Policy,* (Annandale NSW, Federation Press, 2000), p. 12.

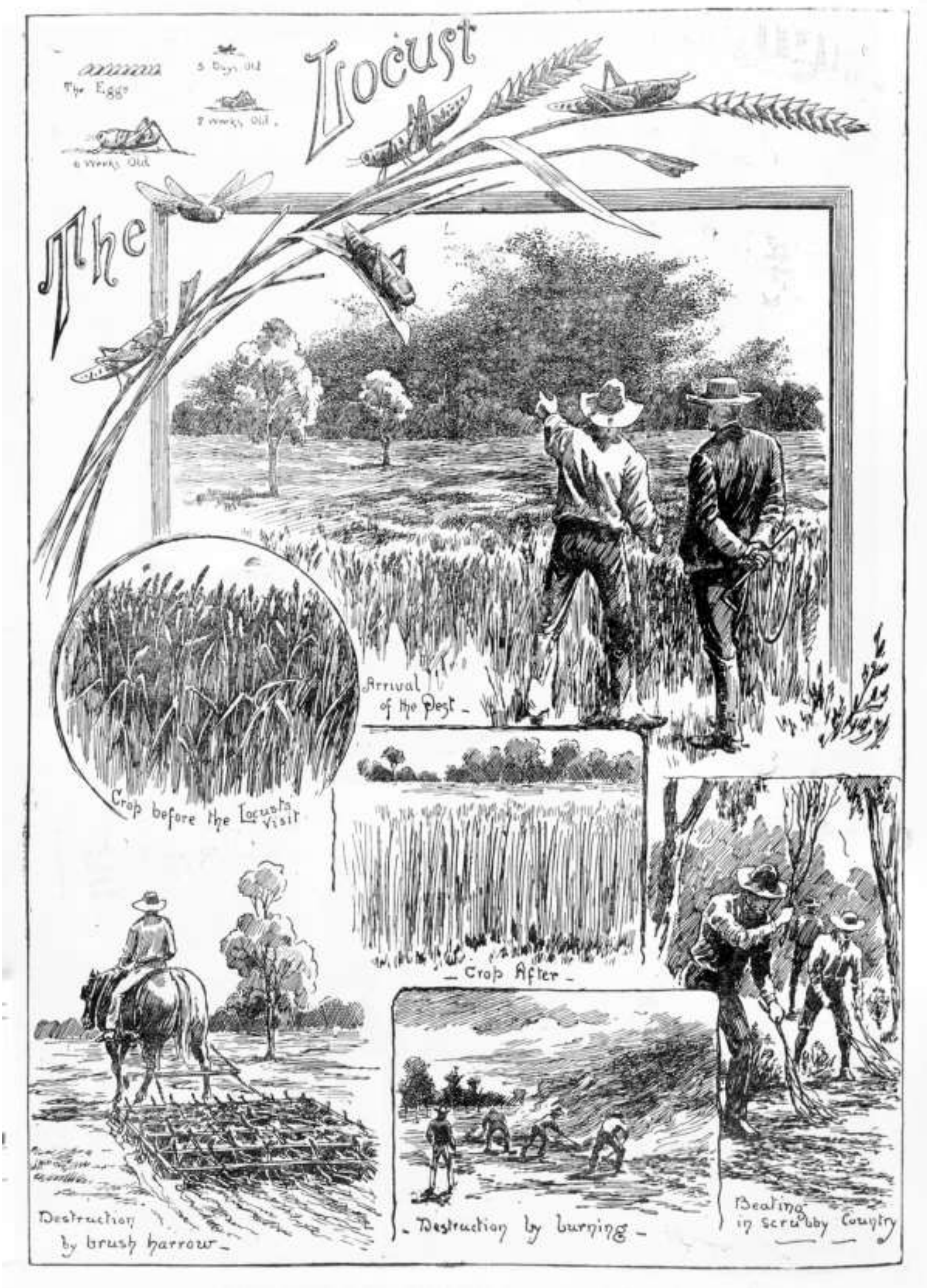
[10] Since 2005 I have written monthly APLC Locust Bulletins and situation summaries in annual reports.

[11] Anna Bramwell, *Ecology in the Twentieth Century: a History*, (New Haven and London, Yale University Press, 1996), p. 13.

enterprise, but not as ruthlessly objective as is often thought. Scientists are influenced by the ideas circulating within their institutions and wider society.

The historical context of locust outbreaks is as long as European settlement in Australia and many practical and scientific issues have been confronted before. There have been many plagues and many scientific players have given them voice, often through familiar concerns but also with some surprising findings and novel methods. These dual histories are run together in ways that help explain the insect outbreaks and enliven the complex experiences of those involved with them.

I end this exploration of the historical relationship between science, government and environmental management in 1976, with the creation of the organisation in which I am employed.



Illustrated Australian News, 'The Raid on Locusts' 1 December 1890, p. 14.

Time marches backwards

We were running our centenary out on the Downs
Rejoicing our pioneer deeds,
When the cursed grasshoppers hopped up and hopped in,
We'd have welcomed a few centipedes.
When the hoppers had finished their feasts in the fields
The country looked empty and black
We'd have thought that we'd not made much progress at all,
But slipped a whole hundred years back.

Weekly Times (Melbourne), 9 March 1940, p. 39.
Written during the Warwick (Queensland) centenary, after a locust plague on the Darling Downs described as the worst in known memory.

Chapter 1. Australia's southern locusts

Figure 1.1. Locust painting from the tomb of Horemhab, Thebes, Egypt, c. 1292 BCE.[1]

Revisiting past infestations and scientific investigations

Locusts have plagued agricultural societies throughout history, seemingly as one consequence of the Oedipal binds of reshaping the earth for human ends.[2] In adopting an agricultural lifestyle, humans were faced with a frequent and destructive competitor for their new food sources. The consequent historical response of organised and increasingly technological attempts to destroy locusts, escalated in line with the scale of agriculture. In a taxonomic coincidence, the locust species in this history belong to the acridid subfamily Oedipodinae; the name, from that of the protagonist of the ancient Greek tragedy whose ankles were pierced at birth, comes from the compound word meaning 'swollen foot'.[3]

While there have been locust species on all the continents where humans conduct agriculture, through time some increased, some disappeared and others mysteriously reappeared. The awesome sight of myriad swarms and their reputation for destruction have an almost mythic hold on the popular

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[1] Horemhab was the last pharaoh of the eighteenth dynasty. The public domain image is from The Yorck Project: *10.000 Meisterwerke der Malerei*, 2002. ISBN 3936122202 https://commons.wikimedia.org/wiki/File:Maler_der_Grabkammer_des_Horemhab_002.jpg, viewed 21 October 2016.

[2] Timothy Morton, 'The Oedipal logic of ecological awareness', *Environmental Humanities*, 1 (2012), 7–21. Morton uses the story of Oedipus in Sophocles' Theban plays to argue, among other things that, in giving birth to agriculture, humans began an inevitable march to the Anthropocene.

[3] Morton 2012, p. 15, Oedipus's ankles were nailed by his father Laius, who was attempting to avert the prophecy that his son would kill him; Francis Walker named the Oedipodinae in London in 1870, after a common European bandwing grasshopper.

imagination in many cultures.[4] News media still regularly report 'Biblical proportions' threatening crops and scientific treatments often emphasise the 'devastating' impacts of 'locusts'.[5] There are also many species called 'grasshoppers' that have similar impacts on agricultural livelihoods.

Not long after European settlers took their livestock onto the inland plains of Australia, they met with swarms of these acridid insects. Their potential to thwart agricultural development was realised when farms and gardens were being established. Australia's locust problems were not unique. Similar experiences and scientific responses occurred as agriculture expanded in other settler societies. During the 1870s in particular there were locust plagues on the temperate grasslands of the USA, South Africa and Argentina as well as Australia. Swarms even appeared on nearby New Caledonia and briefly in New Zealand.[6] During the 1890s, however, it was grasshoppers that swarmed over the grassy plains of Australia, Canada and the USA.[7]

This thesis traces the changing distributions and population fluctuations of two prominent Australian species, the taxonomically related *Chortoicetes terminifera* (Walker F. 1870) and *Austroicetes cruciata* (Saussure 1888), from the time of European settlement to the 1970s. They are labelled 'southern locusts' because that is where their agricultural impacts were felt and because other pest locusts in Australia have largely tropical distributions. They became agricultural 'pests' when large,

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[4] The association of locusts with the cradles of western agriculture, Mesopotamia and Egypt, left its well-known legacy in Jewish, Islamic and Christian religious texts. China has the longest continuous historical record of locust infestations, see L. C. Stige, K.-S. Chan, Z. Zhang, D. Frank and S. D. Stenseth, 'Thousand year-long Chinese time series reveals climatic forcing of decadal locust dynamics', *Proceedings of the National Academy of Science USA*, 104 (2009), 16188–16193; Inca and Mayan agriculturalists in Central America were also occasionally struck by locust plagues.

[5] Scientific articles about the current status of locusts often use such terms as 'devastating' to emphasise the social importance of their research, see V. Guttal, P. Romancsuk, S. J. Simpson, G. A. Sword and I. D. Cousin, 'Cannibalism Can Drive the Evolution of Behavioural Phase Polyphenism in Locusts', *Ecology Letters*, 15 (2012), 1158–1166, 'devastating vegetation and crops'; J. Buhl, G. A. Sword and F. J. Clissold, 'Group Structure in Locust Migratory Bands', *Behavioural Ecology and Sociobiology*, 65 (2011), 265–273, 'devastating manifestations'.

[6] *Logan Witness*, 27 Nov 1880, p. 4, one Nebraska farmer said locusts cease to come to districts brought under regular cultivation, probably constant tilling disturbs their breeding operations; *Colac Herald*, 5 January 1875, p. 6; Jeffrey A. Lockwood, *Locust: the Devastating Rise and Mysterious Disappearance of the Insect that shape the American Frontier*, (New York, Basic Books, 2004); *Locusta migratoria* destroyed early sugar plantations on several Pacific islands, the Philippines, New Caledonia and Fiji, see, *South Australian Register*, 10 January 1872, p. 4, grasshoppers threaten to stop cultivation of sugar in New Caledonia; *Sydney Morning Herald*, 4 April 1876, p. 3, locust damage in New Caledonia; *Adelaide Observer*, 24 April 1875, p. 9, Wairoa, New Zealand. Swarms first reported at Hawkes Bay in 1868; In Argentina, a plague commenced August 1873 and was repeated every year until 1877, see P. A. Conil, 'Etudes sur *Acridium paranense* Burm. ses variétés et plusieurs insectes qui le détruisent', *Periodico Zoologico*, Tomo III, (Cordoba, 1878); Locust plagues also occurred in Spain, Algeria, India, China and Russia during the 1870s.

[7] Grasshoppers increased on the Canadian Plains with the intensification of cattle production from the 1890s, see John Thistle, 'Accommodating Cattle: British Columbia's "Wars" with Grasshoppers and "Wild Horses"', *British Columbia Studies*, 160, (Winter 2008–09), 67–91; Grasshoppers were also a pest in California, see *Oakleigh Leader*, 27 February 1892, p. 2; *The Queenslander*, 3 October 1891, p. 644.

swarming populations damaged crops and pastures. This made them frequent subjects of scientific investigation, conducted largely under government sponsorship since the 1880s. Understanding how and why these irruptions occurred was seen as a necessary step in finding a solution, so their history has close parallels with developments in ecological as well as agricultural science.

Yet despite this frequent attention, the history of these species is marked by scientific confusion: confusion over their correct scientific names, over whether they were the same or different species and even which one was being observed. They look quite similar, although they have minor morphological differences including size and wing markings, and only after the 1930s were entomologists clear about differentiating the two species (Figure 1.3). In addition, there are very few surviving museum specimens collected before 1900.

New information on distributions has come from thousands of Australian newspaper reports, available as digitised text up to the mid-1950s, and from re-examining official government reports and scientific journal articles. Newspaper descriptions rarely give diagnostic details and often the only information is the time of occurrence. For this reason an alternative method of distinguishing between *C. terminifera* and *A. cruciata* is required. Although both species produce large swarming populations, their ecologies are quite distinct. The marked differences in their behaviour and seasonal occurrence provide a set of criteria to distinguish the species involved in many of the historical infestations that are only covered by newspaper reports. Accumulating this information from many reports gives a level of confidence to assigning a widespread swarming event to either species.

There are several reasons for attempting to disentangle which species was involved in the earlier described swarming events and for establishing their geographic extent. First, it is known that both species swarmed at various times, but the historical record of past plagues is based in some cases on fragmentary or assumed information. Identifying which species was involved in particular infestations, or if both or neither was involved, provides a potential test of established views of the history, duration and extent of locust 'plagues'. It also increases the ability to detect changes in the frequency or intensity of plagues over time and the assessment of any relationships with climatic events or European settlement patterns. And it allows an analysis of possible ecological reasons for population changes in different locations and times.

The term 'plague' has connotations of dire consequence and duration and has been used with different and sometimes vague meanings.[8] There is always a tendency to see current infestations in a dramatic

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[8] P. M. Symmons and D. E. Wright described a plague as an outbreak that resulted in migration and further breeding, see D. E. Wright, *The origin and development of the major plagues of the Australian plague locust, Chortoicetes terminifera (Walker)*, (PhD thesis, London University, 1983), Vol. 1, p. 46; P. M. Symmons,

light, with statements like 'the biggest plague for thirty years' being made at much shorter frequencies.[9] 'Plague' is reserved here for those periods when swarms affected numerous regions across several states.

Reconstruction of the population events has been set in the context of the environmental changes that were taking place as a result of the interaction of climatic variations and the activities of humans, primarily those resulting from pastoral and agricultural land use. The timing and distribution of the appearance of large populations were different because of their distinct ecologies, but both are native herbivores that were apparently favoured by alterations to grassy ecosystems. Both responded to habitat changes with an increased frequency and intensity of swarming, which highlights their capacity to adapt, often very rapidly, to changes in environmental conditions.

What makes these two species unique is their central place in Australian environmental, agricultural and scientific histories. Between them, *C. terminifera* and *A. cruciata* have attracted scientific attention almost continuously from the 1840s to the present century because of real and perceived threats they posed to agricultural production. This singular focus provides a continuity through more than a century of changing practices, places, ideas and scientists. Periods of intense scientific research often followed plagues and they span the eras of natural history and evolutionary theory, the professionalisation that accompanied the involvement of government and institutions and the rise of ecology as a theoretical and applied science. This is a history of ideas and practices, a largely untold theme running through Australian biological science, as much as of the locust outbreaks, and it reveals how many current issues have been encountered and considered before.

Previous histories of Australian locust plagues have only been written from a scientific perspective. Entomologists traced their occurrence in an effort to understand the causes of plagues and to support certain ideas about locust ecology. The locusts' place in the broader histories of society, environment, politics and agriculture were outside that perspective. So too was the history of locust science itself. We follow this long scientific history as it gradually and sometimes falteringly unravelled the biology and ecology of these insects, and mirrored the changing concepts and practices of biological science.

'Outbreak phenomena – The Australian plague locust', *Address to Australian Entomological Society, 9 May 1980,* (unpubl.), p. 2.

[9] D. E. Wright and P. M. Symmons, 'The development and control of the 1984 plague of the Australian plague locust, *Chortoicetes terminifera* (Walker)', *Crop Protection*, 6 (1987), 13–19, p. 13, describe the 1984 infestation as the 'biggest plague for 30 years'; D. E. Wright, 'Economic assessment of the actual and potential damage to crops caused by the 1984 locust plague in south-eastern Australia', *Journal of Environmental Management*, 23 (1986), 293–308, p. 293, the 1984 infestation is described as the biggest plague for 50 years.

The bridging of the scientific and environmental histories comes through their interaction. The historical accounts provide evidence of how the environment affected the locusts and reveal how the locusts changed the observers' environmental understanding. The institutional response was to employ a progression of technologies of 'control' on an increasing scale. Environmental changes thus influenced the practice and theory of 'ecological science' itself. Scientists made sense of the locusts, setting out what was and what could be known about them within the methodological and social framework of Western thought. What we know about the entomological scientists, how they thought and what they saw as the causes of the locust plagues, comes through their official writings. Several thematic trends in ecological ideas and technological methods emerge. Some were specific to Australia, others shared through international developments and exchanges.

This chapter introduces the principal non-human 'agents', the locust and the grasshopper, with a historical, material and ecological background of and a summary of current scientific knowledge about each species. It also outlines the methods and thematic scope of analysis, dealing with the amount, chronology and limitations of historical records, including popular accounts, official documents and scientific journals. The criteria developed to distinguish the species from descriptions in the early accounts are explained and justified. Particular emphasis is given to the newspaper record as the primary source for more than half of this locust history. Ancillary information comes from weather, flood, livestock, settlement and crop data. Synoptic climate indices from the El Niño–Southern Oscillation (ENSO) that are linked to Australian rainfall patterns provide further environmental context to the locust events.[10] The next chapter reviews several fields of history and science as a background to the interdisciplinary environmental history of locusts, highlighting some relevant contexts and contributions.

Chapters 3 to 10 tell a new Australian locust history from different perspectives. They are structured around the chronological sequence of plagues and scientific players who engaged with them, alternating between a focus on particular regions and particular individuals, to more widespread effects and responses across several regions. The roles of other environmental agents are explored within each chapter, most notably insectivorous birds, a concern for which remains prominent throughout the locust history. Newspaper sources furnish pictures of rural lifestyles, the landscape and its changes, and how ordinary people responded to the impacts of the swarms. The reciprocal human-locust interactions are also placed within the broader social, economic and political trends of the different periods.

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[10] ENSO Southern Oscillation Index (SOI) and El Niño values are based on recorded temperature differences across the tropical Pacific Ocean.

The thesis is an 'ecological history', a term once used for environmental histories.[11] It is ecological because it traces the history of this branch of biological science through the preoccupation of scientists with understanding the locusts' ecology. It is ecological because the distinct ecologies of the two species allow separate reconstructions from the noise of 'big data'.[12] And it is also ecological because these insects' interactions with all facets of their changing environments, physical, biotic and human, are central to the narrative.

Locusts: what's in a name?

The English word 'locust' comes from the Latin, used by Pliny the Elder in 77 CE for the destructive insect, but it was apparently a category broad enough to include lobsters.[13] Some Australian correspondents writing about the plague of locusts in the 1870s referred to a derivation from two Latin root words; 'locus' meaning place and 'ustus' scorched or burnt, thus describing their legendary effect on vegetation.[14] This etymology appeared first in John O. Westwood's 1839 *Introduction to the Modern Classification of Insects*.[15] Nineteenth century natural history books made regular use of various Biblical descriptions of locusts, such as that from *Joel* 2:3 of 'the noise of a flame of fire that devoureth the stubble'.[16] And those texts became an early point of identification for Australian settlers, wondering if the swarms they saw were indeed the same locusts. But here the sound of moving swarms was likened to that of the wind, water or a 'flock of sheep being rounded up'.[17]

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[11] Donald Worster, 'Transformations of the Earth: Toward an Agroecological Perspective in History', *The Journal of American History*, 76 (1990), 1087–1106, p. 1088; Tom Griffiths, 'Ecology and Empire: Towards an Australian History of the World', in eds. T. Griffiths and L. Robin, *Ecology and Empire*, (Melbourne, Melbourne University Press, 1997), pp. 1–16, p. 11.

[12] Hamish Maxwell-Stewart, 'Big Data and Australian History', *Australian Historical Studies*, 47 (3) (2016), 359–364.

[13] Some common derivations have 'locust' appearing from the Latin for 'lobster' because in the *Natural History*, Pliny also used 'locusta' to refer to crustaceans. Charlton Lewis and Charles Short, *A Latin Dictionary* (online) http://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.04.0059%3Aalphabetic+letter%3DL%3Aentry+group%3D29%3Aentry%3Dlocusta1 , viewed 1 August 2015.

[14] *The Australasian*, Melbourne, 22 March 1873, p. 8; *Evening Journal*, 27 March 1873, p. 3.

[15] J. O. Westwood, *An Introduction to the Modern Classification of Insects,* Volume 1, (London, Longman, Orne, Brown, Green and Longmans, 1839), pp. 438–439; William Kirby and William Spence do not refer to this etymology in their standard nineteenth-century entomology reference, *An Introduction to Entomology: or Elements of the Natural History of Insects*, 4 Volumes, (London, Longman, Rees, Orn, Brown & Green, 5th edition, 1828).

[16] *The Holy Bible*, Joel, Chapter 2, *v.3 and v.5.*

[17] *South Australian Register*, 30 December 1870, p. 5, describing 'immense swarms of grasshoppers' near Ashwell, north of Gawler.

The word became a metaphor. By 1546 it was a trope in England, comparing locusts' actions to anyone feeding off the fruits of others' labours.[18] Biblical references gave rise to strange chimeric images of locusts and in the 1620s 'locust' became a 'buzzword' of protestant anti-Catholic polemic to describe the spreading evil of Jesuit priests in Britain (Figure 1.2).[19] In the Australian colonial press, all sorts of middlemen and indigents were described as devouring 'locusts', including lawyers, officials, inspectors, politicians, miners, swagmen and the squatters, whose sheep were likened to locusts — as myriad swarms.

Figure 1.2. Detail from 'The Travels of Time: Loaden with Popish Trumperies : From Great Britaine to Rome', 1624. Locusts (with human heads and scorpion tails) and canker-worms can be seen alighting from the tree of time.[20]

Conversely, metaphors derived from the world of humans were later applied to the behaviour and abundance of locusts; words formerly reserved for disease or warfare such as 'outbreak', 'plague', 'recession', 'upsurge' or 'invasion'. Some of those terms were then specifically defined in a twentieth-century scientific locust nomenclature. Metaphors of war also came to dominate the ways people described the effects of locusts and attempts to control them. They became entrenched during World War I, when the movement and actions of enemy armies were likened to locusts and 'Hun

[18] *The Shorter Oxford English Dictionary, on Historical Principles,* ed. C. T. Onions, Third Edition, (Oxford, Clarendon Press, 1992), usage as 'a person of devouring or destructive tendencies' appeared in 1546 (William Cobbett, 1763–1835), 'those locusts called middlemen'.

[19] Malcolm Jones, 'The Common Weales Canker Wormes or the Locusts Both of Church, and States: Emblematic Identities for Late Jacobean Print', in ed. Michael C. W. Hunter, *Printed Images in Early Modern Britain: Essays in Interpretation*, (London, Ashgate Publishing, 2010), pp. 193–214, p. 209.

[20] From the Bodlean Library, original held at the Society of Antiquaries, London. Image courtesy of Malcolm Jones.

locusts' left French towns devastated.[21] Military metaphors remain in popular and official use for locust control today.

Many different acridid species have earned the ancient title of 'locusts', appearing in swarms and devouring entire harvests, but its meaning for taxonomic labelling has varied with time. During the nineteenth century 'locust' was often used to distinguish the major taxa within the Orthoptera: the acridids (suborder Caelifera) were locusts, while the katydids and crickets (suborder Ensifera) were grasshoppers. In the following century 'grasshopper' found common usage for all members of the family Acrididae, with 'locust' being reserved for the subset of species that produce dramatic massing populations. A feature of Australian historical experience was the interchangeable use of both terms for our species of interest. Perhaps because of their unprepossessing, diminutive appearance and the ongoing taxonomic confusion, the general expression 'the grasshopper problem' was adopted by the public and scientists alike.

The term 'locust' now applies to those species that exhibit changes between two distinct phenotypes and lifestyles; a lone 'solitarious' and a crowded, swarming 'gregarious' phase. This is most obvious in the different colouring and behaviour of 'classical' locusts of history — the desert locust and the migratory locust of Africa and Eurasia. This remarkable phenotypic plasticity is termed 'phase polyphenism' and appears to have arisen independently in several taxa within the Acrididae and also in other insects.[22] The term identifies the occurrence of different phenotypes in the same species, which generally develop in response to high population densities. In short, 'grasshopper + phase polyphenism = locust'. However, the expression of gregarious traits is often graded between species. Some display only one of the features, such as gregarious behaviour, while gregarious traits may develop in only one life stage, so the difference is often not clear-cut. Indeed, some species seen as harmless grasshoppers can express phase characters when in dense populations. More recently the tight definition has been relaxed to a category of 'grasshoppers and locusts', thus including these 'non-model locusts' or any swarming pest acridid.[23]

Locusts and grasshoppers

The difference between grasshoppers and locusts is amplified by the scale of their migrations as well as the phase changes associated with crowding. Species from both groups that become agricultural pests have the capacity to respond rapidly to changed environmental conditions by producing large

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[21] *The West Australian*, 11 September 1915, p. 6; *Northern Territory Times*, 18 March 1918, p. 4, refer to German armies.

[22] S. J. Simpson, G. A. Sword and N. Lo, 'Polyphenism in Insects', *Current Biology*, 21 (2011), R733–R749.

[23] A. Latchininsky, G. Sword, M. Sergeyev, M. M. Cigliano and M. Leqoc, 'Locusts and Grasshoppers: Behaviour, Ecology and Biogeography', *Psyche*, Vol. 2011, 578327, 4 pp.

swarming populations. Their populations also tend to bistability, being maintained at either high or low densities over multiple generations.[24] While these population fluxes are driven by climate and habitat conditions, they are also sensitive to habitat changes resulting from human land use.

'Model' locust species that switch from apparently harmless solitary grasshoppers to a visibly different, destructive gregarious form became the subject of taxonomic controversy and then of intense scientific enquiry after the 1920s, when Boris Uvarov and Jacobus Faure showed they were in fact different morphological forms of the same species.[25] The impressive transformation of the desert locust (*Schistocerca gregaria* Forskål) remains the signal case of phase polyphenism and one of the most intensively studied facets of insect biology.[26]

Some further brief points from history, science and geography can be made about the distinction between locusts and grasshoppers. Historically, the words have deep associative links to the pestilence of divine retribution on the one hand, and to the harmless summer fun of 'high-elbowed grigs' on the other.[27] People's anticipation of an agricultural crisis and official responses could vary depending on which label was being applied to a species. The long-distance mass migration of locusts also propagated the risk of crop damage over larger geographic areas and across borders, resulting in the involvement of states in organising collective control as a public good. Grasshopper infestations often become persistent but agricultural damage is generally more localised and predictable.

There have been many scientific careers and journals filled with studies of the differences and details, the processes and metrics of phase change, its demographic consequences and its wider ecological significance. Because of the practical link between locust biology and insecticide technology, they were merged in the 1950s in the specialised discipline of 'acridology', with its own dedicated

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[24] A. A. Berryman, 'The theory and classification of outbreaks', in eds. P. Barbosa and J. C. Schultz, *Insect Outbreaks*, (San Diego, Academic Press, 1987), pp. 3–33, proposes that outbreaking species can maintain equilibrium populations at both high and low densities. This propensity has been labelled bistability; for a theoretical discussion of the co-correlation of positive stochastic variables producing bistability in outbreaking species, see Y. Sharma, K. C. Abbott, P. S. Dutta and A. K. Gupta, 'Sochasticity and bistability in insect outbreak dynamics', *Theoretical Ecology*, 8 (2015), 163–174.

[25] Uvarov's ideas came from earlier field studies in Russia, while Faure worked in South Africa; B.P. Uvarov, 'A Revision of the Genus Locusta (L.) (= Pachytylus Fieb.), with a New Theory as to the Periodicity and Migrations of Locusts,' *Bulletin of Entomological Research,* 12 (1921), 135–63; J. C. Faure, 'The Life History of the Brown Locust (*Locustana pardalina* (Walker))', *Bulletin, Faculty of Agriculture Transvaal University Collection. No 4*, (1923); for a discussion of 'non-model' locusts, see, H. Song, 'Density-dependent Phase Polyphenism in Non-model Locusts: A Mini-review', *Psyche*, Volume 2011, article 741769, 16 pp.

[26] M. P. Pener and S. J. Simpson, 'Locust Phase Polyphenism: An Update', *Advances in Insect Physiology*, 36 (2009), 1–286.

[27] A. Tennyson, 'The Brook' in *Maud, and Other Poems*, (London, 1855); Australian newspapers in the 1870s often referred to the 'grigs', *Australian Town and Country Journal*, 15 February 1873, p. 10; *The Express and Daily Telegraph*, 28 December 1872, p. 2, cites a farmer from Wagga who took 'the part of the grigs', that took the grass before the seed could set and injure his sheep.

journals.[28] While the biological distinction between locusts and grasshoppers remained a research focus, these were subsumed by an economic criterion for control which, being generic, was turned on both. This spawned an industry that linked chemical companies with international development aid, created institutions devoted to locust control in several parts of the world and produced cadres of travelling 'locust experts'.

In terms of biogeography, many locust species inhabit the margins of deserts, in 'ecotones' where different vegetation structures merge, mostly in regions where habitat conditions are highly variable. Such environments usually favour species with high fecundity, short generation times and migration; species traits grouped with those known as 'r' selection.[29] We generally find only one species within a genus on each continent is a locust, except where there is a significant geographical barrier, such as an expanse of equatorial forest but not desert. In contrast, there can be many species of grasshoppers within a genus occupying the same continental region (such as *Melanopus* in North America or *Austroicetes* in Australia). The implication is that long-distance migration — co-evolved with phase change and large populations in locusts — maintains regular gene flow that limits allopatric speciation.

The nature of the beasts

> *But practically it matters nothing as to the place of the animal in the classification of the natural historian. The creature now visiting us is as destructive as any locust could be imagined to be … There seems little doubt that the fly we are suffering from is the same that is translated in the Bible "locust," and which is numbered among the plagues of Egypt, and now popularly designated "locust".*
>
> *Border Watch*, 15 March 1873, p. 3.

In Australia, the inland southern grasslands overlap with the range of two swarming acridid species, which brought them into collision with European settlers establishing agricultural livelihoods. They are currently known as the Australian plague locust, *Chortoicetes terminifera*, and the small plague grasshopper, *Austroicetes cruciata* (Figure 1.3), but they were known long before their ontology as named entities of Western science in the late nineteenth century.

[28] Examples of specialised journals are *Acrida* (1972–1981), *Anti-Locust Bulletin* (1948–1975), *Anti-Locust Memoirs* (1946–1976), *Locusta* (1954–2017) and more recently the *Journal of Orthoptera Research*.

[29] T. R. E. Southwood, 'Habitat, the Templet for Ecological Strategies', *Journal of Animal Ecology*, 46, (2) (1977), 337–365, p. 347.

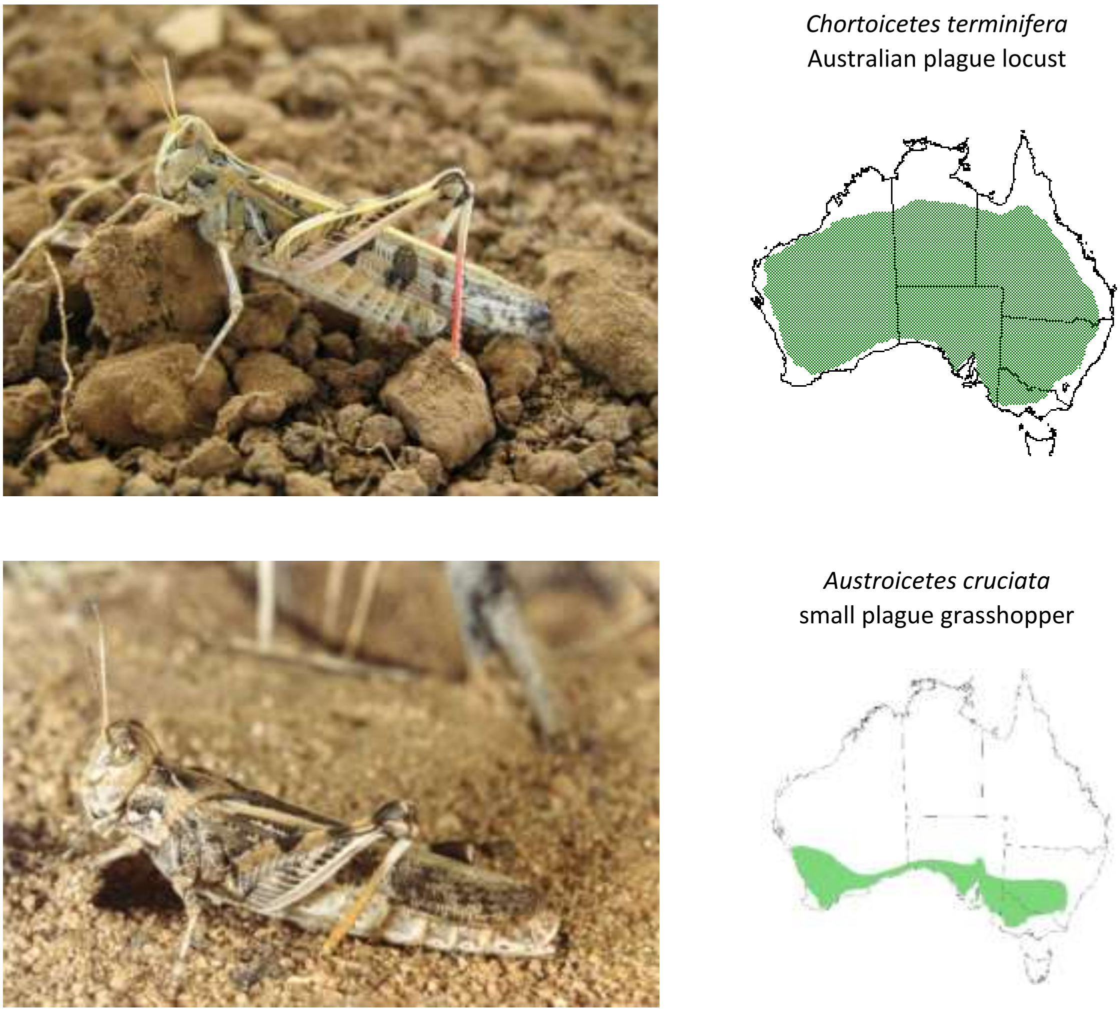

Figure 1.3. The locust and the grasshopper. Adults and distribution maps of *Chortoicetes terminifera* (top) and *Austroicetes cruciata* (photographs courtesy of James Woodman and Bob Lewis).

Their general similarity and individual pattern variability caused ongoing confusion over their separate identities, even among the experts. Both species display similar phenotypic variation within populations, sharing several genetically determined, homologous 'pattern morphs'.[30] The Linnaean binomial names were reworked several times and even their common names were not fixed before a scientific 'consensus' in 1938.[31] *C. terminifera* was known by various names: the 'common

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[30] K. H. L. Key, *The taxonomy, phases and distribution of the genera* Chortoicetes *Brunn. and* Austroicetes *Uv. (Orthoptera: Acrididae),* (Canberra, Division of Entomology, CSIRO, 1954), Key identified 15 homologous varieties in the two genera, based on distinct patterns on the body, wings and femurs. Seven of these occur in both *C. terminifera* and *A. cruciata*.

[31] At the first Australian Locust conference in 1938, South Australian entomologists proposed different common names to the CSIR choices adopted; Typical of the circuitous and arcane track of entomological authority and revisions, the locust was named *Epacromia terminifera* by Francis Walker in London in 1870, labelled as *Edipoda musica* by Professor McCoy in Melbourne during the 1873 plague and the current genus name established in Vienna in 1893 by Brunner von Wattenwyl. The grasshopper was named *Cortolaga*

Victorian', 'wandering', 'larger plain' and 'black-tipped' locust. *A. cruciata* was the 'smaller plains locust', 'small plague grasshopper' and the 'yellow plague grasshopper'.[32] To avoid constant repetition of the scientific or common names, in the following chapters I use the general terms 'locust' for *C. terminifera* and 'grasshopper' for *A. cruciata*. When quoting from generic or mistaken historical uses of these terms, they appear in quotation marks.

The monotypic *C. terminifera* and the genus *Austroicetes* are endemic to Australia, together forming a distinct phylogenetic clade within the subfamily Oedipodinae.[33] They are autochthonous, having a shared evolutionary history and are widely distributed on the Australian mainland. Phylogenetic analyses based on several cladistic models of mitochondrial genes suggest that the current genera shared a common ancestor in Miocene times. Other species of locusts and pest grasshoppers in Australia have much closer taxonomic relatives on other continents. There are currently nine recognised species of *Austroicetes,* five of which have a mainly inland distribution. *A. cruciata*, *A. interioris* and *A. pusilla* are recorded as displaying gregarious swarming behaviour, but only *A. cruciata* as forming persistent infestations.[34] Distinguishing between these species is based on a combination of features, some not easily seen with the naked eye.[35] The holotype of *C. terminifera* came from the Swan River colony and *A. cruciata* from Quorn in South Australia.[36]

C. terminifera is considered a 'model' locust in that it forms dense gregarious aggregations at both nymph and adult life stages, which, because of their consequences for abundance and behaviour, have

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australis, by Saussure in Vienna in 1888, then synonymously as *C. jungii* by Brancik in 1898. During the plague in 1899, NSW entomologist Walter Froggatt presented specimens of *A. cruciata* as a new species (*Pachytylus australis*) and Uvarov established the genus *Austroicetes* in a 1925 revision of specimen collections. Ken Key revised the genus in 1954 and established the nine current species.

[32] W.W. Froggatt, 'Locusts and Grasshoppers', *Agricultural Gazette of N.S.W.*, 14 (1903), 1102–1110; W.W. Froggatt, 'Locusts in Australia and Other Countries', *Department of Agriculture N.S.W. Farmers Bulletin No. 29*. (Sydney, 1910); James Davidson, 'Memorandum on: Popular names suggested for the major pest species', in *Proceedings of the First Australian Locust Conference, Melbourne, 19–22 July 1938*, (Council for Scientific and Industrial Research).

[33] M. Fries, W. Chapco and D. Contreras, 'A Molecular Phylogenetic Analysis of the Oedipodinae and their Intercontinental Relationships', *Journal of Orthoptera Res*earch, 16 (2), (1997), 115–125, p. 119, cladistic trees suggest a divergence ~ 40 million y BCE. This is perhaps a maximum age of the divergence and the extant species are likely to be considerably younger.

[34] *A. cruciata, A. pusilla, A. tricolor, A. frater* and *A. interiori*s have an inland distribution. *A. vulgaris* and *A. frater* also occur in Tasmania, see D. C. F. Rentz, R. C. Lewis, Y. N. Su and M. S. Upton, *A Guide to Australian Grasshoppers and Locusts*, (Kota Kinabalu, Borneo , Natural History Publications, 2003).

[35] K. H. L. Key, *The taxonomy, phases and distribution of the genera* Chortoicetes *Brunn. and* Austroicetes *Uv. (Orthoptera: Acrididae),* (Canberra, Division of Entomology, CSIRO, 1954), p. 91, the diagnostic feature for distinguishing several species is the intercalary vein on the wing or male genital plates.

[36] Francis Walker, *Catalogue of Specimens of the Dermaptera Saltatoria in the Collection of the British Museum*, *Part IV*, (London, Trustees of the British Museum, 1870), p. 777, the specimens named in 1870 were presented by Sir J. Richardson and were possibly several years old. *A. cruciata* was collected by Alfred Koebele in 1888 and sent to Geneva.

contributed to its status as a serious agricultural pest.[37] Unlike 'classical' locust species of the Old World, however, there is no chromatic and little morphological change associated with the gregarious phenotype, or any known epigenetic maternal transfer of phase state to the offspring. Only the behavioural traits of phase polyphenism, mutual attraction and coordinated movement, have been experimentally demonstrated.[38] *A. cruciata* is often called a 'gregarious grasshopper', because it has limited migratory capacity and displays weak mutual attraction, with only loose coordinated movements. However, in high densities males can develop a distinct yellow pigmentation, a trait seen also in the gregarious phase of some locust species.[39] *A. cruciata* therefore also conforms to the defining criteria of a locust: periodically forming large populations in dense groups, where individuals differ in several characteristics from those living separately.[40]

The two species look generally similar, with no remarkable features and are small compared to many other locust species. Both are herbivores of inland open grasslands. Like all acridids, the females lay eggs in clusters, or 'pods', in the soil and they have a straightforward lifecycle in which hatched juveniles are miniature, wingless replicas of the adults. Juveniles go through a series of moults between discrete development stages called 'instars' before fledging to adulthood. They are often referred to as 'hoppers' or 'nymphs' rather than larvae because they are morphologically similar to the adults. The primary habitat of both species is open tussock grassland and grassy open woodland, natural and anthropogenic vegetation formations that cover vast areas of southern Australia. Egg-laying locations in both species are also similar, showing preferences for compact soil surfaces and some bare ground.

Other aspects of their ecologies, however, are very different. *C. terminifera* (the locust) can complete two or three generations each year depending on latitude.[41] The first generation of locust nymphs typically appear in September and October, fledge in November and lay eggs in December or January. The second generation develops during January–February and the third in March–April.[42] Autumn

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[37] S. J. Simpson and G. A. Sword, 'Phase polyphenism in locusts: mechanisms, population consequences, adaptive significance and evolution', in eds. D. Whitman and T. Ananthakrishnan, *Phenotypic Plasticity of Insects: Mechanisms and Consequences*, (Plymouth UK, Science Publishers, 2009), pp. 147–190.

[38] L. J. Gray, G. A. Sword, M. L. Anstey, F. J. Clissold and S. J. Simpson, 'Behavioural Phase Polyphenism in the Australian plague locust (*Chortoicetes terminifera*)', *Biology Letters*, 5 (2009), 306–309.

[39] *L. migratoria* gregarious adult males turn distinctly yellow.

[40] M. P. Pener and S. J. Simpson, 'Locust Phase Polyphenism: An Update', *Advances in Insect Physiology*, 36 (2009), 1–286, pp. 7–8.

[41] Three complete generations are usually detectable in areas north of 34°S, and two in the southern part of the distribution area.

[42] R. A. Farrow, 'Population dynamics of the Australian Plague Locust, *Chortoicetes terminifera* (Walker), in Central Western New South Wales I. Reproduction and Migration in Relation to Weather', *Australian Journal of Zoology*, 27 (1979), 717–745.

laid eggs remain dormant until spring. In contrast, *A. cruciata* (the grasshopper) has a single annual generation. Its nymphs emerge from late July to September, fledge into adults in October and lay eggs during November–December.[43] The adults die out during January, while their eggs remain dormant until the following spring.

This crucial difference in voltinism is the result of life history 'strategies' evolved in response to differences in the reliability and variability of habitats within their geographic ranges. In both species there is an embryonic diapause — an anticipated dormancy process where metabolic rates are slowed — induced by environmental cues that occur prior to the period inimical to active life stages. Diapause in the locust is 'facultative', occurring only in eggs laid by adults that experience a decline in day length during autumn.[44] In contrast, diapause in the grasshopper is 'obligate'; all eggs become dormant and remain in this state throughout summer and autumn.[45] In both species, the enzymatic processes of diapause development are enhanced by a period of chilling and usually end during winter, when normal embryonic development resumes.[46] The diapause state also confers eggs with a level of resistance to desiccation, most strongly in the grasshopper.[47] Developing embryos of the locust can also enter a quiescent state in direct response to low soil moisture, often in association with diapause, and can survive in dry soil for several months.[48]

Locust plagues can develop from sparse initial populations in a single year, following two to three generations of high recruitment.[49] A unique feature of *C. terminifera* population dynamics is frequent high altitude, wind-assisted nocturnal migration that can result in overnight displacements of several

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[43] L. C. Birch and H. G. Andrewartha, 'Influence of weather on grasshopper plagues in South Australia', *Journal of Agriculture South Australia*, 45 (1941), 95–100, p. 95.

[44] K. G. Wardhaugh, 'The Effects of Temperature and Photoperiod on the Induction of Diapause in Eggs of the Australian plague locust, *Chortoicetes terminifera* (Walker) (Orthoptera: Acrididae)', *Bulletin of Entomological Research,* 70, (1980) 635–647; K. G. Wardhaugh, 'Diapause Strategies in the Australian plague locust, *Chortoicetes terminifera* (Walker)' in eds. F. Taylor and R. Karban, *The Evolution of Insect Life Cycles*, (New York, Springer, 1986), pp. 89–104; E. Deveson and J. Woodman, 'Embryonic Diapause in the Australian Plague Locust Relative to Parental Experience of Cumulative Photophase Decline', *Journal of Insect Physiology*, 70 (2014), 1–7.

[45] H. Vevers Steele, 'Some Observations on the Embryonic Development of *Austroicetes cruciata* (Sauss. Acrididae) in the field', *Transactions of the Royal Society of South Australia*, 63, (1941) 329–332.

[46] H. G. Andrewartha. 'Diapause in the eggs of *Austroicetes cruciata*, (Sauss. Acrididae), with particular reference to the effect of temperature on the elimination of diapause', *Bulletin of Entomological Research*, 34 (1943), 1–17.

[47] D. C. Swan, 'Locusts and grasshoppers in South Australia', *Journal of Agriculture South Australia*, 59 (1955), 85–99; H. G. Andrewartha and L. C. Birch, 'Measurement of Environmental Resistance in the Australian Plague Grasshopper', *Nature*, 161 (20 March 1948), 447–448.

[48] K. G. Wardhaugh, *A study of some factors affecting egg development in* Chortoicetes terminifera *Walker (Orthoptera: Acrididae)*, (PhD Thesis, Australian National University, Canberra, 1973), pp. 47–59.

[49] R. A. Farrow and B. C. Longstaff, 'Comparison of the annual rates of increase of locusts in relation to the incidence of plagues', *Oikos,* 46 (1986), 207–222.

hundred kilometres.[50] Grasshopper infestations build up over several annual generations, tend to recur in the same regions and become persistent once established. Grasshopper swarms also migrate, but individuals rarely travel more than 30 km in a lifetime.[51]

The distribution area of each species provides some biogeographic context for their different life histories (Figure 1.3). The graphical model proposed in the 1970s by entomologist Richard Southwood and others provides a useful conceptual framework for the ecology of the two species.[52] The temporal and spatial characteristics of habitat define multidimensional 'templets' for the selection and co-evolution of specific life history traits. The locust occurs across a wide latitudinal range, which includes semi-arid and arid regions where rainfall variability is very high. Habitat in the centre of its range is notoriously unreliable, often becoming only locally favourable and usually for brief periods. Rainfall events synchronise the timing and location of gregarious adult egg laying. This results in dense nymph populations, the survival of which are related to the persistence of green vegetation after the initial and any further rainfall.[53]

The grasshopper is largely confined to the southern semi-arid zone, which has a winter-dominant or 'Mediterranean' rainfall distribution. Habitat conditions in the range of *A. cruciata* are more predictable, with hot-dry summers and cool-wet winters when rainfall is usually evenly distributed across the landscape. There is usually green vegetation in early spring, but little available food during summer. Explorer Charles Sturt was struck by this climatic polarity in his description of the settled districts around Adelaide in 1845. In winter the country was fresh with green herbage, but in the dry heat of summer it assumed a 'withered and parched appearance … the earth is almost herbless, and the ground swarms with grasshoppers' (about which we will hear more in Chapter 3).[54]

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[50] P. M. Symmons and D. E. Wright, 'The Origins and Course of the 1979 Plague of the Australian Plague Locust, *Chortoicetes terminifera* (Walker) (Orthoptera: Acrididae), Including the Effect of Chemical Control', *Acrida,* 10 (1981), 159–190.

[51] L. C. Birch and H. G. Andrewartha. 'Influence of Weather on Grasshopper Plagues in South Australia', *Journal of Agriculture South Australia*, 45 (September 1941), 95–101, p. 95.

[52] Southwood 1977; K. Korfiatis and G. P. Stamou, 'Habitat Templets and the Changing Worldview of Ecology', *Biology and Philosophy*, 14 (1999), 375–393.

[53] D. M. Hunter and M. Melville, 'The Rapid and Long Lasting Growth of Grasses Following Small Falls of Rain on Stony Downs in the Arid Interior of Australia', *Australian Journal of Ecology,* 19 (1994), 46–51; D. M. Hunter, P. W. Walker and R. J. Elder, Adaptations of Locusts and Grasshoppers to the Low and Variable Rainfall of Australia', *Journal of Orthoptera Research*, 10 (2001), 347–51.

[54] *South Australian Gazette and Mining Journal*, 21 April 1848, p. 4, 'Captain Sturt on Central Australia', taken from Sturt's *Narrative of an Expedition into Central Australia, performed under the authority of Her Majesty's Government, during the years 1844–5–6, together with a notice of the Province of South Australia in 1847*.

These different spatial and temporal patterns of habitat suitability selected for the evolution of the nomadic migratory behaviour in the locust and the more sedentary lifestyle of the grasshopper.[55] The ecologies of the species can therefore be viewed as complex 'syndromes' of linked life history, genetic and behavioural traits that are subject to contemporary selection forces exerted by habitat characteristics.[56] In common with many species of arid environments, habitat productivity in response to rainfall is considered the primary environmental influence on both *C. terminifera* and *A. cruciata* irruptive population increases.[57] Rainfall across the main habitats of the locust is infrequent and unpredictable, so migrations enable rapid colonisation of ephemeral habitat conditions in arid areas and between summer and winter rainfall regions.[58] Rainfall for the grasshopper is strongly seasonal with long periods either too dry or too cold for active stages, favouring the univoltine life history and extended egg dormancy.[59] The development rate of non-dormant life stages in both species is a function of temperature, although nymphs and adults behaviourally regulate body temperature to an optimal range of 37–42 °C by basking or seeking shade.[60] Locust lifecycle turnover during summer can be as short as 60 days and nymphal stages can be completed in 25–30 days.[61] The grasshopper lifecycle is annual and nymphal development takes 30–45 days during spring.[62]

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[55] D. P. Clark, 'The Plague Dynamics of the Australian plague locust, *Chortoicetes terminifera* (Walk.)', in eds. C. F. Hemming and T. H. C. Hemming, *Proceedings of the International Study Conference on Current and Future Problems of* Acridology*, 1970*, (London, Centre for Overseas Pest Research, 1972), pp. 275–87, p. 284, Clark likened locust swarm movements to those of many arid zone birds, as 'essentially nomadic'.

[56] H. Dingle, 'Behaviour, Genes and Life Histories: Complex Adaptations in Uncertain Environments', in eds. P. W. Price, C. N. Slobotchnikoff, and W. S. Gaud, *A New Ecology: Novel Approaches to Interactive Systems*, (New York, John Wiley & Sons, 1984), pp. 375–415; H. Dingle. 'The evolution of insect life cycle syndromes', in eds. F. Taylor and R. Karban, *The Evolution of Insect Life Cycles*, (New York, Springer, 1986), pp. 11–26.

[57] D. P. Clark, 'The influence of rainfall on the densities of adult *Chortoicetes terminifera* (Walker), in central western New South Wales, 1969–73', *Australian Journal of Zoology*, 22 (1974), 365–386; in contrast, *A. cruciata* is favoured by lower than average rainfall, but the distribution of early spring and November rainfall influences the size of the population in the following year, see L. R. Clark, 'Ecological observations on the small plague grasshopper, *Austroicetes cruciata* (Sauss.), in the Trangie district, central western New South Wales', *C.S.I.R. Bulletin No. 228*, (Melbourne, 1947), p. 12.

[58] E. Deveson, V. A. Drake, D. Hunter, P. Walker and H. K. Wang, 'Evidence from traditional and new technologies for northward migrations of Australian plague locusts (*Chortoicetes terminifera*) (Walker) (Orthoptera: Acrididae) to western Queensland'*, Austral Ecology*, 30 (1995), 928–943.

[59] H. G. Andrewartha, 'Diapause in relation to the ecology of insects', *Biological Reviews*, 27 (1), (1952), 50–107.

[60] Peter C. Gregg, *Aspects of the Adaptation of a Locust to its Physical Environment*, (PhD thesis, Australian National University, 1981), p. 175.

[61] P. Gregg, 'Development of the Australian plague locust, *Chortoicetes terminifera*, in relation to temperature and humidity', *Journal of the Australian Entomological Soc*iety, 22 (1983), 247–251.

[62] L. R. Clark, 'Ecological observations on the small plague grasshopper, *Austroicets cruciata* (Sauss.), in the Trangie district, central western New South Wales', *C.S.I.R. Bulletin No. 228*, (Melbourne, 1947), pp. 12–15.

Renewed research interest in locust phase polyphenism during this century has brought a closer understanding of its underlying mechanisms and ecological significance.[63] In the locust *C. terminifera* this is shown to be induced primarily by antennae contact at high densities and manifests as gregarious behaviour that is reversible within the lifetime of individuals.[64] Less is known about the gregarious phase properties of the grasshopper as it received little research attention after the 1950s, a consequence of its declining pest status. In the desert locust, *S. gregaria*, the femur is a primary site of contact-stimulated phase change that is mediated by serotonin levels, but the gregarious state is reinforced by olfactory and visual cues and can even be induced by showing nymphs film of other moving locusts.[65]

Early historical descriptions of impressive masses of locust nymphs likened their movement to armies marching under the direction of their generals: 'like men-of-war they have a government among themselves like bees and ants'.[66] Recent research has shown that the cohesion of migratory bands containing millions of individuals is a consequence of their alignment with the movements of close neighbours.[67] The mass movement is an outcome of nutritional interactions, partly driven by cannibalism and the depletion of proximate food resources.[68] Against these apparent disadvantages there is a reduced risk of predation through dilution effects and in some species by aposematism, but living in such dense groups is still described as 'a compromise that makes the best of a seemingly very bad situation'.[69]

Cohesion of flying adult swarms is also maintained by close visual and olfactory contact, and they bring advantages in terms of mating success, food resources and colonisation of new habitats.

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[63] A new phase of intense research on locusts and on *C. terminifera* commenced in 2005 under the impetus of Stephen Simpson and colleagues at the University of Sydney.

[64] D. A. Cullen, G. A. Sword, T. Dodgson and S. J. Simpson, 'Behavioural phase change in the Australian plague locust, *Chortoicetes terminifera*, is triggered by tactile stimulation of the antennae', *Journal of Insect Physiology*, 56 (2010), 937–942; Gray et al. 2009.

[65] M. A. Anstey, S. M. Rogers, S. R. Ott, M. Burrows and S. J. Simpson, 'Serotonin Mediates Behavioural Gregarization Underlying Swarm Formation in Desert locusts', *Science*, 323 (2009), 627–629; H. Tanaka and Y. Nishide, 'Do desert locust hoppers develop gregarious characteristics by watching video?', *Journal of Insect Physiology*, 58 (2012), 1060–1071.

[66] Kirby and Spence 1825, p. 299.

[67] J. Buhl, D. J. Sumpter, I. D. Couzin, J. J. Hale, E. Despland and S. J. Simpson, 'From disorder to order in marching locusts', *Science*, 312 [5778],(2006), 1042–1046.

[68] S. Bazazi, J. Buhl, J. J. Hale, M. L. Anstey, G. A. Sword, S. J. Simpson and I. D. Couzin, 'Collective motion and cannibalism in locust migratory bands', *Current Biology*, 18 (10), (2008), 735–739, p. 735, 'estimated to affect the livelihood of 1 in 10 people on the planet'.

[69] S. J. Simpson and D. Raubenheimer, *The Nature of Nutrition: a Unifying Framework from Animal adaptation to Human Nutrition*, (Princeton and Oxford, Princeton University Press, 2012), pp. 117–119; S. J. Simpson and G. A. Sword, 'Phase Polyphenism in Locusts: Mechanisms, Population Consequences, Adaptive Significance and Evolution', in eds. D. W. Whitman and T. N. Ananthakrishnan, *Phenotypic Plasticity of Insects: Mechanisms and Consequences* (Boka Raton, Florida, CRC Press, 2009), pp. 146–189.

Crepuscular mass take-off of *C. terminifera* occurs in response to meteorological conditions, but the subsequent nocturnal long-distance migratory flights are largely an individual activity. For social insects the emergent properties of individual interactions enhances the fitness of the colony as a superorganism; for locusts the formation of transitory population 'superorganisms' also enhances the fitness of its members, and increases the numerical abundance of individuals carrying random genetic variants.

But these species are not simple automatons. They are not uniformly subject to the same environmental variables, only becoming and being identified by the emergent properties of their mass populations. Individual locusts exercise diet preferences, adjusting their food selection to optimise carbohydrate, protein and water intake, and the selected combination of nutrients changes with life stage and temperature.[70] Locusts and grasshoppers are affected by visual, acoustic, olfactory and pheromone as well as tactile stimuli, and some species have been shown to have a level of cognition in associative learning for diet selection.[71] Experiments show locusts are quick to learn in choice-maze experiments for positive food rewards, associated with colour and odour.[72] They also display communication behaviours for identifying conspecifics and assessing their reproductive receptivity. These involve male stridulation noises and ritualised movements, as well as body positions and leg-waving signals in both sexes.[73] Being grassland herbivores they have clear vision over a range of distances that helps in avoiding predators. Anyone who has observed them in the field knows they are aware and wary of large moving animals, and know when they are being pursued.

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[70] F. J. Clissold, H. Kertesz, A. M. Saul, L. J. Sheehan and S. J. Simpson, 'Regulation of water and macronutrients by the Australian plague locust, *Chortoicetes terminifera*', *Journal of Insect Physiology*, 69 (2014), 35–40; F. J. Clissold, N. Coggan and S. J. Simpson, 'Insect herbivores can choose microclimates to achieve nutritional homeostasis', *The Journal of Experimental Biology*, 216 (2013), 2089–2096.

[71] D. Raubenheimer and S. J. Simpson, 'The geometry of compensatory feeding in the locust, *Animal Behaviour*, 45 (1993), 953–965; D. Raubenheimer, S. J. Simpson and D. Mayntz, 'Nutrition, ecology and nutritional ecology', *Functional Ecology*, 23 (2009), 4–16.

[72] S. T. Behmer, C. E. Belt and M. S. Shapiro, 'Variable rewards and discrimination ability in an insect herbivore: what and how does a hungry locust learn', *Journal of Experimental Biology*, 208 (2005), 3463–3473; P. M. V. Simoes, J. E. Niven and S. R. Ott, 'Phenotypic transformation affects associative learning in the desert locust', *Current Biology*, 23 (2013), 2407–2412; There are also phase differences in aversive learning related to certain plant compounds, with gregarious locusts accepting toxic food plants avoided by those raised in solitary conditions

[73] Daniel Otte, 'Communicative aspects of reproductive behaviour in Australian grasshoppers', *Australian Journal of Zoology* 20 (1972), 139–152.

The biases of historical records

> *The old settlers of '49 still talk of that terrible Black Thursday* [Bushfire] *which swept over the land, but I question if the locust visitation will not be more terrible than any day that Victoria can point to in her history, and who can say that it will not be an annual occurrence … the settlers of thirty four years' experience never saw locusts before, whence then do they come? The explorers, to the best of my recollection, never mentioned them.*
>
> *Hamilton Spectator*, 18 December 1872, p. 4.

Historical documentation of Australian locusts is of two broad types — records of when and where there were notable numbers, or more detailed discussions by people investigating their ecology or dealing with their populations. The former provide a century of detail for species distributions and impacts, while the latter also expose the passage of scientific ideas. Ecological knowledge was transmitted in colonial newspapers and only became the domain of professional scientists in the twentieth century. Even then scientific explication, exchange and conjecture continued in the press, giving different descriptions of events, ideas about what was important and political views on necessary actions. Government entomologists acted in their public role by representing policy and providing prescriptions for control. From the 1930s, ecological scientists needed to satisfy their scientific peers as well as the sponsors and recipients of their research.

Newspapers are my principal information source up to the 1930s. They are dense with reports and accounts, as locusts held considerable interest for settler societies focused on agricultural development and its comparative limitations. The period from 1880 to 1930 was a never-to-be repeated heyday of the local newspaper in Australia. Many were spawned in towns with less than a thousand people and there were multiple titles in the larger towns and the capitals. From 1871 the establishment of the Australian Associated Press, using the expanding telegraphic network, allowed the papers to rapidly translate and transmit each other's stories, which for grasshoppers and locusts they often did.[74] When things were bad, editors thought people wanted to hear that they could be worse in other towns and other countries. Between 1900 and 1910 there was at least one daily, bi-weekly or weekly paper for every 10,000 settler persons over fourteen years old. The number of titles peaked in every state during the following decade, with more than 500 nationwide.[75]

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[74] *The Sydney Morning Herald*, 28 January 1870, p. 6, arrangements were being made for intercolonial telegraphic rates and cables, including to New Zealand; In April 1871, Australian Associated Press Telegrams were being sent between the Australian colonial capitals and other major towns, such as Geelong and Newcastle.

[75] In the period 1900–1910, there were over 160 newspaper titles in NSW, 72 in Victoria, 39 in South Australia, 35 in Queensland, 40 in WA and 11 in Tasmania; one for every 10,000 persons (Trove, http://trove.nla.gov.au/newspaper/search?adv=y) accessed 10 Feb, 2015. This does not include many short-

The digitisation of historical newspapers has created a new tool for 'digital humanities' research. Conditional searches from massive textual databases can unearth hitherto unavailable detail for reconstructing locust distributions, although the method is not exhaustive and the data continue to grow.[76] I have largely ignored records from coastal areas, Tasmania and the northern tropics, because our species of interest rarely inhabit those areas and would be hard to distinguish from other possible species when they did. There have been other regional historic analyses of infestations for different periods; those of Charles Birch and Herbert Andrewartha in 1941, and Diana Wright in 1987 also made use of newspaper records as sources.[77] Ken Key used mostly secondary sources in his 1938 comprehensive historical review.

Big data comes with its own problems, including a high error rate in text recognition and the loss of archival context.[78] Digital keyword searches can create the impression that 'locusts' were the principal focus of settler concerns, whereas they were just one among many trials of establishing a viable agricultural livelihood. Reading other articles around those about locusts allows a broader perspective on local and national issues, on politics, causes of death, harvests, stock prices, and environmental conditions. Certain city papers saw the rural population as part of their constituency and picked up the dramatic descriptions and currents of discontent over the locusts, while others retained a largely mercantile interest in the economic fortunes of industry and government.

Newspapers tended to overstate and embellish observations with contemporary metaphors for dramatic effect. The awesome vision of swarms of locusts passing in myriads for days got a good airing in the Australian press as it did in other countries. Nevertheless, the quantity and geographic coverage of the reports makes them suitable for establishing distributions.[79] They constitute an expanding geographic frame of sampling as settlement progressed. It could also be argued that they were not influenced by institutional or political motives towards particular conclusions, giving only local impressions and concerns.

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lived titles that have not survived for digitisation and many others that are yet to be digitised, and therefore represents a minimum; ABS – 4102.0 Australian Social Trends, 2000 - http://www.abs.gov.au/AUSSTATS/abs@.nsf/7d12b0f6763c78caca257061001cc588/db7193812e1efc92ca2570ec000e215a!OpenDocument , for total population in 1910.

[76] My results represent a sample up to 2015. Numerous instances of either 'grasshopper' or 'locust' were not recognised because of poor text recognition of scans, page damage or hyphenation at line breaks.

[77] Birch and Andrewartha 1941; D. E. Wright*, The origin and development of the major plagues of the Australian plague locust,* Chortoicetes terminifera *(Walker),* (PhD thesis, London University, 1983).

[78] Maxwell-Stewart 2016, p. 361.

[79] There is an inherent lag in many reports, as the transmission of information from a distance and then its publication created delays. In the years before 1860 this could be months, or as little as a few days, particularly for local papers.

The first official report on the locust appeared in Victoria in 1873, but it contained far less information on locust distributions than the newspapers. After 1900, when government entomologists in several states were producing publications in agricultural journals, their content was repeated in the press, and complemented the variety of local experiences and scientific views circulating in wider society. The information available to the public only diverged after the 1950s when ecological scientists published larger and more complex articles for a scientific audience, while state government entomologists continued the public communication role.

Newspaper reports also show how science was represented to the public and by the public. They were a forum for the other side of science; the unofficial scientific discourse about the pests and the importance of science to society. But perhaps the greatest value of newspapers is in revealing the wider social, economic and environmental contexts in which these events took place.

Those who wrote the early newspaper reports were the literate of colonial society: the traveller, the editor, the correspondent, the free settler and the squatter. Even brief notes often mention the location relative to the district centre, direction of movements, hopping or flying stages, numbers, egg laying and details of the damage they caused. Newspapers were part of the communication network of agriculturalists. Town-dwellers were dismayed by the insects' antics around and in their homes. Stories of 'locusts' eating curtains and wallpaper, or causing horses to shy were common and there were occasional humorous views, such as the account of locusts joining a band parade and flying into the brass instruments in Forbes in 1882.[80] Editorials also discussed intellectual views on the causes of plagues and on government performance in dealing with them.

Many reports detail crop losses and even a few bankruptcies were blamed on the locusts.[81] They were often described as making the landscape appear like a desert but, unlike in other countries where they caused famine, there are few descriptions of locusts adding such extreme hardship to the plight of small farmers. One exception was in South Australia in the 1890s, after wheat farming extended into the arid north. Here the combined effect of grasshoppers, drought and rabbits left farmers destitute, forcing some to abandon their holdings. On marginal country in all states, wheat farmers lived out a precarious 'one in three' year existence, expecting to lose two crops either to drought, storms, rust or locusts.

The overwhelming view was of substantial losses to crops, pastures and gardens. It would have been difficult to challenge the prevailing public and official view that locusts were a calamity for farmers,

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[80] *Bathurst Free Press*, 15 November 1882, p. 2, the Oddfellows brass band, main street Forbes.
[81] *Chronicle*, 4 August 1900, p. 23.

but there was an occasional voice of dissent. During the locust plague in December 1890, Victorian agriculture department 'fruit expert', Mr D. A. Crichton, wrote that 'the ravages had been much exaggerated' and locusts were largely gone from along the Murray River near Yarrawonga.[82] But on the same day, a locust army 'twelve miles long' was advancing on Albury, while at Numurkah and Shepparton, farmers, orchardists and vignerons were reporting serious losses from the plague, the likes of which had 'never before been known in northern districts'. The swarms were so thick, 'the buzzing sounded like the distant roaring sea', leaving the whole 'country-side devastated'.[83]

Such disparate descriptions demonstrated the capricious, localised and transitory nature of damage caused by the insects, even during a plague. Adjacent districts and sometimes even adjacent farmers could have different experiences and losses during the passage of swarms, or from the more limited movement but voracious appetites of their offspring. They also highlight the difficulties of estimating the total area affected or the overall economic impacts of historical 'plagues'. Such comparisons are not easily made even for the twentieth-century plagues, when more systematic distribution records were collected and some estimates of economic losses were made.

It is this local and subjective experience, the sheer numbers and visible presence of locusts in descriptions that colour the production of the historical record. Just how bad the plagues were depended on location, perception and memory of the events, although some districts certainly suffered disproportionately and repeatedly. The cognitive psychology of how people cope with the risk and uncertainty of other natural disasters could be extended to locust plagues. Risk assessments and the preparedness of individuals and states to act were relative to an event having occurred in the recent past, but memory could also exaggerate the severity of plagues in the distant past.[84] Fear also plays a part in the perceptions of the threat and entomologists or institutions could overstate or underplay the risks, depending on their political motives.

Figure 1.4 gives the total number of separate (non-advertising or sport) newspaper entries of 'grasshoppers' or 'locust' for each year from 1850 to 1954. In 2015, newspaper digitisation went no further than the mid-1950s. The early trend of increasing numbers of reports as the number of

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[82] *The Horsham Times*, 5 December 1890, p. 3, reporting from Melbourne, Chrichton wrote that the crops had suffered little; *Ballarat Star*, 5 December 1890, p. 4, appears to be referring to country along the Murray, particularly Yarrawonga Shire.

[83] *Riverine Herald*, 5 December 1890 p. 3; *The Telegraph* (Brisbane), 4 December 1890, p. 4, 'Curse of the Locusts.

[84] Nikki Pfeifer, 'Cognition and Natural Disaster: Stimulating and Environmental Historical Debate', in eds. Estelita Vaz, Cristina Joanaz de Melo and Lígia M. Costa Pinto, *Environmental History in the Making: Volume 1 Explaining*, (Switzerland, Springer International Publishing, 2017), pp. 3–14, p. 5, Pfeiffer discusses the 'availability heuristic', that the probability assessment of an event occurring is modulated by the ease with which it comes to mind, overestimating risk if it was observed recently.

newspaper titles increased, stabilised in the 1880s at around 1,000–2,000 annually. That trend is punctuated by peaks in certain years when swarms were widespread and there was intense public interest. During the first locust plague, for example, reports tripled from 650 in 1871 to over 2,000 in 1872 and 1873, before dropping again to 800 in 1875 (a sample of my report summaries from that period is given in Appendix 1). The graph highlights a number of other likely plague years, when articles referring to 'grasshoppers' or 'locusts' peaked above the trend in mean numbers.[85] However, there were many reasons other than local swarming for generating correspondence, including political and scientific conjecture, popular anecdote or the reporting of overseas events.

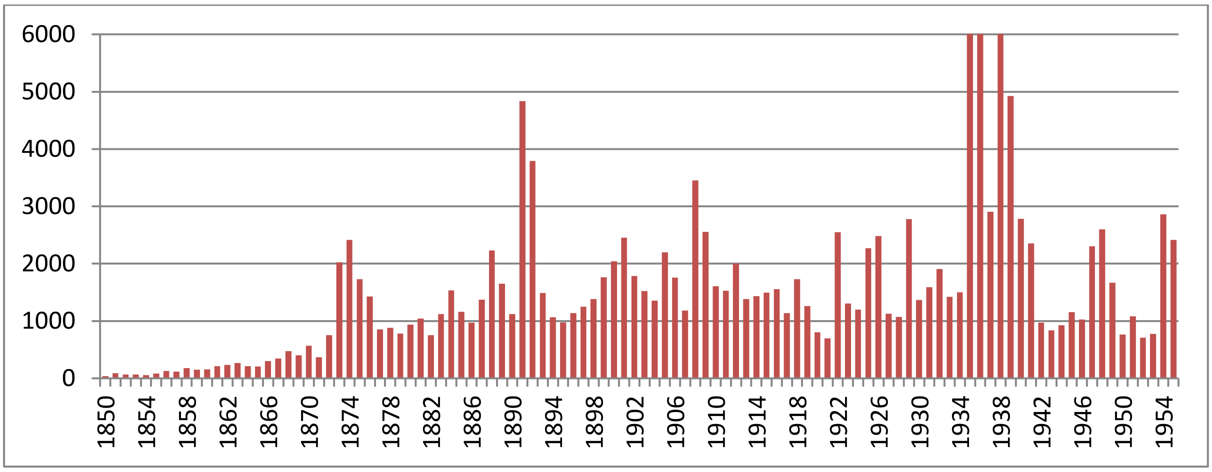

Figure 1.4. Annual totals for newspaper articles (excluding advertisements and listings) containing text 'grasshoppers' or 'locust' appearing in Australian digitised issues, 1850–1954 (Trove — National Library of Australia, 2015).

Journals of explorers and early settlers are a potential source of locust references, but compared to records of mosquitoes and flies, references to locusts are conspicuously absent. Appendix 2 lists the early historical sources examined. Even in the 1870s and 1880s when locust swarms were widespread, few autobiographies include recollections of them.

Scientific locust articles appeared in agricultural journals in the 1890s, but only in the mid-twentieth century did these reports and research papers in scientific journals become the principal source of information on locust distributions. These publications offer a different set of concerns and a window into the history of scientific ideas and the development of ecological theories. They also present a different set of potential biases, often to do with the anticipated scale and consequence of outbreaks to

[85] The years 1871–76, 1884, 1886–87, 1890–91, 1904, 1907–08, 1911, 1917–18, 1921, 1925–26, 1928, 1934–35, 1937–38, 1946–47, 1954–55 show peaks in reporting and represent locust plagues. Reports during 1898–1902 represent the grasshopper plague during the Federation drought. The peaks in 1934–35 and 1937–38 exceeded 6,000 reports.

reinforce the need for community actions. While scientific papers are usually scant on reflection, the discussion sections often cover the prevailing knowledge, the questions of concern and theoretical conjecture. They encapsulate the history of locust science, as the source of the accumulation of our understanding of the biology and population dynamics of our species.

The locust problem was geographic and dynamically changing. From the 1930s maps became an increasingly important representational tool for understanding and explaining the development and extent of plagues. They were a communication device with an assumed objectivity, despite the mixed quality of some sources and potential bias in the knowledge they represented. Maps are an inscripted data source for the locust reconstructions, but are also cognitive artefacts of the ecological interpretation of their creators, so they are treated as secondary sources. I use maps to demonstrate swarm extents in different seasons and use capitalised names to refer to the adopted regionalisation shown in Figure 1.5.[86]

Each generation of applied entomologists sought to find reasons for and solutions to the development of large pest populations, but each approached the problem within the influential paradigms of their era when determining the important questions and how to interpret research results. The scientists rarely engaged with the historiography of ideas about the ecology of the locusts before the 1970s, but they did produce different versions of the history of plagues.[87]

Criteria for distinguishing species from newspaper reports

Public reports often treated all swarms as the same, and prior to the 1940s there was confusion even among scientists over which species was being observed. Fortunately, the material ecological differences between *C. terminifera* and *A. cruciata*, chiefly in behaviour and seasonal phenology, often make discrimination of the species possible from cumulative information in the historical record.

[86] The mapping of infestations uses a grid of 0.5 × 0.5 degree cells, assigned by reporting locations occurring within them.

[87] G. E. Belovsky, D. B. Botkin, T. A. Crowl, K. W. Cummins, J. F. Franklin, M. L. Hunter, and others, 'Ten suggestions to strengthen the science of ecology', *Bioscience*, 54 (4) (2004), 345–351, p. 347.

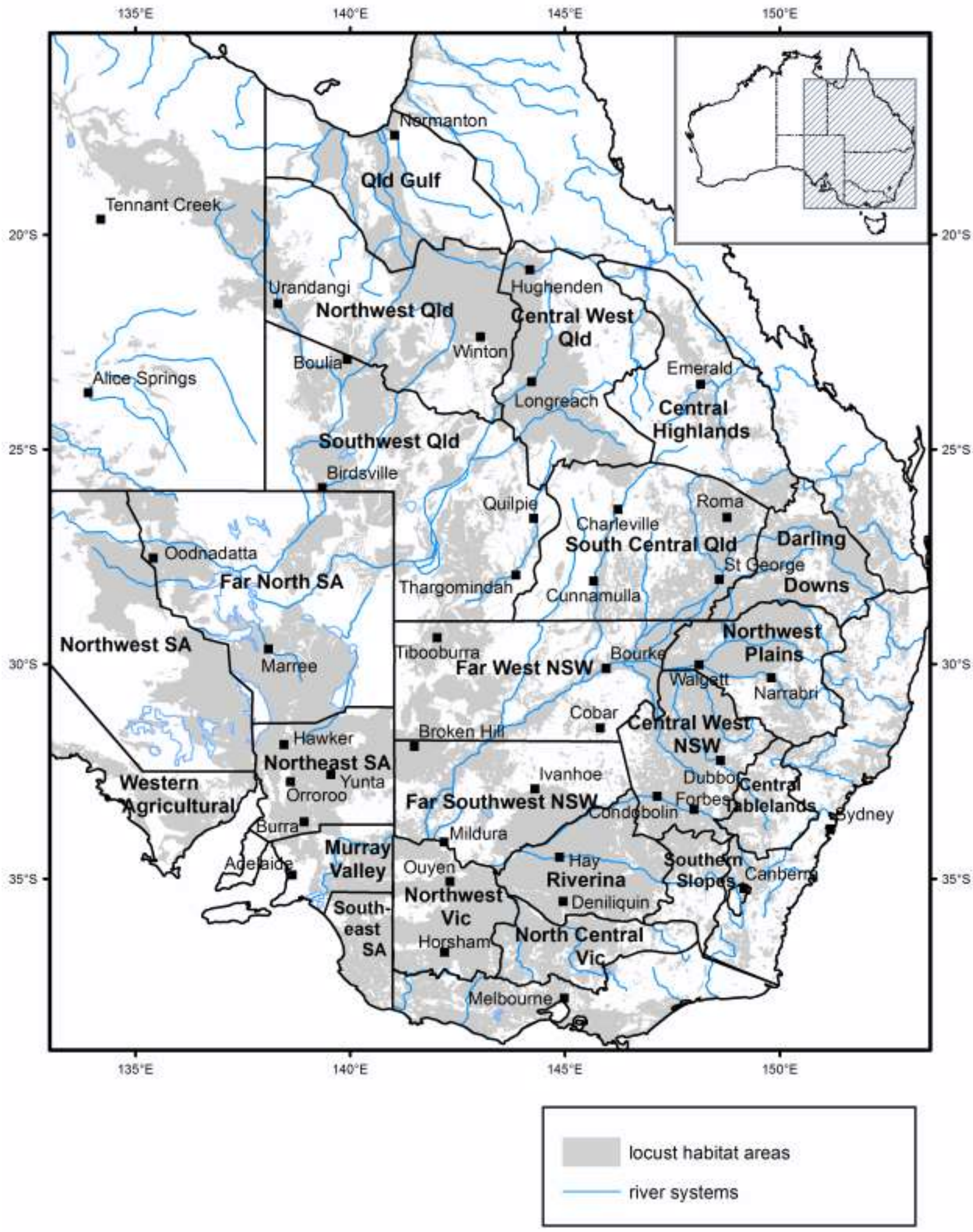

Figure 1.5. Regions and locust habitats of eastern Australia

Diagnostic morphological descriptions in nineteenth-century reports sometimes allow a species to be clearly identified. These include mentions of size, the distinctive yellow colour of swarming male grasshoppers or the red shanks and black wing tips of locusts. More commonly, ecological differences between the locust and the grasshopper from many reports in a region provide the weight of evidence to assign the main species.

These ecological differences are in behaviour, phenology and distribution. While grasshoppers are often described as swarming in myriads, and sometimes in densities of fifty per square metre, the impressive gregarious behaviour of locust nymphs, forming dense masses, hundreds or thousands per metre, moving together and 'making the ground black' is diagnostic. Similarly, grasshoppers form loose, low flying swarms, while those of the locust are an order of magnitude larger and denser, often flying at great heights and over long distances. The passing of swarms across several districts usually indicates locusts. Female locusts lay eggs in dense, clumped groups, often crowding on roadways and leaving the ground honeycombed with holes. Although there can be many grasshoppers in a metre, egg laying occurs individually, the majority are males engaged in the distinct guarding behaviour as they crowd around ovipositing females.

Grasshopper nymphs appeared earlier in spring than the first locusts and usually fledged earlier, commencing in October. Since there is only one annual generation, any report of nymphs from December to April will not be the grasshopper and is likely to be locusts, as are reports of more than one brood during spring–autumn. A series of generations, such as hatchings in the month after swarms passed through, also indicates locusts, as do September–October hatchings where swarms were present in autumn. The sudden arrival of swarms during January–May is likely to be locusts.

Occurrences outside the known distribution limits of either species are suspect, although their range could have changed and locusts are known to migrate to areas where they are unable to establish more than a brief presence. On the other hand, certain districts were repeatedly infested over a sequence of years, where in some years the species identity was well established. Moreover, the pattern that quickly emerges from the diagnostic, behavioural and phenological evidence is that the grasshopper is a dry-year species and the locust a wet-year species.

Table 1. Criteria for identifying the species, grouped by behaviour, phenology and diagnostic features.

	Locust (*Chortoicetes*)	**Grasshopper (*Austroicetes*)**
Behaviour	Dense gregarious bands, directed movement (blacken the ground)	Loose aggregations, undirected movement
	Coherent Swarms flying at height (up to 1000 m) over long distances, arriving suddenly in new areas. Strong directed flight 3m/s	Loose swarm, low flights <10 m, migrations <30 km
	Dense, gregarious egg-laying females crowding on roadways and leaving the ground honeycombed with holes (>100 m^2)	Egg laying occurs individually, female surrounded by males, (guarding behaviour (<100 m^2)
Phenology	Multi-voltine, 2–3 generations/year, hatchings Sept–Nov, Dec–Feb, Mar–May (series of generations) nymphs Jan–Apr (‘second brood’)	Univoltine, hatch Jul–Oct, adults Oct–Dec (decline)
	Arrival of swarms or egg laying Jan–May	Egg laying Oct–Dec
Diagnostic	Size (20–45 mm), colour, red shanks and black wing tips, pattern morphs	Size (15–35 mm), colour, yellow swarming males, pattern morphs

Distinguishing between species is most difficult between September and January, because both can occur in the same districts. The grasshopper and the locust can even form mixed populations in some regions, and both co-occur with several other species. The picture is further complicated by several other species that at times occur in damaging numbers, such as *Oedaleus*, *Aiolopus* and *Gastrimargus* species. In the case of the grasshopper, *A. cruciata*, there are also several other species of *Austroicetes* that occur in high numbers within its range and some have overlapping phenologies.

Despite these limitations, the sheer number of consistent reports allows a reasonably accurate assignment of one of the two species being dominant in many years. And although Peter Hobbins has warned against ‘imagining’ a putative early arthropod history, or even prehistory, I present the historical ecological evidence for changes in the frequency and distributions of both species in the following chapters.[88]

[88] Peter Hobbins, ‘Invasion Ontologies: Venom, visibility and the Imagined Histories of Arthropods’, in eds. J. Frawley and I. McCalman, *Rethinking Invasion Ecologies from the Environmental Humanities*, (Oxon & New York, Earthscan, 2014), pp. 181–195.

Chapter 2. Ways of seeing locust ecology: an interdisciplinary background

I give fair warning to all those who has reason to fear me to sell out … neglect this and abide by the consequences, which shall be worse than the rust in the wheat in Victoria or the druth of a dry season to the grasshoppers in New South Wales.

Edward Kelly, *The Jerilderie Letter*, February 1879.

Figure 2.1. Ned Kelly in 1880, (National Archives of Australia, Canberra).

When Ned Kelly concluded dictating his 'Jerilderie Letter' to Joe Burns in February 1879, he used local agrarian metaphors for the consequences of ignoring his demand for the wealthy to give money to a widows and orphans fund.[1] The destructive impact of the 'grasshoppers' and cereal rust were already etched in the psyche of rural society as symbols of the endless trials of the farmer.

The letter did more than insert Kelly into history 'in his own voice', it inserted Australian cultural myth into the environment.[2] Newspaper records show that the plains of the Riverina and northern Victoria had been subject to grasshoppers swarming almost annually since the 1860s. At the start of summer each year from 1876 to 1879, they were 'occasioning havoc' in the towns, while on the sheep runs the crows grew fat on this 'native game'.[3] Kelly associated grasshoppers with the thirst of hot, dry seasons. 1877 and 1878 had been drought years, typical of periods when *Austroicetes cruciata* swarms increased. Locusts came in the good years of the early 1870s and the alternation of the two species contributed to the overwhelming sense of a worsening problem. Later in 1879, citizens of the southern Riverina petitioned government for legal protection of birds, the insects' most obvious predators. In an expression of ecological awareness, they linked the decline of

[1] 'The Jerilderie Letter', p. 39. http://www.nma.gov.au/collections/collection_interactives/jerilderie_letter , viewed 16 June 2015; The Widows and Orphans Fund was an Oddfellows' institution at the time.

[2] Alex McDermott, Introduction to *Ned Kelly: The Jerilderie Letter*, (Melbourne, Text Publishing, 2001), 'with this letter Kelly inserts himself into history, on his own terms, in his own voice'.

[3] *Wagga Wagga Express,* 29 November 1879, p. 5, the grasshopper pest benefits the crows. 'They have so far thriven from this form of native game that they are absolutely too fat and lazy to fly away from the fences'; *Wagga Wagga Express*, 17 Sep 1879, p. 2, (from the *Jerilderie and Urana Gazette*), Spring Plains and North Yanco, coming out of the ground in untold numbers, travelling towards Jerilderie.

insectivorous birds to the increase in swarming and were unified by the need to lessen the 'public calamity' caused by the 'insect known as the grasshopper'.[4]

Kelly's letter was not published.[5] Colonial administrations chose to suppress what they saw as a subversive threat. The Kelly gang were gaining a reputation as legendary as Robin Hood, and were giving the police a bad name. There were many rural selectors willing to harbour them and Ned even had sympathisers in Melbourne society. Ideas of secession had been running along the Murray River districts for a decade and Kelly threatened armed rebellion.

The story of the letter, taken to Melbourne for Kelly's trial, and the reappearance of a backup transcript a century later, highlights how fragmentary and accidental is history made only from found records. Now held as museum treasures, a different history might be told had these documents not survived. Even now, myth surrounds the possible existence of Kelly's declaration of the 'Republic of North-East Victoria'.[6]

I use Kelly to introduce themes of environmental and agricultural history, and the nature of history itself; how it is written and what is selected to be captivating and still remain a disciplined representation of the past. Science was not one of Kelly's concerns, although in his time experiments in scientific farming were being conducted by progressive agriculturalists in Victoria, while scientific authority was guarded in the Melbourne museum and university.

This thesis is a history of science and an environmental history, with locusts and their ecology as the central subjects. It reconstructs the past outbreaks and the environments in which they occurred as well as attempts to understand and control them. It sheds light on how environmental changes affected those population fluxes and the different eras of science that have shaped locust research. As a background to an interdisciplinary treatment, this chapter explores some branches of history and science relevant to locusts and their ecology. Several publications from within those disciplines have resulted from research conducted for the thesis (see Appendix 3).

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[4] *Australian Town and Country Journal*, 29 November 1879, pp. 38–39; heavy rains at the end of 1879 brought back the locusts.

[5] The Jerilderie letter was an attempt to justify the shooting of several policemen by explaining the circumstances which resulted in their deaths and the injustices suffered by the Kelly family and other Irish Catholic selectors. A previous letter sent to Donald Cameron and John Sadlier, was passed to the Premier, who suppressed it. Samuel Gill, editor of the new *Jerilderie and Urana Gazette*, a newspaper that has not survived for digitisation, had escaped, so bank employee Edwin Living was coerced to give the letter to him to print; see, Ian Jones, *Ned Kelly: A Short Life*, (Sydney, Hachette Australia), p. 222, Gill had all but invited them to hold up the town in the *Gazette*, 11 January 1879, writing that, in the absence of any police protection, the Kellys 'could, with impunity, visit Jerilderie and carry off every shilling'.

[6] Ned Kelly Forum, http://nedkellyforum.com/forums/topic/declaration-of-ne-victoria/ , a copy was apparently taken from Kelly at his final arrest, and one may have ended up in Britain.

The roots of ecology

> *If one wishes to understand the development of biological systems in full hierarchical detail … then one must abandon the assumptions of closure, determinism, universality, reversibility and atomism and replace them by ideas of openness, contingency, granularity, historicity, and organicism respectively.*
>
> Robert E. Ulanowicz, 1999.[7]

'Ecology' has a wide common usage in the public sphere, but a variety of meanings in different contexts and communities. There is general understanding that it deals with biotic relationships within environments that affect how organisms live and die. The manifestations of these interactions are tangible because they are not removed from everyday experience and they are the fabric of our external material reality, of being an 'organism-in-its-environment.[8] Ecology is also seen as scientific, involving observation, experiment, quantification or theory. The term is often used as an encompassing scaleless noun. We can refer to the 'ecology' of a species, region, city, farm, biome or planet, intuitively knowing that this represents intricate processes and complex networks.

Whether ecology is seen then as a state of mind — one of spiritual awareness and connection with the processes and inhabitants of the natural world — a preservationist or conservationist ethos, a political philosophy and stance on how we should live in the world, or a way of observing and explaining the patterns of organisms in space and time through formal experimental science with testable explanatory theories, its central theme remains the study of interactions of species with each other and their environment. Ecology cannot be defined or operate without environment so the two concepts are inseparable.

Although ecological ideas can be found in many early natural history texts, the roots of the modern scientific discipline have been seen as the merging of European intellectual traditions of romantic naturalism and scientific empiricism in the early nineteenth century.[9] Donald Worster characterised these different impulses as the 'Arcadian' and 'Imperial' spirits, and identified Gilbert White of

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[7] 'Life after Newton: an Ecological Metaphysic', *Biosystems*, 30 (1999), 127–142, p. 140.

[8] Gregory Bateson, *Steps to an Ecology of Mind*, (Chicago, University of Chicago Press, 2000), p. 455, 'what sort of a thing is this, which we call "organism plus environment"?'; "Form, Substance and Difference", 19th Annual Alfred Korzybski Memorial Lecture, 9 January 1970, Oceanic Institute, Hawaii, in ed. Richard Grossinger, *Ecology and Consciousness*, (North Atlantic Books, 1978) pp. 30, 32, Bateson 'aestheticised human experience and the mind/nature dichotomy, extending consciousness and self to interactions outside the body'; Anthropologist Tim Ingold also took up Bateson's question on the nature of mind, experience and ecology in *The Perception of the Environment; Essays on Livelihood, Dwelling and Skill*, (London and New York, Routledge, 2000), pp. 16–18.

[9] Stuart Shapiro, 'Caught in a web: the implications of ecology for radical symmetry', *Social Epistemology*, 11 (1997), 97–110, p. 98.

Selborne and Henry Thoreau of Walden as early exemplars of the former.[10] Both made meticulous records of the natural world and its inhabitants, but their environmental experiences were somewhat different. White's nature included the rural human population, Thoreau's yielded to it. White preceded the industrialisation of the British landscape, while Thoreau witnessed the rapid impacts of European land use in changing and depleting nature.

Nature was not separate from agriculture in eighteenth century Europe. Its inhabitants were in the fields and copses, where domesticated and natural species interacted. When Gilbert White roamed the fields and margins he watched nature in the thatched roofs and streams, and the woods were a source of resources. There were 'wilds', defined by the presence of mountains and the absence of historical relics of human habitation. In this rural idyll, the seasonal activities of farming families were part of the cycles of nature.

In eastern USA, a new nature was discovered 'pasturing freely where we never wander' in the forests and mountains, and it was being rolled-back by agriculture. Thoreau saw the landscape transformed from pockets of agriculture within a limitless wilderness to its inverse.[11] His emotional attachment to that nature saw him seek solitude within it and with its inhabitants, and to relate his spiritual reflections 'refreshed by the sight of inexhaustible vigor'.[12] The primitivist and conservationist view of Thoreau was shared by his mentor, Ralph Waldo Emerson and later by John Muir, contributing to ideas of 'pristine' nature as wilderness and movements for the preservation of natural areas.

The Arcadian spirit was one of deep immersion in and reverence for nature, but the unifying thread for ecology is close observation of behaviours, distributions, seasonal patterns and interactions among organisms. White's work became an inspiration for naturalists in the 1830s, including John L. Knapp, William Howitt and Charles Darwin.[13] The agricultural expansion, industrialisation and population growth that had such an impact on Thoreau also influenced the British roaming naturalists, visible in their sentimentality for a vanishing landscape. Howitt opened his 1831 *Book of Seasons*, a poetic celebration of the bucolic pleasures and certainty of English rural life, with the observation:

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[10] Donald Worster, *Nature's Economy. A History of Ecological Ideas*, (Cambridge, Cambridge University Press, 1994), (Originally published 1977, Sierra Club), p. 29, introduces 'imperial' ideas and approach as opposite to the 'arcadian'.

[11] Gordon Whitney and William Davis, 'From primitive woods to cultivated woodlots: Thoreau and the forest history of Concord, Massachusetts', *Journal of Forest History*, 30 (1986), 70–81.

[12] Henry David Thoreau, *Walden; or, Life in the Woods*, (Boston, 1854).

[13] John L. Knapp, *Journal of a Naturalist. Country Rambles in England*, (London, John Murray, 1829), Knapp prefaces his book with a dedication to White, who had impressed in him 'an ardent love of nature'; The young Charles Darwin had wanted simply to be 'parson naturalist' like White, see Worster 1994, p. 14.

> In truth, there is no spirit which it is more important to cherish, in a commercial people, as we are, than a spirit of attachment to Nature … It is a spirit which, however, as commerce advances, becomes more and more endangered by the very circumstance of our population being engulphed in great towns.[14]

For Howitt, who linked this 'love of nature' with the poets, it was an 'animating fellowship' and the 'natural aliment for human hearts'. Natural history provided continuity between science and art by blending objective 'direct knowledge and personal delight'.[15] With his two sons, Howitt tried his luck in Australia in the 1850s, but found a rapidly changing and less forgiving nature, where he was swept up in the social and environmental experiments of colonial and goldfields life.[16]

But the Imperial drive to hold nature fast 'in the spirit of Bacon' until she yields up her secrets, could also operate alongside the Arcadian tradition.[17] Many romantic naturalists were also empiricists in their concentration on collections, precise measurements, species numbers and Linnaean taxonomy, if not in the harnessing of nature for human material ends. These apparently disparate impulses were also more entangled with colonial expansion during the rapidly changing nineteenth century. The emphasis on agricultural development in settler societies brought a paradoxical interplay of improvement ideology and environmental awareness.[18] Even in the same individuals, faith in large-scale developments could co-exist with a moral respect for nature. There was no conflict when environmental change was proportionally small and nature was still perceived as limitless. Concern for the preservation of nature increased as the wildlands contracted to become islands in a sea of agriculture.

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[14] William Howitt, *The Book of the Seasons; or, a Calendar of Nature*, (London, H. Colburn and R. Bentley, 1831), pp. xvii, xviii, The book dealt with English wildlife and agricultural activities in each month, which Howitt embellished with passages by numerous poets, including his wife Mary Howitt; Thoreau had been impressed by Howitt's 'phenology' on reading the book in 1835, see Frank N. Egerton, 'History of Ecological Sciences, Part 39: Henry David Thoreau, Ecologist', *Bulletin of the Ecological Society of America*, (July 2011), 251–275, p. 252.

[15] Howitt 1831, p. xxvii; Lynn L. Merrill, *The Romance of Victorian Natural History*, (Oxford UK, Oxford University Press, 1989), p. 15, Merrill explains how natural history provided continuity between science and art, by blending objective observations and the theoretical atmosphere of science with the joyous response to seeing the detail and fact of concrete natural objects.

[16] Howitt 1831, p. 28, Howitt continued to contribute to natural history in Australia after his return to Britain and wrote of his colonial experience in *A Boy's Adventures in the Wilds of Australia, or Herbert's Notebook*, (Boston, Ticknor & Fields, 1854) and *Land, Labour and Gold. Two Years in Victoria*, (London, Longman, Brown, Green, Longmans & Roberts, 1858).

[17] *The South Australian Advertiser*, 5 September 1872, p. 3.

[18] James Beattie and John Stenhouse, 'Empire, environment and religion: God and the natural world in nineteenth-century New Zealand', *Environment and History*, 13 (4), (2007), 413–446.

A number of prominent nineteenth-century naturalists and entomologists were also artists, illustrating their own works.[19] Because of their size, beauty and diversity insects were ideal subjects for cabinet collections and for conjecture on taxonomic or phylogenetic relationships. Entomology struggled to shake off the label of hobbyists with green nets, but the limitless diversity revealed by naturalists on imperial explorations and insects' direct relevance to agriculture and human health greatly helped its scientific standing.[20]

In continental Europe, the advance of natural sciences, evolutionary theory and biogeographic concepts of distinct communities of interacting organisms, led to Ernst Haeckel's conceptual synthesis of humans and other organisms interacting with environment in the science of 'Oecologie'. Haeckel cited Humboldt and Darwin as the inspiration for his hope of 'mechanistic' explanations of all the relations 'partly organic, and partly inorganic' that affect the 'physiology' of individual organisms in the economy of nature.[21] He saw that populations vary relative to each other, but over time achieve a balance relative to their conditions of life. The European intellectual climate was ready for this 'holistic and contextual' vision for biological science unearthing the 'natural laws' operating at all levels, including the human, to explain the history and complexity of life.[22]

European plant geographers produced the first theoretical models in ecology by identifying patterns of growth forms and species association in relation to soil and climate. These were extended in the early twentieth century with concepts of succession and stable climax communities that were likened to superorganisms.[23] Animal ecology followed with studies of environmental effects on species traits and diversity, such as in restricted or extreme habitats, as well as description and generalisation of complex food webs. Entomological studies contributed many early examples to support the theoretical

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[19] Notably in Britain, Edward Donovan illustrated his own books, John Curtis trained as a lithographer and illustrated for Kirby and Spence, and John Westwood illustrated his own works. In Germany, Ernst Haeckel illustrated his own works.

[20] *South Australian Advertiser*, 9 September 1872, p. 3, even in 1928, Robin Tillyard repeated the general impression of 'queer old-fashioned men hunting butterflies with a net', *The Mercury*, 17 October 1929, p. 5.

[21] Frank Egerton, 'History of ecological sciences, part 47: Ernst Haeckel's ecology', *Bulletin of the Ecological Society of America*, 94 (3), (2013) 222–244, p. 226, 'Ecology' was among several lasting biological terms defined by the German zoologist. Haeckel's books were well-known in his lifetime; Anna Bramwell, *Ecology in the Twentieth Century: A History*, (New Haven & London, Yale University Press, 1996), p. 40, Bramwell also discusses how Haeckel's views were extended to the political sphere, and how other geographers and social scientists adapted them to seeing human agricultural activity within a framework of resource economics linked to formulae for organising and maintaining populations.

[22] E. D. Deveson, 'The Adelaide Philosophical Society and the Early Accommodation of the Darwin-Wallace Theory of Natural Selection', *Transactions of the Royal Society of South Australia*, 137 (2013), 67–83, pp. 73–75, In Adelaide, the spirit of free thought and scientific enquiry into all aspects of nature was epitomised by the 1860s 'Law in Nature' lecture series by Richard Davies Hanson. The lectures were 'holistic' in attempting to identify 'natural laws' unifying humans and nature, and even the course of human history.

[23] F. A. Clements, *Plant Succession: An Analysis of Development of Vegetation*, (Washington, Carnegie Institution, 1916).

underpinnings of ecology and evolution.[24] Insects were convenient experimental vehicles because of their abundance and short generation times, ease of sampling, rearing and dissection, their obvious population fluctuations and the practical-ethical benefits of studying pest species.

Animal ecology was established as a scientific discipline in the 1920s, through dedicated scientific journals and its consolidation in the first comprehensive textbooks.[25] These took the form of chapters on the constraints of each abiotic variable, sampling and numerical methods, and the developing concepts of niche, life histories, communities, competition and population growth. From the 1930s the application of mathematical and statistical techniques to enumerated empirical data allowed the formulation and testing of deterministic and then stochastic explanatory models, and these have continued as the mainstay of both applied and theoretical ecology.

The science of ecology blossomed in the late twentieth century, expanding into numerous theoretical areas underpinned by Darwinian theory and its associated concepts of fitness as the central explanatory model for behaviours, trait distributions, genetics, population biology and interspecies relations. However, ecology suffered a crisis of confidence over a lack of general testable laws, like those of the physical sciences, and failures of fit with deterministic models, while crisis often meant something different to those dealing with real-world environmental issues.[26] Systems theory gave a hope that if all potential variables were accounted for and enumerated, the principles driving each ecosystem would reveal underlying fundamental patterns and processes for generalisation. Borrowing from physics, ecosystems were viewed as integrated processes of matter and energy transfer.[27] Ecological science has been further reassured by the evolutionary framework, some metaphysical self-examination and a general theory based on numerous mature constituent models.[28]

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[24] B. Statzner, A. G. Hildrew and V. H. Resh, 'Species traits and environmental constraints: entomological research and the history of ecological theory', *Annual Review of Entomology* 46 (2001), 291–316, the authors present a historical framework of the early development of international ideas in animal ecology, focusing on contributions made by entomologists. They identify three overlapping conceptual lineages of investigation: species traits and ecological constraints (with associated concepts of succession and equilibrium), niche theory, and population demography based on logistic growth.

[25] Arthur S. Pearse, *Animal Ecology*, (New York, McGraw Hill, 1926); Charles Elton, *Animal Ecology*, (New York, Macmillan, 1927).

[26] Peter Turchin, 'Does population ecology have general laws?', *Oikos*, 94 (2001), 17–26, Turchin posits exponential growth and self-limitation through resource oscillations as basic laws.

[27] Eugene and Howard Odum, *Fundamentals of Ecology* was first published in 1953 and went through several editions.

[28] S. M. Scheiner and M. R. Willig, 'A general theory of ecology', *Theoretical Ecology*, 1 (2008), 21–28.

Ecology in Australia

Several historians have explored the emergence of Western ecological ideas in Australia. Tim Bonyhady finds examples in moves to preserve forests in Victoria as early as the 1860s.[29] Drew Hutton and Libby Connors traced the conservation ethic through the merging of natural history societies and grass-roots ornithologists' organisations for the preservation of species and wildlife habitats.[30] Martin Mulligan and Stuart Hill identify an attachment to the distinctive Australian landscape in visual art and literary movements as inherently ecological.[31] Many artists and writers became active in nature conservation movements, introducing the radical actions of 'political ecology' and later the rhetoric of ecocriticism. Later innovators from outside the academy, some of them farmers, who worked to establish systems of sustainable agricultural production are also featured as 'ecological pioneers'.

There was significant growth in Australian contributions to the wider science of ecology from the 1930s. It has been suggested that the unique and challenging Australian environment, and the ongoing crises resulting from the collision of native and alien species, fostered ecological understandings and demanded ecological solutions.[32] This 'scientific ecology' started as applied research on pest species, becoming increasingly quantitative and statistically sophisticated. Its scope widened to include physiology, reproduction and behaviour, nutrition, genetics and conservation biology.

The applied tasks of entomology presented opportunities to engage with ecological theory, including for those dealing with locusts and grasshoppers. Several overlapping historical trends are evident in locust science, from 'ecological natural history' through applied 'scientific ecology' to the start of 'pure ecology', where locusts are used as models for wider generalisations and theory. These trends in Australian ecology become evident through the practices and conjectures of the scientific players featured in the following chapters. Each scientist is also a representative of an era of wider, even global, ideas and influences.

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[29] Tim Bonyhady, *The Colonial Earth*, (Carlton Victoria, Miegunyah Press, 2000), pp. 108–112.

[30] Drew Hutton and Libby Connors, *History of the Australian Environment Movement*, (Cambridge, Cambridge University Press, 1999), the authors cite learned societies as places where the threat of extinction of native fauna was discussed along with the role of the Australian Ornithologists Union in protection for birds and their habitats.

[31] Martin Mulligan and Stuart Hill, *Ecological Pioneers: A Social History of Ecological Thought and Action*, (Cambridge, Cambridge University Press, 2001), the authors focus on numerous individuals: Georgina Molloy as an early naturalist, Australian impressionist and mid-century landscape expressionist painters, poets from Paterson to Judith Wright, novelists from Eleanor Dark to Patrick White, and conservationists from bushwalkers to protesters.

[32] Tom Griffiths, 'Environmental History, Australian Style', *Australian Historical Studies*, 46 (2015), 151–173, p. 171.

Before the 1930s, the dominant ecological view about Australian locust and grasshopper swarms was that they demonstrated the human disruption of the 'balance of nature'. This explanation went with the widespread perception that the outbreaks were becoming more frequent. After a promising early start to ecological observations in the 1840s, and the first physiological experiments in the 1880s, locust research turned to finding the means of destroying them. This led to an ecological impasse because of the effects of insecticides on other organisms. A return to fundamental ecological questions came in two pulses, first in the 1930s and then in the 1960s.

Mulligan and Hill select the work of Herbert Andrewartha and Charles Birch in South Australia on the demography and environmental limits of *A. cruciata* grasshoppers as the start of empirical scientific ecology, recognising that its institutional impetus came from the need to understand agricultural pests.[33] Andrewartha and Birch were part of the international growth of ecology and of its early adoption at the University of Adelaide. At the same time, Alexander Nicholson in Sydney developed ideas about trophic species interactions in an evolutionary framework. He formulated a mathematical model of dependencies in host-parasite population numbers that was relevant to the practices of biological control. These separate branches of early animal ecology were both funded by the federal government during the 1930s, as part of a national science project.

The science of locust ecology

The dominant world figure in twentieth-century locust ecology was Russian entomologist Boris Uvarov. His theory of phase change as phenotypic plasticity and the associated concept of 'outbreak areas' became the focus of locust research conducted by Australian entomologists from the 1930s to the 1970s. Migration, too, is such a characteristic feature of locust behaviour that it also became central to research on their ecology. It was an issue of conjecture as well as practical consequence. In the 1920s Uvarov rejected proposed teleological explanations such as lack of food sources, escaping parasites, avoiding overpopulation or locating new breeding grounds, asserting that the answer would be found in the study of their physiology.[34] He viewed locust migration as part of physiological development, similar to the 'nuptial flights' of termites and ants.[35]

Insects were known to occur in high altitude airstreams from the 1920s, but the movements of most were seen largely as passive dispersal.[36] The main insect agents in the development of an ecological theory of migration were aphids, moths and locusts. Several prominent entomological figures in

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[33] Mulligan and Hill 2001, pp. 167–177.

[34] B. P. Uvarov, *Locusts and Grasshoppers*, (London, Imperial Bureau of Entomology, 1928), pp. 87–88.

[35] Uvarov 1928, p. 303.

[36] C. G. Johnson, *Migration and Dispersal of Insects by Flight*, (London, Methuen, 1969), p. 297.

behavioural ecology and migration theory had considerable locust experience. Carrington B. Williams and John S. Kennedy both worked on locusts in Africa early in their careers and later generalised their observations of the distinct migratory behaviours in evolutionary terms.[37]

In the 1950s, Williams identified that migration with 'to and fro' movements occurred in many species of moth and butterfly, and that often dramatic movements in one direction were often matched by less conspicuous returns at another time. He argued from an evolutionary standpoint that migration was widespread but not always recognised, observing that 'a habit that is fatal to all individuals could not persist for countless generations'.[38] Large populations in insects such as locusts were therefore a requirement for successful migration, with its risk of high mortality, rather than its cause.

Kennedy studied locust behaviour in Sudan for Uvarov's Anti Locust Research Centre in the 1930s and worked on swarm control during World War II. On returning to Imperial College London, he developed experimental methods to study insect flight behaviours.[39] The idea that migration was an evolved behavioural adaptation, subject to selection forces, developed during the 1960s. Kennedy added clarity to concepts around migration in insects, identifying particular behaviours of sustained, undistracted and directed flight as migration, in contrast to foraging flights.[40]

Migration became the focus of research on Australian locusts in the 1960s, and studies of *C. terminifera* nocturnal migrations were seen as the key to its ecology and, potentially, to the control of plagues. Kennedy came to Australia in 1972, where he addressed the Australian Entomological Society on the evolution of insect behaviours and, like Uvarov, warned against finding teleological explanations for locust migrations.[41]

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[37] C. B. Williams, 'Observations on the Desert Locust in East Africa from July, 1828 to April, 1929', *Amani Memoirs, Annals of Applied Biology*, 20 (1933), 463–497, p. 477, Williams worked on locusts with the Egypt Ministry of Agriculture during 1921–27 and then as government entomologist of Tanganyika during 1927–29, before moving to Rothamsted Experiment Station in Britain.

[38] C. B. Williams, *Insect Migration*, (London, Collins, 1958), pp. 132, 143, 144.

[39] Kennedy conducted experiment on aphids, moths and mosquitoes.

[40] J. S. Kennedy, 'The migration of the desert locust (*Schistocerca gregaria* Forsk.).1. The behaviour of swarms II, a theory of long-range migrations', *Philosophical Transactions of Royal Society of London Series B*, 253, (1951), 163–290.

[41] J. S. Kennedy, 'The emergence of behaviour', *Proceedings of the 14th International Congress of Entomology*, (Canberra, 1972), pp. 19–27, p. 22.

The nature of environmental history

> *This blooming, buzzing, howling world of nature that surrounds us has always been a force in human life … despite all our efforts to free ourselves from that dependency until it is too late and crisis is upon us. Environmental history aims to bring back into our awareness that significance of nature and, with the aid of modern science, to discover some fresh truths about ourselves and our past.*
>
> Donald Worster, 1990.[42]

Environmental history emerged as a self-declared discipline in the 1970s, as awareness of the reciprocal relationship between humans and other entities of the environment became central to historical interpretations. The material contexts of changing physical conditions and interactions with other occupants of the surrounding environment were increasingly recognised as historically formative. Since all history takes 'place', it is entwined with the geography and ecology of places and the histories of other organisms. The dimension of environmental change is the unifying theoretical basis of this retelling of many human histories, including of agriculture, disease, science, state, empire, natural resource exploitation, industrialisation and waste, though in concomitant and adaptive rather than deterministic ways. These inherently material histories enhance the texture and understanding of social, political and cultural events where environmental forces have relevant explanatory significance. As Timothy Mitchell found in examining the interplay of engineering, colonialism, agriculture, mosquitoes and culture in modern Egypt, what happens in one place can be related to global forces of modernity, technology or capitalism, but it is infinitely more complex than any such abstract force has the inherent power to explain.[43]

As a new historical discipline, environmental history subjected itself to early historiographic scrutiny and found its many antecedents in earlier works of history and geography. It focused on the features it offered as distinct from, but also contributing to, other established histories as well as its relevance to present environmental issues of crisis and change. Environmental history is interdisciplinary and generalist, drawing on contributions and perspectives from historical geography, ecology, anthropology and other social and natural sciences.[44] Authors of environmental histories have come from these disciplines, sometimes in collaboration with historians, leading to the expansion of its

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[42] 'Transformations of the Earth: Toward an Agroecological Perspective in History', *The Journal of American History*, 76 (1990), 1087–1106, p. 1106.

[43] Timothy Mitchell, *Rule of Experts: Egypt, Techno-Politics, Modernity*, (Berkeley, University of California Press, 2002), p. 11.

[44] Crosby 1995, p. 1181, environmental historians must be 'generalists' because of the deep scales of time and space over which environmental changes occur and become realised. Crosby mentions the fundamental link of environmental history with ecology, but also archaeology, palaeohistory, sciences, as well as the impetus of the environmentalist movement of the 1960s and 1970s.

scope and output in recent decades. The discipline is inclusive, taking in an increasing array of human settings and concerns, including inequality and justice, environmentalism, technologies, cities, identities, art and human-organism relationships at micro- and global scales.

In 1990, Donald Worster identified several modes of environmental history. These were the reconstruction of past environments, their interactions with productive technologies and human social relations, and with ideologies, perceptions and ethics.[45] Similarly, in 2003 John McNeill identified ‘intellectual-cultural’ and ‘political’ strands in addition to the ‘material’ framework of physical and biological changes.[46] The former analysed representations of the environment and other species in literature and arts, and their role in forming identities or ‘place-making’. Integrating this ‘perception of environment’ and environmental understanding with cultural, political, ideological and emotional histories opened the way to ecocriticism and environmental humanities. The ‘political’ strand examines state policies and laws, acknowledging that governments and nation states play a primary role in regulating human actions and make decisions with environmental antecedents and consequences.[47] This led to challenges of conventional views of ‘nature’ and ‘wilderness’ and to the position of scientists in controlling knowledge about complex environmental problems.

Environmental history has continued to draw in ever-widening contributions. In a 2013 synthesis of the breadth of US environmental history, Paul Sutter added the human-built world, disease and health, and ‘the environmental-management state’ to the burgeoning of specific transnational agroenvironmental histories. But these categories barely touched on the scope of many new ‘deep, spatial, sensory, energy, disaster’ and technological environmental histories, as well as increasing engagement with social history and critical studies of science.[48] There has also been a ‘hybridisation’ of natural and cultural landscapes, of the social construction of science with its material constraint and direction, and of concepts of historical agency.[49]

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[45] Worster 1990, p. 1090.

[46] J. McNeill, ‘Observations on the nature and culture of environmental history’, *History and Theory*, 42 (2003), 5–43.

[47] Sverker Sörlin and Paul Warde, ‘Making the Environment Historical, an Introduction’, in eds. S. Sörlin and P. Warde, *Nature’s End: History and the Environment*, (Hampshire, Palgrave Macmillan, 2009), pp. 1–19, p. 14; see also E. M. Bsumek, A. Kinkela and M. A. Lawrence, eds. *Nation-states and the Global Environment: New Approaches to International Environmental History*, (Oxford, Oxford University Press, 2013), p. 2, in summarising the relevance of the transnational contributions to current environmental dilemmas, such as climate change, the editors state that ‘nations have long confronted the need to manage the features of the natural environment’ which extend beyond geopolitical boundaries.

[48] Paul S. Sutter, ‘The World with us: the state of American environmental history’, *Journal of American History*, 94 (2013), 94-119, p. 97.

[49] Linda Nash, ‘Furthering the environmental turn’, *Journal of American History*, 94 (2013), 131-135, p. 133.

Insects and locusts in environmental history

Insects have been a frequent subject in environmental histories since Edmund Russell's 2001 *War and Nature* that documented the parallel development of chemical warfare and insecticides. They are often linked with pesticide use and related institutional decision-making, because this relationship is unavoidable in the arena of modern humans' most fundamental environmental activity — agriculture.[50] The consequence of the 'war' against insects, both for other organisms and human health was the trigger for Rachel Carson's *Silent Spring*. However, most histories of human–insect relations cast insects as antagonists and 'unwanted others', rather than as companions or heralds of the procession of seasons. Insects' transnational colonisations, their interactions with environmental changes, geographies and policies of public health, even their representation in film, have featured in recent environmental histories.[51] Insects have also been a vehicle for exploring spatial, intellectual and sociological networks between scientists, framed by their institutional settings.[52]

In a foundational text of American environmental history, George Perkins Marsh's *Man and Nature* noted that one common response to the alteration of vegetation for European modes of land use was the increase of indigenous insect populations, wherever bird numbers were reduced.[53] In Alfred Crosby's 1986 *Ecological Imperialism*, reviewing the global ecological consequences of empire building, not only did Europe populate other regions with people, but its animals, plants and diseases were also either unknowingly or deliberately introduced. The arrival of these organisms was as much part of the subjugation of new lands and their existing inhabitants as the human arrivals.

Crosby argues that in temperate environments, the 'neo-Europes', this was most rapid and the changes fundamental. Dramatic examples come from the grassy biomes in North and South America, southern Africa, Australia and New Zealand. Insects were among those exchanges and many agricultural pests, both from Europe and the new lands, were introduced in imports of agricultural products.[54] The ecological changes were assisted by the relatively smooth transplantation of European domestic

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[50] E. M. Russell, *War and Nature; Fighting Humans and Insects with Chemicals from World War I to 'Silent Spring'*, (Cambridge, Cambridge University Press, 2001).

[51] The linkage between malaria mosquitoes and major engineering projects in Egypt are treated by Mitchell 2002, pp 19–54; between mosquitoes and yellow-fever by P. Suttor, 'Nature's agents or agents of empire – mosquitoes and the Panama Canal', *Isis*, 98 (4), (2004), 724–754; giant insects in film by W. M. Tutsui, 'Looking straight at "Them!" Understanding the big bug movies of the 1950s', *Environmental History*, 12 (2007), 237–253.

[52] S. Castonguay, 'Naturalising federalism: Insect outbreaks and centralisation of entomological research in Canada, 1884–1914', *Canadian Historical Review*, 85 (2004), 1–34.

[53] G. P. Marsh, *Man and Nature; or Physical Geography as Modified by Human Actions*, (New York, Charles Scribner, 1865), pp. 32–33.

[54] E. Deveson, 'Parasites, politics and public science: the promotion of biological control in Western Australia, 1900–1910', *British Journal for the History of Science*, 49, (2016), 231–258.

livestock, where 'the efficiency and speed that they altered the environment was greater than any machine devised'.[55] These grasslands, however, were also the habitats of native grasshoppers and locusts, some of which responded not with a decline but with increasing sporadic irruptions.

Spreading swarms of locusts have been an environmental challenge for farmers and their administrators for millenia. They were accompanied by organised collective actions, public extermination campaigns and recourse to religious supplication. Reconstructing the history of plagues in relation to climate and institutional responses are subjects of recent environmental histories. China has the longest continuous historical record of locust infestations and they have been linked to rainfall cycles.[56] Chinese Imperial Court records also document proactive public locust extermination campaigns during the Tang dynasty, with political as well as practical motives, organised by the Imperial Court as early as 715 CE.[57]

Locusts regularly invaded southern Europe, occasionally spreading to northern agricultural regions. Medieval responses included ecclesiastical court actions, where locusts were tried for crop damage and enjoined to depart, as well as mandated collective actions organised by regional city-state institutions.[58] Similar remedies and extermination methods were developed in Asia and Europe. They included driving nymphs into trenches, chasing adults out of fields, cultivating egg-laying sites and burning infested vegetation.

Grasshoppers and locusts are in some ways emblems of environmental history. When Boris Uvarov pointed out in the 1950s that many of the world's locust and grasshopper problems were the result of human-induced environmental change, his symbolic use of the Arabic name for the Moroccan locust, 'djerad el adami' or 'man's locust', a pest of overgrazed land, recognised that this had long been

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[55] Alfred Crosby, *Ecological Imperialism: The Biological Expansion of Europe 900–1900*, (Cambridge, Cambridge University Press, 1986), p. 173.

[56] L. C. Stige, K. -S. Chan, Z. Zhang, D. Frank and S. D. Stenseth, 'Thousand year-long Chinese time series reveals climatic forcing of decadal locust dynamics', *Proceedings of the National Academy of Science USA*, 104 (2007), 116188–16193; several early Chinese texts referring to locusts are listed in S. T. Behmer and A. Joern, 'Insect Herbivore Outbreaks Viewed Through a Physiological Framework: Insights from Orthoptera', in eds. P. Barbossa, D.K. Letourneau and A. A. Agrawal, *Insect Outbreaks Revisited*, (West Sussex, Wiley Blackwell, 2012), pp. 3–20, p. 3.

[57] N. Harry Rothschild, 'Sovereignty, virtue and disaster management: chief Minister Yao Chong's proactive handling of the locust plague of 715–16', *Environmental History*, 17 (4), (2012), 783–812; Shin-Yi Hsu, 'The cultural ecology of the locust cult in traditional China', *Annals of the Association of American Geographers*, 59 (4), (1969), 731–752, in the eighteenth and nineteenth centuries, temples were constructed by swarm-affected communities as part of a 'locust cult'.

[58] E. P. Evans, *Criminal Prosecution and Capital Punishment of Animals*, (London, Heineman, 1906); J. Sprenger, 'An ocean of locusts – the perception and control of insect pests in Prussian Brandenberg (1700–1850)', *Environment and History*, 21 (2015), 513–536.

known.[59] Uvarov's warning related to the economic development of arid lands at a time when desertification, particularly in North Africa, became an international concern. Farming and pastoral practices have altered or created habitats in ways that resulted in increased or reduced swarming of acridid species in various parts of the world.[60] This was noticed as early as the 1840s in Australia, and again in the 1940s when scientists investigated the circumstances and locations where locust swarming occurred. However, the direct relationship between environmental change resulting from agricultural land use and increased swarming in the Australian species has not previously been historically examined.

Conversely, declines of grasshoppers have been used to represent the level of human environmental disturbance to their habitats. In central Asia, comparison of grasshopper assemblages recorded in the 1980s and the 1930s in the grassland valleys of Tajikistan showed a change in numbers of species. This was attributed to environmental changes due to irrigation, but two of the species apparently displaced since the 1930s, the Moroccan and Italian locusts, are indicators of agriculturally modified landscapes.[61] In Wisconsin USA in 2005, the diversity of grasshopper species in recovery prairie areas was used as an indicator of their relative ecological health, while some of those species were being sprayed by aircraft as rangeland pests in states further west.[62]

Analyses of the political geography of environmental challenges have focused on the relative spatial scales of ecosystems and the institutions that are created to manage them. Inappropriate management

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[59] B. P. Uvarov, 'The Locust and grasshopper problem in relation to the development of arid lands', in *The Future of Arid Lands*, (Washington, American Association for the Advancement of Science, 1956), pp. 383–389, p. 384.

[60] Examples of land use change resulting in increased swarming: R. A. Farrow, 'Causes of recent changes in the distribution and abundance of the migratory locust (Locusta migratoria L.) in Australia in relation to plagues', CSIRO Division of Entomology Report No. 9, 1979; R. A. Farrow, 'Effect of Changing land use on outbreaks of the tropical migratory locust *Locusta migratoria migratorioides* (R. & F)', *International Journal of Tropical Insect Science*, 8 (4,5,6) (1988), 966–975; A. V. Latchininsky, 'Moroccan Locust *Dociostaurus maroccanus* (Thunberg, 1815): a faunistic rarity or an important economic pest?', *Journal of Insect Conservation*, 2 (1998), 167–178; A. J. Cease, J. F. Elser, C. F. Ford, S. Hao, L. Kang, and J. F. Harrison, 'Heavy livestock grazing promotes locust outbreaks by lowering plant Nitrogen content', *Science*, 335 (2012), 467–469; B. P. Uvarov, 'The aridity factor in the ecology of locust and grasshoppers of the Old World', *Arid Zone Research: Human and Animal Ecology*, (Paris, UNESCO, 1957), pp. 164–198; L. L. Barrientos, 'The present state of the locust and grasshopper problem in Brazil', *Journal of Orthoptera Research*, 4 (1995), 61–64; M. M. Cigliano, S. Torrusio and M. L. de Wisiecki, 'Grasshopper (Orpthoptera: Acrididae) community composition and temporal variation in the Pampas, Argentina', *Journal of Orthoptera Research*, 11 (2002) 215–221; L. Benfekih, B. Chara and B. Doumandjie-Mitiche, 'Influence of anthropogenic impact on habitats and swarming risks of *Dociostaurus maroccanus* and *Locusta migratoria* (Othoptera: Acrididae) in the Algerian Sahara and the semiarid zone', *Journal of Orthoptera Research*, 11 (2002), 243–250.

[61] A. A. Pokivailov, 'Long-term dynamics of orthopteran assemblages (Orthoptera) of the Hissar Valley (Tajikistan)', *Entomological Review*, 87 (4), (2007), 383–393.

[62] C. R. Bomar, 'Comparison of grasshopper (Orthoptera: Acrididae) communities in remnant and reconstructed prairies in Western Wisconsin', *Journal of Orthoptera Research*, 10 (2001), 105–112.

of these problems can result from a mismatch between the ecosystem-wide dimension of natural resources and the governance structures of response. Locust plagues are good examples of such social-ecological problems, because they frequently cross jurisdictional boundaries and their control is an expression of state authority. The fostering of technoscientific methods of locust surveillance and control has been seen as bolstering French and British colonial power in North Africa.[63] Conversely, the increase in locust infestations and chemical pesticide use in Kazakhstan after the collapse of the Soviet Union was attributed to the cessation of state-organised integrated monitoring and collective management.[64]

The environmental background to Australian locust history

The effects of pastoralism on Australian environments have been described by numerous historians and scientists, several emphasising the previously absent, hoofed ungulates compacting soils, silting streams and altering vegetation composition.[65] The impacts have been described as 'apocalyptic', a 'cataclysm, a watershed beyond which ecosystems were permanently changed, with no steady state in sight'.[66] However, while many examples of the changes to vegetation and vertebrate communities have been detailed, the effects on insect distribution and abundance have received little attention.

In a detailed historical analysis of the nature of pre-European vegetation structure and composition, Bill Gammage argues that the entire continental landscape was carefully shaped by Aboriginal burning regimes, intricately managed to maximise the range of animal and plant resources.[67] Many early descriptions and art works likened the '1788 vegetation' to an 'Englishman's Park', a landscape familiar to many explorers and early settlers. Beneath the open tree cover dense, tall perennial grasses, dominated by *Themeda triandra*, 'kangaroo' or 'red oat' grass, grew up to the horses' flanks and they

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[63] Claude Peloquin, 'Locust Swarms and the spatial techno-politics of the French Resistance in World War II', *Geoforum*, 49 (2013), 103–113.

[64] K. Tolubayev, K. Jansen and A. van Huis, 'Locust control in transition: the loss and reinvention of collective action in post-Soviet Kazakhstan', *Ecology and Society*, 12 (2), (2007), article 38, https://www.ecologyandsociety.org/vol12/iss2/art38/, viewed 11 September 2013; James M. Acheson, 'Institutional Failure in Resource Management', *Annual Review of Anthropology*, 35 (2006), 117–134.

[65] Eric Rolls, 'The Nature of Australia', in eds. T. Griffiths and L. Robin, *Ecology and Empire*, (Melbourne, Melbourne University Press, 1997), pp. 35–45; J. C. Noble and D. J. Tongway, 'Herbivores in Arid and Semi-Arid Rangelands', in eds. J. S. Russell and R. F. Isbell, *Australian Soils: the Human Impact*, (Brisbane, University of Queensland Press, 1986), pp 243–270, p. 244, the authors question the lack of data behind the assumption of hard-hoofed animals causing greater erosional impact, citing data on static foot pressures of different animals.

[66] D. A. Adamson and M. D. Fox, 'Change in Australian vegetation since European settlement', in ed. J. M. B. Smith, *A History of Australian Vegetation*, (Sydney, McGraw Hill, 1982), pp. 109–146.

[67] Bill Gammage, *The Biggest Estate on Earth: How Aborigines Made Australia*, (Sydney, Allen and Unwin, 2011), Gammage uses historical descriptions and contemporary Aboriginal explanations of responsibilities and skills in managing the land to make a compelling case for intricate seasonal fire management regimes. He cites over 45 separate references by explorers or early settlers of 'Englishman's Park' or 'Parklands', and also to early descriptions of the density and composition of grasslands.

sank to their fetlocks in the soft, spongy soils.[68] The rapid disappearance of *Themeda* under heavy sheep grazing was noticed by many early settlers. In the Victorian Wimmera it was already being replaced by short, wiry annuals in the 1840s at the same time as the soils became hard packed, with eroded gullies and silted creeks.[69]

The realisation that livestock were fundamentally altering the landscape came in the 1860s, at the same time that the need for preservation of forest resources emerged around the Victorian gold diggings. At the Victorian Acclimatisation Society in 1864 Edward Wilson put forward the view that mass tree death would result from the trampling of their hooves:

> Any one who had watched pretty closely the progress of settlement, will have noticed that the soil became firmer as it was trampled down by cattle, sheep … and the crust of the soil acquired a hardness not known before the country was occupied by European animals.[70]

He was at a loss to know what could be done to save the great bulk of the trees in the country areas to prevent the destruction of timber on 'such a scale as to influence climate'.

When *Man and Nature* was published in 1864, George Perkins Marsh wrote that newly settled Australia could be a test case of the effects of 'civilised man' on forest and meadow, but the experiment was already well under way. Squatting was a rapid and uncontrolled land grab of a million square kilometres carried out by a few thousand men.[71] The limiting resource was not land, but grass.[72] The 'ungulate irruption' continued with increasing momentum in the following decades and was slowed only by droughts. The Australian boom mentality of unlimited resources, driven by speculation in land and livestock, and by immigration, was a shared vision of future greatness. In characterising that mid-century mood, historian James Belich has argued that to question the direction of progress would have been to challenge one's own reason for being there.[73]

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[68] Gammage 2011, pp. 151, 205, 269; C. E. W. Bean, *On the Wool Track*, (Sydney, Angus and Robertson, 1945), p. 6, near Menindee a settler told of soils in which his horse had first sunk up to its fetlocks that had become hard and bare.

[69] Neill Barr and John Cary, *Greening a Brown Land: the Australian search for Sustainable Land Use*, (Melbourne, MacMillan Educational, 1992), pp. 14–18.

[70] *The Courier*, 10 March 1864, p. 3.

[71] The sheep owners often made exploratory journeys, but the business of establishing and maintaining the sheep was done by their rural employees. Many shepherds were ex-convicts, usually poorly paid and poorly resourced, see Philip McMichael, *Settlers and the Agrarian Question: Capitalism in Colonial Australia*, (Cambridge, Cambridge University Press, 1984).

[72] G. P. Marsh, *Man and Nature; or Physical Geography as Modified by Human Action*, (New York, Charles Scribner, 1864), p. 51.

[73] James Belich, *Replenishing the Earth. The Settler Revolution and the Rise of the Anglo World, 1783–1939*. (Oxford, Oxford University Press, 2009) pp. 203–204, the boom was not driven by the export of staples, as

For the squatter, the real value of sheep before the 1870s was in breeding more to sell to maintain the rush. As the distance to port increased, the cost of shearing, washing, baling and getting wool to market was less of an incentive than the prospect of an eighty percent lambing rate (Figure 2.2). In the rush for new land in Queensland in the 1860s, Cuthbert Fetherstonhaugh recalled the 'lure was to take up a big area, then in three years when our sheep had increased, to sell out at a good big price and repeat the performance'.[74] For the farmer as well, particularly in South Australia, new land gave higher yields than soils exhausted after several years of cropping, so an 'earth hunger' fuelled a continual movement to new land releases.[75]

By the 1890s the landscape over vast areas of heavily-stocked country had changed from being covered in dense, drought-hardy perennial grasses to carrying sparse ephemerals, and from having deep, soft soils to compacted, scalded and often bare ground. That this occurred in a single human generation is considered by historians to be phenomenal, but Leigh Dale finds evidence in C. E. W. Bean's 1945 environmental history, *On the Wool Track*, that irreversible changes could occur in some places in one bad season.[76] Similar descriptions of rapid vegetation change came from squatters in Victoria in the early 1840s. Robyn Ballinger cites E. M. Curr noticing several saltbush species virtually disappear in two years in the Terricks area of northern Victoria.[77] After the Federation drought in the early 1900s, the once well-grassed plains were an unrecognisable 'howling wilderness' of sand-drift and bare ground.[78]

This rapid transformation of landscape is the backdrop to the environmental history of locusts and grasshoppers in southern Australia. Settlers altered their habitats, and the 'locusts' impacted on agricultural production, changing the settlers' image of the land. In addition to this reciprocal relationship with humans and their concerns, ecological interactions with certain other animal groups run through the southern locusts' history. They are livestock, native birds and other insects. It will be argued that sheep had an indirect effect by modifying the environment in a way that created and expanded habitats favoured by the insects. Their swarms then competed with the sheep for the grass and the farmers for crops. Birds were such visible predators of the pests that they became a symbol of

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imports exceeded exports in a boom. Belich cites one British Government migration agency finding 300,000 settlers for Australia between 1843 and 1869, p. 193.

[74] Cuthbert Fetherstonhaugh, *After Many Days: Being the Reminiscences of Cuthbert Fetherstonhaugh*, (Sydney, John Andrew, 1918), p. 206.

[75] *Bendigo Advertiser*, 26 September 1876, p. 3.

[76] L. Dale, 'Empire's proxy: sheep and the colonial environment', in ed. H. Tiffin, *Five Emus and the King of Siam: Environment and Empire, Cross/Cultures 92*, (Amsterdam, Rodopi B.V., 2007), pp 1–14, pp. 5–7.

[77] Robyn Ballinger, *An Inch of Rain*, (North Melbourne, Australian Scholarly Publishing, 2012), p. 27, cites Edward Curr's *Reminiscences of Squatting in Victoria*, p. 83.

[78] *Albury Banner and Wodonga Express*, 20 October 1899, p. 25, describing the country along the Darling River.

the humans' negative impact on the natural environment, disturbing pre-existing ecological interactions — 'the balance of nature'. The decline of insectivorous birds became the explanation for an increase in locust swarming. Relationships with other invertebrates, particularly insect parasites and predators of the locusts, was a recurring thread in the hope of finding scientific solutions to the locust problem.

Figure 2.2. Woolwash on Natiola Creek, Momba Station, northeast of Wilcannia, NSW. ca, 1870s. The labour involved in processing wool before transport is evident (Frederick Bonney, National Library of Australia, Canberra. obj. 147333242-1).

The longer environmental history of Australian locusts

The locust has a much longer history than that of European description. It was known to the Aboriginal inhabitants of its inland habitats and so were details of its ecology. Theirs was an oral and visual symbolic history, from which little has been documented, although some well-known grasshopper species were clearly identified.[79] Zoologist Walter Baldwin Spencer recorded one name for the locust in northern South Australia in 1894.[80] Two other sources indicate that *C. terminifera*

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[79] Leichardt's grasshopper, *Petasida ephippigera*, was known by Jawoyn and Gudjeibni people of western Arnhem Land as a harbinger of the wet season.

[80] W. B. Spencer, 'Horn expedition to Central Australia Diary', *Spencer and Gillen: a Journey through Aboriginal Australia*, pp. 3–5, http://spencerandgillen.net/objects/50ce72f4023fd7358c8a938e, accessed 29 September 2016, on May 5 1894 near Bopeechee, west of Maree, Spencer recorded an Aboriginal name for locusts,

was known and closely observed, while numerous records show they were also an opportune food source.

In 1935, the private owner of a local museum at Kyancutta on South Australia's Eyre Peninsula, Robert Arthur Buddicom, (alias Robert Bedford) sold two Aboriginal engraved artefacts to the British Museum. These were stone 'tjurungas' he had collected from Aboriginal people some years earlier, along with documentation of the significance of their motifs. One of the objects was a large engraved oval stone from the Ngalia people of north-western South Australia, depicting the 'tjukurpa' of the 'Tonanga' grasshopper totem.[81] The story is of the grasshoppers' travels in numbers between different named places near the MacDonnell Ranges, leaving 'trails', entering the ground and emerging again, flying up and returning, and multiplying after rain. The insect was clearly well-known, and at times prominent in the landscape. These details are suggestive of the ecology of the locust, *C. terminifera*. The long-distance movements and the sequential entry and re-emergence from the ground after rains are not the dynamics of any grasshopper, and few other known species would match those descriptions.

Another possible link to the locust comes from the historical period. Erlikilyika (1865–1930), a southern Arrernte man, also known by the English name Jim Kite, was an artist and sculptor who accompanied Spencer and Gillen to the Northern Territory in 1901. He later settled at Charlotte Waters in his homeland of northern South Australia and was well-known for his art works, which he sold to passing travellers and exhibited in Adelaide in 1913. Erlikilyika's genre included distinctive miniature kaolin sculptures or tablets, depicting people, animals and closely observed insects. Among the works obtained from the 1913 exhibition by Herbert Basedow are two depicting 'grasshoppers', which were named locusts at that time. The shape and patterning of one of the sculptures bear several characteristics resembling the locust (Figure 2.3).

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indildja, as they were 'fairly plentiful' at the time. As the expedition zoologist, and the first chair of Biology at Melbourne University, Baldwin Spencer was likely to have been familiar with the locust that caused plagues in Victoria in 1890–91 and 1894–95.

[81] H. T. Braunholtz, 'Two Stone "Churinga" from Central Australia', *The British Museum Quarterly*, 10, (1), (1935), 26–27, the actions and increase of the 'Tonanga' may have been linked to fertility and to knowledge of habitats in productive condition; in a 1976 book *New and Old Aboriginal Art*, Roman Black used the 'grasshopper tjarunga' as an example of traditional practices, and redrew the motifs, providing a key to their meanings, following Buddicom's documentation.

Figure 2.3. Erlikilyika, *Locust,* from the 1913 exhibition of works in Adelaide (L 50, W 40, H 70 mm), (National Museum of Australia).[82]

The raised head, constricted thorax, dark shanks and irregular dark mottled patches on the wings all suggest *C. terminifera*. The sculpture originally included antennae.[83] A visitor to the exhibition described the locust sculptures as subtly coloured in green and brown, which would preclude many other common grasshoppers of the region. Indirect evidence that the locust is a particular species can be seen in Erlikilyika's other works that represent clearly identifiable species.[84] One sculpture depicts the culturally significant Yipirinya caterpillar, *Hyles livornicoides*, which is shown in sequential life stages of moth, caterpillar and pupa (Figure 2.4).[85] Around the life history sequence on the sculpture is a beetle with characteristics of a predatory *Calosoma* species, known as caterpillar hunters, and a leaf-tailed gecko. Also prominently depicted is another large predatory beetle, unmistakably *Euryscaphus waterhousei*.[86] Like the locust, the Yipirinya produces abundant populations that cluster

[82] Herbert Basedow collection (oai:nma.gov.au:4:5754-1985.0060.0788).

[83] *The Australasian*, 2 August 1913, pp. 58, 62; other possible features are the pale stripe over the head and the triangular mark below the eye.

[84] Several tablets depict the desert banded snake.

[85] National Museum of Australia, Erlikilyika collection, image (oai:nma.gov.au:8:4016-1985.0060.0799).

[86] Geoff Monteith (Queensland Museum) and Chris Reid (Australian Museum) provided identification of *Calosoma* and *Euryscaphus waterho*usei, based on the image of the kaolin carving by Erlikilyika, held in the collection of the National Museum of Australia, (oai:nma.gov.au:5:4056 - 1985.0060.0800).

on the ground in wet years. The sculpture shows the complete life history and trophic ecology of the Yipirinya, as Erlikilyika explained at the exhibition in 1913.[87]

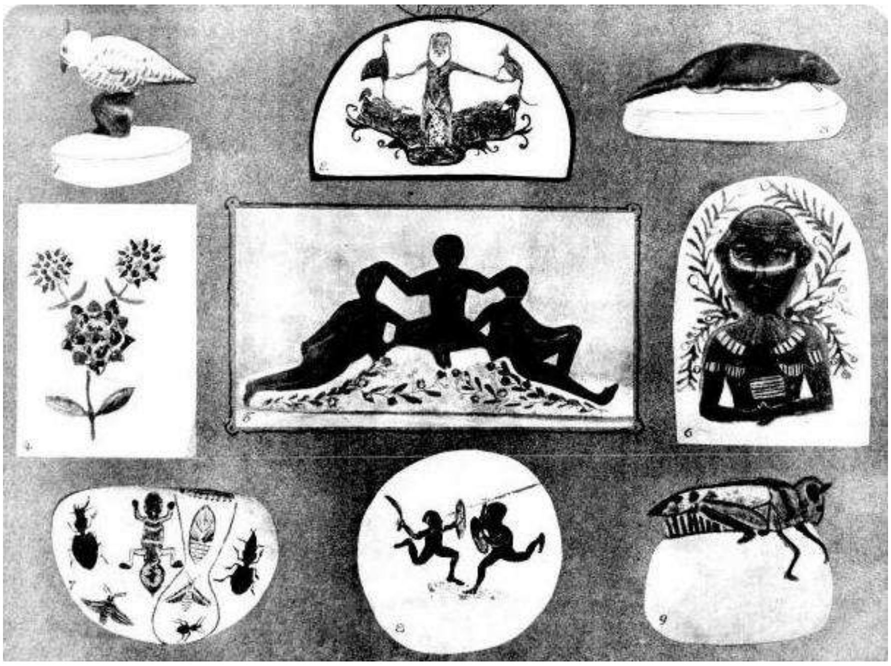

Figure 2.4. Erlikilyika's drawing of some of his 1913 exhibited works in Adelaide. The Yipirinya life cycle is on the lower left and the locust on the lower right, *The Australasian*, 2 August 1913, p. 58.

Both of these possible depictions of the locust come from its arid habitat in northern South Australia, where the 'boom and bust' population cycles linked to rainfall would have been be apparent. They contrast starkly with records of Aboriginal unfamiliarity with the grasshopper *A. cruciata* around Adelaide in the 1840s, where swarms were said to be previously unknown. Similarly, when swarms of *A. cruciata* appeared at Mullewa in WA in the 1870s, the species was unknown to local Aboriginal people.[88]

A short history of the histories of science

> *In these modern times, when emigration has opened so many new stores of insect life, it is curious to observe the changes which have occurred, which in Entomology … have been more the case than in any other branch of Natural History. The great Linné, though he must*

[87] *Telegraph*, 11 August 1913, p. 12, 'glossy coats of faint green, touched here and there with faint brown'. The telegraph officer at Charlotte Waters, H. O. Kearnan, organised the exhibition in Adelaide. In an interview, Kite describes the life history of the caterpillar, named 'Oolamunga', 'he go down in ground, walk about. Rain come, then "undea". He fly. All the same this way', the black finger points to "undea", which appears to be winging its course … to the freedom of the world, seen through the tiny hole. Then there is shown a beetle. 'That fellar catch him and eat him up'.

[88] *The Inquirer and Commercial News*, 15 November 1871, p. 2, Aborigines did 'not remember ever seeing anything like this plague before and have no name for the insect'.

have been aware that his system was limited and very incomplete (even after employing a life in the development and classification of every branch of this interesting and engrossing science), could hardly have imagined what great alterations and extensive additions would have been made … many of the divisions considered for some time only as genera, have not only been raised to the title of families containing other genera, but in many cases to classes containing several families.

Charles Wilson, 1841.[89]

In 1841, Charles Wilson in Adelaide reflected on the rapid reorganisation of insect taxonomy resulting from the age of discovery, imperial explorations and colonisation. The rise of natural sciences in the nineteenth century also changed ideas about history; that its methods could be codified and made scientific or that human events might follow the same underlying natural laws.[90] It also gave to history a self-reflection, a historiography, as its writers engaged with previous versions of the same events, also needing explanation. History's professionalisation and the attentions of philosophers turned its focus inwards during the twentieth century to examine history's own narratives of events in the past. These involutions led to a postmodern 'crisis' of history in the 1970s and 1980s, when its purpose, its claim to producing valid knowledge, its methodologies and even its identity as other than fiction or myth were challenged.[91] Historians were forced to see what and how they wrote as being governed by the same social forces and intellectual fashions as their subjects.

Early histories of science were often lists of discoveries made by inspired individuals, struggling alone and often against ideological dogma, but contributing to its inevitable and cumulative progress. This might have suggested the power of ideas to gain currency and be maintained within the social milieu of practitioners, but the status science gained in the twentieth century as objective, abstract and concerned with 'truth' seemed to set it outside such scrutiny. The tendency of scientists to view their heroes idealistically, as more-than-human and removed from social influence, coloured many 'involved' histories.[92] But those narratives, too, came under historiographic re-examination, which

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[89] C. A. Wilson, 29 June 1841, 'Natural History of the Colony, No. 16', *South Australian Register*, 10 July 1841, p. 4.

[90] David Livingstone, 'The geography of Darwinism', *Interdisciplinary Science Reviews*, 31 (2006), 32–41, p. 33, Livingstone cites Foucault that the nineteenth-century preoccupation was time, against the present 'epoch of space'; The nineteenth-century historicist preoccupation with time and the course of civilisation, class and nation spawned new specialised frameworks for exploring economic, political, social and cultural explanations of human events.

[91] Roger Chartier, 'History, Time and Space', *Republics of Letters*, 2 (2), (2011), 1–13, Chartier takes three examples of the epistemological challenges that confronted history in the 1970s by examining the writings of Paul Veyne, Haydon White and Michel de Cerceau; Anne Curthoys and John Docker, *Is History Fiction?*, (Sydney, University of NSW Press, 2010), the authors follow the historiography of the paradox of the narrative device in attempting to produce a true representation of the past.

[92] P. G. Abir-Am, 'How scientists view their heroes', *Journal of the History of Biology*, 15 (2), 1982, 281–315, Abir-am uses treatments of the career of Jaques Monod at the Pasteur Institute to show how scientist-

found frequent demonstrations of individuals developing theories through their interactions with contemporaries and ideas circulating more widely in society.

When the sociologists turned their irreverent attention to scientists and their practices, they showed them to be as human as everyone else.[93] Ludwig Fleck pioneered a sociology of science in the 1930s, viewing its observations and experiments as pre-conditioned by styles of thought. Scientific 'facts' were determined within 'thought collectives'; communities of initiated people exchanging ideas that are constrained within hierarchies of esoteric knowledge.[94] Karl Popper theorised the progress of scientific knowledge as the cumulative addition of facts and theories through an objective process of 'falsification' of propositions.[95] Thomas Kuhn revolutionised the way its progress was conceived, being punctuated by radical advances made from outside the 'paradigms' established by the cognitive frameworks of 'orthodox knowledge'.[96]

Other sociologists, notably Pierre Bourdieu, scrutinised the impartiality principle of scientists in applying the universal social construct of 'habitus', or norms, to the scientific 'field'.[97] Bourdieu proposed that counter to the values of intellectual openness, self-interest, even subconsciously, acted to gain the valued rewards of the community: the 'scientific capital' of recognition, publications or grants. Authority structures suppressed 'intellectual deviance' by defining scientific facts, relevant questions and how to address them. This model of scientific practice has been criticised as closed to radical changes by missing the creative effects of individual agency, interactions and collaborations across disciplines, and the 'utopian' group motivational threads of Karl Manheim.[98]

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historians contribute to and align with myths of precedence, genius and objective disinterest; Anna Bramwell, *Ecology in the Twentieth Century: a History*, (New Haven and London, Yale University Press, 1996), p. 13.

[93] They viewed all thoughts and activities at individual, group and institutional levels through the prism of social motivations and collective views.

[94] Ludwig Fleck, *Genesis and Development of a Scientific Fact*, eds. T. J. Tren and R. K. Merton, (Chicago, University of Chicago Press, 1979), (original 1935 in German), pp. 98–105. Fleck's work was not translated from German to English until the 1970s, so much reinvention was done in Anglophone circles.

[95] Michael Mulkay, *Sociology of Science: A Sociological Pilgrimage*, (Milton Keynes, Open University Press, 1991), pp. 109–119.

[96] Stephen Webster, *Thinking about Biology*, (Cambridge, Cambridge University Press, 2003), pp. 33–35.

[97] 'Habitus' is defined as normative patterns of conduct and thought.

[98] D. L. Swartz, 'The sociology of habit: the perspective of Pierre Bordieu', *The Occupational Therapy Journal of Research,* 22 (2002), 61S-69S, Bourdieu's model of scientific practice was closed to radical changes, although the 'habitus' concept allowed for diverse individual dispositions; O. Lizardo, 'The cognitive origins of Bourdieu's habitus', *Journal for the Theory of Social Behaviour*, 34 (2004), 375–401, Lizardo identifies the roots of 'habitus' in Levi Strauss' 'structuralism', a useful and flexible way to conceptualise agency and the ability to transform social structure; R. M. Simon, 'Habitus and Utopia in Science: Bordieu, Manheim, and the Role of Specialties in the Scientific Field', S*tudies in the Sociology of Science*, 2 (1), (2011), 22–36.

Against this unsettling background of scientific knowledge being 'socially constructed', historians were still faced with its continuous and cumulative expansion, the obvious reductive and emergent refinement of this body of knowledge and, through its applications, the fundamental impacts and consequences on how people live. They attempted more than just 'setting the record straight' on precedence and influences, historians of science examined how knowledge operates in different contexts and is converted to specific actions in different places. Focus turned to the sites of production, means of communication and uses of scientific knowledge, advancing and contesting comparative models of its diffusion, exchange and translation.[99]

Science was also examined as cultural practice, through human-material operations and its close linkages with advances in technology, mathematics, statistics and instrumentation.[100] The detailed experience of science could be examined in micro-histories, but it was also enmeshed with political, economic, colonial and institutional histories, operating within broader transnational and global trends. Academic science blossomed and public science was created in parallel with the rise of the nation state.[101] Science is a collective effort that results in gradual refinement of concepts and theories, but history inevitably highlights its big names.

Since the 1970s, contributions by French philosophers and the 'sociology of knowledge' school have influenced ways of examining the processes and places of scientific activity. Michel Foucault's critical analysis brought a radical view of the history of knowledge, through novel interpretations of the distinctly modern way it was socially defined and used. Focusing on the places and institutions of social control, he redefined 'discourse' as the setting of contexts and limits for what can be known and expressed, and saw 'power' as necessary for the creation of knowledge as well as its use.[102]

Bruno Latour also examined science as emerging from social and institutional interactions, but within the materiality of settings that also come with many other inhabitants. He ascribed agency to all relevant entities, human and non-human, technological and environmental in 'heterogeneous

[99] G. Basalla, 'The spread of western science', *Science*, 156 [3775], (1967), 611–622, Basalla's early model of the diffusion of scientific knowledge in the colonial context introduced the terms 'metropolitan' and 'peripheral' centres of knowledge.

[100] Andrew Pickering, 'Sociology of knowledge and the sociology of scientific knowledge', *Social Epistemology*, 11 (2), (1997), 187–192.

[101] Hilary Rose and Steven Rose, *Science and Society,* (Harmondsworth England, Pelican Books, 1970), the authors discuss the rise of public science and the disciplines of chemistry and physics in Britain, largely as a response to its wartime applications.

[102] Foucault's early focus was on the places where scientific knowledge was accepted and practiced in institutions of social control, identifying the power relations in exercising control of people's bodies, of surveillance and of 'truth' over domains such as the abnormal or criminal.

networks'.[103] This methodological approach was refined by 'sociologists of scientific knowledge', who identified familiar processes of translation, enrolment, explication as necessary relationships in the production and consolidation of scientific knowledge.

Latour and Steve Woolgar even entered the unfamiliar culture of the laboratory space as ethnographers, observing the actions of scientists as arcane rituals involving various instruments. The purpose of these 'rituals' was converting statements into 'scientific facts' that that were constituted in 'inscriptions', such as graphs, tables, diagrams and texts.[104] That way of seeing science in action would ring true for many current scientists. The 'actor-network' approach was a novel reminder of anthropocentrism in history, but has been criticised as ultimately leading to relativism.[105] These sociological and anthropological approaches to the acts of science contributed to the growth of 'science studies' and historians absorbed these tools in their theoretical frames.[106]

Science is now frequently viewed by its operations, as the material activities of observers among communities of trained individuals. By consensual agreement about valid ideas, methods and data, they create and permit the existence of scientific entities such as concepts, object classes or theories. These symbolic representations of reality are not confined within scientific communities, but in the words of Katherine Pandora, 'carry various meanings within a larger culture, used to construct and debate both shared and contested realities'.[107]

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[103] Latour's analysis of the way that different 'control groups' were unified through 'networks of association' around the central scientific figure of Louis Pasteur during the French microbiological 'revolution', in which even the microbes had a role, set the example for agnostic reading of documentary historiography in scientific journals. Among the tools in this 'actor-network' sociological perspective (or theory) for analysing these relationships across 'heterogeneous networks' of *actants* was to give equal consideration to the non-human, termed 'general' or 'radical' symmetry.

[104] Bruno Latour and Steve Woolgar, *Laboratory Life: The Construction of Scientific Facts*, (Princeton, Princeton University Press, 1979), p. 52, the doctors spent most time reading and writing texts, while technicians played with apparatus; for an Australian example, see Max Charlesworth, Lindsay Farrall, Terry Stokes and David Turnbull, *Life Among the Scientists: an Anthropological study of a Scientific Community*, (Melbourne, Oxford University Press, 1989).

[105] Shapiro 1997, p. 107.

[106] Lorraine Daston, 'Science studies and the history of science', *Critical Enquiry*, 35 (2009), 798–813, pp. 804, 813.

[107] Katherine Pandora, 'Knowledge Held in Common', *Isis*, 92 (2001), 484–516, p. 492.

The history of locust science in Australia

> *We have had some gratifying evidence by Governments, especially the Federal Government, that Science is the Natural ally of government … Seeing that the Commonwealth Scientific Departments are necessarily very limited at present, it is gratifying to note the readiness of the State Governments and the Universities to lend their experienced scientific officers to the Federal Government, for the purpose of investigating important matters which concern more than a single State.*
>
> Walter Froggatt, 1912.[108]

Western science arrived in Australia at the very start of the Imperial enterprise. Ann Moyal has provided a sweeping historical guide to the range of colonial sciences.[109] Much attention has been given to the development of the national science institution, the Commonwealth Scientific and Industrial Organisation (CSIRO), and there are internal treatments of its separate Divisions. CSIRO now hosts the only Australian journal for history of science, originally established to carry memoirs of deceased members of the Australian Academy of Science.[110] Melbourne University established formal teaching in the history of science as early as 1946, and several universities currently offer higher degrees in the history and philosophy of science.[111] Histories of individual disciplines or of specific research projects are often written by senior scientists from within. Ecological science, perhaps because of its prominence, complexity and its connection to the Australian environment, and medical science, because of its local contributions and theoretical innovations, are exceptions.[112]

Agriculture was a fundamental shared enterprise for Australian settlers and governments alike. Colonial administrations took an active role of encouraging and assisting agricultural development through exploration, settlement policies and assessing the limitations to development. Like many early innovations in science and industry in Europe, however, agricultural expertise often emerged from committed groups outside formal accredited institutions. As any local experience was of

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108 W. W. Froggatt, 'Presidential Address, 1912', *Journal of the Linnean Society of NSW*, 37 (1913), 1–43, pp. 5, 12.

109 Ann Moyal, *A Bright and Savage Land*, (Ringwood Victoria, Penguin Books, 1986).

110 *Historical Records of Australian Science* commenced in 1966 as *Records of the Australian Academy of Science*, and took its current name in 1980.

111 The University of Melbourne began degree courses in the history and philosophy of science in the 1980s, http://arts.unimelb.edu.au/shaps/study/history-and-philosophy-of-science/history viewed 16 June 2017; Postgraduate degrees are now also offered at Sydney and Deakin universities.

112 For examples see Libby Robin, 'Ecology: A Science of Empire', in eds. T. Griffiths and L. Robin, *Ecology and Empire: Environmental History of Settler Societies*, (Carlton South, Melbourne University Press, 1997), pp. 63–75; Warwick Anderson, 'Postcolonial ecologies of parasite and host: making parasitism cosmopolitan', *Journal of the History of Biology*, 49 (2016), 241–259; W. Anderson and I. R. Mackay, 'Fashioning the Immunological self', *Journal of the History of Biology,* 47 (2014), 147–175.

immediate value, farmers' groups and agricultural societies were active in sharing knowledge of successful practices and they were encouraged by government.

Agriculture had developed through continual local experiment, but its modernisation brought a new applied relationship with other sciences, particularly chemistry, biology and engineering. Agriculture adopted useful scientific outputs, providing a demand for new products and stimulating industrial development. The involvement of governments in fostering this relationship started in the mid-nineteenth century in Europe and the USA, with the funding of professional scientists, agricultural colleges and the creation of government departments dedicated to agricultural development. This model was adopted in colonial and settler societies, where rapid agricultural development was essential.

Colonial governments established bureaucratic instruments for agriculture, firstly in the form of specially appointed boards, and then as dedicated departments staffed by experts. In a show of faith in the scientific direction set by the USA, Victoria was first to establish an agriculture department in 1873. The other colonies followed in the 1880s and 1890s. The departments' primary function was adapting European practices to specific Australian environmental conditions and finding prescriptions to be shared with those on the land. The task of finding the right combination of manuring and cropping inputs for each soil situation was repeated in early Australian agricultural journals into the twentieth century.[113] Pastoral practice however, remained that of 'opportune use'.[114]

This new alliance of science and government was not a *fait accompli*, particularly as Britain had yet to follow the US example. Early issues of agricultural journals in all Australian colonies included justifications for establishing scientific, not just experimental, practices. This was described as 'progressive agriculture', with improvement based on scientific direction and education. Numerous articles also included pictures of imposing overseas colleges, along with their impressive student enrolment and government agricultural employment numbers.[115]

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[113] European farmers had long been aware that continuous cropping resulted in soil exhaustion and systems of fallowing, grazing and manuring were formalised in the three-field rotation system during the eighteenth century. In Australia the principle was adapted by well-resourced colonial agriculturalists in the mixed-farming model, see Paul Warde, 'The environmental history of pre-industrial agriculture in Europe', in eds. S. Sörlin and P. Warde, *Nature's End: History and the Environment*, (New York, Palgrave McMillan, 2009), pp. 70–92; Paul Warde, 'The Invention of Sustainability', *Modern Intellectual History*, 8 (2011), 153–170, Arthur Young produced standard British texts on experimental agriculture in the late eighteenth century that set the balance between pasture and cropping area, and on manuring as the key to soil improvement.

[114] Tim Bonyhady, *The Colonial Earth*, (Carlton, Victoria, Miegunyah Press, 2000), p. 284.

[115] Alexander Wallis outlined a vision for scientific agriculture in the 1873 and 1874 Victorian annual reports; In the first colonial agriculture journals in Victoria, WA, Tasmania and NSW, there were articles about industrious

At Federation in 1901, the agriculture departments of the new Australian states employed experts in livestock breeding and health, viticulture and horticulture, forestry, soil chemistry, plant pathology and entomology. As well as their scientific and educational roles, the government entomologists formulated and communicated state policy on specific insect pests — including locusts. They identified as 'economic entomologists' with a practical purpose to their investigations, distinguishing themselves from museum systematists or mere collectors.

Economic entomology was public science in the historical sense of government-funded 'applied' science, linked to government policies and under the imperative to demonstrate its worth to agriculturalists. It was part of the grand project of building Australian identity through agricultural development.[116] Although the entomologists needed to satisfy their constituents, they were not under the same complex federal–state pressures to be 'research entrepreneurs' as their counterparts in the USA.[117] University faculties of agriculture were first established in 1911 and formal qualifications only became necessary for departmental appointment during the 1920s.

However, NSW government entomologist Walter Froggatt commented on the positive cooperation between scientists from state and federal governments and the universities in 1912. He was anticipating the creation of a national science agency, which would consolidate the 'alliance of science and government'.[118] Froggatt was a public scientist from the era of Economic Entomology at the start of the twentieth century. From his time, locust science in Australia was dominated by government scientists employed to assist agricultural development and state entomologists remained responsible for control of locusts and grasshoppers.

Froggatt's vision of scientific collaboration at all levels of government came in 1926 with the establishment of the Council for Scientific and Industrial Research (CSIR) by the Commonwealth Government. Locusts, however, were not made a priority for Commonwealth scientists until 1935. Following on from the work of the CSIR, the CSIRO launched an intensive locust research program in the 1960s that continued to 1976 and resulted in significant contributions to the understanding of the ecology of *C. terminifera*.

Scots who had made abandoned English farms viable, about the 'philosophy of manuring', and even about irrational resistance to 'progressive' methods.

[116] Libby Robin, *How a Continent Created a Nation*, (Sydney, UNSW Press, 2007), Robin traces the history of agricultural and environmental sciences, including the wool industry which was seen as a patriotic project of economic nation building, and multiple attempts at the agricultural development of northern Australia.

[117] Charles Rosenberg, 'Science, Technology and Economic Growth: The Case of the Agricultural Experiment Station Scientist, 1875–1914', *Agricultural History* (1971) 45 (1), 1–20, Rosenberg discusses how the politics of dealing with multiple constituent interests required directors to become 'research entrepreneurs'.

[118] Froggatt 1912, p. 10.

This chapter briefly reviewed the fields of science and history which have informed the analytical framework of my interpretation of locust histories. It also summarised how insects and locusts have been treated by scholars in different disciplines. During this century there have been attempts to bring an interdisciplinary convergence of perspectives from history of science, science and technology studies, the sociology of knowledge and environmental history. The contribution of this merging has been to bring another reflective approach to broad concepts at the base of environmental history — those of ecology, environment, science and nature itself — categories that are also historically contingent and constructed.[119] This has placed scientific knowledge and how it is exercised for environmental management as a component of human activity for critical analysis.

In this thesis I have made use of such conceptual tools as expertise, frame-making, enrolment, translation, techno-politics, institutional and material constraints and non-human actants to analyse the production and use of scientific knowledge about locusts, but as implicit perspectives for the construction of narrative sequences rather than adopting any particular theoretical standpoint. The purpose is to illuminate changing human-environment relationships in different times and places, both regional and local, as both lived agricultural and scientific experiences. It is a contribution to the growth of ecological science with the materiality of organisms, technologies and environments of interest, and in parallel with the agricultural dilemma of locust outbreaks.

I focus upon the work of particular scientific players to highlight the research concerns in each succeeding era of locust science. Their scientific ideas were constructed within broader networks of social and economic relations, material constraints and for particular ends.[120] With few archived personal documents for the main characters, the biographical connection comes from their official writings and newspaper coverage. The trajectory of entomological science runs from the ‘amateur naturalists’ in Chapters 3 and 4, through various institutional pathways to professionalization in Chapters 5 to 7, to the expression and quantification of increasingly sophisticated ecological insights in Chapters 8 to 10.

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[119] Sarah B. Pritchard, ‘Joining Environmental History with Science and Technology Studies: Promises, Challenges and Contributions’, in eds. D. Jorgensen, F. A. Jorgensen and S. B. Pritchard, *New Natures: Joining Environmental History with Science and Technology Studies,* (Pittsburgh, University of Pittsburgh Press, 2013), pp. 1-18, p. 10.

[120] Gregg Mitman, ‘Where ecology, nature and politics meet: reclaiming *The Death of Nature*’, *Isis*, 97 (2006), 496-504, p. 498.

Chapter 3. The ‘locusts’ of colonisation and their observers, 1840–1869

Figure 3.1. Martha Berkley (Australia, 1813–1899) *Charles Algernon Wilson*, c.1843, Adelaide (Art Gallery of South Australia), Wilson was twenty five and is shown as the naturalist with a Gould-type microscope and reference book.[1]

[1] Watercolour on card, 15.5 x 12.5 cm. Gift of Miss Emily Wilson 1950, image HQ-0.1474.

The squatter as locust

> *When flocks and herds are depastured for any length of time upon any given area, they abstract day by day, the substances requisite for animal sustenance and growth, and every beast or sheep deported, carries with it a share of the natural wealth of the soil on which it grew. And, unless this wealth is restored to the ground, each living thing that goes away is, to some extent, a robber…They take, from the public, every ounce of flesh they form ; they abstract from the soil, each so much producing power as is necessary for the perfecting of its own bone and muscle, fat and skin ; and … an equivalent amount of substantial wealth producing power has been removed, the land is so much the poorer, and by so much less able to continue its production. The labour of the squatter tends thus to poverty …*
>
> *Empire*, 10 May 1866, p. 5.

The Australian 'Free Selection' movement of the 1860s heightened the polarisation of ideas on how the land should be managed and who would control it.[2] The ecological view above, reprinted from the *Morpeth Leader*, argued on economic grounds that squatting was an inherently unsustainable extractive industry.[3] Some newspapers aligned themselves to either the squatters' or the selectors' position, but the sentiment against squatting was not new.[4] It is telling that the earliest mention of locusts in the colonial press in 1835 actually referred to the squatters, whom it was predicted would become a landed aristocracy and political elite, as a 'flight of land-locusts … attacking the roots and sources of our liberties'.[5]

Records of real swarms of grasshoppers first appear in the early 1840s in parts of New South Wales (NSW), but they contain few diagnostic details as to the species involved. From the first report, however, their close ecological relationship with one type of bird was notable and diagnostic. In the hot and dry November of 1841, 'immense numbers' of grasshoppers appeared in the Goulburn district. They were followed by 'large flocks of strange blue-coloured birds, which by their number and noise filled the air. That the former eat up the latter is evident, as after the appearance of the birds

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[2] Free Selection was a policy adopted by Australian colonial governments to increase the number of farms and farmers. It was driven by public demands for land ownership as the population of free settlers and gold-miners increased. The 1860 *Nicholson Act* in Victoria and the 1861 *Robertson Land Act* in NSW provided for the excision of blocks of land for individual settlement from large areas then held by squatters; 'Free Selection' came from demands to able to occupy farm land before survey, *The Sydney Morning Herald*, 11 December 1860, p. 4, Caroline Chisolm gave a lecture on 'Free Selection Before Survey' in Sydney.

[3] The quote above from the Sydney newspaper *Empire*, was taken from the *Morpeth Leader*, a short-lived bi-weekly, published by Hugh Norris at Maitland, from 1863 to 1866. It gives an apparent economic argument in favour of selectors. The *Maitland Mercury* also at times appeared anti-squatter. An article on 3 June 1869, p. 1, wrote of the squatter as 'constrictor'.

[4] R. Kirkpatrick, 'The Provincial Press and Politics: NSW, 1841–1930', *Australian Studies in Journalism*, 8 (1999), 96–117, pp. 102–104, lists several titles with clear political allegiance and others declaring independence.

[5] *The Sydney Monitor*, 14 November 1835, p. 2.

the hoppers disappeared'.[6] The description of their colour and behaviour makes it clear those birds were one of the woodswallow species.

Around the same time in the drought-stricken northwest, where 150,000 sheep perished, the plains of the Namoi and Barwon Rivers, as well as the Bathurst and Hunter Valley districts, were also briefly covered by grasshoppers as thick as a 'snow-drift'.[7] They appeared again in those areas in November 1844 and also on the Liverpool Plains, described as 'half to an inch and a half in length', occasionally in swarms.[8] Reports came again in the early 1850s, now including the plains of the Lachlan and Murrumbidgee rivers, and the settlements at Orange and Molong, by which time settlers regarded them as a 'certain indication of a dry season'.[9] This association and the timing of all reports in early summer tend to discount the locust, but the identity of the grasshopper species involved remains unknown.

Nineteenth-century newspaper reports reveal an early link between pastoralism and grasshopper swarms that goes beyond the squatters and their employees being the first people in an area, and therefore first to see them. Virtually no-one saw them in unstocked country. The journals of explorers and early travellers make no mention of swarms, although mosquitoes and flies do feature. Aborigines in South Australia and Western Australia (WA) attested to swarms being new to them and the species being unfamiliar. The later appearance and spread of locust swarms in the 1870s also occupied the pastoral country in South Australia, NSW, Queensland and Victoria.

The sheer scale and speed of the squatting boom and its transformation of ground vegetation and soils have been analysed by historians and scientists, who trace its progress and its negative consequences for Aboriginal people and native organisms. This history is briefly revisited here because of its apparent association with changing population irruptions, first of the grasshopper and then of the locust. 1840 is a suitable starting point, as Hamilton Hume's route from Sydney to Melbourne was already well-trodden by intrepid squatters and there was already frequent overlanding of livestock between NSW, South Australia and Australia Felix (Victoria).[10] The date also coincides with the first reports of grasshopper swarms.

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[6] *Australasian Chronicle*, 4 April 1842, p. 2.

[7] *Sydney Herald*, 11 July 1842, p. 7, reported there had been no rain for 15 months, sheep and cattle lost, grasshoppers as thick as a snow-drift; *Sydney Gazette and NSW Advertiser*, 24 May 1842, p. 3.

[8] *South Australian*, 24 December 1844, p. 3.

[9] *Maitland Mercury & Hunter River General Advertiser*, 27 November 1852, p. 2; In Victoria swarms appeared near Geelong and around the gold diggings at Bendigo in the 1850s.

[10] Further north, the Hunter Valley and the Liverpool Plains were already occupied by sheep.

Victoria provides the dramatic early example because all its suitable grazing country was occupied in just twenty years, while the pastoral expansion continued unabated in the other mainland colonies. The colony began as an expansionist enterprise by graziers from Van Diemen's Land in 1835. One needed only the capital to purchase a flock and employ shepherds to make a claim over any suitable land, so settlement moved rapidly westwards from Melbourne across the natural grasslands and north along the river frontages to the Murray.[11] By 1838 all the available land on the Goulburn River and its tributaries in northern Victoria was already occupied by men with cattle and sheep, who were engaged in a 'battle royal' with the Aborigines to assert their claim.[12] Between 1844 and 1847 sheep numbers doubled to three million and almost all suitable grassland and open woodland country was taken up by squatters in a rush that preceded that for gold. As William Westgarth recounted, adventurous settlers in the northwest were 'still occasionally rewarded by the discovery of portions of open and available pasture land' and any clear patches of grass were 'greedily seized among the swamps and scrubs'.[13]

So frantic was the Victorian squatting rush to claim 'unoccupied' land that 'run-hunters' in the interior resorted to extraordinary means to secure a right of possession. A traveller to the north in 1847 saw men 'actually travelling with a pocketful of sheep's trotters, with which they indented the ground' to make it appear their flocks depastured such localities.[14] A more common method of inland squatting was to establish a presence by bringing in a mobile herd of cattle and then later stocking the run with sheep. Cattle rapidly destroyed the fragile drought water sources of the Aborigines.[15] At the same time the Aboriginal inhabitants were being dispossessed, often violently, and were also decimated by disease. By 1851 there were 6.5 million sheep in Victoria, more than in any other colony and almost a thousand for every colonist.[16] Sheep numbers increased more slowly in the following decades, even declining slightly in 1860, suggesting that grazing capacity had been reached.

This chapter examines the appearance of the first swarms of 'locusts' and their subsequent frequent and expanding infestations around two places where they were documented in the press — Adelaide in South Australia and Deniliquin in NSW. These are set in the context of environmental changes taking place, as a result of both climate variability and the huge increase in livestock numbers.

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[11] William Westgarth, *Australia Felix; or, a Historical and Descriptive Account of the Settlement of Port Phillip, New South Wales*, (Edinburgh, Oliver and Boyd, 1848), p. 192.

[12] C. Fetherstonhaugh, *After Many Days, Being the Reminiscences of Cuthbert Fetherstonhaugh*, (Sydney, John Andrew & Co, 1918), pp. 70–71.

[13] Westgarth 1848, p. 193.

[14] *Geelong Advertiser*, 28 December 1847, p. 2.

[15] Cameron Muir, *The Broken Promise of Agricultural Progress: an Environmental History*, Routledge Environmental Humanities series, (Oxon and New York, Routledge, 2014), p. 26.

[16] H. Munz, *The Australian Wool Industry*, (Sydney, Angus and Robertson, 1950), p. 18; *Statistics of the Colony of Victoria, compiled from the official records of the Registrar General's Office*, (Melbourne, 1862).

Settlers' experience and responses to these increasingly visible agents of material agricultural life are framed by the broader historical trends of the times. At Deniliquin we see the political and economic forces driving inland pastoral expansion, while colonial life in Adelaide was punctuated by the sudden appearance and brief annual recurrence of 'locusts', prompting the first scientific investigations and identification of the species involved.

Naturae Amator in South Australia

> *It has been said, that perhaps it would be better to prevent the knowledge spreading of the injuries done here by the locusts. This might have served the purpose formerly but the colony is now too firmly established to be much affected by it. Our colonial papers are read but by very few in the mother country … and those who do read them will see not the suppression of the truth, but a partial injury thus temporarily sustained side by side with accounts of the increasing success and exportation of our various articles of colonial produce.*
>
> Charles Wilson 'Naturae Amator', *The South Australian Register*, 5 November 1845, p. 2.

'Locust' swarms suddenly appeared in Adelaide in November 1843 and returned in early summer each year until 1848. Settlers saw the potential for a 'serious consequence' as the area infested expanded, but the insects' taxonomic position relative to the Old World species was unknown. A series of articles on the 'locusts' by one natural philosopher, Charles Algernon Wilson (1818–1884), are the first clear observations of such infestations in the new European colonies of Australia (Figure 3.1). The intricate details of their morphology, ecology, behaviour and distribution in his entries are the keys to reconstructing a different history of grasshopper and locust swarming to the one that prevailed in the twentieth century.

After settling in the new town of Adelaide with his parents and siblings in July 1838, Charles' passion for South Australia's insect life and his youthful exuberance spilled over in a series of articles on 'The Natural History of the Colony' written from 1841 to 1845. He was already steeped in the rapidly changing discipline of entomology as it came to terms with the immense and intricate diversity of insect life being revealed by global explorations.[17] Wilson's writings would have been familiar to his readers as this was the 'heyday of natural history', when all classes in Britain were taken up in observing, collecting and reading about each new craze.[18] They show many of its hallmarks in terms of content and style: enthusiasm for detail, expressions of awe and delight at Nature's diversity, romantic and exotic imagery, frequent Latinate taxonomic information and reference to authorities.

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[17] His familiarity with the changing state of entomological classification systems in the 1830s is clear from his reference to the works of Kirby and Spence, Linnaeus, Cuvier, Donovan, Leach, MacLeay and Westwood.

[18] L. Barber, *The Heyday of Natural History 1820–1870*, (London, Jonathon Cape, 1980); L. L. Merrill, *The Romance of Victorian Natural History*, (Oxford, Oxford University Press, 1989).

Nevertheless, Wilson's contributions were a serious attempt to catalogue mostly undescribed species within contemporary classifications. The articles span the practical, educational, religious and entertainment aspects of natural history, but have a clear scientific purpose. Like the travellers' works of natural history by Charles Darwin and Alfred Russel Wallace, he concentrates on distributions, behaviours and interactions. They are ecological observations.[19]

Wilson was an avid insect collector and an observant naturalist, a passion that he continued to follow into the 1860s. In the early years he worked alone from his British reference books, including the standard on entomology by Kirby and Spence, but many specimens were brought to him by other residents with an interest in natural history.[20] In the 1850s he befriended other collectors: Hans H. Behr, Charles D. E. Fortnum, George French Angus and Frederick G. Waterhouse.[21] From his large collection, Wilson sent specimens to authorities in England and donated many to the Adelaide and Gawler museums.[22] He was involved in establishing the Adelaide Institute, Philosophical Society and Museum. He made his natural history books available to the Institute Library, which in 1866 had accumulated more than 12,000 volumes.[23] He was also an artist and produced sketches and watercolours of insects (Figure 3.2).[24]

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[19] While it is possible to separate the more scientific purposes of their writings, there are many examples in Darwin's 1845 *Researches* and Wallace's 1869 *Malay Archipelago* of the styles of popular natural history.

[20] William Kirby and William Spence, *An Introduction to Entomology*, in 4 volumes (5th edition), (London, Longman, Rees, Orme, Brown, and Green, 1828).

[21] Waterhouse became the founding curator of the Adelaide Institute Museum in 1860 and travelled with the Charles McDowell Stuart expedition.

[22] Shirley C. Wilson and Keith T. Borrow, *A Bridge over the Sea: Thomas Wilson (1787–1863), Art Collector and Mayor of Adelaide*, (Hawthorn South Australia, 1973), In 1853 Wilson reckoned he had some 2,000 distinct species in his collection. He also exchanged specimens with other collectors in Australia and overseas.

[23] *South Australian Register*, 25 January 1867, p. 2, 'The South Australian Institute', in that year local borrowings and those through regional libraries amounted to 50,000 books; Wilson wrote articles on the destruction of noxious insects in 1842 which he stated were drawn from 200 references, *The South Australian Magazine*, 2 (2), 66–69.

[24] This is one of three pictures from the Rex Nan-Kivell collection in the National Library of Australia, with the only source, 'South Australia 1842'. Two of these are likely to be by Charles Wilson. He wrote detailed articles about the 'Goliah moth' and a green mantis that he kept for some time in 1841. *South Australian Register*, 2 January 1841, p. 4; 20 February 1841, pp. 3–4; 8 January 1842, p. 4. The detail in those descriptions match the features in the two illustrations, which are stylistically similar, on the same paper and clearly by the same artist (image, nla.pic-an624495 and an-6244953); see also S. C. Wilson and K. T. Borrow, 1973, Appendix W, p. 317, the authors list among the items lent by the Wilson family to the Centennial Exhibition of Historical Records, 1836–1936, Adelaide 1936, 'two watercolours from nature, of South Australian insects, by C. A. Wilson'. How they ended up in London after the exhibition is unknown. The distinct lines on the wings of the moth match *A. labrynthicus* as shown in N. B. Tindale, 'Revision of the Australian Ghost Moths (Lepidoptera Homoneura, family Hepialidae), Part 1', *Records of the South Australian Museum*, 4 (1932), 497–536.

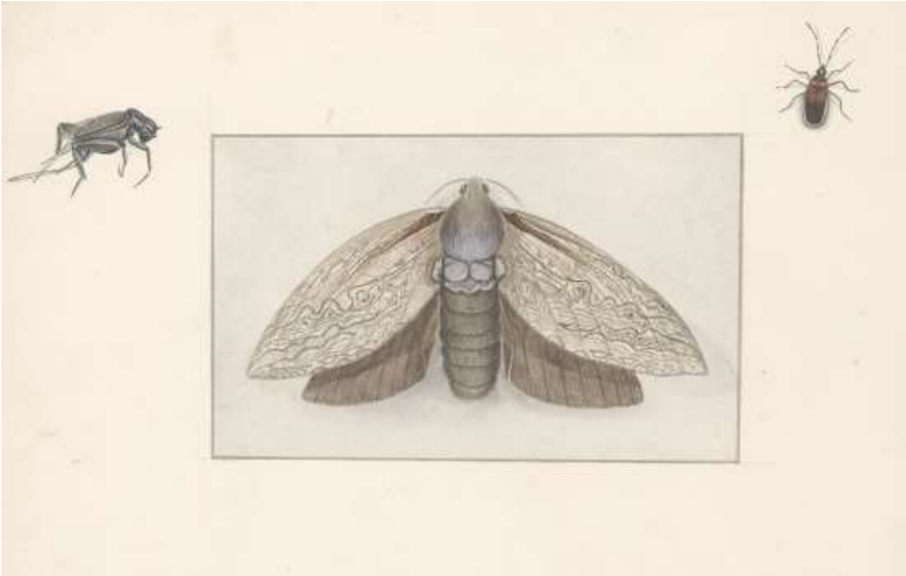

Figure 3.2. The 'Goliah moth', *Abiantes labrynthicus* or *A. marcidus* (Hepialidae), attributed here to Charles Wilson c. 1841 (National Library of Australia, Canberra).

Writing as *Naturae Amator*, Latin for 'lover of nature', Wilson's first contributions to *The South Australian Register* during October–December 1840 announced the form and spirit of his 'Natural History of South Australia'.[25] Over the next four years he presented descriptions of local insects within each of the known orders, including monthly diary entries of their appearance and activities.[26] The taxonomic classification and features of interest in these entries drew on the understanding of the natural world encapsulated in the references at his disposal. Wilson's exhaustive insect descriptions and romantic natural history earned him the honoured title of 'our Colonial White of Selborne'.[27]

The 1840s infestations

In 1841, Wilson expresses the colonists' fortune in not being visited by that 'scourge to mankind' – locusts.[28] Considering the great size and abundance of other insects here, 'Locusts, if we possessed any, would be on a proportionate scale'. He had seen Old World locusts at the Cape Verde Islands on his emigrant voyage.[29] His descriptions of the Orthoptera seen around Adelaide allow the

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[25] *South Australian Register* (Adelaide), 24 October 1840, p. 2; C. A. Wilson, 'The Natural History of the Colony No. 1', *South Australian Register* (Adelaide), 7 November 1840, p. 4.

[26] C. A. Wilson, 'The Natural History of the Colony — No. 10', *South Australian Register* (Adelaide), 27 March 1841, p. 4.

[27] *South Australian Register*, 2 January 1872, (Suppplt.) p. 3, in an editorial, *Delta* (a later pseudonym) was mentioned as 'Our Colonial White of Selborne', an allusion to the popular work by the Rev. Gilbert White, originally published in 1789, which took the form of a series of letters describing the seasonal activities of the wildlife of Selborne in Hampshire.

[28] C. A. Wilson, 'The Natural History of the Colony, No. 5', *South Australian Register*, 16 January 1841, p. 4.

[29] *South Australian Register*, 8 November 1845, p. 1.

identification of several distinctive species that are typical late summer inhabitants of grasslands in southern Australia.[30]

During the first few years of the colony the variety and abundance of grasshoppers peaked in summer, and in 1842 the most common species were 'everywhere in numbers'. But in November 1843 the population of one species became so large it formed swarms. When swarms came again in November 1844, Wilson confirmed that they were the same species.[31] He wrote 'other species of locusts have always appeared in the colony in great numbers, though not to the extent of this, nor has this destructive species been noticed in particular'.[32] In 1845, when the swarms became a problem for gardeners and farmers alike, Wilson produced twelve articles covering his observations of the 'locusts' that remain the most detailed descriptions for some aspects of the species' behaviour.

In December 1844, *Naturae Amator* described the 'habits and economy' of the locusts, giving meticulous details of the morphology of the 'most common injurious species'.[33] It not only demonstrates his mastery of the style of taxonomic definitions, but identifies the species and its different pattern morphs (see 'The Locusts – description of the species', page 92). The yellow colouring of gregarious males in contrast to the larger, mostly grey and brown females, the dark patterning on the tegmen (outer wings) and femur, and the dorsal stripe with pale lines diverging outwards from the centre to the base of the pronotum (thorax) are characteristic of *Austroicetes cruciata*. He was also explicit about the length of males (20–23 mm) and females (27–28 mm), which are shorter than the average length of the locust *Chortoicetes terminifera* (male 20–30 mm, female 30–45 mm). The morphological details alone allow the identification of the grasshopper *A. cruciata*, but Wilson's ecological observations make it crystal clear.

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[30] C. A. Wilson, 'The Natural History of the Colony, No. 6', *South Australian Register*, 30 January 1841, p. 3, he gives clear descriptions of the yellow-winged locust, *Gastrimargus musicus* (Fabricius 1775) and the giant green slantface, *Acrida conica* (Fabricius 1781); D. C. F. Rentz, *Grasshopper Country. The Abundant Orthopteroid Insects of Australia*, (Sydney, UNSW Press, 1996), p. 177; for the identification of insects in other orders, see J. G. Wilson, *The Insect Man: Charles Algernon Wilson: Adelaide's first Entomologist*, (Henley Beach South Australia, Seaview Press, 2005).

[31] *South Australian Register*, 5 October 1844, p. 3, having examined a male with yellow striped tegmina and legs in 1843, though he had never before heard of it being destructive.

[32] *South Australian Register*, 5 May 1845, p. 4.

[33] C. A. Wilson, 'The Locusts. Description of the Species', *South Australian*, 3 December 1844, pp. 3–4.

Figure 3.3. Nymphs of *Austroicetes cruciata*, (1–1.5 cm) showing variable colour patterns.[34]

Their behaviour and phenology

Wilson described the 1844 infestation in several articles. He itemised the damage the 'locusts' caused to gardens and the '*capricious tastes*' of the adults, which moved from the Park Lands into the streets where they gnawed vines, trees and melon plants. He noted that further towards the hills the grass was still flourishing and that stock were forced to feed there, as the 'locusts' had consumed everything nearer the town. Around South Adelaide, even the bases of the surrounding hills were being eaten out.[35] But the swarms were only loosely formed and without directed movement, flying less than 10 metres high, their displacement occurred 'by degrees'. In comparing them to the destructive 'Locusta migratoria', Wilson wrote 'they neither migrate nor congregate' and it 'appeared as though each had separate interests'. This was contrasted with descriptions of the 'locusts of the Scriptures' from Kirby and Spence, that mentioned continuous swarms in every case 'flying one way together and descending together', the noise of whose thousands 'compared to the sound of a flame of fire driven by the wind'.[36]

Wilson gives a carefully observed description of the egg-laying behaviour of the females, which were far less numerous than males.[37] Oviposition occurs on 'bare places where grass has worn away, open roads and footpaths'. When a female commences laying, an outward circle of 'a dozen males or so' attend 'as a guard of honour'. 'Two courtiers now advance and press their heads on either side of her, their antennae crossing above her neck'. As the eggs were being laid, he noted that males mimicked

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[34] photograph E. Deveson 2007; the centre insect shows the pattern of Keys' form *albomedia*.

[35] C. A. Wilson, 'South Australian species of the genus Locusta I, What a locust is' and 'II. Local Damages', *South Australian Register*, 5 April 1845, p. 4; 'The South Australian species of the genus Locusta, III. Their Destructive Powers', 'IV. Description of the Species.' and 'V. Their Numbers', *South Australian Register*, 12 April 1845, p. 4.

[36] C. A. Wilson, 'The South Australian species of the genus Locusta. VI. Their Modes of Flight', *South Australian Register*, 16 April 1845, p. 4.

[37] *South Australian Register*, 23 April 1845, p. 4, males are 'very much more numerous' than females.

The locusts — description of the species

I must now describe the species which have been so injurious, and which, I believe, may be reduced to two or three. The males of these, as of all other species of the saltatorial tribes, are much smaller than the females. They are all so very similar in general colour and size, that, were it not for the difference observable in the females, they might be considered as one species. The length of the males from the frons, or forehead, to the end of the tegminal (wing covers or fore wings), which in both sexes are half as long again as the abdomen, is from eight to nine tenths of an inch. The females vary in length from an inch and one tenth to one fifth. The male may be universally distinguished by its yellow appearance, even when flying. It has the face (clypeus) and cheeks of that colour, which is of a gamboge tint; the fore and middle pair of legs, and the thighs (femora) of the posterior pair, are also yellow; the latter bordered with darker markings; claws, black ; the thorax is brown ; the tegmina, when closed, are of a similar color, both spotted with dark brown and black, with white lines running from the base of the tegmina, along its angular projections, and meeting at the apex–these are very faintly expressed. In a variety the flat upper part of the tegminal is of a light yellow or whitish hue, and there are a few other varieties among them. Of the females, one (with wings closed) is grey and brown, variegated with darker markings of the same color; the legs are the same, except the upper part of the thigh, which is straw coloured. A light stripe of the same runs from the apex of the head (frons) to the base of the thorax, through the centre. From the middle of this, on each side, a faint line of the same color diverges outwardly. These two lines the male sometimes possesses. The flat upper part of the tegminal is of the same light colour; the face is yellowish. Another species is of a more general grey, or bluish tint, and the diverging central thoracic lines of a similar but fainter hue, and the face bluish. The upper part of the tegminal is of the same color as the head and thorax, and has the light lines down the sides as in the male. In all the varieties of both sexes, the shanks (tibiae) and the inner parts of the thighs of the posterior legs are orange coloured, and the rest always banded. The antennae in both the males and females are filiform, or very slightly incrassated at the tips; yellow and back in the males, and brown and yellow in the females. The under and gauze-like glossy wings are colourless in all the varieties of both sexes, with exception of a slightly darker tint towards the apices; the under sides of the bodies in all are of a bluish white. These species are very apt to break into varieties, often partaking of the markings of both. A common kind on the south side of the river (which I have reason to consider a distinct species), of those composing the principal part of the wide-spread myriads, is of a more general brown tint, having no light lines or patches on the thorax or tegminal, but variegated with several dark marks. Another variety, or perhaps species, has the white lines only on the tegmina, which are brown with darker spots of the same, and the head and thorax of a greenish hue. There is also a brown and very common variety, with the upper part of the thighs and tegmina as in one of the North Adelaide species (and perhaps identical with it), of a dingy white, which vies in number with the last named species, and one less common, having the thorax alone and conspicuously light colored. In fact, these various differences render it very difficult to determine which is the species and which the variety, though I think that four may be considered as the extent of the number of the former.

C. A. Wilson, Naturae Amator, *South Australian*, 3 December 1844, pp. 3–4.

the female's leg-raising behaviour and were also reported to assist the female to cover the hole after laying was completed. Wilson watched this ritual repeated by several females and their mates, 'with a circle of a few feet containing up to a dozen such companies'.[38]

The eggs were laid in early summer and produced young in the same locations the following spring. His diary of activity for 1844 recorded oviposition on warm days commencing on 24 November and extending to 10 December, often observed in the evening. Wilson also noted that the swarms were mingling with 'a few hundreds of a larger species, having lately got their wings, but confine themselves to the native vegetation'. These could have been *C. terminifera*, but they were not the major species.

In 1845 the 'locusts' appeared in greater numbers than in any other year since the start of the colony, 'possibly from undisturbed laying in the Park Land, mild weather, and rains providing continual renovation of the grass'. Nymphs were noticed about the middle of September 1845 and acquired wings in October, a month earlier than the previous year. By 5 November they had already done as much damage as in the entire previous summer.[39] Of their distribution and density Wilson was also specific:

> It is very singular that the entire town and neighbourhood of Adelaide, should at present, as also last year, be almost the only places attacked by such numbers. It can hardly be from the extra food afforded them by the gardens, for the rankness of the native vegetation in many other parts is much greater.[40]

In his description of their morphology, Wilson paid close attention to the variation seen in females and, finding it difficult to know which were the varieties and which the species, thought that several species might be involved.[41] In fact, he had identified several of the phenotypic variants that occur in populations of both *A. cruciata* and *C. terminifera*, appearing as different, distinct dark and light patterns and striping on the head, thorax and tegmen. Wilson's descriptions match several of the 'forma' identified in *A. cruciata* by Ken Key a century later.[42] As Wilson noted, the pattern variation

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[38] C. A. Wilson, 'The South Australian species of the genus Locusta. VII. Oviposition' and 'X. Journal', *South Australian Register*, 23 April 1845, p. 4; *South Australian*, 13 December 1845, p. 3.

[39] C. A. Wilson, 'The South Australian species of the genus Locusta', *South Australian Register*, 3 May 1845, p. 4.

[40] *South Australian Register*, 5 November 1845, pp. 1–2.

[41] C. A. Wilson, 'The Locusts', *South Australian*, 3 December 1844, pp. 1–2; 'The South Australian species of the genus Locusta, III. Their Destructive Powers', *South Australian Register*, 12 April 1845, p. 4.

[42] K. H. L. Key, *The taxonomy, phases, and distribution of the genera* Chortoicetes *Brunn. and* Austroicetes *Uv. (Orthoptera: Acrididae*), (Canberra, CSIRO Division of Entomology, 1954); Wilson's descriptions match several of Key's forms.

of the different forms is masked in gregarious males by the yellow pigmentation. By 1845, however, he was clearer on the 'singular' identity of the swarming species, writing:

> Our large species of this family are not of the true genus locusta, 'but our present (smaller) injurious species is of that genus... and closely related to the tropical migratory locust. There seems, therefore, to be something more than their numbers connected with their destructive properties …[43]

There was clearly something about the Adelaide environs that the 'locusts' liked. George Fletcher Moore recalled the same phenomenon as Wilson. For two years the 'locusts' were 'confined to some two or three miles around Adelaide; but now they have extended their march, and bid fair to ravage the whole country'.[44]A proposal to open the Park Lands for cultivation rather than for cattle grazing was justified because they were 'grand places for the deposit of locust eggs', which would be destroyed by ploughing.[45]

Figure 3.4. Sturt's overland expedition leaving Adelaide, August 1844. Watercolour by S. T. Gill. (Art Gallery of South Australia).

In November 1845 Wilson noted that swarms appeared to be more extensive on the plains and were reported as being continuous in high numbers up to 100 kilometres north of Adelaide around the new

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[43] *South Australian Register*, 5 November 1845, pp. 1–2.

[44] B. Gammage, *The Biggest Estate on Earth: How Aborigines Made Australia*, (Crows Nest NSW, Allan and Unwin, 2011), p. 183, citing Moore 1886, p. 36.

[45] *South Australian Register*, 13 June 1846, p. 1.

settlement at Burra.[46] The descriptions indicate the gradual expansion of the areas affected. An idea of the increasing scale of swarming is given by a separate dramatic report from December 1846 of strong easterly and northerly winds sweeping 'locusts' into the sea in St Vincents Gulf. The 'shores of the Gulf from Marino to Onkaparinga were strewn with their bodies', said to be two feet thick along the shore.[47] In early September 1847 young grasshoppers, 'the size of a grain of wheat' were again as numerous as ever in the Adelaide Park Lands.[48] The settlers canvassed various means of dealing with the pests, including accommodating them by planting wheat in February so it would ripen before the 'locusts' could do much damage. Wilson suggested planting castor oil and geranium plants, as well as ploughing and burning the grass where they were most numerous.

Several possible explanations for the increase in swarming were discussed in the press. One common perception was that sheep caused the swarming, since the 'runs seemed to favour them' and they came from there into cropped country.[49] A number of newspaper entries in 1845 also put the increase down to the cessation of regular burning of vegetation by Aboriginal people, showing an appreciation of Aboriginal land management practices. One popular explanation was that a decline of native insectivorous birds allowed 'locust' populations to increase unchecked. The pest-eating activities of a number of bird species — quails, crows, bustards, kites, plovers and woodswallows — received comment by correspondents and there were pleas for their protection.[50] That sentiment was part of a growing mood amongst some colonists about the 'fatal mistake' of indiscriminate destruction of birds.[51] Wilson described the close association of woodswallows with 'locusts' in 1845, when 'vast flocks of a new, or at least hitherto scarce kind of bird, in these parts, of the sparrow tribe, are constantly flying over, and settling amongst them in the grass, and they seem to make great numbers of them their prey'.[52]

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[46] C. A. Wilson, 'The Locusts', *South Australian Register*, 8 November 1845, p. 1; Swarms were also seen as far south as Myponga and east to Walkerville.

[47] *The Sydney Morning Herald*, 30 December 1846, p. 2.

[48] *South Australian*, 7 September 1847, p. 3.

[49] J. C. O. Tepper, 'On the decrease of many species of insects and the increase of some in South Australia', *Annual Report and Transactions, Philosophical Society of Adelaide 1878–79*, (February 1878), 56–60; *South Australian Register*, 23 December 1864, p. 3; *South Australian Register*, 2 December 1872, p. 2.

[50] *South Australian Register*, 3 June 1846, p. 3; *South Australian Register*, 23 October 1862, p. 2; *South Australian Register*, 4 December 1863, p. 2, 'thousands of blue-birds have come down with the locusts'; *South Australian Register*, 23 December 1859, p. 3.

[51] *The Express and Telegraph*, 10 November 1869, p. 2.

[52] *South Australian Register*, 5 November 1845, pp. 1–2.

Charles Wilson’s ecology

> *I must begin by remarking that a naturalist must in great measure be an egotist, in his feelings, his pursuits, and observations, and therefore in his descriptions. This particularly applies in a new country, where so little is generally known.*
>
> Naturae Amator, 1841.[53]

Figure 3.5. Charles Wilson in 1876 (photo courtesy of John Wilson, Adelaide).

Charles Wilson’s writings do much more than identify the species involved in the first ‘locust’ infestations. They encompass the dramatic conceptual changes overtaking biological science during his lifetime. The young Wilson is Australia’s romantic natural history writer, but in his painstaking disciplined observations he is also its first scientific ecologist. While other entomologists toyed with cabinet collections, Wilson’s meticulous and patient descriptions of the types, behaviour, interactions and seasonality of nature’s lesser inhabitants are unique.[54] Although he also concentrated on collections and species numbers, his entries show the ‘Arcadian’ pleasures of immersion in nature. Parallels can be drawn with other early naturalists, but Wilson’s adoption of the role of colonial naturalist and his mastery of the entomological discipline resulted in a consistent body of texts.[55]

The precepts of Natural Theology, where each unchanging species was moulded and placed by God with a purpose in

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[53] C. A. Wilson, ‘Notes on the Natural History of South Australia – No. 1’, *The South Australian Magazine*, 1 (5), (1841), 171–176, p. 171.

[54] James Backhouse, *A Narrative of a visit to the Australian Colonies*, (Hamilton, Adams & Co, 1843), Backhouse made detailed notes of the botany and Aboriginal inhabitants at various localities during his travels in the 1830s, but was rarely in one place long enough to be a close observer of nature. In Tasmania he identified several insect species, notably *Gastrimargus musicus*. Visiting Adelaide briefly in December 1837, he made no comment about grasshoppers; Stronger parallels could be drawn with Harriet and Helena Scott, who produced ecological illustrations of NSW Lepidoptera, or with Georgina Molloy in WA and Caroline (Louisa) Atkinson in NSW. Both Molloy and Atkinson provided many specimens with ecological descriptions to gentleman botanists, but they were precluded from presuming themselves scientists and both died young. Molloy died in 1843 and Atkinson in 1872, both as a result of complications following childbirth. Atkinson wrote natural history articles in the 1860s under the title ‘A Voice from the Country’ in the *Sydney Morning Herald*.

[55] Ann Moyal, *A Bright and Savage Land*, (Ringwood Victoria, Penguin Books, 1986), Chapter 6, pp. 90–106.

the economy of nature, remained a unifying principle in British ecological writings in the eighteenth and early nineteenth centuries.[56] *Naturae Amator's* early articles belong to this tradition. In 1845 he wrote 'the timeless preserved instinct, or "*knowledge without reason"* of every little member of creation defies our understanding', but 'we should not doubt the fitness of the divine system'.[57] In rationalising the great destruction wrought by Old World locusts, he quotes Kirby and Spence by invoking the 'Unseen Hand of a Superintending Providence' in 'promoting wise ends and setting limits for each species'. He also borrowed their divine purpose for locust visitations. They created a clean slate for the resurrection of new growth.[58]

Naturae Amator was the epitome of the romantic mid-century natural historian, punctuating his observations with lines from the nature poems of James Thomson, N. T. Carrington and John Cunningham.[59] In the same tradition as White, Thoreau, William Howitt and Mary Howitt, he drew inspiration from Thomson's *The Seasons*.[60] But he also shared this utopian spirit with many people in the early South Australian settlement. Wilson wrote poetry, natural history, entomology and vegetable physiology articles in 1841 and 1842 for the short-lived *The South Australian Magazine*, the colony's own optimistic literary and scientific periodical. The magazine was published by James Allen to match the popular growth of such journals in Britain at that time.[61] Its other contributors conformed to

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[56] It was a central theme in natural history writings from John Ray in 1691 to William Paley's *Natural Theology, or, Evidences of the Existence and Attributes of the Deity*, first published in 1802. Natural history writing was largely the preserve of the clergy during the eighteenth century in England, but expanded to become a craze among all sectors of society in the mid-nineteenth century.

[57] *South Australian Register*, 5 November 1845, pp. 1–2, the phrase 'knowledge without reason' had been in currency since John Ellis, *The Knowledge of Divine Things from Revelation, not from Reason or Nature* (London, 1743), p. 340.

[58] *South Australian*, 17 December 1844, p. 4; *South Australian Register*, 17 May 1845, p. 3. Wilson drew from Kirby and Spence, 1828, p. 252.

[59] Wilson made frequent use of Thomson's 1746 'Four Seasons'. Although Thomson's poetry was almost antiquated by the nineteenth century, he was known as the Landscape Poet, and the epic 'Four Seasons' (1730–46) was seen as reintroducing 'romantic' love to poetry and as instrumental in diffusing the taste for the beauties of nature and landscape into British poetry; see H. A. Beers, *A History of British Romanticism*, (London, Henry Holt & Co., 1899), pp. 102, 116; There are also different interpretations that suggest this romantic ideology was merely a cover for the exploitation of nature.

[60] Lawrence Buell, *The Environmental Imagination: Thoreau, Nature Writing, and the Formation of American Culture*, (Cambridge Massachusetts, Harvard University Press, 1996), p. 222, cites these authors as 'respectfully' reading Thomson's 'loco-descriptive archetype', *The Seasons*, with its temporal and spatial appreciation. Natural history books of the period also made use of romantic and landscape poets. Some of Wilson's quotes could therefore have been drawn from these, rather than reading the original, see for example Frederick Parkington, *The British Cyclopaedia of Natural History &c*., (London, Orr and Smith, 1836), p. 873, published just as the Wilsons were leaving England, which also quotes from *The Seasons*.

[61] James Allen, 'The Use and Advantages of Colonial Periodical Literature', *The South Australian Magazine*, 1, No.1, (1841), 1–6, Allen also published the *Register*; see Robert M. Young, *Darwins's Metaphor: Nature's place in Victorian Culture,* (Cambridge, Cambridge University Press, 1986), pp. 134, 153–54, Young discusses the effect of the periodical magazine on the intellectual climate in Britain. Between 1800 and 1900, over 1,000 titles were launched.

this intellectual ideal, also embellishing their works with romantic poetry and original poems.[62] The scientific articles dealt with topics later taken up by Adelaide's learned societies, including meteorology, exploration geography and agricultural development. Wilson also commenced a series of articles on the destruction of noxious insects, the first economic entomology in Australia, in which he drew moral justification for their destruction from William Cowper's 1785 *The Task*.[63] Admiration for the most noble occupation of tilling the soil also appeared in the newspapers, whose contributors dreamed the colony a romantic pastoral, fulfilling its duty of 'patriotic agrarianism'.[64]

The consolidation of entomological science is apparent through Wilson's acquaintances, although how he attained an intimate knowledge of contemporary taxonomies and authorities as a youth is unclear.[65] There were many colonial collectors and some artist collectors, but no local systematist could assume naming authority for new insect species.[66] Although assigning tentative generic names to the insects he examined, Wilson realised that he was not in a position to be an accredited entomologist. The review and naming of species required access to comparative specimens and that took place in numerous distributed institutions, principally the museums of Europe.[67] Wilson became a corresponding member of the Entomological Society of London from 1847 and maintained a close correspondence with its long-standing Secretary John O. Westwood.

[62] Charles also contributed original poems as *Naturae Amator* or *Delta*. His father, Thomas, was a late editor of the *Magazine* and contributed articles on English poetry and art history, using engraving and printing media.

[63] Naturae Amator, 'On the destruction of Noxious Insects. No. 1', *The South Australian Magazine*, 2 (1), (1842), 6–8; 'On the destruction of Noxious Insects. No. 2', *The South Australian Magazine*, 2 (3), (1842), 94–96; 'On the destruction of Noxious Insects. No. 3', *The South Australian Magazine*, 2 (1843), 304–307.

[64] Shiela Wille, 'The ichneumon fly and the equilibrium of British natural economies in the eighteenth century', *British Journal for the History of Science*, 48 (2015), 639–660; p. 641, Wille cites C. A. Bayly for introducing the term 'patriotic agrarianism' as a fashion for agricultural improvement among British colonial elites.

[65] Charles was educated at Mr Smith's school at Turnham Green, London, and he had no higher education. There is a possible connection between the Wilson and Westwood families. Westwood was born in Sheffield and moved to Lichfield, near where Thomas Wilson held property. Westwood was articled to a solicitor in London in 1821, near to where Thomas Wilson held a practice. Thomas Wilson was a collector of art and Westwood became an authority on early British manuscripts and inscribed stones. Charles' letters exchanged with Westwood are strongly suggestive of close acquaintance, see E. D. Deveson, 'The Adelaide Philosophical Society and the early accommodation of the Darwin-Wallace theory of Natural Selection', *Transactions of the Royal Society of South Australia*, 137 (2), (2013), 151–167, p. 154.

[66] George French Angus was one artist-collector who painted numerous insect collection specimens; William Sharp MacLeay in Sydney is seen as a dominant entomologist of the period. He was a member of the Macleay dynasty of natural historians and numerous Australian insects carry his name as authority, but his taxonomic activities were carried out as a member of the Entomological Society of London, and ceased when he moved to Sydney in 1856. He was a prominent figure in entomological circles in London and gained some notoriety after proposing a circular phylogenetic taxonomic scheme. This 'quinary' concept of animal taxonomy received much attention when it was published. It was criticised by Wallace in his 1855 'Sarawak' paper, where he set out evolutionary lineages in the branching tree form.

[67] British entomological credentials counted for a lot in Australia. Frederick G. Waterhouse was appointed first entomologist of the Adelaide Museum in 1860 on the strength of having worked with his brother in the British Museum. W.S. Macleay's authority in Australia came from his previous involvement with the Entomological Society of London.

Natural history collections remained a popular and potentially rewarding colonial pastime, particularly after tariffs on specimens were dropped in Britain in the 1840s and then in South Australia in 1853.[68] Cabinet displays were the material demonstration of the importance of science and the rapid growth of local collections was the impetus for the establishment of the Adelaide Museum. The exchange of insect specimens expanded local collections, and their sale could be lucrative.[69] Wilson's much admired younger cousin, Alfred Russel Wallace, succeeded in financing most of his explorations of the Amazon and the Malay Archipelago through the sale of natural history specimens in London. Wallace also sent insect specimens to Wilson, who displayed them at meetings of several learned societies.[70]

Wilson's early views of ecological interactions are set in the metaphor of the utilitarian great chain of being, where each link is necessary to maintain the relative proportions for the 'general good of the system'. When one species increases beyond its limits, counter checks in the form of natural enemies or environmental limits are provided; processes that were often obvious among the insects. But in concluding his series on locusts in 1845 he also shows an appreciation of the influence of contingency and environmental variability on population fluctuations. The explanation is drawn from John Knapp's 1829 *Journal of a Naturalist*, from which he paraphrases on the 'limits appointed to the increase of all inferior orders of creation'.[71] Knapp wrote of periodic 'local and temporary occurrences leading to great augmentation' of individual species, and of 'imperceptible or apparent events' resulting in a subsequent decline.[72]

Wilson commented that the colonial 'lower classes', the farmers, in contrast to the superstitious fear and dread that locusts engendered among the common people in Britain, seemed unperturbed and appeared to 'attribute their appearance to natural causes'.[73] Like the early champions of 'Natural Selection' — Darwin, Wallace, Thomas Huxley, Joseph Hooker and Charles Lyell — the settlers saw the diversity of life forms at various stopping points on their emigrant voyages and were coming to

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[68] *South Australian Register*, 24 November 1853, p. 3, customs tariffs were dropped on specimens illustrative of Natural History. Import duties on specimens were dropped in Britain in 1844.

[69] Other entomologists supplemented their incomes by selling collections to overseas museums. Marianne Kreusler and Johannes Odewahn sold and donated insect collections, including to the Museum, see P. Jones, 'Colonial Wissenschaft: German naturalists and museums in nineteenth century South Australia', in ed. P. Monteith, *Germans: Travellers, Settlers and their Descendants in South Australia*, (Adelaide, Wakefield Press, 2011), pp. 204–236, p. 212.

[70] *South Australian Register,* 17 July 1855, p. 2, 'Lecture at the Ladies' Institution'.

[71] C. A. Wilson, 'The South Australian species of the genus Locusta. XII. Conclusion', *South Australian Register*, 17 May 1845, p. 3.

[72] J. L. Knapp, *Journal of a Naturalist. Country Rambles in England*, (London, John Murray, 1829), p. 168.

[73] C. A. Wilson, 'The South Australian species of the genus Locusta', *South Australian Register*, 3 May 1845, p. 4.

terms with the strange biota of Australia.[74] The simple view of each of Europe's animals fitting its designed role was shaken in a world with countless special roles.

Adelaide: a scientific utopia

Unlike the other Australian colonies, South Australia was conceived in Britain as a self-funded and self-governing province of free settlers in 1834. The South Australian Literary and Scientific Association formed at the same time to assemble a reference library for the 'cultivation and diffusion of useful knowledge' to accompany the first colonists. They ferried the chest of precious books ashore with them when Adelaide was established in 1836.

From the 1840s, scientific and literary institutions were the focus of the intellectual and cultural life of Adelaide society and numerous learned societies, including the Adelaide Philosophical Society, were established in 1850s. But amid this uplifting spirit of optimism there were frequent reminders of the risks of colonial science and travel. In one issue of the *Register* in May 1853, Charles Wilson tells of his brother Theodore, who was returning to England to take up a chaplaincy, sitting in a lifeboat and watching his precious violin float past, while on an opposite ocean his cousin Alfred Russel Wallace sat helplessly in a lifeboat and watched as the ship carrying his Amazonian collections burned to the waterline.

The colony became a bastion of scientific free thought, exemplified by Richard Hanson's 1860s 'Law in Nature' lectures. The interest in scientific developments in Adelaide was shown by the large attendances at the Philosophical Society's conversaziones and its diverse membership. In the early 1860s, men and women crowded the Society's rooms, and church halls, whenever the question of evolution was debated. At Society meetings in 1863, Wilson read from Wallace's paper on variation in Malaysian butterflies and in 1864 he discussed Darwin's theory. Matilda Wilson, Charles' wife, was also a natural historian and contributed herbariums of native plants for the 1867 Paris International Exposition.

Wilson lived through a period when the scientific understanding of nature was transformed from a world shaped by divine laws to one governed by natural laws, and his views changed with the revelations of the Theory Natural Selection in the 1860s. This came through the spirit of scientific discovery in natural history, but he was clearly influenced by his colleague, the Chief Justice Richard Davies Hanson and by the works of Alfred Russel Wallace.[75] Any mention of 'Overruling

[74] Historian Iain McCalman makes the case that seeing the diversity of life forms in different parts of the globe, particularly oceanic islands, made Darwin's natural selection more obvious and understandable, see *Darwin's Armada: How Four Voyages to Australasia Won the Battle for Evolution and Changed the World*, (Penguin Group Australia, 2009).

[75] E. D. Deveson, 'The Adelaide Philosophical Society and the early accommodation of the Darwin-Wallace theory of Natural Selection', *Transactions of the Royal Society of South Australia*, 137 (2), (2013), 151–167;

Providence' disappeared from Wilson's writings after Hanson's 1849 lecture on developmental theory.[76] Hanson and Wilson were prominent in the discussions about evolution at meetings of the Adelaide Philosophical Society. Hanson's 1860s 'Law in Nature' papers cemented free thought over theology as the dominant intellectual framework of scientific enquiry. Like Hanson, in 1860 Wilson reflected on the puzzle of the uniformity in the lineage of life forms, writing 'the animal kingdom is not broken up into separate divisions, but is a connected and continued chain of beings… not only in present age, but has been so during each geological epoch by itself'.[77]

Wilson's early view of his new homeland in the 1840s was of a landscape 'peopled and cultivated only in imagination'.[78] After an exhilarating trip to Mt Lofty he wrote 'nothing is wanting but the hand of man to assist by art the works of Nature, where but little is needed to perfect what she has begun with such wild beauty'.[79] In the 1850s the squatters and miners extended the northern limits of settlement in South Australia, but in the drought of 1865 the early optimism was fading to a view that the work of occupying the land must be 'a continual war with Nature'.[80] Wilson's scientific views also, were changed by ideas of 'uniformity' and the natural laws governing both nature and human affairs that culminated in the theories of evolution.[81]

Wilson's final natural history contribution was the 1879–80 series 'The Life and Works of Alfred Russel Wallace', in which the progress of Natural Selection was the underlying theme. He reveals his own accommodation of Darwin's theory within a deistic view of Christianity.[82] Ecological natural history had a promising beginning in Australia. But after *Naturae Amator* gave such a clear picture of the first 'locusts', later decades seem prosaic and marked by an absence of knowledge about them.

South Australian Register, 2 May 1853, p. 3, Wilson recounts the shipwreck of his brother and cousin; *South Australian Advertiser*, 10 December 1866, p. 2, Matilda Wilson botanical collection.

[75] *South Australian Advertiser*, 10 December 1866, p. 2.

[76] *South Australian Register* (Adelaide), 16 May 1849, pp. 3–4, 'Mr. R. D. Hanson's lecture on the theory of development'.

[77] C. A. Wilson, 'Injurious Insects, No. 16', *South Australian Register*, 29 October 1860, p. 3, Wilson was deferring to the works of systematists who were pre-Darwinist: Kirby, MacLeay and Westwood. Wilson wrote that animals from different epochs were only connected by 'analogy', but his use of the term then generally included the sharing of underlying structures and organs, now more correctly 'homology'.

[78] C. A. Wilson, 'The Natural History of the Colony - No. 24', *South Australian Register*, 8 January 1842, p. 4.

[79] C. A. Wilson, 'The Natural History of the Colony - No. 10', *South Australian Register*, 27 March 1841, p. 4.

[80] *South Australian Register*, 15 November 1865, p. 2; By 1880 Adelaide had grown to a city of 38,000 people and wheat growers had pushed north beyond the limits of the imagination, see D. W. Meinig, *On the Margins of the Good Earth - The South Australian Wheat Frontier 1869–1884,* (Adelaide, Seal Books - Rigby, 1970).

[81] The principle of uniformity – that the laws governing nature have acted more or less continuously throughout time – was extended from geology to encompass the observed continuity in structure within and between the groups of extinct and living organisms.

[82] Deveson 2013, p. 161.

Although Westwood named a species of comb beetle after him, Wilson's entomological contributions remained obscure and were lost to further scientific enquiry, leaving later investigators to start again on the 'locust' question.[83]

The plague spreads with the pastoral frontier

The early pastoral history of South Australia, like the other colonies, was marked by a rapid growth in sheep numbers. After the first overlanding of stock to Adelaide in 1838, there were already 300,000 by 1842 and 480,000 in 1845.[84] Most were grazed on the grassy open woodlands between the Murray River and the southern coast, on the plains north of Adelaide and in the hill country south of Clare. Many early reports of grasshopper swarms emanated from these districts. Sheep were not yet established at the head of the Gulf of St Vincent in 1845, despite suitable grassland, and the first pastoral leases were not issued until the following year.[85]

During the 1850s the grasshopper problem declined around Adelaide. In 1850, almost the total area of wheat cultivation in South Australia was in the Counties of Adelaide, Gawler and Light, within carting distance of Adelaide. The area sown to wheat in Adelaide County rose from 7,000 to over 30,000 ha between 1850 and 1856.[86] Wilson withdrew from regular natural history contributions after commencing his employment with the Supreme Court. When he finally revealed himself as being *Naturae Amator* in 1859, in a new series of articles on 'Injurious Insects', he commented that 'locusts have not appeared, or rather exceeded their limit (in numbers) for many years' and further suggested that ploughing had been the main cause of the disappearance of the 'grey and brown locusts'.[87]

Only a few months later, however, grasshopper swarms appeared in October 1859 in the northern pastoral districts and then near Adelaide in December. During the Governor-in-Chief's visit to the drought-stricken northern sheep runs near the present town of Hawker, the descriptions of general desolation and bare ground seen included 'clouds of grasshoppers or small locusts' (Figure 3.6).[88] In early November a correspondent in the vicinity of Mt Brown reported that 'the north has attracted

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[83] *South Australian Register,* 3 October 1856, p. 3.

[84] J. Boothby, *Statistical Sketch of South Australia,* (London, 1876), (Facs. edn. Adelaide, Pioneer Books, 1981), p. 85.

[85] *South Australian Register*, 23 April 1845, p. 3, 'An account of a trip to Yorke's Peninsula' by N.R.F.

[86] E. Dunsdorf and I. Dunsdorf, *Historical statistics of the Australian wheatgrowing industry: acreage and average yield in Counties and Divisions. New South Wales, Victoria, South Australia, Western Australia*, (Melbourne, University of Melbourne Press, 1956), statistics are given as 17,689 acres for 1850, and 95,000 acres for 1856.

[87] C. A. Wilson, 'Injurious Insects, No. 3', *South Australian Register*, 21 September 1859, p. 3.

[88] *The South Australian Advertiser*, 30 December 1859, p. 3.

grasshoppers from the four winds of heaven, with great clouds making havoc among the sheep runs'.[89]

The following year 'the old enemies' reappeared at Mt Remarkable in November and swarms were again widespread on the northern runs.[90] In 1861 there was further expansion of infested areas.[91] On 21 November, swarms of 'locusts' were seen crossing the Spencer Gulf near Port Augusta for several days and 'great hosts of locusts of a bright yellow colour were infesting country' around Angaston.[92] Each year throughout the 1860s, except after the extreme drought of 1865, different pastoral runs in the hill country of the northern Mt Lofty Ranges and southern Flinders Ranges reported grasshopper swarms. Their occurrence during October–December, along with occasional references to the distinctive yellow colouring or the unique oviposition behaviour, indicates the species involved was once again *A. cruciata*.[93]

The northward and eastward shift in reported infestations followed the expansion of pastoral and agricultural settlement. By 1858 squatters were established in all the better-watered country as far north as Maree and Mt Hopeless, north of the Flinders Ranges.[94] The Arkaba and Wonoka runs in the Flinders Ranges, where swarms were seen by the Governor-in-Chief in 1859, were far to the north of any cropping district at that time. However, farmers more often reported grasshoppers because they damaged crops.

The initial impact of the huge influx of livestock on the composition of the native grasslands in South Australia occurred before any botanical surveys. Dense perennial grasses declined as they did in other regions and the dominant kangaroo grass, *Themeda trianda* (Forsskål 1775), was virtually eliminated under continual grazing. Squatting expanded rapidly northward during the 1850s. By 1854 there were an estimated 1.7 million sheep in the colony, rising to 3 million by 1861.[95] Sheep were also established on the Eyre Peninsula in the mid-1850s. When Stephen Hack explored inland from Port Lincoln in 1856, he noted that the accessible grassy country was already eaten bare by sheep. Further inland, there were large patches of 'well-grassed plains' within the mallee scrub, which Hack

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[89] *South Australian Register*, 5 November 1859, p. 3.

[90] *South Australian Register,* 22 November 1860, p. 3.

[91] There were reports from Kapunda, Redruth, Clare, Truro and Angaston.

[92] *The South Australian Advertiser*, 21 November 1861, p. 2; *South Australian Register*, 25 November 1861, p. 3; reports also came from Wheal Barton, Parrot Hill and North Rhine.

[93] *South Australian Register*, 21 November 1868, p. 2.

[94] A. H. Freeling, 'Northern Explorations. No. 193', in *Explorations in South Australia 1856–1882,* (South Australian Parliament, 1857–1882), in 1856 Strangways Springs was the furthest north pastoral station.

[95] Boothby 1981, p. 85.

curiously suggested would improve with stocking.[96] That comment was often given by early squatters, caught in the mismatch between European agricultural traditions and the Australian environment. A thick cover of grass hid the vulnerability of the land.

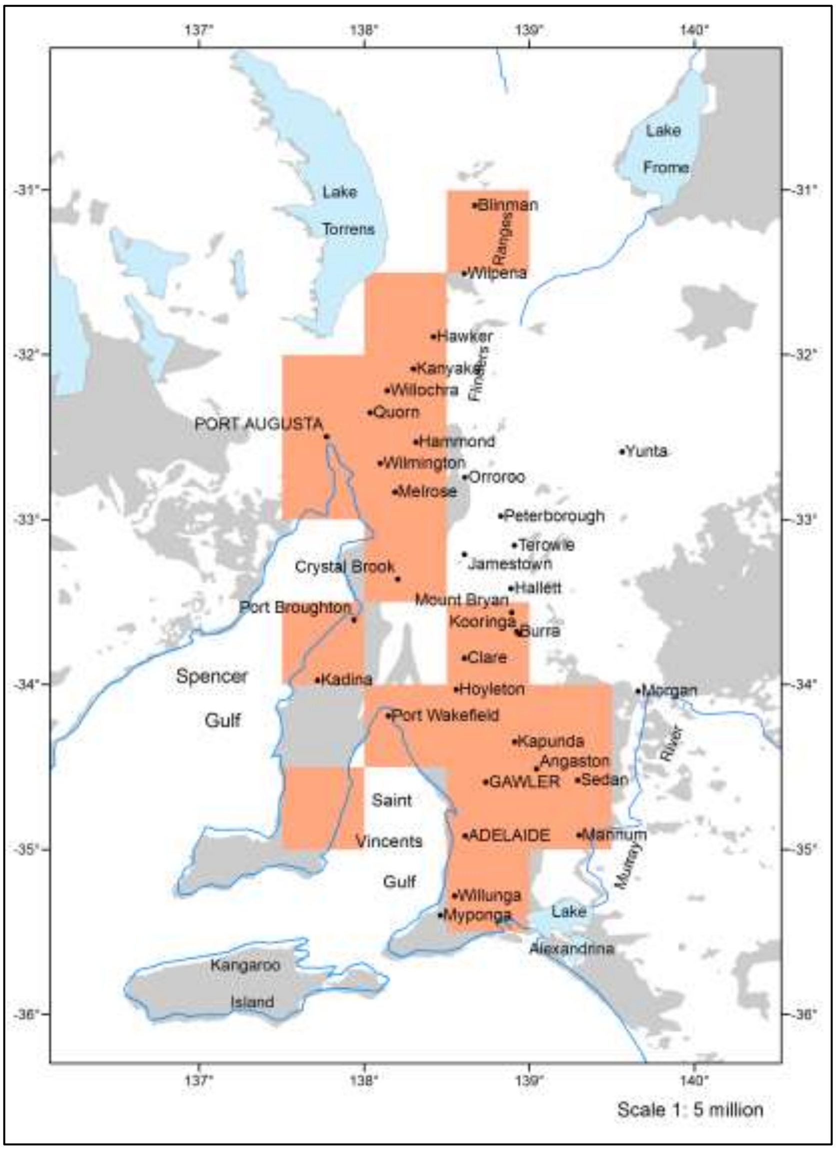

Figure 3.6. Grasshopper outbreaks in South Australia 1859–69. Districts where swarms were reported swarms in newspapers (orange) and current unsuitable habitats (grey).

By the mid-1860s there were probably a million sheep in areas north of Goyder's line and many runs were overstocked.[97] In 1865, the Northern Runs Commissioners, assessing pastoral areas where there

[96] S. Hack, 'Explorations by Mr S. Hack, 1857. No. 156', in *Explorations in South Australia 1856–1882,* (Adelaide, South Australian Parliament, 1857–1882), Hack travelled from Port Lincoln to Streaky Bay.

had been no significant rain for two years, described plains of bare earth littered with the bones of dead animals.[98] The already fragile vegetation and soils were subjected to extreme pressure during times of environmental stress.

A conflict over grass in NSW

> *What must be the social and political prospects of communities whose upper classes are mere squatters, coming to make a fortune, and carry it off, and careless of the country in which that fortune is made, as the locust is of the welfare of the tree on which it feeds ?*
>
> 'The Provincial Press on the Results of Squatting', *Empire*, 10 May 1866, p. 5.

European settlement of the Riverina began in the 1840s when squatters from Victoria came across the Murray onto the plains. Large tracts of land on the Edward River were taken up from 1844. One of the first squatters, who later 'reappeared as a person of substance' in Geelong, euphemistically described the frontier clashes with the existing inhabitants as 'well-fought battles with the blacks' that relieved the 'monotony' of pioneer life.[99] The township of Deniliquin grew around a place said to be 'wrestling grounds' of the local Aborigines and took its name from a prominent Aboriginal leader, who still lived in the area in the 1860s. It later became a major stock crossing point for the pastoral 'invasion' and a punt operated to cross the river.

Deniliquin quickly became the focus for stock movements from the Victorian expansion into NSW and Queensland, and their return as 'fats' to Melbourne markets. Other river towns, such as Hay on the Murrumbidgee and Booligal on the Lachlan, were also crossing points and sites of intense livestock concentration. Sheep and cattle were kept in their thousands on reserves and nearby areas with water access, often waiting weeks before going to sale or crossing the river.[100] A five mile by file mile reserve, surrounding Deniliquin on both sides of the river, was already constantly stocked in the 1850s. Although it was 'as big as London', there was conflict over access to grass near the town and

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[97] Janis M. Sheldrick, *Nature's Line: George Goyder, Surveyor, Environmentalist, Visionary*, (Adelaide, Wakefield Press, 2013); D. W. Meinig, *On The Margins of the Good Earth: The South Australian Wheat Frontier 1869–1884*, (Adelaide, Seal Books - Rigby, 1970), p. 44.

[98] The Commission was sent to assess the situation north of areas previously valued by George Goyder. Goyder established a line, based on the distribution of saltbush, beyond which he thought rainfall was too unreliable to grow wheat. Based on the replies to a survey from squatters, they estimated that more than half of the 50,000 cattle and a quarter of the 827,000 sheep perished. Their report was criticised for its dependence on replies from only 83 squatters, some suggesting the losses were much greater.

[99] L. Dale, 'Empire's proxy: sheep and the colonial environment', in ed. H. Tiffin, *Five Emus and the King of Siam: Environment and Empire. Cross/Cultures 92*, (Amsterdam, Rodopi B.V., 2007), pp 1–14, p. 5, Lynn Dale describes how any man could become 'a person of substance' in the squatting game; *Empire*, 5 June 1872, p. 4, Mr. Lewis, for fifteen years the monotony of his 'pioneer life was chiefly relieved by well-fought battles with the blacks'.

[100] *Empire*, 8 September 1860, p. 3.

along public roadways passing through sheep runs. Travelling and local livestock all converged on the reserve. The squatters exercised their power to impound any stock found on their land and imposed fines.[101] The scarcity of feed led some stockowners to choose different river-crossing points, such as at Moulamein and Swan Hill. When land was surveyed for town farming allotments it was excised from the reserve, which was already seen as inadequate for the increasing numbers of travelling stock and local users.[102] New reserves were created at other nearby stream crossing points further north to deal with the massive livestock movements.[103]

The city on the plains

By 1860 the town had 800 permanent residents, two churches, a court, school, bank, newspaper and five inns. It was now the 'highway' for livestock to and from Victoria and 'the greatest depot for the sale of store stock in the colony … excepting Sydney'.[104] Politics and business were dominated by owners of pastoral runs, reflected by the name of the local newspaper *The Pastoral Times*.[105] Moves to construct a bridge over the Edward River to speed progress of the district began in 1857. The proposal for a bridge, put to the Colonial Secretary of NSW, in 1859 was signed by all the prominent squatters between the Murray and Murrumbidgee. A bridge would not only ensure the town's permanence, it would also generate money. Crossing rates were to be £1 per thousand sheep and sixpence for each wheel and horse of carts.[106] A pile bridge was finally built in 1861 and, although it was in a state of disrepair by 1870, half the income of the municipality came from the tolls.[107]

By 1860 Deniliquin was mature enough to have a racecourse, a brewery, Masonic lodge, a bank robbery and even a 'crisis of development'.[108] New liberal land laws, the 'Selection Acts' in NSW and Victoria, were seen as a threat to existing squatting enterprises.[109] The politically powerful squatters, or pastoralists as they preferred to be known when fences replaced shepherds, were protecting their own interests by attempting to bargain with two colonial governments, first for surety over their land tenure and later for a rail connection. As the town's wealth had grown from the overlanding of stock, its future was also tied to that of the pastoralists. It was even suggested that the uncertainty over

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[101] *The Sydney Morning Herald*, 29 September 1856, p. 2.
[102] *Goulburn Herald*, 5 February 1859, p. 2.
[103] Reserves were surveyed at Wanganella, Barratta and Conargo on Billabong Creek in the early 1860s.
[104] *The Sydney Morning Herald*, 5 November 1861, p. 2.
[105] The newspaper at Hay was *The Riverine Grazier*.
[106] *Empire*, 1 April 1862, p. 5.
[107] The bridge was severely damaged during a flood in 1863.
[108] *The Argus*, 26 October 1859, p. 4.
[109] The Robertson Land Act 1861 in NSW.

squatters' tenure was contributing to overgrazing, as 'every run in these districts, scarcely one excepted, has been overstocked for the last three seasons'.[110]

While the Europeans were engaged in a battle over land ownership, and sheep were the means of legitimising their claims, the conflict centred on the rapidly diminishing resource — grass. There was already an ecological crisis on the surrounding plains, where the grasses and saltbush were being eaten out. The main stock route, the stretch of country south to the Murray River, was described as 'a desert' from the constant livestock traffic. From Deniliquin to Echuca the track ran between the fences of the neighbouring runs. 'In average years the open ground suffers so severely from the constant traffic of the stock and the dry weather that it bears no feed for sheep or cattle. Sometimes the road traverses forests of low timber and sometimes plains, but nowhere is there grass, except behind the fences of the grazier'.[111] It was not just the huge stock numbers involved in the great pastoral expansion, but their reshuffling across the landscape, as properties and flocks changed hands, that created a constant stream of animals. In the early 1860s, typical weekly stock crossings at Deniliquin were several thousand sheep and cattle. Livestock numbers continued to grow with the squatting expansion and by 1865 there was hardly any unstocked country along the Darling River between Wentworth and Bourke.[112] As the boom progressed, so did bridge traffic. The official return for the year 1871 counted over 850,000 sheep, 4,000 cattle and 21,673 bales of wool.[113]

'Our strange visitors'

Deniliquin was also established enough to have gardens and orchards, and to have stirred up its insect inhabitants. In November 1859 swarms of 'grasshoppers and locusts' appeared round the town and for two weeks millions of the 'strange visitors' disported themselves up the river.[114] 'Their appearance, close upon the thousands of hawks, evidently shows there is some great change going on to the southward, from whence they seem to migrate'.[115] By late December they disappeared, having ravaged any grass left by the hot winds.

But swarms appeared again in November 1861 and 1862, rendering horticulture or cropping almost impossible. And the surrounding 'vast inland plains' were alive with the pest, sweeping away the grass at the same time as a rush of gold diggers was taking 'all the necessities of life' from the

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[110] *The Sydney Morning Herald*, 12 March 1861, p. 3.

[111] *The Argus*, 6 February 1872, p. 6.

[112] *Adelaide Observer*, 11 February 1865, p. 7.

[113] *The Argus*, 6 February 1872, p. 6.

[114] *The Argus*, 28 November 1859, p. 5.

[115] *Bendigo Advertiser*, 3 December 1859, p. 3.

shops.[116] In 1862 grasshoppers came in 'clouds like a snowstorm', making 'considerable execution' with the grass on the runs along the Murray as far as Albury.[117] In the words of one correspondent:

> It is difficult to convey a notion of the quantity of these grasshoppers: it is scarcely credible, but the very atmosphere on some of the runs is thick with them … and as they have now made their appearance for three or four successive seasons, those who have hitherto indulged in a little cultivation … are beginning to lose heart …[118]

Figure 3.7. Sketch of the Deniliquin Town Hall constructed in 1876. The prosperity and future prospects of the town was reflected in the imposing building worthy of any capital city (State Library of Victoria).[119]

In 1864 they caused havoc again, some people now calling them the 'greatest pest in the Riverine country'.[120] Each November during the dry years from 1867 to 1869 the 'Riverine curse' returned, although in 1868 tens of thousands of ibis made their own 'great havoc among the grasshoppers'.[121] They were described as 'thick as hail' at Conargo in 1869, but flying only five to fifteen feet off the ground, in contrast to the high flying locust swarms that appeared two years later.[122] Although there are no specimens from the period, the timing and behaviour of the swarms in these descriptions are

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[116] *The Sydney Morning Herald*, 9 December 1861, p. 2; 21 December 1861, p. 13.

[117] *Launceston Examiner*, 6 December 1862, p. 3.

[118] *Maitland Mercury and General Advertiser*, 22 November 1862, p. 6.

[119] A/S23/12/76/156, Image No. b50290, from *Australian Sketcher with Pen and Pencil*, 23 December 1876, p. 156, at the opening ceremony Sir Hercules Robinson saw the building as a credit to the taste and enterprise of this youthful city.

[120] *The Sydney Morning Herald*, 12 November 1864, p. 4.

[121] *Wagga Wagga Advertiser and Riverine Reporter*, 18 November 1868, p. 4; *Geelong Advertiser*, 4 November 1868, p. 3.

[122] *Maitland Mercury and General Advertiser*, 23 November 1869, p. 1.

strongly suggestive of *A. cruciata*. South Australia was suffering annual infestations of this species and grasshopper swarms also increased in northern Victoria during the 1860s.[123]

Deniliquin's position at the centre of pastoral expansion and potentially of a river and rail transport network, also made it central to discussions about secession of a separate Riverine colony from NSW or 'annexation' to become part of Victoria. It also lent its representatives political power, which they exercised in making deputations to the NSW Government calling for spending on infrastructure. Press correspondence helped stir the pot for the 'rebellious people … peacefully and methodically asking for their rights', referring to the 'senseless hate which actuates the leaders Messrs. Cowper and Robertson in their legislating for the extinction of the station holders in this pastoral country'.[124] The Premier, Charles Cowper, on his visit in 1861 was politely presented with a list of wants that included a bridge, a court and gaol, a tramway, a post and telegraph office, as well as the expansion of the town reserve and improved stock impoundment.[125]

Overstocking and conflict over grass around Deniliquin is evidenced by the frequent legal action by some squatter 'ultras' over any selectors' stock caught feeding on their runs. The town's population tripled later in 1861 as Victorian diggers, hoping to find fortune on the Lachlan goldfields, passed through. Like a description of weekly stock crossings, 1,800 men, women and children crossed during one week in December 1861, and they were 'of the best description, robust and tough … few with any spare flesh on them'.[126]

Deniliquin was central to the political turmoil surrounding the 'Land Acts', 'universal' suffrage for white men, free selection, intercolonial customs duties and in the short-lived secessionist 'Riverine Association'.[127] An influx of potential settlers and squatters came from Victoria in a 'selection rush'. Now squatters, selectors and swagmen were all likened to the locusts. The squatters, by the way they spread themselves over the country, while 'their sheep and cattle did eat up everything green' and 'because they will concede no portion of the public herbage to any but themselves'.[128] The others were perceived by the squatters to be feeding off the fruits of their labour. While *The Pastoral Times* did not detect hostility between squatters and free settlers in their creative attempts to gain title over

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[123] The grasshoppers were described as 'one inch long and grey' at Bendigo in 1860.

[124] *The Sydney Morning Herald*, 12 March 1861, p. 3.

[125] *The Argus*, 26 August 1861, p. 5, Cowper looked favourably on most suggestions, but the reserve issue would involve excision from pastoralists' runs, who he also had discussions with about the repercussions of the Land Act on their interests.

[126] *The Sydney Morning Herald*, 21 December 1861, p. 13.

[127] *The Cornwall Chronicle*, 12 November 1864, p. 2, the conflict over customs and imports duties was described as a 'species of border warfare'.

[128] *Wagga Wagga Advertiser*, 29 May 1869, p. 4; *Empire*, 6 June 1865, p.5.

the land, chiefly using 'tulchan' selectors to create 'dummy runs', blocks along the river on former sheep runs were being forfeited because of failure to comply with the residence clause of the selection act.[129] In 1873, about 800,000 acres had been selected for freehold between the Murray and Murrumbidgee rivers, and Deniliquin grew at pace with the boom to become 'the city on the plains'.[130]

The late sixties — drought and more grasshoppers

> *A more calamitous season of drought has not been known in Victoria since its surface was first broken by either plough or spade. The consequent loss to farmers and graziers is incalculable. The swarms of grasshoppers – or locusts in miniature – which everywhere infested the country, bore more in the character of an Egyptian plague than anything else to which it could be compared. They attacked and devoured all living and green vegetation, from the grass on the plains and meadows to the uppermost branches of the vines and fruit trees.*
>
> *Ballarat Star*, 3 May 1869, p. 1.

In the early 1860s the squatters were the 'locusts'. In the harsh drought at the end of the decade their animals became 'herds of travelling locusts', as millions of sheep were moved in search of grass and took what little remained.[131] There were several drought periods in the second half of the decade, with widespread and protracted dry conditions in the pastoral country. The outward movements of livestock to new runs in NSW and Queensland were reversed, with hundreds of thousands of sheep crowding and denuding river frontages on the Murrumbidgee, Bogan, Darling, Namoi and Barwon rivers.[132]

In 1868 most of NSW, Victoria and South Australia was in drought. Conditions were so desperate in the Riverina that stockowners paid high prices to agist their sheep in the hill country of the upper Murray. The different routes of the exodus along the eaten-out frontages could be traced by carcases of sheep. One stockowner reported 'three or four lots of sheep of ten and twenty thousand each', passing through his run every day.[133] On the Northwest Plains of NSW, from Wee Waa to Walgett, there was 'not enough grass to' fill a tobacco pipe', cattle were dying in the mud of dried up waterholes and the absence of feed forced many stations to remove their stock. Thousands of 'sheep

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[129] *The Argus*, 30 September 1873, p. 4.

[130] *Australian Town & Country Journal*, 11 September 1875, p. 10.

[131] *South Australian Register*, 2 September 1868, p. 4.

[132] *Gippsland Times*, 5 January 1869, p. 3.

[133] *Sydney Mail*, 2 January 1869, p. 5, 'and as these swarms were divided into flocks, a continuous line of sheep often stretched across the run for ten or twelve miles'.

or shadows of sheep haunted the main lines of road seeking for what they cannot find' only to line the roads with their carcases.[134] Old timers said there had been bad droughts before but, as one writer from the Castlereagh River in NSW noted, the stocking rates were now many times higher, making the effects so much worse.[135]

South Australia bore the brunt of the 1865 drought and the northern districts continued to suffer during 1868 and 1869.[136] Average crop yields in 1867–68 and 1869–70 were half those of the previous years.[137] In January, stock inspectors complained of 300,000 sheep coming down the Murray from NSW onto the already 'overstocked runs'.[138] So prolonged had the dry weather been that 'anticipation of disaster' brought church leaders together to set aside a day in September for 'humiliation and prayers for rain' in many Adelaide churches and throughout the colony.[139]

On the Keilor Plains, within 100 km of Melbourne, the situation was similar. There were flocks of sheep 'literally starving, and scores of them dead on the land, while the others were digging up with their feet the roots of any grass left, trying to keep themselves alive'.[140] In western Victoria, emus and other wild birds thronged the frontages and their presence near houses was proof of conditions in the back country. 'When the wild animals of the bush forget their fear of man, and confidently approach, and even enter his dwellings … for water, we can need no further evidence to prove to us that the drought through which we are passing is one of terrible severity'.[141] Squatters in Queensland were affected as well. They petitioned the government to relax the land rents and provide more secure tenure in return for 'improvements' during the drought of 1869.[142]

1868 and 1869 were, however, 'good' times for the grasshoppers. Landholders across the south-eastern colonies suffered increasing grasshopper swarms in the spring and early summer in both years. In Victoria, the 'Egyptian Plague' epithet was used for the grasshoppers in the Wimmera district.[143] There were swarms on the northern plains at Echuca, and from Bendigo to Ballarat, where there was 'never witnessed during the driest seasons so large an amount of destruction by grasshoppers as in the

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[134] *Maitland Mercury*, 28 January 1869, p. 4.

[135] *Riverine Herald*, 3 March 1869, p. 3.

[136] *South Australian Register*, 16 September 1869, p. 2.

[137] Boothby 1891; *Northern Argus*, 21 May 1874, p. 2, contains Boothby's table from 1859 to 1874.

[138] *Riverine Herald*, 23 January 1869, p. 3.

[139] *The South Australian Advertiser*, 23 September 1869, p. 2.

[140] *Bacchus March Express*, 23 January 1869, p. 3.

[141] *Inquirer and Commercial News*, 10 March 1869, p. 3.

[142] *Maryborough Chronicle and Wide Bay and Burnett Advertiser*, 27 February 1869, p. 2.

[143] *Ballarat Star*, 2 December 1869, p. 4, on the Richardson River at Donald; *The Mercury*, 14 Jan 1870, p. 3, at Bolangum near St Arnaud, it was difficult to walk through clouds of insects a foot thick.

present one'.[144] Across the plains of NSW between the Lachlan and Murray rivers, where grasshoppers had been increasing for a decade, they were now an 'intolerable affliction'.[145] In South Australia the grasshoppers appeared from Port Augusta to Burra, with swarms of a 'yellowish colour' filling the air around Port Wakefield, while on the Adelaide Park Lands the 'supply largely exceeded the demand'.[146]

1869 was an ecological turning point on the grazed landscapes. The complete denudation of ground vegetation after several drought years was a reminder of the limits of pastoral carrying capacity and it contributed to a fundamental change in species composition of much pasture country. Dust storms swept across Victoria and South Australia, affecting Melbourne and Adelaide several times.[147] The drought was relieved in different areas gradually in late 1869, but was really only broken by widespread heavy rainfall in 1870.[148]

Landscape change and the 'locust' in question

> *Assertions of the natives that they have not before seen them in anything like the numbers in which they presented themselves last year and at present, we think, to be quite correct … if this matter were patiently inquired into by someone sufficiently acquainted with their language – we believe the practice of burning that was the custom of the natives before we settled amongst them to be the principal means of limiting the peril.*
>
> *The South Australian Register*, 5 November 1845, p. 2.

Aboriginal people around Adelaide in 1845 expressed the view that the swarming of 'locusts' was a new phenomenon and several newspaper entries identified the disruption of Aboriginal fire management practices as the cause. This suggests that the swarms recorded from 1843 to 1848 developed in direct response to the establishment of European land use. They were not part of a cycle of occasional outbreaks. The pattern of *A. cruciata* infestations in South Australia, appearing suddenly within five years of colonisation and then increasing in areas to the north and east also points to this

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144 *Bacchus Marsh Express*, 23 January 1869, p. 3, the report was from Ballan, between Ballarat and Bacchus Marsh.

145 *Wagga Wagga Advertiser & Riverine Reporter*, 18 November 1868, p. 4; *The Argus*, 4 December 1869, p. 7.

146 *South Australian Register*, 21 November 1868, p. 2, described as 1–1.5 inches long, with numerous clusters of the creatures … 10–20 yellow caste surround 1 larger brownish one laying eggs near Pt Wakefield clearly identifies *A. cruciata*; At Crystalbrook, a report of them never before in memory of the white man as numerous, with an estimate of 1,364,896,121/square mile was from October 9, also suggestive of the species; *South Australian Register*, 2 January 1869, p. 2; *The South Australian Advertiser*, 15 November 1869, p. 2.

147 *Bendigo Advertiser*, 28 January 1869, p. 2; B*order Watch*, 25 December 1869, p. 2, at Adelaide; *Brisbane Courier*, 16 March, p. 3.

148 *Southern Argus*, 6 March 1869, p. 4, drought 'broken' after rains on the upper Darling; *Adelaide Observer*, 10 April 1869, p. 6, Riverina 'a swamp' after rains.

species responding rapidly to landscape changes. Their appearance just around Adelaide in 1843 and 1844, then expanding in area annually until 1848, implicates the effects of a concentration of grazing stock on soil and grass cover in that population change.

Wilson's identification makes it clear that the small plague grasshopper, *Austroicetes cruciata*, was the species in South Australia in the 1840s. Other descriptions in the South Australian press indicate it was the principal species involved in all infestations before 1870. The exclusive occurrence of reports during September–December in inland NSW and Victoria, and occasional descriptions of the insect size and loose swarm behaviour are the main criteria for concluding that it was also the swarming species in inland areas of those colonies. Although other *Austroicetes* species may have been involved, notably *A. pusilla*, there is little evidence of the locust *Chortoicetes terminifera*.

The ecology of *A. cruciata* described by Wilson also presents several distinguishing features for separating the grasshopper from the locust in other reports. The eggs hatched earlier (August–September) and the nymphs were 'scarcely noticed in their primary state'.[149] Unlike locusts, they were never dense enough to blacken the ground. Fledging commenced in October and egg laying followed in November and December. The adults formed only loose, disorganised swarms with just a few females flying up to ten metres high. Numbers dropped during December and very few were left by mid-January.

Although several species of *Austroicetes* can be difficult to distinguish, having variable brown and green colouration, the yellow colour of males in high densities has only been identified in *A. cruciata* and *A. nullarboriensis*.[150] The ritualised male guarding behaviour during oviposition appears to be unique to *Austroicetes* in Australia and has been described only for *A. cruciata* and *A. pusilla*.[151]

Such a rapid and localised response is harder to establish in other colonies, but the appearance and increase of swarming in grazing areas is detectable, particularly near river-crossing towns where stock was concentrated. Nowhere were swarms described before the country was stocked. From their first surprising appearance at Deniliquin in 1859, however, they became an almost annual pest. The persistent swarming populations in the 'grasshopper belt' across South Australia, NSW and northern

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[149] *South Australian Register,* 12 April 1845, p. 4.

[150] M. J. D. White and K. H. L. Key, 'A cytotaxonomic study of the *pusilla* group of species in the genus *Austroicetes* Uv. (Orthoptera Acrididae)', *Australian Journal of Zoology*, 5 (1957), 56–87, p. 57, *A. nullarboriensis* shows 'kentromorphic phase differences'. Morphological features cast doubt on the distinction of *A. interioris* at the species level from *A. pusilla*, although there were cytological differences.

[151] W.W. Froggatt, 'Plague Locusts', *Agricultural Gazette of New South Wales* 11 (3), (1900), 175–183; D. P. Clark, 'On the sexual maturation, breeding and oviposition behaviour of the Australian plague locust (*Chortoicetes terminifera* (Walk.)', *Australian Journal of Zoology*, 13 (1965) 17–45, p. 40, Clark reported group laying of *A. pusilla*, with each female attended by many males, in southern NSW.

Victoria that continued throughout the rest of the century demonstrates an intensification of swarming.[152]

The evidence from the early outbreaks suggests an increased intensity and frequency of high density *A. cruciata* populations, which were sensitive to habitat changes and became persistent once established. The obvious landscape changes which stocking would have produced were soil compaction, increase in patches of bare ground and a decline of dense grass cover. In the grassland environments there was a rapid diminution of dense perennial grasses under continual grazing and the curtailment of Aboriginal burning regimes. The sheer increase in livestock numbers hides the added effect of their constant movements between owners, colonies and any available grass.

This possible causal relationship between the actions of livestock on the Australian landscape and habitat changes that favoured grasshopper swarming is hard to disentangle from increased reporting, which may simply have been a function of the spread of settlement. As settlers encroached on the range of *A. cruciata*, which already regularly formed swarms in grassland areas, they encountered more swarms. While the association of livestock and grasshoppers could therefore be coincidental, the implication is that soil structure and ground vegetation composition were altered in a way that increased the area of habitat and egg-laying sites for the grasshoppers. Soil compaction, particularly in areas of regular stock movement or watering, appeared to favour them. Wilson saw egg laying on bare ground and roads, and the preferred oviposition sites of *A. cruciata* were later described as hard-packed, bare soil in areas of short grasses.[153]

These landscape changes came first with the pastoral expansion and only later with farming. The establishment of pastoral runs in South Australia, NSW and Victoria preceded the northward extension of wheat cropping by twenty years. Making the case for an environmental cause of the grasshopper outbreaks is also tenuous with limited knowledge of pre-European distributions. Nevertheless, the clear increase in swarming frequency and its geographic pattern of occurrence leads to the conclusion that the squatters' livestock created the grasshopper problem and wheat farmers suffered the consequences. The numerous documented overseas examples of increased swarming linked to habitat change resulting from agricultural practices suggest that *A. cruciata* reacted in a

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[152] H. G. Andrewartha, 'The small plague grasshopper* (*Austroicetes cruciata* Sauss.). Notes on the present position in South Australia and recommendations for control measures', *Journal of the Department of Agriculture South Australia,* 43 (2), (1939), 99–107; H. G. Andrewartha, 'The distribution of plagues of *Austroicetes cruciata*, Sauss. (Acrididae) in Australia in relation to climate, vegetation and soil', *Transactions of the Royal Society of South Australia*, 68 (1944), 315–326.

[153] J. Davidson, 'The locust and grasshopper problem in South Australia', *Journal of the Department of Agriculture South Australia,* 41, (1938) 241–249; Andrewartha 1939.

similar way. Of particular relevance is recent research that demonstrates an increase in locust populations on overgrazed grasslands in response to the reduced protein content of grasses.[154]

Bad grasshopper years were also often hot, dry seasons when there was more crop damage and therefore more reports.[155] Grasshoppers stripped the flag, or chewed the green stems below the ripening heads causing them to drop to the ground. There were localised reports in South Australia of half the yield lost and the losses were often as significant as those from the other plagues of the farmer — red rust and hot winds. In pastoral country, grass cover could be eaten bare in spring, leaving the sheep without feed throughout the summer. Sparse grass cover and bare ground on the sheep runs was a feature of the grasshopper outbreaks in each colony.

The vegetation of the Adelaide plains and hills at the time of settlement was dense grassland and open woodland.[156] Forests only grew on the higher ridges of the southern Mt Lofty Ranges. This vegetation pattern was maintained by careful Aboriginal burning regimes. Bill Gammage cites several settlers' descriptions of kangaroo grass up to their elbows, so thick that people became lost in it.[157] The open woodlands extended eastward to the Murray and northward into the arid lands. There are also numerous early descriptions of dense, tall kangaroo grass in NSW and Victoria.[158] The plains of the Riverina at first presented a limitless resource of grass and chenopod shrubs. The depletion of these resources commenced in the 1850s, resulting in conflicts over access to grass. Wherever stock were concentrated, the ground was now often bare and the sheep more vulnerable to starvation. By the 1860s 'overstocking' was recognised as the common condition of pastoral leases in all colonies and in 1870 it was considered a 'crying colonial sin' by some progressive agriculturalists.[159]

Previous historical investigations attributed the 1840s outbreaks in South Australia to *C. terminifera*. In 1937, H. G. Andrewartha tentatively assigned all outbreaks up to 1875 to that species, after

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[154] A. J. Cease, J. F. Elser, C. F. Ford, S. Hao, L. Kang, and J. F. Harrison, 'Heavy livestock grazing promotes locust outbreaks by lowering plant Nitrogen content', *Science*, 335 (2012), 467–469.

[155] L. C. Birch and H. G. Andrewartha, 'The influence of weather on grasshopper plagues in South Australia', *Journal of the Department Agriculture South Australia,* 45, (1941), 95–100.

[156] D. Kraehenbuehl, *Pre-European Vegetation of Adelaide. A survey from the Gawler River to Hallett*, (Adelaide, Nature Conservation Society of South Australia, 1996).

[157] Gammage 2011, pp. 266–269.

[158] See for example, *Journey of Discovery to Port Phillip, New South Wales by Messrs. H. W. Hovell and Hamilton Hume in 1824 and 1825*, on 19 November 1824 near the Murray River, the grass now in full seed, frequently as high as their heads and seldom lower than their waists.

[159] *The Argus*, 28 June 1871, p. 3, Mr Scott, in giving a talk at the Ballarat Farmers Club on crop rotation and ratios of grazed pasture and crop to reduce the rapid exhaustion of cultivated soils, refers to overstocking as a colonial sin.

reviewing mentions of locusts in a 1918 book of South Australian rainfall records.[160] All records prior to 1872 were from Adelaide and, even though they all occurred during spring, they were outside the known distribution of swarms in the 'grasshopper belt'. Andrewartha's findings were later cited by scientists to demonstrate that locust plagues were occurring at the time of first European settlement.[161] None of them were aware of Charles Wilson's writings. With his clear descriptions of *A. cruciata*, and other supporting newspaper reports, we are now able to reverse this interpretation and present a different course and cause of events during the rest of the nineteenth century.

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[160] H. G. Andrewartha, 'Locusts and Grasshoppers in South Australia – some records of past outbreaks', *Journal of Agriculture South Australia*, 41 (1937), 366–368.

[161] D. M. Hunter, 'Advances in the control of locusts (Orthoptera: Acrididae) in eastern Australia: from crop protection to preventative control', *Australian Journal of Entomology* 43, (2004) 293–303, p. 294; D. W. Wright, 'Economic Assessment of actual and potential damage to crops caused by the 1984 locust plague in south-eastern Australia', *Journal of Environmental Management*, 23, (1986), 293–308, p. 294; K. H. L. Key, 'The Regional and Seasonal Incidence of Grasshopper Plagues in Australia', *C.S.I.R. Bulletin No. 117*, (Melbourne, 1938), p. 12, Key at first argued there was insufficient evidence to support Andrewartha's 1937 attribution, being based on the known regional incidence in the 1930s, but then concluded that since *A. cruciata* swarms were unknown in Adelaide, *C. terminifera* would appear to have been the species involved.

Chapter 4. Playing sad havoc with everything green: the first locust plague 1870–1875

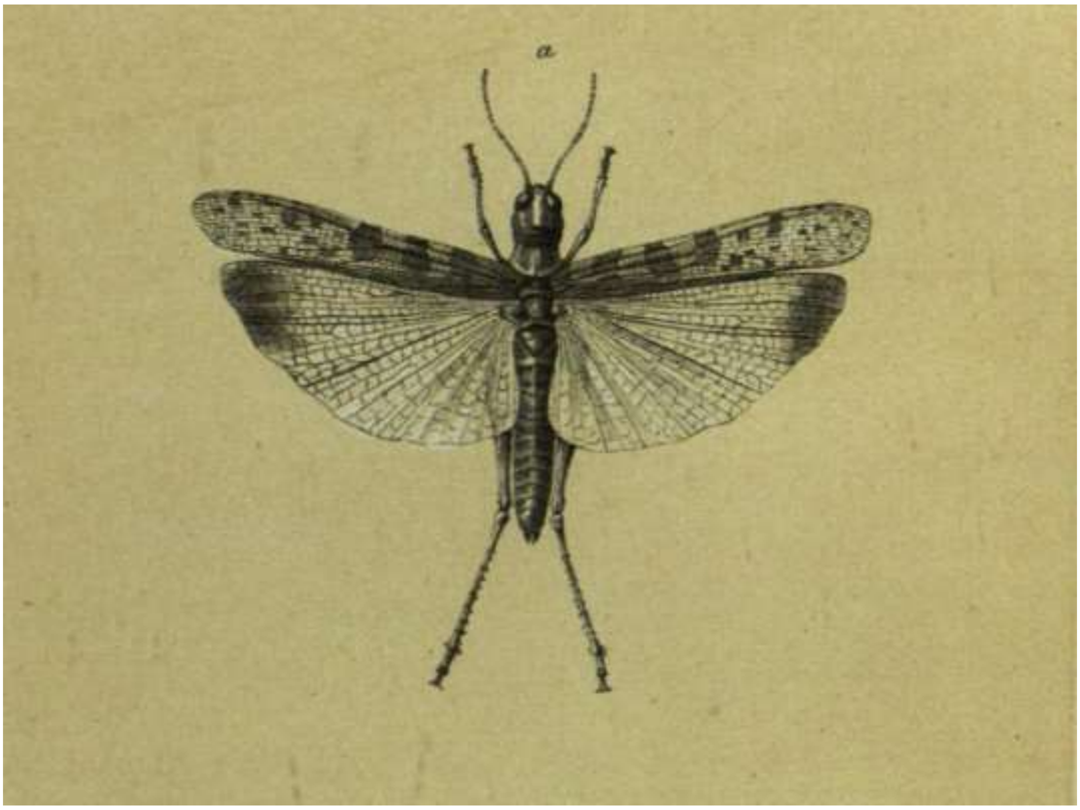

Figure 4.1. The first published diagnostic illustration of the locust. Figure 3a (detail) from the 'Report of the Secretary for Agriculture', *Department of Lands and Agriculture, Victoria* (Melbourne, 1873).

WALGETT — Locusts, Locusts, Locusts

This township and district is plague-stricken with the larvae, the pupae and the perfect insect … whole runs are being devastated; valuable gardens… stripped … they penetrate into dwelling houses and stores — damask coverings, table cloths, horsehair furniture, muslin, curtains, carpets, rugs, wearing apparel of all kinds, the serge lining of saddlery, billiard cloths, books and wallpaper —these are but a few items in the catalogue of damages sustained.

A description, of the insect … may be interesting, much diversity of opinion existing as to their being grasshoppers or locusts ... but whether the specimen under the tumbler before me is of the exact order which was as meat to John the Baptist… or the Easterns dry, pound, and in dry harvests use for food — I cannot say. The body … fully two inches … is long in proportion to its size, and is defended on the back by a strong corslet of light brown hue… It is furnished with four wings, of which the exterior pair are tough, straight and larger than those they cover, which are pliant, reticulated, semi-transparent, and fold up in the manner of a fan. These wings are of a delicate and beautiful texture, and in the fine fibres by which the transparency is traversed, Moslemic tradition has it that an Arabic sentence may be deciphered, signifying "We are the destroying army of God."

The Maitland Mercury and Hunter River General Advertiser, 28 January 1873, p. 3.

‘A recent institution’

The harsh experiences of the 1860s droughts seemed forgotten when the squatting business resumed after heavy rainfall in 1870. It was the start of a protracted La Niña climatic phase, the first for which El Niño–Southern Oscillation values are available.[1] The rush for land and grass recommenced as squatters pushed further inland in New South Wales (NSW) and Queensland. In the south, there was a new rush of ‘selectors’, intent on building their own pastoral empires or growing wheat on any suitable country. *Austroicetes* grasshoppers had caused concern when they ate the gardens, the crops, or the feed, but their depredations were confined to the months before Christmas. Even where they were seen to be increasing, their effect was largely as an accompaniment to drought. Only South Australia produced regular wheat surpluses before 1870 and grasshoppers did cause significant crop damage in some years.

Things changed dramatically in the summer and autumn of 1871 when locust swarms of a very different character spread across South Australia, NSW and Victoria. This was the first recorded plague of *Chortoicetes terminifera*, although its identity was not made clear until 1873, and it continued unabated until 1875. Migrating swarms of this new locust spread right across the altered grasslands of the south-eastern colonies, producing several generations each year. The swarms were large and mobile, leading to reports from various locations of them appearing in such numbers that even the oldest residents could not recall seeing before. The swarms flew high in the air and over long distances to invade areas hundreds of miles from their initiation. And the nymphs were in such numbers they clumped together, making the ground appear black (Figure 4.3). Although similar in appearance to the grasshoppers that had swarmed in previous years, they were larger and exhibited very different behaviour. Many farmers realised these insects did not fit the pattern they had become used to.

Dismayed by the millions of locust nymphs, a correspondent from Hay in NSW labelled them ‘a recent institution’, adding ‘that they are here is all that is generally known of them’.[2] These new locusts not only damaged the agricultural and domestic environments of the settlers, they stirred popular imagination. Were they the locusts of European and Arabic cultural myth? Would their decaying bodies in rivers and tanks cause a pestilence? Comparisons were made with those historical

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[1] J. Gergis and A. M. Fowler, ‘A history of ENSO events since A.D. 1525: implications for future climate change’, *Climatic Change*, 92 (2009), 342–387, Table 10, p. 375, lists the period 1870–1875 as one of the longest protracted La Niña events on record. The categorisation is strongly supported by available ice-core and other proxy data sources. Niño 3.4 values have been calculated from 1871, while Southern Oscillation Index (SOI) values commence in 1876.

[2] *Empire*, 2 November 1874, p. 4, and ‘some account of their origin and family arrangements would be interesting and useful’.

descriptions, and invoked deep associations with the very word ‘locusts’ and their legendary actions, but as often in humour as in fear.

The many descriptions show that the insect was recognised as different by its size, behaviour, numbers and seasonal occurrence. The appearance of swarms in autumn and the hatching of a second and sometimes a third generation within the same season were completely unfamiliar and disconcerting. Farmers who had experienced the grasshoppers expected them to appear in early spring and to have disappeared by January. The locusts also invaded many areas that had not suffered from the earlier grasshopper infestations.

Each colony had different historical experiences of ‘locusts’ and therefore different public and institutional responses to them. The swarms were so widespread and produced so many generations that this chapter treats the sequence of events in each colony separately, even though they were largely synchronous. A tripling of the number of newspaper reports from previous years in 1872 and 1873, only dropping again in 1876, itself attests to a dramatic change.[3] Together, the reports give information on the geographic spread and generation sequence of the plague in as much detail as some memorable locust plagues in the following century.

Newspapers provide many observations on the timing, changes in distribution, behaviour and appearance that establish the species involved and show it was the same in each colony. This chapter presents a reconstruction of the plague in South Australia, NSW and Victoria from 1870 to 1875. Information is limited to those areas with correspondent coverage, although numerous districts reported locusts each in season for several years (Figure 4. 2). The reports often include some diagnostic details, but rarely enough to identify the species with confidence at any one location, so the weight of evidence for assigning the species as *C. terminifera* is supported by cumulative synchrony. They also show that the phenomenon was recognised as different from all previous infestations — so

[3] The total number of reports of non-advertising or listing entries from the Trove Australian libraries digitised newspapers in April 2015 keyword searches for ‘locust’ or ‘grasshopper’ was 1868 – 327, 1869 – 457, 1870 – 305, 1871 – 620, 1872 – 1,713, 1873 – 1799. Report numbers were influenced by the establishment of the Australian Associated Press telegraphic network in 1871, which gave rise to newspapers summarising each other’s reports, but the number of separate locations mentioned shows a similar trend. Many individual reports list several locations and there were also many missed by keyword searches, because of unreadable words, hyphens or line breaks. A keyword search in April 2016 gave increased numbers, 1871 – 751, 1872 – 2025, 1973 – 2417, 1874 – 1732, 1875 – 1428, 1876 – 856, reflecting the capture of new articles by the ongoing digitisation program.

different that its unique features drew comment, frequently that nothing like it had occurred before in the experience of the settlers.[4]

South Australians had endured swarms of the grasshopper *Austroicetes cruciata* during spring and early summer for twenty-five years, and farmers had already tried a range of methods to deal with them. They were in the best position to notice the difference between what happened in the 1870s and those earlier infestations. Settlers in NSW and Victoria were also shocked by the arrival of locusts, despite the grasshoppers having swarmed almost annually in the Riverina during the 1860s.

Victoria was the only colony to have a government department with responsibility for agricultural development, although in 1873 it was only just finding its role. After disbanding the ineffectual Board of Agriculture, The Department of Lands and Agriculture was established in the middle of the plague and its first annual report in 1873 provides the first official coverage of locusts and our first view of public science in Australia (Figure 4.1). Nor was Queensland immune to this locust plague. The Darling Downs were affected by swarms during 1874–1876 and the pastoral areas further west were involved, though they were poorly represented in newspaper correspondence.[5]

Swarms of *A. cruciata* had been prominent in the years prior to 1870 and now formed mixed swarms with *C. terminifera* in some areas, contributing not only to agricultural damage, but to the confusion over identity and the sense of a continual increase.[6] The larger size of the locust and other more subtle physical differences eluded many observers. What was not missed, however, were the very densely packed patches of locust nymphs, or bands, now appearing in late summer and autumn as well as in spring, and of the large and gregarious swarms migrating in waves over long distances.

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[4] *Hamilton Spectator*, 18 December 1872, p. 4, 'settlers of thirty four years' experience never saw locusts before. The explorers to the best of my recollection never mentioned them'.

[5] *Darling Downs Gazette and General Advertiser*, 19 December 1874, p. 3, myriads of grasshoppers in clouds, while travelling sheep in the thousands, 'through overstocking'; 23 October 1875, p. 5, Charleville area; there were several reports from settlements on the Darling Downs in 1874 and 1875; There was a rush of squatters to country along the western rivers in the early 1870s and, by 1877, nearly all the frontage country along the Diamantina had been 'taken up'.

[6] *Kapunda Herald and Northern Intelligencer*, 5 December 1872, p. 3. At Waterloo (South Australia), an observer wrote 'they belong to the species we have here every summer. I have examined hundreds of grasshoppers, and have not found one of those mischievous travelling locusts'; *South Australian Advertiser*, 11 November 1873, p. 3. A report from Auburn in early November 1873 of 'a flock, scarcely a quarter the size of the unwelcome visitors of last season, and were also darker in colour and proportionately heavier in body, and consequently not so agile in their movements', suggests *A. cruciata*.

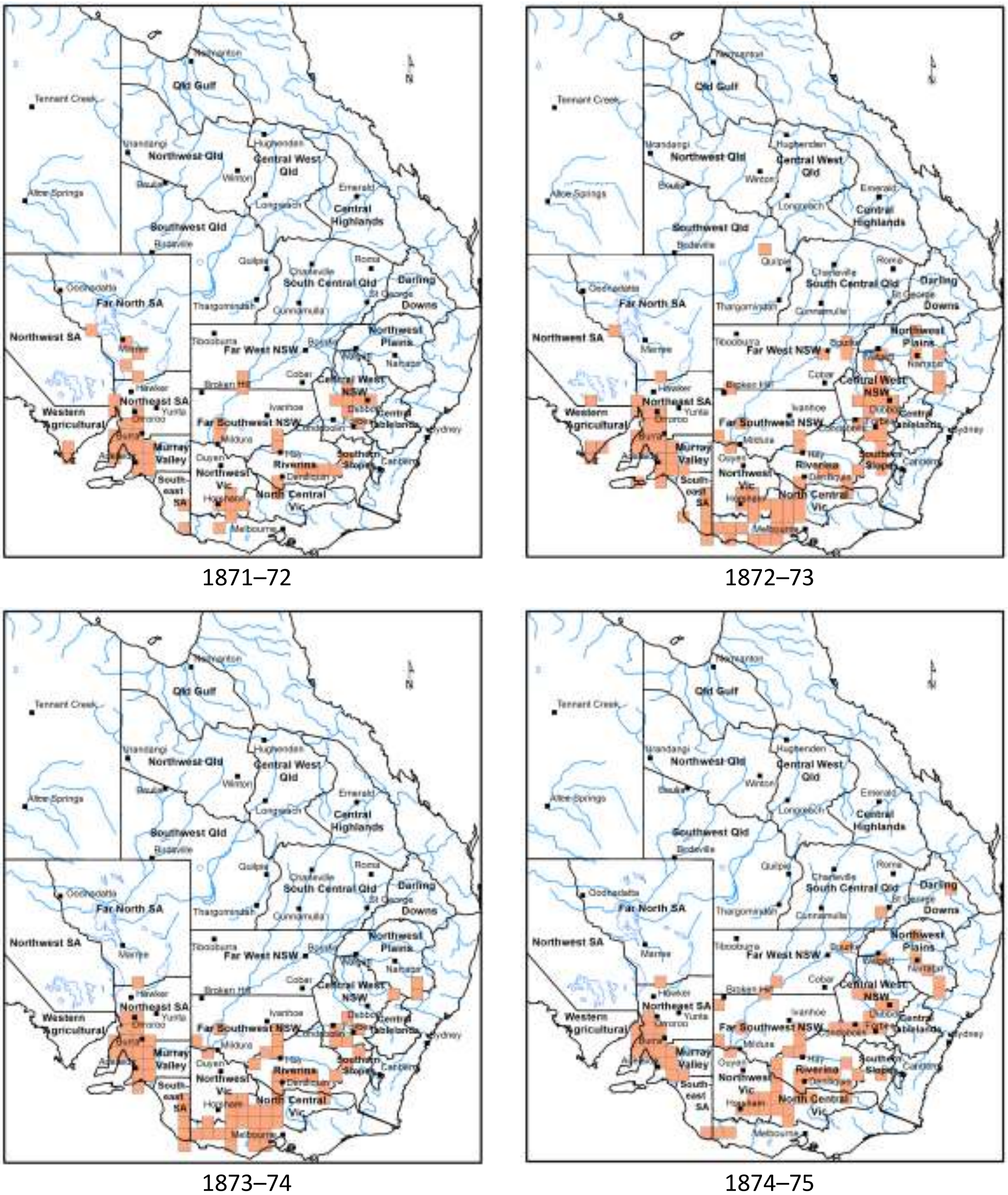

Figure 4.2. The 1870s locust plague. Locations reporting locust swarms during 1871–1875.

The frequency and detail of newspaper reports during the 1870s plague enables the timing, sequence and regional spread of each generation to be followed in the settled areas. There are numerous reports of the spring emergence of nymphs and later of their 'taking to the wing'. This was followed during summer by further hatchings several weeks after flying locusts had been in an area. Two generations, and sometimes three, are discernible each year, the timing of each matching recent sequences of locust development. In southern areas, for example, locusts generally hatch during October, a month later than the grasshoppers, which were often flying adults by this time. Hatching in late December or January (sometimes February) is the typical pattern for the development of a second generation of locusts. Depending on latitude, nymphs in March or April, as seen in 1872 and 1873 at places as widely separated as Burra in South Australia and Casterton in Victoria, 'brown to black and the size of a housefly', represented a delayed second, or a third generation.[7]

South Australia, with its network of agricultural correspondents, contributed the majority of locust reports in both 1872 and 1873 and they provide numerous accounts of the appearance of a 'second crop' of tiny locusts in summer or autumn.[8] At Port Augusta, it was even thought there had been four generations in 1872.[9] Multiple generations were also seen in NSW and Victoria.[10] The reports contain information on agricultural damage, with some balance between the anticipated ravages to the wheat and the actual damage in the good harvest years of 1873 and 1874. There were observations on mortality due to parasitism, with locusts dying in thousands in some places, and also much discussion of the nature of their parasites.

Hints of the plague in South Australia

> *The bulk of my wheat is very backward; the grasshoppers made sad havoc, so that I had to sow over again. For weeks they moved to and fro with the wind. The atmosphere was one living sheet of grass hoppers; as fast as a blade of wheat grew they nipped it off, and as the dry weather continued the plant could derive no nourishment from the dews by night; consequently it perished. The reason of their long continuance in one place I attribute to the grazing land that bounds me on the east, south, and west. They knew when they were well off; they could get a change of diet. John King, Unique Farm, near Pt. Wakefield.*
>
> *South Australian Advertiser*, 11 June 1870, p. 3.

This is the very first description identifiable as *C. terminifera*. Swarms had never appeared in the autumn before 1870, when they were seen from Burra to Port Wakefield at the top of the Gulf of St Vincent. Following the drought of 1869, the heavy rainfall in early 1870 in the northern districts brought with it the promise of good wheat yields, but also the first signs of a different seasonal pattern of 'grasshopper' activity. John King's description of having to re-sow a crop after it was destroyed as it emerged in autumn expressed the view that their persistence was due to being surrounded by sheep

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[7] *Portland Guardian*, 21 April 1873, p. 5, near Casterton; *South Australian Register*, 25 April 1872, p. 3, at Kooringa, near Burra, in South Australia.

[8] James Belich reports 12 newspapers in 1870, Trove has 12 in English and one German newspaper.

[9] *South Australian Advertiser*, 8 May 1873, p. 3.

[10] In the Ballarat area for example, swarms from the first generation appeared in late January 1873, laid eggs in February and by late March there were nymphs and fledgling adults, which in turn laid eggs in April to produce the following spring generation.

runs, implying that they developed there. In May, swarms were also reported from several areas north of Clare and, with no instance in memory of them ‘being about so late in the season’, they created apprehension.[11] Five hundred acres of young wheat were destroyed at Hoyles Plains. The novelty of such an event is evident from the doubt expressed by the editor of the Adelaide newspaper that these could be the ‘locusts’ that were such a regular feature of the spring and early summer landscape in the north.[12]

Feed was abundant during the spring of 1870 and, while young ‘grasshoppers’ were reported in numerous places, they appeared too late to do much crop damage. But in early December swarms suddenly flew into Port Augusta, Clare and Burra, and moved south onto the plains north of Adelaide. There were immense swarms of ‘grasshoppers’ for three days, ‘the noise of whose wings as the vast bodies of insects rose resembled ‘a flock of sheep being rounded up’.[13] By the autumn, their size drew comments, as ‘immense swarms’ flew through the district, appearing to be ‘of the ordinary type, but of a large size and strong in the wind’.[14] More importantly for our identification, a correspondent urged ‘that scientific men might consider’ the unusual fact that a second generation had hatched from eggs laid by the first in the same season.[15] In April 1871 swarms again flew into Adelaide. They could be collected in ‘bucketfuls’ in the surrounding Park Lands and Aborigines were said to fry and eat them, something they apparently had not done during the earlier grasshopper infestations.[16] At the same time, swarms were reported at Burra and as far north as Blinman, and a plague of travelling rats also appeared in the far northern districts. These were the long-haired rat (*Rattus villosissimus*)[17] Population eruptions of this species often occur after the heavy rainfall experienced during La Niña periods.[18]

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[11] *Northern Argus*, 6 May 1870, p. 2; *South Australian Advertiser*, 14 May 1870, p. 2.

[12] *South Australian Register*, 23 May 1870, p. 3; *Adelaide Observer*, 28 May 1870, p. 9.

[13] *South Australian Register*, 30 December 1870, p. 5, At Ashwell they did ‘no mischief in the fields, but gardens visited by them were stripped of everything green’.

[14] *South Australian Register*, 24 March 1871, p. 3, at Salters Springs; *South Australian Register*, 16 December 1871, p. 5, near Athelstone, now on the outskirts of Adelaide.

[15] *South Australian Register*, 11 March 1871, p. 3, a correspondent from Hamley Bridge.

[16] *Riverine Herald*, 12 April 187l, p. 3, this suggests that the locusts may have been a known food source by Aboriginal people then in the Adelaide area; Charles Wilson had commented in 1845 that the grasshoppers were not eaten.

[17] *Adelaide Observer*, 17 December 1872, p. 3, the long-haired rats were in such numbers that they obliterated the tracks of cattle. From Mundowdna, a Protection Station for Aborigines near Maree established two years earlier, they were named ‘my-ar-roo’ and said to seldom appear, the last time before the whites. It was recognised they came from Queensland because of the floods and they were also seen by Charles Todd north of Alice Springs in 1872.

[18] Large migrating populations of the long-haired rat also occurred in 1886 on the Georgina River in Qld, and in northern South Australia during the 1950s, 1970s and in 2011.

The plague sets in, 1872–74

> *Hosts on Hosts of Locusts*
>
> *… near Booborowie ... the swarms were so vast that in their flight they caused a deep shade in places as if from a cloud, and for a short time during the passing of one dense army they were so thick as to shut out objects at a little over 100 yards distant. Besides the myriads flying, they were so numerous on the ground that a track, such as seen behind a vessel at sea, could be noticed behind a horse, where the winged nuisances had moved out of the way ... Our informant had for some time to stop and turn his back, as neither man nor horse could well face them, it being like trying to go against a heavy hail storm. The scene was novel and bewildering, as around, above, and below was one living, moving, roaring mass of insect life.*
>
> *South Australian Register*, 28 March 1872, p. 4.

In the spring of 1871 there were locust swarms from Port Augusta to Port Wakefield. In mid-December they swept into Adelaide a third time, where millions were drowned in reservoirs and Glenelg residents watched them flying over the sea at sundown.[19] An east wind brought swarms 'all day like a dense fog, flying up to a hundred feet in the air and the noise of their wings a constant hum'.[20] Charles Wilson joined the growing correspondence, drawing on his experience of grasshoppers from the 1840s.[21] Confirming descriptions by 'Observer', who recalled dirty brown females and smaller yellow males from the 1850s, Wilson reiterated that every year they had been active in November and December, but had disappeared by January. Judging from 'past experiences of their migratory habits and times of appearance', he thought 'there would be no more than usual to fear from their depredations this season except in limited localities'.[22]

However, in the autumn of 1872, migrating swarms again spread throughout the settled districts of South Australia, reaching coastal areas beyond the Murray River mouth, and laying enormous numbers of eggs that hatched the following spring. Neither Wilson nor 'Observer' had seen the locusts then swarming on the Murray Flats and it appears Wilson did not examine specimens in Adelaide.[23] Another entomologist, the Rev J. N. Hinterlocker, who had specimens of desert locusts

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[19] *South Australian Register*, 18 December 1871, p. 5.

[20] *The South Australian Advertiser*, 21 December 1871, p. 3, on December 17, report from Williamstown in the Adelaide Hills.

[21] *South Australian Register*, 27 December 1871, p. 6.

[22] *Adelaide Observer*, 16 December 1871, p. 9; 23 December 1871, p. 9.

[23] *South Australian Register,* 19 December 1971, p. 6; E. D. Deveson, 'The Adelaide Philosophical Society and the early accommodation of the Darwin-Wallace theory of Natural Selection', *Transactions of the Royal Society of South Australia*, 137 (2013), 151–167, p. 154, Wilson had given his collections to the Gawler and Adelaide museums in 1865. His preoccupations were now more in the line of urban amenity and philosophical pursuits.

from Egypt in his collection, thought this an 'unusual appearance' of the much smaller Australian locust.[24]

Up to two-thirds of the expected 1871 wheat harvest was reportedly lost to the combined effects of red rust and locusts in districts from Adelaide to Jamestown, the northern limit of cropping at the time (Appendix 4).[25] The following spring, the 'grass was so plentiful that what they took was not missed'.[26] But they left eggs in many places during December and a 'second crop' of nymphs appeared on country north and east of Adelaide in January and February.[27] When these in turn fledged in March 1872, migrations again took them south to Robe and Naracoorte, and onto the Yorke Peninsula and Eyre Peninsula (Figure 4.2), where they were 'more numerous than had ever before been observed'.[28]

The locusts also remained in the northern districts, with swarms at settlements from Adelaide to Port Augusta, and even beyond the Flinders Ranges. From Mundowdna, Mr. G. Debney wrote in March 1872:

> The last time I wrote you was about the rat pest; since then abundant rains have fallen, filling all the lakes and waterholes, and causing the feed to spring abundantly over the North. I considered that I had feed and water sufficient for the next 18 months, even supposing that no further rain fell during that time. But on Monday the illusion was dispelled by clouds of locusts flying through the air from the north, and settling where the feed was greenest, devouring all before them. This morning they appear to have departed, their place being taken by a small grasshopper in greater numbers than the locusts. They have every appearance of young locusts with undeveloped wings.[29]

John Lewis, who worked as a courier to Overland Telegraph teams, later wrote of encountering swarms at many locations between Leigh Creek and Lake Eyre during February 1872, passing overhead for hours and appearing at night in such numbers they put out the campfire.[30] Locust

[24] *South Australian Register*, 30 December 1871, p. 6, Hinterlocker too may have been confused, because he had 'single samples' from six years earlier, and thought it was the same as a species from southern Europe, most likely the Moroccan locust.

[25] *South Australian Register*, 22 December 1871, p. 5; 29 December 1871, p. 5; 30 December 1871, p. 5; 12 January 1872, p. 6, heavy losses were reported at many locations. Most of the damage was to young crops in autumn or to the ripening heads in late spring.

[26] *South Australian Register*, 10 January 1872, p. 5, reported from at Angaston, Gladstone and Narridy.

[27] Nymphs were reported also from Pinkertons Plains, Keyneton, Kapunda and Burra.

[28] *South Australian Register*, 4 April 1872, p. 6; Reports also came from Noarlunga and Goolwa.

[29] *South Australian Register*, 28 March 1872, p. 4.

[30] *The Mail*, 17 May 1874, p. 2; John Lewis, *Fought and Won*: *autobiography of a South Australian*, (Adelaide, W.K. Thomas & Co., 1922), pp .68–69, in February 1872, locusts were numerous at Pekina Creek, Moolooloo,

breeding and swarms were also described at Thylungra at the end of 1872 in the recollections of the Durack family, the first settlers of the Cooper Creek–Bulloo River country in Southwest Queensland.[31] The arid regions of northern South Australia and western Queensland were sparsely populated by Europeans, but these reports attest to multiple generations, which probably contributed to the autumn invasions further south (Figure 4.2).[32]

A common metaphor for the flying swarms was snow storms, as many of the correspondents were settlers from Europe. The size of the swarms, too, was impressive, sometimes miles wide, mistaken in the distance for smoke or dust clouds and sometimes, so dense as to 'cast a shade'.[33] Locusts also flew at great height. In March 1872, William Forrest observed a swarm that 'filled the air three feet from the ground to as high as we could notice them. From observations and measurements I suppose we could see them 1,000 feet high. The higher the fewer at first, but soon they became so dense that a hill quarter of a mile off could only barely be discerned through them'.[34]

The resurgence of swarms in spring 1872 led Adelaide newspapers to announce 'the locust question is assuming an increasingly alarming aspect… their hunger is insatiable, and the distances they travel in attempting to appease it are almost past belief'. There was now 'no season of the year at which they are not to be dreaded.'[35] But the emerging detail of locust life history also offered some chance of defeating them. The concentration of young nymphs in small patches became the best hope for control in an otherwise chaotic and increasingly widespread problem. It was observed 'that they do not distribute themselves over the whole countryside, but are to be found in patches, and this gregarious habit of theirs greatly facilitates the task of destroying them, whether … by fires kindled round their camping place' or by other expedients to such as by beating, trenching or trampling by sheep.[36] In October 1872, near Lake Alexandrina, Edmund Hughes reported on local experiments in manual control, using fire and sweeping with bushel bags fitted on a wire hoop, which netted four men a

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My Lyndhurst, Mundowdna, between Lake Phipps and Lake Eyre…. country covered with grass as far north as Mt Margaret in Queensland.

[31] Mary Durack, *Kings in Grass Castles*, (London, Corgi Books, 1981), p. 137, after rain and floods in November 1872, locust nymphs destroyed gardens at Thylungra.

[32] Innamincka had only just been settled as a stock-route stopover in that year.

[33] *Bendigo Advertiser*, 28 December 1871, p. 2.

[34] *South Australian Register*, 28 March 1872, p. 4, at Pinkertons Plains, north of Adelaide, describing in detail swarms on 14 March, 'about 10.45 a.m. they began coming in numbers from a little north of west, and in a few minutes they had had filled the air'.

[35] *South Australian Register*, 18 November 1872, p. 5.

[36] *Adelaide Observer*, 16 November 1872, p. 9.

million locust nymphs in a day. Children, too, attacked patches of a few square yards with bags or boughs, which reportedly worked quite well.[37]

At the same time as locust swarms covered the country in 1872, new agricultural land selections were being surveyed and rapidly taken up to the north and west of Jamestown.[38] On the Yorke Peninsula there was a 'genuine rush as ever was attracted by a gold-field', the high number of applicants for land warranting limited auctions for blocks.[39] Donald Meinig described this rapid expansion as a phase of 'industrial-age folk-agriculture', made possible by the partnership of the frontier wheat farmer and the 'country machinist'.[40] Grand plans were being made for a rail transport network through the new wheat lands. The high yields of the wet 1870s supported the view that 'conditions had changed' since George Goyder had identified the northern limits of reliable seasons for cropping.[41] New settlers, as well as experienced selectors and 'land locusts', those abandoning farm land after a just few years, were pushing north continuously. But at the same time, amid the clouds of locusts at Kanmantoo, wagons of disheartened settlers were seen heading for Victoria, where generous land selection laws were now in place to encourage farming.[42]

The cycle started again in spring 1872 and this time bands of nymphs developed in southern districts that had never before seen them, including Robe, Naracoorte and Port Lincoln, where their movement was described as 'a living stream'.[43] Swarms formed in November and December but were too late to do much damage to crops, and on 16 December they entered Adelaide, the same day as a year previously.[44] Again there was a second generation of nymphs and, in early 1873, further swarms.[45] The southward autumn migrations were even more dramatic this time. In March 1873 locusts were

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[37] *Southern Argus*, 25 October 1872, p. 2; 15 November 1872, p. 3, the report was from Wellington. The men collected 2,340 lb of young locusts, and Hughes estimated that represented 1.2 million locusts.

[38] New agricultural surveys were made at Crystalbrook, Belalie, Caltowie, Yarcowie, Gulnare and the Broughton Extension in 1872; D. G. Meinig, *On the Margins of the Good Earth: the South Australian Wheat Frontier, 1969–1884*, (Adelaide, Seal Books, Rigby, 1970), pp. 43, 48, Meinig details the boom of the 1870s, with sequential annual releases of new surveyed Hundreds, adding 250,000 acres of wheat cropping in the two years 1872–74, after land laws were changed to allow any farm to be purchased on credit.

[39] *South Australian Register*, 14 October 1872, p. 7.

[40] Meinig 1970, pp. 122–123.

[41] *South Australian Register*, 23 September 1878, Supplement, p. 1, crop statistics; Meinig, 1970, pp. 61–73, the old 'folk idea' that rain follows the plough took hold during the land boom of the late 1870s; for a detailed coverage of Goyder's ideas and ecological contributions, see Janis M. Sheldrick, *Nature's Line: George Goyder, Surveyor, Environmentalist, Visionary*, (Adelaide, Wakefield Press, 2013).

[42] *South Australian Advertiser*, 29 March 1872, p. 3, at Kanmantoo.

[43] *South Australian Register*, 29 November 1872, p. 5, near Tunby.

[44] *South Australian Register*, 30 December 1871, p. 6; *South Australian Advertiser*, 16 December 1872, p. 2, the damage was reported to be less than expected in several districts.

[45] Young locusts and tiny hoppers were reported from Woodside, Gulnare, Watervale, Neales Plains, Auburn, Buschfelde and Dry Creek – most of these localities are near Adelaide.

‘visiting’ Kangaroo Island and, after one phenomenal night, dead locusts were washed up in heaps along beaches at Port Elliot, ‘banked up a foot deep’ for eight miles along beaches near Port McDonnell and they floated on the water at Encounter Bay, where snapper were caught ‘crammed full of them’.[46]

Recording locust arrivals

A correspondent from Koonunga says:

> South Australia has beaten the world in wheat growing, but in all probability she will this year beat herself, surpassing all her previous productions in the grain department. I have to report the arrival of what appear to be fashionable, but certainly unwelcome, visitors — the locusts. I find from my note-book that in 1871 they put in an appearance on November 30; in 1872 they were very accurate, arriving on precisely the same date. In 1873 they lagged somewhat, as it was 6th December before they showed up. Last year I think there could not have been many down our way, as I did not note their arrival. This year … they did not arrive till the 17th, and no one would have quarrelled with them if they had been ever so much later; as yet, however, with us they have done no damage …

‘Farming Notes’, *Kapunda Herald and Northern Intelligencer*, 21 December 1875, p. 3.

There had been no precedent to such continuous swarming. After widespread hatchings in spring 1873 there were several generations each year in 1874 and 1875. Aware of their agricultural significance, some farmers recorded the arrival of locust swarms in their area (box above). While grasshoppers were also present in some areas in spring, the characteristic thick patches of nymphs made the locust more obvious (Figure 4.3).[47] Local impressions of the locusts getting worse were repeated many times, as were dramatic descriptions of their depredations. In the new cropping country at Broughton, the backward crops were ‘black with locusts’ in numbers not seen in thirty-four years.[48] But there were also descriptions of dying masses of locusts and much discussion of the actions of certain parasites.

[46] *South Australian Register*, 7 March 1873, pp. 3, 4, 7; *South Australian Advertiser*, 6 March 1873, p. 2.

[47] *Adelaide Observer*, 23 October 1875, p. 5; 13 December 1873, Strathalbyn; 27 December 1873, Melton;

[48] *South Australian Chronicle & Weekly Mail*, 8 November 1873, p. 7, a report from the Broughton Extension, a new agricultural area.

Figure 4.3. A dense band of locust nymphs (photo courtesy NSW Local Land Services).

The plague in New South Wales

> *A TRIP FROM WAGGA WAGGA TO FORBES ACROSS THE LEVELS*
> *About four miles on the Wagga side of Junee I fell in with a 'plague' of grasshoppers, and I have had them all day. I have never, seen anything like it before. They appear like a swarm of bees, but that they extend as far as one can see on every side, and mile after mile as I travel. I have come through thirty miles of them, and people say they are thicker further on. If so, it must be a case of uncomfortable squeeze for the weaker ones …*
>
> *Empire*, 30 April 1872, p. 4.

NSW pastures were in 'magnificent order' in early 1870. In April all the western rivers were full and families moved to high ground at Bourke as Darling River floodwaters rose.[49] By June the country from Dubbo to Warren was 'one vast swamp' and in November the Riverina town of Deniliquin was isolated for weeks by a flood that 'no white man ever saw' before.[50] But the good seasons brought the locusts with them.

The quotation above, describing swarms near Junee in autumn 1872, gives us one of the few pictures of the settlers who are mostly silent in the newspaper record. Amid the endless flights of locusts, a

[49] *Ballarat Star*, 26 January 1870, p. 4, country 'from Dubbo to Coopers Creek was in magnificent order' and the Riverina was covered in deep fine grass in January; *Riverine Herald*, 30 July 1870, p. 2; the Paroo, Warrego, Wilson, Darling, Barwon, Balonne and Castlereagh rivers were all full.

[50] *The Darling Downs Gazette and General Advertiser*, 1 June 1870, p. 2; *Goulburn Herald and Chronicle*, 18 November 1870, p. 3, Deniliquin was isolated by flooding of the Murray River and its tributaries.

few struggling families lived in slab shacks among the 'disreputable trees and scrub' north of Junee.[51] While the plague was obvious to anyone west of the Dividing Range in 1872, reports suggest they had been active on the western plains since 1870. Bourke, on the Darling River, 'was completely infested by an army of locusts' in December, appearing 'like a heavy fall of snow, and, what is strange, they move always together, sometimes going west and sometimes east'.[52] The appearance of masses of 'diminutive grasshoppers' in January 1871 indicates they were locusts.[53]

Suddenly in March 1871, enormous flights of locusts swept across the Riverina flying southeast. The weather recorder for the Government Observatory at Deniliquin, in operation since 1858, thought the passage of these massive swarms notable enough to include in the monthly report.[54] The following spring, hatchlings covered the plains of the Riverina, and in summer the travelling millions did 'incalculable mischief to the standing crops'.[55] After a brief hiatus in January 1872, autumn swarms invaded the entire southern half of the colony from Lake Victoria in the west to Forbes in the east. They ate all the feed along the Darling River, spread right across the plains of the Riverina and, at Dubbo, the swarms were recognised as immigrants and 'played sad havoc with the feed'.[56]

Many lasting anecdotes of the effects of the locusts were set during this time. They filled the houses, crawled into and died in walls, ate wallpaper, curtains and anything containing starch. They contaminated water tanks and caused general distress. There were frequent comments on the difficulty of getting a horse to face the locusts, and of them striking people's faces in carriages or in the street. It

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[51] *Empire*, 30 April 1872, pp. 4–5, describing people living at The Levels, 'Number of population-3 men, 1 woman, and 18 children to 20 square miles; amount of clothing-2 seedy coats, 3 seedier unmentionables, 1 gown, and some indescribable articles made up of rags and patches ; education-0 ; civilization-000'. The writer was relieved to see the first 'comfortable homestead with substantial improvements' of a squatter when he reached the plains north of Temora. Of the locusts he wrote, 'It is amusing to notice them in camp towards evening. Every log, stump, and tree, not too high, is covered so thickly that some unfortunates are being constantly pushed off, and have to select somewhere else'.

[52] *Australian Town and Country Journal*, 17 December 1870, p. 7; *Empire*, 31 December 1870, p. 3, a brief report from Dubbo, the first also from that town, mentioned that 'grasshoppers' threatened to overrun the district.

[53] *The Maitland Mercury & Hunter River General Advertiser*, 26 January 1871, p. 4, the appearance of hatching nymphs in January after swarms in December conforms to the breeding cycle of locusts, and reduces the probability of any other species, except *Oedaleus australis*.

[54] *The Sydney Morning Herald*, 12 April 1871, p. 4, swarms recorded on 2 and 8 March.

[55] *Riverine Herald*, 2 December 1871, p. 2, there were reports from Booligal in the west to Wagga in the east.

[56] *Empire*, 6 April 1872, p. 3, the swarms at Dubbo were described as immigrants*; South Australian Register*, 25 April 1872, p. 3, reports from Lower Darling of 'eating down green growths'; Similar reports came from Lake Victoria, Tarcoola Station, Wilcannia and Weinteriga in April and May 1872; *Empire*, 18 April 1872, p. 3; *The Sydney Morning Herald*, 13 April 1872, p. 7, describes the plains round Wagga; *Riverine Herald*, 8 May 1872, p. 2.

was in the gardens that the destruction was often hardest to take, as years of effort in establishing green and familiar surroundings were wiped out.[57]

The summer of 1872–1873 saw an almost complete occupation of NSW, from Wentworth in the west, right across the Riverina to Forbes and Grenfell in the east (Figure 4.2).[58] Swarms also formed in the Bourke, Brewarrina, Walgett, Moree and Narrabri districts of the northwest, flying closer together than a swarm of bees.[59] In the Central West, the sheep runs along the Bogan, Macquarie and Castlereagh rivers were all infested, first with hoppers and then in December with swarms.[60] Everywhere the grass was totally consumed. Along the Bogan, there was 'damage tending to Biblical', and on the Macquarie, 'they were on the ground for six days … as thick as shrimps in a dish … eating salt bush, grass, cotton bush, and … the whole distance of our run (ten miles by ten) was covered'.[61]

A second generation of nymphs in January 1873 was followed in February and March by swarms that swept eastwards to Barraba and Murrurundi, Grenfell and Gundagai.[62] At Hay, migrating swarms 'a mile in width' passed over, flying from twenty to several hundred feet in the air.[63] The Deniliquin weather observer again noted an 'immense flight of grasshoppers, lasting two hours, darkening sky, making noise like a high wind'.[64] By April swarms had again spread over the Riverina from the Darling River to Albury, Grenfell and Gundagai in the east.[65]

The plague peaks in NSW 1873–74

> *The summer season of 1874 will be memorable from the general havoc committed by grasshoppers. Never since the white man set his foot in the saltbush country have these pests visited us in such numbers, and with so much intent to destroy. They first began to make an appearance here about four weeks ago, although their advance was heralded by some of our*

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[57] *The Sydney Mail and NSW Advertiser*, 21 November 1874, p. 647, a description from Hay NSW of domestic and garden devastation, and dead locusts had been 'going down the river for days in black masses'.

[58] Reports also came from Booligal, Hay, Merool, Jerilderie, Deniliquin, Wagga and Condobolin.

[59] *Maitland Mercury &c.*, 5 December 1872, p. 3.

[60] *The Sydney Morning Herald*, 6 November 1872, p. 4; *Maitland Mercury*, 6 December 1872, p. 1.

[61] *Brisbane Courier*, 5 December 1872, p. 3.

[62] Reports from Cobbadah (near Barraba), Murrurundi, Grenfell, Gundagai, Wellington, Hay, Walgett, Dubbo and Narrabri.

[63] *Hay Standard*, 5 March 1873, p. 2, on 1 March.

[64] *The Sydney Morning Herald*, 29 March 1873, p. 6. 'Deniliquin weather station report: swarm on Sunday, the 9th, bottom of flight only three feet from ground'; *Geelong Advertiser*, 18 February 1873, p. 2, another local described their 'brizy' amounted to a kind of a roar, like distant sea.

[65] *South Australian Register*, 10 April 1873, p.5, a report from 'Tarcoola', near Pooncarie; *The Maitland Mercury &c.*, 6 March 1873, p. 4, swarms at Gundagai and Grenfell.

far-off subscribers living between the Darling and Cooper's Creek, where then the insects appeared, destroying the grass, or even the young saltbush. They came, then, from the north-west, and possibly made their way from dry and arid lands in the centre of the continent. Having swept the Darling, Lachlan, and Murrumbidgee plains, they fell foul of the lands around Deniliquin, and, in the course of three weeks or so, have managed to eat up all they could get that promised them a grain of nourishment.

Maitland Mercury, 28 November 1874, p. 4.

After three years of locust swarms, writers in NSW still expressed shock at the sheer numbers and the damage they caused. The comments above from the Riverina may have been overly dramatic, but were typical of the descriptions of an unprecedented event, and explored the possibility of locusts coming from desert breeding grounds. Ideas about the locusts' life cycle and possible ways of dealing with them also circulated in the newspapers. It was even thought that the nymphs and adults might be different species.[66]

There was much conjecture about whether these were the real locusts of Africa or Asia, about which so much was written. Some saw no doubt from its destructive behaviour that it was the 'locust of the East', while others declared it just the 'Australian grasshopper'. They surely were not the grasshoppers 'accepted by poets as the emblem of mirth and sunshine'.[67] But as several correspondents put it, whatever those learned in such matters called them was irrelevant; the 'creature now visiting us is as destructive as any locust could be imagined to be and it necessarily becomes an object of anxious reflection'.[68]

In the spring of 1873, in addition to the Riverina and Central West regions, the Liverpool Plains and Hunter Valley were infested with hopper bands; one landholder near Tamworth reporting 5,000 acres of foot-high grass destroyed in three weeks.[69] Swarms remained in those regions the following summer and autumn, but local impressions during spring and early summer 1874 suggest an intensification of swarms and there were more newspaper reports than during the previous summer.[70] On the Riverina in particular 1874 was considered worse than ever before.

[66] *The Sydney Morning Herald*, 7 November 1872, p. 4.

[67] *Sydney Mail and NSW Advertiser*, 20 November 1872, p. 679, 'it is the locust of the East'; *Maitland Merc &c*., 26 November 1872, p. 6, Dubbo; *Empire*, 16 November 1872, p. 2.

[68] *Border Watch*, 15 March 1873, p. 3; *The Brisbane Courier*, 5 March 1873, p. 2.

[69] *Empire*, 1 December 1873, p. 3.

[70] *Riverine Grazier*, 17 December 1873, p. 2.

Riverina graziers, farmers and townspeople had suffered so often that by 1874 'grasshoppers' were now considered part of the lot of the farmer or squatter and a 'serious drawback to settlement'.[71] What they saw around Hay in November 1874 was unnerving. 'Nothing has ever been witnessed to equal the way in which they are sweeping everything before them. What is to become of the millions of sheep depastured on the plague stricken lands thus "cleared" is a problem which puzzles not a few'.[72] Graziers were cautious about restocking their runs with pastures already depleted, some even moving stock to Queensland on account of the locusts.[73]

Deniliquin too saw swarms each year from 1871 to 1874, sometimes just flying over, sometimes covering the plains in myriads 'taking all before them'.[74] Here the locusts were still 'the pest of the squatter' and one estimate put the loss of grass on one run equivalent to grazing 20,000 sheep. At that time only 300 acres of wheat was grown within ten miles of the town.[75] But they could not dampen the land rush, with selectors and squatters contesting every sale along the rivers. It would 'take more than grasshoppers to check the demand for land' though, with the selectors 'invading the squatters and the grasshoppers preying on both'.[76] Sheep numbers also continued to boom. While the surrounding plains were alive with locusts, 107,000 sheep crossed the bridge in October 1874 and some 5,700,000 were due to be shorn across the Riverina, more than in all of South Australia (Figure 4.4).[77]

Many observations in late 1874 of 'millions of dead and dying' heralded the collapse of the plague in NSW.[78] At Deniliquin and Hay, their 'disappearance was miraculous', the ground was covered with

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[71] *Adelaide Observer*, 28 November 1874, p. 12.

[72] *Gippsland Times*, 12 November 1874, p. 3.

[73] *Adelaide Observer,* 28 November 1874, p. 12; *The Sydney Mail and NSW Advertiser*, 28 November 1874, p. 679.

[74] *Advocate*, 22 Feb. 1873, p. 16, 'passed over town in such dense clouds as to throw shade on the ground… they did not alight'; *Gippsland Times*, 10 Nov 1874, p. 3.

[75] *Australian Town & Country Journal*, 30 November 1872, p. 11, 'the pest of the squatter'; *Armidale Express*, 16 November 1872, p. 2, only 300 acres were grown within a 10 mile radius of town in 1872.

[76] *Empire*, 2 Nov 1874, p. 4; *Evening News*, 23 Nov 1874, p. 4.

[77] *Wagga Wagga Advertiser & Riverine Reporter*, 7 November 1874, p. 2; *The Argus*, 24 November 1874, p. 4, in one week during 7–14 November 1874, 36,800 sheep crossed going north to the Lachlan, Darling and Queensland. The following week 31,000 crossed, apparently for Victoria, and another 30,000 were reported near; *South Australian Register*, 25 April 1874, p. 5, the battle over access to grass continued too, but the tables were turned on one squatter in 1874 when a young selector, Mr. Joachim, won damages in court against Sir John O'Shannassy, Melbourne owner of the Moira run south of the town, over his sheep grazing on Joachim's selection.

[78] *The Argus*, 30 Nov 1874, p. 7; *Empire*, 1 December 1874, p. 4; *Empire*, 14 December 1874, p. 4, 'disappearance miraculous, the ground covered with slain',

the slain, apparently 'leaving no ova'.[79] Although swarms appeared along the Darling River and at Brewarrina, Moree, Narrabri and the Liverpool Plains in summer, the reports stopped in autumn 1875.

The plague arrives in Victoria

> *The grasshoppers from Drung Drung to Antwerp are numerous, and will prove a scourge to the grass this season. At a distance of a mile or more they appear like a cloud of dust or smoke. One gentleman rode several miles, thinking that it was the smoke of a bush fire in the distance. When close at hand they appear like a snow storm, filling the air to a height of 100ft or more; my horses refuse to face them … Nine months ago a swarm of them came over the country, and deposited their eggs about an inch and a half below the surface in all spots of hard red soil, especially on beaten tracks or roads. This operation was performed by the insect boring into the ground with its extremity or tail, or whatever you like to term it, and depositing a large number of eggs in each hole … In some spots hundreds were at the same time depositing their eggs on a square yard of ground. It was well known at that time that this scourge was only a few months ahead, and stock was sold off to lighten the runs on account of it.*
>
> *The Argus*, 18 December 1871, p. 4.

This report from near Horsham in the Wimmera district gives the first clear indication of the plague in Victoria. The arrival of high flying swarms in autumn and their dense, gregarious egg-laying in hard red soils are characteristic of *C. terminifera*.[80] A possible earlier locust report came from Benalla in February 1871, of 'grasshoppers beginning to cover the country in myriads … a kind of locust, and where they are plentiful soon cause the country they "infest" to become bare of grass'.[81] The picture is complicated because grasshoppers had increased during 1868 and 1869, and some saw the locust swarms of 1871 as an extension of those outbreaks.[82]

In early December 1871 locusts 'of large size, apparently in good condition, and extremely vigorous' swept through Echuca and Bendigo, and 'made sad havoc among everything green', a phrase that

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[79] *Riverine Herald*, 26 November 1874, p. 1S; *Empire*, 14 December 1874, p. 4; *Advocate*, 2 January 1875, p. 14.

[80] While it is possible that some locust swarms moved into the northwest earlier than autumn 1871, few newspapers were based in the Wimmera and one on the Murray at Echuca, so reports were occasional and, as they all came from early summer, make a distinction difficult. Of the 16 non-metropolitan newspapers in Victoria in 1871, there were only three based in the Wimmera - the new *Hamilton Spectator*, *Pleasant Creek News* and the *Avoca Mail*, the latter two and several other briefly operating newspapers, have not survived for digitisation. The *Portland Guardian* mostly covered areas near the southern coast.

[81] *Benalla Ensign*, 11 February 1871, p. 2, the local report is likely to have been from this date, which is late for *A. cruciata* to 'start to appear'.

[82] *Riverine Herald*, 15 September 1869, p. 3, it was *A. cruciata* along the Murray River in spring 1869, since myriads had hatched near Rochester by 9 September on the plains around Swan Hill, weeks earlier than locusts would be expected to hatch there.

became a popular metaphor for locust damage during the plague.[83] Swarms reached Kyneton, south of Bendigo, travelling in 'quite a living stream throughout the day'.[84] By Christmas, the northern districts had 'assumed the character of a plague' and there were swarms throughout the Wimmera, the sound of their take-off in the grass like that of travelling sheep, leaving 'acre upon acre profitless to the cultivator'.[85] At Horsham they moved with the wind, 'frequently in continuous masses so dense as very forcibly to remind one of the locust swarms of Africa'.[86] A second nymph generation produced migrating swarms in autumn that laid eggs in many areas.

When nymphs developed in the Wimmera region in spring 1872, *The Argus* reported it was 'no unusual thing at this time of year', but the number of places reporting dense masses of nymphs and then swarms was far from usual.[87] The Wimmera district was hit particularly hard, with locusts in 'such swarms they actually covered the ground for miles and miles, feet thick in places' and, when passing though the bands, hundreds were crushed at every revolution of a buggy wheel.[88] The swarms in January 1873 were even more widespread and, as in South Australia, dead locusts piled two feet thick along the southern coast near Portland, resembling heaps of seaweed.[89] The summer swarms had deposited 'eggs at a rate beyond calculation' and the females clustered so densely in places 'the colour of the ground could not be seen'.[90] Again, the next generation of nymphs in February and March 1873 were followed by swarms in April.[91]

The public and official response

As swarms moved closer to Melbourne during the peak of the plague in 1873, questions over their identity increased. Were they locusts or grasshoppers? Were they the locusts of Asia Minor and Africa or of Biblical Egypt, and were they becoming a 'permanent scourge'?[92] Amid this dismay and uncertainty, the new Department of Lands and Agriculture made the first official attempt at collating

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[83] *The Argus*, 7 December 1871, p. 6; *Melbourne Punch*, 7 December 1871, p. 3.

[84] *Geelong Advertiser*, 19 December 1871, p. 3, Kyneton description is from 9 December.

[85] *The South Australian Advertiser*, 19 December 1871, p. 2; *Launceston Examiner*, 23 Dec 1871, p. 2.

[86] *The Argus*, 22 December 1871, p. 2.

[87] *The Argus*, 12 December 1872 p. 6.

[88] *Maitland Mercury*, 24 December 1872, p. 1, north of Horsham; *South Australian Advertiser*, 24 December 1872, p. 3; Reports also came from St Arnaud, Ararat, Stawell, Warracknabeal, Swan Water, Bridgewater, Horsham and Richardson River in Nov-Dec 1872. The swarms also extended east to Bendigo, Castlemaine, Heathcote, Elmore and Ballarat.

[89] *Portland Guardian*, 20 February 1873, p. 2, beaches between Portland and Narrawong covered.

[90] *Advocate*, 18 January 1873, p. 14, near Ararat.

[91] Nymphs were reported near Hamilton, Ballarat, Casterton and Castlemaine.

[92] *Advocate,* 17 May 1873, p. 9.

scientific information on the biology and history of the locusts.[93] That job fell upon its first Secretary, the twenty-six year old Alexander R. Wallis (1848–1928), whose education guided his vision of developing Victorian agriculture on solid scientific foundations (Figure 4.4).[94] Wallis arrived in Melbourne in 1871 with qualifications from agricultural colleges in Britain and Germany, but little entomological experience.[95]

He was appointed to the new department through an anonymous essay selection process from a field of fifty applicants in 1872. He soon found, however, that the demands of running many of the new department's activities almost single-handedly left him little time for any scientific work. When it came to presenting information on the locust plague for the first annual report, Wallis drew on local experience by co-opting Thomas Bath (1820–1901), a prominent landowner in the Ballarat district and member of the Ballarat Farmers' Club, to provide first-hand observations.[96]

Bath recorded the development of the plague on his farm at nearby Learmonth. The first locust swarms arrived in January 1873 and in February laid eggs that produced a second generation of nymphs, while swarms still filled the skies. On the shores of Lake Learmonth there were so many washed up dead that farmers carted the heaps away to use as manure.[97] Bath reported on the course of the plague at several club meetings. He described the crowding of females in certain spots to lay eggs, the development of nymphs, and the 'strange peculiarity' of some adults containing eggs and others,

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[93] The early emphasis in Victoria on the value of science as a practical aid to the development of the colony led the government optimistically to appoint a Board of Science in 1858 and in the following year a Board of Agriculture to advise on relevant issues. The principal activity of the Board of Agriculture, under chairmanship of William H.F. Mitchell, was the distribution of revenue to fund country agricultural societies and an experimental farm at Royal Park near Melbourne. Its early preoccupations included the eradication of thistles and an attempt to import a steam plough, an enterprise in which it was soon overtaken by a private company. The Board was disbanded a decade later and the Victorian Department of Agriculture established in July 1872.

[94] Richard Wright, *"Dispensed with" A.R. Wallis, first Secretary for Agriculture in Victoria 1872–1882,* Department of Agriculture of Victoria, Research Project Series No 150, (Melbourne, 1982), pp. 7, 12.

[95] Wallis attended Britain's Cirencester Agricultural College; *The Brisbane Courier*, 13 October 1865, p. 3, the need for agricultural education and colleges like that at Cirencester in England, was discussed; *The Australasian*, 30 March 1872, p. 26; *The Argus*, 21 May 1872, p. 6.

[96] Thomas Bath and his wife Johanna, who was later celebrated as the first woman to arrive at the diggings, came to the Ballarat goldfields from Geelong in 1851. After some success at mining, Bath, along with his friend James Oddie, saw that more certain money was to be made servicing thousands of hungry, thirsty and tired miners and visitors to the fields. Bath sold his first hotel in 1857, but it was still known as Bath's Hotel well into the twentieth century; *The Argus*, 9 December 1869, p. 3, in 1854 Bath purchased farmland on the shores of nearby Lake Learmonth. In the 1860s, he owned several buildings in Ballarat and for a time even held several sheep runs along the Darling River. Bath became a JP, a territorial magistrate in the Ballarat Circuit Court, and was active in local agricultural societies, the Ballarat Agricultural and Pastoral Society and the Ballarat Farmers' Club; *The Star*, 14 November 1859, p. 2; *Bacchus March Express*, 4 November 1871, p. 3; *Australasian*, 12 April 1873, p. 25.

[97] *The Australasian*, 22 March 1873, p. 8, locusts arrived at Learmonth on 17 January; *South Australian Register*, 27 March 1873, p. 5.

live grubs resembling a full-grown maggot.[98] He considered it important that a sketch of the locust be made so that their 'peculiarities be recorded' for comparison with those in other seasons.[99]

Dynamic Ballarat

In 1873, Ballarat rather than Melbourne was the centre of technological and agricultural innovation. A sense of the dynamism of Ballarat society at the time can be drawn from the activities and industries that flourished around the mines — public buildings, schools, a college of mining and design, engineering and machinery workshops, newspapers, a library, art gallery and museum, and hundreds of drinking establishments.

Some of the district's new-found farmers had both land and money to commit to experiment. Its Farmers' Club, established in 1865, had discussed the development of mixed grazing and cropping, irrigation, introduced pastures and crop rotation, and the need for agricultural colleges. Many members were admitted amateur experimental farmers, attempting to adapt European principles of agricultural improvement, such as ratios of manuring, grazing and ploughing, to local conditions. Alexander Wallis was influenced by ideas and practices already established at Ballarat before his arrival in Australia. He attended a number of their meetings, first as a journalist for *The Australasian* in 1872 and later representing the department.

Thomas Bath was an active member of the Farmers' Club and other local agricultural institutions. After early success on the goldfields, he had the means to indulge a passion for 'scientific farming'. His animals, crops and machines were regular winners at agricultural shows. Bath engaged a local instrument-maker to construct a mileometer, for measuring distances from his buggy wheel. His model farm 'Ceres', on the shores of Lake Learmonth, described by visitors as a 'farmer's paradise', was equipped with the latest machinery: a steam thrashing machine, hay elevators and 500 acres under flood irrigation channelled from the lake. Official visits to the district usually included a tour of 'Ceres'. Bath hosted guests at the Learmonth Regattas and had a yacht built in Geelong for the purpose. In the 1860s, Bath was credited with pioneering mixed farming, combining sheep grazing and cropping, an enterprise Wallis later expounded as the way of the future in drought-prone Australia.

Ballarat in 1874, part of panorama by
Charles Bayliss (Mitchell Library, NSW).

[98] *The Argus*, 17 March 1873, p. 6. *The Argus*, 27 March 1873, p. 6.
[99] *South Australian Advertiser*, 30 April 1873, p. 3.

At the April meeting, Bath presented the first detailed sketches of locusts, their eggs and of an apparent parasitic wasp, drawn by the young artist Mary A. Gatliff of Ballarat.[100] In October, Bath reported that a plague could be expected in the summer, because the ground was beginning to swarm with the young insects.[101] *The Argus* took the more sanguine view that there was nothing in the history of the locusts' occurrence to 'justify the belief they will be equally numerous in any place two years in succession', trusting that 'Nature may do for us in time what we could never do by any ingenuity of our own'.[102] In fact, the autumn 1873 swarms spread even further south to Casterton, Colac, and Terang, where egg laying literally 'honeycombed' a hard, metalled road.[103] The widespread hatchings in spring stretched from Wodonga in the northeast to Hamilton in the southwest.[104] The plague continued in the north and the Wimmera for a further two years, but by 1876 even those who indulged in 'evil prophesy' of 'prospective grasshoppers' were silent.[105]

Figure 4.4. Alexander Wallis, c. 1890.

[100] *The Argus*, 29 April 1873, p. 4, Mary Gatliff and her sister Annie were regular entrants in art exhibitions held at Ballarat and Sandhurst during the 1870s. Mary, a schoolteacher, specialised in drawing and went on to become a professional art teacher in Bendigo in 1879; *Bendigo Advertiser*, 20 January 1879, p. 3; Other young Ballarat women also produced scientific drawings for the club. Natural history illustration was one area of colonial science in which women excelled and for which their skill was acknowledged; Women also practised agricultural science, for example The Victorian Women's Sericultural Company established a mulberry orchard and buildings for silk production near Castlemaine in 1872, established by Florentine Bladen Neill and Jessie Glover. The silk farm was moved to the Murray district in 1877 and subsequently failed.

[101] *The Argus*, 9 October 1873, p. 6.

[102] *The Argus*, 30 September 1873, p. 4, the first point may have been justified before 1869 and the southward migration of swarms during the plague did suggest they would all end up in the sea.

[103] *Advocate*, 26 April 1873, p. 15, Terang egg laying report; Egg laying also reported at Mortlake and Camperdown.

[104] *The Argus*, 21 April 1873, p. 6, 'not a blade of grass… the western district losing its reputation as stock fattening country'; In spring 1873 hatching was reported at Wodonga, Ondit, Maryborough, Kyneton, Glenorchy, Bacchus Marsh, Ballan, Hamilton, Byaduk, Casterton, Ararat, Avoca, Richardson River and Stawell; *The Australasian*, 28 June 1873, p. 24; *Advocate*, 3 January 1874, p. 15; *Geelong Advertiser*, 5 December 1873, p. 3.

[105] *Australian Town and Country Journal*, 13 November 1875, p. 15, it is also likely the thick patches of nymphs near Geelong in November, as well as the clouds flying across the Werribee rail line at Christmas, were also locusts, which would make this event the most southerly dense breeding of the species on record.

The first annual report of the Department of Lands and Agriculture

The annual report released in July 1873 provides a view of contemporary concerns and prospects for new agricultural enterprises in the colony. It was wide ranging in scope, with articles by men with expertise in forestry, livestock parasites, horticulture, pasture grasses and plant pathology, as well as entries by Wallis and Bath on the locusts. The report was the first of its kind in Australia and set the format that others later followed.[106] Wallis's 'Secretary's Report' gave his views on the value of practical instruction and technical education in agriculture and its allied sciences.[107]

The section on locusts reveals just how little was known about this serious new pest. A single letter from a farmer near Stawell, Thomas Davey, represented the accumulated historical knowledge from rural Victoria. Wallis's 'Prefatory Note' included familiar stories of the prodigious destructive powers of Old World locusts from entomological texts, notably by Kirby and Spence.[108] Frederick McCoy, professor of natural sciences at the University of Melbourne and museum director, offered an identification as *Aedipoda musica* of Fabricius, smaller than the true 'migratory locust' and 'possibly related to the red-legged locust of America'.[109] He also summarised organised collective actions and manual control methods employed overseas, which he thought would not work in sparsely populated Australia.

Bath's description of the size, markings and colouring of the adult insect clearly identifies *C. terminifera*. In describing their variable pattern morphs, he comments that 'strange to say, you could not find two alike' and he lamented the absence of 'an entomologist in the colony who could give us a record of our locust to compare with other places.' They were much smaller than he had expected locusts would be and, though flying at heights of one hundred yards, they did not darken the

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[106] In NSW a department was established in 1890 and commenced publication of the monthly *Agricultural Gazette*, but the first annual report did not appear until 1900. In South Australia, central and regional Agriculture Bureaus were established in the 1880s and played a similar role, but the government department was only formed in 1902.

[107] Wallis also favoured the amalgamation of small agricultural societies into Boards to take statistics and professionalise communication with the department; *The Argus*, 20 July 1871, p. 7, this was the view of several Ballarat Farmers' Club members. W.H. Bacchus, the Club President, and W. Scott gave a paper about the advantages of such clubs to 'forcibly inculcate the principles of self-reliance and inveigh against that system of governmental coddling which is now practised' and has failed to establish any industry. Wallis echoed this in the first annual report, supporting Farmers Clubs in preference to the agricultural societies, as the appropriate forum for discussion of mutual interests 'for the education and social well-being of agriculturalists'.

[108] William Kirby and William Spence, *An Introduction to Entomology*, 4 volumes (5th edition), (London, Longman, Rees, Orme, Brown, and Green, 1828).

[109] It is possible that the names McCoy assigned to the two pictured specimens also got mixed up in labelling the lithographs. *Aedipoda musica* (i.e. *Gastrimargus musicus*) was first collected in 1770 and named in 1775.

sky.[110] Bath was clear that the most common locust was the smaller one with the 'black spot at the outer corner' of the wings, while a larger one with yellow and black fanlike wings was not very plentiful. By the time reports and specimens reached the Melbourne press, however, the emphasis was reversed.[111]

Thomas Davey wrote that there were three distinct swarms the previous year and that locusts had been present for three years (1871–1873). He in turn had been told by Mr C. Wilson from Walmer of previous outbreaks in 1848 and 1862, and that during winter 1869 locust egg beds had been flooded several times but still hatched. Although the species and even the dates are uncertain, they were quoted in many later reports.[112] Davey had noticed many flies apparently laying eggs on locusts in the autumn and, recalling his previous observations of wasps on caterpillars in England, they became part of the 'Ichneumon parasite' myth.

The report detailed the different views on the so-called 'Ichneumon parasites'. It included the illustrations of locusts and their parasites, redrawn in Melbourne by the department illustrator, Mr Howitz, from the 'detailed and accurate' drawings by Gatliff. A whole page was devoted to the 'parasitic wasp' that Bath had collected at Learmonth from Davey's description and passed on to Gatliff to draw (Figure 4.5).[113] Based on his own recollections and diagrams from Europe, Howitz suggested it was an ichneumon wasp. A photograph of his illustration was sent back to Davey, who, confirming it as what he had seen, wrote that the drawing 'must have been made by a close observer'. Another scientific associate of Wallis, the Rev. John Bleasedale, weighed into the debate, citing a letter from French naturalist Count Castelnau, that the ichneumon would one day rid northwest Victoria of the locust.[114]

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[110] Thomas Bath, 'Notes on Observations Made during the Late Locust Plague', in *Report of the Secretary for Agriculture, Department of Lands and Agriculture, Victoria*, (Melbourne, 1873) pp. 70–73, Bath's description on p. 72, the common locusts are brown with black spots on the wing covers and thighs, legs reddish, head and body nearly black…The wings have a black spot at the outer corner. The length 1.6 inches, antenna 0.35 inches and outstretched wings 2.5 inches.

[111] *Australasian*, 22 March 1873, p. 8, this was possibly because the larger species, *Gastrimargus musicus*, had caused some damage to vineyards in the Yarra Valley at that time.

[112] Davey's mention of 1848 could have been *C. terminifera*. There is another possible reference to this species from April or May 1848 on the Lachlan River in NSW on the overland expedition of John Keighran; In 1862, the insect is more likely to have been *A. cruciata*, because the only other reports in that year are from November, and the identification is clear in South Australia. The veracity of the 1869 inundation of eggs may not be reliable, as winter 1869 was one of the driest on record in that area of Victoria (Bureau of Meteorology locality, Bendigo Gaol). That event was more likely to have been in the winter of 1870.

[113] *The Argus*, 27 March 1873, p. 6, Bath collected a wasp at Learmonth, based on Davey's description, but was unable to find it again.

[114] 'Report of the Secretary for Agriculture, Department of Lands and Agriculture, Victoria', (Melbourne, 1873), p. 69; Francois de Laporte, who was French Consul in Melbourne, assumed the name Count Castelnau.

Professor McCoy recognised that wasps of the Ichneumonidae were not parasites of grasshoppers and that the larvae drawn were those of a two-winged tachinid fly parasite. Although Wallis emphasised the difference of opinions, the technical power of the illustration established its veracity. Another reason for the misidentification was the attention these insects received during the 'heyday of the ichneumon fly', which in Britain had commenced in the previous century. The fascination stemmed from more than their well-known evil actions of eating their caterpillar hosts from the inside out. Their role in the 'self-equilibrating economy of nature' became a political metaphor for a combination of agricultural production, human population and social control issues in Britain.[115]

Figure 4.5. Parasites of the locust. *Aedipoda musica* with *Ichneumon* on back (a) *Bracon capitata* male and female, (b, b1) and a soil clump showing locust eggs, (c) Figure III, in *Report of the Secretary for Agriculture*, Department of Lands and Agriculture Victoria (Melbourne, 1873).

The 1870s locust plague sparked a wider interest in their parasites and the ichneumon 'flies' became a central character of conjecture in ecological natural history that continued throughout the century. Questions were also asked in South Australia about the maggots found behind the head of easily caught locusts in 1872.[116] Charles Wilson commented that, although specimens he had seen were like those of the blowfly and unlike larvae of Hymenoptera wasps, it was likely that 'Ichneumon flies' were parasitising locusts.[117] He made the point that parasites increase in number when 'insect life prevails to an unusual extent', but would provide only a partial check. However, the maggots had been

[115] Sheila Wille, 'The ichneumon fly and the equilibration of British natural economies in the eighteenth century', *British Journal for the History of Science,* 48 (2015), 639–660, p. 641.

[116] *South Australian Register*, 16 December 1872, p. 6.

[117] *South Australian Register*, 17 March 1873, p. 6; 31 March 1873, p. 6; Wilson found a supporting reference from J. O. Westwood.

incubated by another observer and the resulting flies, not wasps, were carefully described as having longer hairs on the body than the housefly; typical of the parasitic tachinid fly genus *Ceracia*.[118]

Reaction to the report in Sydney

The advice afforded by the Agricultural Department of Victoria to the sufferers by the locust appears to be taking effect — namely, to study the habits of the creature in order to learn how to counteract it. The locust is being watched. The destroying insect has brought many eyes upon it. It has been detected in the very act of depositing its eggs, and it is said that a period of twenty-one days elapses before they come to life ... others aver that they have had the ova of the locust deposited in their land for the last six months, and they still remain unaltered in appearance . . . There prevails amongst the farmers much anxiety on this subject, and their observations, it is clear, must be continued, as they are yet too uncertain to act upon ... If a locust could be brought up before a Parliamentary committee and examined, he might probably let fall some facts concerning his mode of life that might be useful to those who are investigating the matter.

The Sydney Morning Herald, 1 October 1873, p. 7.

Upon its release, the 1873 Victorian annual report became an authority on locusts and was quoted for many years. The findings were translated in other metropolitan papers.[119] In January 1874, Wallis and the Minister, James Casey, toured the Sandhurst, Loddon and Murray River districts to the north, giving glowing accounts of the success of the plough and the crops in the next annual report, but they were strangely silent on the locusts that were still swarming in places.[120] The 1874 annual report also contained a paper on wood-boring insects by Charles French, then working at the nursery of the Botanical Gardens, whom Wallis recommended as a consultant to the department on entomological matters.

The early annual reports were a brief demonstration of Victoria's faith in an independent, progressive future and they reflected Wallis's commitment to science as fundamental to agricultural development. In 1874 he emphasised scientific planning as 'a matter of national policy to teach the people how to feed men scientifically'.[121] Their publication was suspended after 1875 and in 1882 Wallis, too, found himself 'dispensed with', after ongoing personal and bureaucratic conflict with the Minister, Charles Young, resulted in a Board of Inquiry finding against him.[122] The agricultural emergency posed by the

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[118] *Northern Argus*, 1 April 1873, p. 3; *South Australian Register*, 12 March 1873, p. 5.

[119] *Second Annual Report of the Secretary for Agriculture, Department of Lands and Agriculture, Victoria*, (Melbourne, 1874); Other Ballarat Club members, Mr W. H. Bacchus with an illustrated report on native grasses, and Mr W. Scott on the cultivation of mangel wurtzel, also got their official recognition in the second and third annual reports.

[120] *Advocate*, 10 Jan 1874, pp. 8, 15, locusts were reported 'playing sad havoc on the runs' at Lancefield, Corop, Castlemaine and Wangaratta.

[121] Wright 1982, pp. 12–13, throughout his tenure, Wallis maintained that agriculture must be built on scientific foundations, and practical research on soil capabilities.

[122] Wright 1982, pp. 27–33, Wallis was dismissed over his handling of the outbreak of Phylloxera in vineyards; He had worked to establish agricultural colleges and the Industrial and Technological Museum. The 1874

locusts brought them into the first report as a subject for the attention of Melbourne's clique of scientific authority. It was the start of a century-long pattern of outbreaks prompting official response.

The end of the plague

While the start of the plague was covered in dramatic detail in each colony, its end is less clear-cut. This may be due to an exhaustion of interest in reporting, but also because of the overlap in the timing of locusts and grasshoppers during spring.[123] Taking only autumn occurrences of nymphs or swarms, the locust plague clearly continued in the Victorian Wimmera during autumn 1875, but not in 1876.[124] In NSW, following the reported mass deaths in late 1874, locusts were hardly noticed in autumn 1875.

However, in South Australia the plague continued in some areas until 1877. There were swarms in autumn 1874 from Blinman to Burra, and the many descriptions of swarm flights during the following summer of 1874–75, with 'dense clouds passing Koolunga and Mintaro every day making a noise like a strong wind', make it clear these were locusts.[125] Areas from Port Augusta to Burra were infested again in autumn 1875, persisting as late as May and June. There were even swarms in the Adelaide Park Lands again that autumn.[126] Settlers in some parts had suffered from the invaders for five years, to the point where it was suggested the colony be renamed 'Locustland'.[127] Dense patches of nymphs were reported in places as far apart as Blinman, the Yorke Peninsula and Lake Albert in spring and summer 1875, and Adelaide was again visited by swarms in December.[128] In April 1877, the plains south of Port Augusta were still infested and 'tons were lying dead on beach' at Port Pirie, while at Telowie millions were making holes to lay eggs.[129]

Annual report included illustrations of agricultural colleges at Cirencester in England, Hohenheim and Wurtemburg in Germany and Iowa, USA; Wallis' proposed Museum of Industry and Technology was finally built after his dismissal.

[123] There were still many reports of nymphs and swarms at densities indicative of locusts, but many in 1874 and 1875 in Victoria and NSW are from spring and summer, so do not allow for a clear separation of locusts from a return of the grasshoppers; *Border Watch* (SA), 5 December 1874, p. 4, the description of bands from the St Arnaud area, 'they move with the order and compactness of an immense flock of sheep, the vanguard being a semi-circle, and fully a mile from point to point', is clearly *C. terminifera*.

[124] *Advocate*, 13 March 1875, p. 15; 3 April 1875, p. 15, millions of young locusts were reported from Horsham, Casterton, Wando, Donald, Loddon and St Arnaud in early 1875.

[125] *South Australian Register*, 25 December 1874, p. 7.

[126] *The Maitland Mercury & Hunter River General Advertiser*, 24 April 1875, p. 5; *South Australian Register*, 22 June 1875, p. 5.

[127] *The Maitland Mercury & Hunter River General Advertiser*, 14 January 1875, p. 3.

[128] *South Australian Advertiser*, 9 November 1875, Supplement p. 2; 20 December 1875, p. 5.

[129] *South Australian Chronicle & Weekly Mail*, 6 April 1877, p. 12.

Locusts and birds

The interaction of the locusts with birds became more obvious during the plague and certain species received special mention. Ibis and crows were observed making 'their own havoc among the grasshoppers' and native companions (brolgas) appeared in numbers not seen before. As it had been so often observed, one type of bird, the woodswallows, arrived in flocks and fed voraciously wherever the 'locusts' were dense.[130] Several species of woodswallow follow a loose, nomadic and seasonal migration pattern, forming breeding colonies where insect populations boom.[131] The species which received most attention was the distinctive white-browed woodswallow (*Artamus superciliosis*), or 'white-eye', particularly in Victoria (Figure 4.6). Their noticeable arrival and nesting during summer lent them the name 'summer bird', while their slate colour and appearance gave rise to 'blue marten' or 'martin-swallow'.

Along with reports of birds' usefulness in eating the locusts, came calls for their preservation. Seeing birds as part of the checks and balances in the 'economy of nature' became a popular topic, sometimes supported by statistics of insect reproductive potential and of birds' appetites.[132] Ideas expressed in Europe and the USA about insect plagues occurring as a consequence of the destruction of birdlife found a ready audience in Australia, as did arguments by local acclimatisation societies for introducing other well-known feathered insect destroyers.[133] Birds were the natural enemies of insects, in ordinary cases keeping a balance, but when man altered those conditions 'the balance of nature is deranged' and 'injurious multiplication of insects' results.[134]

These were also ecological explanations of the 'factors' which prevent any one species becoming overabundant, and the law of 'inflexible interdependence' even suggested that 'without birds, no agriculture or even vegetation would be possible'.[135] The prairie states of the USA were also suffering from locust swarms at that time, and the parallel idea of the American plague occurring

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[130] *Geelong Advertiser*, 4 November 1868, p. 3, at Deniliquin, tens of thousands of ibis … make great havoc among the grasshoppers.

[131] L. Joseph, 'Woodswallows: a longer term, evolutionary view of boom and bust', in eds. L. Robin, R. Heinsohn and L. Joseph, *Boom and Bust: Bird Stories for a Dry Country*, (Collingwood Victoria, CSIRO, 2009), pp. 205–222, discusses the nomadic behaviour of white-browed and masked woodswallows, as well as the evolutionary consequences of boom populations.

[132] *South Australian Register*, 2 January 1869, p. 2; *South Australian Chronicle & Weekly Mail*, 1 January 1870, p. 8; 16 April 1870, p. 3.

[133] *South Australian Register*, 24 October 1870. p. 6; *South Australian Advertiser*, 31 December, 1873, p. 3, the writing of Horace Greeley in the USA, C. O. Groom Napier and later, the Rev. J.G. Wood in Britain, were cited by local advocates of the birds.

[134] *The Argus*, 20 February 1877, pp. 4–5.

[135] *Cootamundra Herald*, 6 March 1877, p. 4.

‘coincidentally with the thinning of insect-eating birds’, reinforced Australian views.[136] The US Entomological Commission established to investigate the 1870s Rocky Mountains locust plague included an ornithologist. In Australia, such ideas supported settlers’ own observations. Farmers, hunters and scientists alike engaged in the popular scientific pastime of counting out the crop contents of shot birds to count how many insects they had eaten.

In the 1873 Victorian annual report, McCoy identified the white-browed woodswallow, based on Davey’s description of the large flocks devouring locusts on the Wimmera. Wallis concluded his entry with the importance of ‘strictly preserving all insectivorous birds’ in this country where ‘insect blights are becoming more and more prevalent’.[137] Wallis praised the agricultural value of the ‘summer bird’, that was even seen nesting around Melbourne in 1874. In the second annual report, he inserted woodcut of the woodswallow, its first official recognition and inscription as the pre-eminent locust controller (Figure 4.6).

Figure 4.6. The white-browed woodswallow.[138]

Acclimatisation theories were extended to the locusts. They were now considered to be ‘acclimatised’ in all colonies and it was suggested that plagues would continue ‘so long as insectivorous birds were

[136] *Riverine Grazier*, 29 September 1875, p. 4.

[137] A. R. Wallis, *Annual Report of the Secretary for Agriculture, Department of Lands and Agriculture, Victoria*. (Melbourne, 1873), p. 70.

[138] A. R. Wallis, *Second Annual Report of the Secretary for Agriculture, Department of Lands and Agriculture, Victoria*. (Melbourne, 1874), p. 286.

exterminated'. However, birds presented a potential paradox for conservation or introductions on pest control grounds, because some birds also damaged crops and fruit, while others preyed on smaller insectivorous species. It was even argued that insectivorous birds might reduce the effect of the ichneumon wasps.[139]

Residents of the Riverina had witnessed a continual increase in grasshoppers during the dry 1860s and, awestruck by the locust plague of the 1870s, there was now a view of them 'every year becoming more serious'.[140] At Deniliquin, in the early days of settlement 'they were seen, but in such small quantities as not to excite much attention and no anxiety, but they have … gone on increasing in quantity and in their power to destroy, and it is feared they have become acclimatised here, and … ought to be accepted as one of the drawbacks in pastoral enterprise'.[141] People found an explanation for this, not in the changed grasslands on the plains, but in the decline of native bird life. They were well aware of the flocks of ibis that fed on grasshoppers, and also of the 'Wilsonic theory' of acclimatising various small birds to reduce insect pests.[142] By 1879, many agriculturalists considered the preservation of birds to be economically vital. A petition to the NSW Parliament from the Deniliquin and Moama Railway Company stated that 'the insect known as the grasshopper threatened the extinction of … pastoral and agricultural interests'. The petitioners called for legal protection of 'emu, turkey, ibis, native companion, wild duck, magpie and other such birds' for three years, ascribing the surprising increase in the insects to the destruction of native birds.'[143]

Some residents in areas surrounded by forest found their crops had escaped locust damage. This was noted in the red gum forests on the Murray River, and in South Australia, where there were calls more forest reservation, to leave 'half the land for timber and half for corn' and for 'making wooden spectacles to allow purchasers to look further into the future'.[144] It was argued the positive effects of planting woodlots or saving trees from 'ringing' would do more than provide barriers against the

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[139] *Sydney Morning Herald*, 1 October 1873, p. 7.

[140] *Evening News*, 23 November 1874, p. 3.

[141] *South Australian Register*, 2 October 1875, p. 5.

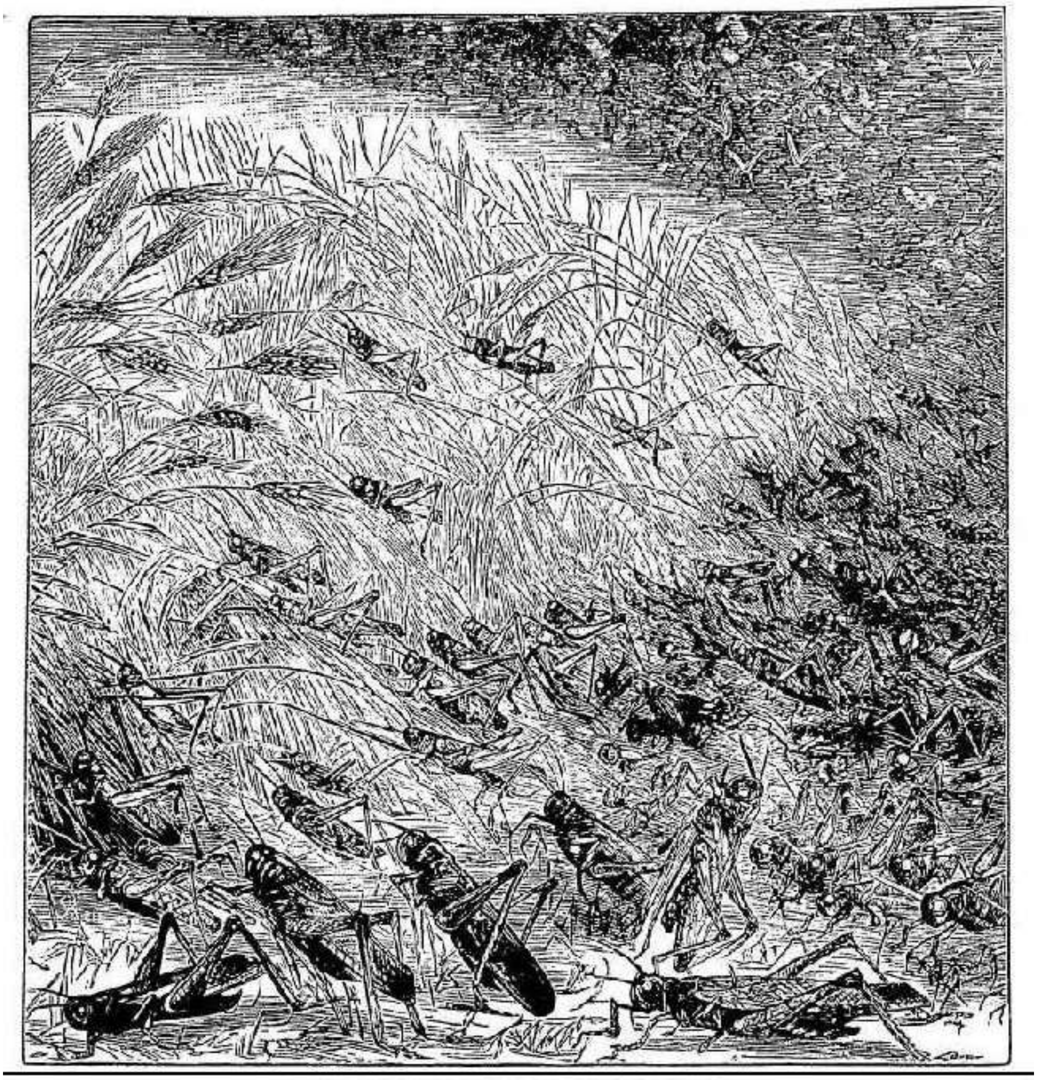
[142] *Launceston Examiner*, 6 December 1862, p. 3, this was a reference to Edward Wilson, the President of the Victorian Acclimatisation Society.

[143] *Australian Town and Country Journal*, 29 November 1879, p. 38; *The Singleton Argus and Upper Hunter General Advocate*, 28 April 1880, p. 2, in the mood of Riverina optimism, shares were issued for the company to raise funds to build a railway between Echuca and Deniliquin. The petition was supported by the Echuca Council. There were 196 signatories to the petition, 'this public calamity' could only be appreciated by those 'familiar with the extent of the desolation they caused'.

[144] *Maitland Mercury*, 24 November 1874, p. 2, at Redbank, near Moama NSW; *South Australian Chronicle*, 5 December 1874, p. 6; *Riverine Herald*, 28 November 1874, Supplement p. 1, the plague was just as easily blamed on 'the immense destruction of timber which is everywhere going on' as on the direct loss of birds.

locusts. As well as having climate-ameliorating effects, trees supported the 'winged wardens'.[145] In the saltbush country, the impact of feral cats on birdlife was given as a cause of the locust plague.[146] One solution, wrote 'V.L.' of Blayney in NSW was to 'kill all cats that you do not feed; smash all guns, and punch the heads of those who shoot insect-eating birds'.[147]

The damage done by the locusts



GRASSHOPPERS ATTACKING A FIELD OF GRAIN.

Figure 4.7. *Australian Town and Country Journal*, 2 January 1875, p. 9, reproduced from an American publication.

[145] *Riverine Herald*, 28 November 1874, Supplement p. 1.

[146] *The Australasian*, 6 February 1875, p. 14.

[147] *Australian Town and Country Journal*, 5 December 1874, p. 28.

There were many reports of crop damage during the plague, reflecting the actions of passing swarms and the more localised effects of the hopper bands. Significant crop damage was detailed in 1871 and 1872 in South Australia (Appendix 4, 'How bad were the locusts?'). Wheat could now be damaged as it emerged in autumn as well as in spring, but in the following two years green feed was so abundant that the locusts had less impact than had been expected.

As with the grasshoppers, locust damage was hard to take in gardens, orchards and vineyards. Those engaged in directly feeding townsfolk often felt it most. To save his cabbages, one Chinese market gardener at Hay cut and piled them in a heap, which he covered with a tarpaulin pegged close to the ground. To his shock on uncovering it next day, the place where the pile of cabbages had been was a 'heap of rubbish with myriads of locusts finishing up their feasts'.[148] Market gardeners outside Adelaide lost over ten thousand young cabbage plants in autumn 1872 and again in 1873, the locusts leaving such immense quantities of manure that it could be taken up in handfuls.[149]

Locusts damaged pastures as well as crops, and were often described as 'stripping the plains'.[150] The loss was more acute near stock crossing towns, where any feed was already contested and during drought there was a struggle just to keep animals alive. This was the central material plot of Joseph Furphy's novel *Such is Life*, set in the Riverina and based on his time as a bullock driver in the late 1870s. The continual concern of bullockies was where to find enough grass to feed their animals on plains that would 'starve a locust'.[151] So jealously was any feed guarded by the squatters, that they regularly exercised their power to impound stock and charge a fine for their release.

Complaints of the lack of grass in pastoral areas were often attributed to locusts during the plague, despite good seasons. That impression may have had as much to do with the loss of native grasses that had already become a serious issue. The failure of the pastures was clearly due to 'injudicious grazing and overstocking'.[152] Where 'kangaroo grass once abounded on the plains', now not a blade was to be seen and, after a few years of close grazing, grasses that once grew that up to a man's waist and

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[148] *Riverine Grazier*, 9 December 1874, p. 2.

[149] *Kapunda Herald and Northern Intelligencer*, 4 April 1873, p. 2; *South Australian Advertiser*, 22 March 1872, p. 3.

[150] *Advocate*, 21 November 1874, p. 16; *Adelaide Observer*, 28 November 1874, p. 12; *Empire*, 26 November 1874, p. 4, Riverina plains 'literally stripping the country of all vegetation'. Such reports were frequent when the plains dried out in summer, particularly in late 1874.

[151] J. Furphy, *Such is Life; Being Certain Extracts from the Diary of Tom Collins*, (Sydney, Angus and Robertson, 1945), p. 76, 'starve a locust'. Their campfire discussions, when not of philosophy or politics, were about where any patch of grass might be found, or a squatter who would allow their bullocks to feed. The fictitious employment of the protagonist Tom Collins, was based on that of an impoundment inspector.

[152] *South Australian Chronicle and Weekly Mail*, 25 January 1873, pp. 3–4.

yielded heavy crops of hay were replaced by the 'silken kind not a foot high'.[153] Similar rapid declines were reported on the Queensland Darling Downs and NSW Liverpool Plains, also affected by the swarms. The Wimmera district in Victoria was losing its reputation as stock fattening country and the loss of native grasses spurred the acclimatisation of all kinds of imported pastures.[154] On the 'sheep-walk plains', there was no such alternative and the huge livestock population was more vulnerable to starvation, in even short dry periods.

Ecological implications of the plague

The arrival of the locust swarms in 1871 coincided with a protracted La Niña climatic phase and a run of wet years, with brief local droughts in 1872 and 1874. The duration of the 1870s plague and of the La Niña has only one historical equivalent, coincidentally that of a century later, lasting from 1970 to 1975. There were two earlier La Niña events of five year duration during the historical period, 1847–51 and 1860–64, which could have provided the opportunity for locust invasions of the grazing lands, but it appears the conditions were not yet right for them.[155]

Using the criteria of swarms or dense nymphs during January–May, and the behavioural or morphological descriptors, the historical record offers very few possible occurrences of *C. terminifera* prior to 1870.[156] However, the argument that there were no earlier historical plagues is compromised because so few people seemed to make the distinction between the locust and the grasshopper. Thomas Bath did not mention any earlier visitations, despite the Ballarat-Sandhurst area hosting swarms of grasshoppers in the 1860s, and Charles Wilson in Adelaide only commented in 1872 that

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[153] *South Australian Chronicle and Weekly Mail*, 15 February 1873, p. 6.

[154] *The Argus*, 21 April 1873, p. 6.

[155] Gergis and Fowler 2009, Table 10, p. 375, lists those as protracted La Niña periods lasting five years.

[156] Possible earlier records of *C. terminifera*: *Sydney Herald*, 11 July 1842, p. 7, grasshoppers on the lower Namoi and the Barwan [rivers], 'some two months ago' as 'thick as a snow drift'. (The timing makes the locust a possible candidate); *South Australian Register*, 30 September 1848, p. 4, overland expedition of John Keighran — left Sydney April 19, arrived Adelaide 11 August. 'Proceeding along the Lachlan we saw a prodigious quantity of grasshoppers, averaging about an inch and a half in length. They covered a space of about a quarter of a mile at a time, and rising all at once came toward us on the wing with great force, almost blinding the horses. Alighting suddenly in a dense mass, they destroyed every blade of grass in their range, and then started for a fresh spot'. (this probably occurred in late April or May, therefore, he timing makes the locust a possible candidate); *South Australian Register,* 10 December 1859, p. 3, Mr Onesimus Hewitt … just returned from a visit to the north-eastern districts, and passing through Hampstead, between Houghton and Hope Valley ... He describes the grasshopper as being rather more than an inch long, with a tail of about equal length; its colour is a greenish brown, and it eats the kernel of the wheat, leaving the chaff. Mr. Hewett states that besides the busy destructive insect referred to, the ordinary grasshopper was abundant in the neighbourhood of Hampstead. Although not seen previously by Mr, Hewett, we would remark that it is possible the grasshopper referred to has long been a denizen of our colony (The comparison makes the locust a possible candidate).

there were apparently no males, remembering male grasshoppers as being much more numerous than females and bright yellow.[157]

However, the heightened public reporting of the 1870s plague suggests that any similar previous occurrence in the settled areas would also have been noticed. Its sudden onset, geographic extent and duration was different to anything experienced in the previous thirty years. Some observers, such as Edward Curr, noted the increase in frequency of swarms during their occupancy of the land.[158] In South Australia, the sheep runs and the cessation of Aboriginal burning practices had already been implicated in grasshopper outbreaks. Observing locust swarms coming from Booborowie in 1872, a correspondent wrote:

> The runs in that quarter have escaped fire for several years, and so long as they do I think the pests will continue. Farmers turn over the ground and destroy eggs, but the runs most certainly harbour them, to the detriment of farming interests.[159]

C. terminifera had been present in the southern grasslands before Europeans, and its swarms must have intermittently spread across the plains. But swarms moving to the south were now able to colonise, breed and persist in large areas that had previously carried dense tall grasses. The reduction of perennial grass cover and compaction of soils under the impact of millions of sheep appears to have reproduced habitats found in the more arid part of the species range. Not only were the plains now frequently bare or covered by short annual growth, but the locusts sought out certain introduced pasture species.[160] On the Victorian Wimmera in 1873 they totally consumed 'the English grasses and clover of pastures, but left the native kangaroo grass.'[161]

Scientific solutions

Numerous correspondents called for science to be applied to the locust problem. The application of science to agricultural practice still largely involved amateurs and local associations with a direct interest and experience. A local attempt to find a remedy came from the Talbot Agricultural Society in

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[157] *South Australian Register*, 2 January 1872, p. 3, Wilson writes that 'few of those now passing alight, and these are principally females. The flights in the air are mostly males, which in this species seem much more numerous; *Evening Journal*, 19 December 1871, p. 3. Delta writes, males 'yellow'.

[158] E. M. Curr, *Recollections of Squatting in Victoria*, (second edn.) (Melbourne, Robertson, 1883), p. 189.

[159] *South Australian Register*, 2 December 1872, p. 4.

[160] *Bendigo Advertiser*, 16 Dec. 1872, p. 2, at Marong Victoria, English or prairie grass was eaten away to the roots; Numerous European and Mediterranean *Bromus* spp. were being introduced by graziers and distributed through acclimatisation networks during the 1860s and 1870s, to supplement or replace the lost native perennials on sheep runs. These were the 'prairie grasses' frequently referred to; *Advocate*, 3 April 1875, p. 15, 'stations where overstocking was the rule'.

[161] *South Australian Register*, 27 March 1873, p. 5.

Victoria, offering a prize of ten guineas to the best amateur essay on 'The locusts and the means of preventing their ravages'.[162]

It was to chemistry that most hopes for agricultural advances were pinned. Alexander Wallis in Victoria succeeded in having 'a chemist, not just an analyst' appointed to the new chemistry branch of his department.[163] In South Australia, E. M. Hewett presumed chemists could prepare some palatable poisonous mixture to be sprinkled upon hay and strewn in the locusts' way.[164] Another correspondent experimented with bran and, seeing that the nymphs 'ate it readily', called for chemists to infuse it with poison to make a bait.[165]

Ideas were also drawn from overseas collective actions. A government reward of 'half-a-crown per bushel for dead locusts' was put to the South Australian Legislative Assembly, but drew only a promise that it would be considered.[166] There were practical suggestions for legislation to allow district councils to levy a 'locust rate', to be expended on the destruction of the early stages.[167]

The locust had now been clearly illustrated and delimiting its habitats seemed a logical next step in understanding its ecology. It was suggested that a 'correct map could be made of the localities which they invaded, and those that they evaded' to help physiologists determine what useful part in nature they perform'.[168] The species had come into being by being 'named', but there was still confusion over the 'locust or grasshopper' question. Gerard Krefft at the Sydney Museum and McCoy as 'M' in Victoria both attempted to sort out the differences in nomenclature with suitable taxonomic references.[169] Writing as 'Delta', Wilson cited Westwood over the distinction. But natural history was gradually becoming the domain of professional scientists, as specialist disciplines were carved from its former holistic breadth.

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[162] *The Australasian*, 1 November 1873, p. 32, the full name of that society was The Talbot, Evansford, Majorca and Lexton Agricultural Society, a district centred on Maryborough. The judges were to be McCoy, Wallis and the agricultural editor of the *Australasian*.

[163] Wallis 1874, p. 8, the inclusion in the second and third Victorian annual reports of a report of the Chemical Branch, was formed on Wallis' insistence to appoint a chemist. The appointment of W. E. Ivy, from Britain's Cirencester College, reflected Wallis's view that chemistry was crucial to all facets of agriculture.

[164] *The South Australian Advertiser*, 18 November 1872, p. 2, he recommended its early use, as the young were more readily destroyed.

[165] *The South Australian Advertiser*, 5 Dec. 1874, p. 7, also complained that people were allowed to kill emus which ate the locusts.

[166] *The South Australian Advertiser*, 13 November 1872, p. 3, question put by Mr Krichauff.

[167] *The South Australian Register*, 30 November 1872, p. 6.

[168] *The Maitland Mercury & Hunter River General Advertiser*, 16 May 1874, p. 6.

[169] *Sydney Mail & NSW* Advertiser, 10 February 1872, p. 168, Krefft used leg articulations; *Australasian*, 22 March 1873, p. 8, 'M' in Victoria used Kirby & Spence, ('M' is most likely to have been McCoy); *South Australian Register*, 27 December 1871, p. 6.

Chapter 5. Victoria's plagues and 'Locust Days', 1883–1895

Figure 5.1. 'The Plague Locust', *Australian Town and Country Journal*, 29 January 1898, pp. 22–23.[1]

Oh! Mark how the corn is ripe in the ear,
How the snakes and the locusts once more re-appear,
How deep is the mud where the water has dried,
In the tank where the creaking frogs used to abide …
Again caws the crow o'er the sheep that is dead,
And the bugs and the fleas are infesting each bed;
And hear how the cockies' curse rings o'er the plain,
When he sees all the locusts devouring his grain …

Kerang Times and Swan Hill Gazette, 27 January 1888, p. 5.

[1] Article by M. L. S. 'our artist (E. Le B.) has succeeded in conveying an admirable idea of what is experienced by settlers in a plague-stricken district'.

The lead from Victoria

During the 1880s Victoria was still the only Australian colony to have a dedicated department of agriculture and, with repeated locust infestations, it was the first to address the problem of those agricultural pests through 'public science'. Its scientists conducted the first controlled physiological experiments on locusts and engaged in a broad public discussion of the ecological nuances of its population biology. Only late in the decade did Queensland and New South Wales (NSW) follow in establishing agriculture departments in 1888 and 1890 respectively. In South Australia, specific agricultural issues that had been handled through commissions and advisory roles, were transferred in 1888 to the Bureau of Agriculture.[2]

The 1880s were unique in that large areas of Victoria experienced persistent infestations of *Chortoicetes terminifera*, while NSW and South Australia were only briefly affected at different times.[3] Locusts caused some serious crop losses and were seen as a threat to agricultural development at a time when Victorian cereal cropping and horticulture industries were expanding, so the department was forced to act.[4] Victoria's early lead in the fight against locusts came from a justified perception that plagues were increasing.

In autumn 1890, however, migrating locusts entered Victoria from NSW. The perception that Victoria was on the receiving end of other colonies' locusts placed it in the forefront of moves for interstate cooperation in controlling them. Locust plagues are now considered almost 'exotic' in Victoria, since invasions from interstate and persistent infestations have been relatively rare in recent decades.[5]

After the 1870s plagues, there was a lull in locust activity during the dry years of the early 1880s, although there were short-lived, early summer grasshopper swarms on the northern plains. The Loddon and Campaspe rivers ceased flowing in early 1882, after months without rain. (Figure 5.2).[6] In NSW the squatters were implicated in making the situation worse by deliberately overstocking to

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[2] The Bureau of Agriculture formed as an extension of the Gardeners' Society.

[3] There were swarms in South Australia in autumn 1880 and briefly in 1883. In NSW swarms were reported in spring 1880, autumn 1883 and locally in 1886 and 1887. Multiple generations are not detectable in either state.

[4] *Riverine Herald*, 16 January 1884, p. 2, the area of land under cultivation in Victoria more than doubled between 1872 and 1882 and Victoria was then second behind South Australia in total cultivated area.

[5] In preparation for the response to the 2010 locust plague, the locust was declared an exotic pest to enable the rapid appropriation of state funds.

[6] *Kerang Times*, 24 March 1882, p. 2, Loddon River dry, rainfall Oct 1881 – February 1882, only 2 inches of rain recorded, nil in January; *The Australasian*, 8 April 1882, p. 27; *Southern Argus* (Goulburn NSW), 27 April 1882, p. 2, one blessing of the drought for the squatters … among the thousands of kangaroos lately destroyed, not a single "joey" has been observed; *The Shoalhaven Telegraph*, 8 June 1882, p. 3, one estimate of sheep losses in the Dubbo district was 1.2 million.

make the land unattractive to selectors.[7] The weather changed in 1882, with flooding recorded on numerous inland rivers. By the end of the year in Victoria, the dry Loddon and Avoca rivers had been flooded several times.[8] Commencing in 1883, there were widespread locust infestations that culminated with a Victorian Department of Agriculture public campaign to check the pests in 1890. It was coordinated by its 'little army of experts' and carried out by the entire male rural populace.

Figure 5.2. Crowding of people and livestock at the Queen's Gully Water Reserve, Wedderburn, 1882, *The Illustrated Australian News*, 22 March 1882 (State Library of Victoria IAN22/03/82/41).

Victoria then had more official experience with locust plagues than the other colonies, along with a greater sense of its boundedness and knowledge of all its territory. The vast unpopulated 'steppes' from which the locusts might arise, as they did in other continents, were outside its colonial domain.[9] Locust invasions could therefore be beyond control and some people saw any planned response as doomed to failure. The 'locust days' campaign was the first government attempt at stopping the plagues. It bore some similarities to present-day emergency planning and response in its command and coordination structures; a reminder of our long shared history with these insects. In 1890 though, all these functions were assumed by just two people and the field units were to be the farmers and the public, with even a special role for schoolboys.

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[7] *Northern Star*, 13 May 1882, p. 5, Dubbo absolutely rainless time … has produced a state of desolation … not intended to say that the land law has caused the drought … but …'nothing attracts the selector so much as a fine show of feed…and to keep the feed down was the squatter's aim. This could not be done without plenty of stock; and hence sheep were put on the runs in much larger quantities than was prudent'.

[8] *The Argus*, 2 August 1882, p. 8; *Bendigo Advertiser*, 9 December 1882, p. 2.

[9] *The Argus*, 11 January 1888, p. 4.

The 1880s infestations — impetus for government action

THE LOCUST PLAGUE

For at least three years past the migratory locust has become so constant in its visits to Victorian fields that, conjointly with the rabbit it commands the serious attention of all engaged in agricultural or pastoral pursuits. Capricious as the swarms are in their invasions, there is an alarming suddenness in their appearance and the devastation succeeding it which make it utterly impossible for any wheat grower to count himself safe until his harvest has been absolutely garnered. The density of the flying swarms, extending perhaps over an area of ten miles, has been often described, and is a too familiar spectacle to every summer traveler upon the northern plains.

The Argus, 9 January 1888, p. 6.

In the autumn of 1883 locust swarms appeared suddenly in northern and western Victoria, including the recently settled areas of the western Wimmera.[10] These were not the common grasshoppers, but larger 'long-winged, fast moving locusts'.[11] The swarms were still laying eggs in May. By June there was 'not a blade of grass for hundreds of miles' around Lake Hindmarsh and millions of dead locusts covered the ground.[12] The following summer, their progeny swarmed from Echuca to Shepparton, described as worse than for many years.[13] Drought returned to northern Victoria and the Riverina in 1884 and it was grasshoppers that took the 'few meagre crops' in November.[14] Of the few Victorian reports at that time, several appear to have been *Austroicetes cruciata*, which were in myriads across the Murray districts of NSW, along with 200,000 travelling sheep in search of grass.[15] But locusts probably persisted in some places, as there were reports from Wonwondah and Learmonth in February 1885 of the ground covered with young locusts.[16]

Locust swarms developed across western Queensland and in parts of NSW in early 1886, and probably contributed immigrants to the next Victorian infestation.[17] Locusts appeared in the Wimmera and northern Victoria in autumn 1886, but this time they continued swarming for a further two

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[10] *The Argus*, 15 May 1883, p. 9, including Nhill, Kiata, Lorquon and Dimboola.

[11] *Maitland Mercury*, 24 July 1883, p. 7.

[12] *Portland Guardian*, 30 June 1883, p. 2.

[13] *The Argus*, 4 December 1883, p. 4.

[14] The earliest specimen of *A. cruciata* in the Museum of Victoria collection is from Kewell, north of Horsham, collected in November 1884.

[15] *Bendigo Advertiser*, 12 November 1884, p. 3.

[16] *Horsham Times*, 6 February 1885, p. 3, Wonwondah is south of Horsham; *Kerang Times*, 6 February 1885, p. 4, appearing at Learmonth.

[17] Widespread swarms were reported in western Queensland from Winton, Boulia, Aramac, Diamantina country and east to Charleville and Mitchell.

years.[18] Again they were larger than the ordinary grasshoppers, in swarms described as 'a plague never before experienced'.[19] Older residents recognised they were locusts, saying their advent at that time was an indication of wet weather.[20] The St Arnaud Shire Council sent some eggs to the department. In reply the Secretary of Agriculture, Mr Martin, wrote 'I have the honour to inform you that the eggs are those of some kind of grasshopper, commonly called locusts by Victorian farmers'.[21] The following spring, nymphs were 'hatching in masses in the Wimmera from autumn laid eggs'.[22] Some farmers recalled 1872, but others were dismayed that locusts had laid eggs in their area. At Charlton, north of Bendigo, the locusts took over settlers' homes, forcing some residents to camp out.[23]

Figure 5.3. *Melbourne Punch*, 17 January 1884, p. 9.

Many swarms formed in December, seen flying south 'in belts half a mile wide and several miles in length'.[24] At Marong 'the stillness of the air was disturbed by a low humming sound, resembling the noise of a distant thrashing machine, and this announced the approach of countless myriads of locusts, filling the air as completely as falling snow or rain'.[25] Trains were held up near Ararat in December

[18] The earliest specimen of *C. terminifera* in the Museum of Victoria collection was collected from Ararat in December 1886.

[19] *Evening News*, 17 March 1886, p. 6, at Dimboola.

[20] *Horsham Times*, 26 February 1886, p. 2.

[21] *Bendigo Advertiser*, 10 November 1886, p. 2.

[22] *The Argus*, 9 November 1886, p. 5; *Horsham Times*, 9 November 1886, p. 2; *The Argus*, 22 November 1886, p. 5; *Horsham Times*, 23 November 1886, p. 2, at Murtoa they never laid here before; *South Australian Weekly Chronicle*, 11 December 1883, pp. 13–14.

[23] *The Mercury*, 27 November 1886, p. 1S.

[24] *Bendigo Advertiser*, 12 December 1886, p. 3.

[25] *Bendigo Advertiser*, 14 December 1886, p. 3, at Marong, south of Bendigo.

1886, when traction was lost due to masses of crushed locusts greasing the rails.[26] Train stoppages were picked up by the press as an impressive demonstration of how nature's tiny multitudes could foil humans' foremost machines. The metropolitan press took the train 'hold-up' allusion and likened it to bushranging (Figure 5.3).

Locust swarms infested much of Victoria throughout 1886–88. There were clearly two generations each year in the Wimmera and northern Victoria during 1886 and 1887. The repeated appearance of swarms at Wallaloo prompted a pictorial depiction of the plight of the farmer (Figure 5.4).[27] The swarms penetrated east to Rutherglen and south to Warrnambool, where in autumn 1887 there were 'thousands dying in the streets'.[28] By autumn 1888 they had contracted to the Wimmera, but remained a source of consternation and curiosity. A resident of Stawell reported that his children had pointed out the locusts were dying in thousands from maggot parasites.[29]

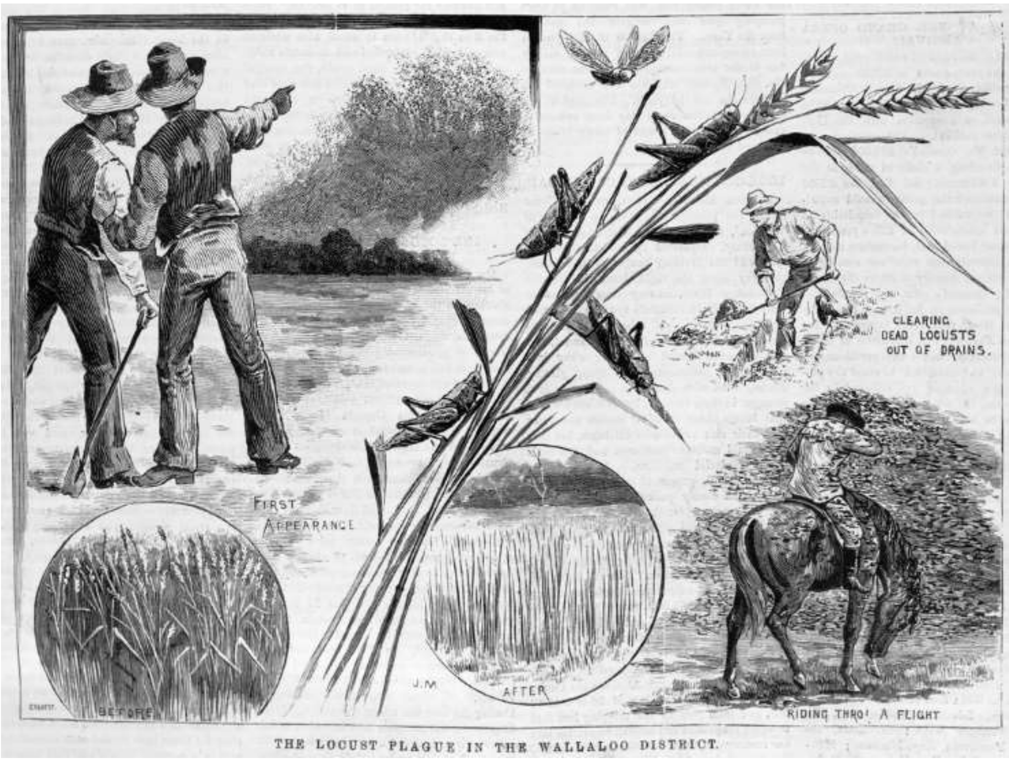

Figure 5.4. The locust plague in the Wallaloo district, *Illustrated Australian News*, 8 January 1887, p. 9. The panels depict the progression of the plague: the dismay of powerless farmers facing the 'first appearance' of swarms, the rider and horse stopped by flying locusts, the 'before' and 'after' views of the wheat crop and clearing dead locusts from drains (digitisation, State Library of Victoria).

[26] *The Argus,* 11 December 1886, p. 12.

[27] Wallaloo is in the Wimmera region, between Stawell and Donald; further north near Warracknabeal locusts took the first crop from mallee country cleared only the year before.

[28] *Kilmore Free Press*, 10 March 1887, p. 3S, also reports from Benalla and Kilmore.

[29] *Portland Guardian*, 2 March 1888, p .3.

There was a brief respite in 1889 before swarms again arrived from NSW in the autumn of 1890. The 1880s were characterised by an alternation of La Niña and El Niño indicators and corresponding wet and dry years in different regions of south-eastern Australia.[30] There was good rainfall in 1883 and 1886–87 in Victoria, while 1884 and 1888 were dry.[31] While only a limited set of rainfall recording stations operated in south-east Australia, even less information is available for inland areas but newspapers reported flooding in Queensland rivers during 1882 and 1886. The persistence of *C. terminifera* swarms in Victoria may have been the result of environmental changes. Apart from a continued intensification of land use, livestock numbers had been relatively stable since the 1860s, with around ten million sheep and a million cattle, but now rabbits teemed over the colony.[32] The landscape alternated between short-lived flushes of mostly ephemeral pasture grasses and almost bare ground during dry times, while crowding of livestock around watering points intensified the loss of ground cover.

Although the locust was now fairly well known, various names were still being applied to it. People in the bush recognised when they had the locust, noting its behaviour and larger size, which suggests they were also familiar with swarms of the smaller grasshopper that came in other years. However, there was still no official recognition of the existence of *A. cruciata*. Unlike the field of botany, where Victoria had an internationally recognised taxonomist in Ferdinand von Mueller, there was less Antipodean confidence in naming orthopteran insects. That authority still remained in European seats of knowledge. Although Professor McCoy now correctly applied Walker's 1870 taxonomic label, *Epacromia terminifera*, to *C. terminifera*, drafts of an 1888 'Noxious Insects Bill' still named it '*Edipoda musica'*, the name he had mistakenly used in 1873.[33] Serious questions were raised over whether this locust was the same as the famed overseas species that would soon darken the skies, or

[30] J. L. Gergis and A. M. Fowler, 'A history of ENSO events since AD 1525: Implications for climate change'. *Climatic Change*, 92 (2009), 343–387, p. 368; J. Gergis *et al*., 'On the long-term context of the 1997–2009 'Big Dry' in South-eastern Australia: insights from a 206 year multi-proxy rainfall reconstruction', *Climatic Change*, 111 (2012), 923–944; C. Fenby and J. Gergis, 'Rainfall variations in south-eastern Australia part 1: consolidating evidence from pre-instrumental documentary sources, 1788–1860', *International Journal of Climatology*, 33 (2013), 2956–2972; J. Gergis and L. Ashcroft. 'Rainfall variations in south-eastern Australia part 2: a comparison of documentary, early instrumental and palaeoclimatic records, 1788–2008', *International Journal of Climatology*, 33 (2013), 2973–2987.

[31] Bureau of Meteorology, rainfall records are available for Bendigo Prison, Ballarat and Deniliquin.

[32] *The Brisbane Courier*, 19 August 1889, p. 4; *The Queenslander*, 15 November 1879, p. 24; *Riverine Herald*, 16 January 1884, p. 2.

[33] *The Victorian Naturalist*, 3 (10), (February 1887), p. 182; *The Argus*, 18 October 1888, p. 9; *The Argus*, 24 October 1888, p. 9, on Dr George Le Fevre's suggestion, the name was wisely withheld 'subject to professional opinion that this was indeed the locust common to the colony'.

whether it was changing its habits and becoming 'endemic', no longer occurring only 'promiscuously at intervals'.[34]

Minister Dow's plan for checking the plague

The persistence of *C. terminifera* swarms in Victoria during the 1880s resulted in renewed public interest and anxiety, which brought mounting pressure on the agriculture department. In 1886, the Minister, John L. Dow, was questioned in the Legislative Assembly by the Member for Avoca, Thomas Langdon, who called for a 'professor or expert' to investigate the 'calamity' around Charlton.[35] Louis L. Smith, Member for Mornington, recommended he appoint 'a gentleman with a thorough knowledge of entomology from the Lands Department'.[36] The only such person at the time was Charles French, then working in the National Herbarium under Mueller. French had been accumulating his knowledge of insects for many years and in 1887 received an award for a collection at the Adelaide Jubilee Exhibition.[37] Dow resisted the push for an entomologist, as he was formulating his own plan of action on the locusts. Instead, he conscripted the newly appointed department agricultural chemist, Alfred N. Pearson, to investigate the situation in the northern districts and confirm the statements of 'fearful ravages of locusts'.[38] British-born Pearson was well suited to the diversity of work that confronted him on joining the department, having experience in chemistry, meteorology and biology.[39] He collected information on the soil types of the apparently restricted, regular breeding grounds, as well as local ideas on the use of fire or chemicals to kill the young hoppers.[40]

In early 1887, Pearson carried out the first controlled insect physiology experiments in Australia on locust egg incubation times. His results gave hatching after 31 days at 85°F and 116 days at 50°F, not too different from more recent estimates.[41] He also contributed to ideas of host-parasite population

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[34] *The Horsham Times,* 10 January 1888, p. 2.

[35] *Kerang Times and Swan Hill Gazette*, 26 November 1886, p. 4.

[36] *The Argus*, 8 December 1886, p. 4.

[37] *South Australian Register*, 21 September 1887, p. 7.

[38] *South Australian Weekly Chronicle*, 11 December 1886, p. 10.

[39] Educated at the Halton Mechanics' Institute in Leeds, he became an associate of the British Chemical Society and Meteorological Society before working in India as Professor of biology, museum curator and engineer in Bombay during the 1870s, see W. R. Jewell, 'Pearson, Alfred Naylor (1856–1933)', Australian Dictionary of Biography, National Centre of Biography, Australian National University, http://adb.anu.edu.au/biography/pearson-alfred-naylor-8002/text13945 , viewed 7 November 2013.

[40] *Colac Herald*, 1 April 1887, p. 2.

[41] *The Argus*, 12 January 1888, p. 11, Pearson's experiments must have taken place the previous summer to have incubated eggs for 116 days. Pearson found that incubation time could be indefinitely prolonged by cold, even suggesting also that they might withstand freezing. 85°F is equivalent to 29.5°C, at which *C. terminifera*

interactions in relation to the locust plagues, before returning to soil chemistry and 'artificial manuring' experiments in the 1890s.

A report by the British colonial engineer of Cyprus, S. Brown, claiming the virtual elimination of locusts on the island after annual organised mass action campaigns under his direction, had repeatedly done the rounds in the press and the Victorian Parliament.[42] Brown's highly numerical report described mobilising Cypriot labourers to collect eggs and to trap locusts with cloth screens.[43] Dow took Brown's report, with its surety of success through British logistical engineering, into account in his plans.[44]

The department received numerous complaints about the locust plague from country districts during 1887 and in December, Langdon again asked Dow 'what action his department had taken toward the appointment of an entomologist, particularly for the purposes of dealing with the locust plague'.[45] Dow replied that the problem did not necessarily require the appointment of an entomologist, mentioning the British success in Cyprus and adding 'what was needed was simultaneous intercolonial action'. Newspaper correspondents interpreted his statements as suggesting premiums would be offered for the destruction of eggs, adding that 'covering with straw and firing it was sufficient to check the plague, and special officers were not required'.[46]

At the start of 1888 the pastures were as lush as in 1870 and the locusts were 'never known to be so numerous'.[47] Around Echuca, only '2–3 bushels were harvested, 6–10 were left on the ground from locusts and storms' and similar losses occurred along the Loddon and Goulburn rivers.[48] After three years of continuous locust swarming, in January 1888, newspapers were swamped with questions and opinions about their biology, parasites, impact on crops and control.[49] In the vacuum of official information, snippets from the 1873 annual report were repeated and an *Argus* editorial complained

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eggs take 20 days to hatch. However, 50°F is close to 10°C, below the temperature threshold for development. The 116 days duration would result from an 18°C.

[42] *The Argus,* 21 October 1884, p. 4, in the 'Report of the locust campaign-1884,' Brown detailed using 1,882 Cypriot labourers, exclusive of superintendents, to kill 56 million locusts.

[43] *The Argus*, 1 December 1884, p. 4, referring to Brown's report the editorial asked 'is there not a lesson here for the people of this colony, where the pest is more ignoble than the Victorian rabbit?'.

[44] *The Argus,* 15 December 1887, p. 4.

[45] *Riverine Herald*, 15 December 1887, p. 2.

[46] *Kerang Times and Swan Hill Gazette*, 16 December 1887, p. 4; *The Horsham Times*, 10 January 1888, p. 2.

[47] *The Brisbane Courier*, 3 January 1888, p. 3.

[48] *Bendigo Advertiser*, 10 January 1888, p. 3; *Riverine Herald*, 16 January 1888, p. 3.

[49] Over 100 non-advertisement entries in Trove keyword search for 'locusts' or 'grasshoppers', accessed 12 August 2013.

that, after fifteen years of 'special attention', farmers were no more in a position to deal with the locusts than they were before.[50] The opinion among farmers was that locusts were becoming a greater pest that rabbits, as they were more destructive, more difficult to exterminate and 'cleared everything before them'.[51]

Dow called for a full report on control methods and in January 1888 Pearson produced 'Preventive Measures against Locusts', a review of overseas methods of control, drawing mostly from US Entomological Commission reports from the late 1870s.[52] It listed heavy rollers, trenching and kerosene, as well as anecdotes such as castor oil plants, poultry and payments for collection of eggs. Pearson quoted from Eleanor Ormerod's 1884 *Guide to Methods of Insect Life* on US experiments of burying eggs at different depths to prevent hatchlings reaching the surface.[53] Of all the methods, he thought covering 'patches of ground in which the eggs have been laid with three or four inches of soil' was the most promising for dealing with the 'Victorian locust plague'.[54] But he emphasised the need for efforts to be organised and general to be effective, stating that 'it is useless for one man to spend time and money... if his neighbour allows his land to become a breeding ground'.[55] Pearson's report was read in the other colonies and, as any government scientific offering invited derision, his suggestions were criticised as impractical. One newspaper editor wrote that 'it is all very well for an agricultural chemist, whose knowledge of farming is limited to what he has learned in his laboratory, to suggest the burial of the insects, but who is to do it and how is it to be done?'[56]

Could parasites hold an answer?

With the emergence of a second generation of nymphs in January 1888 there was a renewed interest in the biology and natural enemies of the locust. Robert Pudney, at Longeronong Experimental Farm near Horsham, expressed the hope that the locust swarms might 'cease for a series of years' because of the actions of several parasites. He had observed a high incidence of maggot parasites in March 1887, which he thought must be the 'ichneumon' of earlier description, because flies could not pierce

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[50] *The Colac Herald*, 3 January 1888, p. 4, 'it may be that the rate of increase is in proportion to the abundance of feed'; *The Argus*, 11 January 1888, p. 4.

[51] *The Horsham Times*, 17 January 1888, p. 4.

[52] *The Argus*, 10 January 1888, p. 4.

[53] J. F. Clark, 'Ormerod, Eleanor Anne (1828–1901) Economic Entomologist', *Oxford Dictionary of National Biography* (2004), http://www.oxforddnb.com/view/printable/35329. Ormerod was acknowledged as Britain's de facto government entomologist during the 1880s and was instrumental in the development of economic entomology. During the 1890s her annual booklets on injurious insects were well subscribed by Australian colonial agriculture departments.

[54] *South Australian Advertiser,* 25 January 1888, p. 7.

[55] *The Australasian*, 14 January 1888, p. 20.

[56] *The Mercury*, 16 January 1888, p. 2.

the locusts' body.[57] He also described the red trombid mites found on the locust's body and internal nematode worms.

In a perceptive interpretation of lag responses in host-parasite numbers, Pearson entered into the exchanges in relation to parasites. He wrote that the effect of parasites was to produce irregular 'periodicity' in swarming insect occurrence.[58]

> Thus, owing to favourable combinations of circumstance, the locusts are plentiful in one year, but the parasites, having had but few locusts during preceding years are few in number and only affect a small percentage of their hosts. But the second year they become almost as numerous as their hosts and parasitize a large percentage of them, so that in the third year the swarms dwindle and the parasites are so numerous, few locusts have the opportunity of propagating their kind. This goes on until the cycle is repeated.
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> *The Argu*s, 12 January 1888, p. 11.

The close observations of amateur naturalists made valuable contributions to the knowledge of locust ecology. Richard H. Nancarrow, a farmer near Bendigo, made records over two consecutive years, finding that locust eggs laid in the heat of summer hatched in just twenty days and that there were two generations each year in Victoria. He reported observations of a tiny parasitic wasp of the 'fossorial hymenoptera', which he thought 'more potent in checking the plague' than all the other described agents put together, and which had hitherto been overlooked.[59] Nancarrow had seen large numbers of these wasps active at a locust egg bed, and some emerging from the holes after the locusts had hatched. On digging up remains of egg pods he watched wasps emerging from the locust eggs and figured the lifecycle of the parasite.[60] This was the first observation of the parasitoid *Scelio fulgidus*.[61]

Nancarrow went so far as to suggest that some of the planned control methods should be avoided as they would be fatal to the parasite as well as the locust, frustrating 'Nature's admirable plan'.[62] In a considered reply, Pearson argued that for all eggs destroyed, 'Nature's check would remain in the

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[57] *The Argus*, 5 January 1888, p. 9, Pudney observed 25–50 percent of female locusts contained maggots.

[58] *The Argus*, 12 January 1888, p. 11.

[59] In a letter to McCoy at the Victorian Museum in 1865, which included an illustration of the bandy-bandy snake, Nancarrow wrote: 'I cannot claim to be a naturalist and yet few can love Natural History more ardently than I do — but while I have been in this country I have had to read Nature instead of books and however much knowledge I may have thus acquired I feel unable to communicate the results of my observations, on account of my almost total ignorance of scientific nomenclature. What I should fail to do with my pen, I might to a certain extent succeed in doing with my pencil'.

[60] *The Argus*, 17 January 1888, p. 9, Nancarrow's farm was at Neilborough.

[61] Nancarrow had enclosed some wasps in a letter to the department.

[62] *The Argus*, 20 January 1888, p. 9.

same proportion' and that because of the delay in parasites becoming sufficiently abundant to reduce locust populations, 'artificial measures have to be resorted to'.[63]

Unofficial ecological understanding

One detailed report in the *Argus*, in summing up what was known and contentious about the Australian locusts, revealed a greater understanding of *C. terminifera* ecology than any official report. It suggested experience gained in the USA and 'contained in the annual issue of blue books … may save a good deal of expense and labour with schemes for destruction which have in that country proved ineffective'.[64] The Victorian locust was compared with the Rocky Mountains locust in an attempt to make sense of its observed ecology, particularly the apparently opposite migration directions which were to the cooler south in Australia.

In the very first examination of migratory behaviour relative to wind directions, the article compared predominant winds with the general southward movement of swarms. The idea that opposing wind directions in different seasons might influence the observed migrations was tested using average wind directions over seventeen years. The findings were that during spring and summer the predominant winds were to the northeast, so that southward flights in summer were not simply a function of wind trends. The article explored ecological ideas of seasonal distributions being aligned with habitat favourability, and of migratory behaviour being triggered by local overpopulation, suggesting 'hunger prompts immigration'.

The known details of locust biology were also summarised, including the controversy about differences in egg development time between those laid in summer and autumn. The apparently contradictory observations from December egg laying, of hatching within thirty days, compared with those laid in March, remaining in the ground until spring, were noted. In addition, possible environmental reasons for the increasing frequency and intensity of outbreaks were discussed:

> The theory that locusts have increased largely in numbers through the destruction of insectivorous birds, has very much to recommend it, and, as has been suggested by a correspondent of 'The Australasian', the thinning out or total decimation of timber areas has no doubt cleared the way for the locusts to many localities which formerly were not visited by them.
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> *The Argus* 9 January 1888, p. 6.

[63] *The Argus*, 21 January 1888, p. 4.
[64] *The Argus*, 9 January 1888, p. 6.

Proposed methods of destruction of young nymphs — ploughing, harrowing, rolling, trenching and burning with straw — were canvassed: some described as too primitive and tortuous for any wide scale action, but the article suggested they would be tried in several parts of the colony next spring. Drawing on descriptions of US locust parasites, the author also correctly identified the so-called ‘ichneumon’ to be a tachinid fly, as well as identifying the five distinct nymphal stages in the Australian locust. Although it is uncertain who wrote this article, the author had clearly closely observed locusts in Victoria. It was possibly one of the last entries by the *Argus* agricultural reporter, Robert Savage.[65]

The 1890–91 locust plague

The arrival of swarms in western Victoria in autumn 1890 heralded a new locust plague. It was shorter lived than those in 1871–75 and 1886–88, but was as geographically extensive and destructive across South Australia and NSW as the 1870s plague. There was widespread heavy rainfall in inland eastern Australia from early 1890, associated with the commencement of a protracted La Niña event.[66] In February there were reports of locusts from western Queensland, Innamincka in South Australia and Tibooburra in NSW. The infestation spread southwards across NSW and South Australia and the first swarms arrived in Victoria during March. Reports came in from Nhill in the west to Wodonga in the east. Extensive egg laying followed throughout April, setting the scene for massive hatchings in the spring.

With a serious hopper infestation imminent, the moment had come for Dow to enact his plan for ‘checking’ the pest. The department would lead the entire farming community in a coordinated collective action. Having finally appointed French in October 1889, he now had a government entomologist with the scientific authority of the profession to oversee operations. French first investigated the new spray technologies and chemicals for controlling orchard insects. He travelled to South Australia to discuss pest insects with Frazer S. Crawford of the Bureau of Agriculture and

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[65] Savage was a regular agricultural writer for *The Argus*. He farmed near Casterton and Northcote and lived in Echuca in the 1870s. Pearson may have contributed, but the criticism of the proposed control methods would suggest he was not involved. However, Savage was ill in early 1888 and died in July.

[66] Gergis and Fowler 2009, Table 10, p. 375, lists 1890–1894 as a protracted La Niña event.

returned with his patent spray pump.[67] French and Joseph K. Knight, the government fruit expert, demonstrated the equipment in orchards with various insecticides.[68]

French upheld Wallis' 1870s vision for science-based research and engagement with farmers through practical demonstrations and technical education. In early 1890 he was involved in the production and editing of an educational colour chart of twelve destructive insects that was distributed to schools. He also commenced a series of 'pamphlets' on insect pests and remedies that emerged later as his handbooks on *The Destructive Insects of Victoria*.[69] Soon after the death of his wife Janet in August 1890, French was thrown into managing the department's locust control project, travelling to the Wimmera region where major hatchings were expected. His energies now focused on the first and most ambitious government attempt to stop the pest. It involved a statewide unified human, animal and mechanical effort based on overseas colonial models of mass action against the nymph stages, supplemented by some home-grown remedies.

The 'battue' begins

It may have been Dow's idea for a coordinated control effort, but French engaged in its planning and operation with enthusiasm and urgency. Once the campaign was underway, newspapers linked it entirely with French and his media statements show he believed it could succeed if all parties acted together. Most of the methods and novel ideas, including burning, trampling and making use of boys' 'destructive instincts' had been previously floated in the press.[70]

In late September, at the same time as the Minister's unified action campaign was announced, French sent a letter to the regional newspapers, suggesting setting apart a 'Locust Day', where he considered

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[67] Frazer Smith Crawford was part-time Government Inspector of Fruit and Vines as well as photolithographer and amateur entomologist. In 1886 he produced a widely distributed pamphlet on insect and fungous pests of apple and pear orchards. He continued the 'Injurious Insects' series started by C.A. Wilson in Adelaide's *The Garden and the Field* magazine. Crawford also adapted spray technology from Florida and designed his own patent pressure spray equipment. Crawford died on 29 October 1890.

[68] *The Argus*, 7 February 1890, p. 4, they conducted spray trials in vineyards of the Rutherglen area; *Warragul Guardian and Buln Buln and Narracan Shire Advocate*, 11 March 1890. p. 3, French demonstrated with benzole, kerosene and Quibells's mixture on scale-infested bushes in the Melbourne Exhibition Grounds.

[69] *The Mildura Cultivator*, 22 November 1890, p. 3; *Bairnsdale Advertiser and Tambo and Omeo Chronicle*, 28 June 1890, p. 2.

[70] *Colac Herald* 3 January 1888, p 4, mentioned 'enlisting the services of boys' to kill nymphs; *Australian Town & Country Journal,* 12 January 1889, p. 23, in 1888 the Ballarat Agricultural Society 'conceived of exciting the destructive instincts of boys' in a trial that proved to be a very costly reward system for exterminating sparrows. Offering 3^{d} per dozen for sparrow eggs or heads, in 20 days Thomas Bath was inundated with 47,000 eggs and heads.

beating with branches an excellent idea, especially as children could be set to assist.[71] The letter included his proposal for horse-drawn bush harrows to damage the nymphs' wings so that they would fail to develop. At the start of October, Joseph Knight, now the 'well-known Government Travelling expert', was touring the northwest while French travelled to Horsham, Dimboola and Nhill in the Wimmera (Figure 5.5).[72] They deliberated with shire councils and agricultural societies, requesting them to nominate the most suitable date and likely locations for the coordinated 'battute'.[73]

In early October, French sent out a departmental circular to local agricultural societies urging farmers to unite against the locusts as they emerged, by means of bush harrows, burning straw and beating sticks on egg beds, writing 'we do not have a locust day as well as an arbor day — we must fight these locusts'.[74] Thomas Bath approved of the plan, recalling 1873 and the numerous outbreaks in the 1880s. He echoed the perception of a 'national calamity', as 'the visitations are becoming more frequent', but he thought the task of locust eradication would be 'a small matter' compared to the rabbit pest.[75]

Replies from the districts came in slowly and, as hatchings were commencing at Swan Hill and Knight had already returned from Dookie with a bag of nymphs, time was running out.[76] On October 23 French and Knight commenced a 'whistle-stop tour' of northern Victoria, and from Mitiamo to Swan Hill it was just that — a briefing on the locust situation and the need for united action on each station platform.[77] At Swan Hill, where there were already dense bands of nymphs, they had a rude horse-drawn harrow constructed from local timber and dragged it over them. In an effort to engage the new irrigation community at Mildura, French telegraphed the local newspaper about the 'great success' of his harrow trial and proposed two days in November be set aside for a 'general rail' on the destructive insect.[78] The train tour then took them across northern Victoria to Sandhurst, Echuca, Shepparton and Numurkah.[79] At each place the tactic was to brief the shire council, agricultural society and editors of the local press. After a departmental report of hatchings at Donald they again headed west.

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[71] *The Bacchus Marsh Express,* 4 October 1890, p. 7, suggested by Thomas Brown at Dookie Agricultural College.

[72] *South Australian Chronicle*, 18 October 1890, p. 12, reports French inspected an egg bed at Nhill, and would recommend the government compensate farmers who destroy the pest.

[73] *The Bendigo Advertiser*, 3 October 1890, p. 2; a misspelling of 'battue', the driving of game towards hunters by beaters.

[74] *The Bacchus Marsh Express*, 4 October 1890, p. 7; *The Mildura Cultivator*, 15 October 1890, p. 3.

[75] *Bairnsdale Advertiser and Tambo and Omeo Chronicle,* 14 October 1890, p. 4.

[76] *The Bendigo Advertiser*, 1 October 1890, p. 2.

[77] *Department of Agriculture Victoria, Bulletin No. 14*, (December 1891), p. 58.

[78] *The Mildura Cultivator*, 29 October 1890, p. 2.

[79] *Warwick Argus*, 11 November 1890, p. 3.

The grasshopper plague

When people thought we were going to have a short visit of the locust or one visit was only expected, whoever promised themselves such luck has been very much disappointed, for not only have they come a first and second time but a third and fourth is nothing uncommon, and each army seems to have its own work to do. The first and most advance army began work by walking or hopping through the grass eating all blades or leaves within a few inches of the ground. Second detachment worked on every thing within two feet of the land, thus destroying all thistles, nettles, cockspur, etc. Third, anything within three feet of the ground they churned as their share; among these may be noticed the lower vines and fruit trees, the flag and chuff of the wheat, then most all growing flowers and vegetables, the lower heads of wheat together with all barley and oats. The next will most likely be the entire crop of wheat. Nothing near the ground and green has been refused by this host but the Johnston grass.

Riverine Herald, 8 December 1890, p. 3.

The proposal was discussed at meetings of shire councils and local agricultural societies, and it received mixed reactions. Those along the Murray River at Echuca and Numurkah thought that such efforts should take place in the NSW Riverina ‘where they were hatched’, despite millions of nymphs now emerging in their own localities. That view was reiterated by the Wimmera Farmers Protection Association, which also pointed out government responsibility for Crown reserve areas.[80] Others were quick to point out practical difficulties. Because locusts hatched earlier in the north, a single day was inappropriate and it was already too late in some places as the pests had been out for several weeks. However, many farming communities embraced the idea of doing something rather than nothing.[81]

The ‘locust days’

Buoyed by his assessment that one man and a horse could destroy fifty acres of locust hoppers in a day, French pressed ahead with the plan.[82] By October 21, the Minister had endorsed November 7 and 8 the ‘locust days’, and induced the Minister for Education to proclaim the Friday a public holiday so that school children could be employed in ‘thrashing’ the young insects.[83] French prepared plans for the coordinated raid on the locusts, issuing detailed instructions to state school teachers:

[80] *The Horsham Times*, 18 October 1890, p. 2; 24 October 1890, p. 2.

[81] Communities and Shires engaging in the ‘locust days’ campaigns included St Arnaud, Boort, Wycheproof, Horsham, Charlton and Swan Hill.

[82] *The Bendigo Advertiser*, 29 October 1890, p. 2.

[83] *The Argus*, 21 October 1890, p. 4; *The Horsham Times*, 21 October 1890, p. 3.

1. The boys should be summoned by the schoolteacher and the nature and object of the undertaking explained to them.
2. Male scholars over 10 years of age should be requested to obtain reliable information from their parents, presuming them to be farm people, as to the most likely places where locusts abound ... so teachers can arrange the meetings.
3. The ground to be treated should be raked off with poles, to which a piece of rag or paper ... be attached, so that the whole of the infested block might be thoroughly gone over, and, unless found necessary, the beating operations need not be repeated.
4. The ground to be beaten over should be closed off somewhat in the ... style of crop lines ... so that few of the locusts would be likely to escape unhurt; it is necessary to kill them to prevent them from depositing their eggs.
5. The operations of the scholars should be inasmuch as possible confined to such places as amongst the timber, stumps &c. — that is, where the brush harrows or rollers could not be worked. The branches for beating the insects should be, if possible, of either Bull Oak or Murray Pine; although if these be not available, dense branches of any of the gum trees will do for the purpose.
6. The results of the beating to be noticed by the head teachers and reported to their Department.
7. Prizes of books will be given by the Department of Agriculture to the school library of the school which has, in the opinion of the Government entomologist, performed the best work.

The Horsham Times, 28 October 1890, p. 3.

The 'Locust Days' came and there was no shortage of hoppers to attack. Male employees of the Forests Branch and Lands Department were sent to assist and thirty men worked for a fortnight at Murray Downs. At St Arnaud, young miners were brought up to aid in the destruction.[84] Some fires got out of control and damaged fences during attempts at the 'straw-burning' method. French distanced himself from these, writing he would not have recommended it under the conditions.[85] He toured infested areas of the Wimmera and Knight returned to Cobram, where they 'directed operations' and were appraised of the successes. French visited Boort, hurried south to St Arnaud and returned by train to the north via Dunolly, Charlton and Wycheproof (Figure 5.5).

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[84] *The Argus*, 6 November 1890, p. 6; 6 October 1890, p. 4; 16 December 1890, p. 6; *The Horsham Times*, 18 November 1890, p. 2, there was one tragic death near Clear Lake when a fourteen year-old boy carting hay for burning the hoppers died when the horses bolted. William Jackman Jnr was killed; p.4, Lowan Shire Council advertisement requesting all landholders to take action.

[85] *The Argus*, 7 November 1890, p. 5.

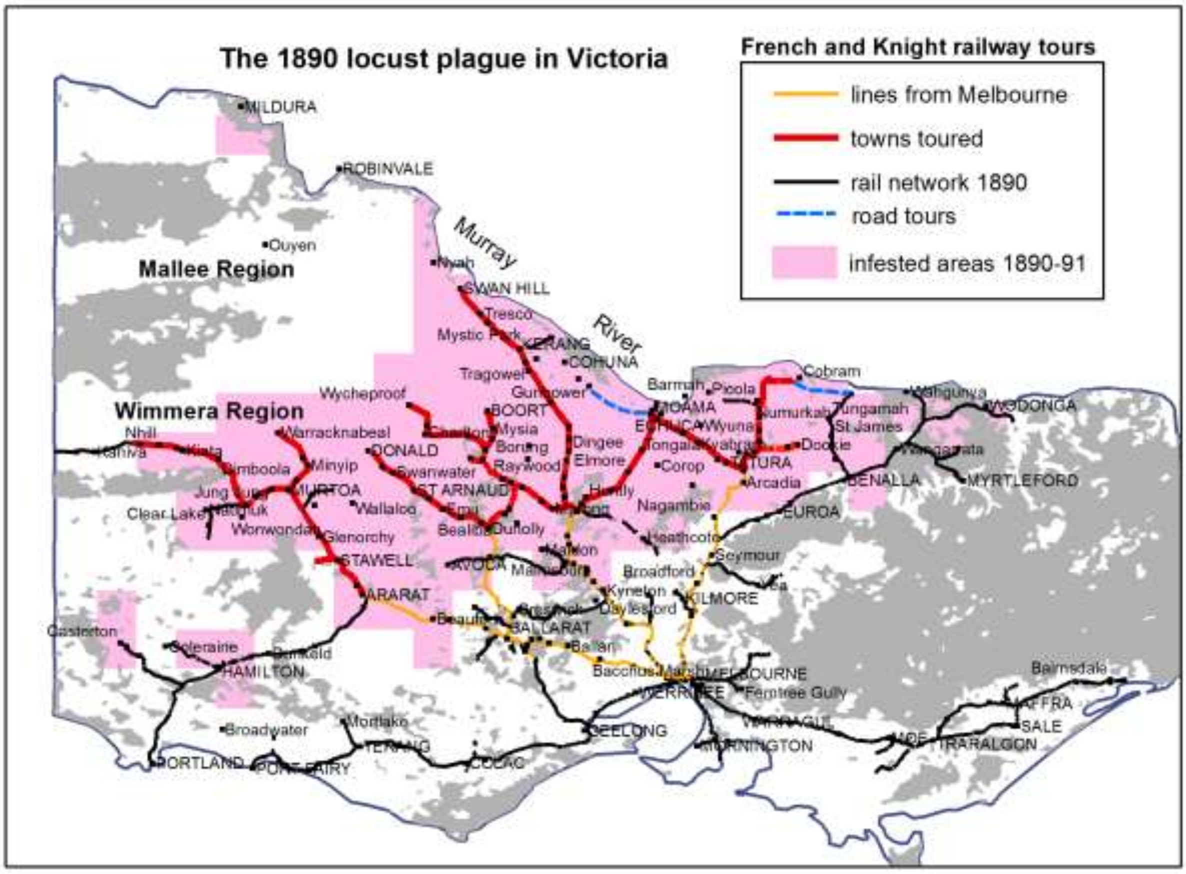

Figure 5.5. The 'Locust Days' train journeys of Charles French and Joseph Knight in 1890. Locations reporting infestations during 1890–91 shown in pink. Areas of present-day forest vegetation shown in grey.[86]

One problem was that there were not enough rollers or other suitable machinery available and, even though a harrow could be constructed in a few hours, in some places a branch dragged by a horse was the most effective tool.[87] Other creative methods were also employed, including the old remedy of trampling hatching sites with mobs of sheep. At Mitiamo a landholder diverted the river to construct a moat around his house and gardens to stop the nymphs and at Pyramid Hill householders put up canvas around their houses and gardens.[88] Some farmers' groups expressed interest in obtaining arsenic insecticide and at Numurkah people experimented with arsenic solutions of London Purple, developed by Professor Lowie at Roseworthy Agricultural College in Adelaide, with no reported success.[89]

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[86] The 1890 rail network adapted from digital data produced in 2000 by Andrew Waugh, 'Victorian Railway Maps 1860–2000', http://www.vrhistory.com/VRMaps/intro.pdf - downloaded 20 November 2013.

[87] *The Argus*, 8 November 1890, p. 10.

[88] *The Argus*, 7 November 1890, p. 6

[89] *The Argus*, 2 December 1890, p. 10.

On the issue of the involvement of schoolchildren, F. M. Linley of Kerang asked if the government could really have been serious when they gave them days off to exterminate the locusts. Given the immense numbers between Numurkah and Swan Hill, they might just as well have 'distributed pannikins' and told the youngsters to bail out the Murray.[90] Needless to say, however, many of the 'scholars' were excited by the plan and participated in the 'locust day' in numerous localities. At Jung Jung the school picnic was postponed to allow for participation and a report of the event at Swan Hill suited the atmosphere of a military campaign.[91] The attack was led by the 'schoolmaster on horseback', the schoolchildren 'turned out in great force … and the onslaught was determined and severe'. Although the 'raid' was reported to be very successful, many millions still remained.[92]

The *Illustrated Australian News* produced a heroic rework of its 1887 'locust manga' graphic (see frontispiece, page 22). The text praised the efforts of the schools campaign and squarely laid the blame for any failures upon the 'supineness of the farmers in whose interests the work was carried out'.[93] French had expressed disappointment at the lack of participation in some northern districts, where, despite young locusts being present in millions, he found a 'strange apathy on the part of the people, who simply abstain from making any effort'.[94] He also took the unprecedented step of engaging the local press in interviews to spruik his message. It was suggested by an interviewer at Albury that it would be a waste of time for farmers on the Victorian side of the river to take action, seeing that such myriads of the insects come from NSW:

> 'Not so', said Mr. French; 'local action can do a lot of good … while yet young, [the insects] can do an immense amount of harm. Besides, this action taken locally will show the New South Wales people that we are in earnest regarding the pest, and will induce the Government of that colony to legislate for future years. In any case, every farmer should do his share of destruction, and by this means help to keep in check the plague, which will yet become more serious than the rabbits in this country.' 'That may seem an extraordinary statement', continued the Government entomologist, 'but it is no exaggeration. Locusts are becoming more numerous and destructive each year, and unless the various legislatures take measures to compel, or at least to encourage their destruction, the consequences will be very serious indeed.'
>
> *Bathurst Free Press*, 12 November 1890, p. 3

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[90] *The Argus*, 14 November 1890, p. 6.

[91] *The Horsham Times*, 7 November 1890, p. 3.

[92] *The Argus*, 8 November 1890, p. 10, the attack was led by schoolteacher Mr. Gambetta.

[93] *Illustrated Australian News*, 1 December 1890, p. 14, the 1890 pictorial story used elements from its 1887 version, but only men, no schoolboys, and locusts are shown as actors in the panels. This time men defiantly face the enemy, sleeves rolled, or are hard at the methods of control. The older, experienced man holds a whip, a symbol of control, and wears the hat of a pastoralist. The individual locusts aren't drawn as malintents and remain oblivious in their business of eating.

[94] *The Riverine Herald*, 7 November 1890, p. 2.

The ‘locust days’ campaign was described in some metropolitan papers as ‘spasmodic’ or ‘dilatory’, but among the many reports of success and failure one entry in *The Argus* put the scheme into perspective by highlighting the mismatch in scale of human capabilities and locust numbers (see ‘Notes and Comments’, next page).[95]

Seemingly unruffled by such declarations of futility, French released other prophetic reports in December; that the current flights of locusts crossing the Murray were simply an ‘early advanced hatching’ and when they laid eggs, sustained control actions would again be needed to avoid agricultural disaster from the ‘second crop’ of hoppers.[96] He telegraphed Rutherglen and Mildura, offering to supply kerosene emulsion free of charge to horticulturalists.[97]

The new minister, Allan McLean, stated that he was ‘very satisfied’ with the result of the ‘exterminations’, which gave reason to believe the plague would be averted.[98] Thomas Bath, in commenting on the department’s ‘little army of experts’, praised Knight ‘the insect exterminator’ and French as ‘one man picked out of ten thousand’.[99] In his official report on the 1890 campaign, French concluded that the only way to successfully combat locust plagues was by compulsory concerted action, backed up by legislation, and that the cooperation of adjacent states should be secured.[100] The following year French obtained a canvas ‘locust fence’ from the Government of Cyprus. He intended constructing ten miles of fence at a cost of £10 per mile to test its efficiency.[101]

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[95] *The Sydney Morning Herald*, 12 December 1890, p. 4; *The Age*, 12 November 1890, p. 5, this newspaper hardly mentioned the locust campaign, but one comment about the department being ‘too dilatory in appointing a day’ spurred French into demonstrating otherwise.

[96] *Geelong Advertiser*, 10 December 1890, p. 4.

[97] *The Mildura Cultivator*, 17 December 1890, p. 3.

[98] *The Mercury*, Tasmania. 14 November 1890, p. 3.

[99] *Bairnsdale Advertiser and Tambo and Omeo Chronicle,* 4 December 1890, p. 3.

[100] *Department of Agriculture Victoria Bulletin No. 14*, (December 1891), pp. 63, 70.

[101] *Queanbeyan Age*, 13 January 1892, p. 3, the ‘locust fence’ was a gift and was later displayed by the department.

Notes and Comments, by Meddler

We have heard a little about the locusts in Melbourne. We have been told of plans to fight with them, to destroy them in their infancy to prevent the whole harvest of the lands falling to them as a prey. But townsfolk, as a rule, have a difficulty in realising what a plague of the sort really means … Here is a little bit of description, very fresh, and somewhat graphic … from the officer in charge of Tintarra State Nursery, in the Gunbower Forest, on the Murray River, about 30 miles below Echuca.

We have been these three days past all hands engaged in destroying grasshoppers. This pest is here so numerous that on one occasion they threatened to destroy everything green. They come in such a mysterious way. We are on an island here of about 150 acres, and surrounded on all sides by water ... and the insects being so small and wingless in their present stage leads one to suppose they must have been hatched on the place. They ... covered the ground so thickly, that it appeared one moving mass for an area of three or four acres in each mob or brood. I have had everything tried I can think of to destroy them, but brush harrowing, beating with bags and bushes, seemed to have no effect on them that could be observed, they were so numerous, and the rolling with a heavy roller was not more effectual, owing to unevenness and hard lumpy ground. The most effectual thing we could think of was a wet cornsack on a pole, and when this was used it took effect, but then owing to the millions that were present our 10 men's endeavours were just futile. In ditches I had dug when draining this place … the grass hoppers were a seething mass of over 6in. deep, and one could shovel them up in … one living mass, so I was at my wits' ends what to do … we are beating them down with showers of bags and shovels flat into the water, but this seems just a waste of time … All that labour is on a patch of ground 150 acres in extent, and there is reason to believe that the plague extends over as many thousand square miles. What will be the end, or rather, what is the remedy for it?

The Argus, 14 November 1890, p. 7.

French's media statements about the situation getting worse each year fuelled the growing public perception of locusts becoming an increasing and dire problem. The well-known descriptions of devastating plagues in other parts of the world haunted settlers in the 1890s. The possibility that the situation would become as bad in Australia as was being reported from South Africa, Algeria, Russia, the USA, Argentina, India and China was alarming and frequently aired in the press. For some it was already 'evident that we have the insect pestilence in all its essential Oriental features'.[102]

The plague in other colonies

The 1890 plague also affected South Australia and NSW, but the official response was more muted. In NSW, the plague came at the same time that parliament was grappling with the 'Rabbit Bill' and the comparison of political inertia and a slow evolution of legislative action, occurring only after a

[102] *The Sydney Morning Herald*, 12 December 1890, p. 4.

problem became a crisis, was drawn with the locust situation.[103] The newly established NSW Department of Agriculture was in no position to respond in the manner that the Victorians wanted. It sent Richard Helms, from the Sydney Museum, to collect information in 1890 and Arthur M. Lea, then an entomological collector, to the Riverina in 1891. Helms' report was used by the first government entomologist, Arthur Sidney Olliff, in his entries on locusts in the *Agricultural Gazette* in 1891.[104] Helms concluded there were two locust generations each year, a possibility doubted by Olliff. Helms also collected the same minute wasp parasites of locust eggs identified by Nancarrow and Olliff sent samples to the US Department of Agriculture, which were identified as a species of *Scelio* by Leland O. Howard, an expert on parasitic Hymenoptera.[105]

Swarms spread throughout the agricultural districts of South Australia in 1890, reaching Adelaide in December.[106] The Central Bureau of Agriculture attempted to coordinate control activities from its district branches, requesting information on hatchings and sending circulars of suggested remedies. The reply from Burra expressed the more general opinion that 'nothing could be done owing to the large extent of government land and sheep runs swarming with them'.[107] French had called for intercolonial cooperation in dealing with the locusts, but the South Australian government received no formal correspondence until January 1891, when a telegram from the Victorian Premier proposing an intercolonial conference finally arrived.[108] Thus, by the time French's plan was discussed by the Bureau it was too late to do anything.

The Legislative Council dealt with various internal proposals, usually as motions put forward for 'strenuous efforts' to check the plagues.[109] One estimate of lost production in 1890 was one million pounds, yet the wheat harvest was larger than the previous year. Several Members pointed out that because of the vast unpopulated northern areas where locusts bred, there was no means of stopping the swarms.[110] Otto Tepper, entomologist at the museum, saw the Australian locust problem as

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[103] *The Sydney Morning Herald*, 12 December 1890, p. 4.

[104] *Agricultural Gazette of NSW*, 2 (1891), pp. 74–78, 678–777.

[105] Leland O. Howard, who became head of the USDA Bureau of Entomology, was then assistant entomologist under Dr Riley.

[106] The Argus, 16 December 1890, p. 6.

[107] *The Garden and the Field,* November 1890, p. 95; *The Argus*, 18 October 1890, p. 7; *South Australian Register*, 23 October 1890, p. 5, French mistakenly identified Frazer Crawford as his South Australian counterpart and as endorsing intercolonial effort in the mass action program. Crawford replied that neither was the case, and that if locusts were on the wing, all such efforts would be futile.

[108] *South Australian Chronicle,* 8 November 1890, p. 4; *South Australian Register,* 1 January 1891, p. 6; *Bendigo Advertiser*, 2 January 1891, p. 2.

[109] *South Australian Register*, 1 November 1890; 23 September 1891, p. 3.

[110] *South Australian Register*, 29 October 1890, p. 4.

‘literally nothing’ compared to overseas. He thought that local experience had repudiated overseas methods, and also expressed doubt that locusts bred in the far interior of South Australia.[111]

Those whose livelihood was not directly affected could see a lighter side to the plague. At Moama on the Murray River, one of the most stable institutions, the Bank of NSW, had to close its doors in consequence of a raid by the locusts.[112] Near Quorn in South Australia the delay of a train gave rise to an unlikely social exchange:

> The train from Port Augusta to Quorn encountered a living barrier, in the shape of a dense mass of peregrinating locusts ... the wheels of the locomotive and carriages dipped and slid most aggravatingly. When the minimum of speed had been reached some diabolical shearers and rouseabouts from the Saltia woolshed, on sarcasm bent, kept up a fusillade of jokes and humorous allusions concerning the advantages of latter day locomotion … the “knights of the shears,” however, relented, and proceeded to pass up to the passengers light refreshments! After a fair amount of tea had been imbibed by the “toasted travellers” the block ended, and with one disdainful snort the much maligned motor bounded away, leaving behind an object lesson in natural history for the now discomforted toilers to ponder over.
>
> *The Advertiser*, 3 November 1890, p. 4.

The end of the plague and its upshot

Locusts persisted in the Wimmera and northern Victoria during early 1891, but fewer hatchings were reported the following spring. In NSW, however, a traveller who saw ‘indescribable numbers’ in the Riverina in November 1891 was dismayed by the pronouncement of the ‘Victorian expert’, French, that owing to late hatching ‘the extent need not be apprehended this year’.[113] There had been many reports of fly maggots killing the adult locusts in autumn 1891 and a schoolteacher from Corowa, Mr. Buggy, gained notoriety as the first to ‘identify’ the ‘Tachina’. Buggy was engaged to supply the flies to an American company aiming to breed and distribute them the following year, but by then there were no locusts at Corowa.[114]

As Pearson had observed, parasites catch up with their host and this was noticed by those on the ground. At Mildura in December 1891, great excitement was caused by the high levels of ‘ichneumon’ maggots causing their own ‘havoc among the locusts’. The phenomenon was suggested

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[111] *The Advertiser*, 7 August 1893, p. 7.

[112] *Riverine Herald*, 5 December 1890, p. 2.

[113] *Freeman’s Journal*, 7 November 1891, p. 21.

[114] *Freeman’s Journal*, 30 January 1892, p. 3.

as a nature study example for all public schools.[115] The American entomologist, Albert Koebele, who visited Hay in 1892 in search of useful insect parasites, considered the freedom from the plague at the time was 'entirely due to the tachina fly'.[116]

In 1891, French published a *Handbook of the Destructive Insects of Victoria*, which would later become a series of five volumes.[117] These were perhaps inspired by Eleanor Ormerod's annual publications on injurious insects and the growth of economic entomology as the useful output of his profession.[118] Like his contemporaries, French's ecological views were framed by the 'balance of nature' metaphor. In the first Destructive Insects book in 1891, he quoted Henry Tryon, the Queensland entomologist, that the 'wholesome equilibrium of destruction', when disturbed by human actions, produced many of the farmer's pest problems.[119]

As a naturalist French was firmly from the nineteenth century romantic tradition, recommending books of self-education in natural history.[120] He also championed the protection of insectivorous birds, as had Wallis in the 1870s. In defence of birds he wrote 'there is the case in a nutshell', they 'will do yeoman service and ask for no wages'.[121] His commitment to bird preservation was justified publicly by their direct economic benefit. French also indulged in the popular listing of the most valuable insectivorous birds and later produced a popular cabinet display of 'Twelve Best Birds'.[122] In

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[115] *Freeman's Journal*, 12 December 1891, p. 3.

[116] *South Australian Register*, 27 February 1892, p. 6; *Border Watch*, 2 March 1892, p. 3.

[117] Charles French*, Handbook of the Destructive insects of Victoria: with Notes on the Methods to be Adopted to Check and Extirpate Them*, 5 Volumes (Melbourne, Victorian Department of Agriculture, 1891–1911).

[118] Charles French, 'Economic Entomology: Some advantages to be derived from its study', in *Monthly Lectures delivers at the School of Horticulture, by Various Experts during 1892–1893*, (Melbourne, Department of Agriculture, 1893), pp. 64–74.

[119] Charles French, *Destructive Insects of Victoria* &c. Part 1, (Melbourne, Victorian Department of Agriculture 1891), p. 24, French quoted Tryon from the *Queensland Department of Agriculture 1889–90 Annual Report*, p. 20, who also used the phrase as a quote.

[120] French 1893, p. 66. French recommended the romantic books by Smiles, *Life of a Scottish Naturalist* and *Lives of the Earlier Lancashire Botanists* to the students.

[121] French 1891, p. 24; French also led numerous Field Naturalists' excursions to places near Melbourne, but their activities at that time were focused on collections and rare specimens; *Victorian Naturalist*, 3 (10) 1887, p. 141, an article on the sale of a famous collection, with eggs of over 2,000 bird species, was praised for the astonishing patience, skill and perseverance it represented; In recommending legislative rules for bird protection in 1895, French wanted commercial taking of nests and eggs prohibited, but would allow private collection and licenses for scientific shooting.

[122] Part of French's cabinet displays were taxidermy specimens of 'twelve best birds' that were frequently displayed in the city, see C. French, *Victorian Department of Agriculture Annual Report 1907–10*, p. 41.

the 1890s French had resisted recommending arsenic sprays for widespread use against locusts, perhaps because of the risk of bird poisoning, though he endorsed their use in orchards.[123]

French was a foundation member of the Victorian Field Naturalists' Club and contributed to its activities, through which he expanded his specimen collections, which included 'useful birds' with their nests and eggs. In 1890 French announced the collection as the most complete in economic entomology in the southern hemisphere and by 1895 visitors to his offices could view his 'Museum of Economic Entomology and Ornithology'.[124]

Locust swarms arrived again in Northwest Victoria in autumn 1895 following heavy rainfall in the inland the previous summer. Swarms were also recorded in western NSW and northern districts of South Australia, so the event qualifies as a brief plague. There were spring hatchings in Victoria, and in December swarms from NSW crossed the Murray and invaded the Goulburn Valley. In anticipation of the problem, French engaged in correspondence on protection for insectivorous birds, entreating hunters to avoid them over the Christmas break. He reiterated that of all birds, there should be legislative protection for the white-fronted woodswallow. The plague, however, did not last through the dry year of 1896.

Locusts' contribution to 'public science'

The first experimental applied ecological science in Australia, that of A. N. Pearson on locust egg development, was sponsored by the Victorian government in direct response to pressure by farmers and their Parliamentary representatives. Charles French's appointment as the first government entomologist in the Australian colonies also resulted from those demands, after repeated locust infestations of the 1880s.

The attempt to mobilise the entire rural populace shows the centrality of agricultural development in the 'improvement' ideology of that time. However, it placed the burden of action on the rural community and underestimated the scale and complexity of the locust situation. French's role demonstrated scientific prestige within a government agency now relying on specialist 'experts' not only to legitimise, but to fulfil its public role. The 'Locust Days' came at the peak of the period of 'colonial socialism'.[125] The government proportion of total employment doubled between 1860 and

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[123] *Department of Agriculture Victoria Bulletin 14*, (December 1891), pp 57–63, p. 62; *Wagga Express*, 13 January 1898, p. 2.

[124] *Victorian Department of Agriculture Annual Report 1889–90*.

[125] H. M. Boot, 'Government and colonial economies', *Australian Economic History Review*, 38 (1998), 74–101, 'colonial socialism' had been used by Noel Butlin to characterise the period 1860–1891.

1891, and the growth of the agriculture department was part of that expansion.[126] Although the cost to government was small, the campaign's rapid organisation was only made possible by the expansion of the Victorian rail network during the 1880s. It was also assisted by the growth of local agricultural associations, the telegraphic network and rural newspapers. The large government borrowings to finance railway extensions in the 1880s had the hallmarks of bureaucratic 'public choice', and they contributed to the balance-of-payments crisis that followed.[127]

In late 1890, cracks were appearing in the economic wonder of Victoria. The locust plague came amid a 'crisis of capital against labour' and a precarious budget situation, where 'boom budget' talk was suddenly a thing of the past.[128] Apart from *The Argus*, the Melbourne press was preoccupied with strikes at the waterfront and coalmines. However, one article in *The Age* prompted French to defend the campaign.[129] He obtained locust eggs and repeated Pearson's egg development experiments to ascertain the duration of nymphal development, 'partly for the purpose of refuting statements that our Department ... were too late in taking action'. He reported it took eight weeks from hatching to fledging.[130]

French's use of newspaper interviews was the first such manipulation of the Australian media. His confident but alarmist message went to the heart of the practice of economic entomology — how to get all agriculturalists to comply with the recommended actions. But there was a level of public scepticism about the practical worth of some branches of government. Even Thomas Bath, somewhat jaded by his long experience of the department, was ambivalent in his commentary on the bureaucracy and the machinations of its 'professors', who seemed often to be away 'writing a book'. As the plague and the economy collapsed in 1891, Bath questioned if anything had been learned; 'even the exact distinctions of its varying species have not yet been accurately determined, and the

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[126] Boot, 1998, p. 77, public sector employment in Australia reached 270,000 in 1890, rising from 5% in 1860 to 12%.

[127] Public choice theory holds that government decisions may be influenced by individual self-interest rather than the interests of the general public; Boot, 1998, pp. 90–91, railways were the main item of public capital spending in the 1880s. By 1891 rail expenditure was equivalent to 77% of colonial public debt; James Belich, *Replenishing the Earth. The Settler Revolution and the Rise of the Anglo World, 1783–1939*. (Oxford UK: Oxford University Press, 2009), p.359, describes government overfunding of railways during booster development in Canada and Victoria as an example of bureaucratic 'public choice' theory.

[128] *The Age*, 23 October 1890, p. 4, Editorial, after a £4 million loan to the colony had been spent, there was a no-confidence motion in the new Premier James Munro; *The Age*, 21 October 1890, pp. 5–6; 23 October, pp. 4–5, 'boom budget a thing of the past; October 24, Editorial, p. 4.

[129] *The Age*, 12 November 1890, p. 5, the newspaper criticised the department being 'too dilatory in appointing a day'.

[130] *Department of Agriculture Victoria Bulletin No. 14*, (December 1891), pp. 63, 70, French also claimed by 'actual experience' that it took over three months from hatching to the winged stage. He later corrected this mistaken calculation to two months.

causes of its sudden invasion of distant localities and its disappearance from them are not fully understood'.[131]

The ecological natural history observations of amateur naturalists contributed more to the accumulated knowledge on the distribution, parasites, behaviours and migration patterns of the locusts than those of the experts. However, the only information that endured was that which made it into the official 'blue books'. The distinction between the main swarming pests, *C. terminifera* and *A. cruciata*, remained elusive, as did the identity of 'ichneumon' and fly parasites, despite the attentions of a government entomologist.

The taxonomic confusion was not restricted to Victoria. It also perplexed Otto Tepper at the South Australian Museum. In 1890 he complained of an apparent synonym for the locust (*Cortolaga australis*), given by Saussure in Vienna from samples taken from Quorn in 1888. Tepper had been using the name *Epacromia terminalis* [sic. *terminifera*] given by Francis Walker in London.[132] Saussure's specimen, collected by visiting American entomologist, Albert Koebele, was *Austroicetes*, while Walker had named *C. terminifera*. Tepper opined that there should be a system of returning specimens to the colonies after names had been given by authorities in the museums of Europe. His 1891 description of the 'wandering locust' of South Australia identified the black wing spot of *C. terminifera*, but described a life history more consistent with *A. cruciata*.[133]

The increase in the frequency of locust plagues was clear to settlers who had been on the land before the 1870s, and there was real apprehension about further increases. Ideas that locusts were becoming worse than the rabbits seem mistaken in the hindsight of the twentieth century, but both problems were still relatively new and their outcomes unknown. There was also an optimistic view that, as the inland plains came under cultivation, plagues would decrease and the means of dealing them would increase.

The divide between pastoralist and farmer willingness to act on locusts became apparent in 1890. One north-western grazier commented that, since those with experience knew the locusts would move away as soon as they developed, he objected to the idea of graziers 'having to burn all their grass to

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[131] *Bairnsdale Advertiser and Tambo and Omeo Chronicle,* 4 December 1890, p. 3.

[132] J. C. O. Tepper, 'Notes on synonyms of Australian insects', *The Garden and the Field* 16 (185), (October 1890), p. 51.

[133] J. C. O. Tepper, 'The wandering locust of S. Australia: Its breeding places and checks', *The Garden and the Field*, 16 (189), (February 1891, p. 121; 'Insects of South Australia: An attempt at a census', *Proceedings Philosophical Society of Adelaide*, 1879, p. 21.

prevent them injuring other people'.[134] While grass was the squatters' most valuable and closely guarded agricultural resource and locusts often took its new growth, the threat was buffered by the capital accumulated in livestock, which could be moved or sold. In contrast, most farmers depended on this year's crop for their livelihood and joined the collective actions. By 1890 the locust had revealed its few vulnerable life stages, migratory behaviours and potential distribution, its interactions with predators and parasites and, by sheer force of numbers, its resilience to human efforts to control it.[135]

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[134] *The Argus*, 3 October 1890, p. 7.

[135] *The Kerang Times*, 30 December 1890, p. 3, suggests that the egg or young insect stages are the 'only practical part of the life history over which we have any control'.

Chapter 6. The rise of the economic entomologists, 1896–1925

1 — Charles French | 2 — Walter Froggatt | 3 — Henry Tryon | 4 — Otto Tepper

5 — Charles Hamilton French | 6 — William Gurney | 7 — Robert Veitch | 8 — Arthur Lea

Figure 6.1. The first economic entomologists of Victoria (1, 5), New South Wales (2, 6), Queensland (3, 7), and South Australia (4, 8).[1]

AN AWFUL INSECT

The entomologist, then, is no mere "harmless maniac who goes about with a green net sticking big pins into little beetles". He has, on the contrary, a noble prospect, if he devote himself to his science in the spirit of Bacon, endeavoring to hold Nature fast, as Ulysses held Proteus, until she has answered his minutest question. He can benefit and earn the gratitude of the human race not less than if he made two blades of grass grow where but one grew before.

The South Australian Advertiser, 5 September 1872, p. 3.[2]

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[1] Sources: 1, 5, Victorian Department of Agriculture file photos (courtesy Gordon Berg); 2, 6, Australian National Herbarium, Biography, https://www.anbg.gov.au/biography/froggatt-walter-wilson.html, viewed 24 August 1016, *NSW Department of Agriculture, Annual Report 1901*; 3, 7, John Oxley Library, State Library of Queensland, picqld-citrix03--2007-01-22-11-32, Australian Dictionary of Biography; 4, 8, State Library of South Australia, B14104-10a and SLSA B6184.

Economic entomology

During the late nineteenth century the 'Cinderella science' of entomology metamorphosed from collecting and cataloguing curiosities into an instrument for agricultural improvement and the consolidation of empire.[3] Its practitioners were now patriotically devoting themselves to solving problems caused by a host of new plant pests and of insect-borne human and livestock diseases. Colonial and 'newland' governments now included entomologists in their suite of scientific sponsorships.[4]

> **Progressive agriculture**
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> Preface to Vol 1, 1890, *Agricultural Gazette of NSW*, by Minister for Mines and Agriculture, H. C. L. Anderson, outlining the principles of Progressive Agriculture: '… to lay the best procurable advice before the farming community — advice dictated by scientific investigation combined with practical experiments as to causes of crop failure, working soil, manuring, combating pests, drainage and irrigation, transport, implements …'
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> R. D. Watt — opening lecture as first Chair of Agriculture, Sydney University, 1911.
> 'Agriculture … the most ancient of the arts and the most recent of the sciences … progress made during the last century was greater than that made during the previous eighteen. This was due almost entirely to the advance of science and the application of science to agricultural problems.
>
> *Examiner*, 25 April 1911, p. 2.

By the late 1890s each Australian colony had appointed a government entomologist, whose activities would centre on the new applied science of Economic Entomology. That role was as much educational and political as scientific in providing practical advice, demonstrations and recommendations to agriculturalists about insect pests. South Australia remained the exception, relying on the collective expertise of its Central Bureau of Agriculture and calling on its museum entomologist, J. G. O. (Otto) Tepper, to resolve taxonomic issues.[5] At the start of the twentieth

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[2] The article, reprinted from the *London Telegraph*, was a call for entomologists to contribute to British Imperial expansion and to focus on the Tsetse fly and other African pests.

[3] Isaac Harpaz, 'Frederick Simon Bodenheimer (1897–1959): Idealist, scholar, scientist', *Annual Review of Entomology*, 29 (1984), 1–23, p. 3, entomology was the 'Cinderella' of the sciences; the 'neglected sister', referring to Frederick Bodenheimer in 1920, who met with the view that applied entomology was not a self-reliant academic discipline, but merely an accessory to phytopathology or plant protection.

[4] The terms 'newland' and 'new west' are used by James Belich to characterise settlement booms in the inland of both colonial and ex-colonial countries, see James Belich, *Replenishing the Earth. The Settler Revolution and the Rise of the Anglo World, 1783–1939*, (Oxford UK, Oxford University Press, 2009), p. 85.

[5] *The Register*, 21 May 1907, p. 4. Otto Tepper, the insect curator at the South Australian Museum for 28 years, advocated the appointment of a state government economic entomologist and a field officer in 1907, but this was not acted upon.

century the roll-call was Charles French in Victoria, Walter W. Froggatt in New South Wales (NSW), Henry Tryon in Queensland, George Compere in Western Australia (WA) and Arthur Lea in Tasmania.[6] Lea had been a collector in NSW, then government entomologist in WA from 1895 to 1899. In 1911 he moved again, from Tasmania to the South Australian Museum after Otto Tepper's retirement. Following this initial cohort, their assistants Charles Hamilton French, William Butler Gurney, Robert Veitch and Leslie J. W. Newman, in turn became the entomologists of Victoria, NSW, Queensland and WA.

Most of these men came into the field by circumstance and opportunity without formal qualifications, but, finding they were able to indulge a passion for insect science and natural history, took on the role assiduously. French and Froggatt had distinguished themselves in other areas of natural history and collections, while Lea left an accountancy job in Sydney to follow an interest in entomology.[7] They were native-born, self-taught naturalists, with interests wider than the insect world. Most were active in Australian scientific societies, as well as lecturing to local agricultural and naturalist groups.[8] English-born Tryon and Arthur Sidney Olliff, the first NSW appointment who died aged 31 in Sydney in 1895, were co-opted from curatorial positions at colonial museums.[9]

The historiography of the entomologists from this period derives from their books and collections: French and Froggatt being known for their lavish publications on insects and birds. As officials of the state, they became the experts who provided authoritative answers and demonstrated the use of equipment and insecticides. Their prolonged engagement with the 'locust problem', however, is largely unknown, but explored here through their writings for government publications and newspaper comments. They are shown to be more complex and conflicted characters through their scientific attempts in this practical sphere. This chapter and Chapter 7 follow the outbreaks of different species in different locations and expand the history of the economic entomologists' activities in their attempts to deal with the pests, particularly in the landscapes where they swarmed.

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[6] Lea was appointed in 1899 after Tasmania's Agricultural Council dismissed its first Government Entomologist, apparently for knowing less than the farmers; *Launceston Examiner*, 2 March 1896, p. 3, Tasmania reportedly dispensed with the Rev. Edward H. Thompson after numerous disparaging comments by farmers' groups. Thomson, however, was credited with restoring the orchard industry by scientific spraying and control methods and also authored two books on insect pests.

[7] C. F. H. Jenkins, 'Newman, Leslie John William (1878–1938)', Australian Dictionary of Biography, National Centre of Biography, Australian National University, http://adb.anu.edu.au/biography/newman-leslie-john-william-7831/text13597, published first in hardcopy 1988, accessed online 21 June 2016.

[8] French, Froggatt, Tryon, Gurney, Tepper and Newman were all active members of state naturalist and scientific societies.

[9] *Australian Town and Country Journal*, 4 January 1896, p. 18, Olliff died on 29 December 1895.

The state entomologists now gained the confidence to assert taxonomic authority over the naming of new Australian species.[10] They exchanged correspondence, specimens and knowledge, drawing on worldwide scientific expertise. The exception was George Compere, an entrepreneurial world traveller in search of parasites of pest insects, hired in 1901 by the WA Government from the Horticultural Board of California. His premature claims of successes and 'unscientific' methods led to conflicts with entomologists in the eastern states.[11]

Economic entomology emerged in parallel with the professionalisation of science as an important component discipline of 'Progressive Agriculture' and it was formalised through instruction in agricultural colleges and agricultural science curricula in universities.[12] Of primary interest were the interactions of pest insects with their natural enemies; parasites, diseases and predators, particularly birds. In several affected countries, including the USA and Argentina, the decline of birds symbolised the human causes of locust plagues.[13] In Australia, the role of insectivorous birds was a central part of the entomologists' educational message and later of a challenge to their methods.

The entomologists also conducted trials of the latest control technologies, particularly chemical sprays, following overseas and local experience. The basic tenet of their strategy for management of pests was the necessity for coordinated collective action as a public good, and they communicated and organised control activities. They also investigated the potential for biological control agents, both native and introduced, to rectify ecosystems disturbed by human actions.

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[10] Froggatt named the Queensland fruit fly, *Bactrocera tryonii* in 1897, along with several other synonyms for the same species. Tryon also produced two synonym descriptions.

[11] E. Deveson, 'Parasites, politics and public science: the promotion of biological control in Western Australia, 1900–1910', *British Journal for the History of Science*, 49 (2016), 231–258.

[12] The term 'economic entomology' had been in general use in Britain for more than a decade after publication of the book of the same name by Andrew Murray in 1877. In Adelaide, Frazer Crawford had recommended the creation of a Museum of Economic Entomology in 1881 and referred to students of 'economic entomology' in an address to the Royal Agricultural and Horticultural Society of South Australia; W. W. Froggatt, Presidential Address, *Proceedings of the Linnean Society of NSW*, 37 (1912), 1–43, p. 16, Economic Entomology was formalised in the United States in the 1880s, and the first annual meeting of the Association of Economic Entomologists took place in Washington on 12 November 1889.
Agricultural Gazette of NSW, 1 (1890), Preface by Minister for Mines and Agriculture, H. C. L. Anderson, outlining the principles of Progressive Agriculture; early treatises on Economic Entomology often listed the numbers of agricultural colleges and enrolments in other countries.

[13] E. Deveson and A. Martinez, 'Locusts in Southern Settler Societies: Argentine and Australian Experience and Responses, 1880–1940', in eds. E. Vaz, C. Joanaz de Melo and L. M. Costa Pinto, *Environmental History in the Making: Volume 1 Explaining,* (Switzerland, Springer, 2017), pp. 259–286, p. 274, working in Argentina, US locust expert Lawrence Bruner supported the legal protection of native birds and even suggested that the destruction of rheas and other species had produced the increase of locusts in the previous decade; In the USA, the Entomological Commission reporting on the 1870s locust plagues included an ornithologist.

The period from 1890 to 1925 saw an intense interest in utilising natural enemies of insect pests from their original range, particularly parasites and predators, and their deliberate introduction as a means of biological control. Farmers, naturalists and state institutions joined forces in the transnational exchange of many potentially beneficial organisms.[14] Australia was integral to this circulation of ideas, organisms and people, although the term 'biological control' did not gain currency until 1920.[15] Local interest followed the discovery in South Australia and successful introduction to California of the vedalia beetle (*Rodolia cardinalis*) and a parasitic fly (*Cryptochaetum iceryae*), that together saved its citrus industry from the cottony cushion-scale in 1889.[16] The scale had been accidentally introduced from Australia in imported citrus scions.

Many of these exchanges were between settler societies of the 'neo-Europes', which had accidentally introduced insects from their new environments, as well as many from Europe, through imports of plant and animal materials.[17] The WA department's hiring and decade-long support of their 'travelling entomologist', George Compere, owed much to a faith in the 'parasite theory' as a scientific and natural solution to insect pests. Australian farmers were also on the lookout for potential parasites of pest insects. The entomologists' and plant pathologists' rooms were at times crowded with a backlog of candidate organisms that farmers sent in for evaluation.[18]

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[14] James E. McWilliams, 'Biological control, transnational exchange and the construction of environmental thought in the United States, 1840–1920', in eds. E. M. Bsumek, A. Kinkela and M. A. Lawrence, *Nation-states and the Global Environment: New Approaches to International Environmental History*, (Oxford, Oxford University Press, 2013), pp. 163–180; *Rockhampton Morning Bulletin*, 14 April 1903, p. 6, quoting from the *American Agriculturalist*, 'the knell of the grasshopper is once more sounded', on investigations of a minute insect parasite 'seriously, while attempts of this character have been futile in the past, the possibilities in the application of science to agriculture are illimitable...and the dream of yesterday or to-day may be the reality of tomorrow'.

[15] The term biological control was coined by US entomologist H.S. Smith in 1919. 'On some phases of insect control by biological method', *Economic Entomology*, 12 (1919), 288–292.

[16] *Australian Town and Country Journal*, 13 July 1889, p. 23, the discovery of *Vedalia cardinalis* was locally attributed to Frazer S. Crawford in South Australia, a lithographer, member of the Central Bureau of Agriculture and an observant naturalist. For a discussion of Crawford's role in the 'happy accident' of the rapid control of *Icerya purchasi*, see Deveson 2016, p. 249.

[17] The term 'Neo-Europes' is taken from Alfred Crosby's *Ecological Imperialism: The Biological Expansion of Europe 900–1900*, (Cambridge, Cambridge University Press, 1986), they were the settler societies in grassland biomes occupying temperate latitudes; Donald Meinig used the term thirty years earlier as one of the dominant 'culture worlds', cited in *On the Margins of the Good Earth: The South Australian Wheat Frontier*, 1869–1884, (Adelaide, Seal Books, Rigby Limited, 1970), p. 4; Settler societies are differentiated from colonial societies, by their commitment to permanent residence in the adopted new lands.

[18] D. Mc Alpine, *Agricultural Journal of Victoria*, 3 (1904), p. 469; *The Sydney Morning Herald*, 25 September 1899, p. 3, Froggatt produced a report for the NSW Minister on a fungoid disease of caterpillars, specimens of which had been received from all parts of NSW.

The instruments of economic entomology against locusts

The government entomologists operated through a common set of instruments in applying science to the identification of pest species, elucidating their life histories and prescribing methods for dealing with them. These included collections, artists, libraries, correspondence, demonstrations, publications, insectaries and laboratories. The entomologists also used the media to push the message, particularly for locusts, that collective action was essential to successful control. The phrases that came to characterise every official statement on locust control were 'united action at an early stage' and 'it is a community problem'.

Compared to previous decades, fewer closely-observed ecological natural history findings about locusts reached the press and there was little in the way of physiological or ecological science in the laboratory or the field. The economic entomologists concentrated on control technologies. These were primarily based on the pressure spray pump, kerosene emulsions and the sure kill of arsenic compounds.

But it was also a time of great expectation for finding, culturing and introducing parasites and diseases to control insect pests. There could be no clearer demonstration of the value of scientific developments than the germ theory of epidemiology and of using a 'plague to fight a plague'.[19] Agriculture departments encouraged introductions and experimentation in biological control using microbes as well as arthropods. From 1899 to 1910, Charles French in Victoria conducted an ambitious biological control program against locusts using the South African 'locust fungus'. The Queensland department also obtained and trialled the locust bacterium 'Coccobacillus acridium' from Argentina in 1912, and samples of a 'virus' from the Pasteur Institute in France in 1915.[20]

The ecological premise for the apparent increase in frequency of locust infestations remained that of a disruption to the 'balance of nature'. But this was not simplistic faith or shallow understanding. In a rapidly changing environment, with many species introductions and unpredictable events, it was shorthand for serious attempts to understand the complexity of ecological interactions, without the disciplinary terminology and methods that emerged later.[21] Possible environmental causes of the

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[19] *Border Watch*, 2 March 1904, p. 4. The phrase was used in describing US tests on fungus diseases.

[20] *Cairns Post*, 9 November 1912, p. 7, Tryon cabled the Argentine Bacteriological Institute for samples of D'Hurelle's bacterium and instructions for its culture and use; *Cairns Post*, 13 May 1915, p. 2, the Australian Sugar Producers' Association obtained tubes of a virus shown to kill locusts from the Pasteur Institute in Paris and passed them on to the government bacteriologist for testing.

[21] The term 'interdependence of all life', *Weekly Times*, 20 March 1886, p. 7, Huxley's 'interdependence of all forms of nature', 'seemingly unimportant … even to understand the tendencies of modern thought'; *Hay Standard*, 7 June 1899, p. 1; *Illustrated Sydney News*, 5 August 1880, p. 15, interdependence of all forms of creation'; *Empire*, 3 Dec. 1870, p. 4, 'Hypothesis of Evolution', interdependence was transposed to economics.

'grasshopper' problem were discussed, including the decline of insectivorous birds and the clearing of forests, which brought swarms into new areas. The role of overgrazing and erosion in increasing the frequency of outbreaks, however, was not recognised until the 1930s.

State entomologists were also keen ornithologists and this complemented a duality in their roles, given the importance ascribed to insect-eating birds in controlling insect populations.[22] They became embroiled in the polarised debates that developed among farmers, bird preservation groups and newspaper columnists about the poison cart used to lay bait for rabbits. The entomologists were outspoken advocates of legislation and education to protect birds, but their adoption of chemical pesticides for locusts put them in a paradoxical situation. They maintained professional allegiance to state-sponsored arsenic control programs in the face of public outcry and grassroots agroecological resistance because of bird poisonings. For Froggatt and Gurney in NSW this became a constant and conflicting problem.

The 'locust' events

Newspapers are the primary historical source for reconstructing the timing, extent and identity of grasshopper and locust events during this period. They also reveal landholder and official experience of them and the threat they posed to agricultural production. Western Queensland, however, remained poorly represented in the newspaper coverage. The incidence and effects of locust pests, both in Australia and overseas, remained a matter of serious concern and they were regularly reported as a matter of 'national interest'. Official reports tended to repeat the conventional knowledge of authorities and concentrated on control technologies.

The first historians of the geographical incidence of the plagues, Ken Key for NSW and Clee Jenkins for WA, attempted to understand their spatial and temporal distribution through map reconstructions of the 1920s and 1930s events.[23] Key's 1938 measured maps of those infestations in NSW were drawn from interviews and Pasture Protection Board records and are a close match with the extents derived from newspapers for 1924–25 and 1926–27.

From 1896 to 1903 there were annual grasshopper plagues across the south-eastern states, increasing in geographic extent and intensity. These were drought years and they were accompanied in November and December by swarms of *Austroicetes cruciata*, described by Ken Key in 1938 as being

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[22] Several were members of the Royal Australian Ornithologists' Union and contributed to its journal, *Emu*.

[23] K. H. L. Key, *'The Regional and Seasonal Incidence of Grasshopper Plagues in Australia', C.S.I.R. Bulletin No. 117,* (Melbourne, 1938); C. F. H. Jenkins, 'The plague grasshopper', *Journal of Department of Agriculture Western Australia*, 14 (4), (1937), 367–380.

'more severe and more extensive in a northerly and easterly direction than ever before or since'.[24] This statement held true for the rest of the twentieth century and supports the hypothesis of the grasshopper being the pest of dry years and of responding rapidly to environmental change.

The relief felt by farmers at the return of good seasons in 1904 was tempered by the sudden reappearance of the locust, *Chortoicetes terminifera*. For the first time in many years widespread heavy summer rains fell in inland areas during 1903–04.[25] The first newspaper reports indicating the presence of locusts came in February 1904, when hopper bands developed near Broken Hill and in South Australia, and there were also swarms in western Queensland.[26] By March, swarms spread across southern NSW from Wentworth to Wagga. In South Australia they were reported along the Murray River and in the southern Flinders Ranges, and swarms flew into northern Victoria in April. This was a short-lived plague and locusts had largely disappeared by autumn 1905.

After 1904, the period was punctuated by repeated locust infestations that tended to mask the ongoing and more local swarming of the grasshoppers. Locust plagues affecting several states can be identified during 1906–08, 1910–12, 1917–18 and 1921–22, each linked to a La Niña climatic phase. Persistent infestations remained in NSW during 1912–13 and 1924–26, and the focus of concern for landholders and government officials moved eastwards to its farming districts. Meanwhile, WA and Queensland struggled with the emergence of their own particular locust problems.

Walter Froggatt, New South Wales economic entomologist

Walter Wilson Froggatt (1858–1937) gained entomological recognition as a collector of 'natural history' specimens on expeditions in New Guinea and northern Australia, before his appointment as entomologist to the NSW Department of Agriculture and Mines in 1896.[27] He well remembered the

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[24] Key 1938, p. 73.

[25] Reports in January from Longreach and the Queensland Gulf Country, but the large size of the locusts and descriptions of them stripping trees suggests spur-throated locusts. It is difficult to distinguish possible locust activity from that of grasshoppers in late 1903 because they swarmed on the same country; *Camperdown Chronicle*, 19 December 1903, p. 2, Mr. J. Wiggins 'found several true locusts in his buggy – the ones which caused depredations in past years'.

[26] Reports of locusts came from Winton, Betoota, and along the Warrego, Diamantina and Thomson Rivers.

[27] John Macleay employed Froggatt to collect animals, birds and insects in the Kimberley region of Western Australia in 1887. He also collected Aboriginal artefacts, which he saw as specimens of 'natural history', when he accompanied police on a punitive raid near Devils Pass, http://sydney.edu.au/museums/exhibitions-events/wilson-froggatt.shtml, accessed online 26 August 2016; see also D. I. McDonald, 'Froggatt, Walter Wilson (1858–1937)', Australian Dictionary of Biography, National Centre of Biography, Australian National University, http://adb.anu.edu.au/biography/froggatt-walter-wilson-6251/text10765, published in hardcopy 1981, accessed online 1 May 2014.

locusts that had attacked his family's garden near Bendigo in 1873, where as a youth he was inspired by his mentor in natural history, Richard Nancarrow.[28]

Froggatt quickly adapted to the norms of the profession to become the model economic entomologist. In an 1898 article he set out the boundaries and practices of the emerging discipline, and listed its necessary material instruments; a collection of 'both beneficial or destructive' insects, an insectary, equipment to study life histories, access to a library and an artist, of which his department employed two in 1900.[29] He stressed the importance of promptly dealing with all correspondence and of the professional skills needed to assure farmers of an 'honesty of purpose'. Convincing farmers of the benefits of individual action, in spite of neighbours' inaction, was seen as fundamental to success in controlling insect pests because of their dispersal and reproductive capacity.

Western Australia's program to introduce insects from overseas for biological control in 1901 drew Froggatt into an interstate controversy. He had written in 1902 about the east–west divide among US entomologists over the practical utility of parasites; the Californian school was confident that parasites would solve orchard pest problems, the more reticent eastern school emphasising that successes would be rare. A parallel east–west divide developed in Australia the following year. Froggatt became the target of trenchant attacks on the 'spray-pot' methods of eastern state 'kerosene entomologists', as George Compere and the WA department moved to defend their 'visionary' program of collecting and releasing potential parasites of pest insects from all over the world.[30] For Froggatt, their *laissez faire*, 'let it slide' approach threatened the unified action tenet of economic entomology.[31]

Compere's antagonistic public rhetoric was new to science communication in Australia and made parasites 'popular science', as newspapers covered every detail of the disagreements between the experts (Figure 6.2).

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[28] W. W. Froggatt, 'Locusts and Grasshoppers', *Agricultural Gazette of New South Wales*, 13 (1903), 1102–1110, p. 1108. Froggatt recalled locusts eating a field of beetroot and mangel-wurzels 'right out underground' in his father's garden.

[29] W. W. Froggatt, 'Economic Entomology in Australia', *Agricultural Gazette of New South Wales*, 9 (1898), 131–138. Froggatt was paraphrasing US economic entomologist, H. L. Smith, who had written somewhat patronisingly about farmers' suspicions of scientists; *Agricultural Gazette of New South Wales*, 12 (1901), *Annual Report* 1901, p. 222.

[30] Deveson 2016, p. 240.

[31] W. W. Froggatt, 'Limitations of parasites in the destruction of scale insects', *Agricultural Gazette of New South Wales*, 13 (1902), 1087–1093; *The West Australian*, 27 September 1902, p. 10; *The Advertiser*, 20 June 1901, p. 4, Although Compere sent some grasshoppers to California in 1900 that yielded the tachinid parasite, his poorly-timed expedition through the eastern states in autumn 1902 to search for parasites of the locust was fruitless. It was the grasshopper that swarmed in 1902, so autumn was the wrong time of year for Compere to go looking.

The WA department tried several times to get the eastern states to share in the costs of Compere's world travels. They instead sent Froggatt overseas in 1907 to investigate first-hand the status of parasite programs. The east–west division boiled over in 1909 when Froggatt's final report was released.[32] The report further fuelled WA's claim of scientific authority over biological control methods as a symbol of institutional and even state identity. The WA agricultural bureaucracy established a scientific 'disciplinary space' for its program in opposition to the 'old-fashioned' entomological practices in the east, despite the fact the eastern entomologists, including Froggatt, conducted research into potential biological control organisms for numerous pest insects.

Amid the distractions of the 'parasite war', Froggatt dealt with both grasshoppers and locusts that were becoming a serious problem in various parts of NSW. When locusts entered the Hunter Valley in 1904, he tested the Canadian grasshopper bait mixture of arsenic and horse manure. At Singleton, where woodswallows, or 'blue-martens', were a welcome associate of the locusts, he gave a lecture on the value of insect-eating birds.[33] Before the locust invasions of the Hunter Valley in 1904 and 1907 the region had not featured in reports, but during the following twenty years it was repeatedly infested and became a focus for tests of collective landholder controls.

Problems emerge in other states

Locusts became more prominent in Queensland and WA during the 1890s and so did the involvement of their entomologists. Henry Tryon (1856–1943) became Queensland government entomologist in 1894, after several projects he had undertaken for the Department of Lands and Stock caused frictions at the Queensland Museum, where he was employed. In 1886, while investigating fruit fly on the Darling Downs, he reported on the 'grasshopper' pest infesting the area and gave the first clear description of *C. terminifera* in the colony.[34] Tryon was a committed naturalist, an advocate for bird preservation and a founding member of the Royal Society of Queensland.

Queensland was an exception to the absence of locusts in the southern colonies during 1896–1902. A persistent locust infestation developed in the Clermont-Capella area of the Central Highlands, although several species appear to have been involved.[35] There were also swarms of *C. terminifera* on

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[32] Deveson 2016, pp. 244–245.

[33] *The Sydney Morning Herald*, 17 November 1904, p. 5, tested at Merriwa in the Hunter Valley, the mixture was named after its Canadian inventor, Norman Criddle. He found it to be more effective than the 'locust fungus' and also recommended kerosene spray for the hoppers; *Singleton Argus*, 29 November 1904, p. 4, lecture at Singleton; *Maitland Mercury*, 9 December 1907, p. 4, 'blue-martens'.

[34] Henry Tryon, *Annual Report of the Queensland Department of Agriculture*, 1889–1890, p. 217.

[35] Newspaper descriptions indicate both *Chortoicet*es, 'small brown fellers', and *Gastrimargus*, 'the black and yellow friends', with both achieving multiple generations each year. Although samples were sent to the Undersecretary for Agriculture in 1896, no collection specimens exist.

the Darling Downs and the Diamantina country of the Southwest during 1902 and 1904–06.[36] Tryon, however, was occupied by damage to the fledgling sugar industry being caused by different locusts.[37]

Tryon toured the Bundaberg area in 1904, conducting experiments, making natural history observations and giving public lectures. Cane farmers had a lot to protect considering the efforts they had expended in clearing forest and planting cane, which was particularly vulnerable at the ratoon stage. Whole families joined in the effort for weeks on end and at Gin Gin a hundred and twenty men were engaged in fighting the pest.[38] Ingenious methods were tried, including canvas traps and ‘herding’ the locusts on horseback with stockwhips.[39] Tryon later worked with the Commonwealth Prickly-Pear Travelling Commission — investigating insects for biological control of the rampant weed — and the Federal Cattle Tick Commission.

Swarms reappeared in the Springsure–Capella area in 1904, although once again several species were involved, including *Gastrimargus musicus*, *C. terminifera* and possibly *Locusta migratoria*. The region was dominated by large pastoral runs and Springsure boasted some of the best sheep country in the state. Tryon was called there in 1911, when *G. musicus* was blamed for pasture damage leading to cattle starvation. Landholders were having limited success with arsenic or ‘Sunlight soap and kerosene’ sprays. Tryon advocated unified action and the organisation of a board, similar to the ‘marsupial boards’, with a membership of stockholders. Funds would be expended as soon as the locusts appeared, ‘as much in the interest of adjoining graziers as those directly affected’.[40]

In WA, grasshopper swarms were first reported in the Vasse district in the 1850s, but there is no information on their identity (Appendix 5). Swarms were next reported in the sheep-grazing country north of Perth in 1871. In a parallel with South Australia in the 1840s, ‘immense swarms’ appeared at Irwin River, inland from Geraldton, in early November and astonished everyone, including the Aborigines, who did ‘not remember ever seeing anything like this plague before and have no name for

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[36] Laidley, Gatton, Warwick, Allora, St George and Lockyer all reported locusts.

[37] Doubt remains over whether the species infesting the Isis district in 1904 was the migratory locust (*Locusta migratoria*) or the same species that appeared in 1911, the yellow-winged locust (*Gastrimargus musicus*).Tryon identified the species in the Isis district in 1904 as the migratory locust (*Locusta danica* [sic. *migratoria*]). Later researchers attributed the 1904–1908 infestation of sugar growing districts along the Queensland coast to the yellow-winged locust, *Gastrimargus musicus*, see I. F. B. Common, ‘The Yellow-winged Locust, *Gastrimargus musicus* Fabr., in central Queensland’, *Queensland Journal of Agricultural Science*, 5, 153–219, p. 155; Roger Farrow included the 1904 swarms as *L. migratoria* in a 1990 review of infestations.

[38] *The Queenslander*, 30 January 1904, p. 17.

[39] *The Queenslander*, 20 February 1904, p. 28; *Clarence and Richmond Examiner*, 20 February 1904, p. 3.

[40] Frances C. Hrdina, ‘Marsupial Destruction in Queensland 1877–1930’, *Australian Zoologist*, 30 (3), 1997, 272–286; the following year, desperate stockholders called on government to again send an expert, saying the grasshoppers covered so much country … it would take ‘fifty men’ to spray a 15,000 acre property and some sheep runs were 100,000 acres.

the insect'.[41] By the 1880s the area was well known for grasshopper swarms 'sweeping everything green before them'.[42]

In 1895 the Beverley and Moora districts further south were invaded by grasshoppers, which government entomologist Arthur Lea knew, from his 1890 experience in NSW, were not the locust, but a species of *Austroicetes* he identified as *Aedipoda*. They 'seemed to take advantage of dry seasons to make their disastrous visitations'.[43] The species was *A. cruciata* and its swarms became more frequent on the northern sheep runs. They spread south-east into the newly ringbarked and cleared country around Merredin along with the expansion of wheat growing in the early twentieth century.

Figure 6.2. WA government entomologists, George Compere (left) c. 1906, and Leslie Newman c. 1930.[44]

Following Lea's and then Compere's resignations, the latter in 1910, Leslie J. W. Newman (1878–1938) became responsible for the 'locust' problem in WA. As a student in Victoria in the 1890s, he was inspired to follow a career in natural history and practical entomology by Charles French, who visited Burnley School of Horticulture.[45] After moving to WA, Newman worked as an orchard inspector for the department and became assistant entomologist under George Compere in 1906.[46] He

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[41] *The Inquirer and Commercial News*, 15 November 1871, p. 2.

[42] *The Advertiser*, 22 September 1873, p. 3; West Australian, 3 August 1883, p. 3; Geraldton Guardian, 1 November 1913, p. 1, Geraldton was already known for its grasshoppers in 1874. Swarms occurred in the areas north of Northam, then known as the Victoria Plains, in 1873.

[43] *West Australian*, 17 January 1895, p. 4; *Western Mail*, 31 May 1902, p. 8.

[44] Newman photo*, Western Mail*, 9 February 1939, p. 44; Compere photo, Ann Gaul, http://earlyaviators.com/ecomper2.htm

[45] Jenkins 1937.

[46] Deveson 2016, p. 244; *Western Mail*, 3 June 1907, p. 7, from the windowless brick insectorium 'erected in the interests of science', Newman managed the rearing and release of potential parasites of insect pests collected by Compere on his many overseas trips.

had seen his share of political conflict and influence in science by 1910, but was committed to research on biological and other novel methods of controlling insect pests.[47] Newman remained as 'acting' government entomologist until 1918, when he was finally promoted to the position.

Newman took on the tasks of economic entomology, providing identifications, advice and lectures to scientific and horticultural groups. He was the first to take the term 'outbreak' from its contexts of disease or revolution to 'locust' population growth and, in 1924, first to use radio broadcasts to warn farmers of 'The Locust Danger and its Remedy'.[48] Like his counterparts in the eastern states, he advocated the preservation of all insectivorous birds, including contentious cases like crows and silver-eyes, and he attributed many insect problems to human interference with the balance of nature.[49] Also like them, he called for 'determined cooperative effort' and prompt concerted action at the 'early outbreak' to deal with 'locusts'.[50]

The Federation drought grasshopper plague, 1896–1902

Squatting had expanded unabated until the 1890s when it ran out of new grasslands and exhausted those it had taken. Australian sheep numbers reached 106 million in 1891, with 62 million in NSW alone.[51] Queensland's flock rose from 8 million in 1870 to 22 million in 1891 as sheep were taken onto the vast Mitchell grass plains. Even after a halving of numbers during 1899–1900, there were still four million sheep in districts north of the Tropic of Capricorn.[52] Meanwhile, the rate of increase had levelled off in Victoria and South Australia after the carrying capacity of native grasslands was overreached.

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[47] *The West Australian*, 12 January 1921, p. 6; C. F. H. Jenkins. 'Biological Control in Western Australia', Presidential Address, 1946, *Journal of the Royal Society Western Australia,* 32 (1947), 1–17, p. 12, Newman obtained potential parasites of pest insects from various official sources: the blowfly chalcid from Froggatt in NSW, a hymenopteran parasite of the woolly aphis from Tasmania.

[48] *The Daily News*, 19 July 1924, p. 4.

[49] *Western Mail*, 7 April 1921, p. 15; *Sunday Times*, 6 June 1913, p. 9; *The West Australian*, 10 May 1933, p. 10.

[50] *Western Mail*, 30 May 1913, p. 7; *The West Australian*, 1 August 1923, p. 12.

[51] *Yearbook of Australia*, *1929*, Chapter 16, Pastoral Production, p. 649, reports Australian sheep numbers at 106,421,069 in 1891; *Yearbook of Australia*, *1909*, Section VII, Pastoral Production, (Melbourne, Commonwealth Bureau of Census and Statistics), p. 287, gives NSW sheep numbers in 1890 as 56,986,431; A. G. Shaw, 'History and Development of Agriculture in Australia', in ed. D. B. Williams, *Agriculture in the Australian Economy*, (Sydney: Sydney University Press, 1967), pp. 1–28, p, 13, Shaw cites an estimate of 62 million sheep in NSW in 1891; It is possible the number reached 70 million by 1894.

[52] *North Queensland Register*, 26 August 1901, p. 42, the highest number of sheep recorded in Queensland was in 1892, with 21,708,310. The number dropped rapidly in 1899 to 15 million and then 10 million in 1900. Total north of tropic were calculated from table by districts.

The Grasshoppers

At Coolamon, Grenfell, Gundagai, the grey cloud is driving like a snowstorm. Stores and hotels are closed, outdoor work, and even life is impossible, and all green growths are swept away as by a scythe … it is bad enough through all the good country west from Gundagai. It is curious to remember just how the country there has been very thoroughly ringbarked, consequently it is practically a birdless country. It would be interesting to hear what the State Entomologist has to say on that. There are also other peculiarities to be noticed — one field is taken, and another left. The great army of the grasshoppers is incomprehensibly discriminating, and it is about as well worthy of thorough scientific investigation as anything in the colony just now.

Chronicle, 9 December 1899, p. 11.

The period 1896–1903 spanned Australia's Federation drought, when environments in South Australia, NSW and northern Victoria finally yielded to the pressure of continual overgrazing by stock and rabbits. The soils literally blew away as the collapse of grassy ecosystems left bare, trampled earth exposed to the winds. The perennial saltbush shrublands sustained sixteen million sheep in the Western Division of NSW up until 1898, but they too were decimated in the extreme drought of 1899–1901.[53] The wool industry in western NSW collapsed, leading to a Royal Commission to address problems in the management of the Western Lands. Its submissions remain a stark reminder of the magnitude of environmental changes that resulted from just fifty years of uncontrolled European pastoral land use.[54] Dust storms and desolation spread over the south-eastern states, burying the remaining grass and fences in sand drifts, creating unrecognisable new erosional and depositional landscapes.[55]

Swarms appeared also in the Far Southwest, Riverina and more eastern parts of NSW in 1895 and 1896.[56] Over the next two years they extended north to Condobolin and Narrabri, throughout the Central West and eastwards to Mudgee, Molong, Gundagai, Harden and Yass. Uniquely during this period, large swarms also developed in the Goulburn–Queanbeyan area. In early November 1897 dead

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[53] *Australian Town and Country Journal*, 19 October 1901, p. 14, quotes Crick of the Royal Commission into western Lands, giving 1891 returns of stock in Western Division of 15.4 million, falling to 5.7 million in 1900; Emily O'Gorman, *Flood Country,* (CSIRO Publishing, 2012), p. 84, gives Western Division sheep population 15.5 million in 1890.
M. Barnes and G. Wise, *Celebrating 100 years of NRM Progress in the Western Division of NSW*, (NSW Department of Sustainable NRM, 2000), cites 15.2 million sheep in 1887 and, at its peak in 1891, would have been considerably higher; A. Cannon, 'Woolsheds and catastrophe theory: the lower Lachlan experiment', *Australasian Historical Archaeology*, 10, (1992), 65–74; Geoffrey Bolton, *Spoils and Spoilers*, (Melbourne, Allen & Unwin, 1992), p. 32, cites an 8 year slump in wool prices in the 1890s as contributing to overstocking.

[54] *Royal Commission appointed to enquire into the conditions of Crown Tenants in the Western Division of New South Wales.* 4 Vols.

[55] P. C. Fanning, 'Recent landscape history in arid western New South Wales, Australia. A model for regional change', *Geomorphology*, 29 (1999), 191–210.

[56] Reports at Hay in November 1895, and at Hay, Ivanhoe, Balranald, Deniliquin, Mossgiel, Hillston, Silverton in 1896.

grasshoppers banked up in reeking masses on the western shoreline of Lake George and contaminated wells at Bungendore.[57] Froggatt was aware of this 'locust pestilence in a minor degree', but the only surviving specimens of *A. cruciata* from the time are from Condobolin and Mudgee.[58] The timing of the flying swarms and their contiguity with those further west implicates *Austroicetes* species as contributing to the Lake George event, but their identity remains uncertain.[59]

1899 saw a further expansion of the areas infested and the drought seemed to favour grasshoppers even in near-coastal areas. In NSW swarms were 'continuous from Junee to Hillston' and at Molong the air was 'darkened with clouds of grasshoppers' that rattled on the roofs like a hailstorm.[60] Their geographic extent rivalled the big locust plagues, with swarms reported across NSW from Albury in the east to Wentworth in the west, prompting some to suggest environmental reasons for the increase. In South Australia there were swarms from Blinman in the north, south to Burra and Eudunda, and extending as far west as Bookabie on the Great Australian Bight. Typical of *A. cruciata*, egg laying occurred during November and adult numbers quickly dropped off by late December.[61] The agricultural impacts of the grasshoppers were just as severe as those of locusts because they developed much earlier, attacking both the grass and still-growing crops. The dry summer years left little grass and failing crops, exposing the already struggling farmers to critical losses.

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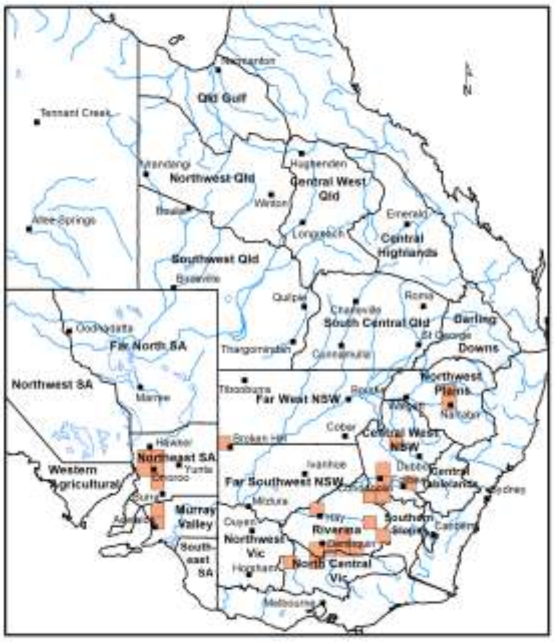
[57] *Barrier Miner*, 1 January 1898, p. 5; swarms were reported from Goulburn, Gundaroo, Sutton, Bywong, Braidwood, Marulan, Queanbeyan, Young and Captains Flat during 1897–99.

[58] W. W. Froggatt, *Agricultural Gazette of New South Wales*, 9, (1898) p. 263. Few nineteenth century Orthoptera specimens survive in any collections. Australian Plant Pest Database lists *A. cruciata* from Mudgee (1899) and Condobolin (1900).

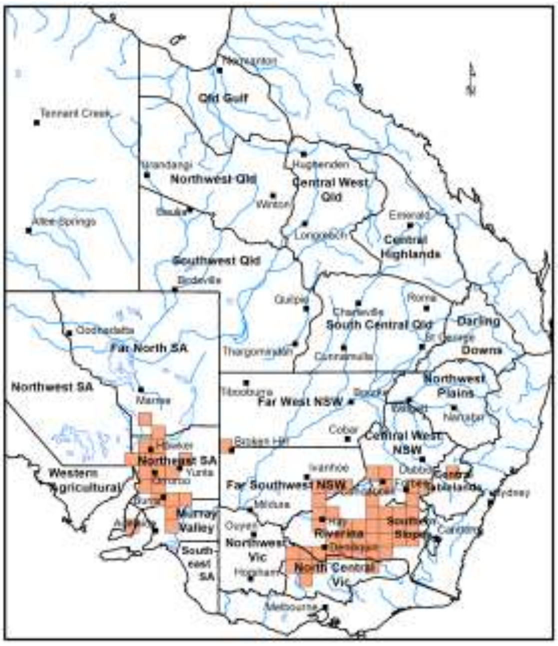
[59] One specimen of *A. pusilla* in surviving collections from the period is from Moruya in November 1903, suggesting that swarms of that species may have extended eastwards. Other likely species were *A. frater* and *A. vulgaris* (Australian Plant Pest Database).

[60] *Australian Town and Country Journal*, 25 November 1899, p. 16; 9 December 1899, p. 20.

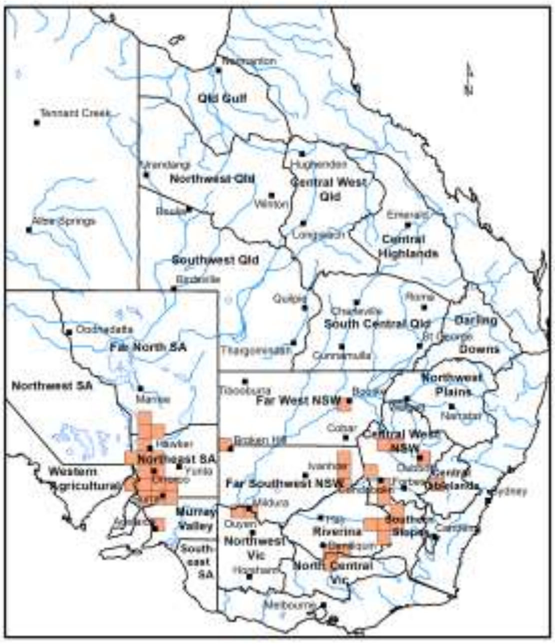
[61] *South Australian Register*, 7 November 1899, p. 3; *Australian Town and Country Journal*, 25 November 1899, p. 16, eggs were laid at Junee on 16 November.



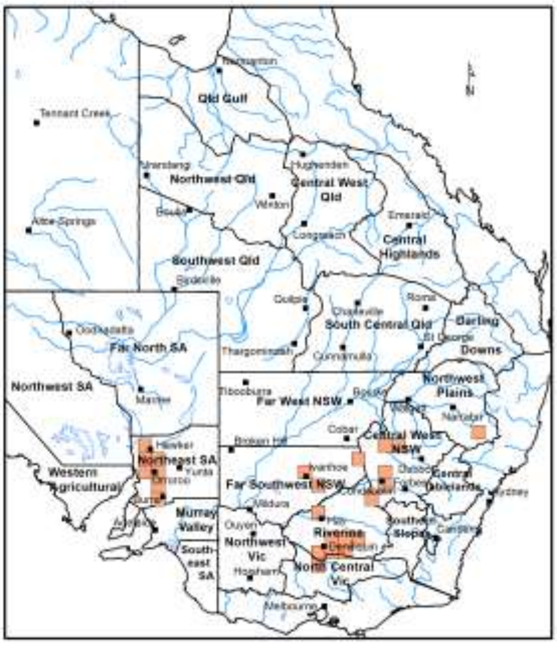
1898–99



1899–00



1900–01



1901–02

Figure 6.3. The progress of the Federation Drought grasshopper plague.
Districts reporting swarms 1898–1902.

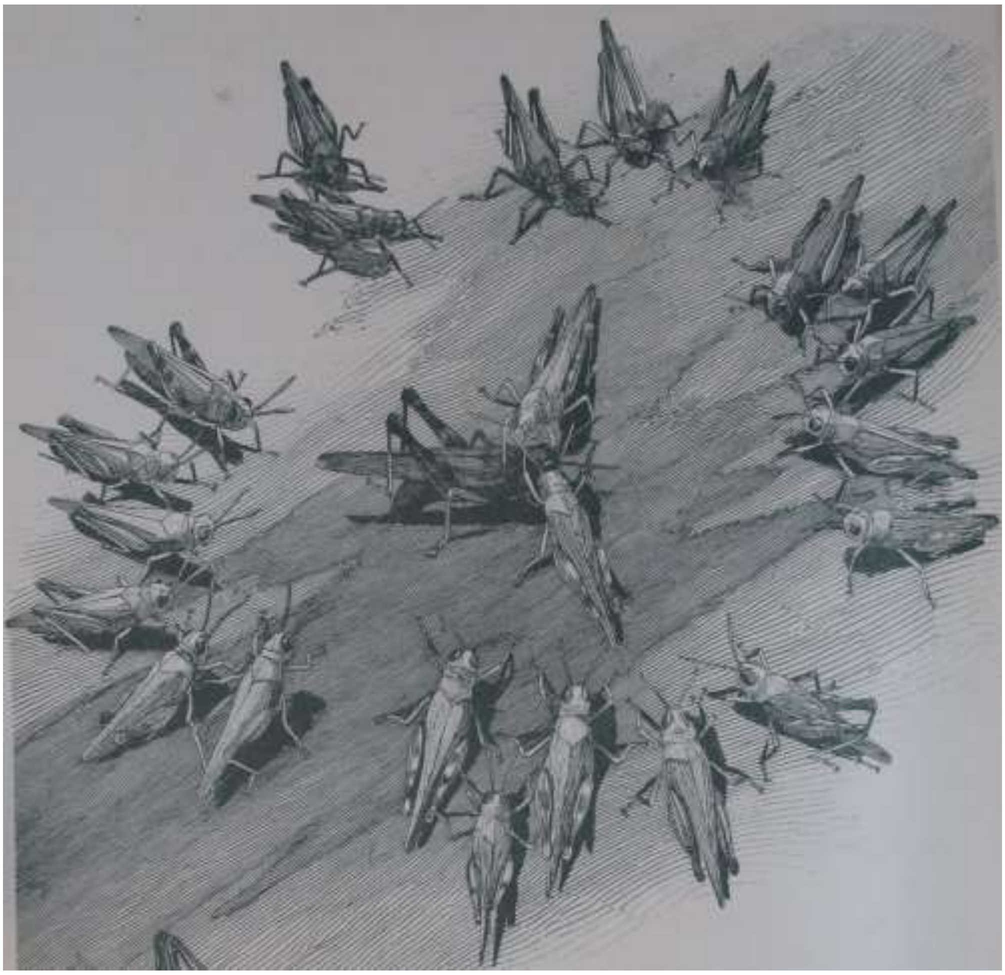


Figure 6.4. Photograph (detail) from lithograph plate by W. E. Chambers, in W. W. Froggatt, 'Plague Locusts', *Agricultural Gazette of New South Wales*, 11 (1900), 175–183, p. 174, showing many male *A. cruciata* encircling, and two attending, the central ovipositing female.

The Condobolin district in NSW suffered grasshopper swarms for five consecutive years from 1897. Here, as elsewhere, they exacerbated the impact of the drought. The estimate of 958,000 sheep in the district in 1898 was described as 'one-third of the number carried years ago', and in the following year a further 378,000 were lost.[62] Further west, the grasshoppers appeared or were blown away with the fearful dust storms, which half-buried the fences in sand as far south as Deniliquin.[63] In October 1899, Condobolin's grasshopper problem was 'worse than it has ever been' and, of the meagre crop, 700 acres of wheat on one property were destroyed in a few days, while another station lost 30,000

[62] *Western Champion*, 20 May 1898, p. 6; 18 May 1900, p. 8.

[63] *Riverine Grazier*, 24 October 1899, p. 2; *The Argus*, 6 December 1899, p. 8.

acres of grass.[64] Farmers recognised the grasshoppers were locally bred and requested the government send an expert to investigate a solution.[65]

Walter Froggatt made the rail journey to Condobolin to investigate the situation and conduct control trials. He recognised the pest was not the locust that had caused the 1890 plague. Although it looked similar it behaved very differently. Observers in the Riverina, who had seen more than their share of swarms of both kinds over the years, already knew that this insect was the grasshopper, not the locust.[66] Froggatt presented specimens to the Linnean Society of NSW in 1899 as a 'new plague locust (*Pachytylus* sp.)' smaller than the well-known '*P. Destructor*', which, because of the ongoing confusion over the identity of *A. cruciata*, he thought to have been first seen in NSW in 1888, possibly coming from South Australia.[67] He published a report on the species, detailing its depredations and the unique guarding behaviour, 'where ovipositing females are attended in a remarkable manner by numerous males' (Figure 6.5).[68]

The descriptions in Froggatt's report seemed so exotic they were taken up and reprinted by Edmund Selous in his 1909 *Romance of Insect Life* (Figure 8.1). Selous made a metaphorical point about Australian natives having been 'got rid of, very much as though they were locusts', in response to Froggatt's mention of local labourers in African colonies being forced into collective control actions by autocratic government 'whether they were inclined to or not'.[69]

At Blinman, in the Far North of South Australia, where farmers were already inured to grasshopper plagues, they left 'hills, gullies, farms and gardens as bare as a road'. The country to the south was in deplorable condition from the effects of the grasshoppers and hundreds of thousands of rabbits dying of starvation.[70] Their combined effect caused heavy crop losses in South Australia. In 1900, after five

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[64] *The Advertiser*, 10 October 1899, p. 5; *The Maitland Daily Mercury*, 31 October 1899, p. 2; *Riverina Recorder*, 1 January 1899, p. 2.

[65] *The Advertiser*, 17 September 1900, p. 4.

[66] *The Argus*, 18 November 1898, p. 6.

[67] *The Sydney Morning Herald*, 1 December 1899, p. 8.

[68] W.W. Froggatt, 'Plague locusts', *Agricultural Gazette of New South Wales*, 11 (3) (1900), 175–183. The distinctive male attendance behaviour was described and illustrated by W.E. Chambers. The illustration was reproduced again by Gurney in 1908.

[69] Edmund Selous, *Romance of Insect Life – Interesting Descriptions of the Strange and Curious in the Insect World*, (London, Seely & Co., 1909), p. 81.

[70] *South Australian Register*, 2 November 1899, p. 4; 3 November, 1899, p. 7; *Horsham Times*, 3 November 1899, p. 4, 'In the vicinity of Blinman, in the north, grasshoppers have stripped the crops so thoroughly that what is left will not return seed. One farmer, with 600 acres of promising wheat, does not now expect to harvest enough to sow the land next year; and others have turned cattle into their paddocks as the crops are now not worth reaping. The grasshoppers are coming south, and between Bruce and Quorn some paddocks are as bare as in the middle of the drought. The wheat north of Petersburg is now almost too tough for grasshoppers'.

years of poor harvests, ‘smitten by drought and locusts’ the distressed ‘agriculturalists had become the white slaves of Australia’.[71] Wheat growers at Kanyaka appealed to government to have their land rents set at the pastoral rate.[72] Few reaped enough wheat for seed and many could not pay their rates or bank loans. Farmers further south started a pool to provide seed to allow those in the north to continue farming. To add to the feeling of disaster, grasshoppers were implicated at the inquest into several deaths caused by a train derailment near Walloway in 1901.[73] 1902 was described as the ‘worst season ever’ in parts of the north where fifty to ninety per cent of crops were lost.[74] Some who had struggled against the odds for twenty-five years abandoned their farms, ‘leaving the pests in possession’ in a final admission that the land north of Goyder’s line was only suitable for grazing.[75]

1898 to 1903 was not a continuous drought. Some years had winter rainfall that favoured the grasshoppers. In spring 1899 for example, the Condobolin district and the Riverina reported good grass growth and the Lachlan River was in flood the following winter.[76] The drought finally eased in 1903 and, judging by the number of reports in that year, either the grasshoppers or interest in reporting them had been exhausted.

Charles French’s biological war — the ‘locust fungus’

What began as a curiosity of natural history in the mid-nineteenth century, the ‘entomophytes’ or fungi that infect insects, became a subject of interest among the economic entomologists for obvious practical purposes.[77] The first experimental control of insects using mass-reared fungi took place in Russia in the 1880s, after observations by the zoologist Elie Metchnikoff, and a flurry of worldwide research followed. In Australia, Henry Tryon presented those developments to the Naturalists’ Society in Brisbane in 1893, while in 1895 Victorian Field Naturalists’ Club members Daniel A. McAlpine

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[71] *South Australian Register*, 5 July 1900, p. 8; 6 November 1900, p. 3; 21 November 1901, p. 5, The perennial member for the north, Thomas Burgoyne, moved in state parliament that government consider action on the grasshoppers, and gave a lengthy description of responses in Natal and Argentina; *The Advertiser*, 21 November 1901, p. 5, Burgoyne was treated facetiously in reply by Mr Peake and Mr Copley.

[72] *The Advertiser*, 8 November 1900, p. 3.

[73] *The Advertiser*, 18 November 1901, p. 5; 21 November 1901, p. 5.

[74] *The Register*, 20 November 1902, p. 3, crop losses of 50–90% were reported due to drought and grasshoppers.

[75] *Quorn Mercury*, 19 October 1900, p. 2, farmers will have to pack up leaving the pests in possession; *Southern Cross*, 21 Nov. 1902, p. 5, north of Goyder’s line of rainfall the present year is, without exception, the worst we have experienced since the settlement of the areas … [the wheat growing] … experiment useless under dry conditions.

[76] *The Australasian*, 25 November 1899, p. 12; *The Maitland Weekly Mercury*, 25 November 1899, p. 18, good rainfall in the Riverina in November 1899; Flooding of the Lachlan at Condobolin in July 1900.

[77] A. S. Olliff, *Australian Entomophytes, or Entomogenous Fungi, and Some Account of Their Insect Hosts*, (Sydney, 1895), Olliff considered these fungi reached their highest development in Australasia. *Agricultural Gazette of New South Wales*, Vol 4, (1895), 401–414, reviewed British works on the subject by George Robert Gray (1858) and M.C. Cook (1892), particularly descriptions of the caterpillar fungus *Cordyceps*.

and Thomas Sergeant Hall discussed similar research on cockroaches and reported on the discovery of a fungus causing mass death of locusts in South Africa.[78] Entomologists began investigating the potential of local fungi and farmers also reported strange, fatal associations between fungi and insect pests.[79]

In 1899 Charles French embarked on a scientific plan for solving Victoria's locust problem with the 'Cape Fungus'. Experiments with the fungus that killed locusts in South Africa led to its distribution to numerous locust-affected countries in the late 1890s, including the USA, India, Italy, Spain, Cyprus, Algeria, Palestine, Argentina and Australia.[80] French imported thirty vials of the fungus from the Colonial Bacteriological Institute that came with an assurance of unfailing success in moist conditions.[81] Like the 'locust days' of 1890, his plan was again for unified mass public action against the pest, and again he would use the media to arrange it. In this hopeful time when the 'applications of science to agriculture were illimitable', the farmers were to conduct the trials and report back their results.[82]

After failed indoor experiments, in October 1899 French warned of a 'locust' invasion in northern Victoria and dispatched Sydney A. Cock, the department fruit inspector, to carry out the first field trials of the fungus at Rochester near Echuca.[83] Cock concluded his report positively, writing 'farmers can rely on this disease as their friend, and should everywhere take up the work of extermination, which is not only useful but pleasurable'.[84] Walter Froggatt joined French in the hope of a

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[78] *The Queenslander*, 12 August 1893, p 318; *Victorian Naturalist*, 12 (5), 141, August 1895, pp. 63–64; *Victorian Naturalist*, 12 (6), 142, September 1895, p. 49, McAlpine discussed investigations on local specimens infected by fungi; *The Australasian*, 14 September 1895, p. 21, Thomas Hall (writing as 'Physicus') reported that the fungus disease was discovered near the coast in Natal in 1894, where dead locusts were found hanging on sugar cane.

[79] *The Sydney Morning Herald*, 25 September 1899, p. 3, Froggatt produced a report for the NSW Minister on a fungoid disease of caterpillars, specimens of which had been received from all parts of NSW.

[80] *South Australian Register*, 13 October 1897, p. 5, Luther Robert Scammell, a Faulding Co. chemist in Adelaide was the first to obtain tubes and of the fungus in 1897 from its 'discoverer' Alexander Edlington, of the Colonial Bacteriological Institute of South Africa. Had his offer of tubes for trials been taken up at that time, the outcome could have been very different for the development of fungal biopesticides; D. McAlpine, *Agricultural Gazette of New South Wales*, 10 (1899), p. 1213, McAlpine listed countries where the fungus had already been sent.

[81] *The Argus*, 21 July 1899, p. 4; 5 September 1899, p. 6.

[82] *Rockhampton Morning Bulletin*, 14 April 1903, p. 6, quoting from the *American Agriculturalist* about the death knell of the grasshoppers and the progress of science.

[83] The grasshopper, *A. cruciata*, was the subject of the first trials in 1899. *The Northwestern Advocate and the Emu Bay Times*, 16 September 1899, p. 2, at Rochester they were described as appearing a month earlier than usual and were winged adults during October, the timing a clear indicator of *A. cruciata*. The 'usual' would have been recollections of locust hatchings in 1890 and 1894, which generally do not occur before mid-October in northern Victoria.

[84] Charles French, *Destructive Insects, Part 3*, p. 36, Cock confirmed that moist conditions were necessary for it to have effect.

collaborative success by undertaking numerous trials in NSW. He and Daniel McAlpine, the Victorian vegetable pathologist, conducted 'partially effective' trials near Wagga, where 'many dead and dying were picked up' (Figure 6.5).[85]

Agriculture departments and local farmer's groups in South Australia, Queensland and WA requested tubes of the fungus from French. The well-publicised methods of preparation, the 'water' and 'bread' recipes, could be carried out in buckets and involved either dunking and then releasing some grasshoppers to spread the disease among themselves, laying the inoculated bread as baits, or spraying them with the water solution.[86] In 1900 Thomas Cherry (Figure 6.5), then Victorian government bacteriologist, established culture facilities at the University of Melbourne and set to producing large quantities of the 'locust fungus' as French pushed ahead with his plan. For several years a small industry produced and distributed it in tubes of gelatine, along with pamphlets explaining its preparation.[87]

McAlpine had wanted to identify and evaluate the fungus before its wholesale use.[88] He published a description of the fungus under culture in 1900, including microscopic illustrations, naming the species *Mucor racemosus*, and also examined another *Mucor* species, a common fungus of rotting fruit not known to be entomopathic.[89] But, regardless of McAlpine's findings, tubes were sent to Mildura, Red Hill, Euroa, Wangaratta, Warrnambool and throughout Gippsland during the following three years. French advertised the product in newspapers as free to farmers, requesting only that they return reports on its efficacy.

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[85] *The Sydney Morning Herald*, 13 November 1899, p. 8.

[86] *Wagga Wagga Express*, 11 November 1899, p. 5.

[87] *The Advertiser*, 11 December 1900, p. 5; *The Australasian*, 17 November 1902, p. 33, Frederick Guthrie, the NSW department chemist also cultured the fungus in Sydney in 1902.

[88] *The Argus*, 25 September 1899, p. 6; McAlpine's life and his diverse interests apart from the locust fungus, are covered in Douglas G. Parbery, *Daniel McAlpine and The Bitter Pit*, (Heidelberg, Springer, 2015).

[89] D. McAlpine, 'The systematic position of the Locust-fungus imported from the Cape', *Agricultural Gazette of New South Wales*, 11 (1900), 184–186.

Figure 6.5. Victorian Department of Agriculture scientists involved with the 'locust fungus', Thomas Cherry (left) and Daniel McAlpine (*Annual Report of the Victorian Department of Agriculture, 1907–10*).

GENERAL VIEW OF SPRAYING OPERATIONS AT GOODWILL. CONDOBOLIN.

Figure 6.6. The locust spraying operations at Mr. G. H. Tasker's garden at 'Goodwill' Condobolin in October 1900, *The Sydney Mail and New South Wales Advertiser*, 3 November 1900, p. 1050.[90]

[90] Two methods were trialled: spraying with a mixture of arsenic soda and treacle using a 'Knapsack' spray pump, and inoculation with the African locust fungus.

Owing to the absence of locusts during the Federation drought, the early inland trials were carried out on the grasshopper, *A. cruciata*, which was swarming across northern Victoria. French appears not to have distinguished between it and *C. terminifera*.[91] He did not travel to the north to attend any trials and, apparently seeing the fungus as a universal solution, in the ongoing confusion over their identities he chose to ignore it.[92] Froggatt conducted well-publicised fungus trials at Condobolin in 1900, but no effect could be seen in the very dry conditions (Figure 6.6). Newspapers reported it a 'complete failure', while the arsenic baits did produce visible results.[93] He returned to Condobolin in 1902 and again the result was unclear. Mr Tasker, on whose property 'Goodwill' Froggatt carried out the trials, wrote 'one week after your experiment at my place every grasshopper was dead, but whether it was from the effects of the fungus I cannot say' (Figure 6.7).[94] Froggatt also organised tubes for farmers at Narrandera, Narromine, West Wyalong, Singleton, Forbes and Cooma, which for various reasons produced equivocal or negative results.

The erratic performance of the fungus, generally explained by dry conditions, was becoming apparent by 1902 and support for the alternative of 'arsenical baits' as a surer method was growing in other states. But French persisted in Victoria, bolstered by positive responses from Gippsland and some of his own propaganda:

> The Government entomologist, Mr. C. French, is constantly receiving satisfactory accounts of the success of the grasshopper killing fungus introduced by him from South Africa, and a large demand for next season is imminent. It is hoped that one of the worst pests in the state is now within measurable distance of being kept in check, if not altogether stamped out.[95]

The grasshoppers on which most trials were conducted, and which had become an annual problem in Gippsland, were a mix of altogether different species.[96] In early 1902 they 'were more numerous than we have ever known them before'.[97] After obtaining an interview with French, one local newspaper,

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[91] In spring 1899, French warned northern farmers of an imminent 'locust' invasion, though it was clear that the grasshopper had been present for several years. This may have been a generic use for the public.

[92] *The Australasian*, 4 November 1899, p. 11, based on reports from Echuca, French gave a warning to the Minister of a locust invasion in northern Victoria and despatched Cock to conduct fungus trials on the locusts.

[93] *The Advertiser*, 17 September 1900, p. 4, Condobolin agriculturalists requested the Mayor to make application for the Government Entomologist be sent to devise a means of dealing with the pest; *Sydney Wool and Stock Journal*, 30 October 1900, p. 8, 'experiments by the government expert have been a complete failure. Grasshoppers usually appear in dry season when grass is none too plentiful'.

[94] *Agricultural Gazette of New South Wales*, 13, (1903), p. 284.

[95] *Bendigo Advertiser*, 18 April 1902, p. 3; The same text was repeated four years later in *The Mornington Standard*, 14 July 1906, p. 4, suggesting that a letter from French in the form of a press release may have been involved.

[96] Gippsland is outside the known range of *C. terminifera* and *A. cruciata*, but several other *Austroicetes* spp. are common, including *A. vulgaris*. The wingless grasshopper, *Phaulacridium vittatum*, is also a common pest in Gippsland, but no other detail is extant.

[97] *West Gippsland Gazette*, 18 February 1902, p. 7.

the *West Gippsland Gazette*, became a distribution outlet for consignments of the fungus. Demand at first far outstripped supply, with the paper pressing the department weekly for more tubes. Many Warragul farmers keen to save their onion and potato crops were given tubes during 1902 and were expected to 'faithfully report results'.[98] But by April only six out of forty-two farmers had reported back and they were split evenly on success and failure.[99]

Figure 6.7. 'Government Entomologist, Mr Walter Froggatt, conducting locust exterminating experiments at Goodwill, Condobolin, NSW' in 1902, watched by interested locals.
The Australasian, 17 November 1902, p. 33.[100]

The campaign began again the following spring and the success of the fungus now seemed assured, with 500 applications in December 1902 and Cherry producing 300 vials per week.[101] The *Gazette* announced that French wanted a hundredweight of dead grasshoppers to make a 'more powerful

[98] *West Gippsland Gazette*, 11 March 1902, p. 7.

[99] *West Gippsland Gazette*, 15 April 1902, p. 2.

[100] The article described the procedure of propagating the fungus in boiled water with indicator corks, and then mixing with stale bread and bran. It described the species as the wandering locust (*Epacromia terminalis*), presumably on Froggatts' advice. Owing to the complete absence of grass at this site, the bunch of leaves around the stump was used to provide shade where the grasshoppers could cluster to eat the inoculated bread crumbs.

[101] *Kilmore Free Press*, 1 January 1903, p. 1; *West Gippsland Gazette*, 3 February 1903, p. 2, others were not so convinced. In an interview during a visit to Warragul, Mr Cock, now the Entomology Branch Inspector, was unable to account for the failures.

supply of the destructive agent', and that 'the efficacy of the fungus is now so thoroughly established by local experiment and experience'.[102] Another Gippsland paper, the *Maffra Spectator* also got involved in the distribution of fungus and quoted testimonials of 'millions of dead'.[103]

The fungus called into question

In 1903 Cherry commented to the Royal Commission into the management of the University of Melbourne that his time had been consumed by preparation of the locust fungus.[104] Production was subsequently moved to the agriculture department Chemical Branch laboratories run by Frederick John Howell, who had a locally educated and trained staff of thirteen. Supported by the positive media coverage, the machinery of French's program gained momentum, with a thousand tubes in production in September, although a one shilling charge added to cover postage did dampen demand.[105] In the Annual Report for 1903, French put the total 'number of tubes posted at nearly 5,000'.[106] The fungus would finally be tested on locusts in 1904 in Victoria and Queensland, but Froggatt discontinued its use in NSW as there 'were too many unfavourable conditions ... attached to its use to be of any great value ... in the climate like our western scrubs'.[107]

For the first time since 1894, locusts arrived in Victoria in autumn 1904 after the 'wettest summer on record'.[108] Between Swan Hill and Kerang a wall of swarms 'twenty five miles wide' crossed the river. Many farmers feared it was just the 'vanguard' of a greater invasion.[109] Huge numbers of eggs were deposited and roadways were 'perforated with tiny holes'.[110] In the spring, hopper bands developed in the Wimmera, Mallee and northern districts. The Mildura community rallied for a systematic protection of crops in the irrigation area. Organised by local councillor, J. T. Grossman, the Mildura campaign had among its impressive arsenal 150 tubes of fungus as well as half a ton of arsenic, 1,000 gallons of kerosene and ten tons of bran. In Grossman's view, the kerosene sprays and arsenic baits were visibly effective, but 'owing to the amount of poisoning done it was difficult to say to what extent the fungus has operated'.[111] In summing up the often improvised but publicly well-

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[102] *West Gippsland Gazette*, 9 December 1902, p. 2; *West Gippsland Gazette*, 6 January 1903, pp. 2, 7.

[103] *The Maffra Spectator*, 4 December 1902, p. 2; 29 January 1903. p. 3, Mr Henry, of Poowong East, first 'thought it didn't work, but looking under clods there were thousands of dead'.

[104] *The Argus*, 12 March 1903, p. 7.

[105] *Bendigo Advertiser*, 17 September 1903, p. 3.

[106] C. French, *Victorian Department of Agriculture Annual Report 1903–04*.

[107] *Sydney Mail*, 23 November 1904, p. 1291.

[108] *The Australasian*, 9 April 1904, p. 5.; *The Register*, 19 April 1904, p. 5., parts of northern South Australia also reported it as wettest summer ever.

[109] *Riverina Recorder*, 6 April 1904, p. 3; *The Argus*, 14 April 1904, p. 6.

[110] *The Argus*, 29 March 1904, p. 6; *Bendigo Advertiser*, 7 April 1904, p. 4; *Euroa Advertiser*, 15 April 1904, p. 2.

[111] *The Mildura Cultivator*, 10 December 1904, p. 8.

supported actions, Grossman wrote that the 'warm reception' at Mildura despatched the locusts 'in a more severe way, perhaps, than has ever been meted out to them in the history of Australia'.

Locust fungus

It is a significant fact most landholders he supplied with the fungus are writing down for more tubes this season … one large wool firm applied for ninety tubes … With proper co-operation among landholders … great loss would be saved by the universal application of the fungus remedy which can be safely be said to have passed out of the experimental stage into a field of practice for immediate profit.

The Broadford Courier and Reedy Creek Times, 31 January 1908, p. 2.

Back in Melbourne, belief in the fungus was self-reinforcing. Dead locusts sent to French from Mildura showed 'large quantities of fungus', apparently demonstrating it had killed them.[112] French continued to cultivate the newspapers while his department cultivated the fungus. Whenever a problem was anticipated, information on the availability of the fungus would appear. With no locusts about in December 1905, there were still several notices urging farmers to 'apply at once' owing to the limited supply.[113] It appears that French mailed out what were in effect 'press releases' and the papers, entranced by a story of scientific triumph, helpfully obliged. If he had any personal doubts they are hidden by the positive public messages.

Despite concern by McAlpine and Froggatt over the identity and mode of action of the fungus, and mounting evidence of failures from overseas, French seemed unperturbed about its efficacy.[114] In 1907, Froggatt collected dead *Oedaleus australis* grasshoppers that were clinging to the grass in the NSW Hunter Valley, a position linked to mortality caused by fungus in the original descriptions from South Africa.[115] Samples sent to McAlpine produced a fawn-coloured fungus, which he identified by

[112] *The Mildura Cultivator*, 3 December 1904, p. 10.

[113] *Bairnsdale Advertiser and Tambo and Omeo Chronicle*, 12 December 1905, p. 4.

[114] D. A. McAlpine, 'A fungus parasite of the codlin moth', *Agricultural Journal of Victoria*, 2, (1904), 469–472; p. 470; *Sydney Morning Herald*, 15 January 1909, p. 4, by 1909 the South African Locust Bureau had abandoned all other control methods in favour of arsenic; D. L. Hostetter and R. J. Dysart, 'The Biological control potential of parasites, predators and fungal pathogens', Section I.12, in *Biological Control: An Introduction,* (Grasshopper Integrated Management Handbook (1–5), tests on fungus samples sent to Kew Gardens in 1899 and in USA in 1900 identified *Mucor* in the South African cultures. L.O. Howard suggested that both *Empusa* and *Mucor* were in the cultures; *Queenslander*, 28 November 1903, p. 40, experiments in 1903 in Colorado had already proven the fungus to be a failure.

[115] W. Froggatt, 'The eastern plague locust', *Agricultural Gazette of New South Wales*, Misc. Publication. No. 1095, June 1907.

its fruiting structures as *Empusa grylli*, known to kill grasshoppers in other countries.[116] The implications for the 'Cape fungus' being used in Victoria were becoming clear.

Now in his sixties, French continued with his media campaign. 1906 was very quiet, even for grasshoppers, but in February 1907 locusts again swept into northern Victoria, followed in spring by dense nymph bands.[117] When swarms formed in December, local papers saw drama in the situation. Trains were stopped near Kilmore by 'grasshoppers six inches thick on the rails', while at Chiltern the plague was compared to 1891.[118] At any rate, it provided an opportunity to renew demand. In January 1908 French emphasised how the fungus remedy was now 'a field of practice for immediate profit'.[119]

French continued to report strong demand during 1909, but the magic finally and quietly unravelled in 1910, when McAlpine went public with the news that a benign fungus had originally been sent from South Africa.[120] The *West Gippsland Gazette* corrected the mistake it had been party to, quoting him:

> The South African locust fungus, which is the same as the Australian one, has attracted considerable attention, because it was at first thought to be capable of being artificially cultivated and used for getting rid of the destructive locust. But, by an unfortunate mistake, the locust fungus which was sent out in tubes with gelatine was not that fungus at all, but a species of mucor or a mould which is not a parasite. The parasitic fungus which killed the locusts was Empusa grylli, but mucor was also present on the dead locusts, and so it came to be mistaken for, and cultivated and sent out as an insect destroyer, which it really never was.
>
> *West Gippsland Gazette*, 16 August 1910, Morning Edition, p. 4.

Explaining the 'scientific blunder' in the *Victorian Naturalist*, McAlpine found it 'amusing to read of the wonderful success of this imaginary parasite, reminding us of the … coloured water of the physician'.[121] To show the irony of the placebo effect eliciting so many positive reports, he quoted French from the 1902 and 1904 annual reports and concluded that this was the only instance of the attribute of 'faith' being applied to the destruction of grasshoppers and locusts'.[122] McAlpine wanted

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[116] D. McAlpine, *Agricultural Journal of Victoria*, 7 (1907), p 41, McAlpine described the fruiting bodies at the joints of dead locusts.

[117] Reports of locusts came from Mildura in the Northwest to Rutherglen in North Central district.

[118] *The Maffra Spectator*, 12 December 1907, p. 3; *North-Eastern Ensign*, 20 December 1907, p. 2.

[119] *The Yarragon, Trafalgar and Moe Settlement News*, 30 January 1908, p. 2.

[120] *The Advertiser*, 22 February 1909, p. 10, French supplied 500 tubes, with strong demand from the western districts; *Farmer and Settler*, 12 March 1909, p. 7; *Sunday Times*, 9 January 1910, p. 14, French says applications more numerous than previous season; *Kerang Times*, 18 January, 1910, p. 4, French had 150 applications in one week in the last quarter.

[121] D. McAlpine, *Victorian Journal of Agriculture,* 11, (July 1910), p. 436.

[122] D. McAlpine, 'The romance of plant pathology', *Victorian Naturalist,* 27 (November 1910), 127–135, p. 132, McAlpine thought trials with the true locust fungus should commence, writing 'Now that we know that we

epidemiological studies on the Australian *Empusa* fungus ‘to see how far the true locust fungus can be utilised and controlled by us’, but no further research was conducted. French made no public comment on the fungus mistake.

French’s science

French’s place in the scientific history of the period is marked by the enduring legacy of the *Destructive Insects of Victoria* volumes. His energies were focused on this ‘literary task of economic entomology’ and were directed at insect pests other than locusts. As a bureaucrat he was a conscientious correspondent, keeping meticulous account of all letters dealt with.[123]

For French, the ‘Ichneumon wasp’ that had captured imaginations during the 1870s kept its mystique of ‘policing’ the Malthusian population growth of pest insects.[124] For the illustrations of the ‘Common Victorian locust’, which he identified as ‘Pachytelus australis’, in Part 3 of *Destructive Insects* in 1900, French had his artist and field naturalist friend, Charles Brittlebank, reproduce the 1873 diagram of the ‘Ichneumon’ wasp, still poised in action, and included some ‘brachonid’ wasps for good measure (Figure 6.8). Although the illustrations had been prepared in 1893, no species of either wasp family had been identified as a locust parasite in the intervening years, a point noted by Froggatt in 1910.[125]

French’s 1900 chapter on locusts included an appendix with numerous illustrations of ‘locust-destroying’ machines that had been patented in the USA. They were of the ‘hopper-dozer’ type; horse-driven scoops for collecting grasshoppers in bulk that could then be bagged for animal-feed or disposal. Similar machines only ever appeared as ‘backyard’ prototypes in Australia and were never manufactured, despite a thriving local farm machinery industry. It is likely that the irregular appearance and unpredictable location of plagues did not create any demand for locust-harvesting machines and they were also never recommended by state entomologists.

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have been importing the spurious article from the Cape, while the genuine article was produced within our own borders, it behoves us to study the natural conditions under which epidemics of the locust disease occur, and see how far the true locust fungus can be utilised and controlled by us’. But ‘Empusa’ had only been cultured on locust bodies and this difficulty, as well as the loss of face attached to the realisations of the mistake may have contributed to the shelving of such efforts. McAlpine could have added ‘scientific’ to faith, considering the historical association of locusts with acts of divine Providence.

[123] C. French, *Victorian Journal of Agriculture*, 3, 1903–04 Annual Report, p. 854, for the previous year 4,283 letters were dealt with by the Entomology Branch, excluding internal departmental correspondence.

[124] Shiela Wille, ‘The ichneumon fly and the equilibrium of British natural economies in the eighteenth century’, *British Journal for the History of Science*, 48 (2015), 639–660, pp. 648, 655.

[125] C. French, *Destructive Insects &c*. Part. 3. Plates accompanying pp. 23–27, (Melbourne, Department of Agriculture, 1900); W. W. Froggatt, ‘Locusts in Australia and other Countries’, *Department of Agriculture N.S.W. Farmers’ Bulletin No. 29*, (1910), p. 36.

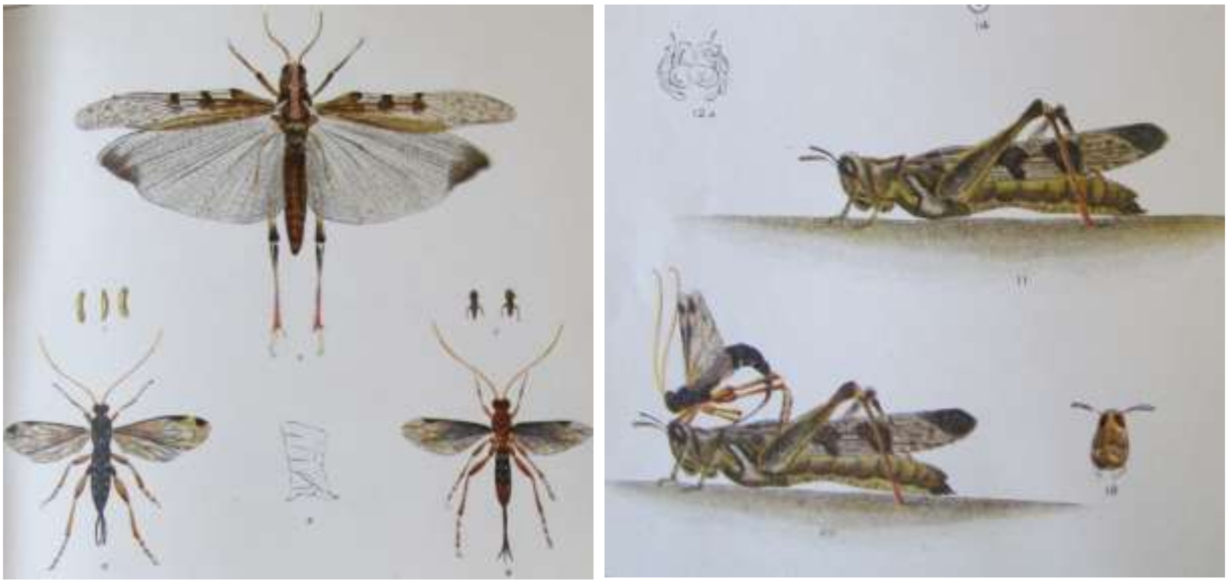

Figure 6.8. The common Victorian locust (*Pachytelus australis*), wings outstretched, with Brachonid wasps (left) and attacked by the Ichneumon wasp, by C. C. Brittlebank, (Plates 37 and 38 (detail)) from C. French, *Destructive Insects &c*., 1900.[126]

It appears French preferred the cool forests of eastern Victoria to the sparse grasslands and harsh summers in the north, and was more passionate about his collections than the trying work of 'systematic entomology'.[127] Although his 'Economic Entomology and Ornithology Branch' displays of pinned insects and stuffed birds, with nests and eggs, were popular with visiting nature study school groups and at the Royal Show, they never received museum status or a building like the Department's Technical Museum (Figure 6.9).[128]

French retired in 1911 with a silver tea and coffee service from his departmental friends and Charles Junior became the government entomologist.[129] In honorary recognition, French represented several states at the Imperial Entomological Conference in London in 1912.[130] He took a train to Adelaide to catch the mail steamer, where a local press reporter gave him due scientific acknowledgement, taken

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[126] C. French*, Handbook of the Destructive insects of Victoria: with Notes on the Methods to be Adopted to Check and Extirpate Them*. Part 1, (Melbourne, Victorian Department of Agriculture, 1891).

[127] In Parts 4, 5 and 6 of *Destructive Insects of Victoria*, French concentrated more on the wood-boring beetles of forest trees, in a return to the work which first brought his entomological skills to attention in the 1874 Departmental Annual Report, see Part 5, 'Introduction'.

[128] *Department of Agriculture Victoria Annual Report 1905–07*, p. 193; the French collections were housed in a difficult to find room in the Crown Law Office in Lonsdale St, Melbourne.

[129] *Barrier Miner*, 24 October 1911, p. 2; Charles Hamilton French rarely featured in newspaper entries about locusts.

[130] French represented Victoria, NSW and South Australia.

from *Fred Johns's Annual*, 'Eminent in his science, and for many years in correspondence with renowned scientists in all parts of the world'.[131]

Investigations into the biological control of locusts were exhausted after the loss of face following the 'Cape fungus' mistake. But it had been part of a hopeful transnational phenomenon of using 'nature's own remedies' to deal with pest outbreaks and investigations of their potential were far from over. As the locust and grasshopper were native, classical biological control was unlikely to offer remedies so the focus was turned towards the range of natural enemies. Manipulation of any of these was unlikely, but the protection of birds played a dual role in terms of public and scientific perceptions.

Figure 6.9. Part of the Entomological and Ornithological Branch display at the Royal Melbourne Agricultural Show, *Department of Agriculture Victoria, Annual Report 1907–1910*, p. 41.

[131] *The Mail*, 20 July 1912, p. 3.

Chapter 7. Birds, arsenic and collective action, 1907–1930

RIDING THROUGH THE GRASSHOPPERS AT PARKES, NEW SOUTH WALES.

Figure 7.1. 'Riding through the grasshoppers at Parkes', New South Wales, *The Australasian*, 4 January 1908, p. 4.

All day long, like a shower of rain,
You'd hear 'em smackin' against the wall,
Tap, tap, tap, on the window pane,
And they'd rise and jump at the house again
Till their crippled carcases piled outside.
But what did it matter if thousands died —
A million wouldn't be missed at all.

An Arctic snowstorm was beat to rags
When the hoppers rose for their morning flight
With a flapping noise like a million flags:
And the kitchen chimney was stuffed with bags
For they'd fall right into the fire, and fry
Till the cook sat down and began to cry —
And never a duck or a fowl in sight!

From 'A Ballad of Ducks', *Saltbush Bill, J. P., and Other Verses* by A. B. Paterson, (Sydney, Angus and Robertson, 1917).

Southern hemisphere scientific locust controls

Farmers and governments in the temperate 'newlands' continued battling locust and grasshopper irruptions during the first decades of the twentieth century. The southern settler societies in South Africa, Argentina and Australia looked to the northern hemisphere for scientific expertise in dealing with locusts. The national governments of the former two countries not only imported technologies of locust control, they imported scientists with locust experience. South Africa chose Jacobus Faure, returning from the USA and Natal hired an Australian, Claude Fuller, while Argentina cast its net widely and brought in scientists from the USA, France and Russia.[1] In Australia, by contrast, responsibility for dealing with locusts still rested with the states. They relied on their entomologists not only to uncover the details of locust population cycles, but to find the best methods of destroying them and to single-handedly ensure these were carried out. Despite agriculture departments hiring assistants for their lone government entomologists, the extent of locust infestations and the range of other tasks required of the economic entomologist were continually widening.

Developments in the use of arsenic compounds as insecticides, primarily in the USA, were trialled on locusts and grasshoppers in many countries. In 1906, South Africa embraced arsenic as the solution to the frequent plagues of the brown locust, abandoning the locust fungus that had been developed there a decade earlier. So confident was the agriculture bureaucracy of complete success that in 1910 the Transvaal museum was advised to preserve a locust specimen because they would soon be extinct.[2] Arsenic was used widely in the USA, but in farming country various harvesting machines, or 'hopper dozers' were also built to collect grasshoppers for stock feed. The widespread use of arsenic for locust control was at first resisted in Argentina and Australia, primarily because of the risk of poisoning livestock, people and other animals. Only after World War I did the Australian states uniformly recommend arsenic in bran baits or water sprays. Argentina chose a hybrid system of mechanised and organised collective actions, centred on the local innovation of long barriers of galvanised iron sheeting and the 'state charity' of paying for collected locust eggs and nymphs, or 'saltonas'.[3]

Irrespective of the methods, all three southern hemisphere governments placed the responsibility for providing the physical labour on the farmers and landowners. South Africa and Argentina chose legislation to make locust reporting and participation in control actions compulsory, creating institutional structures to organise and police them. In Australia, not only were landholders expected

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[1] Claude Fuller, born and educated in Sydney, emigrated to the Cape Colony from WA in 1898.

[2] *Evening News*, 24 February 1910, p. 6, Professor Robert Watt gave this example of the advance of progressive agriculture through science when taking up the first chair of agriculture at Sydney University.

[3] E. Deveson and A. Martinez, 'Locusts in southern settler societies: Argentine and Australian experience and responses, 1880–1940', in eds. E. Vaz, C. J. De Melo and L. M. Costa Pinto, *Environmental History in the Making, Volume 1: Explaining*, (Switzerland, Springer, 2017), *Environmental History 6*, pp. 259–287, p. 276.

to carry out the control work, they were left to pay for the insecticidal materials and equipment. With graziers' associations resistant to the idea of government regulations, the entomologists had to entrain community involvement against locusts without legislative support. They attempted this in several ways. First, they conducted demonstrations of the recommended insecticides, preparations and methods. They gave public lectures covering locust identification, lifecycles, natural enemies and the need for local action. Then they encouraged landholders to organise 'locust committees', using the South African legislated hierarchy of coordination and responsibilities as a model. And they used the agriculturalists' own local institutions as the organisational structures and conduit for communications.

This chapter deals with entomologists working on opposite sides of the continent, engaged with the opposite problems of locusts and grasshoppers. *Chortoicetes terminifera* became a perennial problem in New South Wales (NSW) during the first decades of the twentieth century, while *Austroicetes cruciata* was an increasing annual pest in Western Australia (WA) until the 1950s. The other states were only briefly visited and their entomologists were mostly engaged on other projects. While there was little contact between the entomologists of NSW and WA, they finally converged on similar methods to achieve the same outcome. Their shared history as naturalists interested in the diversity of native insects and concerned about the fate of native fauna, in particular birds, placed them in a similar paradoxical position when arsenic became the insecticide of choice for dealing with locusts.

Locusts become the 'settled pest' in New South Wales, 1907–1913

Locusts came and went in Victoria and South Australia, but from 1907 they came to stay in NSW. A much larger proportion of the state was affected during the plagues and they now found their way into its eastern agricultural districts. Heavy rains in the inland in late 1906 were followed by swarms in Southwest Queensland and northern South Australia.[4] In February 1907, locust swarms spread throughout the Central West, Hunter Valley and Riverina regions of NSW, reaching Albury in the south and Broken Hill in the west.[5] As usual there was widespread egg laying in autumn, but

[4] *The Sydney Morning Herald*, 4 November 1907, p. 7; swarms of grasshoppers were also reported at Innamincka and Birdsville.

[5] W.W. Froggatt, 'The eastern plague locust', *Agricultural Gazette of NSW*, Misc. Publication No. 1,095 (June 1907); *The Castlereagh*, 14 December 1906, p. 1, although Froggatt had identified swarms of *Oedaleus australis* mixed with *C. terminifera* in the Hunter Valley in late 1906, it is likely the swarms at Dubbo and Gilgandra, arriving on a north-west wind and 'propagating fast' were the latter.

unusually this time swarms penetrated into numerous districts on the western side of the Great Dividing Range that had rarely experienced them.[6]

A corner of a wheat paddock on Mr. Barden's farm, Narromine, showing every ear eaten off.

Figure 7.2. Locust damage in a wheat crop at Narromine, NSW. While one farmer's crop was destroyed, a neighbour's could escape damage, *Australian Town and Country Journal*, 27 November 1907, p. 35.

The Central West was 'devastated' in spring 1907, pitting farmers against the locusts in a 'race for the crops'.[7] A 'second edition' of hoppers appeared in December, prompting calls for the department to be doing more and to adopt the successful South African use of 'arsenate of soda'.[8] The swarms of the summer generation in February 1908 reached as far east as Tamworth, Bathurst, Grenfell, Yass, Gundagai, Molong, Young, Tumut and Queanbeyan (Figure 7.3).[9] Farmers feared that locusts were becoming a 'settled pest', recurring annually and increasing in destructiveness.[10] Would they become

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[6] *Northern Star*, 7 December 1907, p. 2, locusts leaving Molong, heading for Cudal and Cargo; *Molong Argus*, 20 March 1908, p. 4, at Amaroo, between Molong and Orange; *Albury Banner*, 20 March 1908, p. 33, amid the swarms around Blayney and at Grenfell in autumn 1908, it was said that the area had never before been troubled by grasshoppers; other eastern areas included Mudgee, Cowra, Molong, Orange, Grenfell and Cootamundra, Bathurst and Yass.

[7] *The Sydney Morning Herald*, 4 November 1907, p. 7; *The Sydney Morning Herald*, 9 December 1907, p. 4, in the Dubbo area, an estimated 60% of the wheat crop was cut for hay, or eaten out by the grasshoppers and similar losses were reported throughout the Central West.

[8] *The Sydney Morning Herald,* 18 December 1907, p. 6; 27 December 1907, p. 3; *The Musswellbrook Chronicle*, 27 November 1907, p. 1.

[9] W. B. Gurney, 'Notes on grasshopper (or locust) swarms in New South Wales during 1907–8', *Agricultural Gazette of NSW*, 19 (1908), 411–419.

[10] *The Sydney Morning Herald*, 15 January 1909, p. 4.

like those in South Africa or Argentina, where the stories of swarms served as a chilling portent? Motions were put at Pasture Protection (PP) Board meetings for government assistance and more science to deal with these pests, which jumped to the 'front rank of plagues' and were now 'more dreaded in the central districts than the rabbit'.[11]

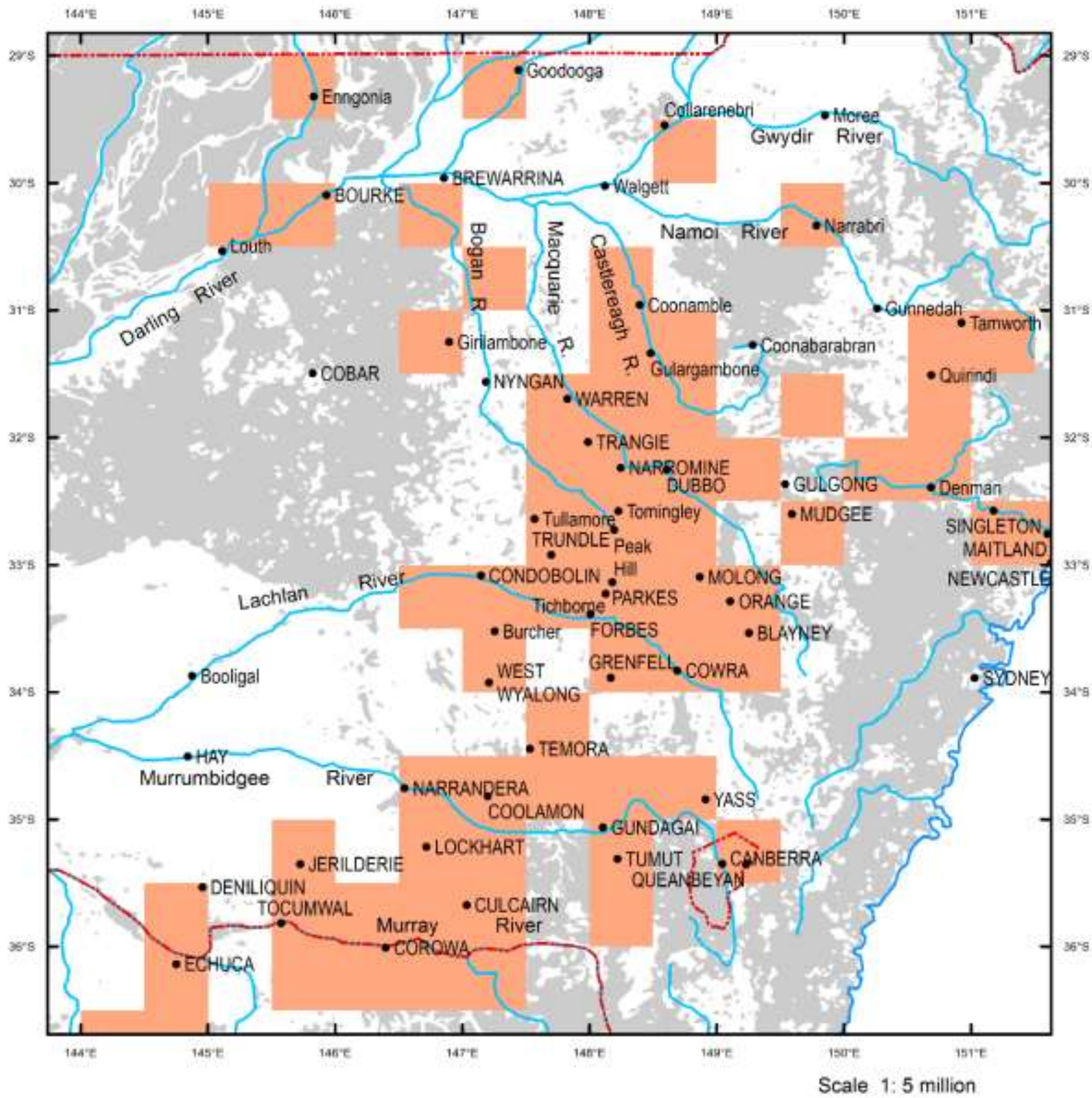

Figure 7.3. Districts in eastern NSW reporting locust swarms during 1907–08 (affected areas shown in orange, current unsuitable habitat in grey).

[11] *Western Champion*, 24 January 1908, p. 14.

Grasshoppers. Millions at Narromine

Whole Farms Devastated. Racing the Insects for the Crop.

On the one hand the drought had permitted only an apology for a crop, and on the other the grasshoppers were disputing the ownership of it. From the field a walk was taken in the farmer's house. Every window and door were shut against the pest, despite the intensity of the subtropical heat. The farmer's wife declared the pest to be ten times worse than the ravages of the rabbit. "The rabbits" she said "you can keep down with the poison, but a plague of grasshoppers may fairly ruin a farmer in a single night".

The Sydney Morning Herald, 4 November 1907, p. 7.

Some farmers pushed for legislation to retain shelterbelts of trees and make landholder control compulsory. This would prevent grazing areas becoming the breeding grounds for 'grasshoppers', which would then devastate the wheat lands. But at the Molong Board the motion for compulsory control was 'fired out' over the 'monstrous' impost it would place on large landholders — the graziers.[12]

The plague continued throughout 1908 with three generations each year, expanding into the Liverpool Plains and Darling River areas.[13] For several years Froggatt and his assistant William Gurney demonstrated kerosene and soap sprays to affected farmers. At Wee Waa, near Narrabri, Froggatt made cost-benefit estimates of kerosene spraying, detailing the time of day and locust development stage for best results, but many farmers considered the cost, then at ten shillings per acre, far too expensive.[14] Kerosene was recommended because of the potential risks of poisoning posed by arsenic. Froggatt was quoted as saying 'it would not be wise to spray the land with … arsenic, which is death to all insects… and it would not be safe to place stock in a paddock thus sprayed even a month or two after'.[15] On the other hand, he was sceptical about reports of fruit trees dying in the USA from repeated arsenic use, suggesting it could be sprayed 'for centuries without injuring trees'.[16]

Locusts subsided in 1909 and most reports are indicative of grasshoppers.[17] But they returned in autumn 1910 and there were widespread swarms across the Central West, Central Tablelands, Southwest Slopes, Liverpool Plains and Riverina regions the following spring. For the first time,

[12] *Molong Express and Western District Advertiser*, 21 December 1907, p. 1; *The Sydney Morning Herald*, 27 November 1907, p. 3; *Western Champion*, 24 January 1908, p. 14.

[13] There were also reports from Bourke, Louth, Collarenebri and Goodooga.

[14] *Clarence and Richmond Examiner*, 29 September 1908, p. 7, Wee Waa demonstrations.

[15] *Bega Budget*, 17 October 1908, p. 5; *The Australian Star*, 8 October 1908, p. 7.

[16] *Chronicle*, 6 February 1909, p. 7.

[17] *The Sydney Morning Herald,* 8 October 1908, p. 4; *Western Herald*, 30 January 1909, p. 7; Locust swarms persisted in the Narrabri area in January 1909, but in spring and summer the majority of reports are from the South Coast, Cooma, Goulburn, Taralga, Braidwood, Queanbeyan and Gundaroo areas; Froggatt collected several specimens of *A. cruciata* at Hay in November 1909 (Australian Plant Pest Database).

swarms persisted in some of the eastern localities almost continuously for three years. South Australia and Victoria were also affected by swarms during 1910–11, making the infestation in that year a plague.

Walter Froggatt and the great bird debate

The association of grasshoppers with certain insectivorous bird species had been noticed from the very first swarm reports in 1841 and it was repeated many times throughout the nineteenth century.[18] The decline, or even the threat of extinction, of some species had been linked to ideas of a disruption to the 'balance of nature' since the 1870s and overseas examples of insect plagues occurring as a consequence of bird destruction were frequently cited.[19] Entomologists were first drawn into a controversy over whether the apparent increase in insect pests was the result of bird deaths caused by legislated compulsory rabbit poisoning during the 1907 locust plague. There was a growing belief among farmers and newspaper commentators that the wholesale spreading of phosphorylated pollard baits and the ubiquitous use of the 'poison cart' was the indirect cause of the increase in grasshopper swarms.

The locust scourge

I was out at Tomingley, 24 miles from here, some days ago … They have eaten everything before them, and when they are going strong they are in countless millions, like a huge dust or snowstorm. People on each side of a street can barely discern the houses on the other side. The grasshoppers will be flying through town for days, and have a frontage of 4, 5, or 6 miles, while millions are in the air 25ft to 50ft high. The earth is like a moving mass. All agree that this is the worst visitation out this side.

The Raleigh Sun, 20 December 1907, p. 2.

The poison cart was introduced in 1895 when rabbits had cut hard into the landscapes and the incomes of farmers and graziers. It was soon part of the local agricultural machinery industry's offerings for 'scientific farming' and one manufacturer sold 7,500 carts by 1915.[20] From 1909, however, the failings of the rabbit poisoning program and its negative consequences in causing bird deaths received greater prominence in rural and city newspapers alike. Farmers in parts of NSW were opposed to the use of poison baits for rabbits and some refused to use them. PP Boards made numerous prosecutions

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[18] *Australasian Chronicle*, 30 April 1842, p. 2.

[19] *Riverine Grazier*, 29 September 1875, p. 4.

[20] The poison cart was a regularly advertised agricultural implement from 1905. A single model by Sydney manufacturer Fortescue, the IXL, had sold over 7,500 units by 1915; *Freeman's Journal*, 15 April 1915, p. 21; *The Land*, 1 March 1918, p. 5; *Sydney Mail*, 14 April 1909, p. 15, machinery displays were described as a centre for those interested in 'scientific agriculture'; *Murray Pioneer and Australian River Record*, 8 March 1918, p. 5, not only did individual landholders purchase them but some Councils obtained them to be let-out to farmers; *The Bathurst Times*, 21 September 1918, p. 2, by 1918, however, in the Trangie district the poison cart had practically disappeared in favour of destruction of cover and digging out warrens.

under the state ‘Rabbit Act’ for failure to carry out control.[21] Most Boards defended the program, arguing there was little evidence of declining bird numbers, but there was a growing belief that the locust would remain a problem unless something was done for its natural enemies — the birds.[22]

Figure 7.4. Advertisement for the IXL poison cart, *Molong Express and Western District Advertiser*, 23 September 1905, p. 13.

In 1909, when the poison cart could be seen working in nearly every PP district west of the Dividing Range and locusts were swarming through many of them, the Chief Inspector of Stock queried the Boards on the effect of phosphorus baits on bird life. Many Boards were of the opinion there was no effect, but others were split by members who were convinced that the increase in grasshoppers was linked to the loss of birds.[23] Among the identified victims were magpies, from eating the pollard, and laughing jackasses (kookaburras), from eating dead rabbits.

The agricultural value of insectivorous birds was championed by newspapers and ordered lists of the most useful species were often compiled. Those representing rural subscribers usually placed the

[21] Newspaper references begin in 1908; *Western Champion*, 29 October 1909, p. 21, the Condobolin PP Board prosecuted 24 farmers for failing to control rabbits to the satisfaction of its Rabbit Inspector; The ‘rabbit act’ was an amendment to the Pastures and Stock Protection (Rabbits) Act 1900, No 37.

[22] *The Sydney Morning Herald*, 15 January 1909, p. 4, a ‘settled pest’; A. J. North, ‘The destruction of native birds in New South Wales’, *Records of the Australian Museum*, 4 (1), (1901) 17–21, Bird Protection Act, 1893- was ‘more observed in the breach’.

[23] *Dubbo Liberal and Macquarie Advocate*, 8 December 1909, p. 4, concerns were also expressed at Orange, Molong, Dubbo and Moulamein.

woodswallow, the bustard and the ibis near the top as destroyers of grasshoppers.[24] The crow and starling generated contentious exchanges. Both were observed to eat locusts, but the crow had a bounty on its head for killing lambs and there were divided opinions over whether the starling was the farmers' friend or foe.[25] There also appeared to be an imperative to report whenever starlings were seen eating locusts, perhaps to reaffirm the rationale for its original acclimatisation.[26]

Discussions intensified in NSW, which remained in the grip of persistent locust infestations during 1907–1913, and reverberated through all levels of society. Farmers felt they were now faced with a 'choice between the grasshoppers or birds'.[27] In the 1908 Presidential Address to the NSW Linnean Society, naturalist Arthur Lucas reportedly expressed belief in the causal link between the poison cart and the loss of useful birds, our 'native police'. He predicted 'an awful plague of locusts in the near future', ten times worse than the rabbits, 'if this suicidal practice is not stopped by public opinion or legislation'.[28]

Gundagai was invaded by locusts throughout 1911 and 1912. The mood of the local PP Board members was with the birds, despite the irony of maintaining the threepenny bounty on crows' heads. As millions of locusts 'emerged from holes just like the Bulgars', one member declared 'cursed be the man who invented laying poison in the paddocks for rabbits … and the so-called authorities can say what they like, but I'm fully convinced that the plagues we now suffer from are due to disturbing the

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[24] *The Sydney Morning Herald*, 2 January 1909, p. 5, those species often appeared further down the lists after various small species in urban lists. In a typical urban plebiscite of the '12 Best Birds', by William Sherrie, the population only selected the straw-necked ibis at number 8, and did not list any woodswallow species. In contrast, rural correspondents defended the straw-necked ibis and the 'blue-lark' as the pre-eminent insect destroyers, see *The Muswellbrook Chronicle*, 21 November, 1908, p. 2; *The Argus*, 26 December 1908, p. 6; *The Sydney Morning Herald*, 23 October 1915, p. 15, W. M. Sherrie, refers to the ibis in the Riverina; Many articles reworked the then famous evidence from the 1870s dissection sampling of a straw-necked ibis done in a Riverina swamp by Albert Le Souëf, Director of the Victorian Zoological Gardens, and cited in his son Dudley's books on Australian birds of 1909–1911. Examination of the crop had revealed 2000 young grasshoppers, and by extrapolation over a rookery of 240,000 birds, a huge daily grasshopper intake was derived by both numbers and weight.

[25] In numerous newspaper reports, supporters were keen to report observations of starlings eating locusts or grasshoppers. Even Froggatt, who had been against their release, was forced to admit it appeared they might be changing their habits in Australia, and becoming grasshopper predators; *The Farmer and Settler*, 15 November 1918, p. 7, Froggatt wrote that the semi-domestic starling was omnivorous and only occasionally ate young locusts, but should not be protected as it 'could thrive and increase at the expense of protected birds'.

[26] E. Deveson, 'Parasites, politics and public science: the promotion of biological control in Western Australia, 1900–1910', *British Journal for the History of Science*, 49 (2016), 231–258, p. 237.

[27] *Molong Argus*, 1 January 1909, p. 2.

[28] *Grenfell Record & Lachlan District Advocate*, 23 May 1908, p. 2, outgoing president, Lucas, had been active in the Victorian Field Naturalist Club prior to moving to Sydney in 1895.

balance of nature … we want a bird league in every centre and a law to prevent the loose way the land owner now puts out poison'.[29]

Native birds were now a 'national asset', a visible aesthetic symbol of the uniqueness of Australian fauna and for the growing conservation ethic.[30] Many species had legislative protection in all states and in 1913 the Commonwealth also gazetted lists of species protected for the whole or part of the year.[31] The widespread perception of birds 'disappearing with alarming rapidity' indicates the decline was real, at least in more closely settled areas, and it was being accelerated by tree clearing, foxes and feral cats.[32]

Like his contemporaries, Froggatt was a bird lover and there was 'no one more interested, from an economic and sentimental point of view, in their protection'.[33] In an article in the *Agricultural Gazette* of 1900, he recalled the 'wild turkey' that lived chiefly on locusts, 'once so common on the plains, now a thing of the past, on account of it eating poison wheat to kill the rabbits', but he suggested the crow had learnt to avoid the baits.[34] As an expert on both insects and birds, Froggatt's views were again sought but his answers were equivocal. He was decisive in asserting that insectivorous birds should be rigorously protected by legislation and education, but wrote that other birds, such as parrots, could be killed where they were pests, admitting that as a boy he had shot hundreds of cockatoos in the wheat fields.[35]

With the damaging, but then unknown, arrival of the sheep blowfly *Lucilia cuprina* into Australia, the anti-poison cause was further bolstered.[36] One prominent opponent of poisoning rabbits and sheep carcases to kill blowflies was William E. Abbott, a state politician who had a farm at Wingen east of the Hunter Valley.[37] The ideas in his 1913 book, *The Rabbit Pest and the Balance of Nature*, were

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[29] *The Gundagai Independent and Pastoral, Agricultural and Mining Advocate*, 27 November 1912, p. 4, 'said a district landholder'.

[30] W. H. D. Le Souëf, *Vanishing Bird Life*, (Melbourne, Bird Protection Court, 1913–23), p. 2.

[31] *The Urana Independent and Clear Hills Standard*, 8 August 1913, p. 5, protections were also partly in reaction to indiscriminate shooting and the boyhood craze of egg collecting, as well as the realisation that some species were threatened.

[32] *The Argus*, 30 August 1910, p. 6.

[33] W. W. Froggatt, 'Several aspects of the protection of our native birds', *Agricultural Gazette of New South Wales*, 20 (1909), 369–376, p. 369.

[34] W. W. Froggatt. 'Insects and Birds', *Agricultural Gazette of New South Wales*, 11, (1900), 437–446.

[35] *The Farmer and Settler*, 5 May 1911, p. 4.

[36] K. R. Norris, 'Evidence for the multiple exotic origin of Australian populations of the sheep blowfly, *Lucilia cuprina* (Wieemann) (Diptera, Calliphoridae)', *Australian Journal of Zoology*, 38 (1990), 635–638.

[37] Abbott was politically opposed to the existence of PP Boards. Two other prominent newspaper opponents of poisoning were Coleman Phillips, who wrote regularly from New Zealand and William Smith from

frequently aired in the press.[38] In his view the use of the poison cart had 'far-reaching and unpredictable effects'.[39] Citing the 'enormous increase in grasshopper swarms in every part of the state', Abbott argued that the decline in sheep numbers between 1911 and 1913, usually ascribed to drought, was in fact the result of grasshoppers and rabbits.[40]

The squatters and the blowflies. A fairy Tale and a prophecy

… The Froggatt's and their Blowfly Men
Have poisoned far and wide,
And all the birds that loved the bush
And wandered free have died.
The Blowflies only laughed and danced,
The gentle Squatters cried.

… And the rats and Mice and Grasshoppers and Caterpillars and Crickets and bugs and Beetles and Microbes all began to sing a new song, which has yet to be written for another generation of Australians.

W. E. Abbott and Lewis Carroll, 1918.

Abbott's later parody of Lewis Carroll's *The Walrus and the Carpenter* had Froggatt as the hapless stooge of the department's chemical programs, while the rabbits, grasshoppers and other vermin inherited the earth.[41] Defending himself, Froggatt said Abbott's views were based on 'local conditions', and made his own prediction that, as the 'conservation of water' in dams extended with inland settlement, 'instead of disappearing, birds will become more and more plentiful in these regions'.[42]

Both in the bush and the city there now appeared to be 'no disagreement among experts that the grasshopper swarms are the result of poison cart', but there were some who had seen swarms 'that no amount of birds could deal with'.[43] Again in 1914 the department wrote to the boards seeking views on the poisoning of birds. Some agreed with stopping rabbit poisoning but most felt they had no choice but to continue baiting, so the arguments continued.[44] Newspapers and naturalists maintained

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Currabubulla. Phillips claimed that he had solved the same problems in New Zealand by allowing the balance of nature to prevail, see *Sydney Stock and Station Journal*, 2 January 1914, p. 14; 5 January 1917, p. 16.

[38] William E. Abbott. *The Rabbit Pest and the Balance of Nature*, (Sydney, Angus & Robertson, 1913).

[39] Abbott 1913, p. 20, to support his ideas, Abbott claimed that, in not poisoning the rabbits on his own farm when they appeared in 1895, the native and introduced carnivores had prevented the rabbits becoming a problem.

[40] Abbott 1913, p. 7; *The Queanbeyan Age*, 15 July 1913, p. 4.

[41] W. E. Abbott (and Lewis Caroll), *The Squatters and the Blowflies: A Fairy-Tale and a Prophesy*, (Sydney, 1918), quotes from p. 5 and p. 8.

[42] *Sydney Mail*, 13 February 1918, p. 10, 'Are Our Insectivorous Birds Disappearing?'

[43] *The Sydney Morning Herald*, 23 October 1913, p. 6, Stock Inspector from the Hunter quoted; *The Sydney Morning Herald,* 12 December 1910, p. 6; *The Land*, 1 February 1918, p. 6, one farmer defends poison cart claiming he had never seen a dead bird.

[44] *Dubbo Liberal*, 24 February 1914, p. 4; *Sydney Stock and Station Journal*, 6 March 1914, p. 14; 31 March 1914, p. 2; *Queanbeyan Age*, 3 March 1914, p. 2.

the conservationist mood by linking bird loss with insect plagues, often quoting British parson-naturalist, James Buckland's 1912 lecture, 'The Value of Birds to Man'.[45]

Froggatt returned to the issue of birds and insects in 1917, but, in contrast to views he expressed in 1900, he maintained that huge flocks of woodswallows still appeared with the locusts and he even found a suitable historical reference to show that locusts had always been a problem.[46] Despite imposing heavy fines for killing protected birds, the government continued to enforce compulsory use of the poison cart. After the paradox of these positions was pointed out in the press, Froggatt disputed the 'emphatic assertions' that rabbit poisoning was responsible for the decrease of bird life.[47] Defending the state policy, he argued his own observations led him to believe the danger of poisoning was slight and, because it also killed reptile and marsupial predators, it had in fact benefited many birds.[48]

The NSW Hunter Valley: Gurney's unified locust control testing ground

> *Is Science Played Out?*
> *There is no class in the world that Science has done so much for as the Man on the Land…The State Government, in this connection, is trying to inaugurate a scheme for the field destruction of the grasshopper pest … It is pointed out that the fight against this pest has been very effective in several progressive countries, and that Science may achieve greater success as it carries on this war… Science is our only hope and should be encouraged.*
>
> *Northwestern Courier* (Narrabri, NSW), 3 August 1925, p. 2.

The Hunter Valley in NSW was infested during each of the four plagues between 1906 and 1922. In 1907 and 1908, the towns of Singleton and West Maitland were at the centre of locust swarming. Local agricultural institutions were then well established and the Hunter was a convenient rail journey from Sydney, so the entomologists made regular visits to engage farmers in monitoring egg laying

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[45] *The Argus*, 26 July 1913, p. 6; *The Register*, 20 January 1914, p. 10; *The West Australian*, 8 October 1913, p.10; *The Farmer and Settler*, 6 January 1914, p. 2.

[46] W. W. Froggatt, 'Destruction of bird life', *Agricultural Gazette of New South Wales*, 28 (1917), 75–79, Froggatt cited Finney Eldershaw, *Australia as it Really Is*, (London, Darton, 1854), p. 46, 'the locust is prolific... a serious inconvenience to the settler'. Eldershaw (p. 142) was talking about 1842, when he travelled to the Darling Downs in southern Queensland, and may have encountered those reported in the Namoi Valley; *Sydney Mail*, 13 February 1918, pp. 10, 23.

[47] *The Sydney Morning Herald,* 24 October 1917, p. 9, the levy of 'heavy penalties for those who kill protected birds does not fit with the poison cart'; *The Sydney Mail*, 13 February 1918, p. 10, Froggatt defends his position, saying most opponents, because of restricted outlook and experience, were undoubtedly wrong.

[48] *Sydney Stock and Station Journal*, 30 October 1917, p. 4.

and hatching of each generation.[49] The region suffered persistent infestations in most years until 1925 and it became the focus for tests of organised collective landholder actions using arsenic sprays.

Locusts during the First World War

"*A WAR OF MACHINES*"

Automatic Death Dealers – Suffocating Shell Fumes.
Only machines ingeniously constructed to destroy men as locusts have to be destroyed when they sweep over fertile land … could carpet the earth with dead in this frightful way.

The Maitland Weekly Mercury, 14 November 1914, p. 6.

The Great War for Civilisation disillusioned people's faith in civilisation's progress and any 'dream of universal peace'. On a more mundane level, even in Australia, far removed from the conflicts, it changed the metaphors used to describe nature and human behaviour. In 1915, while some Australian troops were still enjoying themselves in Egypt, they wrote home about things strange and new, including the locust swarms that made 'our grasshoppers' pale in comparison. In the midst of the conflicts, there was a locust plague in Palestine causing crop failure and 1915–16 came to be known as 'The Year of the Locust'. In the press the wanton actions of warring humans were painted as successive locust plagues and the enemy as 'the Hun locusts'. The movement of armies and the destruction in their wake was similarly likened to the behaviour of locusts. And the metaphor worked both ways, with locust damage in Australia also now likened to the passage of regiments of 'Huns'.

Even before the outbreak of hostilities a new popular vision had emerged, likening the relationship between humans and insects to war. In 1913, the 'greatest battle in world history' was already being played out against locusts in South Africa. By 1915, essayists in Britain sensationalised the threat insects posed for the very survival of humanity. Articles like 'The Next Great War — Man Versus Insects', propounded humans' historical rivalry with the arthropod for the mastery of the planet. Prominent US entomologists Stephen Forbes and Leland Howard helped popularise 'insects as the enemy' to be exterminated. After the war, Howard declared 'Another World War' against insects, and the call was repeated in the Australian newspapers, along with his metaphor of a 'trained army of 400 men' using chemical means of warfare against the insects that fight in billions. Seeing insects as the enemy came easily to farmers and urbanites alike, and this was coupled with the start of mechanised industrial agriculture involving large area cropping, regular use of arsenic insecticides and the adoption of aircraft for crop dusting.

[49] *The Sydney Morning Herald*, 18 March 1908, p. 6; *The Farmer and Settler*, 21 April 1911, p. 3.

Figure 7.5. West Maitland in 1907 (State Library of NSW, image A116602r).

William Butler Gurney (1882–1939) was appointed as Froggatt's assistant entomologist at age eighteen in 1900.[50] Youth entry into the professional stream of the department could then be gained through cadetships and many later entomologists also joined as cadets. Like Froggatt, Gurney was a naturalist with a wider view than pest insects. At a meeting of the Naturalists' Club in Sydney in 1909, he gave a forward-looking lecture on the need for a comprehensive biological resources survey of the entire state like in other advanced countries.[51] He studied part-time for a Bachelor of Science degree, which he completed in 1925 after succeeding Froggatt as Government Entomologist. Gurney was involved in locust investigations for most of his career and also worked on the release of potential biological control agents for other pests in the 1920s.

At the height of World War I, people were preoccupied with the events overseas. In early 1917, locust swarms spread right across NSW, northern Victoria and South Australia, described in a typical

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[50] William Gurney was born the youngest of five children, at Waterloo, Sydney, in 1882. The family had moved from Melbourne in 1879. His father's stated profession was civil engineer. His oldest brother E. H. Gurney had been with the Department as Assistant Chemist since 1897. Little is known of William's early life or interest in entomology.

[51] *The Sydney Morning Herald*, 6 November 1909, p. 13.

metaphor of the time as passing over the country ‘like a regiment of Huns’.[52] The subsequent bands of nymphs in March stopped trains on the Broken Hill line to Peterborough in South Australia, where up to a third of crops were lost to the locusts. This was a forgotten plague in some subsequent historical reviews. Gurney identified the events as a plague, but was only aware of its extent in eastern NSW.[53] It continued the following spring and into the summer of 1918, but collapsed during drought conditions in 1919.

Swarms entered the Hunter Valley in February 1917. After a large spring generation, a second emerged in January 1918, in numbers that had ‘never been seen before by the oldest inhabitants’ of Singleton.[54] Calls for government assistance met with the offer to send an expert on a tour of ‘personal inspection’ to recommend the best means of coping with the pest.[55] Gurney arrived in April, with a plan for an organised landholder response. He started with public addresses calling on farmers to identify and plough autumn egg beds and followed with demonstrations of arsenite of soda spraying.[56] Stock Inspectors would be the district monitors of locust activity and report to the department. He returned in September 1918 and supervised toxicity tests of sprayed pasture on livestock and prepared a report of the findings. However, locust populations crashed in drought conditions of the 1919–1920 El Niño.[57]

With the return of wet conditions there was another locust plague during 1921–22, affecting much of NSW, northern Victoria and agricultural districts of South Australia. Swarms swept into the Hunter Valley in February 1921.[58] They overran the Hunter River towns of Scone, Aberdeen, Muswellbrook and Singleton and flew south over hilly country into cleared valleys at Mudgee and Rylestone. For hours on end ‘wave after wave of grasshoppers, so dense as to resemble travelling sheep in the

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[52] *Young Witness*, 3 April 1917, p. 2, in the Wilcannia district a plague of grasshoppers passed over the country ‘like a regiment of Huns’.

[53] K. H. L. Key, ‘The regional and seasonal incidence of grasshopper plagues in Australia’, *C.S.I.R. Bulletin No. 117*, (Melbourne, 1938), p. 19.

[54] *Singleton Argus*, 28 February 1918, p. 2

[55] *Bathurst Times*, 16 January 1918, p. 2; *Northern Star*, 21 January 1918, p. 8.

[56] *The Maitland Daily Mercury*, 16 May 1918, p. 6.

[57] *The Maitland Daily Mercury*, 7 October 1918, p. 2; *The Sydney Morning Herald*, 8 November 1918, p. 5.

[58] Meanwhile there were good rains throughout the inland in 1920–21 and 1921–22, associated with a La Niña period from 1921–1923; Locusts also infested the Riverina, Central West, Far Southwest, Northwest (Narrabri and Liverpool Plains) regions of NSW, northern Victoria and South Australia (where they were identified by Lea), setting the scene for widespread spring infestations; *Brisbane Courier*, 26 October 1921, p. 6, the 1921–22 plague also involved the Queensland Darling Downs, where the locust was identified by Tryon.

distance' flew through Scone.[59] In March, Gurney watched as a single swarm passed over Singleton for four days and in April swarms reached the outskirts of Newcastle.[60]

The colours of arsenic chemistry

Arsenic compounds were first tested as insecticides in the 1870s and by the 1890s they were widely used in orchards in the USA and Australia. Popular names reflected their original use as dyes. Early trials with London Purple gave way to Paris Green and white arsenic, in turn supplanted in the early 1900s by lead arsenate, which was used widely in agriculture and stock management.

Arsenic, bran and molasses baits were first used on grasshoppers in the USA in the 1880s Arsenite of soda (Sodium Potassium arsenite) became the preferred ingredient for preparing sprays and baits for grasshoppers and locusts in the Australian states after 1912, following the trend set in South Africa and the USA. The arsenite could be produced by boiling white arsenic with washing soda.

Farmers already anticipated that some 'scientific' weapons used in the Great War, such as poison gas and flame-throwers would soon be turned against the pests here, as they had been overseas.

Gurney planned a coordinated response for the following spring that would be a real test of collective action as a public good.[61] It would involve landholders, the Primary Producers' Union, the Pastoral and Agricultural Associations (PAA), the district PP Boards and department Stock Inspectors. Having seen the experts come and go for a decade, members of the PAA thought Gurney's visit 'would not do much toward eradicating the pest'.[62] Hatchings commenced around nearly every Hunter town in

[59] *Singleton Argus*, 17 February 1921, p. 2.

[60] *Singleton Argus*, 12 March 1921, p. 3; *The Sydney Moring Herald*, 25 March 1921, p. 3; *Maitland Mercury*, 13 April 1921, p. 7, swarms were reported at Stanhope and Hillsborough, now outer suburbs of Newcastle.

[61] *Singleton Argus*, 19 March 1921, p. 7, Gurney recommended spraying the autumn bands.

[62] *Muswellbrook Chronicle*, 16 April 1921, p. 2.

September and Stock Inspector, Mr Brooks, announced that arsenic spraying must be carried out by all landholders on whose properties eggs were laid.[63]

In September 1921, Gurney's new assistant, Timothy McCarthy, came to the Hunter and called for united action, saying 'it only means every farmer doing his bit' to get rid of the serious menace.[64] Grasshopper Destruction Committees were formed in the affected townships to organise spraying from fire-carts and share experiences via telephone, while local businesses supplied pumps and arsenic at reduced rates through the PP Boards.[65] Spraying was conducted throughout October and November, with considerable public pressure put on farmers to contribute.[66] The vocal Primary Producers Union announced it would seek compensation for all affected farmers who had obtained spray equipment, but the Minister's position was one of 'self-help', stating that any monetary aid would require a clear demonstration of concerted action by farmers and would only be given where the problem was national rather than local.[67] This drew an angry response from the Union, considering the public efforts of members.[68]

A second generation of nymphs appeared in some places in December and another round of spraying ensued.[69] However, very few swarms formed in early 1922 and by March McCarthy could find only one place where eggs were laid, confirming the view that the collective action had been successful.[70] Froggatt declared it showed that, with even more effective cooperation, invasions of the Hunter Valley could always be controlled and perhaps entirely prevented.[71] The notion of 'control', as the power to direct the course of events, entered the locust response vocabulary during the 1920s, coinciding with the organised insecticide programs. To achieve this control Gurney was recommending a light spray of arsenite of soda, which killed by both direct contact and ingestion, and a barrier of bran bait, mixed with Paris Green or white arsenic and treacle, around cultivation.[72]

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[63] *The Muswellbrook Chronicle*, 30 September 1921, p. 2; hatchings were reported at Aberdeen, Denman, Maitland, Singleton, Muswellbrook, Scone, Broke and Mudgee; *The Muswellbrook Chronicle*, 16 September 1921, p. 2.

[64] *The Muswellbrook Chronicle*, 23 September 1921, p. 2; 30 September 1921, p. 2.

[65] *The Muswellbrook Chronicle*, 7 October 1921, p. 2; *Maitland Mercury*, 11 October 1921, p. 6.

[66] *Singleton Argus*, 18 October 1921, p. 4; *The Sydney Morning Herald*, 30 December 1921, p. 5, Froggatt reported on the success of directly spraying rather than ahead of the bands; over 5,000 acres of arsenite of soda sprayed at Belltrees.

[67] *The Farmer and Settler*, 28 November 1921, p. 8.

[68] *Singleton Argus*, 24 November 1921, p. 2.

[69] *Singleton Argus*, 22 December 1921, p. 1.

[70] *Singleton Argus*, 11 March 1922, p. 3.

[71] *Sydney Stock and Station Journal*, 29 December 1922, p. 16.

[72] *Hillston Spectator*, 16 April 1925, p. 3.

Department objects for 'grasshopper' committees:

1. To enlist the help of every landholder in carrying out … control

2. To make themselves familiar with the methods of control suggested by the Dept. of Agriculture and disseminate such information

3. To receive reports and give warnings to all landholders in the district

4. To establish a fighting fund by subscription to carry out control work on places not under direct supervision, such as roads, reserves etc.

5. To obtain spraying materials in bulk and retail it to landholders at cost price.

Singleton Argus, 22 January 1925, p. 4.

The 1924–26 infestation affected the same regions as in 1921, although it was largely restricted to eastern NSW. Also like 1921–22, it was also associated with a La Niña event.[73] Once more there were heavy infestations and organised arsenic spraying in the Hunter Valley and again the issue of legislating for compulsory control received institutional attention. The 1925 'Farmers and Settlers Conference', attended by Country Party leader Earle Page, called on government to convene a conference of all stakeholders to find a solution.[74] There was consensus that the NSW government should act on locusts, but just how that would be best achieved was contentious. Suggestions included amending the noxious pest legislation, appointing a responsible authority and making landholder control compulsory. It was argued that by declaring locusts 'noxious animals' the PP Boards could levy a rate to assist with control operations. A levy on rateable land area seemed fair because egg beds occurred 'proportionally in one of each 500 acres'.[75] However, the Graziers' Association and most PP Boards were still against legislation to make landholder control compulsory.[76]

In 1925, the Minister for Agriculture directed the PP Boards to consider the government entomologist's suggestions for achieving organised collective control. At their annual conference, there were resolutions to declare 'grasshoppers' a noxious animal under the Pastures Protection Act, to make notification of infestations compulsory and to levy rates on owners and occupiers to fund grasshopper control.[77] All those proposals were enacted in the following decade and they remained the general framework for locust responses in NSW for the rest of the century.

[73] The 1921 infestation also extended north to Moree and Walgett.

[74] *Daily Advertiser*, 8 August 1925, p. 4.

[75] *Sydney Stock & Station Journal*, 16 September, 1921, p. 11.

[76] *The Farmer and Settler*, 3 July 1925, p. 11; *Muswellbrook Chronicle*, 2 October 1925, p. 6.

[77] *Western Star*, 10 October 1925, p. 5; *Maitland Mercury*, 7 July 1925, p. 10.

Arsenic and bird poisoning return with the 1928 locust 'recrudenscence'

> *'POISONING OF HOPPERS MEANS DEATH TO BIRDS'*
> *The farmers are in a difficult position for, in endeavouring to eradicate the grasshopper pest, they are also destroying their native birds, some of the best co-workers in keeping the hopper pest in check.*
>
> *Cootamundra Herald*, 29 October 1928, p. 1.

Some agricultural districts of NSW were beset by locust swarms almost continuously during the 1920s. Another sudden population upsurge occurred in the Central West at the start of 1928 and by February it had spread across much of the state. Widespread egg laying produced a massive nymph generation in March and the resulting swarms caused alarm among farmers who were preparing to sow wheat. There were 'remarkable scenes' in the Riverina. Farmers who had plenty of feed after the heavy rains in February were 'eaten out' in a day.[78] Locusts roosting on wire-netting fences were so dense they looked 'like hessian bagging', while at Temora 'a plague three miles wide and extending back for nearly twenty miles' was approaching Junee.[79] Swarms were still damaging emerging wheat crops in May and June.

The NSW department Entomology Branch prepared the first map of where the swarms had been to predict spring infestation areas, and these stretched from Coonamble to the Murray River.[80] After warnings about the scale of the anticipated outbreaks, landholders made preparations for baiting and arsenic spraying. The coordination of local agricultural groups was strengthened by the formation of 'Grasshopper Destruction Leagues', whose members were mostly farmers. Shire councils and PP Boards took responsibility for reserves and roads, and local bushfire brigades made trucks available for spraying.[81]

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[78] *Cootamundra Herald*, 11 May 1928, p. 1.

[79] *The Sydney Morning Herald*, 21 March 1928, p. 17; *The Week*, (Brisbane), 20 March 1928, p. 19; *Daily Standard*, 26 March 1928, p. 7.

[80] *The Independent* (Deniliquin), 20 October 1928, p. 2.

[81] Grasshopper Destruction Leagues were mostly organised by Farmers' and Settlers' Associations. Leagues were created in Gunnedah, Lockhart, Ganmain and Narrandera, with donations by members to purchase sprayers.

Grasshopper plague – formulae for destruction

Bran bait — Paris green 1 lb, Molasses 4 lb, Bran 24 lb.

… Care should be taken to scatter it in a finely divided state to prevent pellets or heaps. As it has not been proved definitely that the bait is harmless to stock when scattered in the manner recommended, it is important that stock should not be permitted … where the poison bran has been scattered until several days have elapsed to allow the bait to become dry and unattractive.

IMPRESS UPON YOUR NEIGHBOR THE NECESSITY FOR SPRAYING

West Wyalong Advocate, 2 October 1928, p. 4.

Departmental officers were at pains to point out that control was essential because the problem was hatching after local breeding in autumn. But there was still a widespread view that 'grasshoppers' flying in from 'further back' were the problem and without statewide action 'we just have to grin and bear it'.[82] Bands developed across the Riverina and Central West in spring, and farmers in many areas used the methods recommended in press statements and leaflets.[83] The department also supplied spray pumps on loan, and arsenic and molasses for distribution at cost, but the Minister claimed it would be impossible to defray the entire cost of a statewide campaign.[84]

More than the damage to crops, it was observations of birds destroying the 'grasshoppers' that featured in newspaper reports. Flocks of dusky woodswallows, *Artamus cyanopterus* known as 'blue martins' or 'martens', were prominent in many areas, followed in places by ibis and starlings. The grassroots ecological dissent against arsenic poisoning of 'grasshoppers' re-emerged and there were numerous champions for the birds. From Tamworth it was reported that no ibis had been seen since the poisoning and a Narrandera alderman reported seeing 'a great number of dead birds where poisoning had been carried out'.[85] Sensitivities were heightened after European scientists attributed the decline in stork numbers in Germany and Holland to the poisoning of locusts in South Africa, where whole flocks were reportedly killed.[86]

The defence of the birds was most strident in the Riverina, where large flocks of dusky woodswallows appeared with the 'grasshoppers'.[87] From Barellan one correspondent wrote 'has anyone enquired, or is it anyone's business, whether martens will eat arsenically poisoned grasshoppers and so perish? …

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[82] *Western Champion*, 10 September 1928, p. 1, views expressed at a meeting of the Parkes Agricultural Bureau attended by several local branches and agricultural instructor Harold Bartlett.

[83] *West Wyalong Advocate*, 2 October 1928, p. 4; *Canberra Times*, 3 February 1928, p. 5, experiments by H. R. Seddon, director of Veterinary Science at CSIR, concluded that bait should be spread not pelleted, that Paris Green should be discontinued because of the colour and that stock should be excluded for at least two days.

[84] *The Farmer and Settler*, 5 October 1928, p. 10.

[85] *The Land*, 5 October 1928, p. 16; *Narrandera Argus and Riverina Advertiser*, 26 October 1928, p. 1.

[86] *The Farmer and Settler*, 24 June 1927, p.19.

[87] Flocks of blue martins were reported devouring grasshoppers from Wagga, Hay, Bodangera, Narrandera, Leeton, Lockhart, Junee, Young, Boree Creek and Tichborne.

surely a day of wrath is storing up for the agriculture department which advises the spray'.[88] And from Lockhart, 'I saw 2,000 bluejackets doing more good than I could do with the spraying … I may destroy the little willing workers and I am not about to do them out of a job'.[89] The PP Board spraying in the Wagga area was halted because of the birds' good work, while at Narrandera it was said that spraying had been unnecessary because the woodswallows had consumed all the locusts.[90]

The question of bird poisoning was put to the Legislative Assembly. The subsequent report from the Minister stated there was nothing to prove birdlife was being destroyed and even if a few birds were killed it would not justify ceasing the campaigns.[91] The entomologists also defended the policy which they had formulated. McCarthy wrote 'that if any great reduction of birdlife had been caused by poison, it was due entirely to the use of the poison cart … birds always preferred live hoppers … and rarely picked up those killed by spray or baits'.[92] In a similar vein, the *Sydney Mail* quoted a practical-minded farmer's wife, who said 'no blue martin would eat a dead grasshopper when a live one was in range'. They took most on the wing and apparently enjoyed taking the insects on the hop, while poisoned hoppers quickly became dried and mummified.[93]

The issues in the bush prompted Froggatt to return to public commentary on the locust problem.[94] He stressed that it was a community problem and all landowners should act together to kill the locusts in their early, vulnerable stage. On the most pressing public issue of birds he wrote that 'insectivorous birds have a good time in a locust season', recalling how in 'the old days' flocks of bustards crossed the Murray River soon after the locust swarms reached the Victorian plains. And addressing 'bird lovers' troubled about the poisoning of insectivorous birds, 'even if they did eat some dead locusts the amount of arsenic is so minute it is not likely to affect them, while where locusts are being poisoned there are always plenty of live ones on the ground or on the wing'.[95]

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[88] *The Sydney Morning Herald*, 12 October 1928, p. 13.

[89] *Lockhart Review*, 9 October 1928, p. 5.

[90] *Daily Advertiser*, 28 October 1928, p. 2.

[91] *Daily Advertiser*, 29 November 1928, p. 2, Mr Bruntnell, Member for Wagga, tabled the report after having put the question to the Assembly.

[92] *Farmer and Settler*, 12 October 1928, p. 14.

[93] *Sydney Mail and NSW Advertiser*, 21 November 1928, p. 40.

[94] *The Land*, 26 October 1928, p. 4, Froggatt's description of the 'small brown and yellow grasshoppers' that had spread over hundreds of miles of the northwest in late 1926 seem to refer to *A. cruciata* and probably recall 1927, which suggests a disconnection with the locust situation in 1928.

[95] *The Sydney Morning Herald*, 1 December 1928, p. 6.

The locust poisoning campaign heightened the growing mood for preservation of native wildlife, particularly birds and their remaining forest habitats. Newspapers were swamped by questions over the damaging effects. While some saw the birds and poisoning as both inadequate in the face of a plague, others viewed them as a combined effort.[96] One correspondent noted that '… scientific workers pin their faith on spraying them as they emerge – but those methods cannot cope with what happened in the central west and southwest districts … had it not been for millions of blue martens in October and November, very heavy damage would have happened'.[97] There was also much interest in the smaller enemies of the locusts. Nymphs were reported dying in millions in some locations. At Forbes, Lockhart and Moombooldool, maggot parasites and tiny wasps were destroying thousands. In some places, even the threadlike internal nematode parasites were observed.[98]

Insect kills grasshoppers

Many farmers, especially in the Moombooldool district, are jubilant over the fact that young grasshoppers are dying by the thousand. They attribute the hasty despatch of the threatened plague to a little wasp-like insect which stabs the 'hopper behind the fast growing wings and deposits a tiny egg. A quickly maturing grub completes the act of death. In other parts of the district farmers are alarmed at the army of hoppers appearing, and hope for a visit of the Moombooldool fairy. The use of poison for the hopper may be very effective, but it will be just as effective on the flock of blue martins and starlings to be seen greedily devouring the young hoppers in every part of the district.

Murrumbidgee Irrigator, 26 Oct. 1928, p. 6.

Despite the best efforts of the birds and the farmers, swarms formed and drifted east as far as Eugowra and south to Jerilderie, but locusts disappeared after December and there were no further reports in NSW. The twelve month period to July 1929 was one of the driest on record in the south-east.[99] The entomologists had no real alternative to arsenic insecticides if they were to be seen to have a solution. On his return from a congress in the USA, Gurney reassured the public that 'our insect pests were no

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[96] *The Australasian*, 17 November 1928, p. 48; *Daily Advertiser*, 31 March 1928, p. 2, from Marrar, between Junee and Coolamon, there was a call to preserve the last patches of forest in the district for the birds.

[97] *The Australasian*, 5 January 1929, p. 40.

[98] *Murrumbidgee Irrigator*, 28 December 1928, p. 8, Forbes Branch, Farmers' and Settlers' Association, 'as many as four maggots in one grasshopper, while in the abdomens he found a thread-like worm, about half an inch long'. Cr. Griffiths on ibis, estimated he had 10,000 of these useful birds on his property in one day.

[99] http://www.bom.gov.au/climate/enso/lnlist/, The Bureau of Meteorology class 1928–30 as an anomalous 'dry La Niña' in the south-east, based on Niño 3.4 values; Joelle L. Gergis and Anthony M. Fowler. 'A history of ENSO events since AD 1525: Implications for climate change', *Climatic Change*, 92 (2009), 343–387, the authors found no accumulated proxy values to assign these years. They identify no La Niña years between 1923 and 1932 and give 1930 as a moderate El Niño; K. H. L. Key*, The Regional and Seasonal Incidence of Grasshopper Plagues in Australia. C.S.I.R. Bulletin No. 117,* (Melbourne, 1938), p. 22, in his reconstruction of events, Key found that reports ran from January to December 1928, and included most of localities identified in the newspaper reports; There were also some hatching reports in spring 1929 around Thuddungra, Whitton and Quirindi.

worse than those overseas' and the same grasshopper control methods were being used in the USA, Canada and Russia.[100] But the poisoning of birds continued to haunt the NSW entomologists in the 1930s. Gurney also had to defend arsenic bran baiting against concerns over poisoning of beneficial insects. He considered the vulnerable groups to be pests themselves, while predatory beetles and parasitic wasps were not 'specially attracted to either the poison bran or the poisoned insects'.[101]

Newman grapples with grasshoppers in Western Australia

By the 1920s, Leslie Newman's time was increasingly taken up by the 'locusts' that became a serious problem as more country east and north of Perth was cleared. The swarms in the Murchison, Geraldton and Midlands districts during the drought of 1914, when the scarce pastures were eaten by grasshoppers, began a series of infestations in the 'northeastern wheatbelt' that became an increasingly widespread annual event during the 1920s. In the spring of 1922, just as clearing and ringbarking was opening up new cropping areas in the semi-arid country around Merredin, grasshopper swarms appeared at Kunopoppin, Bruce Rock, Trayning, Nungarin, Bencubbin and Merredin, as well as in the Murchison district.[102] Newman was dispatched to investigate and mistakenly identified the species as the Australian plague locust. He described the known biology of *C. terminifera*, which didn't completely match with the insect he had observed. But he did notice that swarms were prevalent on bare ground in ringbarked 'Morrell' woodland country that hadn't yet been turned under the plough.

The increase in grasshopper swarming paralleled the expansion of WA wheat farming during the 1920s. Newman identified the problem becoming worse from 1922, at the same time as the Director of Agriculture, G. L. Sutton, launched an 'Increased Yields' campaign.[103] Newman was called in to be the scientific support on a conference tour to promote the program. The government took a technocratic approach to the grasshopper problem as well as the issue of unreliable rainfall. The state wheat acreage grew from 650,000 to 2 million hectares during the 1920s and wheat production doubled between 1924 and 1929 as government-sponsored land subdivisions and loans boosted the industry.[104]

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[100] *The Land*, 2 August 1929, p. 2, Gurney attended the 4th International Congress of Entomologists in New York, USA.

[101] *Burrowa News*, 18 June 1937, p. 5.

[102] *The West Australian*, 16 August 1922, p. 6.

[103] *The West Australian*, 18 July 1923, p. 7.

[104] Ruth A. Morgan, *Running Out: Water in Western Australia*, (Perth, University of Western Australia Publishing, 2015), p. 65.

Figure 7.6. Experimental wheat crop at Merredin, 1924 (State Library of Western Australia).

Newman looked overseas and interstate for experience and remedies at a time when arsenic sprays and baits were almost universally used. His trials with baits of Paris Green, bran and treacle killed many grasshoppers and the baits were considered less difficult and less destructive than sprays. However, the RSPCA immediately challenged the baiting program for poisoning insectivorous birds and therefore making the situation worse by destroying natural controls on grasshopper populations.[105] Without an alternative, Newman continued to recommend using baits, but also advocated shallow ploughing of egg laying sites.[106] In the badly affected new croplands at Kunupoppin in 1923, he again demonstrated arsenic baiting to encourage farmer participation and supporting reports of 'millions killed' came from surrounding districts.[107]

[105] *The West Australian*, 30 October 1922, p. 8.

[106] *The Daily News*, 24 April 1926, p. 9; *Sunday Times*, 8 March 1925, p. 31; *The Daily News*, 2 May 1925, p. 4.

[107] *The Register*, 7 November 1923, p. 14; *The West Australian*, 14 July 1925, p. 6, Newman and an assistant killed an estimated 2,800,000 hatched 'locusts' on one acre.

Like the NSW entomologists, Newman returned to Kunupoppin in 1924 with a plan to coordinate unified collective actions, by recommending the South African model of organised 'farmer circles'. The plan included the department purchasing bait materials and making them available at cost through local stores. The WA department took the issue of ensuring participation on all affected farms further than the eastern states, having provisions in its Plant Diseases Act to impose penalties for failing to control.[108] Bencubbin farmers even suggested claiming compensation from the 'neglect of neighbours', particularly properties under the control of the Agricultural Bank.[109] They thought this was necessary because of the number of properties cleared and then left abandoned. In the face of a worsening grasshopper situation, agriculture minister M. F. Troy toured the region and saw first-hand the damage done to crops.[110]

Government makes war on locusts

Mr. Newman interestingly shows in a leaflet on the Plague Locust, how interference with the course of nature brings its own punishments ... The clearing of the timber and scrub belts has reduced the insectivorous bird life which, under natural conditions, acted as a check or barrier and confined the pest more or less to given areas. By ring-barking large areas of timber years before the land has been cultivated, we have created open grassed country, which makes ideal laying grounds for the locust. So we see the progression - trees, to birds, to locusts ... High on the list of suggested methods of making war on the locusts, is the exhortation to so-called sportsmen, not wantonly to destroy insectivorous birds.

Daily News, 7 October 1935, p. 6.

Again in 1925 Newman had a 'campaign of war mapped out' for July, when hatchings commenced, to October, when eggs were laid.[111] In 1925, the pattern of swarms appearing in newly-cleared farming areas was repeated again, with swarms expanding into the Wilgoyn, Westonia, Muckinbudin, Bullfinch and Southern Cross districts. Newman noted that as settlement 'pushed out to the north and east, it encroached upon the locusts' natural breeding grounds. Ringbarking and clearing created artificial bare areas and reduced the natural barriers to their movement.[112]

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[108] *The West Australian*, 12 August 1924, p. 5; *Western Mail*, 4 September 1924, p. 7, Newman intended to implement the South African cooperative system of 'farmer circles' in which elected local chairmen of the were given power under the Plant Diseases Act to report where necessary controls were being neglected. The Department could then enter the land and charge the cost of any control to the landowner; *Toodyay Herald*, 28 November 1925, p. 5, failure to control could carry a penalty of £100; *The Daily News*, 29 July 1925, p. 3.

[109] *Western Mail*, 4 September 1924, p. 7, complaints that the insects breed in abandoned farms controlled by the Agricultural Bank; *Kalgoorlie Miner*, 8 October 1924, p. 1, one reason given for the number of abandoned farms was a 'land grab' resulting from easy loans for 640 acre farm blocks.

[110] *The Daily News*, 21 October 1924, p. 5.

[111] *The Daily News*, 15 July 1925, p. 4; *The Daily News*, 29 July 1925, p. 3, hatchings reported in July; *Western Mail*, 28 July 1932, p. 43, Newman writes eggs were laid from October.

[112] L. J. Newman, *Journal of Agriculture Western Australia,* 7, (1934), p. 545.

Watching the 'locusts' increase as the landscape was transformed, Newman developed a view of environmental causes which he explained in several articles in the state agricultural journal. The fact that they were absent from timber country, that breeding was concentrated on bare ground in recently ringbarked areas, and that abandoned uncultivated farms were readily infested, led him to conclude that tree clearing not only reduced insectivorous bird life it also created the open grassed country favoured by the 'locust'. He recommended cultivating land soon after clearing and went so far as to predict that when 'all ringbarked country is brought under the plough the locust problem would disappear'.[113]

Newman identified the species in all the WA infestations as the locust, *C. terminifera*. However, the single annual generation, the early timing of emergence and egg laying, as well as descriptions and photos of the courtship behaviour in his official reports, show that the insect was the grasshopper, *A. cruciata*.[114] The reason for the misidentification is unclear, since entomological confusion over the difference was largely resolved in the eastern states, but it appears there were no east-west exchanges of Orthoptera specimens between 1915 and 1935.[115]

1925 was an exception to the grasshopper years however, with *C. terminifera* swarms flying into the Avon Valley in March, after the usual spring grasshopper 'outbreak' further east.[116] Nymphs developed the following spring at York, Beverley and Northam. The autumn arrival and hatchings as late as October indicates they were locusts.[117] Newman attributed this event to the unusual summer rainfall, but did not comment on the autumn appearance or late hatchings.[118] Their appearance simply contributed to the view of a growing annual menace and that 'the locusts are spreading'.[119]

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[113] *The Daily News*, 29 July, 1925, p. 3.

[114] L. J. Newman, 'The Plague Locust', *Journal of Agriculture Western Australia,* 1, (2nd series), (June 1924), 199–208.

[115] Newman corresponded with the eastern entomologists over potential parasites, but exchange of collection specimens may have been limited to orchard pests. There might have been some residual antipathy from his department over the eastern entomologists' expertise as a result of the 'parasite war' precipitated by George Compere. Froggatt published the description of *Austroicetes* (as Pachytylus) in 1900, the same genus Lea had used for the WA pest in 1896. Newman's error was not corrected until Ken Key visited Perth in 1936.

[116] *Toodyay Herald*, 5 December 1925, p. 2, Newman reports swarms flew into Avon Valley last March after unusual summer rains; *Western Mail*, 5 March 1925, p. 5, Newman reports summer rains occurred throughout the locust infested areas; *The West Australian*, 26 May 1925, p. 4, one idea was that they had flown in from the Murchison.

[117] *Eastern Districts Chronicle*, 27 November 1925, p. 3; *Sunday Times*, 14 February 1926, p. 10.

[118] *The Daily News*, 7 January 1926, p. 5, given the general similarity between *Chortoicetes* and *Austroicetes*, had it been any other species, the difference is likely to have been noticed.

[119] *The West Australian,* 4 April 1925, p. 13.

At Kunupoppin again, in September 1926 Newman experimented with arsenite of soda powder as a way of reducing water carting costs and he reported rapid results.[120] Following good rainfall in that winter, he predicted there was unlikely to be a plague, but he warned farmers not to 'sit back and let things rip'. They should be on the offensive by plotting egg beds and cleaning up any hatchings.[121] It turned out to be a 'fantastic year for wheat' from Merredin to Southern Cross, but not for 'locusts'. There were only a few reports of crop damage.[122]

Grasshopper swarms returned in force to their usual haunts during the 1930s, spreading westwards and southwards and increasing annually in extent. Newman explained their spread as the result of the abandonment of more farmland after the crash in wheat prices in 1930. His solution was a state-funded program of ploughing neglected farmland that increased in area each year in parallel with the grasshopper problem. The area affected by grasshopper swarms increased further in the mid-1930s after several years of below average rainfall in the eastern wheat belt. Newman's assistant entomologist, Clee F. H. Jenkins (1908–1997), mapped the area affected by swarms during 1935–1937, along with isohyets of average and recorded rainfall to demonstrate that association (Figure 7.7). In 1937, the Agricultural Bank was contracted to plough 30,000 hectares of infested farms on land under its control. The grasshopper ploughing program peaked at 57,000 hectares in 1950.[123]

Environmental change and ecological views

After the Federation drought there was a return to alternating wet and dry periods in eastern Australia from 1906 to 1911 under a predominant La Niña influence. This was followed by drought years corresponding generally with El Niño years in 1914–15 and 1919–20, and wet years during the La Niñas of 1916–18 and 1921–23.[124] Wheat yields reflected these climatic fluctuations and so did the sequence of grasshopper and locust outbreaks. Locust plagues occurred in 1906–07, 1910–1911, 1917–18, 1921–22 and 1924–25. The clearing of forest lands in NSW created continuous open areas of habitat and potential 'routeways' for swarm movement through former forest barriers.[125] This not

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120 *Journal of Agriculture Western Australia*, 4, (1927), 101–104.

121 *The West Australian*, 12 October 1926, p. 24.

122 *Western Mail*, 7 October 1926, p. 11.

123 C. F. H. Jenkins, 'Grasshoppers and locusts in Western Australia', *Journal of Agriculture Western Australia*, 22 (1945), 322–333, p. 325.

124 Gergis and Fowler 2009, Table 10, p. 375; Bureau of Meteorology, 'La Niña – Detailed Analysis', http://www.bom.gov.au/climate/enso/lnlist/

125 J. Magor, 'Outbreaks of the Australian plague locust (*Chortoicetes terminifera* Walk.) in New South Wales during the period 1937–1962, particularly in relation to rainfall', *Anti-Locust Memoir 11*, (London, Anti-Locust Research Centre, Ministry of Overseas Development, 1970), p. 33.

only allowed swarms to enter eastern valleys such as the Hunter more frequently, but to breed successfully after their arrival.

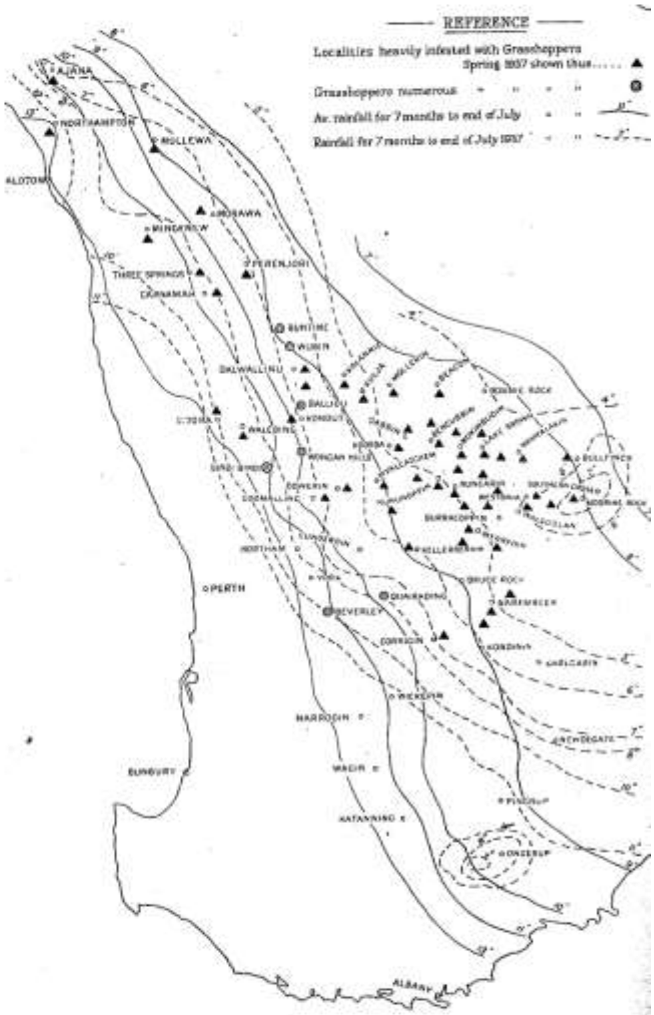

Figure 7.7. Grasshopper swarm locations in the WA wheatbelt, spring 1937.[126]

This eastward expansion of locust-affected areas in NSW was unprecedented. So was infestation frequency, which drew comment from many observers. However, while *C. terminifera* was the predominant species, in many eastern areas the total abundance was boosted by high numbers of other species of grasshoppers. There had also been a redistribution of sheep to the eastern half of the state in the first decades of the century. Prior to the Federation drought one-third were in the Western Division. Although NSW sheep numbers had returned to near 40 million by 1906, eighty per cent were now in the eastern half of the state and they were concentrated in some areas that became more frequently infested by locusts (Figure 7.8).

[126] C. F. H. Jenkins, 'The plague grasshopper', *Journal of Department of Agriculture Western Australia*, 14 (4), (1937), 367–380, pp. 374–376, the number of localities affected increased each year from 1935 to 1937.

The increase of *A. cruciata* swarming in WA occurred in opposite climatic conditions. Bad grasshopper years were those with below average rainfall. WA shared some El Niño droughts with the east, including 1896–1902, 1914 and 1918–19, but sometimes received a reprieve with an anomalous wet year, such as in 1900. The areas affected by swarms were directly related to the landscape changes that occurred with the growth of the wheat industry, but large areas of cleared land were subsequently converted to sheep grazing.

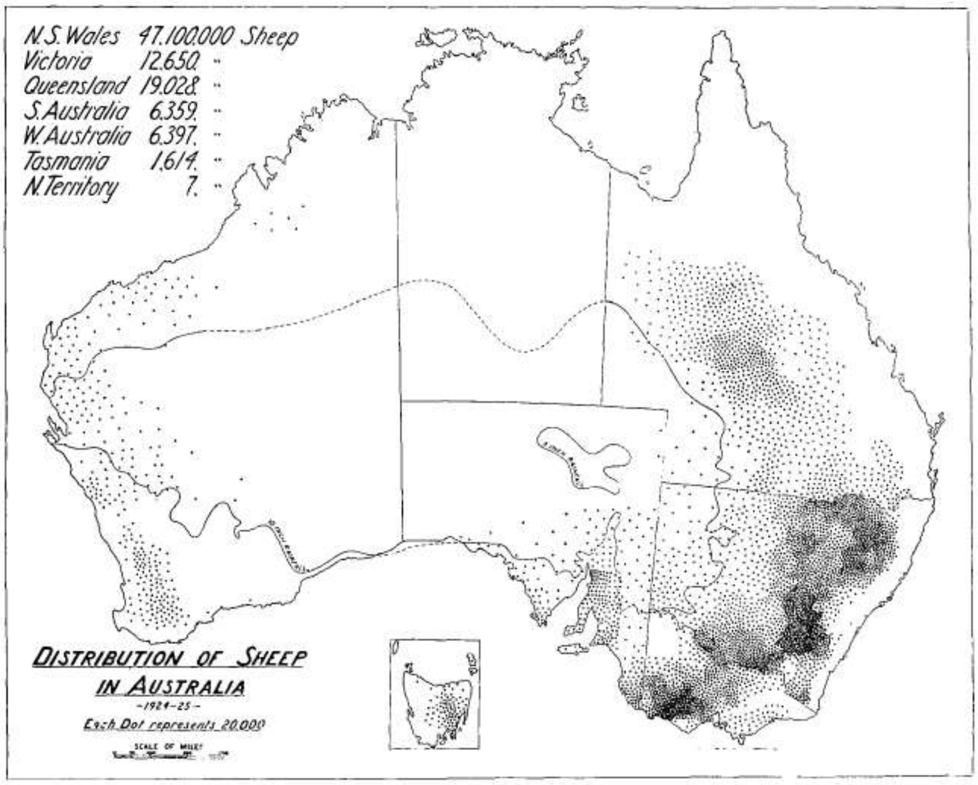

Figure 7.8. Distribution of sheep in 1924–25, *Yearbook of Australia 1929*.[127]

Ecological ideas about causes of the 'locust problem' were still framed by disturbances to the balance of nature. Froggatt likened the abundance of insect pests to a 'balance of power' between supply and demand by predator species.[128] Under altered conditions 'caused by destruction of forests, fodder and native grasses', pests may develop in great quantities. At the same time he believed that grazing

[127] *Yearbook of Australia 1929*, (Melbourne, Commonwealth Bureau of Census and Statistics), Chapter 16, 'Pastoral Production', p 659.

[128] W. W. Froggatt, 'Friendly Insects', *Department of Agriculture New South Wales, Farmers' Bulletin No. 34,* (1910).

country in the inland was in ‘exactly the same condition as when it was first leased by the pioneer squatters’.[129]

The cyclic nature of locust plagues was recognised, but there was a widespread view among the entomologists they resulted from dry conditions. This arose in part from comparisons with some overseas species, the failure to distinguish locusts from grasshoppers during some ‘plagues’ and the frequent arrival of locust swarms from the ‘hot dry interior’.[130] The entomologists identified that locusts had two or even three broods a year and that plagues tended to occur ‘about every five years’, but gregarious change was still ‘for as yet some unexplained reasons’ related to wet and drought periods.[131]

Given that several locust plagues had occurred in wet years, local impressions that the first decades of the twentieth century were dry and hot, and ongoing confusion over the identity of the locust and the grasshopper may have influenced the entomologists’ views.[132] Reflecting on earlier ideas that the locust problem would go away as more land was brought under cultivation, Froggatt now admitted that the locust was an insect that breeds in the desert or unoccupied land and flies to cultivated areas. There would always be uncultivated land in central Australia, so ‘we may expect this plague at any time’.[133]

The professionalisation of agricultural science in Australia

> *In presenting to the Legislative Council the second interim report of the Agricultural Select Committee, Sir Joseph Carruthers eloquently appealed for adequate recognition of science… Science is the miracle-worker, the great hill-climber, the obstacle over comer. Here in Australia insect and vegetable pests are robbing us of millions every year, yet what chance are we giving science to overcome them? A poorer chance than any other country would give! Mr. Froggatt stated in evidence that by the expenditure of about £20,000 something like £750,000 could have been saved our wheat pools from the ravages of pests.*
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> *The Sydney Stock and Station Journal*, 19 November 1920, p. 6.

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[129] W.W. Froggatt, ‘Locusts in Australia and other Countries’, *Department of Agriculture New South Wales, Farmers’ Bulletin No. 29*, (1910); *The Land*, 18 June 1915, p. 12; *The Farmer and Settler*, 8 August 1915, p. 6.

[130] *Wagga Advertiser*, 24 September 1909, p. 1.

[131] *The Farmer and Settler*, 8 August 1915, p. 6, Froggatt’s view of unexplained reasons.

[132] A local perspective of swarms in summer may have influenced both Gurney and McCarthy, who repeated that view in articles and lectures at agricultural societies; *Murrumbidgee Irrigator*, 12 October 1928, p. 1, Gurney wrote, ‘following several dry seasons, they increase to appear in swarms ... conversely wet seasons seem adverse to the increase of grasshoppers; *Delegate Argus*, 20 June 1927, p. 2, in a lecture, McCarthy said there are two main broods (indicating he meant the locust), but that dry conditions favour the pest.

[133] *The Advertiser*, 15 November 1921, p. 7.

Without any qualification other than their commitment, by the 1920s Walter Froggatt, Arthur Lea and Charles French junior were perhaps the last ‘amateur’ public entomologists.[134] The process of professionalisation within government science now encouraged staff to obtain academic accreditation and the establishment of agriculture curriculums in universities in 1911 created an alternative pathway to degrees in biological sciences. From 1911 to 1921, Froggatt lectured in entomology at the University of Sydney agriculture department. Entomologists in Australia were required to satisfy their agricultural, bureaucratic and scientific constituents in the manner of ‘research entrepreneurs’, but without the complex of federal–state and academic–applied tensions that characterised the development of agricultural science in the USA.[135]

Like Charles French, Froggatt published several books. His 1907 *Insects of Australia*, illustrated by department artists, followed the 1895 classification scheme of British entomologist David Sharp. The book became a standard Australian entomology reference, although it is difficult to know which species Froggatt referred to as *Chortoicetes pusilla*.[136] It was followed in 1921 with the lavishly illustrated *Some Useful Australian Birds*.[137] His daughter Gladys also produced popular childrens’ nature study books based around insect life cycles.

At the height of his career in 1912, in the presidential address to the Linnean Society of NSW Froggatt reflected on the progress of economic entomology and the benefits of the ‘new alliance of government and science’.[138] He noted that locusts had featured among the national agricultural issues mentioned by Prime Minister Hughes at meetings held to consider a federal science bureau. Froggatt saw that ‘as the farmer pushes west the locusts will be among his wheat paddocks’ and that the removal of timber and scrub now provided uninterrupted flight across the plains. He also predicted a time rapidly approaching when the ‘united action of all the States would need to be brought against the locust plague’.[139]

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[134] Charles Hamilton French in Victoria contributed entomology articles to the *Journal of Agriculture* during 1912–1930, but did not comment on locusts in the press.

[135] Charles Rosenberg, ‘Science, Technology and Economic Growth: The Case of the Agricultural Experiment Station Scientist, 1875–1914’, *Agricultural History*, 45 (1971), 1–20, Rosenberg discusses how the politics of dealing with multiple constituent interests required agricultural research station and university faculty directors to compete and become ‘research entrepreneurs’.

[136] W. W. Froggatt, *Australian Insects*, (Sydney, William Brooks and Co., 1907), pp. 40–43, the Illustrations of the species identified as *C. pusilla* are not diagnostic. Illustrations by artists Grose, Burton and Chambers, and photographs were taken by Gurney.

[137] W. W. Froggatt, *Some Useful Australian Birds*, (Sydney, William Applegate Gullick, 1921).

[138] W. W. Froggatt*, ‘Presidential Address 1912’, Proceedings of the Linnean Society of N.S.W.,* 37 (1913), 1–43.

[139] Froggatt, 1913, p. 24.

Both Froggatt and Gurney alluded to overseas experience in suggesting that government responsibility and legislation would be necessary to achieve landholder compliance.[140] Froggatt had already hinted that government responsibility was inevitable, writing '… we know how locusts can be destroyed; the question is, who is to do it? – the landowners who get the direct benefit from their destruction, or the general community who indirectly gain by their destruction in the added wealth of the country'.[141]

At the NSW Select Committee on Agriculture in 1920, Froggatt complained that Australia's nine economic entomologists could not deal with all the agricultural pests and he called for greatly increased expenditure and more federal–state coordination. Men were not 'coming forward prepared to take up the work'. The 'department's cadets at the University would not take up entomology because it was the worst paid branch in the department'.[142]

The trend towards scientific specialisation and an elite position of authority over public policy had yet to fully develop, but the entomologists formulated the methods and advised on state regulations for dealing with the locusts. The goal of control was immediate crop protection, but it was increasingly justified as preventive by arguments of potential geometric population increase. It was rationalised as a public good because of the spatial externalities of risk due to migrations, so the 'dilemma of collective action' was played out in similar ways in across state borders.[143]

The logic of legislating for compulsory actions came from the economic entomologists' goal of achieving full participation in collective actions for successful locust control. But the graziers' associations and, through their membership structure, many PP Boards were against such a move. Froggatt commented that the average squatter 'will ride through them day after day and console himself they will move onto someone else's place' and he thought the fact that the locust was not a regular pest accounted for the apathy. The failure of some landholders, or derisively-labelled 'conscientious objectors' to participate was seen as potentially nullifying the efforts of all others.[144]

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[140] *The Sydney Stock and Station Journal*, 16 September 1921, p. 11.

[141] *The Gundagai Independent*, 28 August 1912, p. 8, quoting Froggatt in his department bulletin, 'Locusts in Australia and Other Countries'.

[142] *Chronicle*, 20 November 1920, p. 8.

[143] The study of 'collective actions' and 'public goods' are an integral part of 'group theory' of economic behaviour, first articulated by Mancur Olsen in *The Logic of Collective Action*: *Public Goods and the theory of Groups*, (Cambridge Massachusetts, Harvard University Press, 1965).

[144] Froggatt, 1910, pp. 4- 5.

Chapter 8. International locust research and nationalising the ‘grasshopper problem’ 1926–1939

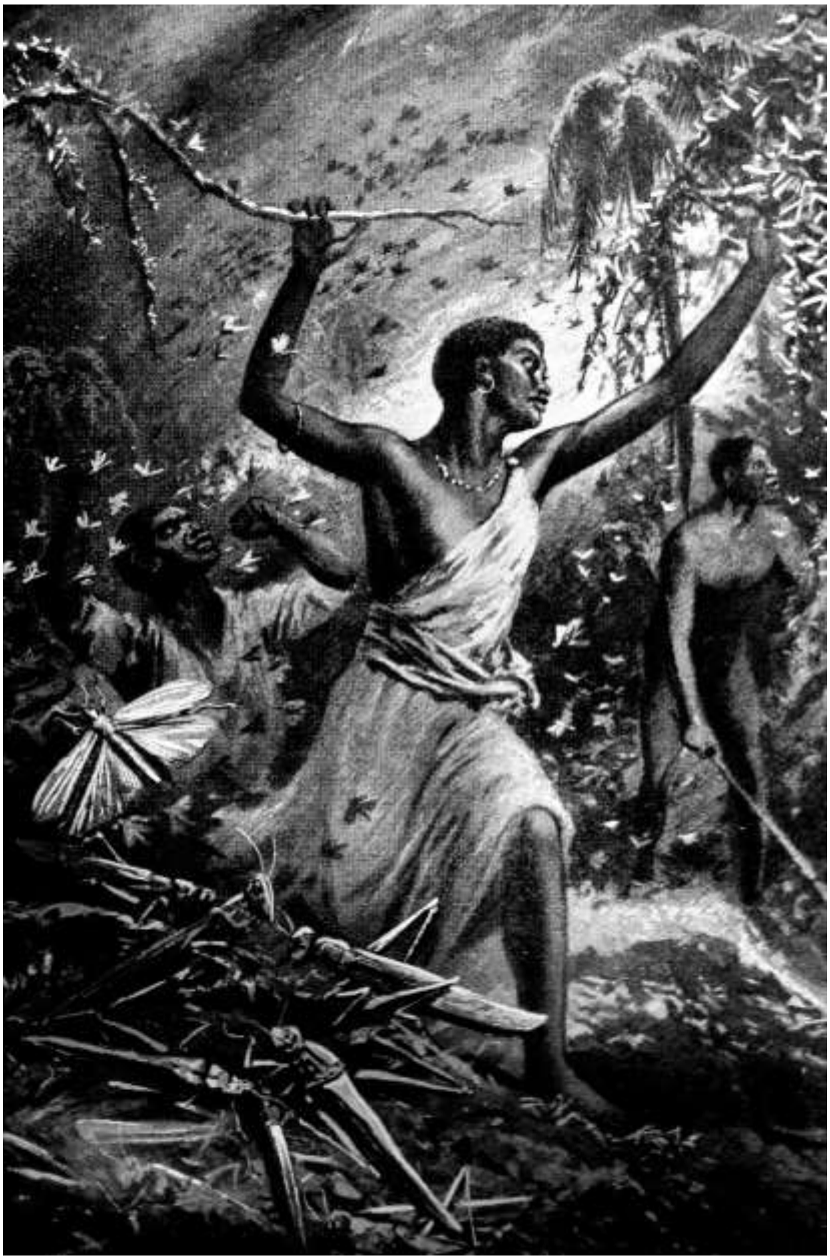

Figure 8.1. Illustration of a locust plague in Africa, from Edmund Selous, *The Romance of Insect Life*, (London, 1909), p. 76.[1]

[1] The original caption reads, ‘the dark cloud is entirely composed of locusts, which sometimes fill the air from twenty feet to two or three thousand feet above the ground. The poor people attempt, in vain, by shouts, by lighting fires and waving branches, to avert the attack’. Illustration by Carton Moore Park.

Locusts and empire — 'living like a locust'

Although in 1900 Britain had established schools of tropical medicine in London and Liverpool to study insect vectors of human disease in its African colonies, it had little expertise in locusts before the 1920s.[2] France had been directly organising collective manual control of locusts in Algeria since the 1880s and had sent its scientific workers to address the problem.[3] Throughout the 1920s and 1930s swarms spread across North Africa, the Middle East and India, prompting imperial nations to expand their locust research and monitoring efforts.

In Australia, each state relied on its entomologists to manage locust outbreaks and they remained committed to the international standard and sure kill of arsenic insecticides. However, ecological research on locusts was gaining in momentum in the wider British Empire under the influential figure of Boris Uvarov, whose expertise in locust control and taxonomy was consolidated by his 'phase theory' of plague initiation and decline. Uvarov saw the key to control in understanding the ecology of each species through intensive field observations. The interwar period also saw imperial nations gradually replace the methods that had mobilised subject populations to manually destroy locust eggs and nymphs with those symbolising modernity and power.

Australian federal government involvement in agriculture increased after the impact of the Depression, as it attempted to restructure wheat markets and growers' debts. The development of a locust plague affecting New South Wales (NSW), South Australia and Victoria in 1934, prompted the newly formed Australian Agricultural Council to recommend that the Commonwealth Government address what was considered a national problem. Aware of the growing British expertise in locust ecology, the national science agency, Council for Scientific and Industrial Research, joined the internationalisation of locust research in 1935. It hired Ken Key, a South African entomology postgraduate working for Uvarov in London, to investigate their 'habits and economy' and to find their 'permanent breeding grounds'. His first task was to review the history of locust outbreaks, and his 1938 report remains the only reconstruction of events prior to that time. Key's report is therefore my principal secondary information source.

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[2] The external architectural features of the School of Tropical Medicine in London depict the flea, tick, louse, mosquito, tsetse fly and bedbug.

[3] E. Deveson and A. Martinez, 'Locusts in southern settler societies: Argentine and Australian experience and responses, 1880–1940', in eds. *Environmental History in the Making, Volume 1*, (The Netherlands, Springer, 2017), pp. 259–286, p. 274, French entomologist Philippe Alexandre Jules Kunckel d´Herculais worked on locusts in Algeria and Corsica several times between 1880 and 1895. In 1891 it was widely, but erroneously, reported that he had been killed and eaten by locusts in Algeria.

Boris Uvarov and imperial acridology

In 1924, French entomologist Paul Vaissière recognised that the transborder nature of locust migrations required international actions in combating them.[4] France and Britain created an International Locust Intelligence Office in 1926, based in Damascus, to gather locust information for their interests in the former Ottoman Empire.[5] A desert locust plague erupted in North Africa in 1928. As swarms flew across Kenya, its government agreed with Australian Claude Fuller, who, after thirty years' entomology experience in Africa in his final, fatal position as Chief Entomologist for Mozambique, argued there should be some permanent organisation for dealing with the movement of swarms.[6]

As numerous British colonies and dominions were subject to the plagues, a small research unit was established within the Imperial Bureau of Entomology in 1929, under the supervision of Boris Uvarov. It came to be known as the International Centre for Locust Research after organising a series of international locust conferences in the 1930s. Boris Petrovic Uvarov (1886–1970) grew up in Uralsk, southeast Russia, attended university in St Petersburg and held various entomological positions in the Caucasus region from 1912 to 1919.[7] It was during an invasion of migratory locusts (*Locusta migratoria*) in Stavropol province in 1913 that he began systematic field investigations of swarming locusts which resulted in a different view of the marked phenotype variation seen in that species and the associated *L. danica* that later came to be known as the 'phase theory'. Amid the turmoil in the aftermath of the Russian revolution, Uvarov took an opportunity that came through an acquaintance with a British army officer to come to Britain, where he was appointed to the Imperial Bureau of Entomology in 1920. In the following decades his name became synonymous with expertise in locust taxonomy and control.[8]

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[4] Antonio Buj Buj, 'International experimentation and control of the locust plague: Africa in the first half of the 20th century', *Nature et Environment*, 3 (1995), 93–105, http://www.ub.edu/geocrit/sv-31.htm#N_5_ accessed, 24 April 2016.

[5] Etienne Peyrat, 'Fighting locusts together: pest control and the birth of Soviet development aid, 1920–1939', *Global Environment*, 7 (2014), 536–571, p. 560, a treaty was signed between Syria, Jordan, Iraq, Palestine and Turkey in 1926, creating the *Office International de Renseignement sur les Sauterelles*.

[6] *The West Australian*, 21 November 1928, p. 17; *Advocate* (Burnie, Tasmania) 21 November 1928, p. 1; *Observer* (Adelaide, SA), Under-Secretary for Colonies, William Ormsby-Gore, and the Governor of Kenya agreed with Dr Fuller's suggestion, (Claude Fuller, b. 1 October 1872, Sydney, d. 5 November 1928, Mozambique). Fuller was killed in a car accident during an entomological survey.

[7] Anti-Locust Research Centre, '*"In Memorium" – Sir Boris Uvarov K.C.M.G., F.R.S. 1888–1970*', (London, ALRC, 1970), p. 1.

[8] The British officer was entomologist P. A. Buxton, serving with the British Army of Intervention, who later became head of the London School of Hygiene and Tropical Medicine; see also, A. A. Fedotova and A. V. Kouprianov, 'Archival research reveals the true date of birth of the father of the locust phase theory, Sir Boris Uvarov, FRS', *Euroasian Entomological Journal*, 15 (2016), 321–327, the authors corrected Uvarov's birth date

Figure 8.2. Sir Boris Uvarov K.C.M.G., F.R.S. in 1969.[9]

In 1921 Uvarov published a revision of the genus *Locusta*, proposing that two identified species *(L. danica* and *L. migratoria)* were in fact different forms, the 'solitary' and 'gregarious' phases, of the same species, which underwent transformation from one state to the other within 'permanent breeding grounds'.[10] The two phases differed in morphology; the gregarious *migratoria* form having longer wings and body different colour patterns, and in physiology, eating less but developing fat and air sacs for flight.[11] Their behaviour was also different. While *L. migratoria* formed swarms at nymph and adult stages, the solitary *L. danica* avoided conspecifics. In addition, there were intermediate specimens, showing transitional features between the extreme forms. Breeding experiments by another Russian entomologist also demonstrated that *gregaria* progeny could be produced from *danica* in crowded conditions.[12] The radical revision was supported by similar observations on *Locustana pardalina* (Walker) by Jacobus Faure in South Africa.

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to 3 November 1886; N. Waloff and G. B. Popov, 'Sir Boris Uvarov (1889–1970): The father of Acridology', *Annual Review of Entomology*, 35 (1990), 1–24; "*In Memorium" – Sir Boris Uvarov K.C.M.G., F.R.S. 1888–1970*. (London, Anti-Locust Research Centre, 1970).

[9] Anti-Locust Research Centre 1970, Uvarov's energies and commitment are undisputed. He remains the only professional entomologist to have been knighted (KCMG) for services to the British Empire.

[10] B. P. Uvarov, 'A revision of the genus *Locusta* (L.) (= Pachytylus Fieb.), with a new theory as to the periodicity and migrations of locusts', *Bulletin of Entomological Research* 12 (1921), 135–63.

[11] 'gregaria' forms also have a distinctive pronotum shape.

[12] Uvarov 1928, p. 165; the entomologist was Boris Plotnikov.

More than resolving a taxonomic dilemma, phase change offered a theory to explain the sudden appearance, development and periodicity of plagues. Examination of specimens from many regions showed that, although they shared the same range, *L. danica* was widespread and appeared to have no habitat preference, while *L. migratoria* was associated with specific floodplain and lakebed reed vegetation.[13] The transformation to the gregarious phase occurred in these permanent habitats, or 'outbreak areas', and plagues resulted when swarms migrated to open grasslands. After the emigration, only solitary locusts remained to repeat the cycle when habitat conditions again caused phase change. Uvarov argued that environmental modification of the permanent breeding grounds could make them unsuitable for gregarious transformation, citing land use change in the Black Sea basin as an example.[14] This opened up the possibility that control measures could be directed at the ecological conditions that were the cause of the swarming phase rather than the resulting swarms.

Despite some initial resistance, Uvarov's findings were confirmed and were found to apply to other species, including the desert locust, spurring a spate of research on the details and consequences of phase change. This was concentrated on the morphological distinctions between phases and on the intermediate '*transiens*' forms, which were subdivided to represent either transition towards the gregarious phase or return to the solitary phase.[15] In 1928, Uvarov consolidated the phase theory in *Locusts and Grasshoppers*, published in both English and Russian. The book was a worldwide review of the ecology and control of acridid species and it became the standard reference on locust problems. It included a chapter on Australian pest species. In Uvarov's opinion there was 'not a single really scientific paper' from Australia, and he further suggested that *Chortoicetes terminifera* was not a true locust in its habits.[16]

Locust plagues continued in Africa and Asia at the start of the 1930s, described as the worst ever in Egypt and India, prompting imperial nations to cooperate on research and surveillance. Although the French established an institution to coordinate locust research across its colonies in 1932, after the first International Locust Conference in Rome, they and the Italians accepted the Imperial Institute of Entomology in London as the central authority for collating locust information across Africa.[17] They also agreed to collaborate on discovering the 'permanent breeding grounds' of each species.[18] In 1932,

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[13] Uvarov 1921, p. 143.

[14] Uvarov 1921, p. 155.

[15] Waloff and Popov 1990, p. 11.

[16] Uvarov 1928, p. 303.

[17] The *Comité d'études de la Biologique des Acridiens* was established in Algiers; The Imperial Bureau of Entomology became the Imperial Institute in July 1930.

[18] *The Telegraph* (Brisbane), 31 March 1932, p. 4, British entomologists strongly suspected that the Timbuktu area in Mali, then under French colonial rule as French Soudan, was the source of the 1930s plagues; The Soviet Union did not attend any of the international locust conferences.

Uvarov dispatched British entomologists to several African colonies to closely study different locust species, believing that field study was crucial to understanding their ecology. The research was jointly funded by the Empire Marketing Board and the affected African colonies. By 1933 there were five British and three French scientists working in Africa to inaugurate a 'big push against the locust plague'.[19]

WENT 'LOCUST' — For sake of science

A British scientist has completed his first year of 'living like a locust' in the heart of the Soudan, where he has been sent by the Imperial Institute of Entomology, London, which is in charge of the world attack on locusts. "Central Africa has three bad kinds of locusts," Dr. B. P. Uvarov told an Interviewer. "A year ago we sent a scientist to Uganda and another to the Soudan to study two of these kinds. The third kind is in Northern Rhodesia, and we have just sent out another man to see if he can locate it and then settle down alongside to watch it . . .

PASSION FOR THEM

"His sole Interest Is the locusts all round him, for which, fortunately, he has a passion. He feeds and observes them in cages round his tents. Every day he records the temperature, the moisture, the sunshine, and sees how the local locusts like it. He also looks at the locusts nearby, notices whether they are lively or inactive, whether they are eating well, breeding prolifically, and so on. Then he goes riding to see how the locusts further afield are doing. The rest of the day is spent recording all he has seen the locusts do, with speculations on the effects of the weather on them, and why they swarm, and what things kill them ... He will shortly be giving us his complete account of the life of the locust all through the year, which has hitherto been unknown. That may bring us further on the way to understanding why locusts swarm and how to stop them — a knowledge worth many millions of pounds."

The Telegraph (Brisbane), 28 April 1933, p. 7.

The plagues spurred the growth of technoscience solutions to colonial agricultural problems.[20] These included the World War I technologies of aircraft and chemical warfare (Figure 8.3). After the War, there was a deliberate diversion of chemists and their products to a new war with insects-as-enemy, which also spurred the use of aircraft for crop dusting in the USA during 1920s. As Edmund Russell observed in *War and Nature*, 'the triviality of insects removed the stigma of poison gas and the technical achievements of war elevated the significance of entomological pest control'.[21] The British

[19] *Canberra Times*, 7 January 1933, p. 4, French scientists included another Russian exile, Boris Zolotarevsky.

[20] Bernadette Bensaude Vincent, 'Technoscience and convergence: a transmutation of values?', *Summer School on Ethics and Converging Technologies*, (Alsfeld, Germany, 2008), (halshs-00350804), definitions hold that science and technology cannot be separated, and there is no distinction between 'pure' and 'applied'.

[21] E. M. Russell, *War and Nature; Fighting Humans and Insects with Chemicals from World War I to 'Silent Spring'*, (Cambridge UK, Cambridge University Press, 2001), pp. 76–83. Russell sets out the reciprocal

Government's Committee for Civil Research called for the Royal Air Force to be mobilised for surveillance and insecticide 'spraying' in a first 'anti-locust campaign' in 1928.[22] The other European empire, the Soviet Union, had shown the way, using aircraft to spread insecticides on locusts in northern Persia and the Transcaucasian states in 1927.[23]

Figure 8.3. Flame gun for locust control being tested in Palestine, 1915. Similar designs were still used in Egypt during the 1930s (photo courtesy Keith Cressman, FAO).[24]

In Britain, the first 'colony' of African locusts was established at Kew Gardens in 1933 to provide a test 'swarm' for aircraft 'to discharge a cloud of poisonous material', while experts from the War Office Chemical Department prepared insecticides for the experiments planned to take place on the Salisbury Plain.[25] In the following year, the dusting of real swarms with finely ground sodium

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reinforcement of chemical warfare proponents and entomologists in both portraying chemical warfare as pest control and insect pest control as war.

[22] *Western Mail*, 29 July 1929, p. 17.

[23] Peyrat, 2014, pp. 543–546; *The Mercury*, 2 March 1927, p. 9, Airplanes planned to be used to exterminate locusts in the reed beds of the Kuna River in Russian Turkmenistan; *World's News*, 1 November 1933, p. 18; D. Jones, 'The rise and the fall of Aeroflot: Civil aviation in the Soviet Union, 1902–91', in eds. J. Greenwood, V. Hardesty and R. Higham, *Russian Aviation and Air Power in the Twentieth Century*, (Routledge, 2014), pp. 94–95.

[24] A. M. Mistikawy, 'Flame Guns For Use Against Locusts', *Plant Protection Section Leaflet No. 8*, (Cairo, Ministry of Agriculture, Egypt, 1930), 20 pp.

[25] *Northern Star*, 31 March 1933, p. 5; *Central Queensland Herald*, 8 May 1933, p. 54.

arsenate was trialled in Rhodesia.[26] The use of aircraft to poison flying swarms gave poor results when insecticide was formulated as dry powder, and only began to show real promise when liquid sprays were developed during the Second World War.

Behind the face of benevolent development assistance, however, lay the machinations of inter-imperial and counter-imperial intrigues, in which science played a multifarious and reciprocal role. More than simply building knowledge about locust population ecology, locust research enhanced the status of scientists and entomological institutions, assisted the advance of insecticide technologies, cemented transnational and regional allegiances and assisted imperial intelligence and power networks. Out of this came a purposive strengthening of techno-politics, as a consequence of the contingencies of human-insect interaction within the engineering and environmental limits of the geographic settings in which they evolved.[27]

How well the institutions created to manage the locusts matched the scale of the ecosystems in which plagues developed hinged on the conjunction of scientific knowledge, technologies and political operations brought to bear on them.[28] Uvarov's thesis that plagues began in permanent outbreak areas provided support for linking insecticide technoscience to locust ecology, because plague suppression could focus on attacking the locusts in just a small proportion of their vast range. He believed that plagues could be prevented, because if a 'sufficiently effective poison is found the actual spraying from aircraft offers few difficulties'.[29] The strategy was completed by an economic justification based on assessment of the massive crop losses and control expenditures, which Uvarov and his assistant Miss B. M. Bowman calculated cost the world at least £15 million sterling a year.[30]

Although far removed from the Australian rural setting, the European ecological science and technological solutions were followed closely by those concerned with the local 'grasshopper problem'. There was also hope that Uvarov's 'outbreak areas' would be found for Australia's locusts in the vast and thinly populated inland. The local institutional framework for managing locusts saw

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[26] *Dubbo Liberal*, 3 March 1934, p. 7*; The Northern Miner*, 9 April 1934, p. 3, Mr H. King, government entomologist of the Anglo-Egyptian authorities, devised the system of using finely-ground sodium arsenate, with 'apparatus shipped from England'.

[27] Timothy Mitchell, *Rule of Experts: Egypt, Techno-Politics, Modernity*, (Berkeley, University of California Press, 2002), p. 312.

[28] Claude Peloquin, 'Locust Swarms and the spatial techno-politics of the French Resistance in World War II', *Geoforum*, 49 (2013), 103–113, p. 104, cites Timothy Mitchell's (2002, p. 302) definition of techno-politics as 'kinds of social and political practices that produce simultaneously the powers of science and the power of modern states.

[29] *Geraldton Guardian*, 26 January 1934, p. 4.

[30] *Daily Advertiser*, 30 December 1938, p. 4, the estimates were presented at the 1938 Brussels Locust Conference based on responses from 41 countries for the period 1925–1934.

each state organising collective controls using arsenic insecticides. Primary responsibility for such actions was placed upon landholders, who often had disparate motivations. How well this arrangement matched the broad ecosystems in which locust outbreaks developed was being regularly tested.

At the same time the clouds of war were again building over Europe. Newspapers painted horrific visions of the form the next war would take, with lines of aircraft raining incendiary bombs and poison gases on cities, leaving populated areas laid waste like fields devoured by locusts.[31] And the 'war on insects' reappeared with commentaries that this too was a war that all humankind could lose. In Australia it was red dust clouds that were obscuring the view of a bright agricultural future.

The early entomological preoccupations of the Council for Scientific and Industrial Research

The high-browed scientists prate much about what they can do;
To doubtings of their cleverness they simply say Pooh, pooh.
But when a plague of hoppers comes they are as meekly mute
as those who got a reprimand from ancient King Canute.
Aye, Science Is progressing — yes, and heavy is the bill …
But, ah, it seems the hoppers are progressing faster still!

The Australian Worker, 10 October 1928, p. 1.

The formation of a national science bureau had been part of Australian federal-state discussions since 1908, and it was strongly supported by Prime Ministers Hughes and Bruce.[32] In 1926 the Commonwealth Government established the Council for Scientific and Industrial Research (CSIR) as a statutory authority to replace its post-war science advisory bodies, with chemist David Rivett as its Director. The Council executive was explicit about collaborating with existing research institutions in the states, rather than imposing any centralisation of scientific authority, and about its applied focus of promoting 'primary or secondary industries'. The makeup of original CSIR Divisions and research

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[31] *Sunday Mail*, 20 November 1932, p. 1

[32] G. Currie and J. Graham, *The Origins of the CSIRO: Science and the Commonwealth Government 1901 – 1926,* (Melbourne, CSIRO, 1966), there were calls for a national department of agriculture along US lines soon after Federation and several Bills for establishing a Bureau of Agriculture failed prior to 1915. The long gestation of federal involvement in scientific research for industrial development, with establishment of the Advisory Council in 1916 and its successor The Commonwealth Institute of Science and Industry in 1921, reflected the competing interests and sensitivities of state institutions, as well as difficulties of financing scientific research, during the first decades of the Federation. Several state governments and universities were against the idea of CSIR conducting its own research in its own facilities (pp. 137–143). The administrative linkage of these bodies to departments through which the Commonwealth engaged with agricultural exports - the Departments of Trade and Customs, Markets and Migration and finally Commerce - as well the lists of issues to be addressed, show the importance that primary industries held in the vision of broader national development (pp. 51, 121).

centres in 1928 reflected this scientific function, particularly for agriculture. The Divisions of Economic Entomology and Economic Botany were created in Canberra in line with a 'national science' vision for the new capital city.[33]

The rhetoric of a new war, with insects as the relentless enemy, still held sway in public and scientific imaginations. Locusts continued their attacks on farms during the 1920s, particularly in NSW, and some earthy scepticism about whether scientists would defeat them remained. They only became the target of a concerted scientific research campaign after the plague of 1934–35, when the CSIR and the states came together in the nationalisation of the locust problem.

Robin J. Tillyard was appointed first Chief of Economic Entomology and outlined a program to attack the major insect and weed pests of agriculture by biological control. The very real prospect of success against 'prickly pear' in 1928 earned Rivett's support for this approach and, in this heyday of biological control, it matched the views of the Empire Marketing Board (EMB) in Britain.[34] The EMB had been created in the same year as the CSIR to fund science for colonial agricultural production.[35]

In 1927 the EMB converted a country house in Buckinghamshire into a 'Parasite Zoo' for the evaluation, breeding and dispensing of insects for biological control throughout the dominions. Under the direction of Canadian entomologist William Robin Thompson, scientists from the Imperial Bureau equipped Farnham Royal 'to provide the sinews of a war to the death on insects that are the deadly enemies of farmers and fruitgrowers in every country under the sun'.[36] Tillyard visited Britain and the EMB and established a relationship that sustained the Division through its tenuous early years, and several young CSIR entomologists received training at Farnham Royal.

Tillyard had difficulty recruiting senior entomologists from overseas for his ambitious projects. He interviewed candidates in Britain and the USA, but apparently the £700 salary was unattractive.[37] By 1929 however, zoologists in Australia, Ian Mackerras, George A. Currie and Alexander J. Nicholson,

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[33] C. B. Schedvin, *Shaping Science and Industry: a history of Australia's Council for Scientific and Industrial Research, 1926–49*, (Sydney, Allen and Unwin in Association with CSIRO, 1987), p. 87; The Commonwealth Solar Observatory was also built at Mt Stromlo, near Canberra, in 1924.

[34] Schedvin, 1987, p. 90, Tillyard's previous success in introducing a parasite for the woolly aphis in New Zealand bolstered his appointment and his hope for success.

[35] Libby Robin, 'Ecology: A Science of Empire?', in eds. T. Griffiths and L. Robin, *Ecology and Empire: Environmental History of Settler Societies*, (Melbourne, Melbourne University Press, 1997), pp. 63–75, p. 67.

[36] *Brisbane Courier*, 10 September 1927, p. 26.

[37] *Newcastle Morning Herald*, 18 July 1928, p.6; Schedvin, 1987, p. 96, Tillyard's own negotiated £2 000 salary was 25% more than other divisional chiefs; In Tillyard's book *The Insects of Australia and New Zealand*, (Sydney, Angus and Robertson, 1926), p. 89, 'inland plague locusts belong to *Chortoicetes* and *Calataria*, the worst species being *C. pusilla* and *C. terminifera'*.

had accepted the now reduced key positions overseeing work on the buffalo fly and blowfly, noxious weeds and orchard pests.[38] Belgian systematist André L. Tonnoir was hired for taxonomic work, along with Australians Gustavus A. Waterhouse, as curator of a national collection, and Gerald F. Hill, to carry on with work on crop pests and white ants.[39] Walter Froggatt had retired from the NSW entomologist position in 1923, but continued work on forest insect pests.[40] His collection of Australian insects, said to be the largest in the world, was acquired for the proposed National Museum of Zoology in Canberra, but remained temporarily in the private museum at his Croydon home in Sydney.[41]

Figure 8.4. The new CSIR Economic Entomology building at Black Mountain, Canberra in 1929, and the entomology insectaries under construction.[42]

Tillyard made a lecture tour of the states, declaring war against pests and giving glowing accounts of the demise of the prickly pear, the weed scourges St John's wort, blackberry, thistles and burrs, as well as the blowfly, buffalo fly and codling moth.[43] The hopeful linkage with Farnham Royal resulted in Tillyard's release of a French blowfly parasite, *Alysia manducator*, but the more significant outcome was the EMB offer to provide the Division with £25,000 for capital expenditure and £37,000

[38] Schedvin 1987, p. 100.

[39] Tonnoir had been a colleague of Tillyard in New Zealand.

[40] *Sydney Morning Herald*, 25 July 1927, p. 9, Froggatt worked with NSW Forestry Board in an advisory capacity and also came to Canberra to lecture on forest insect pests at the invitation of the Commonwealth Scientific Advisory Council.

[41] *Canberra Times*, 10 March 1927, p. 8, with 40,000 pinned and labelled specimens.

[42] Images from the National Library of Australia, nla.pic-an12107347-2-v and National Archives of Australia, image B5626-640.

[43] *Mirror* (Perth), 21 September 1928, p. 14, 'WAR ON PESTS', Royal Society meeting; *The Mercury* (Hobart), 17 October 1929, p. 5; *News* (Adelaide) 6 September 1929, p. 9.

over five years for maintenance, subject to the Commonwealth making similar contributions.[44] This funding allowed the completion of the CSIR buildings in Canberra and the continued operation of entomology programs during the Depression (Figure 8.4). There were trial releases against several insect and weed pests in the early 1930s but a clear success that the Division badly needed, like that of the *Cactoblastis* moth released just before its creation, was not realised.[45] Australia fared better financially than other dominions during this time of Britain's 'science for empire', when its pre-war foreign policy of 'constructive imperialism' was replaced by an unstated 'defensive imperialism'.[46]

The new science of animal ecology blossomed in the late 1920s with the publication of the first textbooks by Arthur Pearse and Charles Elton.[47] Numerous scientists advanced the view that climatic variation, through temperature and humidity, was clearly the primary population regulating factor.[48] This position came to be known as the 'climate school' in ecology in the 1930s.[49] In 1931 Uvarov placed himself firmly in that group, reviewing numerous studies which demonstrated climate as the predominant control of insect population numbers. He saw intrinsic factors simply as 'inefficient adjustments to environmental conditions, among which first place undoubtedly belongs to climate'.[50] In discussing the 'balance of nature', Uvarov pointed out there was already a 'well-established idea of "stable equilibrium" in populations regulated by interactions within and between species', but in his view the conception of a normal number was a 'fiction'.[51]

At the same time the influence of biotic interactions — predator-prey, host-parasite, disease and competitive relationships — both within and between species came to prominence as ecologists attempted to generalise how these affected population fluctuations. Experiments by Warder Allee in the USA showed that population growth rates could be affected by abundance in what came to be

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[44] *Western Mail* (Perth), 3 January 1929, p. 43; *Argus*, 22 December 1930, p. 9, in 1930, the EMB also funded the Australian Pastoral Trust Ltd. £3,000 annually on an equal basis with the Commonwealth.

[45] The control of prickly pears was achieved by the Commonwealth-funded Prickly Pear Commission in 1926, just before the creation of the CSIR entomology division.

[46] Michael Worboys, 'British Colonial Science Policy', in ed. Patrick Petitjean, *Twentieth Century Sciences: Beyond the Metropolis, Vol 2. Colonial Sciences: Researchers and Institutions*, (Paris, Orstrom, 1996), pp. 99–111, p. 101.

[47] Arthur S. Pearse, *Animal Ecology*, (New York, McGraw Hill, 1926); Charles Elton, *Animal Ecology*, (New York, Macmillan, 1927).

[48] B. Statzner, A. G. Hildrew and V. H. Resh, 'Species traits and environmental constraints: entomological research and the history of ecological theory', *Annual Review of Entomology* 46 (2001), 291–316, p. 305.

[49] C. J. Krebs, *Ecology: The experimental analysis of distribution and abundance*, 3rd Edition, (New York, Harper and Rowe, 1985), Chapter 16, pp. 328–334.

[50] B. P. Uvarov, 'Insects and Climate', *Transactions of the Entomological Society of London*, 79 (1931), 2–247, Uvarov referenced over 400 papers in several languages to support the 'climate' position.

[51] Uvarov 1931, pp. 155–157.

known as ‘density-dependent’ effects.[52] Combining the intrinsic geometric population growth potential of a species with those of a competitor produced logistic models of fluctuations through time, known as Lotka–Volterra equations after the mathematicians who independently developed them. They were brought into ecological literature by US biologist Raymond Pearl.[53] Alexander Nicholson in Sydney, translated a conceptual model of lagged, compensating fluctuations of host-parasite species that varied with relative densities into a similar mathematical model. Nicholson had come to Australia from Birmingham University in 1921 to take up a position as lecturer in entomology. His observations on numbers of mimetic and closely related non-mimetic species suggested a manner of speciation mediated by predation and parasitism. This led to his idea that populations were fundamentally ‘regulated’ by density-dependent competitive relationships.[54]

Nicholson deduced that, while climate variations obviously affected population numbers, it was competitive biotic interactions that stabilised abundance. These varied with the ability to find food and therefore operated in proportion to population densities. As only this type of feedback interaction could prevent unlimited growth or extinction, it was related to a ‘balance of nature’.[55] He extended this idea in a mathematical model of host-parasite fluctuations developed with Sydney University physicist Victor A. Bailey. They modified the Lotka–Volterra model to include age distributions and intraspecific competition for food. Nicholson’s hope of publishing their work as a book, which was written in 1931, did not come to fruition because of difficulties in finding a publisher and some negative referee reports.[56] W. R. Thompson had criticised Nicholson’s model as dealing with only one of many ecological limiting factors and he viewed it as an ‘abstraction unsupported by facts’.[57] Their journal publications, however, did put biological control principles on a theoretical grounding, consolidated the field of mathematical population ecology and established Nicholson’s ecological authority.[58]

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[52] Gregg Mitman, *The State of Nature: Ecology, Community and American Social Thought 1900–1950*, (Chicago, Chicago University Press, 1992), pp. 124–129.

[53] S. Kinglsand, ‘Alfred J. Lotka and the origins of theoretical population ecology’, *Proceedings of the National Academy of Sciences of the U.S.A.*, 112 (2015), 9493–9495.

[54] M. J. Whitton, ‘Australian Insects in Scientific Research’, in *The Insects of Australia: a textbook for students and research workers*, Vol. 1. 2nd edition (Melbourne, CSIRO, Melbourne University Press, 1991), pp. 236–251, p. 239.

[55] A. J. Nicholson, ‘The balance of animal populations’, *Journal of Animal Ecology*, 2 (1933), 132–178, p. 136.

[56] John L. Hopper, ‘Opportunities and handicaps of antipodean scientists: A.J. Nicholson and V.A. Bailey on the balance of animal populations’, *Historical Records of Australian Science*, 7 (2001), 179–188, p. 184.

[57] Hopper 2001, p. 182, Nicholson spent part of 1930 in London working to find a publisher for their book manuscript.

[58] Nicholson 1933; A. J. Nicholson and V. A. Bailey, ‘The balance of animal populations’*, Proceedings of the Zoological Society of London,* 3 (1935), 551–559*.*

CSIR research priorities had been decided by the divisional chiefs and the executive, with input from the Standing Committee on Agriculture (SCA), but its influence increased from the first meeting of the Australian Agricultural Council in 1935, which set a new research agenda for national issues. After Tillyard's retirement in 1936, Nicholson became the divisional chief and his focus moved to the wool industry's chief concern — the blowfly problem.

The situation in the bush 1928–1932

Grasshoppers

The expert said:
'If you spray and spray
They will all be dead,
It's the only way.'
But some said. 'Wait,' And left it late.
And the 'hoppers won the day.

The Land, 5 October 1928, p. 2.

While the CSIR was concentrated on biological control of weeds and pests of the pastoral industry, wheat farmers struggled on with poor seasons, low prices and locusts.[59] Good rains in February 1928 prompted NSW farmers to plant the highest acreage of wheat for a decade, over four million acres, but this coincided with *C. terminifera* swarms appearing in familiar districts of the Central West and Riverina.[60] Breeding produced another generation and swarms persisted into May and June, damaging emerging cereal crops and forcing many farmers to replant. The NSW government listed its largesse of more than £800,000 in direct grants to 'necessitous' farmers for fodder, fuel, seed, super-phosphate and debt deferments.[61] The £10,000 given direct to farmers who lost crops to grasshoppers in autumn 1928 suggests the relative scale of locusts among the many problems in the bush.[62]

Hopper bands developed in spring and there were more swarms in November, but locusts disappeared after December. The twelve months to July 1929 was one of the driest periods on record in the south-

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[59] Edgars Dunsdorf, *The Australian Wheat-growing Industry*, 1788–1948, (Melbourne, Melbourne University Press, 1956), pp. 245–250, p. 246, table on share-farming in NSW represented 20–30% of total wheat acreage between 1926–27 and 1936–37. Although this level was higher than in other states and had reflected local historical inertia from the 'selection acts'. The continued prominence of share-farming in NSW perhaps indicated that wheat growing remained a 'gamble'.

[60] *Grenfell Record*, 18 October 1928, p. 3, in NSW the area sown to wheat was 4,420,000 acres, an area not seen 'since the patriotic war effort' in 1917.

[61] *Sydney Morning Herald*, 26 July 1929, p. 11, the Nationalist Party, led by Thomas Bavin, was elected in October 1927. Grants in the form of seed wheat were given to 224 farmers whose crop was damaged by grasshoppers. Farmers' groups were also supplied with arsenic, bran and molasses to bait the hoppers.

[62] *National Advocate* (Bathurst), 26 July 1929, p. 5.

east.[63] In his reconstruction of events, Ken Key found reports from January to December 1928, which included most of the localities identified in the press.[64] He had no information on how the '1928 recrudescence' developed, but there had been locusts in the Narromine–Tullamore area of the Central West NSW in early summer 1927–28, and around Broken Hill and White Cliffs in autumn 1927.[65]

Figure 8.5. Grasshoppers on a car radiator at Wagga, 1931
(NSW State Records, image 549_a029_a029000379).

A new way of reporting locusts came with descriptions of the fronts of cars caked with their bodies, or from drivers passing through swarms or bands on the roads (Figure 8.5). This was the case in February and March 1930, when locusts swarmed from Charleville to Aramac in Central West Queensland. An Augathella man offered his invention to stop them clogging car radiators for free — gauze wire from the radiator to the front bumper.[66] The infestation continued the following summer in the Longreach–Winton area, destroying the summer grass growth. The Land Court subsequently rejected government proposals to increase lease rents on the sheep runs of western Queensland, actually reducing the rates in some areas, because of the poor pasture conditions attributed to the 'grasshoppers'.[67] Key identified the Queensland locusts in 1930–31 as *C. terminifera* from several museum specimens, and the timing of autumn swarms at Charleville, Barcaldine and Winton also

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[63] The period from August 1928–March 1930 was an anomalously dry La Niña period, the driest on record in South Australia, http://www.bom.gov.au/climate/enso/lnlist/ , viewed 3 November 2016; see also http://www.bom.gov.au/climate/influences/timeline/ .

[64] K. H. L. Key, 'The Regional and Seasonal Incidence of Grasshopper Plagues in Australia', *C.S.I.R. Bulletin No. 117*, (Melbourne, 1938), pp. 20–22, although Key noted that parasites were prominent in autumn, rather than spring 1928, when they featured in the press.

[65] There were also some hatching reports in spring 1929 around Thuddungra, Whitton and Quirindi.

[66] *Western Champion*, (Barcaldine Qld), 29 March 1930, pp. 7, 10; Key, 1938, p. 22, CSIR samples were collected near Binalong in February 1931.

[67] *Daily Mercury*, (Mackay Qld), 16 June 1930, p. 6.

conform to the locust phenology. The more consistent newspaper coverage from western Queensland during the 1930s indicates ongoing locust infestations from 1930 to 1933.

> **Grasshoppers great trek: billions pass over Young, making for the south-east**
>
> All day long could be heard the soft rustle of the flying insects interspersed with the shouts of children as they caught and tortured them. The motor cars … slaughtered them by the hundreds, but for every insect killed a thousand more appeared in its place. Like grey snowflakes, they were without end.
>
> *Daily Examiner*, 7 February 1931, p. 6.

Locusts also reappeared in NSW from Walgett to Dubbo in autumn 1930, leaving just the stems of green Mitchell grass in some places.[68] This was the start of an infestation that lasted until 1932. Ken Key's interpretation of events over the following two years highlights the complexity of interpreting spring reports. He found evidence that both species were active during 1930–32 and newspaper reports accord with that conclusion (Appendix 6). In contrast to the swarms of *C. terminifera* increasing during December each year in central and eastern NSW, swarms of *Austroicetes cruciata* were subsiding in the southern Riverina and northern Victoria in December each year.[69] Wheat growers suffered under swarming populations of both locusts and grasshoppers, although to many they were all 'grasshoppers'.

Questions about the appropriate level of organisation to coordinate locust information, control efforts and funding, and the need for Commonwealth-state collaboration, were debated by agricultural institutions.[70] Hoping for a scientific solution, the United Graziers' Association of Queensland requested that CSIR investigate reported bacterial disease trials on locusts in Palestine. The Junee Graziers wanted research to find a parasite and others wished to emulate the wartime technologies of flame-throwers and poison gas being tried overseas.[71] There were also accommodating ecological views of the harsh alternations of Australian conditions. Droughts were again seen as cleansing the landscape, while 'pests appeared when nature is generous with bountiful seasons'.[72] On the other

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[68] *Mudgee Guardian*, 4 April 1930, p. 19; *The Land*, 18 April 1930, p. 18, grass was abundant at Walgett, but districts further south and the Riverina remained dry. At Cargo, 'even the grasshoppers had sore eyes looking for green pick'; *The Land*, 9 April 1930, p. 12, at Martindale, near Denman, motorists had radiators splashed with locusts; *Gilgandra Weekly and Castlereagh*, 17 April 1930, p. 3, reported in various parts of the district in all stages.

[69] *Albury Banner*, 12 December 1930, p. 43, 'plague has subsided at Finley'.

[70] The raising of revenue, funding and community level controls were variously suggested as best done through PP Boards, shire councils or agriculture department.

[71] *The Week*, 28 November 1930, p. 11.

[72] *Muswellbrook Chronicle*, 31 January 1928, p. 2.

hand, the sight of birds devouring grasshoppers was visible proof of nature's ecological balance and recurring pest outbreaks were the result of its disruption.

Figure 8.6. Sheep-feeding at Hay, NSW, 1938 (State Library of NSW).[73]

Australia's sheep flock reached 100 million in the mid-1920s and 110 million in the late 1930s, finally exceeding the 1891 peak. Half of the total was in NSW and sheep numbers in Queensland now exceeded Victoria, fluctuating around 20 million.[74] Like in NSW in previous decades, there were constant movements of stock in Queensland between areas with available grass.[75] Wool provided half of total export earnings and twenty-five per cent of world supply, so national prosperity still clung firmly to the sheep's back. The value of wool dropped sharply in 1930 as a result of a slump in world commodity prices and it fluctuated for several years, contributing to continued high stocking rates in attempts to maximise returns.

Wheat growing was an even more tenuous enterprise by 1930, particularly so in the western areas of NSW and Victoria but also where it was now part of a mixed grazing-cropping cycle. After struggling with droughts, low grain prices and devastating soil drift during the 1920s, the Depression brought

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[73] Image, oasl.nsw.gov.au, 394617, bcp_0666r.

[74] *Yearbook of Australia 1929*, (Melbourne, Commonwealth Bureau of Census and Statistics), 'Pastoral Production' pp. 648–649, map p. 659.

[75] *Western Star*, 5 August 1931, p. 5, over 200,000 sheep passed through Charleville during winter 1931, leaving the main route from NSW bare; *Townsville Daily Bulletin*, 27 January 1934, p. 12, sheep movements through Winton in the 1930s were reminiscent of those through Deniliquin in the 1870s. For the week to 25 January 1934, over 50,000 sheep were transited through the Winton district.

more hardship, with many farmers unable to purchase machinery or fuel.[76] Cameron Muir has examined the social, racial and Imperial roots of governments' focus on fostering the growth of wheatgrowing in Australia.[77] The EMB push for increased wheat production in the dominions contributed to an Australian Government 'grow more wheat' campaign in 1930.[78] The hopes for a bumper crop in 1930–31, though, were crushed when the export wheat price crashed to half that of the previous year due to a worldwide stockpile. One third of farms in newly established wheat areas in Western Australia (WA) failed and grasshopper populations exploded on the abandoned cropland.

1933–1935, 'one of the worst "grasshopper" plagues on record'

When Ken Key wrote the above words in 1938, he noted that improvements in the reporting of swarms made 'knowledge of the distribution of the infestation' relatively more complete in comparison with earlier outbreaks.[79] It was the first time since 1921 that all the south-eastern mainland states were affected by *C. terminifera* swarms and, for the first time, estimates were made of the economic losses and control costs.[80] The plague featured so prominently in the press and the minds of agricultural bureaucrats that it spurred a major federal-state research effort, contributing to its almost legendary historical status. The detailed chronology of its development by Ken Key make it one of the more closely documented outbreaks.[81]

What marks the beginning of this plague as different is the lack of reporting in newspapers compared to the official record. Key also noted this 'deficiency of normal records', so his reconstruction came in turn from those of James Davidson and Herbert Andrewartha in South Australia, John A. Weddell and

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[76] In 1930, horse teams returned to prominence in ploughing and harvesting operations in the Riverina because farmers could not afford petrol.

[77] Cameron Muir, *The Broken Promise of Agricultural Progress: an Environmental History*, Routledge Environmental Humanities Series, (Oxon and New York, Routledge, 2014), pp. 47-48, 95-104.

[78] *Brisbane Courier*, 25 October 1930, p. 14, the EMB should have warned the Dominions of Russian wheat expansion before they adopted the 'grow more wheat' slogan; Examiner, 9 April 1930, p. 7, 'grow more wheat' is stamped on letters; Ruth A. Morgan, *Running Out: Water in Western Australia*, (Perth, University of Western Australia Publishing, 2015), p. 65.

[79] Key, 1938, p. 23.

[80] *Daily News* (Perth), 10 November 1934, p. 1, NSW estimated damage at £3.6 million last year; *Kalgoorlie Miner*, 14 November 1934, p. 5, Adelaide, 150,000 acres of crops and 400,000 acres of pasture destroyed in South Australia; Australia reported to the 1938 International Locust Conference in Brussels that the plague had caused £3.6 million damage to agriculture.

[81] The plague was re-analysed by Diana Wright, geographer and APLC forecaster in the 1980s, see D. E. Wright, 'Analysis of the development of the major plagues of the Australian plague locust, *Chortoicetes terminifera* (Walker) using a simulation model', *Australian Journal of Ecology*, 12 (1987), 423–437, Wright used a simulation model based on regional rainfall, but found no evidence of swarm development in the inland.

Jacob H. Smith in Queensland, Richard Pescott and Keighley Ward in Victoria, and Harold Bartlett and William Gurney in NSW.[82]

The first hint in NSW newspapers came from Nyngan in late November 1933, when cars coming from the north-west were plastered with dead hoppers.[83] But even by January 1934, nearly all NSW reports were reprints of the hopper bands story from the Narrabri district.[84] Key's description, from Bartlett's recollection, gives a very different account of 'large swarms' already hatching in the Trangie–Dandaloo–Warren area and at Coonamble, Wagga and Griffith in December 1933 that Key decided must have been a second generation.[85] Why, for the first time, the newspapers failed to receive reports of these hatchings remains obscure. It may have been Depression exhaustion or grasshopper fatigue, but the official and newspaper sources only realign after February 1934. By the time farmers around Narromine reported locusts in March 1934, one complained they had been 'getting more serious each year' for the last ten years.[86]

Similarly, there are no newspaper reports to support Davidson's reconstruction for South Australia, which was based on later interviews done during fieldwork with Andrewartha in 1936.[87] Davidson posited hatchings in 'northern pastoral districts' in spring 1933 and subsequent swarms moving south from 'west of Lake Gairdner' to the Gawler Ranges, where they bred again in summer before invading the cropping country on the Eyre Peninsula in autumn 1934.[88] Andrewartha concluded that the Flinders Ranges area had not provided an intermediate breeding ground in 1933 or 1934, but that

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[82] Harold Bartlett was a senior agricultural instructor for the NSW department and travelled to several infested areas in 1928 and in 1934.

[83] *Mudgee Guardian*, 27 November 1933, p. 6, Nyngan, 'cars from northwest showed signs of coming through a thick patch … the radiators and wheels covered with dead hoppers'.

[84] Reports of 'bands of brown, wingless juvenile grasshoppers' at Narrabri were repeated in 32 newspapers. Other common reports were about the situation in Canada, Africa and Argentina.

[85] Key 1938, p. 28, the bands at Narrabri were not mentioned and Key disregarded Bartlett's suggestion of hatching at Moree in December 1933. Key recognised that 'normal' reports were deficient for the early part of the plague.

[86] *Richmond River Herald*, 23 March 1934, p. 2.

[87] Key 1938, p. 23, treated the recollected swarms in northern South Australia in autumn 1933 with the same sceptical, specimen-centred rigour he applied to other regional and seasonal incidences.

[88] J. Davidson, 'On the ecology of the black-tipped locust (*Chortoicetes terminifera* Walk.) in South Australia', *Transactions Royal Society South Australia*, 60 (1936), 137–152, the summary, which included several maps, was drawn from two earlier publications by Andrewartha, 'Preliminary survey of the Far North district as a possible endemic area for plague grasshoppers', *Journal of the South Australian Department of Agriculture*, 39 (1936), 1223–1224, and 'Some notes on the breeding grounds of the plague grasshoppers in South Australia, *Journal of the South Australian Department of Agriculture*, 39 (1936), 1031–1036.

grassy flats and 'shooty' regenerating cleared country west and north of the Gawler Ranges probably had.[89]

Reconciling official and newspaper reports now is similar to the problem faced by those 1930s interpreters trying to understand how the plague developed. However, the maps they produced formed a documentary history that hides some uncertainties in the original sources. The sudden increase in newspaper reports in April 1934 suggests either embellished recollections of late 1933 or that such information lags are also a feature of reports from all plagues.[90] Either way, this presents problems for the interpretation of historical plagues.[91]

The overwhelming peak in newspaper reports from November 1934 to January 1935, with more than 2,000 entries each month, attests to the level of public concern and the geographic reach of the plague. The range of issues discussed included relief funding and compensation for farmers, the uptake and effectiveness of the recommended control methods and calls for coordinated scientific research to find a solution. State governments reported on the value of crops threatened and lost to the 'grasshoppers' as well as the amounts expended on their control. More hopeful notes about the actions of parasites — fly maggots and *Scelio* wasps — in contributing to the collapse of the plague also featured from places as far afield as Goondiwindi in Queensland and Murray Bridge in South Australia.[92] NSW entomologist Norman Scott Noble published the first intensive field and laboratory studies of the biology of the primary egg parasite, *Scelio fulgidus* (Figure 8.7), as well as describing sarcophid fly and beefly locust parasites.[93]

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[89] Andrewartha 1936, p. 1035, Andrewartha based this on the recollection of a landholder, who said locusts flew in in the latter part of 1933, laying eggs in October and November, which hatched in February 1934. For Davidson, the earlier generations were not noticed because the sheep stations were sparsely-settled, while Key suggested they were likely to have been in low numbers in NSW.

[90] There were 450 non-advertising reports in April 1934, twice that of January or February, and four times as many as in December 1933.

[91] A reconstruction based only on newspaper reports might simply start with 'swarms appearing in January 1934 in NSW, followed by southward autumn migrations to agricultural regions of the Central West and Riverina, and also appearing on the Eyre Peninsula in South Australia'.

[92] *Central Queensland Herald*, 10 January 1935, p. 28; *Maitland Daily Mercury*, 8 January 1935, p. 2; Davidson, 1936, p. 151.

[93] N. S. Noble, 'An egg parasite of the plague grasshopper', *Agricultural Gazette of NSW*, (Sept 1935), 513–518; N. S. Noble, 'Fly parasites of grasshoppers.' *Agricultural Gazette of NSW*, Miscellaneous Publication 3056, (July 1936), 383–385, Noble described *Blaesoxipha rufipes* under the name *Locustivora pachytyli* and the beefly *Trichopsida ostracea*; Noble entered the department as a cadet in 1924 and became assistant entomologist after completing a BSc Agriculture in 1928. He completed an MSc in entomology studying parasites of orchard pests at the University of California in 1931.

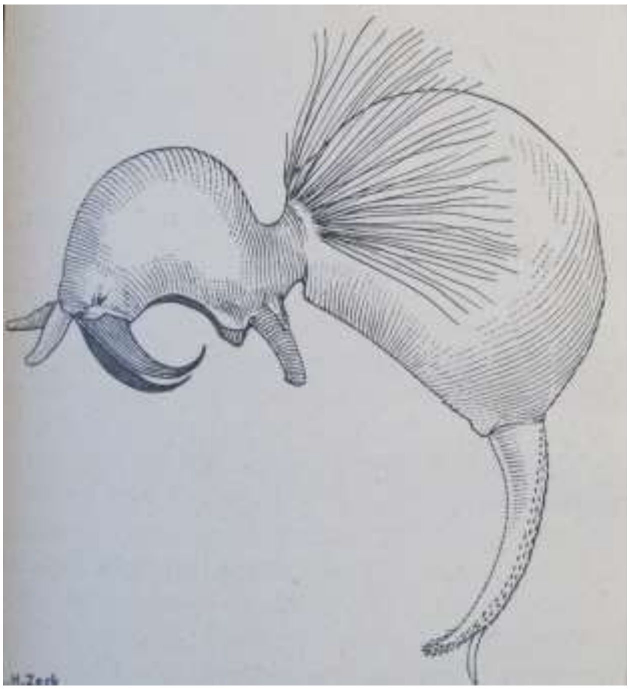

Figure 8.7. First stage larva (greatly enlarged, actual size 0.2 mm) of *Scelio fulgidus*, from N. S. Noble, *Agricultural Gazette of NSW*, (Sept 1935), 513–518, p. 515 (drawn by E. H. Zeck).

The progression of the plague then followed a familiar pattern of generation sequences and extents, spreading across the agricultural districts of South Australia and NSW and appearing in western Victoria in autumn 1934. Pastures Protection (PP) Board reports in NSW indicate almost the entire state west of the Great Dividing Range was briefly infested in 1934. However, swarms did not reach the southern coasts as they had in the 1870s and 1890s. This plague differed also in the known extent in Queensland, which was documented in some detail by Weddell during 1934–35. Weddell observed several generations on the Darling Downs and, in December 1934, large swarms moving from NSW in a wide swathe from Charleville to Eulo and north to Tambo.[94] Swarms were also reported in the Longreach–Winton area, making 1934 the fourth consecutive year of locust breeding in that region.[95]

Key's 'infestation area' map of autumn 1934 is still largely confined to the NSW Central West, but in the spring and summer of 1934–35 nearly every agricultural district was affected. A third generation laid eggs in late autumn in some areas. Hatchings were recorded in locations as far east as Yass and Crookwell.[96] In western NSW, Key records that swarms passed through the Bourke, Brewarrina, Cobar, Tibooburra, Wilcannia, Hay and Balranald PP Board districts, in effect completing the

[94] J. A. Weddell, 'The grasshopper outbreak in Queensland 1934–35', *Queensland Agricultural Journal*, 1 (1937), 246–259, Reports also indicated that the population in the western Darling Downs to the Roma area, migrated in late December and may have made a greater contribution to the western population.

[95] *Warialda Standard*, 7 January 1935, p. 6.

[96] *Braidwood Despatch*, 11 January 1935, p. 2.

statewide picture.[97] In Victoria, the hatchings in spring 1934 occurred north of a line from Seymour in the east to Horsham in the west, while in South Australia the districts south of the Murray River were largely unaffected (Figure 8.8). Most swarms disappeared by February 1935 in Victoria, South Australia and Queensland, and contracted again to the Central West in NSW.

Landholders now actively fighting grasshoppers

"I've killed about umpteen million" added Mr Beilby. "They were chasing me for the poison when I was spreading it. They could smell it, and liked it. By Golly I've stopped 'em. About two o'clock you could not come near here. They would have eaten you. Now look at them."

Shepparton Advertiser, 9 January 1935, p. 1.

At the height of the plague in 1934, NSW, South Australia and Queensland introduced regulations under noxious pest legislation, requiring landholders and local authorities to report and control 'grasshoppers' on their properties.[98] All states provided the ingredients for arsenic baits or sprays in bulk at central locations for free collection by farmer groups. The NSW agriculture department made use of stock inspectors, PP Board and department staff. The response in Victoria was organised around the distribution of bait material by Closer Settlement Commission officers in the Mallee district, advised by department entomologists.[99]

The risk to irrigated crops in the Mildura area also prompted the Chamber of Commerce to organise volunteer labour from the town. In a call for collective action reminiscent of French's 1890 'locust days' and Councillor Grossman's 1904 'warm reception', a local MLA wrote 'If 200 men can kill millions of the grasshoppers, how many more could 8,000 have exterminated' and 'school children could ride on horses to find the swarms quickly'.[100] The Victorian campaign expanded to areas along the Murray during summer 1934–35. At Shepparton in January 1935, large hopper bands elicited many applications for poison, including 'from individuals who previously said it was a waste of time and money'.[101]

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[97] Key 1838, pp. 24–41.

[98] *Burra Record*, 16 January 1935, p. 3, South Australian regulations under the Noxious Insects Act, required occupiers to mark, report and control egg beds and bands, and pastoral Boards to organise bait materials and to map the locations; Weddell 1937, p. 33, Queensland made emergency amendments to the existing *Diseases in Plants Act*; *Barrier Miner*, 27 January 1935, p. 1, NSW made reporting and control compulsory and introduced a levy on landholders to fund grasshopper control; *Geraldton Guardian*, 29 November 1934, p. 1, legislation was called for in Victoria, but existing voluntary arrangements were considered sufficient.

[99] The hierarchy of information flow and practical roles was formalised graphically in a demonstration of departmental capability in an emergency. A schematic of the Victorian locust response command structure, presented at the 1938 Locust Conference.

[100] *Argus*, 9 November 1934, p. 3, in another parallel, entomologist Ward worked with farmers spreading baits at Ouyen and Pescott suggested burning straw over them.

[101] *Shepparton Advertiser*, 9 January 1935, p. 1.

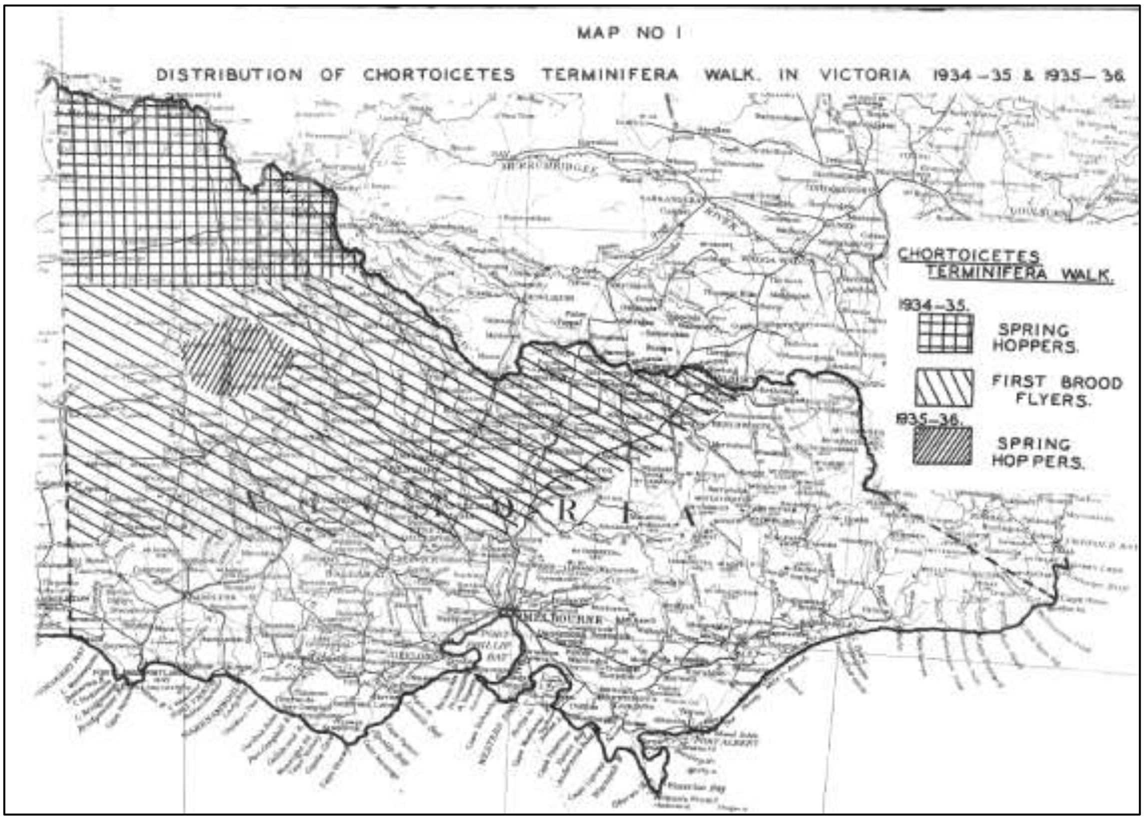

Figure 8.8. Map of the 1934–35 locust plague in Victoria, prepared by Victorian Government entomologists for the 1938 locust conference.[102]

In contrast to previous locust plagues, 1934 was not associated with a sustained La Niña climatic phase, but rather a period of frequent alternation between positive and negative El Niño–Southern Oscillation values.[103] This was reflected in the very wet and very dry months across the south-eastern inland, which corresponded with the locust breeding cycle.[104] It was followed from December 1934 by one of the driest six-month periods on record. The scattered hatchings in spring 1935 in Victoria, north-east South Australia, the Queensland Darling Downs and Central West NSW represented the end of the plague. However, locusts swarms continued in NSW and grasshoppers swarmed in South Australia until 1940. Key's explanation for the population collapse was the combination of parasites, climatic factors and control measures.

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[102] Image courtesy of Department of Agriculture, Victoria, (archive BHZ4899).

[103] Southern Oscillation Index (SOI) values during 1933–1935 alternated between positive and negative values, sometimes on a monthly basis; Bureau of Meteorology, Australian climate influences timeline, http://www.bom.gov.au/climate/influences/timeline/, accessed 21 September 2016.

[104] Rainfall deciles >0.8 occurred in many regions during Nov-Dec 1933, Feb 1934, April 1934, August 1934 and October-November 1934; *Warwick Daily News*, 1 February 1934, p. 1, even in months of average rainfall, single heavy falls could change habitat conditions. The Charleville district received over 200 mm of rain during the last week of January 1934, which flooded the Warrego River and the town of Charleville.

The Australian Agricultural Council and the nationalisation of locust research

Environmental as well as economic crises accompanied the locust plagues of the 1930s. Soil erosion, exacerbated by droughts and in some areas by deep ploughing still recommended by some agrostologists, had so altered the landscapes of semi-arid NSW, South Australia and northern Victoria that in many areas remnant trees were being covered by sand drifts or, if left standing, their roots were exposed ‘like mangroves’ above the denuded soil.[105] Inland Queensland also experienced below-average annual rainfall from 1925 to 1936. This was the time of Australia’s dustbowl, affecting as much country but of longer duration than in the USA, because dust storms were a feature of many earlier droughts and they continued well into the 1940s. There had not been a sustained wet period since the early 1920s and during 1925–29 there were widespread dust storms in winter and spring as well as summer.[106] Farms in marginal areas failed and pastoralists weren’t doing much better, as anywhere that pasture was unburied it was reduced to ephemeral growth eaten down to the ground by livestock and rabbits.

Every state government was carrying considerable borrowing debts, particularly NSW and Victoria, and the total debt of Australian wheat growers exceeded £153 million.[107] Wages were reduced, working hours increased, unemployment reached thirty per cent in 1933 and the Labour Exchanges of country towns each had hundreds of men on their books.[108] The ongoing agricultural crisis, particularly for the wheat industry, was a crisis in hope for national development as well as for immediate production. The Commonwealth Government had attempted to set a base price for wheat by subsidising struggling growers with bounties, expending several million pounds each year from 1932 to 1936.[109] There were a number of international wheat conferences in the early 1930s and, in Ottawa in 1933, general agreement was reached on reducing overproduction through export quotas.

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[105] Francis Ratcliffe, *Flying Fox and Drifting Sand*, (Sydney, Sirius Books, 1947), p. 248, sand to the tops of the needlewood trees, or exposed ‘roots like mangroves’.

[106] *The Argus*, 29 September 1928, p. 22, dust storms reported at Barham, Bendigo, Stawell and Nhill, ‘unprecedented in the history of the Wimmera at this time of year’; 24 August 1929, p. 14, mail plane turned back by dust storms between Mildura and Renmark.

[107] Patricia Hale and Paul Ashton, *Raising the Nation: A history of Commonwealth departments of agriculture, fisheries and forestry, 1901–2001*, (Canberra, Commonwealth of Australia, 2002), p. 63, the total debt was calculated in 1932–33. It was a plan by the Lang government in NSW to default on loan repayments that contributed to the disintegration of the federal Labor government and the election of the United Australia Party under Joseph Lyons in coalition with the Country Party of Earle Page in 1931.

[108] *Australasian*, 12 Jan 1935, p. 8, 114,200 persons applied at NSW Labour Exchanges in 1934, down from 197,068 in the previous year.

[109] Hale and Ashton 2002, p. 75; *Farmer and Settler*, 30 November 1933, p. 14, the Commonwealth commits to raising £3 million to assist farmers with no taxable income; *Wellington Times*, 10 January 1935, p. 3, in response to letter requesting relief for farmers affected by grasshoppers, the Commonwealth will pay 3/- per acre and 6d per bushel, plus £500,000 for specific relief for damage by drought, rust, grasshoppers.

There was also a favourable outcome for Australian exports to Britain.[110] Ironically, another bright note came from Canada in 1933, when the price of wheat rose to its highest level in three years owing to the ‘triple foe’ of drought, heat and grasshoppers seriously reducing yields in Canada and northern USA.[111]

In November 1934, state delegates of the Australian Wheatgrowers’ Federation came to Canberra to ‘stress the plight’ of farmers and pressed the Minister for Commerce, Country Party Leader Earle Page, to establish the national wheat pool, to set a minimum price per bushel and to make special provisions for those who lost crops to rust or grasshoppers.[112] Page then chaired a conference of state agriculture ministers, where they agreed to establish a forum for regular federal-state interchange to develop unified policies on international agricultural marketing and specifically to resolve issues of wheat marketing and farmer debt. The resulting Australian Agricultural Council (AAC) included the Minister for Commerce, as representative for the Commonwealth department dealing with agriculture. The AAC was supported by the Standing Committee on Agriculture (SCA), comprising heads of state agriculture departments, with the CSIR executive representing the Commonwealth.[113] The twice-yearly AAC meetings often included agenda items on scientific research that were developed at the preceding SCA meetings.

The 1934 plague focused the mainland state governments on the locust problem. In November, CSIR head David Rivett foreshadowed the future direction of its locust research and the Standing Committee lost no time, despatching the polyglot Tonnoir to Egypt, Algeria and Europe in December to investigate overseas developments.[114] The ‘grasshopper problem’ was a research agenda item at the very first AAC meeting in May 1935, which endorsed the SCA resolution that CSIR undertake investigations into the ‘habits and ecology of grasshoppers’ to find their major breeding areas.[115] The other nationally significant agricultural issues discussed at the meeting were soil drift, rabbits and weeds.

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[110] Wendy Way, *A New Idea Each Morning: How Food and Agriculture Came Together in one International Organisation*, (Canberra, ANU Epress, 2013), pp. 141–148.

[111] *West Coast Sentinel*, 21 July 1933, p. 1; *Townville Daily Bulletin*, 8 August 1933, p. 3, wheat rose to 3/6d per bushel; locusts also threatened the Argentine crop.

[112] *South Western Advertiser*, 23 November 1934, p. 3.

[113] The Standing Committee, instituted in 1927 to provide advice on Commonwealth-funded (CSIR) research related to livestock and agriculture, was now made permanent.

[114] *Argus*, 13 November 1934, p. 3, Rivett said CSIR would undertake a prolonged study of the biology and ecology of the grasshopper to focus attack on its breeding grounds; *Canberra Times*, 1 February 1940, p. 2, Tonnoir was accomplished in French, English, Spanish, Italian, German and Flemish.

[115] Australian Agricultural Council – Reports of meetings Vol 1. (1934–44), Proceedings and Decisions of Council, First meeting, 28–30th May 1935, pp. 53, 58 (National Archives of Australia. Series A4739, 1808408).

Things moved rapidly from that time and at the third AAC meeting in 1936, Uvarov's ideas on phase change and permanent breeding areas were discussed. A budget for research and the appointment of an assistant locust research officer were also approved.[116] While in London, Tonnoir met Ken Key, a young South African entomologist, whom he encouraged and selected for the position.[117] Key was working under Uvarov at the British Museum after completing a doctorate. He and his wife, also a specialist in Orthoptera who had worked at Imperial College, commenced work en route to Canberra, stopping at Perth in May 1936 to examine specimens and talk with Leslie Newman, before taking the train via Adelaide to meet researchers at the Waite Institute of the University of Adelaide.[118]

Davidson's team at Waite also wasted no time in commencing its research program. Coincidentally, another husband and wife team, Andrewartha and Harriett Vevers Steele were already conducting field and laboratory studies on the grasshopper and the locust. Making use of a vehicle supplied by CSIR, they made several explorations of the far north of the state, sampling populations and relating them to soil and vegetation type (Figure 8.9). Steele produced a detailed account of embryonic stages of *A. cruciata*, while Andrewartha investigated its embryonic diapause.[119] Davidson's other assistant entomologist, Duncan C. Swan, conducted laboratory breeding and temperature-controlled egg development studies on both species.[120] Swan's illustrations of the life-stages of the locust became the graphical standard for identification used by agriculture departments for many decades (Figure 8.10).

In 1936 Davidson wrote the first ecological synthesis of *C. terminifera* distribution and habitat in scientific literature, continuing the early emphasis on ecology in South Australia.[121] He made use of the new maps of climax vegetation communities, soils and climate by Joseph Wood and James Prescott, using these and climate records to reconstruct a plausible onset of the 1934 plague. It

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116 Australian Agricultural Council - Proceedings and Decisions of Council, 2nd Meeting, 27–28 May 1936, Appendix K, p. 45.

117 M. F. Day and D. C. F. Rentz, 'Kenneth Hedley Lewis Key 1911–2002', *Historical Records of Australian Science*, 15 (2004), 65–76; Tonnoir, visited Uvarov in London in early 1936, where he met Key and encouraged him to apply for the position in Australia. Tonnoir also investigated the hatching of locusts in the Yass area in 1938, suggesting it as a possible outbreak area.

118 While the Key's were in Perth, Newman's specimen identifications of *C. terminifera* were corrected; *West Australian*, 18 May 1936, p. 8, 'Women's Realm', in an interview Mrs Key said her last five years spent as demonstrator at the Imperial College of Science and Technology, London, was a rarity. There were scarcely any opportunities for qualified women in pure science, and she could not recommend entomology as a career for women; *Chronicle*, 4 June 1936, p. 7, Keys in Adelaide.

119 H. Vevers Steele, 'Some observations on the embryonic development of *Austroicetes cruciata* (Sauss. Acrididae) in the field', *Transactions of the Royal Society of South Australia*, 63 (1941), 329–332; Steele had published an article on thrips with the CSIR in 1935.

120 D. C. Swan, *Journal of Agriculture South Australia,* 40 (1937), 719.

121 J. Davidson, 'On the ecology of the black-tipped locust (*Chortoicetes terminifera* (Walk.) in South Australia', *Transactions of the Royal Society of South Australia,* 60 (1936), 137–62, p. 137; *Western Mail*, 18 August 1932, p. 44, Andrewartha too was already committed to ecology, and in 1932 had suggested that while insecticide baits had proved effective for locusts, an ecological solution would ultimately be required.

extended from his tracing of meteorological opportunities for locust population growth using rainfall–evaporation ratios he published in 1935.[122] Davidson also used calculated monthly Meyer ratios of rainfall and evaporation to generate a map of 'Bioclimatic Zones' in 1937, which showed a close match with the distribution of native vegetation types.[123]

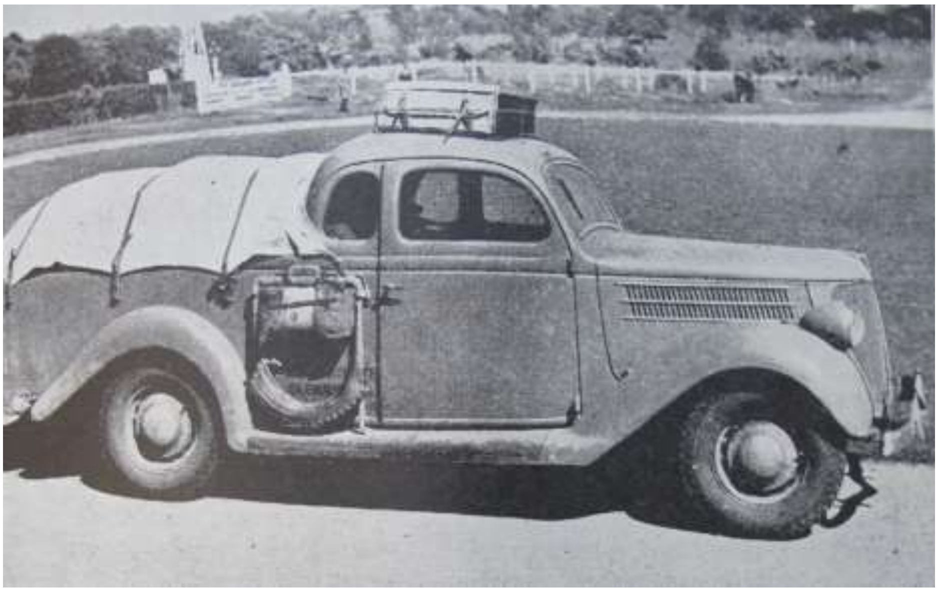

Figure 8.9. 'Motor conveyance used for making grasshopper survey tours', the vehicle used by Waite researchers was supplied by CSIR.[124]

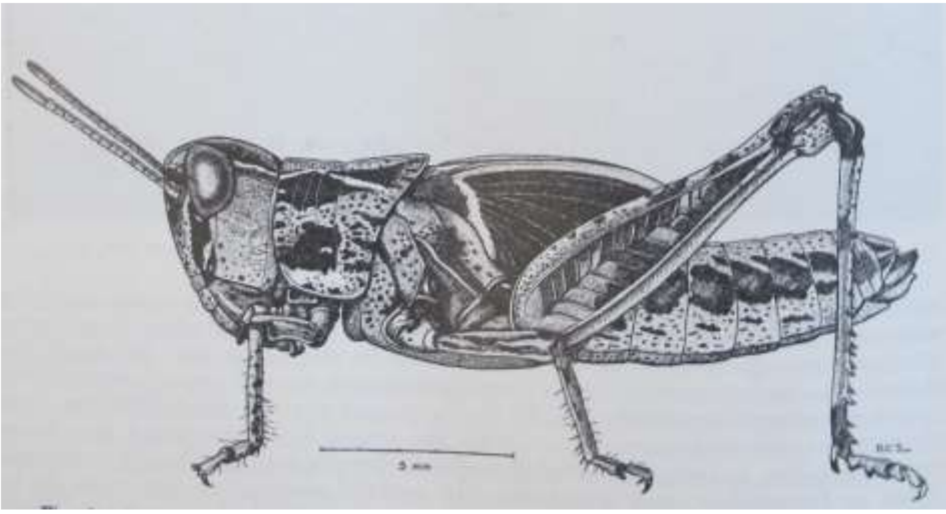

Figure 8.10. Fifth instar locust nymph by D. C. Swan.[125]

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[122] J. Davidson, 'Rainfall-evaporation ratio in relation to locust and grasshopper outbreaks', *Nature*, 136 (3434), (1935), 298–299.

[123] J. Davidson, 'Bioclimatic zones of Australia', *Nature*, 140, 3537, (August 1937), 265–66.

[124] H. G. Andrewartha, *Journal of Agriculture South Australia*, 42 (1938), p. 571.

On his return, Tonnoir confirmed that European research was concentrating on locating locust outbreak areas in Africa, and this was conceptually transposed to arid inland Australia because of long-held views that swarms came from unknown desert breeding areas. Key's arrival generated much anticipation of a scientific solution. David Rivett outlined the first steps in CSIR's prolonged study of 'grasshopper' ecology to find their breeding grounds, which he suggested were on the edge of the mallee country across southern Australia.[126] This was amplified in the press as science 'declaring war' on locusts, but it also generated diverse and perceptive public scientific conjecture on desert breeding areas (see 'Swarms from inland', p. 271).[127]

The first Australian locust conference

By 1938 the SCA was urging 'intensification of investigations into the control of the grasshopper problem' and the AAC resolved that CSIR organise a national 'grasshopper conference' with state entomologists, to plan for further research.[128] At the first locust conference in Melbourne in July, opened by federal Treasurer R. G. Casey, situation reports and research summaries were given by the entomologists. Tonnoir presented a report on natural controls that listed known insect parasites, including detail on fly species by Mary Fuller of CSIR. Key gave a summary of his taxonomic and historical research as well the rationale for investigations of locust outbreak areas in Central West NSW. Queensland delegate Jacob H. Smith identified the point of the conference in terms of Commonwealth-state relations. He outlined the structure of state financial responsibilities for locust control, pointing out that risks were highest for small-holders. Smith concluded that 'interfarm and interdistrict risks were pooled at the state level', but that the interstate risks from migration gave the states a legitimate claim for Commonwealth assistance.[129] He also thought that estimates of economic damage would be so inaccurate as to be 'academic', but the conference resolved that each state would present annual estimates of damages and costs.

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[125] D. C. Swan, *Journal of Agriculture South Australia,* 40 (1937), p. 719;

[126] *Argus*, 13 November 1934, p. 3.

[127] *Cairns Post*, 19 May 1936, p. 8, 'declares war', CSIR motor van for use as a travelling laboratory'.

[128] Australian Agricultural Council - Proceedings and Decisions of Council, 7th Meeting, 12–13 May 1938, pp. 8–9; Australian Agricultural Council – Summary of Decisions and Resolutions, 8th Meeting, Perth, WA. 8–9 September 1938, p. 2. (National Archives of Australia. Series A4739, 1808408).

[129] J. H. Smith, 'Memorandum on losses and expenditure due to grasshoppers', in *Proceedings of the First Australian Locust Conference*, *Melbourne, 19–22 July 1938*, (Melbourne, Council for Scientific and Industrial Research) Appendix 11, pp. 112–117; Resolution H (ii) 29, p. 21, Smith and explained the perceptions, motivations and spatial externalities of risk resulting from locust migrations; *Daily Mercury* (Townsville), 9 March 1944, p. 2, J. H. Smith was an entomologist with the Qld Department of Agriculture and Stock.

Swarms from inland. By 'Mopoke'

For ages plague locusts have been believed to rise in the desert. Investigations are being made in Australia to ascertain where grass hopper or locust swarms have their origin with a view to coping with such swarms before they spread … If you pick up any natural history work dealing with animal life of deserts, you are almost certain to find the locust prominently mentioned therein; whilst the great arid stretches of land in Africa, Palestine, and South America are frequently the scenes of great swarms brought before us in story or photograph. A century ago, in 1835, to be exact, we find Charles Darwin repeating the accepted view that locusts swarmed from desert places …

In the true deserts of permanent sand dunes, where nothing ever grows, there can be no breeding places for locusts. But in the so-called deserts where either seasonally or irregularly an abundance of verdure alternates with a lack of it, conditions favour the breeding of the insects. This type covers many millions of square miles in Australia. Why do locusts swarm in the desert? The question is not so important as why do they swarm from the desert? Both questions remain to be investigated by the officers of the Council of Scientific and Industrial Research, but it will be of interest to touch on them in a general way. Most of us know that in the inland seasons of luxurious growth of plant life follow on periods, usually long periods, of drought … And where such a growth of plants occurs, there is usually a correspondingly rapid multiplication of plant-eating forms of life. The season of growth is short, and yet it influences in some way an enormous increase of the pest … and because these creatures swarm, appearing in most extraordinarily amazing numbers in small areas, they migrate …

Plagues from the inland descend into cultivated parts in New South Wales and Victoria from time to time, but more often there are local plagues - grasshoppers hatching, swarming in rural districts, very often emerging from the hard bare ground of country roads. But it is likely that these local plagues are generations descended from desert swarms …

The West Australian, 23 May 1936, p. 5. ('Mopoke' was James Pollard.)

The question of birds had not gone away for Gurney in NSW. He reported that dead 'blue martens' he had collected in 1937 showed traces of arsenic in their stomach contents. However, he and McCarthy were assured by the majority opinion that birds payed a negligible part in controlling outbreaks and that bran baits had no apparent effect on them.[130] Conference members also discussed the effects of other natural enemies, noting examples of high rates of *Scelio fulgidus* parasitism, but concluded that there was little hope of plague prevention by biological control.[131]

Leslie Newman's report on the situation in WA told a similar story about what he now knew to be a different pest species. There had been an increasing annual *A. cruciata* problem in the wheat belt from 1923 and the succession of light rainfall years since 1935 contributed to the westward expansion of

[130] *Proceedings of the First Australian Locust Conference*, *Melbourne, 19–22 July 1938*, Resolution No. 29, p. 21.

[131] *Proceedings of the First Australian Locust Conference*, *Melbourne, 19–22 July 1938,* pp. 12–13, Resolution No. 28, p. 21, with Tonnoir dissenting.

swarming populations. The agriculture department expenditure on arsenic bait supplied to growers had increased dramatically over the previous three years, with 1937 being ‘the most widespread outbreak ever recorded’. Dense populations often occurred on neglected or abandoned farms and Newman had instigated a state-funded ploughing program to destroy grasshopper eggs.[132]

CSIR’s Ian Mackerras suggested a way forward, moving that the research arrangement whereby the Waite Institute had concentrated on *A. cruciata*, CSIR on *C. terminifera* and the states on control methods, should continue. Davidson offered to share the Waite findings on *A. cruciata* but, rejecting any such disciplinary restriction, stated that South Australia would continue research on the locust.[133] A budget for research was endorsed, particularly for Key’s program for identifying locust outbreak areas, and the prospect of ecological control by ‘rendering them unsuitable for swarm formation’ was emphasised.[134]

Davidson and Andrewartha gave details of *A. cruciata* biology and behaviour and listed recent Waite Institute publications.[135] The descriptions of loose adult swarms, where ‘a measure of individual action is retained’, each flying in different directions, and of the ritualised egg laying behaviour are reminiscent of Charles Wilson’s from a century earlier. Andrewartha tentatively attributed all outbreaks in South Australia prior to 1875 to *C. terminifera* after reviewing mentions of locusts in a 1918 book of South Australian rainfall records.[136] Andrewartha’s conclusions were made without knowledge of Wilson’s 1840s descriptions. Davidson, however, had apparently read some newspapers and recognised swarms of the grasshopper had been present from 1846.[137]

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132 L. J. Newman, ‘Report of work carried out in Western Australia’, *Proceedings of the First Australian Locust Conference*, *Melbourne, 19–22 July 1938*, Appendix 8, pp. 96–103.

133 *Proceedings of the First Australian Locust Conference*, *Melbourne, 19–22 July 1938*, pp. 14–15.

134 The funding included overseas travel for McCarthy to investigate control in other countries and continuation of the information service Key had established in cooperation with NSW PP Boards was endorsed. Key’s historical and taxonomic results were presented by Nicholson at the 1938 International Locust Conference in Brussels and then published as ‘The regional and seasonal incidence of grasshopper plagues in Australia. *C.S.I.R. Bulletin No. 117*, (Melbourne, 1938).

135 Including H. G. Andrewartha, J. Davidson and D. C. Swan, ‘Vegetation types associated with plague ‘grasshoppers’ in South Australia’, *Department of Agriculture of South Australia, Bulletin No, 333,* (1938).

136 H. G. Andrewartha, ‘Locusts and Grasshoppers in South Australia – some records of past outbreaks’, *Journal of Agriculture South Australia*, 41 (1937), 366–368.

137 J. Davidson, ‘The locust and grasshopper problem in South Australia’, *Journal of the Department of Agriculture South Australia* 41 (1938), 241–249.

 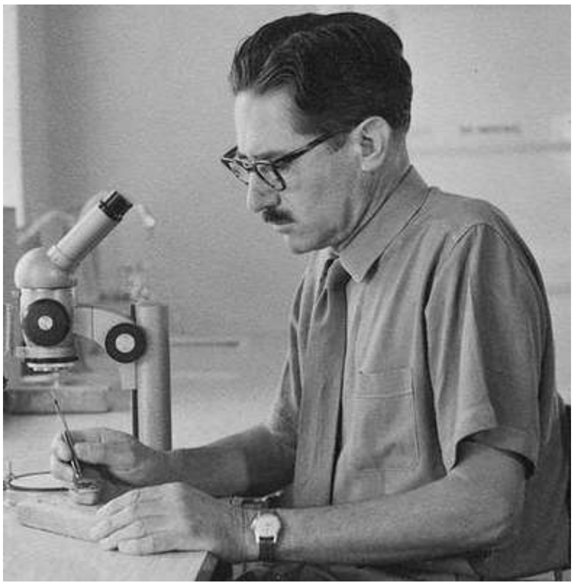

Figure 8.11. H. G. (Bert) Andrewartha in 1933 (left) and K. H. L. Key, c. 1960.[138]

There was an entomological conference in 1940 where coordination of grasshopper actions was followed up. Key had been producing monthly summaries and forecasts, which were sent to all the eastern states. It was concluded that there were no ‘outbreak areas’ in Victoria and that invasions of that state came mostly from the western Riverina. NSW chief entomologist McCarthy would therefore provide fortnightly reports of any locust activity.[139]

The intensification of ecological research

> *It has been found that that swarms maintain themselves as long as temperature and rainfall remain within certain limits, which have been defined … This knowledge may be of considerable importance in forecasting the course which an outbreak will take … it should now be possible to predict when and where fresh outbreaks will arise.*
>
> K. H. L. Key, 1942.[140]

There had been a rapid accumulation of scientific knowledge about locusts in the two years before the 1938 conference and that impetus continued in a productive and intense period of Australian research. In 1939, Andrewartha was joined by a young agriculture graduate, Charles Birch, and Key by science

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[138] Sources: Andrewartha, *Sunday Times*, 15 January 1933, p. 6; Key, CSIRO Entomology 1930–1960, (National Library of Australia, P13571/1-52 LOC Album 894, obj. 143075386).

[139] *Report on Entomological Conference (Sydney) to discuss Grasshoppers, 24–26 June 1940*, (Victorian Department of Agriculture archive, BHZ 4899).

[140] K. H. L. Key, ‘The outbreak of the Australian plague locust *Chortoicetes terminifera* (Walk.) during the seasons 1937–38 and 1938–39’, *C.S.I.R. Bulletin No. 146*, (Melbourne, 1942), p. 1.

graduate Laurance Ross Clark, on a Commonwealth Research Scholarship.[141] Andrewartha and Birch continued field and laboratory studies on the grasshopper, correlating its distribution and abundance with climatic data and concentrating on its egg diapause. Key and Clark concentrated on vegetation and soil mosaic habitats in relation to locust abundance in Central West NSW.

The growth of animal ecology and development of the 'niche' concept during the 1930s saw the convergence of ideas of environmental constraints on species distributions with the biophysical factors and species interactions which imposed selection for particular traits.[142] In 1933, Oxford animal ecologist Charles Elton had proposed the general use of 'climographs', plots of temperature and moisture budget developed by entomologists in the 1920s, for identifying the environmental limits of particular pest insects.[143] Australian researchers applied this methodology to the locust and grasshopper, by matching the observed distributions with a calculated temperature-rainfall index, the Meyer ratio values of rainfall to saturation deficit, to map and model the climatic limits to population growth. However, their different ecologies led to different approaches and outcomes. The largely sedentary grasshopper fitted spatially with definable long-term limits, while the nomadic locust found transitory favourable conditions in different parts of a wide distributional range.

The 1934 plague appeared to have commenced in the Warren–Trangie–Dandaloo area of Central West NSW. This was the logical starting point for Key's investigation of locust outbreak areas that later expanded as the 'Bogan–Macquarie outbreak area', taking its name from the two inland river basins it covered. The region was involved in the infestations that continued in NSW and Queensland from 1936 to 1940, which Gurney described at its peak in 1937–38 as severe as the 1934 plague. That view was shared by Queensland entomologists and, because of crop damage on the Darling Downs, the government passed the 'Plague Grasshoppers Extermination Act'.[144] Gurney made several radio announcements on the situation and the need for combined action in 1938, and NSW spent £42,000 organising and distributing 7,000 tons of arsenic bran bait and 1,000 gallons of spray from hundreds of mixing stations throughout the state (Figure 8.12).[145]

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[141] Francis Ratcliffe was also a research officer with the Economic Entomology Division from 1939 to 1942; P. W. Geier, 'Laurance Ross Clark', *Australian Journal of Ecology*, 2 (1977), 3–8, Clark was born in 1916.

[142] Statzner *et al.*, 2001, pp. 302–307, lists the works of several entomologists in the 1920s, notably Frederick Bodenheimer; A. G. Hamilton, 'The relation of humidity and temperature to the development of three species of African locusts – *Locusta migratoria migratorioides* (R. & F.), *Schistocerca gregaria* (Forsk.), *Nomadacris septemfasciata* (Serv.)', *Transactions of the Royal Entomological Society of London*, 85 (1936), 1–60.

[143] Charles Elton, *The Ecology of Animals*, (London, 1933), cited in Statzner *et al*., 2001, p. 306.

[144] W. B. Gurney, 'Grasshopper swarms, a review of methods of control', *Agricultural Gazette of NSW*, 49 (1938), 431–434.

[145] W. B. Gurney, 'Report on locust control in NSW', *Proceedings of the First Australian Locust Conference*, *Melbourne, 19–22 July 1938,* Appendix 1, Attached papers No. 16, p. 6, costs for 1937–38.

Figure 8.12. Photomontage of NSW Government Entomologist William Gurney laying down the law to a giant locust in a 1938 radio interview (NSW Department of Agriculture, held at APLC Library).

Key tracked the distribution of locust generations from 1936 to 1940, travelling in the CSIR Ford panel van equipped as a 'mobile laboratory' and drawing on observations from the NSW Locust Information Service. Stock inspectors in each PP Board district marked every occurrence of swarms or nymph bands on specially prepared district maps, which were then transcribed to tables and gridded on statewide maps. Key produced monthly 'bioclimatographs' of temperature and Meyer ratio for infestation sites in NSW to define the optimal and limiting conditions for *C. terminifera*. These plots were used to follow the sequence of population increase and decline, and in the 1945 synthesis to discuss bioclimatic conditions and extent of the probable outbreak areas.[146] The analyses were summarised in a single bioclimatograph, which established a correlation between swarm formation and above-normal rainfall (>50 mm per month) during October–February in NSW, with population collapse occurring after prolonged dry or very wet periods.[147]

Key published separate detailed reports on the 1936–38 and 1939–40 events, but the more outbreaks he studied the more outbreak areas he identified and they extended further into Queensland in 1940.[148] At the time 'outbreak area' was used in the sense defined by the 1934 International Locust Conference; any area that can generate swarms from low density populations, by implication through

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[146] K. H. L. Key, 'The general ecological characteristics of the outbreak areas of the Australian plague locust *Chortoicetes terminifera* (Walk.)', *C.S.I.R. Bulletin No. 186*, (Melbourne, 1945).

[147] Key 1945, p. 115.

[148] K. H. L. Key, 'The outbreak of the Australian plague locust *Chortoicetes terminifera* (Walk.) during the seasons 1937–38 and 1938–39', *C.S.I.R. Bulletin No. 146*, (Melbourne, 1942); 'The outbreak of the Australian plague locust *Chortoicetes terminifera* (Walk.) in the seasons 1939–40, with special reference to the influence of climatic factors', *C.S.I.R. Bulletin No. 160*, (Melbourne, 1943).

local breeding.[149] In 1938 there were twenty-three outbreak areas where habitat and climate were suitable for swarm developments, mostly in NSW.[150] By 1945 the list expanded to include several areas of inland Queensland, including the Mitchell grass downs of the Central West and Northwest regions and the floodplains of the Cooper Creek in Southwest Queensland. They were based primarily on soil types and reports. Key also investigated the periodicity of recorded outbreaks but found no conclusive relationships with flood records of the Diamantina River or with sunspot cycles.[151]

Andrewartha and Birch undertook similar investigations of the climatic limits to both *C. terminifera* and *A. cruciata* distributions in South Australia. Using monthly precipitation/evaporation (P/E) ratios, they showed that favourable soil moisture conditions had occurred in critical months to allow successful breeding sequences in locations where swarms were reported during the *C. terminifera* plague of 1933–35.[152] The boundary between the outbreak and invasion areas was taken to be where the winter P/E ratio was <0.5 and maximum temperatures >16^{o} C, north of which habitat was determined by local landscape variation. However, they and Key saw winter temperatures and high moisture as limiting survival of *C. terminifera* in the southern parts of its range.

The areas where swarms of *A. cruciata* developed were more easily delineated by average climate values. The 'grasshopper belt' was bounded in the north by an average October P/E ratio of 0.25 and in the south by a September P/E ratio of 0.5. Within this zone conditions were favourable during the critical period in the early spring for *A. cruciata* nymphs.[153] After finding that eggs collected from the field did not develop at fixed temperatures in the laboratory, they made detailed studies of egg diapause in the species. They showed that it was an obligate dormancy that was broken by a period at

[149] Key 1938, p. 52; Key 1945 p. 10, Key used the definition the 1934 Third International Locust Conference in London — 'an area in which quite a small initial population can multiply to produce a swarm which migrates'.

[150] Key 1938, the 23 areas included those in South Australia identified by H. G. Andrewartha.

[151] Key 1945, p. 12, Map 3, the outbreak areas identified by Andrewartha in northern South Australia were dropped from Key's 1945 list, on the grounds that the area was too arid to support breeding and swarms in that area were probably immigrants from elsewhere; see E.D. Deveson, 'The search for a solution to Australian locust outbreaks: how developments in ecology and government responses influenced scientific research', *Historical Records of Australian Science*, 22 (2011), 1–31, Key made inconclusive attempts to correlate records of flood heights at Birdsville from 1913 to 1939 with widespread locust infestations in agricultural regions, and with sunspot cycle data.

[152] H. G. Andrewartha, 'The environment of the plague locust (*Chortoicetes terminifera* Walk.) in South Australia', *Transactions of the Royal Society of South Australia,* 62 (1940), 76–94, p. 90, P/E ratios were modified to account for soil moisture loss.

[153] H. G. Andrewartha, 'The distribution of plagues of *Austroicetes cruciata*, Sauss. (Acrididae) in Australia in relation to climate, vegetation and soil', *Transactions of the Royal Society of South Australia* 68 (1944), 315–326; H. G. Andrewartha and L. C. Birch, *The Distribution and Abundance of Animals*, (Chicago, University of Chicago Press, 1954), p 593.

low temperature and was associated with a strong resistance to desiccation.[154] They discussed the adaptive value of this in relation to the strongly seasonal environment of its range.

It now remained to incorporate the closer details of habitat suitability within the broad spatial bioclimatic frameworks to understand the ecology of the locust. Faced with the broad geographic distribution of locust swarms and, frustrated at the lack of basic data on soils or vegetation, Key commenced a detailed study of the habitat characteristics of the Bogan–Macquarie outbreak area, assisted by Clark and several technical assistants.[155] They identified the mosaic nature of breeding and feeding habitats found in the landscape, establishing that both self-mulching clay soils and compact red earths provided characteristic micro-habitats within an outbreak area.

Andrewartha recognised the differences between the environments of arid South Australia and the higher rainfall areas in Central West NSW, identifying the more limited extent of habitats and the importance of drainage and run-off in creating locally suitable conditions. Andrewartha classified particular landscape features such as watercourses, depressions and floodplains, which carried vegetation associations that provided ephemeral conditions for locust breeding. The extremely variable rainfall resulted occasionally in a run of good seasons, which allowed a sequence of breeding and the production of swarms in those landscapes.[156]

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[154] H. G. Andrewartha, ‘The influence of temperature on the elimination of diapause from the eggs of the race of *Austroicetes cruciata* Sauss. Acrididae occurring in Western Australia’, *Australian Journal of Experimental Biology and Medical Science*, 22 (1944), 17–20; L. C. Birch and H. G. Andrewartha, ‘The influence of weather on grasshopper plagues in South Australia’, *Journal of the Department Agriculture South Australia*, 45 (1941), 95–100; L. C. Birch, ‘The influence of temperatures above the developmental zero on the development of the eggs of *Austroicetes cruciata* Sauss. (Orthoptera)’, *Australian Journal of Experimental Biology and Medical Science*, (1942), 17–25.

[155] Day and Rentz 2004, p. 68, point out that Key could get no authoritative advice on vegetation ecology for the Bogan Macquarie area, and no detailed soil maps were available, so he dug soil profiles to assess variation in soil relative to creek positions. His CSIRO assistants included Brian Cameron of Trangie and Lee Chinnick.

[156] Andrewartha 1940, pp. 81, 84.

Technological and ecological outcomes of the 1930s plagues

The Flame-Thrower at Work — Destroying Grasshoppers in the Crawling Stage

Figure 8.13. Flame-thrower trials at Leeton, NSW. *Sydney Mail*, 20 October 1937, p. 46.

Concern over the ‘grasshopper’ problem in all mainland states in the 1930s made it an issue of national concern and one which the states could not individually solve, driving the federal funding and intensification of scientific research. There was also an upscaling of the technologies of control. But the limits of programs based in increasing amounts of arsenic insecticides were being reached as state-funded campaigns became larger, more frequent and more expensive.

Locusts were now a perennial pest in NSW, while in WA and South Australia it was the grasshoppers. Locust swarms were recorded in some part of NSW in every year between 1920 and 1945 (except 1923), the longest period of continuous infestations on record.[157] The regions of swarm breeding included the eastern half of NSW, sometimes extending over its entire latitudinal range. During the 1930s breeding occurred in districts further east than previously recorded. Hatchings at Yass and Young in 1934 even led Tonnoir to suggest the area as a ‘permanent breeding ground’ and locust

[157] This may have been a function of the increase in official recording and it is possible that some reports were the grasshopper. Key noted that the first reports for 1927–28 came in January 1928, but there are newspaper reports for March, November and December 1927 from the Central West; *Narromine News*, 14 December 1927, p. 2, ‘cars from infested areas with front bonnets and windscreens plastered … the highway a moving mass’; Rainfall deciles were very low for the 12 months to May 1933 in NSW.

swarms reached Canberra in 1938.[158] Key found no evidence during 1936–43 that infestations came from Far West NSW, which experienced severe drought during most of that period.[159]

State entomologists and farmers experimented with other control technologies. In WA, the 'largest and most widespread' plague yet recorded occurred in spring 1935. Newman attributed this to more abandoned farm country, owing to a fall in the price of wheat.[160] Farmers' groups used improvised cart-mounted arsenic-bait mixing and spreading machines to cover the large areas involved and Newman introduced an ambitious scheme of ploughing abandoned fallow farmland. Landholders in several states were captivated by the idea that wartime flame-throwers would check the pest. State departments tested them but concluded they were more costly than arsenic and potentially dangerous. The Argentine technology of using long sheets of galvanised iron to funnel hopper bands into pit traps was even tried in South Australia, but it was used against grasshoppers and was considered less effective and more labour-intensive than poisoning.[161]

Where the technoscience solution of arsenic baits and sprays did not match the ecosystems where it was applied was in its effects on other organisms — livestock, useful insects and wildlife, particularly birds, and with the public sensitivities to those effects. The effect on birds was a more metropolitan concern in the 1930s than it had been in 1928, when residents over the entire Riverina had watched the woodswallows in action. The *Sydney Mail* received many letters from ornithology groups on the subject in 1934 and the issue was raised again in the NSW Parliament.

In 1935 the NSW agriculture department contracted the prominent museum ornithologist Roy Kinghorn to tour infested areas where arsenic baits were used and assess the impact on birds. In his report he found no evidence of bird poisoning.[162] Kinghorn suggested that the alarm was created by those opposed to the baiting for other reasons. Clee Jenkins in WA echoed a similar view that few objections to the poisoning were based on more than 'surmise' and quoted from an American study on

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[158] *Central Queensland Herald,* 21 May 1936, p. 15, during 1938–1940, breeding also occurred in the Inverell–Tenterfield area of the Northern Tablelands and in the Bathurst–Blayney area.

[159] It is possible that western NSW and the Far North region of South Australia carried no significant populations during the period because of the absence of vegetation on the denuded landscapes in the core area of Australia's dustbowl.

[160] L. J. Newman, *Journal of Agriculture W.A.*, 10 (1937), 24–27.

[161] W. C. Johnston and F. C. G. Gross, 'Some field observations on the grasshopper pest, with details of trapping experiments conducted at Snowtown', *South Australian Journal of Agriculture*, 39 (April 1935), 1072–1081.

[162] *Albury Banner & Wodonga Express*, 4 January 1935, p. 15; 1 February 1935, p. 18, the Albury PP Board opposes the Noxious Insect Act; *Narrandera Argus & Riverina Advertiser*, 4 January 1935, p. 6.

feeding fowls known quantities of white arsenic.[163] The reassurances of these ornithologists did little to allay the negative perceptions among bird preservation groups.

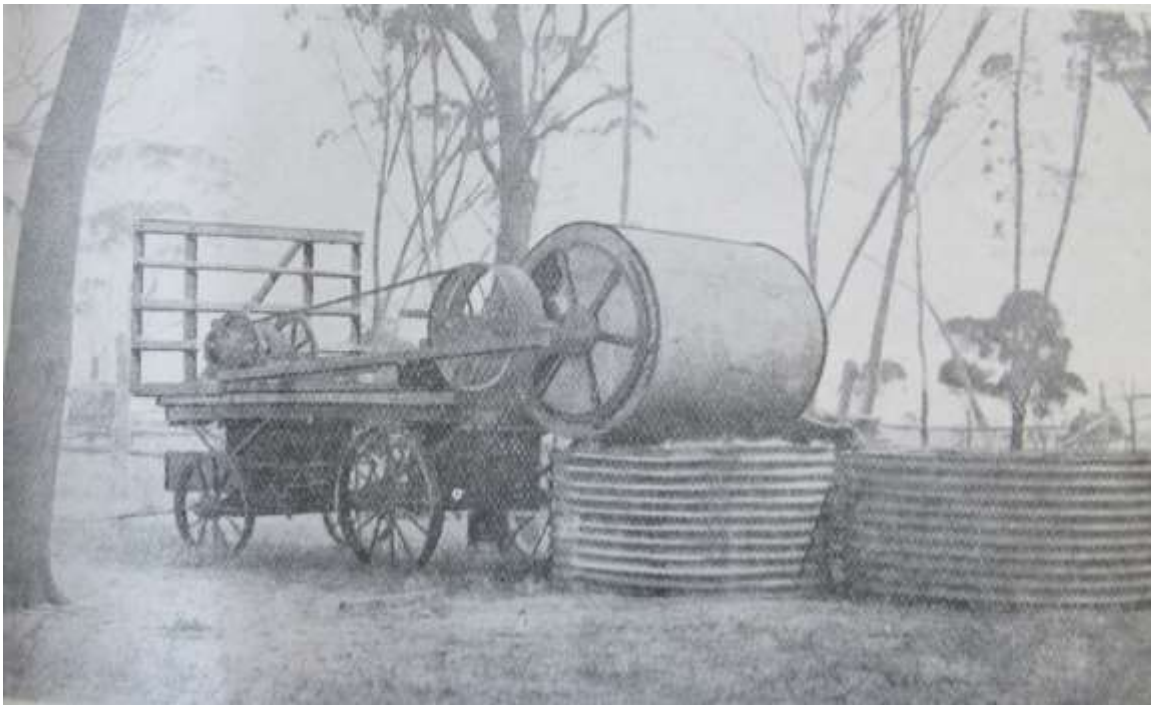

Figure 8.14. Cart-mounted bait mixing machine for grasshopper control, *Journal of the Department of Agriculture of Western Australia*, 10 (1937), p. 28.

At the 1938 conference it was recognised that the significance of outbreak areas was dependent on them occupying only a small proportion of the total areas infested, so that either ecological modification or control of incipient swarms would be feasible. The idea that local control could be construed as preventive in the face of migrations from numerous inland outbreak areas, where control was logistically impractical, was becoming untenable.

The strategy of the responsible institutions also fell down in maintaining the landholders' faith that baiting or spraying was worthwhile, because of apathy of neighbours both near and far. By 1938 all states except Victoria had introduced emergency legislation for compulsory recording, reporting and control of locusts or grasshoppers in the attempt to solve the 'dilemma of collective action' as a public good.[164]

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[163] Clee Jenkins, *Emu*, 34 (April 1935), 311–312.

[164] The study of 'collective actions' and 'public goods' are an integral part of 'group theory' of economic behaviour, first articulated by Mancur Olsen in *The Logic of Collective Action: Public Goods and the theory of Groups*. Cambridge Massachusetts, Harvard University Press, 1965.

Chapter 9. Aerial ‘control’ and ecological research in the war on locusts, 1940–1960

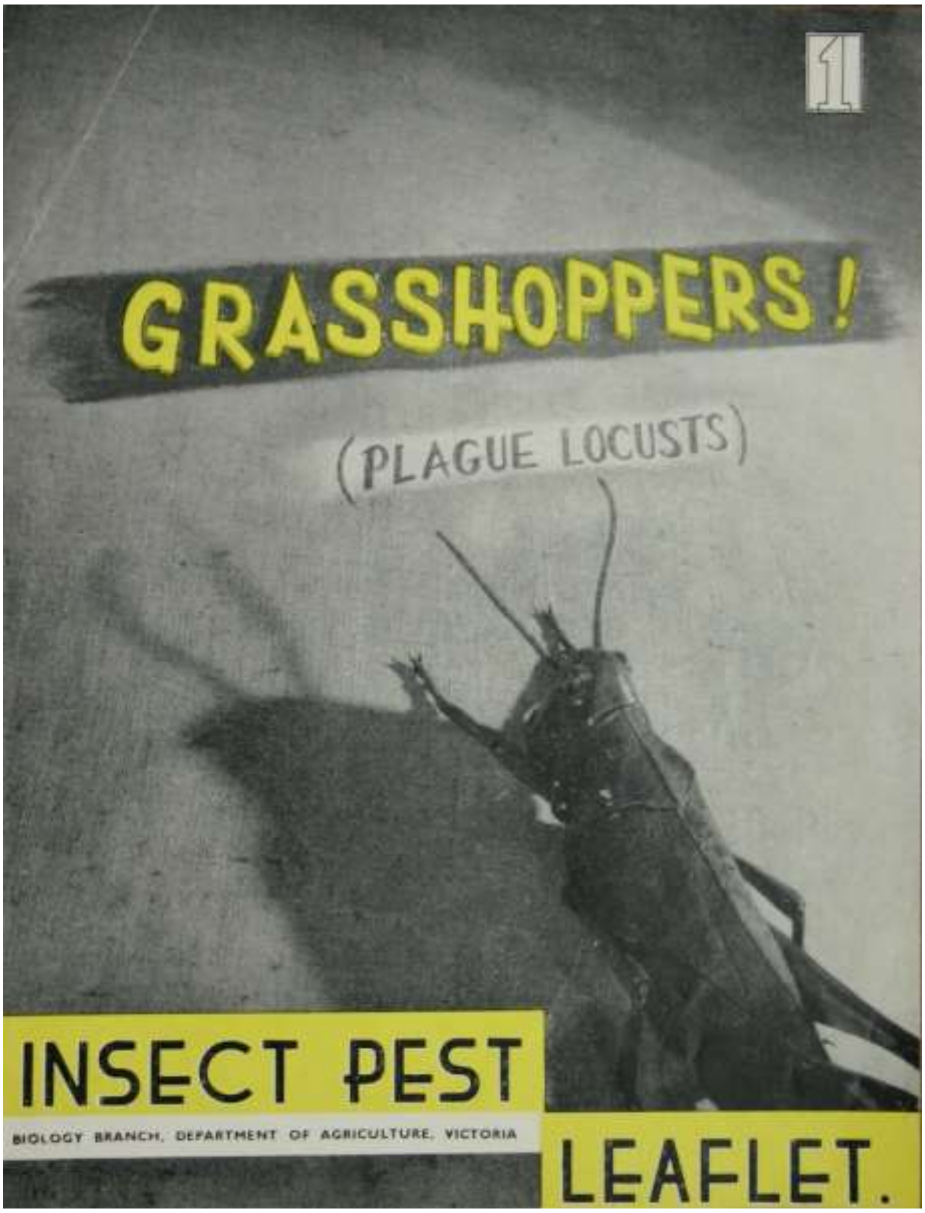

Figure 9.1. Department of Agriculture Victoria pamphlet on locust control, 1954.

Droughts and floods are all despised,

’Hoppers come and go;

Dad and Mum forget their jolts,

Meet them at the show.

From ‘The Show Is On’ by Jack Moses, *Nine Miles From Gundagai*,

(Sydney, Angus and Robertson, 1942).

There was no abatement of locust plagues during World War II. A persistent and dramatic 'major plague' of desert locusts continued in conflict zones of North Africa and the Middle East. By 1941 swarms spread across the entire habitat range of the species from Mauritania and Morocco to Arabia and Pakistan. The first marked decline did not occur until 1946.[1] While there was no major plague in Australia, both locust and grasshopper swarms erupted in different regions and different seasons, despite widespread drought conditions.

At the start of the war, locust control still depended mainly on arsenic chemistry, although fluoride compounds were tried in Africa to avoid the negative reactions to stock poisonings.[2] Work on new insecticides gained impetus as an outcome of chemical warfare research and the need to reduce insect-borne diseases affecting troops. Developments in organic chemistry produced a new class of organochlorine insecticides that were tested before the end of hostilities. These were coupled with methods for delivering insecticides over large areas of by aircraft, promising a technoscientific end to many intractable human health and agricultural problems. The story of the entrainment of developments in chemical warfare onto insecticides, and its metaphors of enemy soldiers as insect pests to be exterminated, has been told in the US context by Edmund Russell.[3] But all Allied powers were engaged in finding and converting promising compounds into commercial insecticides.[4]

At the same time, ecology was emerging as a mature science with, if not testable theories, at least integrative models of individual and population level processes. Its challenge was to account for the stochastic conjunction of both physical and biotic interactions. Australian scientists contributed to the development of animal ecology in efforts to address fundamental questions of how species persist in the face of over-abundance or extinction, although there were differing views about the relative roles of biotic interactions and weather in limiting species distributions and stabilising populations.

This chapter deals with these almost polar approaches to the locust problem. One was the attempt to defeat swarming populations in the field with new chemicals, and the other to use ecological theory to investigate reasons for the dramatic population increases that characterised plague development.

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[1] Zena Waloff, 'The Upsurges and Recessions of the Desert locust Plague: an Historical Survey', *Anti-Locust Memoir 8*, (London, Anti-Locust Research Centre, 1966), pp. 50–52.

[2] Claude Peloquin, 'Locust Swarms and the spatial techno-politics of the French Resistance in World War II', *Geoforum*, 49 (2013), 103–113, p. 109.

[3] Edmund M. Russell, *War and Nature; Fighting Humans and Insects with Chemicals from World War I to 'Silent Spring'*, (Cambridge, Cambridge University Press, 2001), as the war drew to a close there was a race to gain information on German chemical research.

[4] The British also interrogated captured German chemists about experiments on the insecticidal properties of various chemical warfare products, (Vic Department of Agriculture archive, BHZ-4898, file 63/3, 'Aerial Spraying', (18 Nov. 1946), from British War office files, unclassified. Interrogation report 327).

Developments in international locust control

Despite the wartime crises of invasion and annihilation, Imperial nations fostered their connections and interests in Africa, the Middle East and Asia. Locusts provided one means of maintaining influence in an era of widespread scientific diplomacy. While France was under Nazi occupation, the French Resistance in North Africa continued to place importance on locust invasions as a field of colonial rule. It asserted a disassociated presence by organising an Allied locust conference in Morocco in 1943, attended by British entomologists, including Uvarov, and representatives of African dominion nations.[5] France maintained its African locust expertise after 1943 through l'Office National Anti-Acridien (ONAA).[6]

Uvarov's locust unit in London became the Anti-Locust Research Centre (ALRC) in 1945, strengthening its position as the international centre of expertise, although its own data collection was concentrated on British dominions. The ALRC published specialised locust research journals and amassed a library, from which were compiled detailed 'Acridological Abstracts' of worldwide research. When the first series ended in 1964, the abstracts covered over 4,000 publications and listed over 400 researchers worldwide.[7] The ALRC presented itself as the conduit for ecological and control research, and now for locust forecasting, while the control was undertaken by regional anti-locust control organisations. Desert locust swarms were present every year from 1940 to 1962 and there were upsurges of the migratory locusts, *Locusta migratoria migratorioides* (Reiche and Fairmaire), and red locusts, *Nomadacris septemfasciata* (Serville), in other parts of Africa.[8]

By the 1950s chlorinated hydrocarbons were being used against locusts in the Middle East, North Africa and Pakistan in poison baits and sprays from the ground and the air.[9] The cost estimate for one planned campaign on the Arabian Peninsula in 1954–55 was £450,000 and the British government was spending up to £1 million each year on locust control.[10] In 1948 the Desert Locust Survey was established within the ALRC to monitor east Africa, financed by the Colonial Development and

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[5] Peloquin 2013, the French 1943 conference is the central subject of Peloquin's analysis.

[6] Claude Peloquin, *Unruly Nature and Technological Authority: Governing Locust Swarms in the Sahel*, (PhD thesis, University of Arizona, 2012); Roger du Pasquier, Boris Zolotarevsky and Robert Didier were entomologists to the ONAA. The organisation name was subsequently changed several times.

[7] *Acridological Abstracts* were produced monthly and distributed to locust-affected countries. A questionnaire in 1956 showed 220 locust workers worldwide, with 60 in Britain and 11 in Australia, *Current Research on Orthoptera*, No. 1. February 1958, and February 1964, (APLC Library).

[8] R. C. Rainey, E. Betts and A. Lumley, 'The decline of the desert locust plague in the 1960s: control operations or natural causes?' *Philosophical Transactions of the Royal Society B*, 287 (1979), 315–344.

[9] Aerial control campaigns in Africa, Italy and India in the late 1940s were assisted by the Royal Air Force and the US Air Force.

[10] *Advertiser*, 20 September 1954, p. 7, the campaign was to involve Britain, Egypt, Saudi Arabia and Jordan; *Coffs Harbour Advocate*, 20 February 1953, p. 1.

Welfare Fund.[11] An intelligence network was built up by entomologists and European experts, who engaged with emerging states, regional control units and indigenous populations. Among the exotic figures sent out to look for locust breeding grounds was Wilfred Thesiger, who made several traverses of the Empty Quarter of the Arabian Peninsula.[12]

Uvarov continued building a global correspondence network that included Russian entomologists working in Persia and central Asia, and extended as far as Argentina and Australia.[13] He was convinced that targeted control would reduce locust impacts and thought the main obstacle was multinational coordination, particularly for poorly equipped post-colonial African nations. In 1953 an advisory committee of the United Nations Food and Agriculture Organization took over the organisation of locust emergency responses. Locust control thus became part of the process of development aid funding and was later linked to the chemical industries of UN donor countries. Desertification was also seen as a serious issue for agricultural development in newly independent African nations. Uvarov made the connection between environmental changes due to 'thoughtless development' and the likely emergence of new locust problems or the translocation of existing ones.[14]

Uvarov's model for plague suppression by attacking locusts in outbreak areas found support in Africa. Donald L. Gunn summarised the essential features of outbreak areas of the red locust and African migratory locust, primarily river floodplains and swampy occluded drainage basins, as favourable places where these species were always present and in which breeding produced swarms that emigrated to start a plague.[15] Until the 1950s Uvarov maintained that the theory had provided the key to the whole problem because the localised outbreak areas of those two species had been identified and proven control methods had been found.[16] But 'outbreak areas' of the desert locust were found to

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[11] *A Review of Colonial Research, 1940–1960*, (London, Colonial Office, British Government, 1962), pp 191–205, p. 196.

[12] Thesiger was hired to search for locust breeding grounds in the 'empty quarter' of the Arabian Desert in 1946 and Oman in 1948. He is best known for the 1958 book *Arabian Sands*.

[13] Uvarov wrote to Allman in NSW in 1953 requesting information on actions and costs and Hogan corresponded with Uvarov in the 1950s; A. Martinez and A. A. Fedotova, 'Alekhandro Ogloblin, Russian Akridologist in Argentina', *Priroda*, 12, (2015), 60–70, (in Russian), letters between Ogloblin and Uvarov.

[14] B. P. Uvarov, 'The aridity factor in the ecology of locust and grasshoppers of the Old World', *Arid Zone Research: Human and Animal Ecology*, (Paris, UNESCO, 1957), pp. 164–198; B. P. Uvarov, 'The locust and grasshopper problem in relation to arid lands', in ed. G. F. White, *The Future of Arid Lands*, (Washington DC, American Association for the Advancement of Science, 1956), pp. 383–389, p. 385.

[15] D. L. Gunn, 'Nomad Encompassed. The development of preventive control of the Red locust, *Nomadacris septemfasciata*, Serville, by the International Red Locust Control Service', *Journal of the Entomological Society of South Africa*, 23 (1960), 65–125, p. 68; P. M. Symmons, 'The patterns of distributions of adults of the red locust (*Nomadacris septemfasciata* Serville) in an outbreak area', *Entomologia Experimentalis et Applicata*, 6 (1963), 123–132.

[16] B. P. Uvarov, 'The locust plague', *Journal of Economic Entomology*, 37 (1944), 93–99; B. P. Uvarov, 'Locust Research and Control 1929–1950', in *Colonial Research Publications 10*, (London, His Majesty's Stationery

be only occasionally favourable and subject to frequent migratory exchanges between widely separated habitats.[17] Desert locust migrations were shown to follow the seasonal reversal of predominant winds and rainfall about the intertropical convergence across northern Africa, which Uvarov later categorised as a ‘closed circuit’.[18]

The Australian environmental setting

> *State-Wide Duststorms*
> *Position desperate in Western Riverina … conditions have become so grim that rabbits and grasshoppers are fleeing from the desolated areas, while man and beast are still trying to hang on … Farmers are giving up the western Riverina and a mass exodus has begun, it is stated, families camping on creeks where scanty water supplies are still available.*
>
> *Narrandera Argus*, 17 November 1944, p. 2.

The environmental changes that were occurring in western New South Wales (NSW), northern South Australia and north-west Victoria during the 1930s intensified in the drought of the early 1940s. The loss of topsoil and vegetation was seen by those interested in agricultural production and ‘nature’ conservation alike, as degradation. Some regions fared a little better than others. Francis Ratcliffe described Northwest South Australia as a veritable paradise compared to the Far North and Northeast regions in 1935. Sand drift was active as far south as Quorn and some large northern sheep stations were without any ground vegetation.[19] Images from Noel Beadle’s 1940s vegetation surveys of western NSW show landscapes unrecognisable as those of today.[20] The incidence of dust storms is estimated to have been six times higher overall during the 1940s than the 2000s, while at Charleville in Queensland it was twenty times higher.[21] Ratcliffe’s 1936 CSIR report, while acknowledging the

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Office, 1951) pp. 54–56, refers to endogenous drainage basins as outbreak areas for red locust and migratory locust in Africa.

[17] Uvarov 1951, p. 55; Uvarov 1957, pp. 167–168; Uvarov’s later biographies say he was admired by all who worked with him, but he remained staunchly anti-communist, which brought some ambivalence to his relationship with certain British members of his staff, notably J. S. Kennedy.

[18] B. P. Uvarov*, Grasshoppers and Locusts, Vol. 2*, (London, Centre for Overseas Pest Research, 1977), pp. 337–351; *Z.* Waloff, ‘The upsurges and recessions of the desert locust plague: an historical survey’, *Anti-Locust Memoir 8*, (London, Ministry of Overseas Development, Anti-locust Research Centre, 1966); R. C. Rainey, *Migration and Meteorology: flight behaviour and the atmospheric environment of locusts and other migrant pests*, (Oxford, Clarendon Press, 1989).

[19] Francis Ratcliffe, *Flying Fox and Drifting Sand*, (Sydney, Sirius Books, 1963), pp. 225, 248.

[20] N. C. W. Beadle, *The Vegetation and Pastures of Western New South Wales with Special Reference to Soil Erosion*, (Sydney, NSW Government Printer, 1948).

[21] G. H. McTainsh, J. F. Leys, T. O’Loingsigh and C. L. Strong, *Wind erosion and land management in Australia during 1940–1949 and 2000–2009*, Report prepared for the Australian Government Department of Sustainability, Environment, Water, Population and Communities on behalf of the State of the Environment 2011 Committee, (Canberra, DSEWPaC, 2011), pp. 10–11.

impacts of rabbits and drought, was an indictment on poor regulation of the wool industry in South Australia. It clearly implicated overstocking as the cause of vegetation loss leading to wind erosion.[22]

Figure 9.2. Drought in the northern Mallee, Victoria, early 1940s (State Library of Victoria).[23]

Dust storms created strange, even apocalyptic visual effects in country towns. When Sydney was blacked out in November 1944, soil erosion became a serious issue in everyone's mind (Figure 9.2).[24] Soil was labelled the 'Cinderella of Agriculture' by the South Australian agriculture department, as the neglected sister of agricultural management.[25] Claypans formed and irrigation channels filled overnight as soils blew away, while Riverina weather forecasts were more often 'hazy with scattered dust storms' rather than 'showers'.[26] South Australia imposed stocking limits on pastoral country, the NSW government created a Soil Conservation Service in 1938 and in Victoria, a Soil Conservation Authority was established in 1940. After 'suffocating' dust storms across the south-eastern states in

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[22] Francis Ratcliffe, 'Soil drift in the arid pastoral areas of South Australia', *CSIR Bulletin 64*, (Melbourne, CSIR, 1936), pp. 19, 30, 47.

[23] State Library of Victoria, 'Argus Collection', image H2002.199/1382.

[24] *Kalgoorlie Miner*, 18 October 1944, p. 2; *News*, 20 November 1944, p. 3, at Mildura, 'lights in houses turned blue, outside the sun hung in the red sky as a ball of blue or yellow fire' … 'one man telephoned the newspaper … to say he feared the end of the world was setting in'.

[25] *Journal of the Department of Agriculture, South Australia*, 47 (2), (1943), 55–57, also the title of a state-wide radio broadcast.

[26] *Sydney Morning Herald*, 11 November 1944, p. 5; *Daily Advertiser*, 7 November 1944, p. 2.

1944, NSW created a Ministry of Conservation to address the wider problem and the Country Party called for a National Erosion Commission.[27]

Locust swarms appeared on the margins of the 'dust-bowl' during the early 1940s, but the grasshoppers took their place in some regions.[28] Entomologists working in the field could see the agricultural landscape in crisis everywhere around them and related the incidence of both *C. terminifera* and *A. cruciata* swarming to environmental changes. They recognised that the condition of the land, as much as climate and the physiology of the insects, was causing the outbreaks. Both species were seen to have been favoured by soil erosion and the loss of perennial vegetation. In accord with Uvarov's idea that ecological modification of an outbreak area could render it unsuitable for swarm breeding, they suggested land use change and vegetation restoration to reduce the infestations.

In 1946 Australians involved in wartime activities overseas were returning home. Those serving overseas re-entered society and the workforce, while many martial and emergency industries that had been operated by women during the war were restructured. This was also a turning point in Australia's climate history, marking a change from a period of low rainfall during the first half of the century.[29] The good years of the 1950s saw woolgrowers make profits, buy new motor cars and build new houses, while for many small wheat growers and rural workers the agricultural boom came more as a trickle.[30] Sheep numbers peaked in 1955 at 130 million, an increase of 40 million since 1925.[31] The increased numbers were concentrated in the better-watered, mixed farming country of the south-eastern states (Figure 9.3). This was achieved by increased carrying capacity after the widespread introduction of sub-clover and superphosphate to pastures, and was fuelled by strong overseas

[27] *Advocate* (Tas), 19 December 1944, p. 5, the article stated that previous attempts at premiers' conferences had failed due to 'some States' resentment of Commonwealth intervention.

[28] *Farmer and Settler*, 7 March 1940, p. 4, the drought years were unusually severe in the NSW Northern Tablelands, Liverpool Plains and Hunter Valley, where after nine dry summers, the continuing 'hopper plague' was seen as a 'child of the drought'.

[29] B. Vives and R. N. Jones, 'Detection of abrupt changes in Australian decadal rainfall (1890–1989)', *CSIRO Atmospheric Research Technical Paper 73*, (Melbourne, 2005), p. 23; P. N. Holper, *Australian Rainfall — Past, Present and Future*, Climate Change Science Information Paper, (Canberra, CSIRO, Australian Government Department of Climate Change and Energy Efficiency, 2011).

[30] F. H. Gruen, L. E. Ward and A. Powell, 'Changes in Supply of Agricultural Products', in ed. D. B. Williams, *Agriculture in the Australian Economy*, (Sydney, Sydney University Press, 1967), pp. 152–170, p. 160, after the wool boom in 1949–50, the wool:wheat price ratio remained more favourable to wool from 1950–51 to 1956–57 than in any of the preceding 30 years; *Farmer and Settler*, 12 February 1954, p. 8, quotes the Bureau of Agricultural Economics that world demand was outstripping supply and should maintain a 'satisfactory level of prices'.

[31] *Yearbook of Australia, 1957*, p. 911.

demand for wool.[32] Post-war immigration boosted the cities, newspapers and magazines advertised the labour-saving miracles of modern industrial manufacture and chemical science offered arrays of new materials to complement modern lifestyles.

Locust plagues also returned with monotonous regularity and one widespread event during 1953–1955 galvanised the entomological researchers and the Australian Agricultural Council (AAC) to again focus on the problem, but this time backed by the power of new control methods. NSW again bore the brunt of the infestations with a much higher frequency of outbreaks. However, all state entomologists employed the new chemical insecticides, trialling promising compounds in the ongoing ‘locust war’. The CSIR was restructured as the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in 1949, losing defence science but continuing with locust research. ‘Economic’ was dropped from the entomology division name, reflecting a broadening of scope to include cataloguing the natural heritage of Australia’s insect fauna.

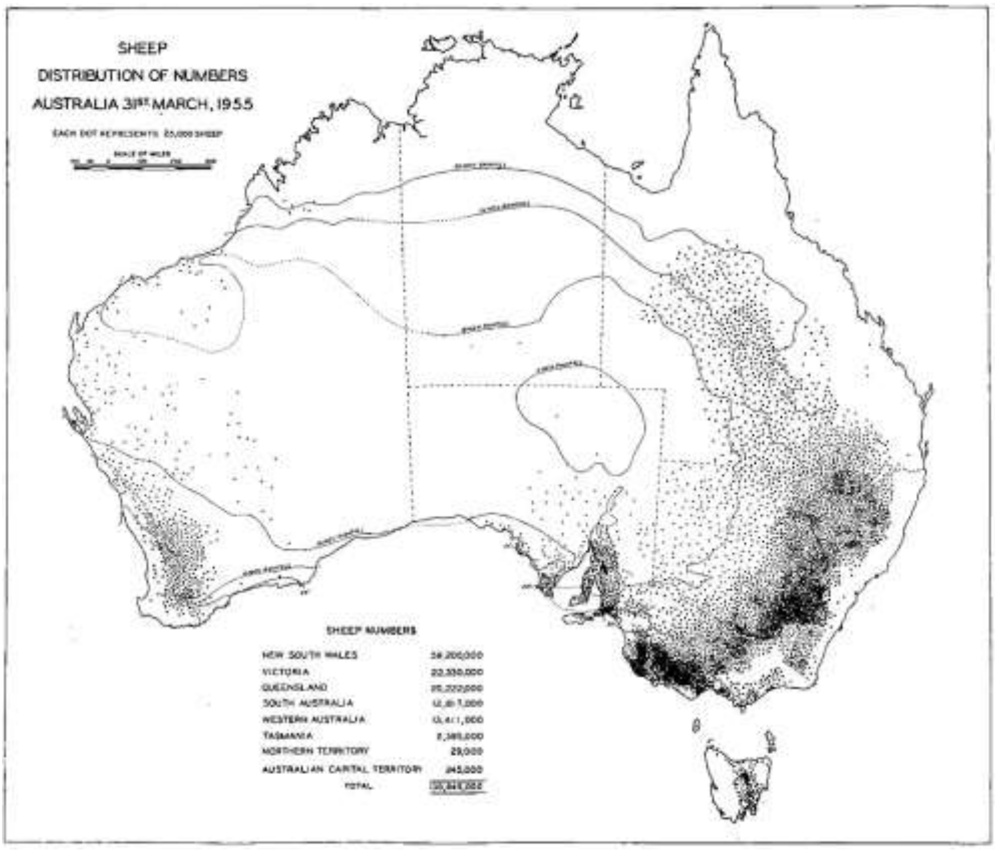

Figure 9.3. Distribution of sheep in 1955 (*Yearbook of Australia*, 1957, p. 911).

[32] Neil Barr and John Carey, *Greening a Brown Land: The Australian Search for Sustainable Land Use*, (South Melbourne, McMillan Education, 1992), pp. 34, 79–80.

The 1940s 'locust' events

Official reports now presented more detailed coverage of 'locust' distributions and the species were confidently distinguished by the entomologists. The press continued to translate the relevant findings and their official message for the public.[33] Newspapers also complemented and extended the official record by expressing the diverse views of the public. The locusts held a firm but localised presence in the Central West and Northwest of NSW, and in the Queensland Darling Downs until 1943, finally contracting to the Hunter Valley in 1944.

The grasshopper reasserted its wide swarming extent in the early forties, but was more prominent in Northwest Victoria, the Riverina and Central West NSW than in South Australia during 1941–1946.[34] In 1944, after several years of grasshopper swarms damaging crops in the Finley–Berrigan irrigation area of the Riverina, NSW sent several entomologists to investigate and Andrewartha was called in from South Australia. Outlooks for Australia's continued agricultural development hinged on irrigation from the inland rivers, and the prospect of annual grasshopper swarming represented a serious threat to the security of production.

There was a short-lived locust plague during 1946–1947 affecting NSW, Victoria, South Australia and Queensland, although swarming continued in NSW until 1949.[35] The first intimations of locusts came from Moree, Maitland and Newcastle in February 1946, when swarms blew in from the north. In autumn, they spread throughout NSW, laying eggs across the 'central districts', from the Queensland border to the Murray River.[36] Swarms also alighted around the Flinders Ranges in Northeast South Australia, and in Northwest Victoria. While they were only noticed when they reached agricultural areas, there had been an earlier infestation in Southwest Queensland after good summer rains.[37] A large infestation followed in spring, though not as widespread in Victoria as in

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[33] *Farmer and Settler*, 22 March 1946, p. 16; *Chronicle*, 27 August 1942, p. 8.

[34] The species was identified by Pescott, McCarthy, Allman and Andrewartha. Even in late 1946, reports of *A. cruciata* came from Hay, Deniliquin, Finley and Jerilderie.

[35] Joyce Magor, 'Outbreaks of the Australian plague locust (*Chortoicetes terminifera* Walk.) in New South Wales during the period 1937–1962, particularly in relation to rainfall', *Anti-Locust Memoir 11*, (London, Anti-Locust Research Centre, Ministry of Overseas Development, 1970), p. 12, Magor, who analysed the history of NSW outbreaks, considered the 'plague' continued until 1949; Joelle L. Gergis and Anthony M. Fowler. 'A history of ENSO events since AD 1525: implications for climate change', *Climatic Change*, 92 (2009), 343–387, Table 9, p. 367, identifies 1946 as a La Niña.

[36] S. L. Allman, 'The 1946–47 Grasshopper Outbreak', *Flock and Herd*, Institute of Inspectors of Stock NSW Yearbook 1947, Proceedings 30th Annual Conference (1948), pp. 107–112, p. 107, swarms in the Pilliga and Moree districts in March, heavy autumn egg laying Dubbo and Tamworth. Locusts in the 'Moulamein and Deniliquin districts probably came from South Australia'.

[37] *Queensland Country Life*, 11 April 1946, p. 1, Diamantina-Georgina hopper plague; *Sydney Morning Herald*, 26 April 1946, p. 10, much inland country from Charleville to the border stripped of feed by grasshoppers; *News*, 7 May 1946, p. 3, large swarms of locusts near Mulyungarie, northeast of Broken Hill.

1934. Locusts came again to NSW, northern Victoria and parts of South Australia in autumn 1950 at the start of another La Niña period.[38]

The scientific players

The momentum of ecological research on insects in Australia was driven by major institutional players both during and after the war. All carried out research that reflected international ecological methods used to determine the environmental constraints on insect populations and distributions.

Agriculture was 'war work' at state level and it was central to post-war reconstruction, including soldier settlement schemes. The Waite Institute team of Davidson, Andrewartha, Birch, Steele and Swan published sixteen papers on locust and grasshopper ecology in agricultural and scientific journals between 1938 and 1945. Many CSIR entomologists were diverted to strategic wartime projects.[39] Key's was an investigation of wool moths, but he was able to publish his locust work in six CSIR Bulletins. The 1945 synthesis on the ecology of outbreaks completed his initial brief to investigate outbreak areas and outbreak years.[40] Laurie Clark's research followed on from Key's field studies and he tracked infestations of both species in NSW throughout the war, producing six CSIR publications from 1946 to 1950.[41]

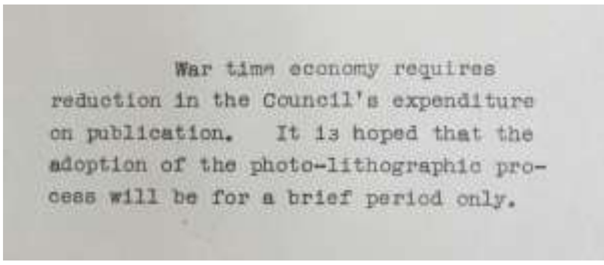
War time economy requires reduction in the Council's expenditure on publication. It is hoped that the adoption of the photo-lithographic process will be for a brief period only.

Figure 9.4. Insert from CSIR publications 1942–46

Entomologists working on locusts recognised that environmental changes were contributing to the 'grasshopper problem'. Clark considered that the frequent locust swarming in Central West NSW was the direct result of human activity, from both tree clearing and soil erosion, and suggested the reforestation of key areas as a possible solution.[42] Key, too, identified wind erosion of the topsoil,

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[38] Bureau of Meteorology, 'La Niña — detailed Australian Analysis', http://www.bom.gov.au/climate/enso/lnlist/index.shtml, viewed 3 April 2017; Gergis and Fowler 2009, p. 367.

[39] Ian Mackerras worked on controlling mosquitoes in New Guinea and Douglas Waterhouse investigated mosquito repellents.

[40] K. H. L. Key, 'The general ecological characteristics of the outbreak area of the Australian plague locust *Chortoicetes terminifera* (Walk.)', *C.S.I.R. Bulletin No. 186,* (Melbourne, 1945).

[41] In 1952, Clark received a CSIRO research grant to work with Elton and Kennedy in England.

[42] L. R. Clark, 'Observations on the plant communities on "Bundemar", Trangie district, New South Wales, in relation to *Chortoicetes terminifera* (Walk.) and *Austroicetes cruciata* (Sauss.)', *C.S.I.R. Bulletin No. 236,* (Melbourne, 1948), pp. 16, 17, 56; L. R. Clark, 'An ecological study of the Australian plague locust (*Chortoicetes terminifera* (Walk.) in the Bogan-Macquarie outbreak area, New South Wales', *C.S.I.R. Bulletin No. 226*, (Melbourne, 1947), p. 68; L. R. Clark, 'On the abundance of the Australian plague locust (*Chortoicetes*

leaving bare subsoil ‘scalds’, as creating important oviposition habitats. He noted that locusts avoided areas of kangaroo grass, *Themeda triandra*, because of its dense growth.[43] When Clark examined plant species around Trangie in the 1940s, the formerly widespread *Themeda* could only be found in the local cemetery.[44] Key saw the outbreak areas in Queensland as being ‘conterminious with naturally treeless plains’ and warned that future tree clearing would expose much larger areas to infestation.[45]

Figure 9.5. Laurie Clark at CSIRO, 1960s (National Library of Australia, image 143075487-1).

Laurie Clark followed the population fluctuations of both grasshoppers and locusts on a property near the CSIRO Mitchell research station at Trangie from 1939 to 1946. Closely observing their behaviour, phenology and annual population sizes relative to vegetation and rainfall, he found that *A. cruciata* was prominent in years with below-average spring rainfall, but that higher numbers were correlated with November rainfall of the previous year.[46] Swarm densities occurred in 1943 and 1944. As in South Australia, hatching started in August and egg laying in mid-October. He considered the species was adapted to prolonged exposure to direct solar radiation and therefore benefited from the bare

terminifera (Walker) in relation to the presence of trees’, *Australian Journal of Agricultural Research*, 1 (1950), 64–75, p. 74; L. R. Clark 1948, pp. 15, 29, most ringbarking and tree-clearing of the complex forested country around Trangie dated from the 1890s.

[43] Key 1945, pp. 35–37, p. 43.

[44] L. R. Clark 1948, p. 29.

[45] K. H. L. Key, ‘The outbreak of the Australian plague locust *Chortoicetes terminifera* (Walk.) in the season 1939–40 with special reference to the influence of climatic factors’, *C.S.I.R. Bulletin No. 160*, (Melbourne, 1943), p. 38.

[46] This referred to the months August to November, when the active stages were present.

ground produced by overgrazing.[47] Clark's observations of swarming locusts were limited to 1939 and 1946, when he made the first quantitative measures of nymphal densities and band behaviour.[48]

The distribution of swarming populations of *A. cruciata* was directly related to landscape changes within a definable climatic zone. Much of the 'grasshopper belt' country in South Australia and Western Australia had been cleared and cultivated, then abandoned and reverted to sheep grazing. Andrewartha considered that the loss of perennial grasses and shrubs, and their replacement with ephemeral introduced species had created ideal food and oviposition habitat for grasshoppers. The abandonment of farm land in both states was implicated in producing persistent large populations in the 'grasshopper belt'.[49]

Andrewartha argued for a change from the 'exploitation' of existing grazing land use, which 'must ultimately produce a desert', to 'recovery' through research to re-establish chenopod shrubs and native vegetation. This would not only preserve the region for future generations, it could put an end to sheet erosion producing the 'scalded patches' that were grasshopper egg laying sites. He compared the highly variable sheep stocking numbers within the 'grasshopper belt' with those in the pastoral zone.[50] Newman, too, attributed the worsening grasshopper situation in Western Australia to ringbarking and tree clearing for wheat. This extended the continuity of grasshopper habitats, which resulted in annual swarms if farms were not cultivated.

Later interpretations of Andrewartha and Birch's work on grasshopper abundance saw the monoculture of wheat itself as the cause of large population build-ups.[51] Although they did mention that the presence of sparse wheat crops in 1939 and 1940 contributed to local *A. cruciata* populations, the fact that both Andrewartha and Newman identified the grasshopper belt as mostly abandoned farms turned over to sheep grazing, conflicts with that view.[52]

The 1938 locust conference had entrenched a dichotomy in roles between the academic entomologists at CSIR and Waite, who indulged in broad ecological research, and the state government

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[47] L. R. Clark, 'Ecological observations on the small plague grasshopper, *Austroicetes cruciata* (Sauss.), in the Trangie district, central western New South Wales', *C.S.I.R. Bulletin No. 228*. (Melbourne, 1947), pp. 12–15.

[48] L. R. Clark, 'Behaviour of swarm hoppers of the Australian plague locust, *Chortoicetes terminifera* (Walk.)', *CSIRO Bulletin No. 245*, (Melbourne, 1949).

[49] H. G. Andrewartha, 'The significance of grasshoppers in some aspects of soil conservation in South Australia and Western Australia', *Journal of the Department of Agriculture South Australia*, 46 (1943), 314–322.

[50] Andrewartha 1943, p. 315.

[51] Martin Mulligan and Stuart Hill, *Ecological Pioneers: A Social History of Ecological Thought and Action*, (Cambridge, Cambridge University Press, 2001), p. 168.

[52] L. C. Birch and H. G. Andrewartha, 'The influence of weather on grasshopper plagues in South Australia', *Journal of the Department of Agriculture South Australia*, 45 (1941), 95–100, p. 95.

entomologists, who concentrated on practical control. There were several staff changes in state agriculture departments. Newman and Gurney both died in 1939, and they were succeeded in WA by Clee F. Jenkins and in NSW by Tim McCarthy, who was later joined by Stuart L. Allman and Allan Wright. Swan became departmental entomologist in South Australia. Thomas W. Hogan (1913–2006), an agricultural science graduate who joined the Victorian department in 1939, became its principal entomologist in 1945.

In 1940, Nicholson emphasised that Australia's practical bait-based locust control research would be more effective with a detailed knowledge of their habits, and noted that other 'spectacular' methods, such as aerial arsenic-dusting, had been abandoned overseas.[53] During the war, however, screening of organic chemicals as potential insecticides changed that situation. Tom Hogan in Victoria saw potential in the wartime developments in insecticides and aerial spraying for controlling locusts.[54]

The Victorian '666' aerial spraying campaigns, 1946–1953

Pyrethrum was the mainstay of vegetable pest control and lice control to reduce typhus transmission in troops at the start of World War II. Wartime uncertainty over supplies from Africa intensified the search for alternative chemical insecticides, while pyrethrum plantations were started in Australia (Figure 9.6).[55] Although first synthesised in the 1870s, the desirable insecticidal properties of DDT, particularly for disease-carrying mosquitoes, were discovered in 1939. It was used to reduce a typhus outbreak in Italy in 1943 and later aerially-spread in the tropical Pacific by the US and Australian air forces.[56] A range of related chlorinated hydrocarbons were also being synthesised and tested.

By 1945 DDT moved into the household and agricultural markets in Australia for flies, mosquitoes and sheep-dips. The 'atomic bomb of insecticides' was publicly accepted because of its scientific representation and economic entomology was already committed to chemical control for agriculture[57] The chlorinated hydrocarbons were advertised as fifteen times more toxic to insects than arsenic, yet less harmful to domestic animals and humans.[58]

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[53] *Telegraph*, 23 February 1940, p. 13.

[54] *Weekly Times*, 21 October 1939, p. 22.

[55] Russell 2001, p. 124.

[56] RAAF planes sprayed DDT in the Northern Territory during 1944–45.

[57] Thomas Dunlap, *DDT: Scientists, Citizens and Public Policy*, (New Jersey, Princeton University Press, 1981), pp. 17–24, in the USA, its 'enthusiastic and almost uncritical acceptance' came from the growth of economic entomology as a powerful component of the US and state departments of agriculture. The entomologists were already committed to chemical control.

[58] *Mudgee Guardian*, 22 August 1946, p. 12; *Northwest Champion*, 16 April 1946, p. 9; *Western Mail*, 14 December 1950, p. 6.

Figure 9.6. Japanese internees harvesting pyrethrum flowers at Barmera in South Australia, 1943.[59]

Continuing locust plagues in North Africa and the Middle East prompted Britain and Russia to test the new insecticides from aircraft in Kenya and Persia. Candidate compounds included DNC (dinitro-ortho-cresol), DDT (dichlorodiphenyltrichloroethane) and BHC (hexachlorocyclohexane or benzene hexachloride). The dramatic insecticidal effects of the gamma isomer of BHC, reportedly discovered when a captive colony of locusts died after it was sieved in an adjacent room, led to the label '666' from its chemical formula $C_6H_6Cl_6$, or more benignly 'gammexane'.[60] Gammexane was touted as an all-British research invention. Michael Faraday's 1825 experiments with benzene were reprised, Imperial Chemical Industries (ICI) commenced mass production and the Colonial Office sent samples across the empire.

The chlorinated hydrocarbons gave the state 'grasshopper controllers' a new scientific arsenal to deal with locust populations and the return of locusts in 1946 gave them the opportunity to test it. In Victoria, Hogan combined the enabling wartime technologies of insecticide spraying from aircraft to defeat the locust invasion of its dry Mallee district in the state's northwest. He conducted an ambitious, decade-long strategic aerial control program, using the British-developed insecticide BHC.

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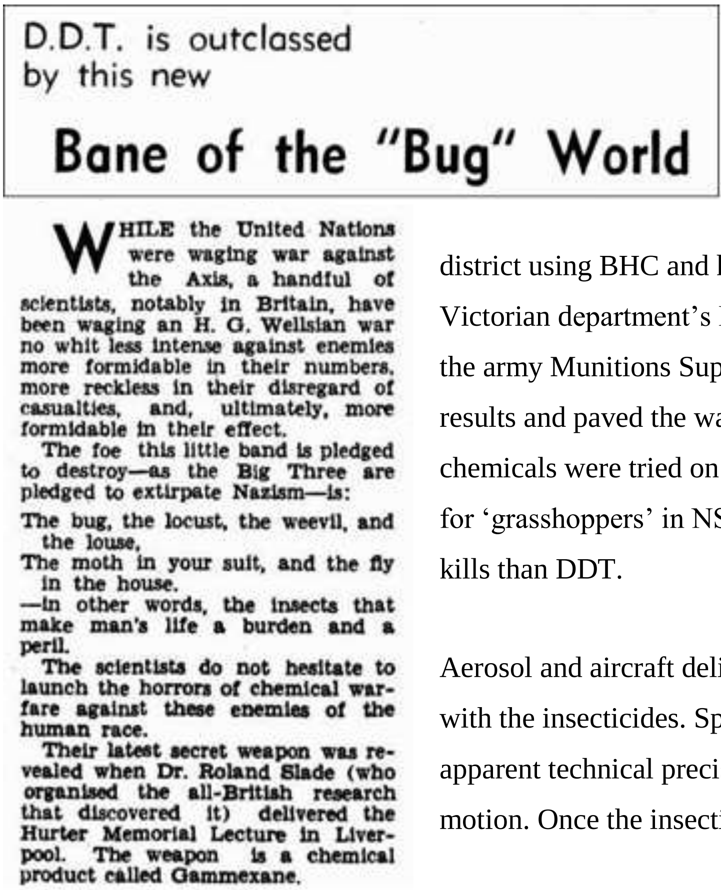
[59] Australian War Memorial, (image 123158), by Sgt. H. K. Cullen; In Australia, irrigated pyrethrum plantations were established in South Australia and Papua to fill the gap in wartime supplies.

[60] *Queensland Country Life*, 15 November 1945, p. 7, quoting from *Monthly Science News* in Britain, the high toxicity of '666' was indicated by the extreme susceptibility of grasshoppers; *The Land*, 1 February 1946, p. 12.



D.D.T. is outclassed by this new

Bane of the "Bug" World

WHILE the United Nations were waging war against the Axis, a handful of scientists, notably in Britain, have been waging an H. G. Wellsian war no whit less intense against enemies more formidable in their numbers, more reckless in their disregard of casualties, and, ultimately, more formidable in their effect.

The foe this little band is pledged to destroy—as the Big Three are pledged to extirpate Nazism—is:

The bug, the locust, the weevil, and the louse,
The moth in your suit, and the fly in the house.
—in other words, the insects that make man's life a burden and a peril.

The scientists do not hesitate to launch the horrors of chemical warfare against these enemies of the human race.

Their latest secret weapon was revealed when Dr. Roland Slade (who organised the all-British research that discovered it) delivered the Hurter Memorial Lecture in Liverpool. The weapon is a chemical product called Gammexane.

Western Mail, 31 January 1946, p. 73.

In April 1946, at the same time as an aerial locust spray trial was being organised in Africa using DNC, Hogan ran a ten hectare aircraft spray trial at Nyah West in the Victorian Mallee district using BHC and he reported a 98% kill.[61] Tests at the Victorian department's Burnley laboratory, in collaboration with the army Munitions Supply Laboratory, also showed good results and paved the way for a larger aerial campaign. The new chemicals were tried on various insect pests. Mixed in bran baits for 'grasshoppers' in NSW and Victoria, BHC gave much better kills than DDT.

Aerosol and aircraft delivery technologies developed in parallel with the insecticides. Spraying locusts from the air, despite an apparent technical precision, was a simple outcome of aircraft motion. Once the insecticide was formulated as a liquid, usually by suspending in diesel fuel, it was drawn through undercarriage pipes with spaced, small holes and shattered into droplets by air drag, dispersed by eddies and downdraft, and deposited by cross-wind drift.

Hogan corresponded with Birmingham University zoologist D. L. Gunn, who was in charge of the spray trials on red locusts in Africa, over the formulations and the physics of aerial delivery.[62] Issues of spray droplet sizes, avoiding thermal up-draughts and high wind speeds were worked out 'on the fly'.[63] Rotary atomisers, which gave greater control over the spectrum of droplet sizes, were later developed by technicians working on an ALRC funded project in Africa in 1953.[64]

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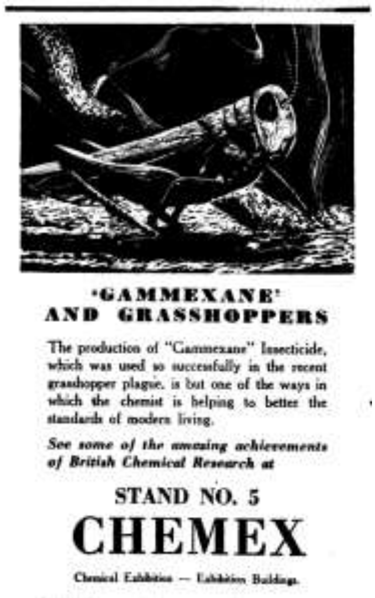
[61] D. L. Gunn, 'The development of aircraft attack on locust swarms in Africa since 1945 and the start of operational research on control systems', *Philosophical Transactions of the Royal Society. Series B, Biological Sciences*, 287 (1022), *Strategy and Tactics of Control of Migratory Pests*), (1979), 251–263, the first ALRC trials were carried out on red locusts in Kenya in 1946, with the cooperation of the RAF and the Chemical Defence Experiment Station, but the date is not specified; *Riverine Herald*, 23 May 1946, p. 2.

[62] 'Aerial Spraying', letter from Gunn, 28 January 1947, confidential report on spraying methods, (Victorian Department of Agriculture archive. BHZ-4898, file 63/3).

[63] T. W. Hogan, 'The ground recovery and drop spectra of sprays dispersed from two types of aircraft', *Australian Journal of Agricultural Research,* 2 (1951), 302–321.

[64] *Coffs Harbour Advocate*, 20 February 1953, p. 1.

In anticipation of a big infestation in spring 1946, the Victorian department rushed an emergency order with ICI, which was able to supply 375 tons of BHC. The logistic arrangements made use of the expertise and equipment of the RAAF and Maribrynong munitions factory, and they mirrored those of a military 'campaign'. This included four RAAF Beaufort Mark IX aircraft modified to deliver the insecticide, which was mixed at the factory. The military provided labour to decant BHC and diesel into drums, lorry tankers for loading the aircraft and military wireless communications (Figure 9.7). In September, Hogan went to Gunnedah in NSW, where aerial trials of BHC and DNC were also being carried out by the NSW agriculture department.[65]



The campaign got underway in Victoria in mid-October 1946. Patches of locusts were sprayed over a total of 12,000 hectares in the northern Mallee, while BHC bran baits were spread over a further 2,800 hectares. Hogan laid claim to the extensive spring campaign being a world first and he justified it as an economic as well as a scientific success.[66] Gammexane was announced as the insecticide to 'ensure destruction of pests for the first time in Australia's history'.[67] It was exhibited at the ICI stand in Melbourne's 'Chemex 1947' exposition and plans were made to manufacture it in Australia.[68] Australia became a major market for ICI gammexane and it was widely applied, including in the sugar industry.

Buoyed by the rapid coverage of such large areas and the visible locust kills, Hogan put forward a new strategy of stopping locusts entering Victoria from NSW. When swarms developed in the Riverina again in 1950 and flew into western Victoria, they provided an opportunity to test the strategy.[69] RAAF planes were not available for the 1950 campaign, but Australian National Airways and Qantas provided several modified Dakota aircraft. Similar areas of the Victorian Mallee were

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[65] *Western Grazier*, 4 October 1946, p. 2.

[66] T. W. Hogan, 'The Australian plague locust aerial spraying campaign, 1946', *Journal of the Department of Agriculture Victoria*, 47 (1949), 369–375; *Weekly Times*, 16 October 1946, p. 14, at the same time British entomologists 'cleaned up' a locust invasion of Sardinia with gammexane; *Weekly Times*, 19 February 1947, p. 20, The Premier estimated the campaign cost £25,000, but saved crops worth millions of pounds; *Argus*, 18 November 1946, p. 4, 'War against Locusts being won'.

[67] *Argus*, 12 October 1946, p. 6, the 'Spray air Offensive successful'.

[68] *Argus*, 6 March 1947, p. 10, gammexane was featured at the ICI stand at the Chemical Exposition. The message is clear that the work of chemists supports modern living. These annual displays of new products by chemical manufacturers, ran from 1938 to the end of the 1950s. A factory was not built and later supplies came from an ICI factory in South Africa.

[69] T. W. Hogan, 'Aerial spraying of locusts: campaign in north-western Victoria', *Journal of the Department of Agriculture Victoria*, 50 (1952), 112–114.

sprayed in spring 1950 as in 1946, but this time intelligence on swarm locations allowed control to cross the Murray River into NSW.

The 1950 locust plague spread into South Australia as well as NSW and Victoria.[70] BHC was used in bran baits in all three states and NSW entomologists tested various formulations of other new compounds, including chlordane or '1086', toxaphene and DNC, using ground-based and aircraft spray equipment.[71] There was a ready acceptance of the new insecticides because of the feeling among pastoralists that arsenic baiting of locusts was futile, having to be endlessly repeated and only useful for the hopper stage. Stock inspectors in NSW attributed the lack of enthusiasm for arsenic during 1947–48 to 'widespread apathy and skinflint organisation' for what was a 'national problem'.[72] Aware of the wartime aerial spraying of DDT, many landholders were looking to science to provide more robust solutions for the 'grasshopper problem'. Many had rejected arsenic sprays or baits in favour of the new chemicals by 1948.[73] In Western Australia, where grasshopper plagues continued to get worse, the new chemicals were trialled in 1946 and gradually introduced across the wheatbelt.[74]

Victoria took the public relations aspect of the locust campaigns seriously, calling landholders to action under the slogan 'help thy neighbour'.[75] The departmental film unit produced 'Winged Plague' in 1947, a 'documentary' complete with a Biblical introduction and a 'triumph of science' ending (Figure 9.7). The message was carefully managed. There were press releases on campaign plans, crafted statements for radio announcers and even a draft for a radio play about helping in a locust campaign.[76]

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[70] 1949–50 was also an intense La Niña period. The details of the development of the plague and its extents are not covered here.

[71] S. L. Allman and J. A. Wright, *Grasshopper Control. Some Recent Developments*, (Entomological Branch, Division of Science Services, NSW Department of Agriculture, 1950), p. 10.

[72] Allman 1948; T. R. Jones, 'Locusts', *Flock and Herd 1948*, Institute of Inspectors of Stock NSW Yearbook 1948, pp. 118–120; E. Scott Rogers, 'Failure of grasshopper control in the Riverina', *Flock and Herd 1948*, pp. 121–122, the increasing grasshopper threat to irrigation districts means vast areas would need baiting.

[73] Allman and Wright 1950, p. 2.

[74] BHC was trialled at Southern Cross in 1946; *Coolgardie Miner*, 2 July 1953, p. 1, pre-mixed gammexane, arsenic and bran bait was distributed throughout the Yilgarn Road Board area. 160 tons of bait were distributed in 1952; *West Australian*, 11 October 1952, p. 7, aerial spraying trials at Southern Cross with Aldrin, dieldrin, chlordane and BHC.

[75] *Weekly Times*, 16 October 1946, p. 14.

[76] Letter to Hogan from John P. Brian, (Agric. Research Officer), 16 June 1955, regarding a draft of "The Grasshopper Menace", asking if Hogan wanted his name mentioned. This play was a follow-up to "Science Declares War", a play about cockchafers and earth mites (Victorian Department of Agriculture Archive, Box BHZ 4920); The Victorian department was so confident in Hogan's aerial treatments, it funded his 1951 trip to Europe and the USA to appraise himself of developments in spray technologies and locust ecology.

Figure 9.7. Images from 'Winged Plague', Victorian Department of Agriculture Cinema Branch, 1947 (stills capture by Pip Deveson).

But amid the accolades for the growing agricultural pesticide industry, there were some warnings. In 1951, Western Australia's entomologist Jenkins pointed out the dangers of 'over-enthusiastic or indiscriminate use of DDT'.[77] Rather than solving all insect problems, the new insecticides merely eased some difficulties and presented others. A number of insects, namely aphids and mites, were resistant to DDT, while useful parasite or predator insects were vulnerable. DDT had already been found to concentrate in mammal body fat, been detected in human milk and was banned from use in US dairies. Poisonings had already occurred overseas and in Jenkins' view the potential hazards of the new materials had been underestimated.

[77] Clee Jenkins, 'Insecticides — New and Old', *Western Mail*, 6 September 1951, p. 63.

The ecological theorists make their mark

Ecology was growing as a theoretical science and entomologists' findings were increasingly framed by its contemporary models. Experimental insect observations were used to formulate and to test theory. In the early 1950s, several Australian entomologists pressed their claims in the international arena of academic ecology, achieving publications in the prestigious British journals *Biological Reviews*, *Quarterly Review of Biology*, *Bulletin of Entomological Research* and *Nature*. Andrewartha published a review of diapause theory and Key published a critique of Uvarov's phase theory. Andrewartha and Birch wrote a comprehensive ecology textbook, using case studies on insects to develop their theory of known factors controlling animal populations.

Andrewartha had attempted an ecological differentiation of locusts and grasshoppers in 1945, comparing the Australian pair with numerous other species. Locusts had no true diapause, plagues started mostly in arid 'outbreak areas' and developed in wet years. Grasshoppers had an obligatory embryo diapause, their plagues were restricted within narrow climatic zones and occurred in dry years.[78] He further speculated a phylogeny of diapause, with locusts like *C. terminifera* representing a 'primitive condition', grading to the highly specialised adaptation in *A. cruciata*.

Charles Birch received CSIR postgraduate fellowships to work with University of Chicago ecologists in 1946 and with Charles Elton in London in 1947. Several publications resulted, notably his work with Oxford statistician, Patrick H. Leslie on the intrinsic rate of insect population increase.[79] On his return he took up a lectureship in zoology at the University of Sydney.[80] One of Birch's first PhD graduates, Douglas Paul Clark (1924–1973), worked with Birch on an ecological systems approach to forest soils that was published in the *Quarterly Review of Biology* in 1953.[81] Doug Clark then joined the CSIRO Division of Entomology and was soon working on grasshopper problems.

In the review of diapause, Andrewartha clarified concepts around the processes of stage-specific, life stage dormancy in insects and favoured the hypothesis of hormone-mediated control during the period of diapause development. Using his work with Birch on *A. cruciata* as a model for adaptation to

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[78] H. G. Andrewartha, 'Some differences in the physiology and ecology of locusts and grasshoppers', *Bulletin of Entomological Research*, 35 (1945), 379–389.

[79] L. C. Birch, 'The intrinsic rate of natural increase of an insect population', *Journal of Animal Ecology*, 17 (1948), 15–26.

[80] David M. Steffes, *The "eco-worldview" of Charles Birch: Biology, environmentalism and Liberal Christianity in the 20th Century*, (PhD thesis, University of Oklahoma, 2008), pp. 217–231, Birch hoped to establish animal ecology on the same footing as Eric Ashby had done for plant ecology in the 1940s, but found it was still viewed as a fringe subject. Steffes details Birch's overseas ecological and metaphysical experiences (pp. 150–215) and the difficulties he experienced obtaining an academic position in the empire, and in Sydney.

[81] L. C. Birch and D. P. Clark, 'Forest soils as an ecological community — with special reference to the fauna', *Quarterly Review of Biology*, 28 (1), (1953), 13–36.

environment, Andrewartha detailed how its obligate embryonic diapause and strong desiccation resistance ensured hatching occurred in the favourable conditions of early spring. The complexities of *A. cruciata* diapause were therefore a 'beautiful example of an adaptation delicately attuned to a harsh environment' and of 'environmental resistance' limiting population development.[82] He suggested that evolution accounted for a difference detected in the optimal temperatures for completing diapause development between races of *A. cruciata* in South Australia and Western Australia, which correlated with warmer winters in the range of the western race.

Key's 'critique' of phase theory was intended to clarify the concepts that were the focus of international locust research at the time.[83] He detailed the confusion in terminology and some technical inadequacies of morphometric indices used to define and determine phase state. These were based on ratio measures of body features, particularly that of elytron (forewing)/femur length (E/F). He saw the emphasis on phase indices as misplaced, particularly the separation of transitional forms used to determine the direction of change, partly because phase state was a characteristic of individuals and could often not be usefully applied to populations.[84] Within a few years the international consensus had moved towards acceptance of some of these arguments.[85]

Key focused on the environmental rather than the physiological triggers of plagues, challenging the inevitability of the phase-induced plague cycle. He argued that the fundamental cause of outbreaks was multiplication due to the periodic occurrence of particular environmental conditions, rather than phase change itself.[86] Migration was also not dependent on phase, nor was phase change necessarily restricted to 'outbreak areas'.[87] He concluded that gregarious behaviour was the characteristic feature of '*phase gregaria*' locusts, and that 'swarming' or 'non-swarming' populations was a more practical

[82] H. G. Andrewartha, 'Diapause in relation to the ecology of insects', *Biological Reviews*, 27 (1), (1952), 50–107, p. 57; H. G. Andrewartha and L. C. Birch, 'Measurement of 'Environmental Resistance' in the Australian plague grasshopper', *Nature*, 161, (1948), 447–448.

[83] K. H. L. Key, 'A critique on the phase theory of locusts', *Quarterly Review of Biology*, 52 (4), (1950), 363–407; M. F. C. Day and D. C. F. Rentz, 'Kenneth Hedley Lewis Key 1911–2002', *Historical Records of Australian Science*, 15 (2004), 65–76, p. 70.

[84] Key 1950, pp. 371, 375, Key noted that a range of phase characters could be present in a single swarm and entirely morphologically 'solitaria' swarms were documented in examples in Africa, citing J. S. Kennedy, 'The behaviour of the desert locust (*Schistocerca gregaria* (Forsk.) (Orthopt.) in an outbreak centre', *Transactions of the Royal Entomological Society of London*, 89 (1939), 385–542.

[85] D. L. Gunn and P. Hunter-Jones, 'Laboratory experiments on phase differences in locusts', *Anti-Locust Bulletin* 12, (London, ALRC, 1952), p. 27.

[86] Key 1950, p. 39, Key was arguing against B. P. Uvarov, 'The locust plague' *Journal of Economic Entomology*, 37 (1944), 93–99.

[87] Key 1950, pp. 400, 403.

workable classification, as 'swarming' expressed the elements of phase: gregarious behaviour, high numbers and migration.[88]

However, former ALRC entomologist John S. Kennedy rejected Key's proposition that 'phase is a secondary concomitant of population increases' and that the most relevant aspect was behavioural change.[89] Kennedy viewed locusts as 'heteroecious'. The sum of their physiological responses, increased mobility and gregariousness, was fundamental to survival outside permanent 'outbreak area' habitat.[90] Kennedy went further, suggesting that phase was analogous to individual ontogeny, with '*solitaria*' as physiologically juvenile to '*gregaria*'.[91]

Key's examples were drawn from African data, but he also investigated phase morphometrics in *C. terminifera*. He identified a small relative increase in wing length in museum specimens taken from swarms. Ranges in E/F ratio for each gender were given to classify individuals into phase *gregaria*, *transiens* and *solitaria*, demonstrating his acceptance of phase change in the Australian species.[92] He also clarified *Austroicetes* taxonomy, identifying the ten species that are still recognised. Several species, including *A. cruciata*, also presented the same genetically controlled pattern morphs he identified in *C. terminifera.*

Climatic limits and trophic interactions in ecology

The development of animal ecology in the first half of the twentieth century has been fertile ground for historians of science, revealing a web of global intellectual activity and institutional intrigues. Ecology encompassed multiple levels of complexity, functional units of study and it found relevance in many branches of biological science. Studies on insects figured prominently in its conceptual lineages of species traits and ecological constraints, niche theory, and population demography based on logistic growth.[93] During the 1920s, the ecological niche concept was built around the duality of

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[88] Key 1950, p. 397.

[89] J. S. Kennedy, 'Phase transformation in locust biology', *Biological Reviews*, 31 (1956), 349–390, p. 356; Key 1950, p. 402.

[90] Kennedy 1956, pp. 360–65; J. P. Dempster, 'The population dynamics of grasshoppers and locusts', *Biological Review*, 38 (1963), 490–529, p. 528, Dempster outlined how Kennedy took this idea further, suggesting that locusts were adapted to two distinct habitats and had morphologies to suit each, and that phase operated to alternate between habitats, using the less favourable '*gregaria*' habitat temporarily.

[91] John Brady, 'J. S. Kennedy (1912–1993): A Clear Thinker in Behaviour's Confused World', *Annual Review of Entomology*, 42 (1997), 1–22, p. 8.

[92] K. H. L. Key, *The taxonomy, phases and distribution of the genera* Chortoicetes *Brunn. and* Austroicetes *Uv. (Orthoptera: Acrididae)*, (Canberra, Division of Entomology, CSIRO, 1954), p. 91, in examining available specimens from across Australia, Key considered that those in Western Australia represented a separate race to those in the east based on various morphometric indices.

[93] B. Statzner, A. G. Hildrew and V. H. Resh, 'Species traits and environmental constraints: entomological research and the history of ecological theory', *Annual Review of Entomology*, 46 (2001), 291–316.

trophic interactions operating within climatic environments that set limits to both species distributions and population numbers.[94]

Nicholson and Bailey's 1930s mathematical model of antagonistic host-parasite interactions continued to stimulate international ecological research and debate about its ability to represent reality.[95] It became the theoretical basis for biological control introductions by entomologists at the University of California, under Harry S. Smith.[96] Nicholson moved on to study intraspecific competition, using sheep blowflies in controlled laboratory conditions. He found that regular population oscillations resulted from food-limitation during larval stages and that competition for food created selective pressures for evolutionary change.[97] Having expressed concepts about the effect of population density on population growth as a 'balance', his model became associated with the 'balance of nature' metaphor.[98] Nicholson's view remained that while animal numbers vary in response to climate, this did not 'regulate' populations.[99]

Nicholson defended and elaborated his basic propositions on population regulation during the 1950s at numerous international congresses and symposiums. In the early 1950s he attempted to set the host-parasite mathematical model in an environmental context, pointing out that population oscillations are common both within a species, as a result of food or other resource limitations, and between species, through trophic interactions. He discussed how behavioural differences could influence populations, contrasting food-limited territorial animals tending to stable populations with locust mass migrations that gave rise to violent long-period oscillations.[100] The ecological standing of his work seemed inviolable in Australia. But different ways of viewing ecological interactions and a desire to include

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[94] C. Elton, *Animal Ecology*, (London, Sidgewick and Jackson, 1927), Chapter 5, pp. 50, 63–68; A. S. Pearse, *Animal Ecology*, (New York, McGraw-Hill, 1926), pp 24–25.

[95] Sharon Kingsland, 'Defining Ecology as a Science', in eds. L. A. Real and J. H. Brown, *Foundations of Ecology: Classic papers*, (Chicago and London, Chicago University Press, 1991), pp. 1–13, British entomologist G. C. Varley designed experiments using multiple parasites to test for fluctuations around equilibrium in the 1940s; Paolo Palladino, 'Defining ecology: ecological theories, mathematical models, and applied biology in the 1960s and 1970s', *Journal of the History of Biology*, 24 (1991), 223–243.

[96] Paolo Palladino, 'Ecological theory and pest control practice: a study of the institutional and conceptual dimensions of a scientific debate', *Social Studies of Science*, 20 (1990), 255–281.

[97] Ian Mackerras, 'Alexander John Nicholson', *Records of the Australian Academy of Science*, 2 (1970), 66–81.

[98] Kim Cuddington, 'The "Balance of Nature" metaphor and equilibrium in population ecology', *Biology and Philosophy*, 16 (2001), 463–479, p. 472.

[99]Nicholson 1933, p. 135; *Andrewartha and Birch* 1954, pp. 18, 582.

[100] A. J. Nicholson, 'Population oscillations caused by competition for food', *Nature*, 165 (1950), 476–77.

the complexities of many factors in mathematical models, as well some climate-school backlash, continued overseas.[101]

James Davidson died in 1945, but Andrewartha published the results of their long-term research on apple-blossom thrips population numbers in 1948, fitting data to a logistic growth model and, by regression, showing densities as a function of weather conditions. The annual variations were explained by entirely density-independent environmental variables and, in contrast to the Nicholson–Bailey theoretical model, there was no evidence for any 'competition'. Rather than any 'balance', populations changed rhythmically with the changing seasons of the year.[102] The paper formalised Andrewartha's opposition to Nicholson's views, but the gestation of the conflict can be seen in 1930s correspondence between Davidson and Nicholson.[103]

Andrewartha and Birch published their ecological synthesis, *The Distribution and Abundance of Animals*, in 1954.[104] The book turned the focus of ecology to the statistical analysis of empirical observational data. It was also seen as demonstrating the dominant influence of climate in controlling animal populations and dispelling an established orthodoxy. In several chapters the authors referred to the 'dogma of density-dependence' and the lack of any field evidence of its effects.[105] Nicholson received special attention for promulgating density-dependent effects as controlling population numbers.[106] The text followed the general structure of the Chicago ecologists' 1949 *Principles of Animal Ecology* and was equally encyclopedic, but 'community' was replaced by numbers of 'organisms of different kinds', as part of the environment section. The book became a standard reference for ecological methodology, particularly for entomology in Australia. In the wider context

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[101] One of William R. Thomson's original criticism of Nicholson's work was that it dealt with only one among many ecological factors.

[102] J. Davidson and H. G. Andrewartha, 'The influence of rainfall, evaporation and atmospheric temperature on fluctuations in the size of a natural populations of *Thrips imaginis* (Thysanoptera)', *Journal of Animal Ecology*, 17 (1948), 200–222.

[103] M. J. Whitten, 'Australian Insects in Scientific Research', in *The Insects of Australia: a textbook for students and research workers*, Vol. 1. 2nd edition (Melbourne, CSIRO, Melbourne University Press, 1991), pp. 237–251, p. 246; Robert K. Peet, 'Lessons from Nature: Case Studies in Natural Systems', in eds. L. A. Real and J. H. Brown, *Foundations of Ecology: Classic Papers*, (Chicago and London, Chicago University Press, 1991), pp. 605–615, p. 607, Peet suggests possible inadequacies for the conclusions drawn in the thrips paper, including seasonal populations being relatively constant from year to year and absence of any data on resource size.

[104] H. G. Andrewartha and L. C. Birch, *The Distribution and Abundance of Animals*, (Chicago, University of Chicago Press, 1954), pp. 582, 592, 594, 782, Chapter 10; the authors had criticised the fundamental basis of the Lotka-Volterra equations the previous year, see H. G. Andrewartha and L. C. Birch, 'The Lotka-Volterra theory of interspecific competition', *Australian Journal of Zoology*, 1 (1953), 174–177.

[105] Andrewartha and Birch 1954, pp. 19, 583, 592–594, 649.

[106] Andrewartha and Birch 1954, pp. 18–22, in addition to Nicholson, they cited H. S. Smith, 'The role of biotic factors in the determination of population densities', Journal of Economic Entomology, 28 (1935), 873–897, and C. Elton, 'Population and interspersion: an essay on animal community patterns', Journal of Ecology, 37 (1949), 1–23, p. 19.

of developments in ecosystem ecology, however, several other influential books were also published at that time.[107]

Andrewartha and Birch saw distribution and abundance as outcomes of the same environmental limiting forces. They used their work on *A. cruciata* to argue that starvation from resource limitation was not competition.[108] Populations of numerous species could be explained without recourse to any theoretical competitive relationships. They proposed a 'general theory of abundance' in animal populations, which integrated international ecological thought at the time.[109] An organism's opportunities to survive long enough to breed were controlled by a 'shortage of time when the rate of increase is positive', because variations in many factors including weather, a shortage of food or habitat resources and natural enemies ensured that populations did not increase indefinitely.[110] They also emphasised the role of dispersal ability, because local populations were subject to stochastic environmental conditions.

Andrewartha and Birch's book was part of a discourse, not only about ecological theory and methodology, but how best to consolidate the discipline as 'hard science'. The Australian ecologists' differences came into the open at the 1957 Cold Spring Harbour Conference on Quantitative Biology in New York. Although Birch attempted some reconciliation between Nicholson and Andrewartha in discussions after the presentations, their positions remained intractable. Other participants were perplexed. Theodore Dobzhansky was incredulous about the Australian intra-antagonism over semantics and G. Evelyn Hutchinson described population biologists as a 'heterogeneous unstable population'.[111] The controversy reflected the division between empiricist and rationalist standpoints on valid methodologies of scientific epistemology.[112] It might also be seen as focusing on only 'top-

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[107] Eugene and Howard Odum's *Fundamentals of Ecology* was first published in 1953. The Chicago ecologists' *Principles of Animal Ecology* was published in 1949.

[108] Andrewartha and Birch 1954, pp. 485, 582.

[109] These included Royal N. Chapman's ideas of environmental resistance as the sum of all impinging factors, W. R. Thomson's rejection of optimum densities and Elton's focus on movements between habitats; C. S. Elton, 'Population interspersion: an essay on animal community patterns.' *Journal of Ecology*, 37(1) (1949), 1–23, pp. 18–19. Elton discusses spatial patchiness of populations resulting from habitat variation, species interactions (trophic), short term oscillations, long term scarcity, and the migratory movement between patches providing for recolonisation and interchange. Elton pointed out that the Nicholson and Bailey model resulted in large oscillations due to density-dependent species interactions and that lateral migration between sub-unit populations compensates for local extinctions.

[110] Andrewartha and Birch 1954, pp. 660–661.

[111] Sharon E. Kingsland, 'Evolutionary theory and the foundations of population ecology: the work of A. J. Nicholson (1895–1969)', in eds. R.B. Floyd, R. B. Sheppard and P. J. De Barro, *Frontiers of population Ecology*, (Melbourne, CSIRO Publishing, 1996), pp. 13–25, p. 14.

[112] D. R. Keller and F. B. Golley, 'Rationalism and Empiricism', in eds. D. R. Keller and F. B. Golley, *The Philosophy of Ecology: From Science to Synthesis*, (Athens Georgia, University of Georgia Press, 2000), pp. 133–140, p. 133.

down' or 'bottom-up' ecological processes and it was placed in that context in the closing address of the conference by Hutchinson, who brought spatial habitat and biotic community concepts together as the 'realised niche'.[113]

Why return to a 1930s debate in a teaching manual for ecological methods? The significance of the conflict with Nicholson has been reviewed by several historians of science and set in the international context of the development of ecological concepts, framed by the institutions in which it was cultivated.[114] Locally, the book was an assertion of a 'disciplinary space' in opposition to established views represented by Nicholson at the CSIR.[115] It has been suggested Andrewartha and Birch's ideas grew out of long discussions in the field while studying grasshopper populations, but Birch's overseas fellowships exposed him to a dynamic environment of ecological enquiry.[116] Unlike in Australia, many postgraduate researchers were working on ecological questions and it was a time of great change in ideas. Prior to the war, ecology at Chicago was dominated by Warder Allee, whose investigations of the properties of aggregations, including density effects on reproduction and survival, established the population as a valid ecological unit of study.[117] But the organicist view of population uniformity with other scales of biological and social organisation, and of their special cooperative qualities, was now yielding to complex ecosystems, mathematical systems and cybernetics.[118]

A parallel can be found in Paolo Palladino's examination of the 1950s conflict between Californian entomologists, who adopted Nicholson's model to justify their biological control releases, and Canadian entomologists, influenced by W. R. Thomson's views, who were attempting to include multiple environmental variables to model pest species. Each viewed the other as failing to match

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[113] G. E. Hutchinson, 'Concluding remarks.' *Cold Spring Harbour Symposium on Quantitative Biology*, 22 (1957), 415–427, this was Hutchinson's 'n-dimensional hyperspace' view of niche; A. Milne, 'Theories of natural control of insect populations', *Cold Spring Harbour Symposium on Quantitative Biology*, 22 (1957), 253–271.

[114] Ian Mackerras, 'Alexander John Nicholson', *Records of the Australian Academy of Science*, 2 (1970), 66–81; L. C. Birch, T. Park and M. Frank, 'The effect of intraspecies and interspecies competition on the fecundity of two species of flour beetles', *Evolution*, 5 (1951), 116–132; Steffes 2008; S. E. Kingsland, 'Mathematical figments, biological facts: population ecology in the thirties', *Journal of the History of Biology*, 19 (1986), 235–256, during the interwar years, competition with physicists for scientific authority forced ecologists to introduce mathematical formulae to express hypotheses and to focus on practical issues, such as biological control.

[115] For the application of the spatial and knowledge domains of disciplinary space in the context of ecological science, see Steven Bocking, 'Science and Spaces in the Northern Environment', *Environmental History*, 12 (2007), 867–894.

[116] Mulligan and Hill 2001, p. 168.

[117] Gregg Mitman, *The State of Nature: Ecology, Community and American Social Thought 1900–1950*, (Chicago, Chicago University Press, 1992), pp. 124–129, Mitman includes many other contributors, including Thomas Park and A. E. Emerson.

[118] Mitman 1992, p. 141.

field practice with ecological theory because of institutional constraints.[119] In the Australian case, neither party were pressured by a need to produce immediate practical results, but perhaps by a need for academic status.

Despite large amounts of experimental data and the clear density-dependence of phase change and its effects, locusts did not feature as examples in arguments at the time, perhaps because of the spatial complexity of their population dynamics. Andrewartha and Birch included a review of *C. terminifera* distribution and habitat in their book, but only within the context of variability of environment. Key took a neutral position on the controversy, commenting only that 'weather, and especially rainfall, is the independent variable to which fluctuations in the abundance of *Chortoicetes* must for the most part be ascribed', although with an indirect influence through the responses of food and shelter habitats and natural enemies, especially diseases.[120]

In a 1963 review of worldwide acridid population dynamics, J. P. Dempster concluded that they were 'mostly controlled by weather, and by imperfect density related factors' (interspecific competition and natural enemies). Unlimited population increase in favourable times was prevented by (density-dependent) intraspecific competition. Local extinctions occurred in severe conditions, commonly at the margins of the species range, offset by repopulation through spread in favourable times'.[121] Dempster suggested the greater mobility and lower fecundity observed in the gregarious phase of some species were possible examples of density-dependent regulating mechanisms in locusts.

The big locust plague of the 1950s

> *I thought I had seen hopper plagues — in 1934 and in the late forties in the Mallee — but this one is really frightening … they get in your car as you drive along … they get down your neck and up your trouser leg … wherever you look you see hordes of hoppers shimmering against the sun and trembling in a continuous swarm.*
>
> Ronald Hobbs, reporting from 'the nice green rich soldier settlement' at Strathmerton, Victoria, *Herald* (Melbourne), 14 December 1955.

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[119] Palladino 1990, pp. 262–264, the Canadians argued that models based on natural interactions would not apply in agricultural environments and that a theoretical single optimal biological control agent would outperform multiple agents. They suggested the single best control agent would be suppressed by 'competitive displacement'. The Californian's requirement for practical results compromised their ability to contribute to ecological theory, while the Canadian's insulation from such demands was seen as leading them to propose unrealistic solutions.

[120] K. H. L. Key, 'Research on the Australian locust and grasshopper problem', in ed. E. C. Becker, *Proceedings of the Tenth International Congress of Entomology, August 17–25, 1956*. Vol 3, (Ottowa, Mortimer Ltd, 1958), pp. 63–67.

[121] J. P. Dempster, 'The population dynamics of grasshoppers and locusts', *Biological Review*, 38 (1963), 490–529, pp. 519, 528–529, the examples were *S. gregaria*, *L. migratoria* and *N. septemfasciata.*

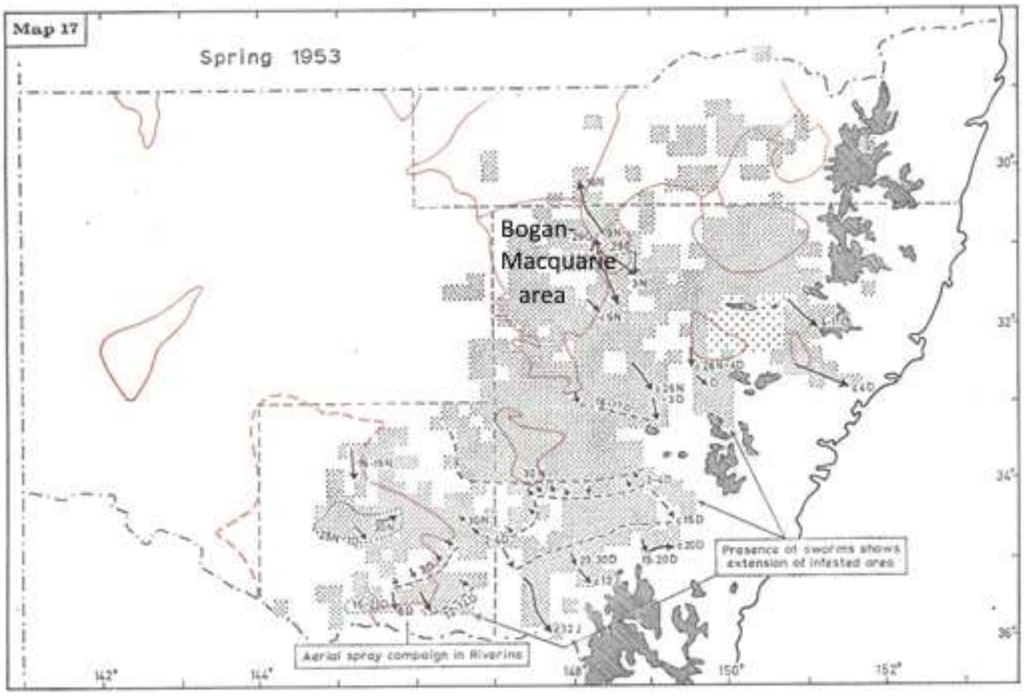

Figure 9.8. Map of locust infested areas (stippled grey) in NSW during spring 1953. Key's outbreak areas (brown outline) and land over 1000 m (dark grey).[122]

The 1953–55 locust plague rivalled all previous infestations in terms of scale and duration, with swarms reaching all four states and continuing for three years. Its course in NSW was documented by Max Casimir (1931–) and later by ALRC geographer, Joyce Magor (1933–2015). It followed a similar seasonal pattern to the plagues in the early 1870s and 1890s, and was also associated with a protracted La Niña event.[123] NSW departmental recruit Casimir was thrown straight into locust control, both on the ground and in the air, as NSW explored the advantages of using light aircraft for swarm spotting and spraying.[124] With responsibility for collation of state insecticide usage and access to the detailed PP Board mapping instituted by Key, his is a first-hand account.[125]

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[122] Joyce Magor, 'Outbreaks of the Australian plague locust (*Chortoicetes terminifera* Walk.) in New South Wales during the period 1937–1962, particularly in relation to rainfall', *Anti-Locust Memoir 11*, (London, Anti-Locust Research Centre, Ministry of Overseas Development, 1970), map 17, infested areas are shown on a 10 minute geographical grid, transferred from the PP Board maps (Bogan-Macquarie outbreak area added).

[123] Gergis and Fowler 2009, p. 375, list 1955–60 as a five-year prolonged La Niña, but the plague ended before La Niña conditions did.

[124] Max Casimir attended Fort Street Boys High School in Sydney and joined the NSW Department of Agriculture as a cadet in 1953, after obtaining a degree in agriculture at Sydney University. By 1970 he was director of entomology at its Biological and Chemical Research Institute.

[125] M. Casimir, 'History of outbreaks of the Australian plague locust (*Chortoicetes terminifera* Walk.) between 1933 and 1959, and analysis of the influence of rainfall on these outbreaks', *Australian Journal of Agricultural Research*, 13 (1962), 674–700, p. 684.

Magor also examined the monthly PP Board maps, producing gridded, statewide infestation maps and transcribing any recorded migration movements. Both authors treated the infestation in western regions separately, identifying the role of interstate migration when South Australia and Victoria became infested in 1955.[126] Much of NSW was infested by continuous locust generations from autumn 1953 to the summer of 1955–56. Magor's maps show the entire eastern half of the state infested from autumn 1953 through to summer 1954–55 (Figure 9.8). NSW was also the scene of concerted baiting and spraying with several organochlorine insecticides from the air and on the ground. PP Board staff distributed enough BHC in bran baits to cover 170,000 hectares in just the eastern half of NSW, including the districts of Warialda, Tamworth, Bathurst and Hunter Valley.[127]

With the plague building in 1953, Hogan conducted another campaign to stop swarms entering Victoria. It hinged on intelligence and reconnaissance of swarm development in western NSW, and pre-emptive spraying of swarms as far north as Hay (Figure 9.9). 18,500 hectares were aerially sprayed with BHC by the Victorian department south of the Murrumbidgee River. The program involved military personnel for logistic support, a modified Dakota aircraft with a crew from the domestic airline TAA and departmental staff from both states.[128]

Hogan's 'air offensive' peaked in late 1955 in a joint campaign by the Victorian and NSW departments. With a million hectares now under irrigation from the Murray and Murrumbidgee rivers, it was designed to minimise damage to high value crops and pasture. NSW sprayed 4,000 hectares of swarms around Jerilderie using a Tiger Moth, while Hogan's task, involving three DC-3 aircraft, stretched from Swan Hill to Shepparton in Victoria and extended north to Deniliquin in NSW. With only one airforce Dakota initially available in 1955, Victorian Premier Henry Bolte successfully pressed Prime Minister Menzies over the urgent need for more, while army personnel and equipment were again mobilised to assist on the ground.[129]

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[126] Magor 1970, p. 23; D. E. Wright, 'Analysis of the development of the major plagues of the Australian plague locust, *Chortoicetes terminifera* (Walker) using a simulation model', *Australian Journal of Ecology*, 12 (1987), 423–37, In a 1983 analysis, geographer Diana Wright interpreted it as two plagues, each generated separately by breeding in the arid interior, but that is not how it was seen on the ground in NSW. Wright was the first forecasting officer in the Australian Plague Locust Commission.

[127] M. Casimir, 'Grasshopper Control Campaign, 1953–55: amounts of Insecticide Used', (NSW Department of Agriculture files, EB 305. 20 March 1957, APLC archive). Total area equivalents of bran bait was 170,000 acres in 1953–54 and 250,000 acres in 1954–55. Figures for the south-western areas were not available, the total area figures included small amounts of toxaphene and aldrin.

[128] TAA, Trans Australia Airlines, was established in 1946.

[129] *The Advertiser*, 7 October 1956, the Stockowners' Association of South Australia called on the Minister to arrange a co-ordinated aerial spraying campaign. The agriculture department emphasised mechanised ground spraying with truck and army jeeps, using modified 'Sayers' exhaust sprayers, only bringing in aircraft to deal with flying swarms.

Figure 9.9. 'Layout of the Big Battle', showing swarms coming from NSW and locations of 'poison dumps', *The Argus*, 25 November 1953, p. 7.

The bulk of the spraying was over northern Victorian irrigated pastures, where 'crude BHC', lindane, aldrin and dieldrin were spread over a total area of 90,000 hectares, while landholders carried out ground control.[130] Casimir joined Hogan's sixty strong 'Operation Hopper' control team, describing it as well-organised even if it had not stopped locusts entering Victoria. Landholder communications demonstrated 'locust worry' was rampant and people now looked to the planes for protection. Soldier–settler dairy farmers near Tocumwal even held a social gathering for Hogan's team.[131] Journalists from Melbourne newspapers highlighted the agricultural losses and the power of aircraft.[132]

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[130] The Victorian department spent £185,000, plus a request for £22,000 more.

[131] Farmers at Yarroweyah, in the new Murray Valley Irrigation District, the largest of its kind in the Commonwealth, organised the event.

[132] *The Age*, 16 December 1955, p. 3, estimated £250,000 damage at the Murray Valley soldier settlement; M. Casimir, 'Australian Plague Locusts. Some impressions of the November/December 1955 DC3 aerial campaign against locusts in south-west NSW and Victoria', 11 January 1956, p. 8, (NSW Department of Agriculture file EB. 305); M. Casimir, 'An experimental campaign with light aircraft against flying locust swarms in NSW', *Bulletin of Entomological Research*, 49 (1958), 497–508; *The Age*, 19 Dec 1955, Minister for Agriculture (Mr McArthur) saved £16 million worth of crops in affected area — anti grasshopper campaign killed dense swarms over 238 square miles, equivalent to a mile wide strip reaching from Melbourne to Swan Hill.

Apart from an influx of locusts to the Southern Flinders Ranges and Riverland in autumn 1953, South Australia was largely insulated from the plague until autumn 1955, when swarms suddenly spread across the Far North, Northeast and most other agricultural districts, even reaching Goolwa at the Murray mouth and Kangaroo Island. It was a brief but intense plague and so was the response. When hatchings commenced in spring, as the agriculture department prepared to 'Blitz the hoppers' in was described as the 'worst plague for sixty years'.[133] At its peak, when swarms formed in November, six light aircraft were engaged in spraying them with lindane and dieldrin, while trucks with air-blast ground sprays and twenty-seven army jeep crews sprayed BHC.[134] The press got behind the campaign, headlining with military metaphors, calling it a 'Hopper War' and applauding the department's plan to protect high value crops with 'Operation On Guard'.[135] For the first time since 1890, swarms entered Adelaide suburbs in December 1955, generating a further storm of press interest.

Figure 9.10. 'Whispering Death', Part of an RAAF recruitment advertisement, *Truth* (Sydney), 26 March 1950, p. 27.

[133] *The Advertiser*, 28 November 1955, 'Blitz on Hoppers', six light aircraft were hired.

[134] *The Advertiser*, 2 November 1955, 27 Army jeep crews working with 50-foot boom sprays, said Major R. J. McGowan, killed a million million locusts, which would have eaten 225,000 tons of fodder a day.

[135] *News* (Adelaide), 16 November 1955, p. 21.

Victoria and South Australia together spent £350,000 on aerial and ground control in 1955.[136] The campaign in NSW had cost £200,000 by mid-1954 and more the following year, considering the increased of area of bran baiting.[137] The total spent on controlling the plague was therefore around £850,000, or $27 million in current dollar equivalents.[138] The states found the resources amid the 1950s economic upturn and the shift to manufacturing, and justified the expenditure through a conjunction of different interest groups. Newspaper articles assured the public that solutions to all pest problems were at hand, citing the success of team-work in overseas locust spraying from 'Kenya to Karachi'. They emphasised the 'sound scientific research' and the miracles of modern chemical science on which it was based.[139] But one *Age* editorial expressed a different view, that 'what is really needed is a central, unified organisation of entomologists fully equipped on a Federal basis to deal with the grasshoppers at their source and exterminate them as they breed'.[140]

The extent of breeding and the subsequent summer generation was much contracted and the plague ended in spring 1956, despite high seasonal rainfall and the continued La Niña influence.[141] The concerted spraying efforts may therefore have been successful in halting the plague, but it was thought that natural factors also played a part.[142] There were 'thin belts' of landholder opposition to the air campaign. Farmers near Mildura refused to allow spraying on their properties because it would damage crops and kill bees, and they threatened to claim for compensation.[143] But negative ecological consequences did not feature in the press as they had in the 1930s. Crosbie Morrison, the Victorian nature writer who challenged the use of arsenic in 1934, wrote a press article supporting the aerial BHC spraying.[144] Nor were insect natural enemies as prominent in correspondence, although *Scelio*

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[136] *The Advertiser*, 22 December 1955, £150,000; *The Argus*, 13 January 1955.

[137] M. Casimir, 'The locust problem — its history and development in New South Wales', *Journal of the Australian Institute of Agricultural Science*, (December 1965), 267–274, p. 270, bait to treat 270 square miles in 1953–54 and 390 square miles in 1954–55, an increase of 30 percent.

[138] Using 'Reserve Bank of Australia Pre-Decimal Inflation Calculator', £1,000 is equivalent to $32,629 (at 2015 values), the total of £850,000 was equivalent to $27,735,000.

[139] *Maryborough Chronicle*, 27 March 1953, p. 2, predicting that stopping the depredations of the Queensland fruit-fly was now certain; Western Mail, 5 February 1953, p. 56, Aldrin, the powerful American Insecticide being used in the Middle East and South Asia, is a "miracle" development of modern chemical science.

[140] *The Age,* 20 December 1955, p. 2, (Editorial). 'This plague has been a repetition of many others over the years, but it has been less costly. Since science has taken a hand in the farmer's problems, the economic loss from insect pests has been greatly reduced. In the present instance the debt to agricultural scientists, entomologists, engineers and aircraft pilots is incalculable … Plans have been put forward in recent years for control at the source to prevent the swarms from developing, but they have yet to be adopted. With the breeding grounds in the NSW and Queensland border areas, control is genuinely a national problem'.

[141] Gergis and Fowler 2009, p. 375, Table 10, lists the entire period 1955–1960 as a 6-year protracted La Niña event; p. 367, 1953 is given a high La Niña proxy value; Casimir 1962, p. 285.

[142] Casimir 1965, p. 270.

[143] *Herald*, 19 November 1955.

[144] *The Argus*, 3 September 1955, (Weekender), p. 4.

wasps were seen attacking egg beds in South Australia and NSW. Hogan found time to investigate rates of *Scelio* parasitism in autumn 1955, getting his field staff to sample many egg beds.[145]

The power of science and in particular of chemistry to design specific solutions for any biological problem assisted state institutions in deciding on appropriate actions. Once committed, the techno-politics of the 'hopper campaigns' gained its own momentum and the costs appeared to compare well against the total value of crops under threat. State governments were spurred by the actions of their neighbours, the urgings of pastoral and cropping industries, and the new public status of chemical companies. Aerial control, as well as most of the new ground-spray equipment, was beyond the means of individual landholders, so governments took over the coordination of control, which was run along military communication lines. ICI and Shell Chemical heightened the urgency and assured unlimited supplies of new insecticides.[146] Their large newspaper advertisements declared technical prowess, economy and success.[147]

By the 1950s the seamless transfer of military terminology onto locusts was complete. Control was organised as 'campaigns', with 'operations' and 'targets'. The involvement of aircraft added an air of military power to the 'offensives'. The novel scientific use of large aircraft was also embraced by those who supplied them. The RAAF used its involvement in the locust campaigns for recruiting advertisements and TAA aircraft and pilots were featured in a 1955 staff magazine (Figure 9.10).[148]

Science had cured infections, dramatically ended the Pacific War and only scientists could control the nuclear genie when it was let out of the bottle. Scientific knowledge was now increasingly esoteric and unavailable to the general public, but at the same time science became more 'glamorous' than ever before and its 'contract' with government was entrenched.[149] Scientists gained greater authority over complex issues concerning society and the environment, and therefore a greater influence over government decision-making. Several historians have examined the 1950s explosion of agricultural

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[145] T. W. Hogan, 'The winter mortality of eggs of *Chortoicetes terminifera* (Walk.) (Orthoptera: Acrididae) during the outbreak of 1955', *Australian Journal of Zoology*, 13 (1965), 47–52.

[146] *Barrier Miner*, 18 September 1953, p. 7, Boris Janes, head of ICI Australia and New Zealand, promotes BHC and says dieldrin and aldrin are still in short supply. Janes had been linked to the discovery of BHC in the 1940s.

[147] *Sun*, 23 December 1955.

[148] *This Air Age*, Trans-Australia Airlines Staff Magazine, 7 (1 and 2), (1956), pp. 1–2.

[149] Drew Hutton and Libby Connors, *History of the Australian Environment Movement*, (Cambridge, Cambridge University Press, 1999), p. 97.

pesticide use as a ‘classic’ example of the dynamic relationship between science and political authority.[150]

Key’s outbreak area plague prevention plan

At a conference organised by the AAC in 1947 at the request of Victoria, Key proposed an experimental preventive locust control trial in a known NSW outbreak area.[151] This would involve controlling locusts at incipient swarming densities, and it rested on Uvarov’s concept that plagues were initiated within outbreak areas. As had been pointed out at the 1938 conference, the strategy depended on outbreak areas occupying only a small proportion of the potential infestation area. But it was becoming apparent that ‘potential outbreak areas’ were widespread. Key was part of the first CSIRO entomology expedition to Southwest Queensland in 1949, and later surveys confirmed his potential outbreak areas on the Cooper Creek and Bulloo River floodplains.[152]

The proposal was discussed again at a 1949 conference and was endorsed by the Standing Committee on Agriculture (SCA). The Prime Minister communicated this to the state premiers, but Victoria was not prepared to contribute financially to the scheme on the scale proposed.[153] NSW continued to push the issue at Standing Committee meetings and there was some conflict over Victoria’s position.[154] After further disagreements over the scale and location of the trial in 1952, the AAC decided that no further action be taken.[155] As the threat of another plague built in 1953, Victoria’s refusal to join the scheme was criticised by its own Grazier’s Association as incomprehensible, since it represented logical federal–state cooperation on a national problem.[156].

The advice of British experts in Africa was to ‘control locusts in outbreak areas’ and, with machines replacing manpower and new insecticides, destroying locusts over large areas was now possible.[157]

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[150] Steven Bocking, *Nature’s Experts: Science, Politics and the Environment*, (New Brunswick New Jersey, Rutgers University Press, 2006), p. 38.

[151] Australian Agricultural Council — Reports of meetings Vol 2. (1945–52), Proceedings and Decisions of Council, 29th Meeting, Canberra 3–4 February 1947, Item 24, p. 44, (National Archives of Australia. Series A4739 – 1808410).

[152] CSIRO, ‘Cooper’s Creek Expedition: Report on the CSIRO Division of Entomology Expedition October–November 1949’, (unpublished report, Canberra, CSIRO, 1950), p. 12.

[153] CSIRO, *Grasshopper Control Conference, Canberra, ACT, May 1954,* (Melbourne, CSIRO, 1954), pp. 2, 12, Hogan was so confident of the ‘air offensive’ solution that Victoria rejected the CSIR plan, arguing that the selection of any ‘outbreak area’ must be relevant and refusing to co-fund the program.

[154] Australian Agricultural Council — Reports of meetings Vol 3. (1953–60), Proceedings and Decisions of Council, 40th Meeting, Canberra 27 July 1954, p. 31, comments by Mr Graham (NSW) about the Victorian attitude were removed from final document. (National Archives of Australia, Series A4739, 1808413).

[155] CSIRO 1954, p. 2.

[156] *The Age*, 3 November 1953, p. 2; 4 November 1953, p. 6.

[157] *Queensland Country Life*, 12 November 1953, p. 1.

From Our Point of View.

Mr. Menzies And Locusts

Mr. Menzies is coming to Forbes next week. He will be very welcome. His visit coincides with that of many locusts, plague of Biblical lands and this modern and possibly more profane Australia.

Some strange and not quite sensible pressures have been put on Mr. Menzies' Government to use 'plane and lorry forces in the fight. The whole set-up was completely wrong and rather futile.

The opportunity should be taken to tell Mr. Menzies how this plague could be wiped out. Federal and State co-operation, indeed legislation, are needed for this, but it is more worthwhile than anything on the political horizon.

Australia's locust plague can be ended, and the Prime Minister, who is a kindly man and keen on production, should be told how this can be achieved.

A heavy DC3 and a dozen boom spray units coming when the pest is on the wing are only expensive heart-breaks. At no stage are they the real answer.

Forbes Advocate, 17 November 1953, p. 1.

In the heat of the 1954 plague, a conference of technical officers was convened by CSIRO to resolve issues around the proposed trial.[158] This time, however, both Hogan and new Queensland chief entomologist, William McDougall, questioned the concept, the costs and the possible outcomes. A conundrum developed over the need to conduct a trial, not only to see if outbreak area control would work, but to be able to give an estimate of the cost that some states wanted before committing to it.

The majority recommendation was to proceed with a trial in a NSW outbreak area, but Victoria again dissented, stating that control methods developed by its department had reduced the urgency and need for the trial as proposed.[159] Victoria's rejection was more than just faith in the aero-chemical solution. It was clear to them that the Bogan–Macquarie area was unlikely to be a direct source of swarm incursions into western Victoria (Figure 9.8). Hogan believed they came from outbreak areas further back in Far West NSW and Southwest Queensland.[160] NSW on the other hand stood to gain if suppression was successful in Key's preferred outbreak area. It had introduced the Noxious Insects Levy in 1934 as a sinking fund, but outbreaks had become so frequent it was dependent on publicly funded insecticide programs in agricultural areas of the state.

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[158] CSIRO 1954, Appendix A.

[159] CSIRO 1954, Appendix F, p. 4, this referred to the aerial control carried out in the NSW Riverina by the Victorian Department of Agriculture in 1950 and 1953. In the two seasons 1953–54 and 1954–55 over 150,000 ha were treated using organochloride insecticides, principally Benzene hexachloride (BHC). Victoria treated a further 30,000 ha of swarms from aircraft in NSW in 1953 and 1955 to prevent swarms entering Victoria; Minutes, NSW Dept. Agriculture 1954–55, (APLC archive); CSIRO 1954, p. 3.

[160] Australian Agricultural Council (53rd Meeting) 16 June 1960. Agenda Item 13 (i), Reports of meetings Vol 3. (1953–60), (National Archives of Australia, Series A4739, 1808413); Memo T. W. Hogan, 7 June 1960. Victorian Dept. Agriculture, (APLC archive); T. W. Hogan, 'The locust problem in Victoria', *Journal of the Department of Agriculture Victoria*, (November 1955), p. 5; T. W. Hogan, 'The history of economic entomology in Victoria from the time of Charles French', *Journal of the Australian Entomological Society,* 33 (1994), 279–288, p. 284, reference to a locust conference held in 1963, was probably an SCA meeting.

The AAC finally authorised the ‘outbreak suppression’ trial in NSW with shared Commonwealth–state funding for equipment and insecticide in 1955.[161] Key organised CSIRO monitoring of the Bogan–Macquarie outbreak area aimed at initiating control when locust densities reached a pre-swarming threshold. The NSW patrol officer, John Walker, not only surveyed outbreak areas throughout the state, but made regular observations within the trial area at a network of ‘outbreak centre’ sites with both food-shelter and oviposition habitats (Figure 9.11).[162] A Trial Campaign Management Committee of state government and CSIRO entomologists was established to oversee the project.

Locusts reached pre-swarming densities in the monitored area in 1958 and a control trial was planned, but the committee decided against it in February 1959, with Key as CSIRO representative dissenting. Uvarov had been invited to Australia by Nicholson after the 1954 grasshopper conference and, on his retirement as head of the ALRC in 1959, he finally visited during a tour of locust affected countries. Plans for his visit included meetings with state and CSIRO entomologists and tours of locust country. In NSW, he attended the trial committee’s next meeting at Dubbo in November. Key outlined the monitoring of the trial area, showing the maps of soils and monitoring sites (Figure 9.11). Uvarov commented that such ‘detail was nowhere equalled’ and identified the ‘artificial’ scalded areas as the crux of the problem, saying that ‘without scalds, food-shelter habitat means nothing’. But he cast doubt on whether a trial in a single outbreak area in only one year could be successful.[163] State representatives noted Uvarov’s last comment and telegrammed their superiors. From that moment the plan for a suppression trial ended.

Uvarov proposed an alternative: creating an interstate locust control service that would monitor regions across state borders and have the capacity to control swarms where they developed. Before leaving Australia he prepared a brief set of recommendations for Australian locust management, outlining an organisational structure and staffing for the interstate organisation. Armed with Uvarov’s report, the Agricultural Council in 1960 endorsed its suggestions for the formation of an interstate locust organisation and that a ‘policy’ of continual monitoring replace Key’s ‘trial’.

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[161] Australian Agricultural Council (41st Meeting), 1955. AAC Reports of Meetings Vol 3. (1953–60), (National Archives of Australia, Series A4739. 1808413).

[162] NSW Department of Agriculture, Locust files, Patrol officer 1958–60, (APLC archive); Backpack spray equipment was also purchased.

[163] Minute — Record of Meeting of the Plague Locust Trial Campaign Management Committee — Dubbo Pastures Protection Board, 13 November 1959, (NSW Department of Agriculture file, APLC archive); SCA, 61st Meeting, Minutes of Meeting of Plague Locust Trial Control Campaign Committee at Dubbo PP Board, 13 November 1959.

Key’s plan had been an attempt to bridge the gap between ecological research and the necessity of practical control and it was based on the phase theory and the associated ‘outbreak area’ concept. A significant outcome of Uvarov’s Australian visit was the start of a long scientific exchange on locust ecology between the CSIRO and ALRC. Uvarov’s recommendations were frequently discussed at Standing Committee meetings during the 1960s, but it was not until the next big plague that the proposal for an interstate locust control service was put into action.

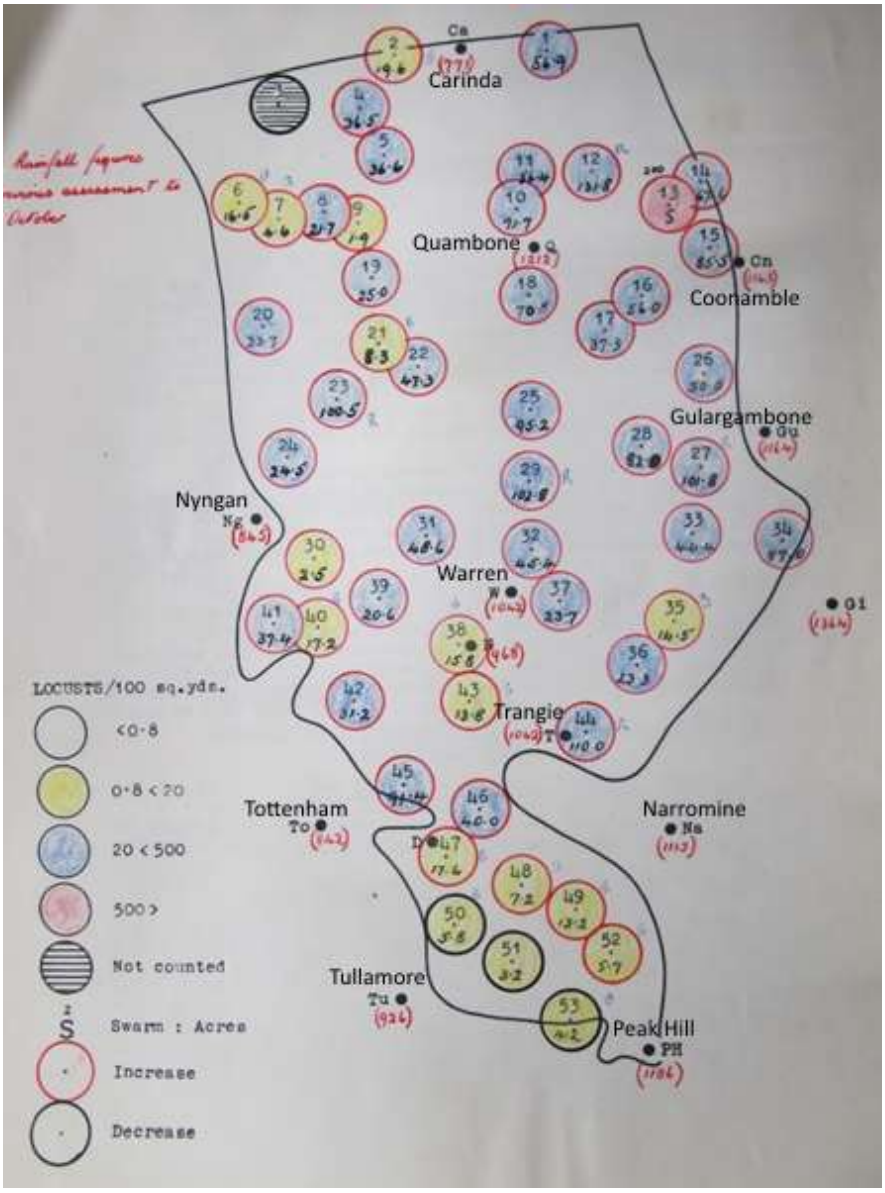

Figure 9.11. Map of locust densities at monitoring sites in the Bogan–Macquarie outbreak area in NSW during November 1958.[164]

[164] Map of locust densities at field sites 19–28 November 1958 (town names added), (NSW Department of Agriculture, file EB. A8.211 pt. 1. Australian plague locust - Field activities, biology, damage 1957–60. APLC archive).

Chapter 10. 'On the track of the locust', 1960–1976: the CSIRO, ALRC and locust ecology

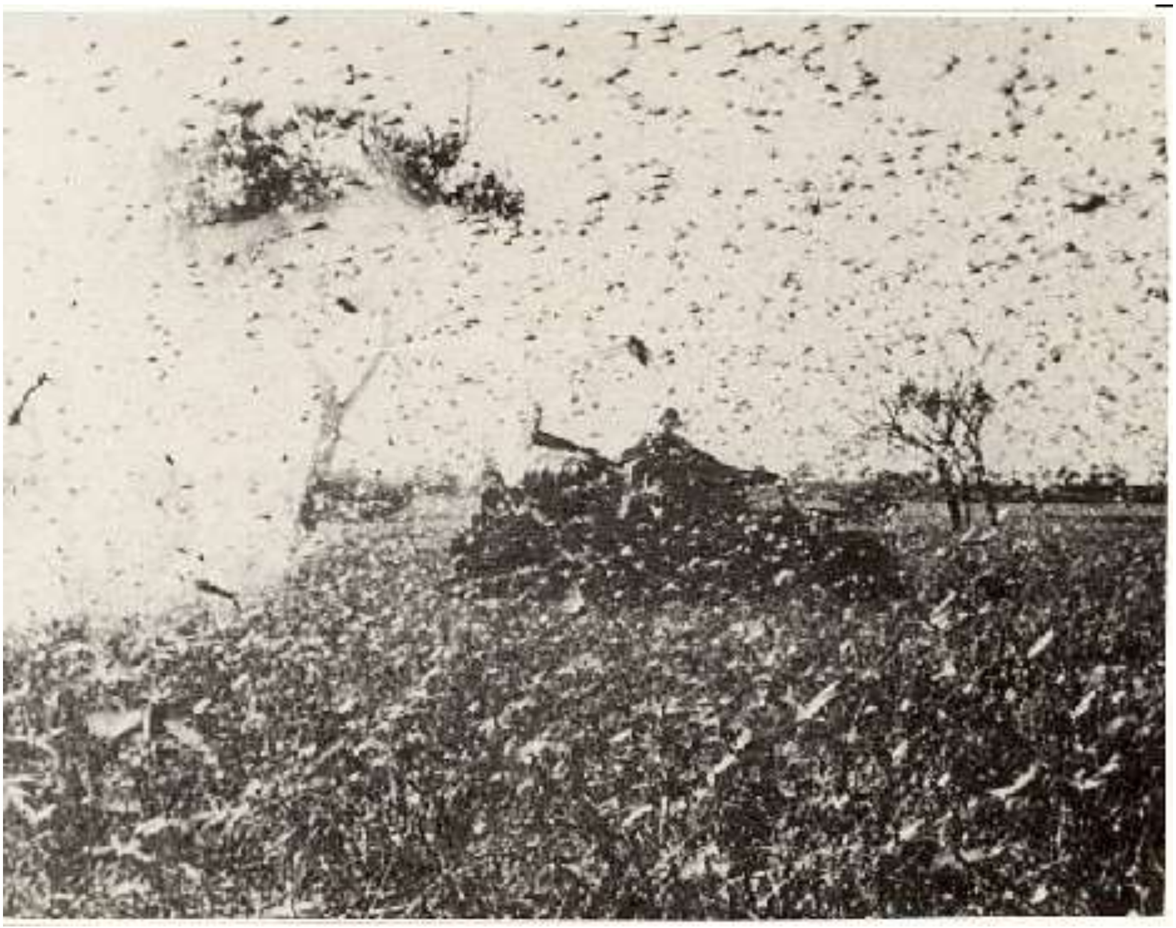

Figure 10.1. An Australian Army tank used during the 1974 locust plague (photograph courtesy of Picture Warren, Warren Shire Library).

Ah Grasshopper Loose in Queensland
Grasshopper Loose in Queensland
Grasshopper Loose as big as any goose
and he spits tobacco juice all over Queensland

Slim Dusty, 1963 (from the 1997 EMI album, *Old Time Drover's Lament*).

In the early 1960s the Australian Agricultural Council (AAC), its Standing Committee (SCA) and the CSIRO executive endorsed Boris Uvarov's proposal for the formation of an interstate agency dedicated to monitoring and controlling populations before they increased to 'plague proportions'.[1] CSIRO research in the 1960s on migrations and rapid arid zone population build-up in response to

[1] Standing Committee on Agriculture, 61st Meeting: AAC 53rd Meeting, Darwin 1960. Agenda Item 13(i). Report to AAC, (National Archives of Australia, Series A4739. 1808413).

rainfall built scientific support to the policy. It took until 1973, however, to find a consensus among CSIRO researchers, state entomologists and the agriculture bureaucracy about how and where locust plagues developed. A major locust plague at the time created the bureaucratic moment and a federalist Labor government took the initiative to negotiate with the states to institute the interstate agency.

Doug Clark, the leader of the CSIRO locust research program, described the lifestyle of the locust as essentially 'nomadic'.[2] Its population irruptions resulted from frequent nocturnal migrations, allowing it to take advantage of brief breeding opportunities in different parts of its vast range. This view came out of a decade of intensive field research, following population fluctuations in New South Wales (NSW) and Queensland. Numerous visiting scientists from Uvarov's Anti-Locust Research Service (ALRC) had contributed to the CSIRO's concerted locust research project. By the early 1970s it had produced a comprehensive understanding of the locusts' ecology. State entomologists continued to investigate control methods and in NSW there were plenty of opportunities to investigate swarm movement and insecticides.

The nomad was now 'encompassed' by knowledge of its habits and habitats, and by the international locust technoscience of insecticide chemistry and aerial delivery.[3] This opened the way for a new strategy of plague forecasting and suppression. The CSIRO ecological locust research forecasting program was largely complete by the mid-1970s and the Australian Plague Locust Commission was created with a new objective. Its focus would be on detecting populations and migrations, and refining spray technologies to support its operational role of controlling populations at source. The paths of scientific research from 1960 to 1975, the detail of several players' preoccupations and the role of the 1973–74 plague in galvanising agreement between scientists and governments about dealing with the locust problem on a national scale are the subjects of this chapter.

The environmental setting

The negative consequences of widespread DDT use in the late 1950s heralded changes in attitudes towards pesticides and a declining public trust in the chemical industry, agricultural practices and governments' scientific judgement. Rachel Carson's *Silent Spring* cemented the negative views by

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[2] D. P. Clark, 'The plague dynamics of the Australian plague locust, *Chortoicetes terminifera* (Walk.)', in eds. C. F. Hemming and T.H.C. Hemming, *Proceedings on the International Study Conference on Current and Future Problems of Acridology, 1970*, (London, Centre for Overseas Pest Research, 1972), pp. 275–287, p. 284.

[3] D. L. Gunn, 'Nomad Encompassed. The development of preventive control of the Red locust, *Nomadacris septemfasciata*, Serville, by the International Red Locust Control Service', *Journal of the Entomological Society of South Africa*, 23 (1960), 65–125.

exposing the trophic effects throughout the ecosystems on which all life depended.[4] Ecology became the well-funded 'subversive science' by demonstrating the inexorable destructive impacts of human industrial and agricultural activities on its own health and on other organisms.[5] Environmental activism emerged along with environmental consciousness. At the same time, entomologists searched for alternatives to reduce agriculture's reliance on single pesticides that were failing due to insect resistance. They moved to employ more diverse, 'integrated' control methods based on ecological research, including biological control, natural enemies and monitoring for damage thresholds.[6] 'Integrated Pest Management' later became a dominant strand of applied research and the recommended, if not adopted, agricultural practice, both in Australia and internationally.

In the response to the increasing use of pesticides and insect resistance in Australia, in 1965 the AAC instituted the Commonwealth and States Entomology Committee (CSEC), advised by CSIRO scientists and the chief biologists from state agencies.[7] Organochlorides (OCs) were gradually phased out, but there were ready replacements among the organophosphates (OPs). The post-war Australian Civil Aviation Authority ban on the aerial use of OPs, imposed because of their origin as potential nerve gases, was lifted in the 1960s and several new insecticides were successfully trialled against locusts. Locust control often took place away from public eyes in the 'shadow places'; landscapes already sacrificed to agricultural production and not seen as having 'natural values'.[8] Although the growing community and scientific concern over pesticide use in the West had little effect on locust control programs in Africa, it pressured agriculture authorities to review their domestic methods and motives.

The 1960s were a quiet period for locusts in Australia as there were no multistate plagues, although infestations continued throughout the decade in NSW. Joyce Magor listed 1961–62 as a 'plague' in

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[4] Rachel Carson's *Silent Spring* was published in 1962, but the impetus came from correspondence with people directly affected by massive DDT spraying programs in the late 1950s. Much of the text for *Silent Spring* was written in 1960. John Paull, 'The Rachel Carson Letters and the making of *Silent Spring*', SAGE Open, (July–September 2013), 1-12.

[5] Paolo Palladino, *Entomology, Ecology and Agriculture: The Making of Scientific Careers in North America, 1885–1985*, (Amsterdam, Harwood Academic, 2002), p. 3.

[6] R. Peshin, R. S. Bandral, W. J. Zhang, L. Wilson and A. K. Dhawan, 'Integrated Pest Management: A Global Overview of History, Programs and Adoption', in eds. R. Peshin and A. K. Dhawan, *Integrated Pest Management: Innovation-Development Process*, (The Netherlands, Springer, 2009), pp. 1–49, p. 2, Californian entomologists coined 'integrated control' in 1959.

[7] T. W. Hogan, 'The history of economic entomology in Victoria from the time of Charles French', *Journal of the Australian Entomological Society*, 33 (1994), 279–288, p. 284; The Commonwealth and States Veterinary Committee was also instituted in 1968.

[8] Cameron Muir, *The Broken Promise of Agricultural Progress: an Environmental History*, Routledge Environmental Humanities Series, (Oxon and New York, Routledge, 2014), p. 5.

NSW and there was even a small immigration into Northwest Victoria.[9] Swarms continued to infest Central West NSW until 1964. There was a prolonged El Niño during 1964–1969 and severe drought in 1965 and 1966, causing a forty per cent drop in the NSW wheat harvest and sheep flock, and prompting extra federal relief funding.[10] Television now brought images of dead livestock and windswept bare earth into urban homes. Despite the drought, there were further locust outbreaks in the Riverina and Central West NSW, which gave the CSIRO and NSW entomologists the opportunity to continue research on population ecology and aerial spraying.[11] More fitting with the dry times, there were grasshopper outbreaks in the southern Flinders Ranges of South Australia during 1964–1968 and near Ceduna on the west coast from 1969 to 1972.[12]

Despite the 1960s droughts, in 1970 the Australian sheep flock peaked at 180 million; a total that has not been repeated. This was largely due to a dramatic increase in stocking in WA following good rainfall there during the 1960s and major land-clearing in the Great Southern region.[13] The 1970s saw a reversal of climatic fortune, with a run of wet years during a prolonged la Niña event. This coincided with the development of a major locust plague — even bigger in extent and duration than those of the 1930s and 1950s. There are different interpretations of the development of this plague, which peaked during 1973–74. Doug Clark viewed the infestations beginning in 1969 and continuing through to 1972 as already a plague.[14] Its intensification in 1971 and 1972 in NSW and western Queensland, brought swarms into Victoria and South Australia and, although not on the same scale as the events of the following two years, it was already affecting several states. Attention was later focused on a small area in Central West Queensland as the precursor to the widespread swarms and population peak during 1973–74.[15] Major migrations spread across all four states in 1973 and 1974

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[9] Joyce Magor, 'Outbreaks of the Australian plague locust (*Chortoicetes terminifera* Walk.) in New South Wales during the period 1937–1962, particularly in relation to rainfall', *Anti-Locust Memoir 11*, (London, Anti-Locust Research Centre, Ministry of Overseas Development, 1970), p. 12.

[10] J. L. Gergis and A. M. Fowler, 'A history of ENSO events since AD 1525: implications for climate change', *Climatic Change*, 92 (2009), 343–387, Table 10, p. 375, 1970–75 is listed as a six-year protracted La Niña event; Julia E. Miller, 'Remembering rain, deciphering drought: climate and the role of perception in land management', *History in the Making*, 1 (1) (2012), 88–100.

[11] M. Casimir and R. C. Bament, 'An outbreak of the Australian plague locust, *Chortoicetes terminifera* (Walk.), during 1966–67 and the influence of weather on swarm movement', *Anti-Locust Memoir 12*, (London, Centre for Overseas Pest Research, 1974).

[12] P. J. Birks and J. W. Goode, 'Biology and Control of *Austroicetes cruciata*, the small plague grasshopper — 1966–68', *Department of Agriculture, South Australia, Agronomy Branch Report No. 9, 1969*.

[13] 'Historical and Geographical Context', *Australian Natural Resources Atlas*, Vol 2.0 (2001), Australian Natural Resources Audit, https://www.environment.gov.au/system/files/.../nlwralandusechangecontext.doc, viewed 16 March 2017.

[14] Clark 1972, p. 276.

[15] APLC geographer Diana Wright later followed this logic to place 1973–74 among those plagues having a source in the arid interior, see D. E. Wright, 'Analysis of the development of the major plagues of the

brought locusts to southern coastal areas and even to northern Tasmania.[16] An outbreak of this geographical extent and duration had not been seen since the 1870s.

Scientific research in the 1960s

At a meeting of the AAC in 1960, the CSIRO executive gave its support to Uvarov's proposed Interstate Locust Control Service, and also to his suggested functions and staffing structure.[17] It recommended the AAC take steps to constitute the body and appoint a director, offering its Mitchell Laboratory at Trangie to serve as headquarters (Figure 10.2). The AAC endorsed the continuation of funding for CSIRO ecological research on *Chortoicetes terminifera*.

Figure 10.2. CSIRO Mitchell Laboratory at Trangie, 2016. The building is now part of the NSW Department of Agriculture research farm (photo Douglas Lawton).

By the early 1960s there was general agreement that, in addition to the major outbreak areas in NSW, its Far West region and Southwest Queensland had contributed to locust invasions of southern agricultural regions.[18] At the 1963 Conference of Commonwealth and State Entomologists, Victoria submitted that major outbreaks in the past originated from within the inland region, 'exact locality unknown' that probably included Southwest Queensland and neighbouring areas of NSW and South

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Australian plague locust, *Chortoicetes terminifera* (Walker) using a simulation model', *Australian Journal of Ecology*, 12 (1987), 423–437.

[16] R. A. Farrow, 'Offshore migration and the collapse of outbreaks of the Australian plague locust (*Chortoicetes terminifera* Walk.) in south-east Australia', *Australian Journal of Zoology*, 23 (1975), 569–595, pp. 570, 584, migrations on 2 December 1973 and 16 February 1974. Farrow also considered the period 1969–74 as a single plague.

[17] Australian Agricultural Council (53rd Meeting), 16 June 1960. Agenda Item 13 (i), p 13, (ii), p.1. Reports of meetings Vol 3. (1953–60), (National Archives of Australia, Series A4739, 1808413).

[18] M. Casimir, 'History of outbreaks of the Australian plague locust (*Chortoicetes terminifera* Walk.) between 1933 and 1959, and analysis of the influence of rainfall on these outbreaks', *Australian Journal of Agricultural Research*, 13 (1962), 674–700, p. 685.

Australia.[19] Victoria's contribution to refunding the locust patrol service was made contingent on regular survey of those inland areas, to act as a warning system for the states when populations reached a dangerous level. Tom Hogan, who took personal credit for the 'discovery' as the result of his insistence on surveying inland areas, got the chance to see the landscape of 'Clancy of the Overflow' through a locust survey in 1964.[20]

The geographic focus of locust ecology research now shifted to 'The Channel Country' in Southwest Queensland as an important outbreak area for *C. terminifera* and a source of plague migrations. The idea that outbreak suppression there might be more useful than in NSW was already set in the minds of the state government entomologists. Douglas Waterhouse, the new head of the CSIRO Division of Entomology, told the executive in 1963 that fragmentary evidence suggested persistence of locusts on the floodplains of this region. He also indicated that the costs of monitoring such a large area, including vehicles and aerial reconnaissance, would be considerable.[21]

Doug Clark conducted intensive field observations in NSW and Queensland, along with parallel laboratory experiments on the biology and ecology of *C. terminifera* during the 1960s. He monitored populations in the Bogan–Macquarie area continuously, making regular population counts from a network of permanent quadrat sites, as well as making numerous surveys in western Queensland. He was assisted in this mammoth longitudinal research effort by a team of CSIRO field technical staff, including Brian Cameron, Louis Chinnick, Bob Lewis and John Dowse. After demonstrating that transect counts gave reliable estimates of actual population densities, Clark collected field data on fecundity, realised fertility, parasitism and mortality during 1961–64.[22] He later showed, by applying maximum likelihood and regression statistics to locust population demography, that variations in adult and nymph numbers were positively correlated with the amount of rainfall over the previous six weeks.[23] Other CSIRO researchers examined different aspects of *C. terminifera* biology. O. R. Byrne investigated the gene frequencies of the common phenotypic colour patterns, or 'forma', that had been

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[19] T. W. Hogan, 'Australian Plague Locust', Conference of Commonwealth and State Entomologists, Hobart, November 1963, (Victorian Department of Agriculture Archive, BHZ-4898).

[20] T. W. Hogan, 'Report on Locust Survey — Channel Country, March 1964, (Victorian Department of Agriculture Archive, BHZ-4898); A. B. Paterson, 'Clancy of the Overflow', a poem written in 1889 set the romantic vision of 'sunlit plains extended' in stark contrast to the urban environment.

[21] Memo G2/113, Waterhouse to CSIRO Secretary, 5 June 1963, (Victorian Department of Agriculture Archive, BHZ-4898); M. F. C. Day, M. J. Whitten and D. Sands, 'Douglas Frew Waterhouse 1916–2000', *Historical Records of Australian Science*, 13 (4), (2001), 495–519.

[22] D. P. Clark, 'On the sexual maturation, breeding and oviposition behaviour of the Australian plague locust, *Chortoicetes terminifera* (Walk.)', *Australian Journal of Zoology*, 13 (1965), 17–45.

[23] D. P. Clark, 'The influence of rainfall on the densities of adult *Chortoicetes terminifera* (Walker), in central western New South Wales, 1969–73', *Australian Journal of Zoology*, 22 (1974), 365–386.

described by Key as a procryptic mechanism.[24] Key and Michael J. D. White examined the microscopic cytology of meotic genes to separate *Austroicetes pusilla* from its northern variety as a new species *A. interioris*.[25]

Uvarov's 1959 visit to Australia initiated a period of intense scientific collaboration between the CSIRO and ALRC that continued until the mid-1970s.[26] Doug Clark was assigned to direct CSIRO locust research in 1961 and made several trips to locust-affected African countries and to London, where future cooperation with ALRC scientists was discussed.[27] His 1965 visit to London with Doug Waterhouse convinced Peter Haskell, the ALRC director, and the Ministry of Overseas Development of the advantages of directing a major research effort on locusts in Australia.[28] Many ALRC researchers subsequently came to Australia to work on missing details of locust population ecology. CSIRO harnessed the international scientific expertise to expand its own research capabilities — particularly in locust migration and processes leading to population increase — to improve its plague forecasts. ALRC staff extended their scientific experience in locations that were not contingent on post-colonial access restrictions.

State entomologists carried on with the more mundane and repetitive tasks of controlling locusts, but there were opportunities to contribute to ecological research. Max Casimir and Reg Bament carried out aerial spray trials on locusts in most years of the 1960s. During many hours spent in small aircraft on swarm reconnaissance, they realised that hopper bands could often be clearly seen from the air and this changed the way control was done. Up to that point, only swarms were treated from the air. In the late 1960s, Casimir and Bament tested the organophosphate insecticides maldison, fenitrothion and carbaryl on swarms, and in 1966 they conducted the first aircraft spray trials on hopper bands. Counts

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[24] O. R. Byrne, 'Polymorphism in the Australian Acrididae 1. Inheritance of colour patterns in the plague locust, *Chortoicetes terminifera*', *Heredity*, 22 (1967), 562–568; O. R. Byrne, 'Polymorphism in the Australian Acrididae 2. Changes in colour pattern gene frequencies in the plague locust, *Chortoicetes terminifera*', *Heredity*, 22 (1967), 569–89, the 'pattern morphs' or 'allelomorphs' are the result of genetic dominance. The frequency of each was found to change within a population during development from hatching to adult and between generations. Byrne studied pattern morphs for PhD research at University of Adelaide, 1962; K. H. L. Key, 'The Ecology and Biogeography of Australian grasshoppers and locusts', in eds. A. Keast, R. L. Crocker and C. S. Christian, *Biogeography and Ecology in Australia*, (Den Haag, W Junk, 1959), Chapter 10, pp. 192–201, p. 195.

[25] M. J. D. White and K. H. L. Key, 'A cytotaxonomic study of the *pusilla* group of species in the genus *Austroicetes* Uv. (Orthoptera: Acrididae)', *Australian Journal of Zoology*, 5 (1957), 55–87.

[26] C. Ashall and D. P. Clark, 'Expanding co-operation in locust research between Anti-Locust Research Centre and the CSIRO in Australia', *Pest Articles and News Summaries* (*PANS*), 12 (3), (1966), 160–161, the authors cite Uvarov's visit as the initiator of scientific exchanges, although Uvarov had earlier corresponded with Allman in NSW and Hogan in Victoria during the 1953–55 plague.

[27] Clark had worked on the wingless grasshopper problems of pastures on the NSW northern tablelands; Helen Clark, pers. comm. 2011.

[28] Australia was in scope when the ALRC was in the Department of Technical Co-operation in 1965, but would have been outside the domain of overseas development assistance in 1967. In 1965 the ALRC was overseen by the Overseas Pest Control Committee.

of dead locusts on the ground showed these were effective, and there were also logistic advantages. Loading and using undiluted 'technical' formulations eliminated pre-mixing and greatly increased the spray coverage from a single plane-load. In 1970, fenitrothion became the 'insecticide of choice' in NSW.[29]

The heyday of the ALRC

The United Nations Food and Agriculture Organization (FAO) provided funding in the 1950s for the ALRC to extend its monitoring and forecasting of locust swarm activity and plague development throughout the range of the desert locust. This resulted in closer integration of the research and control functions of the ALRC and in the establishment of the Desert Locust Information Service in 1958. The ALRC Biogeographic Section, headed by Zena Waloff, was expanded to collate surveillance data from across fifty countries affected by the desert locust and it came to look like a war-room, with large wall maps covering Africa and Eurasia and symbols representing the locations of swarms (Figure 10.3). The geography of population irruptions and migrations was crucial to forecasting and control intervention, and cartographic analysis became integral to understanding how migrations fitted into the wider ecology of plague development. The ALRC system of gridded temporal mapping of reports, which created an archive of historical desert locust distributions, was transferred to Australia by its researchers.[30]

The ALRC Field Research Division established in the 1960s gave many British scientists opportunities to advance their careers by working in locust-affected countries. Chemists, physicists, meteorologists and geographers, as well as entomologists, were given specific postings and research projects.[31] Researchers combined details of lifecycles, behaviour, the mechanics and demographics of phase-change, migrations, swarms and control technologies. Locust surveys may also have had a strategic intelligence role for Britain's post-war activities, particularly in the Middle East and North Africa. Partly because of inadequacies in mapping and the logistics of accessing remote areas, the British Army survey corps and its former staff were also involved in locust monitoring. Suggestive espionage intrigues connected to locust surveillance and control that go beyond building local alliances remain unexplored.

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[29] M. Casimir, 'The aerial spraying of locusts in New South Wales from 1955 to 1970', *Science Bulletin 86, Department of Agriculture New South Wales,* (Sydney, Division of Extension Services, 1971), p. 39.

[30] F. T. Bullen, 'Mapping locusts in Australia: an exercise in mapping biological data', *Cartography*, 9 (1975), 90–96.

[31] Andrew S. Thompson, *The Empire Strikes Back? The Impact of Imperialism on Britain from the Mid-Nineteenth Century*, (Oxon England, Routledge, 2014), p. 27, Thompson incudes the ALRC as one of the institutions which gave opportunities for science-educated Britons to gain overseas experience and expand their career prospects.

Figure 10.3. 'Discussing the current desert locust situation before issuing one of the monthly forecasts'. Desert Locust Forecasting Service staff (left to right) Elizabeth Betts, Anne Batten and Margaret Haggis in the ALRC Biogeographic Section map room, c. 1969.[32]

Uvarov continued an active role as a consultant after his retirement and worked on the updated worldwide review of *Grasshoppers and Locusts* until his death in 1970. Watching over the machinery of an ever-expanding anti-locust empire built on the technoscience of aerial spraying with increasing amounts of new chemical insecticides, Uvarov returned to his ecological roots. He maintained that a detailed understanding of life histories and ecology of each species was the key to locust problems. Only intensive field research could identify the reasons for outbreaks. And he held out hope of environmental solutions to reduce plagues. At his final presentation to the 1968 International Congress of Entomology in Moscow, he reminded entomologists that some species had declined for natural reasons or became economic pests because of land use change. The concentration on direct controls were 'mere palliatives' and lasting solutions would be found through ecological regulation of populations.[33]

[32] J. Roffey, *The Anti-Locust Research Centre: A Concise History to 1970*, (London, ALRC, 1970), p. 18.

[33] B. P. Uvarov, cited in *In Memorium: Sir Boris Uvarov 1888–1970*, (London, Anti-Locust Research Centre, 1970), p. 18.

Staff numbers at the ALRC grew from sixteen in 1950 to over a hundred in 1970, reflecting its diversifying roles and influence.[34] Its scientific program had been reviewed when it was transferred from the Department of Technical Cooperation to the Ministry of Overseas Development in 1966 and its name was changed to the Centre for Overseas Pest Research (COPR) in 1971. The FAO linkage expanded its role to include other agricultural problems relevant to its expertise in controlling locusts. During the 1980s, however, FAO took over the desert locust forecasting role from the COPR, which was transformed again into the Natural Resources Institute. Work on acridology, one of the last vestiges of British Imperial science, was gradually phased out.[35]

CSIRO–ALRC collaborative research

The joint research on Australian locusts commenced in 1962 and gained momentum during the decade. CSIRO scientists were joined by entomologists, ecologists, physiologists, geographers and meteorologists on ALRC-funded secondment, including Clifford Ashall, Elizabeth Bernays, Frank Bullen, Reginald Chapman, Richard Davies, Michael Lambert, Joyce Magor, John Moorehouse, Reginald Rainey, Jeremy Roffey, Phillip Symmons and Zena Waloff. Several remained in Australia to continue their careers. Their diverse research contributed much to the understanding of *C. terminifera* population dynamics, including fertility, mortality, diapause, diet, flight behaviour, plague development and migration.[36] Much of the field research was conducted out of the CSIRO Mitchell Research Station at Trangie, where Ken Key and Laurie Clark based their research in the 1940s.

Ecological methods continued to develop rapidly after the 1950s, in line with more sophisticated means of analysing empirical results against theoretical models. Locust researchers made use of international developments in ecological practice and mathematical applications to deal with complex and spatial field data. Applying statistical tests for estimating abundance to rapidly changing locust populations, or for demonstrating immigration and emigration, was logistically and mathematically challenging. Australian and ALRC locust researchers interpreted their findings in terms of ecological theory, notably developments in understandings of insect migration, but they also referred back to the issues of population regulation and density-dependence that had featured so prominently in Australian insect ecology.

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[34] Roffey 1970, p. 17.

[35] N. Waloff and G. B. Popov, 'Sir Boris Uvarov (1889–1970): the Father of Acridology', *Annual Review of Entomology*, 35 (1990), 1–24, p. 17.

[36] E. A. Bernays, and R. F. Chapman, 'The role of food plants in the survival and development of *Chortoicetes terminifera* (Walker) under drought in New South Wales', *Australian Journal of Entomology*, 21 (1973), 575–592; M. R. K. Lambert, 'Some factors affecting flight in field populations of the Australian plague locust, *Chortoicetes terminifera* (Walker), in New South Wales', *Animal Behaviour,* 20 (1972), 205–217.

Figure 10.4. The CSIRO–ALRC field research team at Noccundra, Queensland, in 1965. (From left) Back row: Ray McGuinness, John Dowse, Reg Rainey (ALRC), Barry McCabe, John Walker, (cook), Brian Cameron, (mechanic — Alex), Cliff Ashall (ALRC). Front row: Zena Waloff (ALRC), Joyce Magor (ALRC), Max Casimir (NSW Agriculture), Lou Chinnick, Doug Clark (photo courtesy Brian Cameron, Trangie, NSW).

Joyce Magor and the biogeographic history of plagues

Geographer Joyce Magor was the first ALRC researcher in Australia, arriving in 1962 to undertake a 'cartographic' analysis of historical locust distributions in NSW, where detailed records were available from the monthly PP Board maps instituted by Key in 1937. Magor, from the ALRC Biogeographic Unit, received a PhD for the analysis of locust breeding and swarm movements in India and Pakistan in relation to weather. Her research contributed to forecasting systems based on spatial population monitoring, and she applied those methods to seasonal swarm extents of *C. terminifera* in relation to rainfall patterns. Magor produced a set of high-resolution gridded maps showing the development of the 1950s plague in NSW and also of the spatial frequency of infestation, by seasonal locust generations, for the period 1937–1962 (Figure 9.8).[37]

The results supported earlier findings by Key, Casimir and L. R. Clark that local development of swarm populations in outbreak areas depended on rainfall, but cast some doubt on their delimitation and role as the only source of swarming populations. Magor addressed the issue of the 'simultaneous' appearance of high density adults in many outbreak areas and general population mobility across the

[37] Magor's infestation maps were calculated on a ten-minute of latitude and longitude (~20 km) grid resolution.

landscape, but data within NSW could not resolve local origin from migration in many cases.[38] Magor also identified 'migratory routeways', paths of frequent diurnal swarm movements, which resulted in the spread of infestations past forested areas and mountain ranges into southern and eastern habitats. Max Casimir and Reg Bament approached swarm movements directly, following individual swarms on the ground and in the air. They observed cumulative diurnal displacements of up to 100 kilometres, which were considered an order of magnitude less than those of the desert locust.

In early 1965, Clark led a team that included Magor, Ashall, Waloff and Rainey from the ALRC, on a field study of *C. terminifera* population changes in Southwest Queensland (Figure 10.4). Their experience with the Desert Locust Information Service and combined expertise on locust migrations in relation to meteorological conditions in Africa, was reflected in the focus of this new research.[39] Locust densities were very low in the region because of general drought conditions, but an ambitious program of intensive observations were conducted on fixed quadrat sites in different habitats. It included repeated transect counts and the first mark-recapture experiments on insects in Australia.[40]

Figure 10.5. Doug Clark (centre) presents photographs of locusts to the Governor-General, Lord Casey, during a 1966 visit to CSIRO, with Division of Entomology Director, Doug Waterhouse (far right) and CSIRO Executive member and entomologist, Max Day (National Library of Australia, obj.143076483).

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[38] Magor 1970, pp. 31–33.

[39] Rainey and Waloff headed the Desert Locust Information Service.

[40] Mark-recapture methods had been tried on rabbits in 1957, G. M. Dunnert, 'A test of the recapture method of estimating the number of rabbits, *Oryctolagus cuniculus* (L.) in a warren', *Wildlife Research*, 2 (2), (1957), 90–100.

The results demonstrated a high mobility of 'solitary' adults, with thirty per cent daily turnover rates of individuals from local migratory movements.[41] Numerous night flights were observed, and their association with the disturbed weather of low pressure troughs was similar to Rainey's findings in low density populations of desert locusts. The implication of migrations occurring during atmospheric convergences associated with low pressure systems, thus concentrating locusts downwind, shifted the focus of research from daytime swarm movements to nocturnal migrations as fundamental to the ecology of *C. terminifera*.[42]

The international aspect of this research boosted the division's profile and Clark's locust work was showcased as leading entomological science during the Governor-General's tour of the CSIRO in 1966 (Figure 10.5). From 1968, the joint CSIRO–ALRC locust research projects were managed by the CSEC.

Keith Wardhaugh and the 'discovery' of locust diapause

Keith G. Wardhaugh came to Australia in 1968 after investigating desert locusts in the Middle East with the ALRC. Extending from that work, he studied egg development in *C. terminifera* using microscopic dissections to describe the distinct stages of embryonic development.[43] He also followed egg development in the field by marking individual pods laid in autumn 1969 in the Trangie area. While some hatched during autumn, there was no emergence from others. Some unhatched pods were collected and left on the laboratory bench at the Mitchell research station. In early spring nymphs began hatching from marked pods in the field and Wardhaugh examined the laboratory eggs under a microscope. Nearly all were at the same point of development, where the embryo rotates in the egg (anatrepsis) before completing development. It was clear that these eggs had been dormant during winter at the pre-anatrepsis stage, despite being in damp soil, and therefore that this represented a diapause. Since it was generally thought at the time that because *C. terminifera* was a locust it did not

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[41] D. P. Clark, C. Ashall, Z. Waloff and L. Chinnick, 'Field studies on the Australian plague locust, *Chortoicetes terminifera* (Walker) in the "Channel Country" of Queensland', *Anti-Locust Bulletin 44,* (London, ALRC, 1969), 1–104.

[42] D. P. Clark, 'Flights after sunset by the Australian plague locust, *Chortoicetes terminifera* (Walk.), and their significance in dispersal and migration', *Australian Journal of Zoology*, 19 (1971), 159–76; D. P. Clark, 'Night flights of the Australian plague locust, *Chortoicetes terminifera* (Walk.) in relation to storms', *Australian Journal of Zoology*, 17 (1969), 329–352.

[43] K. G. Wardhaugh, 'Description of the embryonic stages of the Australian plague locust, *Chortoicetes terminifera* (Walk.)', *Acrida*, 7 (1978), 1–9.

have a diapause, Wardhaugh’s proposal to make a doctoral study of egg dormancy processes was at first treated with some scepticism.[44]

Figure 10.6. Brian Cameron (left) and Keith Wardhaugh taking locust field samples near Trangie, NSW, in 1973 (photo Frank Bullen).

During 1969 and 1970, Wardhaugh detailed the incidence of diapause from egg bed sites across the species range and identified a latitudinal gradation in the proportion of eggs entering diapause in autumn, with those at southern latitudes entering diapause earlier. His subsequent experimental investigations demonstrated that diapause in eggs is primarily induced by a reduction in day-length experienced by the maternal generation during its nymphal development.[45] Diapause eggs therefore form a large proportion of eggs laid during March and April. Egg development was also suspended by a quiescence that was triggered at specific stages by limited soil moisture, delaying hatching until after rainfall occurs. The interaction of these dormancy processes could result in post-diapause quiescence, so diapause eggs also hatch in favourable conditions.

Wardhaugh’s work on embryonic development and dormancy responses in *C. terminifera* showed the complexity of potential developmental pathways, which allowed it to avoid conditions that are either too cool or too dry to support development or reproduction.[46] His use of multiple simultaneous

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[44] Wardhaugh, (pers. comm. 2014), Keith recalled how he discovered diapause in *C. terminifera*. I sent him my summary, and he said it was not quite like that. However, he did not write his own version of events, so we are left with my inadequate interpretation. His CSIRO supervisor, Lindsay Barton-Browne, suggested Keith’s proposal for research on diapause would be a wasted effort.

[45] K. G. Wardhaugh, ‘The effects of temperature and photoperiod on the induction of diapause in eggs of the Australian plague locust, *Chortoicetes terminifera* (Walker) (Orthoptera: Acrididae)’, *Bulletin of Entomological Research*, 70 (1980), 635–647.

[46] K. G. Wardhaugh, ‘The development of eggs of the Australian plague locust, *Chortoicetes terminifera* (Walk.), in relation to temperature and moisture’, in eds. C. F. Hemming and T. H. C. Taylor, *Proceeding of the International Conference on the Current and Future Problems of Acridology 1970*, (London, COPR, 1972), pp. 261–272; K. G. Wardhaugh, *A study of some factors affecting egg development in* Chortoicetes terminifera *Walker (Orthoptera: Acrididae)*, (PhD Thesis, Australian National University, Canberra, 1973); K. G. Wardhaugh, ‘The effects of temperature and moisture on the inception of diapause in eggs of the Australian plague locust, *Chortoicetes terminifera* Walker (Orthoptera: Acrididae)’, *Australian Journal of Ecology*, 5 (1980), 187–191; K. G. Wardhaugh, ‘Photoperiod as a factor in the development of nymphs of Australian plague locust, *Chortoicetes terminifera* Walker (Orthoptera: Acrididae)’, *Journal of the Australian Entomological Society*, 18 (1979), 387–390; K. G. Wardhaugh, ‘The effects of temperature and moisture on the inception of diapause in

treatments to account for divergent life-cycle paths remains a notable experimental example of the complexity of responses to photoperiod, moisture and temperature.[47] Wardhaugh finally earned a PhD for his research on locust egg development.[48]

Doug Clark, locust migrations and plagues

Key had recognised in the 1940s that exchange migration between adjacent regions of Queensland and NSW was common, suggesting that late spring often provided fledging populations in northern NSW that could move into southern Queensland.[49] He concluded that long distance, high-altitude migration over hundreds of kilometres from Queensland into NSW had occurred in the autumn of 1938 and 1940.[50]

Concepts of migration in insects being an evolved behavioural adaptation developed in Britain during the 1960s. Its ethological and ecological dimensions were explored by Cecil G. Johnson, Lionel (Roy) Taylor, John Kennedy and Richard Southwood, and they consolidated migration as a constituent model of evolutionary ecology. Johnson proposed a classification of insect migration types, distinguished 'circuit' and 'exchange' patterns and identified an 'oogenesis flight syndrome' that was common in numerous taxa.[51] In the latter phenomenon, migratory flights are limited to the pre-reproductive period, in some cases obligatory, suggesting a trade-off in energy utilisation between migration and reproduction. Kennedy added further clarity to concepts of insect migration, identifying particular behaviours of sustained, undistracted and directed flight that distinguished migration from

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eggs of the Australian plague locust, *Chortoicetes terminifera* Walker (Orthoptera: Acrididae)', *Australian Journal of Ecology*, 5 (1980), 187–191.

[47] H. V. Danks, 'Key themes in the study of seasonal adaptations in insects II. Life-cycle patterns', *Applied Entomology and Zoology*, 41 (1), (2006), 1–13, p. 7; K. G. Wardhaugh, 'Diapause strategies in the Australian plague locust, *Chortoicetes terminifera* (Walker)', in eds. F. Taylor and R. Karban, *The Evolution of Insect Life Cycles* (New York, 1986), pp. 89–104.

[48] It was Keith's third attempt at a doctorate. He originally studied plant ecology at Durham University (UK). When working on desert locusts in Saudi Arabia with the ALRC, all his field notes were lost after blowing off the back of a motorbike, L. McCulloch, pers. comm., 2016.

[49] K. H. L. Key, 'The outbreak of the Australian plague locust *Chortoicetes terminifera* (Walk.) in the season 1939–40 with special reference to the influence of climatic factors', *C.S.I.R. Bulletin* No. 160, (Melbourne, 1943), p. 38.

[50] Key 1943, pp. 18–19.

[51] Johnson 1969, p. 215.

general foraging or 'station-keeping' movements.[52] Locust flights were also shown to be aligned with the wind rather than randomly.[53]

This understanding of distinct migratory behaviours in insects was applied to studies of *C. terminifera* migration in Australia. It explained the frequent appearance of swarms in previously uninfested areas. Studying the phenomena, however, presented practical difficulties. While the estimation of populations on the ground had its own problems, once the animals were airborne in darkness, their trajectories and destinations could only be inferred from atmospheric conditions. Clark experimented with shielded lamps and spotlights to observe night flights and made detailed recording of dusk take-off events and meteorological conditions in the late 1960s.

Changes in locust numbers in permanent plots around Trangie in late 1967 gave a clear demonstration of a large, single-night immigration from the south. It occurred the day after an estimate of numbers on one experimental plot had been carried out by removing locusts and calculating maximum likelihood statistics.[54] A forty-fold increase was counted the following day and locust numbers had also increased significantly throughout the region.[55] Spotlights detected the arrival of large numbers of immigrants at several sites and the locusts caught in the beams became disoriented and fell to the ground, making trapping and sampling easier. Clark concluded that migratory flights were density-independent and also independent of habitat conditions at the breeding site.[56]

Doug Clark observed dusk take-off behaviour in high density, recently fledged locusts on numerous nights in NSW in 1969. He recognised these directed flights, rising to height, as the 'true migratory flight' described by Kennedy and Johnson.[57] Clark further suggested that it was a regular phenomenon, with some emigration occurring on all warm nights where dusk temperatures exceeded 20 °C, and that high numbers of migrants over a sequence of nights were associated with low pressure trough activity. At the same time, the ongoing program of monitoring of field populations in western

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[52] J. S. Kennedy, 'The emergence of behaviour', *Proceedings of the 14th International Congress of Entomology*, (Canberra, 1972), pp. 19–27, p. 22.

[53] J. S. Kennedy, 'A turning point in the study of insect migration', *Nature*, 189 (1961), 785–789; L. R. Taylor, *Insect flight: dispersal and migration*, (Berlin, Springer-Verlag, 1986), Taylor distinguished between the 'dynamic' downwind migration of locusts, which tended to displace individuals to areas of wind convergence, and 'homeostatic' migration where flight is controlled by the insect's own navigation.

[54] Clark used methods outlined by Australian statistician P. A. P. Moran, 'A mathematical theory of animal trapping', *Biometrika*, 38 (1951), 307–311.

[55] D. P. Clark, 'Night flights of the Australian plague locust, *Chortoicetes terminifera* (Walk.) in relation to storms', *Australian Journal of Zoology*, 17 (1969), 329–352, p. 335.

[56] D. P. Clark, 'Flights after sunset by the Australian plague locust, *Chortoicetes terminifera* (Walk.), and their significance in dispersal and migration', *Australian Journal of Zoology*, 19 (1971), 159–76.

[57] Clark 1971, p. 162.

Queensland revealed the wider demographic consequences of nocturnal migrations. In addition to the regular CSIRO field surveys, there was a network of landholders and observers communicating locust activity via telegram.

Clark and Richard Davies analysed *C. terminifera* distribution changes during 1969–1972 and concluded that interstate migrations to the north and west were frequent. These migrations established infestations in Far West NSW in 1970, and in Southwest Queensland in 1969 and 1971.[58] The findings led to their suggestion of a 'migratory circuit', with dominant southward or northward migrations alternating with season.[59] At the CSEC Locust Subcommittee meeting in 1972, Clark's summary of the joint CSIRO–ALRC research reported that the rapid population build-up in western NSW and Queensland after summer rains, depended on these waves of immigrants. Without this 'priming of numbers', often from the south and east, local populations were frequently too low to reach swarming levels before conditions became dry.[60]

Other technologies were also being applied to the study of locust migrations. In 1968 Jeremy Roffey of the ALRC and G. W. Schaeffer from Landsborough University of Technology used a vehicle-mounted radar to observe nocturnal locust migrations in Africa. They came to Australia in 1971 to conduct the first radar observations of *C. terminifera* migrations. Using mobile equipment purchased by CSIRO, Roffey identified that night flying large insects, including locusts, were aligned with the wind.[61] He also analysed seasonal wind trends in eastern Australia and concluded that migrants from eastern areas would be displaced to the west by general circulation patterns.[62] Roffey conducted further radar field studies with D. G. Reid of the CSIRO Division of Atmospheric Physics in 1972. Large numbers of insects, including locusts, passed through the radar soon after dark, suggesting that wind-assisted flights could last up to fifteen hours and transport locusts 400 kilometres. Roffey conducted a later radar study in northern Victoria with Reid and Wardhaugh, which detected northward insect migrations associated with high locust population levels.[63]

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58 Clark, 1972, p. 284, Fig. 6; R. A. H. Davies, 'Plague locust outbreak 1971–72: distribution and migration of *Chortoicetes terminifera* in western Queensland', *Australian Entomological Society 11th Annual General Meeting 9–11 May 1980* (unpubl.).

59 CSIRO, 'Australian Plague Locust', *CSIRO Division of Entomology Annual Report 1971–72*, (Canberra, 1972) pp. 107–115, p. 109.

60 Commonwealth and State Entomology Committees, 4th Meeting, Adelaide 31 October – 4 November 1972. Agenda Item 23, Appendix 1. 'Report on Progress of CSIRO-ALRC work 1970–72', p. 3.

61 The radar was purchased to study migration in various pest insects in Australia.

62 J. Roffey, 'Migration and dispersal in the Australian plague locust', *Abstracts of the 14th International Congress of Entomology 1972*, (Canberra, 1972), p. 155.

63 D. G. Reid, K. G. Wardhaugh and J. Roffey, 'Radar Studies of Insect Flight at Benalla, Victoria, in February 1974', *CSIRO Division of Entomology Technical* Paper *No. 16*, (Melbourne, CSIRO, 1979).

In 1970 Clark summarised what was known about *C. terminifera* population dynamics leading to outbreaks in terms of rainfall, generations, lifespan, sexual maturity, fecundity and migration. In discussing the relatively lesser mortality in late nymphal stage bands, their mobility was suggested as reducing any effects of the density-dependent mortality posited by Nicholson and Bailey.[64] Overall mortality was lower among gregarious nymphs than those at low densities, possibly due to the dilution and confusion of predator impacts at high densities. Clark conjectured on the possible intensification of plagues as a result of woodland and forest clearing in eastern regions. He thought invasions of northern South Australia and northwest Victoria had probably always occurred, while the expansion of suitable habitats from tree clearing had contributed to an increase in frequency of outbreaks in NSW.[65]

Roger Farrow and population fluxes

British entomologist Roger Farrow studied at Reading University and at Silwood Park, Imperial College London, before joining the ALRC to investigate the dynamics of the migratory locust in Mali. He came to Australia in 1971 to continue on from Clark's longitudinal field population investigations and Wardhaugh's research on egg development in *C. terminifera*. Farrow investigated field mortality of the egg and nymph life stages, and conducted detailed demographic studies of populations in Central West NSW. His field research from 1972 to 1974 captured events during the peak of the plague.[66]

Modifying some of the techniques he developed in Africa, Farrow used caging, dissection and light trapping, as well as regular population counts, to produce life tables of survivorship for each development stage over multiple field generations.[67] He compared stage-specific mortalities with potential fecundity, based on logistic growth models. Realised fertility was dependent on habitat conditions and ranged from a thirty times increase in productive habitat to nil, mostly as a result of high nymph mortality in very dry or very wet vegetation. While there was a proportional mortality in each nymphal instar stage, the highest rate occurred at the hatching and early nymph stages.[68]

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[64] Clark 1972, p. 281.

[65] Clark 1972, p. 275.

[66] R. A. Farrow, 'Population dynamics of the Australian Plague Locust, *Chortoicetes terminifera* (Walker), in Central Western New South Wales I. Reproduction and Migration in relation to Weather', *Australian Journal of Zoology*, 27 (1979), 717–745.

[67] R. A. Farrow, 'Population Dynamics of the Australian Plague Locust, *Chortoicetes terminifera* (Walker) in Central Western New South Wales II*. Factors influencing natality and survival', *Australian Journal of Zoology*, 30 (1982), 199–222.

[68] Farrow 1982, p. 202.

Farrow also analysed the population developments of the other two species involved in the plague, the migratory locust (*Locusta migratoria* L.) and spur-throated locust (*Austracris guttulosa* Walker). Swarms of both species developed in central Queensland in 1973 and then spread into southern Queensland and northern NSW, continuing until 1977 in some areas. He attributed the outbreak of *L. migratoria* to major land use changes in the region as well as the favourable sequence of rainfall. Forest and woodland clearing, introduced pasture species and summer sorghum cropping had greatly increased the continuity of habitats.[69]

Light trapping had been used to sample nocturnally migrating insects since the 1940s and Farrow designed a trap specifically for overflying locusts.[70] It consisted of a high-voltage incandescent bulb, shielded at the sides and suspended over a pond of water to catch disoriented locusts.[71] Trapping in Central West NSW during 1973–74 detected several large migrations of *C. terminifera*, including southward movements in January and October 1973. Population data indicated that night migration was the most important factor in adult population changes. Combining trap data with synoptic weather information, Farrow analysed likely nocturnal mass migrations during the plague and found those detected in the Central West came from further north in NSW.[72] He made use of the first plots of geostrophic wind vectors produced by computer program, which were generated by Reid.

Farrow confirmed Clark's proposition of the association of major migrations with the southerly incursion of tropical troughs.[73] Placing his findings in the context of ecological theory, Farrow rejected density-dependence as a controlling factor and stressed that heterogeneity of habitat conditions meant that increases in one subpopulation were balanced by decreases in another. These subpopulations were linked by density-independent migration. High densities developed when rainfall produced high pasture productivity, so carrying capacity was never exceeded. Nor did he find evidence of density-dependent stabilisation by natural enemies during a population build-up, but parasitism rate often increased when locust populations were declining. Farrow referred to

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[69] R. A. Farrow, 'Causes of recent changes in the distribution and abundance of the migratory locust (*Locusta migratoria* L.) in Australia in relation to plagues', *CSIRO Division of Entomology Report No. 9, 1979*, p. 26, chiefly winter sorghum for stock feed.

[70] C. B. Williams used light traps to study migrating butterflies.

[71] R. A. Farrow, 'A modified light-trap for obtaining large samples of night-flying locusts and grasshoppers', *Journal of the Australian Entomological Society*, 13 (1974), 357–360.

[72] R. A. Farrow, 'Origin and decline of the 1973 locust outbreak in Central Western New South Wales', *Australian Journal of Zoology*, 25 (1977), 455–489, p. 481.

[73] Farrow 1979.

Andrewartha and Birch in stressing that population size was limited by the heterogeneity of local environments and stochastic variations.[74]

Farrow identified a critical ecological difference between locusts from two distinct types of habitat. Species that concentrate in restricted habitats, often dry-season refuges, were those that had predictable 'outbreak areas'. Species of semi-arid grasslands, including *C. terminifera*, where there is high spatial and temporal variability of resources, have transitory, mobile populations that exploit short-lived favourable habitats. However, the synchronised movement of gregarious populations in both types was seen as an outcome of individual feeding strategies that prevented populations exceeding local habitat carrying capacity.[75] In defining these movements as an 'extended foraging strategy', Farrow recognised Kennedy's ideas about the function of gregarisation.[76]

1971 — 'The plague that failed'

The political and social climate under which locust control was contemplated and undertaken in Australia had changed markedly by the end of the 1960s. The decisions of agriculture departments within state government machinery came under much greater bureaucratic oversight. The consequences of widespread organochlorine pesticide use and the awakening of environmental concerns throughout the community was changing the landscape of recommended agricultural practice.[77] DDT was banned from use on pastures in 1968 because of rejections of contaminated beef exports to the USA.[78] About 1,000 tons of DDT was used in 1970, primarily on cotton, tobacco and vegetable crops.[79] Concerns over indiscriminate or inappropriate insecticide use rose and other

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[74] R. A. Farrow, 'Population Dynamics of the Australian Plague Locust, *Chortoicetes terminifera* (Walker) in Central Western New South Wales III*. Analysis of Population Processes', *Australian Journal of Zoology*, 30 (1982), 569–579, pp. 573–575, Farrow references Andrewartha and Birch for these ideas.

[75] R. A. Farrow and B. C. Longstaff, 'Comparison of the annual rates of increase of locusts in relation to the incidence of plagues', *Oikos*, 46 (1986), 207–223, pp. 217–221, Farrow and Barry Longstaff compared *C. terminifera* biology with several African locust species in a modelling study of the rates of field population growth. They concluded, as had Clark, that small variations in the survival of nymphs, largely controlled by stochastic weather events, account for most population variations. For *C. terminifera*, two or three generations of high recruitment could result in swarms from sparse initial populations, so plagues could develop rapidly. Gregarization was a density-dependent process but not a population regulating process, because phase-related variation in fecundity and growth rates were offset by the variation in immature survival.

[76] R. A. Farrow, 'Flight and Migration in Acridoids', in eds. R. F. Chapman and A. Joern, *Biology of Grasshoppers*, (New York, John Wiley, 1990), pp. 227–314.

[77] With the rapid development of the Australian aerial agriculture industry, by 1961 over 300,000 hectares had been dusted or sprayed with insecticide from aircraft. Department of Civil Aviation letter 12 June 1962, gives 890,000 acres in total to September 1961, half of which was in WA, (Victorian Department of Agriculture archive, BHZ4898, file 63/3).

[78] *Sunday Review*, 13 November 1971, 'Spaceship Earth'.

[79] D. F. Waterhouse, 'Insects and Australia', *Journal of the Australian Entomological Society*, 10 (1971), 145–160, p. 154.

organochloride insecticides came under increasing scrutiny. In 1971, 'lindane', the Shell trade name for gamma-hexachlorocyclohexane, the '666' concentrate of BHC that had been in general use for locusts since the mid-1940s, caused a public furore.

The interplay of public perception and professionalised political control of pests and pesticides was exemplified during state department preparations for an anticipated major control program in spring 1971. Environmental protection was now a political issue, with most states and the Commonwealth establishing environment ministries in the early 1970s. Victoria had not conducted any aerial control since 1955, while in NSW organophosphate insecticides were gradually replacing lindane for aerial spraying, but the latter was still distributed to landholders for use in ground equipment. The arrangements in Victoria, which had legislated for pollution control in 1970, demonstrate the transformation in government communication and bureaucratic control protocols.[80]

Locusts increased in NSW during summer 1970–71 and by autumn much of the state was infested by egg-laying swarms, particularly the Riverina and Central West. The agriculture department organised aircraft and landholder ground spraying that continued until May, and records of egg laying were scattered across 50,000 square kilometres.[81] Government entomologists' warnings of the threat as the 'worst since 1932' or '1955' appeared in the press.

In Victoria, Hogan put his contingency plan for an estimated $200,000 control campaign to protect the state's crops to the Chief Biologist, C. R. Millikan, now responsible for overall strategy on pesticide use.[82] Memorandums were sent to the Director of Agriculture, Premier's Department, Pesticides Review Committee and Information Branch, which would manage public statements and media liaison. The Premier's Department executive questioned whether financing intensive work in NSW might be preferable, and its economists were sceptical of the necessity of control.[83] Hogan justified the plan by arguing the alternatives — not controlling, compensating farmers or subsidising NSW actions— were politically untenable if there were large swarms in Victoria. Hogan visited NSW to assess the situation and gain ministerial level agreement for his departmental staff to operate 'as discrete units' in southern areas of that state.

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[80] Victoria introduced the Environmental Protection Act in 1970.

[81] Don Campbell, 'Operation Plague Locust', *Agricultural Gazette of New South Wales*, 83 (1972), 160–169, p. 160.

[82] Memo, Hogan to Chief Biologist, 'Contingency for 1971 Locust Outbreak', 21 July 1971, (Victorian Department of Agriculture archive, BHZ4898, File 57/21/1).

[83] Memo, Hogan to Chief Biologist, 31 August 1971; Letter Premier's Dept. to Director of Agriculture, 21 September 1971; Memo for Principal Executive Officer, 6 August 1971, (Victorian Department of Agriculture archive, BHZ4898, File 57/21/1).

More than the crops, the whole environmental system was now under threat. Scientists, the public and politicians now used ‘the ecology’ to describe all native species and their interactions in the rural environment. Conservation Councils in both states, academics and even the Field and Game Association in Victoria made representations that lindane should not be used to spray locusts in Victoria or the Riverina. ‘Freelance ecologist’, Peter Bennett, claimed the side effects would last for ten years and challenged officials to a public debate.[84]

in November 1971, the ‘Spaceship Earth’ column in *The Review* satirically suggested NSW agriculture minister Crawford’s intemperate reply to a ‘zoologist’s’ concerns, that ‘we do not need lectures from universities or elsewhere to tell us our responsibilities’, was made under the influence of lindane slipped into his tea.[85] It also quoted Ken Key as commenting that the plague was the result of poor ecological management. Tree clearing and overgrazing had created eroded, sun-baked clay flats, ideal for locust eggs. The replacement of natural vegetation with monocultures of introduced species, like barley grass also favoured them and Key had urged ‘cultural rehabilitation’ measures.

Victoria was undecided on insecticides and the Information Branch watched the media. In anticipation of a major locust invasion, however, the *Vegetation and Vine Diseases Act* was altered to require landholders to notify the department when locusts were seen and to spray with maldison, an organophosphate.[86] Sensitivities over the negative effects on birds, fish and ecologies drove both the NSW and Victorian governments to attempt to reassure the public of the scientific basis of insecticide safety. The Victorian Information Branch and the Pesticides Review Committee advised the Minister to make the ‘utmost use of publicity’ to inform people of the economic necessity and safety of the proposed campaign.[87]

The potential effect of lindane on the ecology of the Riverina was also raised in the NSW Parliament. The ministerial reply was that locusts killed by lindane became unattractive to birds in a few hours and there was no evidence of harmful effects on birdlife when it was used correctly. In addition, the

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[84] *Border Watch*, 23 October 1971; Bennett wrote a popular organic gardening book in 1979 published by New Holland Press. Later revised editions are still available.

[85] Crawford was referring to letters from Monash zoologist Dr D. Dorward, urging that lindane be replaced by maldison, *Border Mail*, 5 October 1971; The *Review* was launched by Gordon Barton in 1970, renamed from the *Sunday Review* and was the precursor to *Nation Review*.

[86] Hogan hadn’t planned to use lindane from aircraft, but suggested it could be given to landholders for ground spraying. The Act regulation stipulated lindane could be used, with the authority of the Director of Agriculture (Victorian Department of Agriculture archive: BHZ4898, File 57/21/1).

[87] Letter, Pesticides Review Committee to Bolte, 29 October 1971 (Victorian Department of Agriculture archive, BHZ4898, File 57/21/1).

department had over a hundred officers directing landholders to use recommended procedures.[88] Agriculture Minister Crawford (Figure 10.7) released a press statement saying in irrigated areas 'we will use other sprays. Because of pollution, my Department will not be party to any saturation spraying programme'.[89]

The spring generation caused major concern in NSW. Starting in October 1971, 'the most intensive control campaign ever organised' was carried out against the nymph stages by Riverina landholders, departmental and PP Board staff. There were weekly broadcasts on radio and television and regular local newspaper updates. The campaign headquarters at Griffith, manned by departmental and Civil Defence staff, handled insecticide logistics and radio communications with aircraft, ground units and bases in other towns.[90] The NSW department announced the program as a success, saying $40 to $50 million of crops and pastures were saved, but one 'ratbag' Melbourne paper labelled it 'the plague that failed', because journalists did not see the massive swarms or the environmental conflict they had expected.[91] Egg laying by the summer swarms produced a second generation and spraying continued in NSW in early 1972. Infestations developed in the Far West and Northwest Plains regions in autumn, and a few swarms entered northern Victoria. In all, ground and aerial spraying covered 80,000 hectares in southern NSW, and 4,000 hectares in Victoria, and lindane was not used in those regions.[92] In Victoria the danger was considered over because it seemed the plague had failed to live up to its anticipated scale.

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[88] NSW Hansard, 12 October 1971, question by Dick Healy, reply by John Fuller, government representative in the Legislative Assembly gives the minister's reply, (Victorian Department of Agriculture archive, BHZ4898, File 57/21/1).

[89] Campbell 1972, p. 167, Crawford referred specifically to the M.I.A., the Murrumbidgee Irrigation area in the Riverina.

[90] Victorian department staff also joined the team at Griffith on rotation and it also provided a helicopter for spotting nymph bands.

[91] *The Review*, 6–12 November 1971, p. 119.

[92] Memo for Director of Agriculture from Deputy Director, Victoria, 18 December 1972, (Victorian Department of Agriculture archive, BHZ4898, file 57/21/1); 'lindane was used in northern NSW districts during 1971–72; SCA 89th Meeting, October 1972, Agenda Item 7, p. 3, NSW spent $430,000 during 1971–72, exclusive of labour and landholder inputs.

Figure 10.7. NSW Agriculture Minister G. R. Crawford (left) meets with Hillston PP Board members in October 1971 (*Agricultural Gazette of New South Wales*, 1972).[93]

The 1973–74 plague

> *Locusts have no respect for State borders. Research results suggest that control measures taken as far north as Queensland should help prevent plagues from invading Victoria or South Australia.*
>
> *CSIRO Rural Research*, 83 (March 1974), p. 2.

The plague was not over in NSW, however, and control efforts moved to the north in spring 1972. Large locust populations developed in the Central West, Northwest Plains regions, and in the Far West around Bourke.[94] The state agriculture department sprayed bands in the Walgett and Narrabri PP Board districts in September. Bands also developed in the Coonamble, Coonabarabran and Mudgee districts. Swarms formed in all these areas in November, but reportedly did not lay in dry conditions and declined in December. The Riverina and adjacent northern Victoria were infested with hopper bands that also formed swarms in December.

What occurred in Queensland during spring 1972 has shaped locust history. Doug Clark fixed on a location on the Barcoo River, south of Longreach, as the only place in western Queensland where

[93] Campbell 1972, p. 165.

[94] NSW Department of Agriculture files, Patrol Officer Reports, 1969–73, (APLC Archive).

spring nymphs could have survived to produce the swarms that appeared in the Charleville–Quilpie area of the Southwest in late November.[95] This became the starting point of the narrative of events that identified the large populations during 1973–74 as a separate plague with a localised origin.[96] Clark identified this single Queensland 'source' population, despite having concluded in 1972 that *C. terminifera* migrated into Queensland at the start of summer every year from the east and south.[97] The large fledging population across northern NSW at the time appears to have been outside the data frame.[98] Nevertheless, it helped explain the locusts' complex migration patterns in the context of the need to resolve the issue of how plagues developed. The development of the plague after that time has been studied several times and its progress from February 1973 is well documented.[99]

By autumn 1973, any sense of relief from the plague was quashed by the arrival of new migrating swarms across the south-eastern states. Migrations from Southwest Queensland to Far West NSW in late January were followed by further southward movements of the subsequent generation into agricultural areas of the Riverina, South Australia and northern Victoria in March and April. Parallel southward migrations from northern NSW brought locusts into the Central West and Riverina. During 1973 and 1974, this plague was a mirror of 1890–91 and 1953–54 in terms of the extent of infested country in the southern states. If the 1973–75 populations are considered as a continuation from 1969–72, it also mirrors the 1870–75 plague in terms of duration. In another parallel, swarming continued in South Australia long after it declined in the other states as it did during 1875–77.[100]

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[95] D. P. Clark, 'Long Range Migrations', *CSIRO Division of Entomology Annual Report 1972–73*, p. 80, The Barcoo location was apparently based on a local report of rainfall. However, BoM records do not show any rainfall in that area from August to mid-November. Regular CSIRO surveys of Southwest Queensland had been disrupted in May 1972 and there was limited distribution information in spring.

[96] Brian Woodruff, 'On the Track of the Locust', *CSIRO Rural Research*, 83, (March 1974), 2–6, the narrative did not appear until after Clark's untimely death in the field in October 1973. It seems paradoxical for Clark to identify this single location, since he concluded earlier in 1972 that *C. terminifera* migrated into Central West and Southwest Queensland at the start of summer every year from the east and south. Clark identified disturbed weather on the east side of a trough on 28 November 1972 as the only night with northerly winds that could have brought locusts from Longreach to the Southwest region, but this was several days after the first reports of swarm arrival at Quilpie on 24 November (CSIRO locust reports, APLC archive).

[97] D. P. Clark, 'Results of Inland Surveys 1969–72', CSEC, Report of Locust Subcommittee, Canberra, 20 April 1972, Agenda Item 1, p. 3.

[98] E. Deveson and P. Walker, 'Not a one-way trip: historical distribution data for Australian plague locusts support frequent seasonal exchange migrations', *Journal of Orthoptera Research,* 14 (2005), 91–105, I argued previously that fledging swarms in NSW in November 1972 were more likely to have provided immigrants to Charleville–Quilpie area. Upper-level winds at Longreach and Charleville were predominantly from the south and east during 11–27 November 1972.

[99] Farrow 1977, p. 481; Farrow 1979; Wright 1987; Bullen 1975.

[100] The state agriculture department conducted further control on the Eyre Peninsula in 1976 and 1977.

The autumn 1973 migrations and the scale of the following spring nymph generation was convincing evidence of the role of arid regions in plague development. Hopper bands developed throughout most inland districts of NSW, as well as northern Victoria and agricultural areas of South Australia in October. Further southward migration of swarms into Victoria and Southeast South Australia in November and December 1973 marked the peak of the plague and a peak in calls for government and scientific solutions (Figure 10.8). Farmers in all states were urged to carry out spraying and baiting. CSIRO flew aerial monitoring teams to assess populations and the army was mobilised to assist with state control operations.[101]

Frank Bullen and economic damage

Frank Bullen joined the ALRC in 1960 after serving in the British Army in the Middle East. Questions about the actual losses caused by locusts increased as control measures became more highly organised and more expensive, and Bullen became a much-travelled technical adviser on agricultural damage. His first visit to Australia was on ALRC secondment during 1967–68 to assess a spur-throated locust outbreak causing damage in the Ord River irrigation area of Western Australia. He returned in 1973 to undertake an assessment of the economic losses caused by the 1973–74 plague at the request of the Reserve Bank of Australia.

In 1969 Bullen compiled an ALRC report on the economic losses caused by desert locusts.[102] Viewing all estimates of losses as too subjective for accurate cost-benefit assessments, he constructed a crop vulnerability index by combining historical locust distribution data with data on field and tree crops to identify regions of highest risk. Anticipated losses were calculated to be highest in Indo-Pakistan and north-west Africa, but because locust incidence was spatially variable and often transitory, he concluded that damage from locusts was only a small proportion of total crop losses caused by all insect pests.

In Australia, Bullen travelled through agricultural districts during the latter stages of the *C. terminifera* plague, interviewing producers and making field observations of crop damage.[103] His analysis of the 1973–1974 plague highlighted some high individual losses, particularly to vegetable

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[101] Bill Mollison, ABC film interview in 1989, (National Film and Sound Archive, NFSA number 434721).

[102] F. T. Bullen, 'The Distribution of the Damage Potential of the Desert Locust (*Schistocerca gregaria* Forsk.)', *Anti-Locust Memoir 10*, (London, Anti-Locust Research Centre, 1969), the report did not factor the greater risks faced by subsistence farmers; F. T. Bullen, 'A review of the assessment of crop losses caused by locusts and grasshoppers', in eds. C. F. Hemming and T. H. C. Hemming, *Proceedings on the International Study Conference on Current and Future Problems of Acridology*, 1970, (London, Centre for Overseas Pest Research, 1972), pp. 163–172, p. 163.

[103] F. T. Bullen, *Economic effects of locusts in Eastern Australia*: *A report to the Reserve Bank of Australia*, (Canberra, July 1975).

crops, but found overall losses to the wheat industry were less than one per cent.[104] This estimate was small in comparison to the reported losses in 1934–35 and the difference was attributed to crops being more vulnerable in the dry seasons of the 1930s, while locusts were diverted by the abundant green native pastures in 1973–74. The study also covered the infestations of spur-throated and migratory locusts, mainly in Queensland. Both species were found to cause more severe damage to cereal crops than *C. terminifera*, because of their more sedentary and persistent swarms.

Bullen outlined some alternatives for managing plagues, including biological control, existing chemical control and crop insurance. Intervention at an early stage in the plague cycle offered the most potential, but estimating the value of control or insurance depended on the frequency of major plagues like 1934 and 1973. He estimated the costs of either option might be equivalent if plagues occurred every twenty years.[105] In concluding, Bullen suggested that the highly visible swarms and 'all-devouring' reputation created a degree of public hysteria disproportionate to the amount of damage they actually did. Rather, it was a 'political problem for which the authorities called on their scientists and technologists to remedy'.

The report also included a detailed sequence of gridded monthly distribution maps covering the development of the plague (Figure 10.8). CSIRO started producing monthly maps as part of a locust forecasting service from late 1974, and Bullen compiled similar maps to extend the series back to the November 1972 'start' of the plague. They show the extent of infestations for eight generations and are a representation of the plague cycle.[106] Locations were estimated from the CSIRO surveys and reporting network information.

Depicting the distribution information as maps rendered it precise and more 'objective'.[107] As an explanatory device, the maps told the story of the plague in a compact and stable form. They were crafted as communication devices to highlight particular areas and significant events in sequence. As such, they are 'inscriptions' in the Latourian sense of creating geographical 'facts' about locust distribution through time.

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[104] Bullen's estimate of total loss to agricultural production by *C. terminifera* was $1.1 million, or 0.2% of total production in the affected regions. His estimate of the cost of control ($500,000) during the plague may have been inaccurate, as this was the amount committed by the Commonwealth Government. South Australia purchased $100,000 of insecticide for 1976–77.

[105] Bullen suggested that the costs of the existing NSW Noxious Insects Levy, the initial budget for the APLC and the cost of insurance, were roughly equivalent.

[106] The November 1972 map shows the extent of infested areas in the NSW Northwest Plains, and in South Central Queensland, as well as the 'Barcoo' source, which was based only on a report of rainfall.

[107] However, there was often some extrapolation between sparse swarm reports from the inland and some interpretation of migration events.

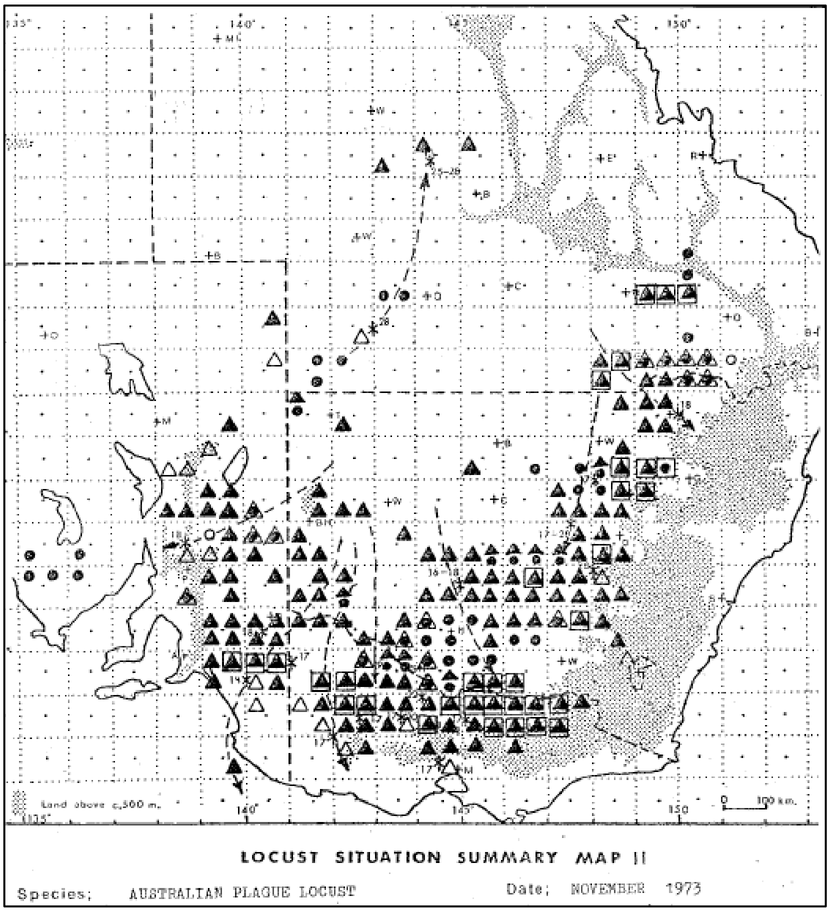

Figure 10.8. Distribution of *C. terminifera* in November 1973. Symbols represent swarm density adults (triangles) and nymphs (circles), (from Bullen 1975).

Bullen's estimate of total control costs for *C. terminifera* in 1973–74 was $500,000 (equivalent to $7.7 million in 2015) was likely to have been an underestimate, as it did not include Victorian or South Australian costs.[108] Control costs by NSW, Queensland and the Commonwealth during 1974–75 were over $1.4 million, which would bring the total closer to the amount expended during 1953–55.[109] After a submission by Commonwealth Primary Industry Minister Kenneth Wriedt, in October 1973 Federal Cabinet committed up to $500,000 to match expenditure by the states in controlling the locust plague. The amount included the provision of Defence Services equipment and personnel that

108 In October 1973, NSW estimated its total costs would be $1 million, including $380,000 for insecticide, Cabinet Submissions, Plague Locust — Decision 1473 (EC) and 1498, (Australian National Archives, NAA: A5915, 725, 6997361); Victoria spent $35,000 in 1972–73, $88,000 in 1973–74 and more in 1974–75. South Australia had spent $150,000 by February 1974 and purchased 100,000 ha worth of insecticide for 1975–76; 20,000 gallons of technical insecticide had been used in NSW by early 1974.

109 A. W. Hogstrom, K. R. Norris and R. A. Powell, 'Australian Plague Locust Commission, A Review of Functions and Activities, A Report to the Standing Committee on Agriculture', December 1982, p. 40, Table 5.1 shows that the Commonwealth contribution was not included in 1973–74, and total costs of control were over $1.4 million in 1974–75.

were deployed in several states. The submission also recommended monthly records of all spraying be supplied to the Minister for Environment and Conservation.

The outcomes of the plague

> *The plague had its origins in the hot dry interior and what is needed is some agency to deal with it in its natural habitation.*
>
> *Wagga Advertiser*, 24 September 1909, p. 1.

The 1970s plague renewed the push for a federal agency to coordinate and contribute financially to locust monitoring and control. The rationale can be traced to several earlier plagues in the press, and came from the recognition that agricultural impacts often resulted from population build-up in one state and migration to another.[110] Uvarov's recommended interstate control organisation remained the preferred model for monitoring the vast area of possible habitats where gregarious populations could develop. The creation of a federal-state body gained public and official support at the height of the 1973–74 plague.[111] However, some politicians and scientific institutions were not convinced about the ability to suppress plagues and of the economic benefit of doing so.

Two separate scientific advisory bodies reporting to the AAC had an interest in the proposal, each with a locust subcommittee. Each had representatives from the states and CSIRO, but while the SCA subcommittee included state entomologists responsible for locust control, the CSEC subcommittee included senior biologists from state government departments.

In November 1972, the CSEC had agreed that a national approach was needed, but was not ready to support the expenditure required for the interstate control service because of deficiencies in the understanding of plague cycles. It considered certain additional investigations were required. In August 1973, the SCA appointed 'technical locust committee' re-examined the locust problem. That committee's report was submitted to the SCA meeting in February 1974. Of the thirteen outbreaks in western NSW between 1946 and 1973, Southwest Queensland was identified as contributing to several that led to immigration into Victoria and South Australia.[112]

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110 Another example comes from an editorial in *The Age*, 20 December 1955, also suggesting that a 'central, unified organisation of entomologists equipped on a Federal basis to deal with grasshoppers at their source' was needed.

111 The Australian Woolgrowers and Graziers Council, and the Australian Wool and Meat Producers Federation made representations during the 1973–74 outbreak, (APLC files 327-4-17).

112 Standing Committee on Agriculture 89th Meeting, February 1974. Briefing Notes, Agenda Item 5.6, part. 4, (APLC files, 327-4-17 pt. 2).

The crucial information in convincing the SCA that the need for further study had been met, however, was a description of the development of the 1973 plague. The sequence of breeding and migrations was listed and encapsulated in a sketch map. The SCA was then satisfied that the 'usual pattern of major outbreaks was locust breeding in arid southwest Queensland and western NSW, followed by migration in a southerly direction'.[113] It recommended the creation of an Australian Plague Locust Commission (APLC), a coordinated national monitoring body with an 'offensive strategy'. It also set out an initial budget and terms of reference for the new organisation, and a staffing structure that was almost identical to that outlined by Uvarov in 1959.

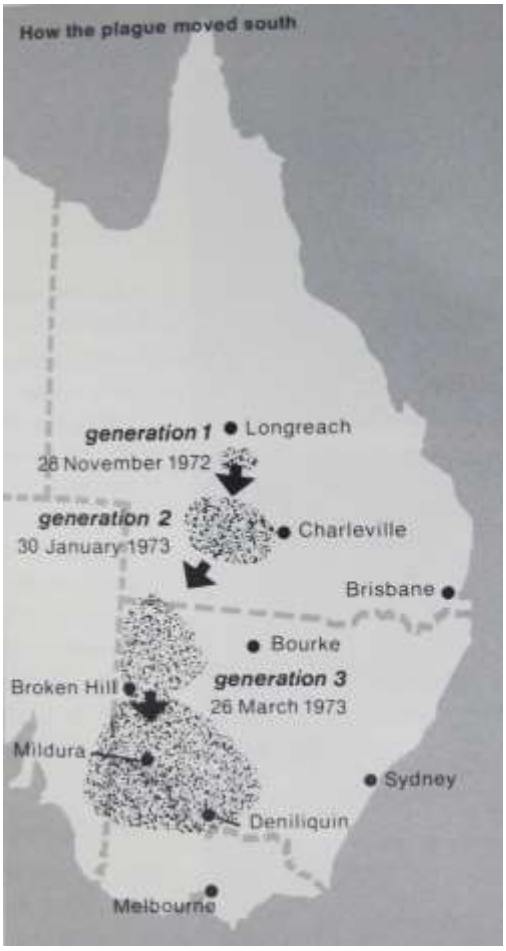

Figure 10.9. 'How the plague moved south', from 'On the Track of the Locust', *Rural Research*, CSIRO, 83 (March 1974), p. 5.

The state agriculture ministers backed the creation of the APLC and, as AAC chairman, Wriedt followed up the resolution with his federal colleagues.[114] The Treasurer, Frank Crean, was against committing ongoing Commonwealth funds to what he viewed as a state issue, but the environment minister, Moss Cass, saw it as an opportunity to reduce the environmental effects of both the locusts and the control operations. It would allow analysis of the effectiveness of control methods and of secondary effects on wildlife.[115] Wriedt put a submission for the creation of the APLC to Cabinet in early August 1974, stressing the ability to operate freely across state borders, the centralisation of technological resources and greater control over the risk of environmental damage.[116] Cabinet endorsed the proposal and Wriedt announced the decision at the AAC meeting the following week.

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[113] Letter, Senator Wriedt (Chairman, AAC) to Treasurer, March 1974, (APLC files, 327-4-17 pt 2.).

[114] AAC Resolution 89/11, (APLC file 327-4-17, Pt2, f. 18); Wriedt's briefing notes from the department's Agriculture and Food Services Division pointed out the potential disadvantages of this precedent of ongoing Commonwealth responsibility for a pest insect. But these would be offset by the centralisation of technological resources and greater control over the risk of environmental damage, (APLC file 327-4-17, Pt2, f. 36).

[115] APLC file 327-4-17, Pt2, f. 38, f. 33.

[116] Wriedt, Cabinet Submissions, APLC — Decision 2551, (National Archives of Australia, A5915–1162, 7100746).

In early 1975, an agreement was reached under an exchange of letters between Prime Minister Whitlam and the premiers of NSW, Queensland, Victoria and South Australia.[117] Ecological research had been conducted by CSIRO up until this time, and was not identified in the original functions of the new organisation. Its role would be collection of distribution data on *C. terminifera*, forecasting outbreaks and control. The monitoring of all control actions and their environmental effects was included in the final terms of reference for the APLC on Cass's advice, and a representative of the Department of Environment and Conservation was added to the list of commissioners.[118]

In his 1985 memoir, Gough Whitlam saw the creation of the APLC as one of his government's achievements of negotiated federalism, and of the first national approach to the locust problem.[119] In fact, the states were ready to accept immediate assistance and an ongoing federal commitment. Under the proposed funding arrangements, the Commonwealth Government would match the total funds provided by the states.

At the height of the 1973–74 plague, the premiers of NSW and Queensland had sent letters to Whitlam urging him to endorse the creation of the APLC. NSW Premier Robert Askin wrote in September 1973 to appraise Whitlam of the dire situation. The letter included the sketch map showing the origin of the plague in western Queensland that became the official history. Queensland was also suffering the onslaught of spur-throated and migratory locusts and, with the considerable costs of insecticides, logistics and manpower involved in controlling them, it was also predisposed in favour. Queensland Premier Joh Bjelke-Petersen wrote to Whitlam in March 1974, urging him to accept the AAC proposal and reminding him of the Commonwealth's ongoing monetary commitment.[120]

The CSIRO–ALRC collaborative research drew to a close in 1976. The British government decided to discontinue funding the ALRC Australian locust research at the same time as Britain joined the European Common Market. CSIRO indicated in 1975 that it intended to continue research on locust ecology through Special Research Grants funding, but later examined the cost-benefit of its Division

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[117] Australian Plague Locust Commission Annual Report 1977–78, (Canberra, 1978), p. vii.

[118] The roles of the APLC had been itemised by the Standing Committee on Agriculture and The Australian Agricultural Council from the first considerations of the issue in 1960; Letter, 30 April 1974 — The Commonwealth Minister for Environment and Conservation (Moss Cass), to Treasurer Frank Crean, endorsing the proposal for establishing the APLC, suggested the inclusion of what became the last point in functions of the APLC — that it be responsible for 'monitoring of all actions and the effects of control', (APLC file 327-4-17, Pt2, f. 33).

[119] Gough Whitlam, *The Whitlam Government 1972–75*, (Ringwood Victoria, Viking, 1985), pp. 268–269, Whitlam wrote of its apparent success in reducing plagues and of the subsequent Liberal razor-gang's failed attempt to return responsibility for locusts to the states in 1982.

[120] Letter, Askin to Whitlam 14 September 1973; Letter, Bjelke-Peterson to Whitlam 18 March 1974, (Commonwealth Department of Agriculture File: 327/11/11. Locust Subcommittee of the SCA, Entomology Committee, 1970–76).

of Entomology agricultural research programs. The Industries Assistance Commission was contracted to consider the role of locust research in improving the ability of CSIRO to forecast agriculturally damaging outbreaks.[121] Discounted benefits of locust research were calculated over twenty-five years, based on Bullen's estimates of damage during 1973–74 and data on the frequency of plagues of different scales compiled by Farrow. The locust research program had delivered a significant benefit, but with comparatively less impact than several of the division's biological control and insecticide research projects that had used far less of the organisation's resources. The report concluded that the economic importance of projects did not always match popular judgements, particularly in relation to locusts.[122]

The CSIRO locust research had paved the way for the control strategy of the APLC by placing the focus on potential plague sources in the arid zone. This seemed a logical applied end point to understanding locust ecology and having a means to control its populations, particularly if any control was to be attempted in western Queensland. The Commonwealth Department of Primary Industry advertised for the APLC director position in 1975, first in Australia and then internationally. Phillip M. Symmons from the COPR, who had experience with the ALRC on locust control and forecasting, became the first director of the APLC in 1976. This was also the end of one of the wettest periods of the century. The plague subsided long before the 'big wet' did in most areas, but swarming populations reappeared to occupy the APLC in 1977.[123] And the commission faced its first big 'plague' before the decade ended.

[121] Industries Assistance Commission Report, *Financing Rural Research,* 25 June 1976 (Canberra, AGPS, 1976).

[122] Industries Assistance Commission 1976, p. 3.

[123] Ian Sinclair, Cabinet submissions 13 September 1977, (National Archives of Australia, A 12909, 1629), The APLC requested additional emergency finance of $300,000 in 1977 for the forward purchase of insecticide.

Conclusion

A scientific worker is necessarily the child of his time and the inheritor of the thought of many generations. But the study of his environment and its conditioning power may be carried on from more than one point of view.

Joseph Needham, 1935.[1]

Locust science, ecology and changing environments

Scientist, historian and Sinologist Joseph Needham's quote came in the context of a 1931 history of science conference, where Russian historical perspectives influenced some British historians' views. Needham's use of 'environment' referred to a Marxist sociological framing of what science was done and why certain ideas were promoted.[2] This institutional constraints approach is appropriate to the history of Australian locust science, but we could extend Needham's concept of the scientific environment to include the ecosystems in which the scientific subjects were encountered. Science is learning through observation and observations are always made in places and from perspectives, not only those set by the intellectual framework of enquiry and extant knowledge, but those emerging from curiosity and interaction with organisms, habitats, instruments and practical events of the day.

By necessity, many research observations took place in the agricultural landscapes where the locusts swarmed. The scientific experience of the insects within those environments was ecological, revealing their interactions, life processes and agency. And it was in the context of these changing environments that early ecological ideas of interdependencies and of nature's delicate balance were framed. Later ideas of the limits to the distribution and abundance of species, of population irruptions, persistence and decline were also shaped by the fluctuations and extremes of those environments.

The history of entomological investigation on locusts gives a unique perspective on the development of broader ecological science. Ecology is the science of the environment, and when it was applied to understanding and managing it, becomes central to environmental history. This thesis sheds new light on the history of locusts, the interaction of environment with scientific ideas and practice, and on the political arrangements which both promoted and depended on scientific knowledge. It identifies previously unknown events and presents new findings about the incidence and distribution of plagues as well the species involved, which challenge some previously accepted views. These have been gleaned from thousands of newly digitised newspaper reports and from a re-reading of official

[1] Joseph Needham, *A History of Embryology,* (1935), p. 231, cited in Robert Young, *Darwin's Metaphor*, p. 164.

[2] Robert M. Young, *Darwins's Metaphor: Nature's place in Victorian Culture,* (Cambridge, Cambridge University Press, 1986), p. 164, presents a Marxist sociological approach to the history of science as the mediation between socio-economic base and intellectual superstructure.

documents to build a more complete history going right back to the 1840s. The historical evidence points to an increased frequency of outbreaks of both southern locust species in response to the environmental changes consequent on European pastoral land use. Newspaper reports document the responses to locusts as an agricultural pest, the methods used to eradicate them and the wider politics of science in society. Popular accounts include the perceptions of those most directly affected by locust swarms, the farmers and townsfolk of the inland, as well as the scientific experts.

The involvement of government in the direction of Australian science came with the early development focus on mining and urban engineering, and on agriculture. Along with chemists, horticulturalists, plant pathologists, soil and veterinary experts, entomologists were first appointed as public scientists to solve farmers' pest problems and underpin progressive agriculture in the late nineteenth century. The entomologists worked within the institutional framework of state agriculture departments, and were only joined by federal scientists in the 1930s with the creation of a national science agency. At its inception, the Council for Scientific and Industrial Research (CSIR) was sensitive and explicit about working in collaboration with state and university scientists, rather than centralising scientific knowledge.[3]

The institutional imperative to deal with the locusts was enacted in the agricultural landscape. Locusts were an environmental management problem, through which states gained and affirmed their relevance. The entomologists and their sponsors developed a mutually dependent relationship. The scientists were required to prove their worth, while the politicians were seen to be solving problems through science. Following overseas trends in insect control, those dependencies led to experimentation with biological, cultural and chemical controls. The latter increased in importance as new outputs from the chemical industry produced more immediate, visible and scientifically supported results. This trend saw the adoption of arsenic in the early 1900s and its immediate replacement by organochlorine insecticides after World War II.

Ecology, too, became a central focus of applied locust entomology. Science offered hope for finding a weakness in the details of their life cycles; an ecological bottleneck that would be the key to stopping plagues or discovering new biological controls. Ecology set about explaining the sudden population increases and declines, where they bred and why they migrated, and it identified the environmental limits on locust population increase. The changing conceptual and methodological contexts of locust

[3] S. Castonguay, 'Naturalising federalism: Insect outbreaks and centralisation of entomological research in Canada, 1884–1914', *Canadian Historical Review*, 85 (2004), 1–34, provides a comparison for federal-state scientific interaction. The creation of a federal agricultural entomology agency in Canada in the late nineteenth century, and national plant protection legislation, resulted in conflicts with provincial entomologists over authority and policy.

science, the actions and ideas of individuals in social and institutional settings, and the explanations of the insects' ecologies together created the scientific history presented here. It encompasses several scientific eras that were characterised by different ecological concepts, entomological practices and technologies of control.

Histories of Australian entomology

Histories of science inevitably establish the names of notable individuals who populated the official and public documentary record. In the colonial era, Charles French and Walter Froggatt stand out because of their practical illustrated books, published or promoted because of their public standing. Other figures include collectors who specialised in certain taxa and sent samples overseas to taxonomists for identification, people who published or illustrated books and those who wrote articles for scientific journals.

There are several inclusive biographical histories of Australian entomology, written at different points of disciplinary self-reflection, including those by Anthony Musgrave in 1930, Ian Mackerras in 1949 and Elizabeth N. Marks in 1991. Each built on Musgrave's early work that distinguished three periods of colonial entomology, named after prominent taxonomic authorities working in Britain who classified Australian collections.[4] The earliest 'Fabrician' period was that of ocean explorations, named after Johan Fabricius.[5] The period of land exploration and early settlers from 1831 to 1861 was named 'Westwoodian' after John Westwood, secretary of the Entomological Society of London. The 'Macleayan' period to 1891 was dominated by dynastic colonial collections and museums.

Westwood identified many insects sent by colonial collectors, and this was also Charles Algernon Wilson's period. Ironically, Wilson was Westwood's closest Australian correspondent and Westwood even named beetle named after him.[6] He sent Westwood many specimens for identification and also donated collections to Adelaide museums, but is not mentioned by Musgrave. Among the entomologists of early Adelaide listed by Musgrave are Wilson's fellow collectors Hans Behr, C. D. E. Fortnum and Frederick Waterhouse. Marks adds the artist-collector George French Angus and later Marianne Kreusler, Otto Tepper and Frazer Crawford, who took over writing 'injurious insect'

[4] Anthony Musgrave, 'The History of Australian Entomological Research', *Australian Zoologist*, 6 (1930), 189–213; E. N. Marks, 'Biographical History', in *The Insects of Australia: a textbook for students and research workers*, Vol. 1. 2nd edition (Melbourne, CSIRO, Melbourne University Press, 1991), pp. 198–220.
[5] Fabricius was a Swedish entomologist and student of Linnaeus, worked in England in the late eighteenth century and identified over 200 Australian species from Cook's expedition.
[6] *South Australian Register,* 3 October 1856, p. 3.

articles from Wilson in the 1870s. However, Wilson remains absent from Marks's grouping of 'some early residents' in the table of major figures in Australian entomology.[7]

In 1937 Wilson did receive local acknowledgement as South Australia's first entomologist by James Davidson, who had read of his contributions to the Adelaide Philosophical Society and newspapers.[8] In 2004, Alan Atkinson quoted 'Naturae Amator' to introduce several chapters of a history of Europeans in Australia, but only to use his entomology descriptions as metaphors of human social and political relations.[9] Wilson's descriptions, however, contain such intricate detail that many South Australian species can be clearly identified. While Wilson is almost entirely overlooked in histories of Australian entomology, his detailed descriptions of the 'locusts' that invaded Adelaide in the 1840s made it possible to identify them as *Austroicetes cruciata* and to rewrite the early outbreak history of the colony.

Ian Mackerras identified a 'period of amateurs' from 1891 to 1927, mostly collectors who specialised in certain taxa and published in scientific society journals, and then the start of the 'period of professionals', coinciding with the creation of an entomology branch at CSIR.[10] Along with the amateurs, came the early professional public entomologists through government appointments. Among the ranks of early appointees, French, Froggatt, Compere, Tepper and Lea were 'amateur' in having no accredited qualifications.

Although outnumbered by the 'amateur specialists' and museum curators by taxonomic contribution, the state department entomologists from 1900 to 1927 were the 'economic entomologists', with a different set of professional goals. One of these was solving the 'locust problem' and the interplay of institutional and economic forces drove many of their actions. It was during this time that technologies of 'control' were investigated and promoted to landholders. Charles French organised the first attempt to use European methods of organised collective manual control. He followed this with the ambitious decade-long biological control program using the 'Cape fungus'.

Walter Froggatt was the model economic entomologist and the last of the self-taught professional naturalists. He was involved in several scientific societies, including the Linnaean, Zoological, Wildlife Preservation and Naturalists' societies of New South Wales (NSW), and also the Gould

[7] Marks 1991, p. 199. The Scott sisters, who illustrated their father's butterfly books, and Silvester Diggles, who collected beetles and butterflies for overseas entomologists are listed.
[8] J. Davidson, 'One hundred years of entomology in South Australia. Centenary Address No 5.' *Proceedings of the Royal Society of South Australia* 60 (1937), 35–40.
[9] Alan Atkinson, *The Europeans in Australia: A History, Volume Two – Democracy*, (South Melbourne, Oxford University Press, 2004).
[10] I. M. Mackerras, 'History of Australian Entomology: Alfred Jefferis Turner and Amateur Entomology in Australia', *Proceedings of the Royal Society of Queensland*, 40 (7), (1949), 69–87, pp. 70–71.

League. He also lectured in entomology from 1911 to 1921 in the University of Sydney agriculture department. After the failure of the fungus and kerosene sprays proved too costly, the entomologists tested, demonstrated and then recommended arsenic baits and sprays. Many other government entomologists dealt with the locust problem and its ecological implications as the plagues continued during the 1930s and 1940s.[11]

The state entomologists in Mackerras's 'professional' period were joined by a new team of ecologists during the nationalisation of agricultural science. The CSIR scientists became involved in agricultural applications of entomological knowledge and after 1949 the Commonwealth Scientific and Industrial Research Organisation (CSIRO) expanded those horizons to include the taxonomy, inventory and ecology of native entomofauna. Ken Key and Laurie Clark were the locust contingent of this national science program, with Nicholson the director of insect ecological research. H. G. Andrewartha, Charles Birch and James Davidson held equivalent roles at the University of Adelaide. The post-war inclusion of PhD degrees by research at Australian universities gave new paths of local entry to careers in entomology and ecology.

Mackerras, himself a CSIR entomologist, received recognition in the dedication of the 1991 second edition of CSIRO *Insects of Australia*.[12] In 1971 Doug Waterhouse, head of CSIRO entomology, reviewed the progress of professionalisation in entomological science. The number of entomologists had doubled since 1960 to 450, with 130 employed by the Commonwealth and a hundred each in agricultural extension or universities. The proportion with university accreditation had also increased. A third now held doctorates and the majority of those were trained overseas.[13]

CSIRO domination of entomological research came in the 1960s under Waterhouse's entrepreneurship, expanding the breadth of research by gaining funding for several integrated entomological research programs. A new suite of scientists and technical assistants joined the ranks of the Division of Entomology, which included the locust research team working with Doug Clark and the many visiting Anti-Locust Research Centre (ALRC) scientists. The disciplinary division created at the 1938 locust conference, giving CSIR responsibility for ecological research and state entomologists for applied control research, continued to the 1970s, but did not exclude the latter from ecological experiments and conjecture. Although specialised perspectives developed, from ecological models to the mechanics of pesticide application, the CSIRO ecologists and practical entomologists often

[11] Before 1945, William Gurney, Tim McCarthy and Norman Noble were followed by Stuart Allman in NSW. The entomologists In WA were Leslie Newman and Clee Jenkins, and in Victoria Richard Pescott and Keighley Ward.

[12] *The Insects of Australia: a textbook for students and research workers*, Vol. 1. 2nd edition, (Melbourne, CSIRO, Melbourne University Press, 1991).

[13] Waterhouse 1971, Table 2, p. 151.

worked together in the field and the conference room. However, a 'knowledge asymmetry' developed with landholders, who became disconnected from policy decisions about insecticides, while usually accepting the purpose of the experimental ecology.[14]

While George Basalla's 1970s model of the metropolitan creation of knowledge and its diffusion to the scientific peripheries could apply to the early 'collections' period of entomology, that central authority disintegrated in many areas except taxonomic expertise as the biological sciences expanded from colonial settings.[15] Even during Britain's late Imperial claim over locust science, knowledge was produced in the infested dominions. Australian locust science became largely public science after the 1880s. This was a political arrangement adopted in other temperate 'newlands', and knowledge about locust control and ecology was shared between them. The transport and translation of scientific knowledge about locusts became increasingly transnational throughout the twentieth century.

The 'grail' for the entomologists was a scientific method of stopping plagues. The early economic entomologists were caught between the traditions of the romantic naturalist and the new authoritative professional, positioning themselves as essential through practical engagement and theoretical justifications. French selected and then remained convinced that the fungus was a complete scientific, natural and biological solution, even when faced with its failure. Froggatt opposed Compere's 'unscientific' biological control releases, to become the authority on scientific sanitary and chemical practices in orchards and farms, where the remedies were 'needed for today'.[16] Those remedies depended on the ideology of unified collective action as essential to success, but ensuring participation remained a perennial difficulty. Locust swarms and crop damage were so obvious that state entomologists easily 'framed' the problem with a technical prognosis, established credibility by demonstrating control methods and 'enrolled' farmers in using arsenic insecticide for many years.[17]

Arsenic remained the technology of organised locust control up to 1945. The rapid transition from arsenic to organic compounds came from a promise of success where arsenic was failing the state entomologists. Hogan's aerial spraying programs were scientifically supported, gave him public

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[14] H. Fjelsted Alroe and E. Noe, 'The Paradox of Scientific Expertise: a perspectivist approach to knowledge asymmetries', *Fachsprache*, 3–4 (2011), 152–167, p. 153.

[15] George Basalla, 'The spread of western science', *Science*, 156 [3775], (1967), 611–622, Basalla's early model of the diffusion of scientific knowledge in the colonial context introduced the terms 'metropolitan' and 'peripheral' centres of knowledge.

[16] E. Deveson, 'Parasites, politics and public science: the promotion of biological control in Western Australia, 1900–1910', *British Journal for the History of Science*, 49, (2016), 231–258, p. 247.

[17] Kevin C. Armitage, 'The Soil Doctor: Hugh Hammond Bennett, Soil Conservation and the Search for Democratic Science', in eds. D. Jorgensen, F. A. Jorgensen and S. B. Pritchard, *New Natures: Joining Environmental History with Science and Technology Studies,* (Pittsburgh, University of Pittsburgh Press, 2013), pp. 87-102, p. 91, Sociologist Erving Goffman's concept of frame-making is applied in an agricultural context.

notoriety and led to numerous publications; the 'scientific capital' of Pierre Bourdieu.[18] Hogan maintained the status of expert in locust control as Victoria's chief entomologist for thirty years.

Locusts and ecology

> *When about to deposit her eggs, the female makes a hole in the ground by means of her ovipositor. This organ consists of two pairs of strong, horny valves, the points of which are pushed into the earth, and by continuous opening and closing a hole is drilled. When this task has been completed some thirty or forty eggs are voided.*
>
> M. L. S., *Australian Town and Country Journal*, 29 January1898, p. 23.

Ecological science gained legitimacy and practicality by addressing agricultural pest problems. Insects featured as the data hosts of many empirical ecological studies and contributed to the development and testing of theory. The southern locusts hold the unique position in Australian science history of attracting continuous attention over more than one hundred and fifty years. The only other insect subjects of as much intensive research are the sheep blowfly and the Queensland fruit fly, but as these only became problems in the twentieth century the locusts had a head start.

Ecology was not established as a formal discipline until the 1930s, but the idea of 'ecological thinking' has been traced through aesthetic or nature conservation activities — through an observed sentiment for nature.[19] Many early naturalists and ecological thinkers, left out of extant official histories have now been identified through their interaction with 'locusts'.[20] The long trail of 'locust' ecology follows changing perspective and concepts, and reveals a series of overlapping intellectual eras. These begin with a recognition of Aboriginal knowledge of locust ecology and, while those that followed can be traced sequentially, they are not bounded by end dates because the practices and frames of enquiry of any one era continued during later eras.

Collections were the material objects of the nineteenth-century European fascination with natural history and were the foundation of Linnaean taxonomy and biological inventory. The size, beauty and diversity of insects made them perfect subjects for large cabinet collections and for conjecture on phylogenetic relationships. *Chortoicetes terminifera* and *Austroicetes cruciata*, however, are poorly represented in early collections and the latter did not receive a name until 1888. They did not preserve

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[18] Pierre Bordieu, 'The specificity of the scientific field and the social conditions of the progress of reason', *Sociologie de la Science*, 14 (6), (1975), 19–47.

[19] Martin Mulligan and Stuart Hill, *Ecological Pioneers: A Social History of Ecological Thought and Action*, (Cambridge, Cambridge University Press, 2001).

[20] Among the observant amateur entomologists, the farmer Richard Nancarrow, agricultural chemist Alfred Pearson, agriculturalist Thomas Bath and possibly journalist Robert Savage contributed to locust ecology before the 1890s.

well, losing their colour and appendages easily. Other than gigantic or colourful species, the Orthoptera were not popular among collector taxonomists, many of whom selectively chose the bright colours of beetles and butterflies.[21]

In parallel with the era of ‘natural history collections’, an ‘ecological natural history’ emerged that focused on observing and recording insect behaviour and interactions. Again, Wilson stands out here as Australia’s true romantic natural history writer and first ecologist. He commenced writing natural history, pest insect and the comprehensive entomological series of articles in the utopian spirit which launched the *South Australian Magazine* in 1841. Wilson took on the role of scientific natural historian for the magazine designed to ‘allay the mental “rustication” too incident in colonial life’.[22] Had this periodical devoted to science and literature continued, his work may not have been left in obscurity. Most of Wilson’s later contributions appeared in newspapers and, though they played a public communication role, once again they were lost to the sphere of later scientific self-enquiry.

Close observation was not the exclusive preserve of the elites. The public, including women and children contributed to the ecological conjecture. This unauthorised ecological natural history covers most scientific observations and engagement with locusts during the nineteenth century, as professional entomologists only rose to prominence in the 1890s. As ecology developed as a science, so too did its methodological premises and the available instruments of measurement and analysis. A nascent scientific ecology, or ‘quantitative natural history’, also emerged in the 1880s with the first experiments in insect physiology on locust egg development. Locust ecology became a nexus of the ‘lab-field border’, propounded for plant ecology by Robert Kohler, as the distinct cultural and geographical divide between the different sites of knowledge production merged and adapted to deal with massive, transitory and migrating populations.[23]

The unifying practice in ecological investigations for more than a century was the discipline of observation in the environment, often assisted in the laboratory by the pre-eminent nineteenth-century optical technology, the microscope. Knowledge was produced by precise description, transferred from eye to text, astute to differences and the unexpected.[24] Ecological natural history continued in field, theoretical and experimental contexts. Nicholson’s 1920s work on mimicry in Australian insects has

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[21] Westwood commenced a catalogue of orthopteran insects in the British Museum, but only got as far as the phasmids and mantids. Francis Walker completed the taxonomy of Orthoptera in 1870.

[22] James Allen, ‘The Use and Advantages of Colonial Periodical Literature’, *The South Australian Magazine*, 1, (No.1), (1841), 1–6, p. 2.

[23] Robert E. Kohler, *Landscapes and Labscapes: Exploring the Lab-Field Border*, (Chicago, University of Chicago Press, 2002).

[24] Lorraine Daston and Elizabeth Lunbeck, eds., *Histories of Scientific Observation*, (Chicago, University of Chicago Press, 2011).

been described as both the 'finest natural history study' and the start of evolutionary ecological science.[25]

By the early twentieth century, ecological generalisations such as disturbances to the 'balance of nature' as the cause of insect outbreaks dominated the views of the public and the entomologists engaged in 'progressive agriculture'. Borrowing a phrase from historian Alfred Crosby, the 'chain of being' was officially drawn into threads and 'woven as the web of nature'.[26] Locust outbreaks were explained by human disturbances of that balance. The role of insectivorous birds in maintaining nature's balance, and the increase in locust swarming that resulted from their decline due to human actions, became the symbol of this paradigm. Ecology was gradually 'applied' to ways of viewing and solving insect pest problems. It was applied through technologies of control, seen as necessary to correct nature's balance. The paradox for the state entomologists, many of whom were also keen ornithologists, was that this solution was seen by others as the cause of the problem.

The perspectives of state government scientists were not always shared by the wider public. Newspaper correspondents engaged with scientific knowledge and constructed unauthorised and counter views. The ecological concern that linked the decline of birds with increased 'locust' swarming was formalised first in 1880 with a petition for bird preservation. It emerged in the 1900s as grassroots dissent over arsenic poisoning that challenged the state recommendation and later subsidisation of arsenic bran baits for locusts. The entomologists went to great lengths to combat these ideas as myth right through to the 1940s. Challenged by the widespread public views, in NSW they engaged a professional museum ornithologist, Roy Kinghorn, to investigate the bird poisoning issue, while themselves concentrating on the risk to livestock.

When organochlorine insecticides were first introduced, the public and even naturalists accepted scientific advice that spraying with them was more efficient and less harmful than arsenic.[27] However, publications like Rachel Carson's *Silent Spring*, and an international realisation that organochlorine insecticides were not as safe as previously thought, brought a new challenge to state locust control programs. This was spearheaded in 1971 by the newly formed state conservation councils and they

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[25] M. J. Whitton, 'Australian Insects in Scientific Research', in *The Insects of Australia: a textbook for students and research workers*, Vol. 1. 2nd edition, (Melbourne, CSIRO, Melbourne University Press, 1991), pp. 236–251, p. 239.
[26] A. Crosby, 'The past and present of environmental history', *American Historical Review*, 100 (1995), 1177–1189, p. 1182.
[27] *The Argus*, 3 September 1955, p. 4 (Weekender), Crosbie Morrison, nature writer for *The Argus* and had challenged the use of arsenic in 1934, wrote an article supporting the aerial BHC spraying.

were joined by other concerned groups, though generally not by the farmers faced with a locust plague.[28]

During the 1930s ecological theory was 'applied' to the field enumeration and laboratory study of insect pests to determine the climatic limits of species distributions and climatic correlations with population peaks. In Australia, an intense period of ecological research began to circumscribe the niches of the grasshopper and the locust after the plague in the 1930s. It was initiated by the Australian Agricultural Council (AAC) directive to CSIR to focus on the locust problem, but was also carried out by entomologists in the states and at Adelaide University. The new ecological entomologists were largely free of the institutional requirement for immediate practical results. Research unravelled the life cycle complexities of the grasshopper, the locust and some of their parasites, as well as identifying the specific habitats in which swarming took place.

Within that applied context, developments in ecological theory were constructed and tested using source data on pest insect populations. Andrewartha and Birch used their observations on *A. cruciata* as an exemplar of climatic control of the distribution and the abundance of species. The fluctuation of grasshopper densities in response to rainfall at different locations contributed to their general theory which included the importance of spatially heterogeneous habitats. Their observations also featured in Andrewartha's elaboration of diapause terminology and theory. Key attempted to clarify the concepts and terms of the dominant theory of locust ecology, the role of phase change in plague cycles, but struck resistance to his questioning of some of its precepts. Laurie Clark's comparative field experiments were used to integrate quantitative data on population and behaviour with vegetation, soil and climate.[29]

The joint CSIRO–ALRC research that ran from 1962 to 1976 was the second intensive phase of ecological research and was concentrated on *C. terminifera*. The concerted research on multiple aspects of its biology aimed to establish some generalisations appropriate to locusts in other countries as well as to solve Australia's locust problem. Locust populations were too vagile and their fluctuations too complex to measure or categorise easily within the available ecological tools and frameworks. Only in the 1960s, when methods for rapidly enumerating populations by field sampling and appropriate statistical adjustments were developed, were the intricacies and rapid turnover of *C. terminifera* demography made clear.

[28] With an impending locust plague and the creation of state Conservation Councils in 1971, objections to the use of lindane for aerial locust spraying were given a prominent public voice.

[29] W. Geier, 'Laurance Ross Clark', *Australian Journal of Ecology*, 2 (1977) 3–8, pp. 6–7.

Developments in migration theory used locust behaviours as a model, and the importance of migration in *C. terminifera* population dynamics made it the central research issue in the 1960s and 1970s. The significance of wind-assisted nocturnal flights was revealed by concerted longitudinal field research and the application of novel technologies. This feature of the locusts' migratory behaviour became the explanation for the event sequences in the development of plagues and migration research remained prominent throughout the twentieth century.

Certain ecological ideas exerted an enduring influence on the ways that locust biology was seen to fit within wider ecosystems. Uvarov's phase theory of locusts became central to research in all locust-affected parts of the world after the 1920s and it has remained important as a model of phenotypic plasticity into the current century.

The contentious thread in ecological theory that developed in the 1930s around the meaning of terms like 'density-dependence' and the relative roles of biotic interactions or climate variation in 'regulating' population growth, continued in the 1950s debates between Andrewartha and Nicholson.[30] Hypotheses about innate properties of trophic effects on populations were harder to demonstrate empirically than the effect of climate parameters. The apparently unresolved issues over density effects in insect ecology continued to be referenced by locust researchers in Australia in following decades. In both plant and animal ecology, there was a parallel 'fragmentation' of dominant holistic concepts followed by a reorganisation under pluralistic concepts and models during the 1950s. The Andrewartha–Nicholson conflict might be seen in this context of paradigm change. The 'organismic' view of communities and aggregations as emergent and stable entities gave way to concepts of a continuum of overlapping individual species distributions and local populations in ecosystems.

Historians have examined this change of scientific perspective in relation to social changes in post-war USA, such as the entry of many mature-age postgraduates and the increase in research funding for ecology.[31] On the broader cultural stage, Michael Barbour has posited the rise of individualism, the challenge of establishment and convention, and even post-modern intellectual uncertainty as influences on the social climate of ecologists.[32] Any such influences are hard to detect in Australia,

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[30] Salvador Herrando-Perez, *Resolving conceptual confusion and quantifying cross-taxa patterns of 'density dependence' in population ecology*, (PhD thesis, University of Adelaide, 2012), pp 29–30, discusses the misunderstandings caused by the semantic polysemes associated with 'density-dependence'.

[31] Paolo Palladino, 'Ecological theory and pest control practice: a study of the institutional and conceptual dimensions of a scientific debate', *Social Studies of Science*, 20 (1990), 255–281.

[32] Michael G. Barbour, 'Ecological Fragmentation in the Fifties', in ed. W. Cronon, *Uncommon Ground: Rethinking the Human Place in Nature*, (New York, W. W. Norton, 1995), pp. 233–255.

partly because there were fewer players and because some cultural changes, like those in ecology, mirrored those in Europe and America.[33]

Ecology historically played a role in the selection and representation of practical locust management strategies. Early attempts at accommodation by altering wheat planting times in South Australia during the 1840s were based on observations of the phenology of *A. cruciata*. It was recognised in the 1870s that the vulnerable nymph life stages of *C. terminifera* were locally restricted, which offered the best chance of controlling them. Economic entomologists later argued that control was preventative because of the potential geometric population growth of untreated locusts. The adoption of different insecticides was driven by expediency but was often justified as being less harmful to other organisms. Locust migration later became central to identifying the role of different regions in plague initiation and in the selection of areas for monitoring and control.

Outbreak areas of locust ecology

One ecological construct that pervaded locust research was Uvarov's 'outbreak area' concept, not just as a theoretical model but as a practical means of plague suppression. Much attention was therefore paid to the geographical delineation of individual outbreak areas and the processes leading to phase change within them. Uvarov's view was that ecological modification in outbreak areas could make them unsuitable for phase transformation. The representation and employment of the outbreak area model in Australia began when the federal government first entered the locust arena in the 1930s and was still important in the 1970s. It also struck a note with popular imagination. Ever since the 1870s there had been conjecture about locusts coming from the vast uninhabited 'steppes' as they did in other lands. But the idea also compromised the economic entomologists' attempts at coordinated local control, because the problem was seen to come from 'further out'.

Until 1935, the CSIR Division of Economic Entomology concentrated its research on biological control and, as native insects, locusts were unsuitable for classical approaches. The creation of the AAC and its advisory Standing Committee, the SCA, changed the focus, because the states saw locusts as a serious national problem. At the first AAC meeting, the implications of Uvarov's outbreak areas were discussed and CSIR hired Ken Key, then working with Uvarov, to 'investigate their habits and find their permanent breeding places'.

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[33] There was no changing of the guard in the 1950s, although there were some mature-age students like Doug Clark. The interdisciplinary adventures of Charles Birch and Laurie Clark influenced their ideas and methods. Future research might turn to unravel the philosophical and political background to the ideas of individuals.

Key's research focused on identifying all potential locust outbreak areas. The agreed definition as any area where swarms could be produced from low initial populations challenged categorisation for *C. terminifera*. The more he investigated, the more potential outbreak areas were found and they occupied more than just a small proportion of its range. Nevertheless, Key proposed an experimental test of the outbreak area model of plague initiation and suppression in 1947. He later found himself in an institutional and geographical schism between academic ecology and practical entomology over the relative importance of different outbreak areas.

The trial was an attempt to bridge ecological theory and the need for practical results. The selection of the accessible and frequently infested Bogan–Macquarie outbreak area in Central West NSW was contested by state entomologists. Not convinced that it would have any benefit for them, several states were unwilling to contribute to the cost. In Victoria, Tom Hogan already believed the state's locust problems came from further west in NSW and from Southwest Queensland. NSW was faced with outbreaks in agricultural districts nearly every year, so it was in favour of Key's plan. Outbreak areas were the subject of the 1954 CSIRO Grasshopper Control Conference, and issues revolved around their relevance, relative importance and ecological significance. The outbreak area control trial went to several SCA meetings and was finally endorsed in 1955, along with the creation of a trial campaign committee to oversee the project.

Key scheduled the spray trial in 1958, but state entomologists in the trial committee vetoed its commencement. The issue was only resolved when Uvarov himself attended the committee's next meeting during a brief visit to Australia. His view was that a single trial in just one among many outbreak areas could not work. State entomologists took note and the trial proposal ended. Key, however, remained committed to the practical and ecological implications of the outbreak area concept. He and Lou Chinnick mapped soil surface characteristics of the Bogan–Macquarie area in detail during the 1960s, hoping the mosaics of food, shelter and oviposition habitats would provide the basis for later research on the environmental precursors of swarm formation.[34]

Different perspectives on the importance of certain outbreak areas continued during the plague in the wet years of early 1970s. While Uvarov's proposal for an interstate locust control service had been endorsed by the AAC and state entomologists since the 1960s, it received renewed attention when the state and federal governments were faced with the mounting costs of controlling locusts. However, the SCA considered that further scientific investigations into the role of inland areas in plague development were required. An examination of historical locust outbreaks by its 'technical locust

[34] L. J. Chinnick and K. H. L. Key, 'Map of the Soils and Timber Density in the Bogan–Macquarie Outbreak Area of the Locust *Chortoicetes terminifera*', *Division of Entomology Technical Paper No, 12* (Melbourne, CSIRO, 1971).

subcommittee', focusing on the role of populations in Southwest Queensland, convinced the SCA that breeding in that region and subsequent migration to agricultural areas was the general pattern of plague development. With AAC endorsement, the federal and state governments moved quickly and established a jointly funded Australian Plague Locust Commission (APLC). The APLC commenced operations with an ecologically justified strategy and an explicit focus on plagues originating in the Channel Country. The outbreak area model and its corollary of plague suppression by control at source, became the 'arid source area' concept.

Up to the 1970s the explication of ecological research on locusts was framed largely as collaborative additions to the accumulation of knowledge. However, Key was positioned in the later history of Australian ecology as a 'straw man', reflecting a different way of expressing the significance of research findings. Instead of contributing to existing knowledge, new research was framed as challenging it by introducing interpretations of the history of scientific ideas. In the 1980s he was used to represent an established 'theory' that most plagues arose locally from major outbreak areas in the agricultural belt of NSW, as opposed to the 'new' arid source area model of plague initiation.[35] More recently, his critique of phase theory was interpreted as a denial of phase change in *C. terminifera* by researchers wishing to present an orthodoxy against which to emphasise their findings as paradigm-shifting.[36] Perhaps, like the cultural influences that fragmented ecological theories in the preceding era, 'individual competition now displaced group cooperation'.[37] This trend in presenting scientific research, where 'thought collectives' emphasise the novelty and presage the significance of their work, is in part driven by the pressures of securing funding and achieving publication in prestige journals.

The environmental history of locusts and grasshoppers in southern Australia

> *It is very difficult though, to find out the precise cause to which we are indebted for the visitation. Some think that the denudation of timber by settlement, or rather the neglect to*

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[35] D. E. Wright, 'Analysis of the development of the major plagues of the Australian plague locust, *Chortoicetes terminifera* (Walker) using a simulation model', *Australian Journal of Ecology*, 12 (1987), 423–437, p.423, Key was cited as the source of a 'readily accepted theory'. This opposition was used despite Key having identified the potential outbreak areas on the floodplains of Southwest Queensland and l long-distance exchange migrations between NSW and Queensland.

[36] L. J. Gray, G. A. Sword, M. L. Anstey, F. J. Clissold and S. J. Simpson. 'Behavioural Phase Polyphenism in the Australian plague locust (*Chortoicetes terminifera*)', *Biology Letters*, 5 (2009), 306–309, pp. 306, 308, the authors cite Key for an 'assertion' that *C. terminifera* does not display phase polyphenism and its lack of morphological change for 'fostering a notion' that phase polyphenism did not play a role in gregarious behaviour; Key had distinguished different phase states in this species based on the accepted morphometric indices, therefore an acceptance of phase change in the species.

[37] Barbour 1995, p. 250.

> *plant belts of timber in the arid plains, produces climatic conditions favourable to the development of the locust brood. Others are of opinion that, in these latitudes, bush fires are an essential for checking the too numerous increase of the vermin, which bush fires the progress of settlement has extinguished. Others, again, consider that we are paying the penalty of receiving the unwelcome guests, by reason of our destruction of the native game which feeds on locusts. All this, however, is merely theoretical, and what the country wants is a little practical information on the subject.*
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> *Hamilton Spectator Journal*, 18 December 1872, p. 2.

There are now many documented overseas examples of changes to the frequency and distribution of population irruptions of locust species in response to human alteration of environments. The role of land use in altering habitats of Australia's southern locusts hasn't really been addressed since the 1940s, when the entomologists stood on the scalded plains of several states in the wake of the dustbowl years and saw them doing quite well. Those environments heightened an awareness of ecological change and its link with grasshopper and locust swarming. Herb Andrewartha, Ken Key and Laurie Clark all viewed the problem as a result of overgrazing and soil erosion. They each proposed ecological restoration of infested regions to reduce swarming, that would require changes to stocking rates and the protection of tree and shrub cover. In practice, those measures were impossible to implement over such large areas where landholders depended on continuing an 'opportune use' land management, on which they believed their livelihood depended.[38]

In the later twentieth century, for several reasons, the effects of soil erosion and overgrazing on locusts seemed less relevant. Landscapes and land use stabilised after the return of wet conditions in the 1950s and tighter regulations on pastoral stocking rates. There were also new technologies for rapid control over large areas, which gave rise to technocratic solutions of scientific prediction and 'control' by responsible institutions. Moreover, many of the entomologists came from overseas and had no experience of the history of the inland landscapes. Researchers then mistakenly cited the first swarms around Adelaide in the 1840s as evidence that locust plagues had always been common.

The historical records presented here show that there were changes in the frequency and distribution of outbreaks of both *C. terminifera* and *A. cruciata.* They also provide evidence to support a conclusion that those changes were largely responses to environmental change, resulting from climatic variations and heavy pastoral land use. Extended periods of favourable seasonal conditions, although different for each species, set the potential for population increase, while the compacted soils and reduction of perennial grass cover presented them both with favourable new habitats.

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[38] Tim Bonyhady, *The Colonial Earth*, (Carlton, Victoria, Miegunyah Press, 2000), p. 284.

Significantly, this thesis presents new findings and some different interpretations of the historical sequence of early grasshopper and locust plagues. The criteria used to distinguish between them identifies the species with certainty in many cases. Their distinct seasonal phenologies make the separation clear in summer and autumn. Because *A. cruciata* has a single annual generation, nymphs or swarms reported after January were more likely to be *C. terminifera*. Only during spring do their potential occurrences overlap. The big locust plagues of 1873 and 1890 were already known, thanks to Key's 1938 reconstruction. So too was the grasshopper plague during the Federation drought. But these events, as well as several other little-known plagues, are now documented with details of their geographic extent, duration, generation sequence and environmental settings.

Finding Charles Wilson's crucial descriptions of the 'locusts' in South Australia from 1843 to 1845 made it possible to be certain they were *A. cruciata*. His and other diagnostic reports, along with the timing of all reports in spring and early summer, make this the most likely species in the outbreaks in other colonies. In the absence of any specimens, it provides corroboration for the conclusion that all recorded inland swarm infestations in South Australia, NSW and northern Victoria prior to 1870 were the grasshopper.

The 'singular' concentration of swarms just around Adelaide in the first two years and then spreading to surrounding districts, once again suggests grasshopper swarming started with and followed the arrival and spread of livestock grazing. This species became an almost annual pest in South Australia for the rest of the century. The reporting of grasshopper outbreaks in NSW was also geographically coincident with pastoral expansion in the NSW Riverina. The pattern was repeated in Western Australia from the 1870s, but intensified with the accelerated clearing of woodlands for wheat growing in the 1920s. Had there only been scientific descriptions and farmer reports, the appearance of *A. cruciata* swarms around Adelaide in 1843 and their persistence for five years could be seen as just part of an irregular cycle. But Aboriginal people there and in WA said the swarms were a new phenomenon. Settlers also considered that the sheep runs favoured these insects.

In contrast, *C. terminifera* swarms first appeared in the south-east in 1870, starting one of the longest and most geographically widespread plagues on record. They arrived with the onset of a sequence of wet seasons and a prolonged La Niña climatic event. There are few earlier reports, either in newspapers or the writings of explorers and settlers that could be of the locust. The outpouring of public dismay in so many reports in the 1870s attest to those events being unprecedented, unseasonal, and the species unknown, and suggest that had there been any earlier locust plague or swarm activity in settled districts, it would have been noticed. There were prolonged La Niña events during 1847–1851 and 1860–1864, so climatic opportunities similar to 1870–74 had existed for plague development in the previous thirty years. In the thirty years following 1875, there were six identifiable locust plagues that affected more than one colony so that, while it can be supposed locust plagues occurred in pre-European times, the evidence points to a dramatic increase in frequency.

A unique locust situation developed in Victoria during the 1880s. After immigration of swarms in 1883, there were continuous generations in western and northern Victoria for five years, while other states were only briefly infested. Since that time, however, Victoria has only been part of brief multi-state plagues. The longest subsequent continuous infestation was four years during 1971–1975. While it is possible the 1883–1888 event appeared as an artefact of the greater public concern during the expansion of cropping in the colony, the fact that it has not been repeated suggests an environmental influence.

There was a clear increase in the frequency of locust outbreaks affecting NSW from 1907 and swarm breeding moved into many eastern districts that had previously been rarely visited. *C. terminifera* was involved in these infestations, but it was not the only species present. It was often mixed with other species, particularly on the margins of its range, which would have boosted its apparent abundance. The establishment of persistent populations in the Hunter Valley, a region that in recent times has only occasionally affected by immigration, again indicates that environmental change influenced both the increase and the decline of outbreaks. Locust swarms were reported in parts of NSW every year from 1921 to 1948.[39] Forest and woodland clearing during the early twentieth century in the eastern half of NSW and, in the case of the Hunter Valley, between Merriwa and Dubbo and on the Liverpool Range, extended the continuity of habitats for migration and breeding. Higher livestock numbers are likely to have maintained low pasture densities, but 1920–1945 was also a dry climatic period.

Landscape changes due to squatting did not create the swarming behaviour. Both species are native, grassland herbivores with a shared evolutionary history and a propensity to develop large gregarious populations,and both would have intermittently swarmed over the southern grasslands. Historical evidence now shows the frequency and distribution of swarming populations of both species increased during the late nineteenth century. The grasshopper responded almost immediately, the locust only swarmed when migrations brought it to the new habitat conditions on the southern plains. Their responses to different seasonal conditions, however, diverged in the twentieth century.

A. cruciata declined in prominence as an agricultural pest in the south-east after the 1940s, with the return to wetter conditions and improved land management in the second half of the century.[40] While swarms still sometimes develop in parts of Andrewartha's 'grasshopper belt', they no longer illicit a

[39] Except in the drought year of 1923.

[40] B. Vives and R. N. Jones, 'Detection of abrupt changes in Australian decadal rainfall (1890–1989)', *CSIRO Atmospheric Research Technical Paper 73*, (Melbourne, 2005), p. 23.

government control response. The locust, on the other hand, maintained irregular plague populations through frequent migratory exchanges between summer and winter rainfall regions. Some regions experienced a much greater frequency of swarm infestations during the twentieth century, particularly the anthropogenic grassland habitats of the Riverina and Central West of NSW.

A clear association of swarms of each species with different climatic conditions emerged from the detail given in reports and the environmental context presented in each of the thesis chapters. The locust came in wet years and the grasshopper in dry years. Most locust plagues occurred during La

The environmental prehistory of the locust and the grasshopper

Imagining the pre-European population patterns of *C. terminifera* and *A. cruciata* is beset with uncertainty. We know their current species ranges, habitat preferences, migratory capacity and behaviours. The gregarious phenotypes develop in crowded populations under particular environmental conditions, and those conditions must have occurred before the arrival of Europeans. However, the extent and duration of suitable habitats in south-eastern Australia would have been more restricted.

Both species depend on green vegetation during the active stages of the life cycle, but also on bare ground for basking, displaying and egg laying. They are therefore creatures of open grasslands, whereas dense perennial grasses previously dominated temperate habitats. Nevertheless, the Aboriginal practice of regular vegetation firing may have produced many temporary favourable habitats within the expanse of kangaroo grass. Conversely, the curtailment of Aboriginal burning is implicated in dense tree and shrub regrowth in areas such as the Cobar Peneplain, that now form barriers to diurnal swarm movements. *A. cruciata* swarming followed the expanded continuity of grazed and unstable habitats within its range.

It could be argued that *C. terminifera* migrations are an adaptation to the spatially variable and temporary habitats within its arid core habitat, and that winds associated with low pressure systems always brought some migrants southwards. Although the southern grasslands were usually too densely covered for widespread egg laying, the species photoperiodic diapause response appears to be adapted to avoid winter conditions that are too cold in the southern, as well those that are too dry in the northern parts of the species range. This could indicate that southern and eastern regions were regular refuge habitats during extreme droughts.

The change to a sparse and often ephemeral grass cover in the southern grasslands produced an expansion of favourable habitats. Combined with later extensive tree clearing in eastern regions, this allowed populations to establish more frequently, explaining the increase in locust infestations in NSW in the early twentieth century. The southern populations often flourished during autumn and spring, therefore providing larger and more frequent return migrations into summer rainfall areas in Queensland. Thus, the feedback of population exchanges between summer and winter rainfall zones could have increased the frequency of *C. terminifera* plagues. The common pattern of infestation development seen in the twentieth century might also be the result of previous landscape changes in southern Australia.

Niña phases of the El Niño Southern Oscillation (ENSO). Grasshopper swarming often intensified during El Niño periods, most clearly shown during the Federation drought. The information is summarised graphically in Appendix 7, although a multivariate statistical test of those associations has not been attempted. While the measured Pacific Ocean temperature differences used to calculate ENSO values are often maintained over many months, inter-month variation is also common. The shift between opposite states can be rapid and the establishment of either condition rarely matches calendar years, so assigning a year as El Niño or La Niña may often not reflect regional rainfall.[41] Ocean–atmosphere teleconnections with rainfall in eastern Australia are also regionally variable.

The use of ENSO indices to categorise time periods is a blunt instrument for explaining plague occurrence and data on which ENSO values are based are only available from the 1870s. However, proxy reconstructions for Australia based on multiple information sources, including tree ring, ice-core and coral data now extend back beyond the historical period. These reconstructions also identify protracted ENSO events, periods of three or more years of consistent trends of either El Niño or La Niña conditions.[42] The scale of those persistent trends often match prominent locust or grasshopper plague periods.

The human dimension

While this environmental history has focused on the response of the two insect species to landscape and climatic changes, human 'players' were also living in changing environments. The responses of succeeding generations of politicians, scientists, farmers and others to the insects' repeated occurrences are framed by the landscape, but were linked to broader economic, political and cultural histories. Newspaper sources bring a perspective to the locust events and the views of all those affected that is not available in official records.

The direct experiences of generations of rural communities and the vicarious experiences of their urban cousins are part of this story. Farmers watched many seasons and the soils fail, as they saw locust experts come and go. Their views of the practical and ecological science are sometimes expressed in the newspapers. Most accepted the recommended ways of dealing with the pests, but there was always a degree of scepticism about the scientists' capacity to grasp the practicalities and the scale of the problem.

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[41] G. McKeon, W. Hall, B. Henry, G. Stone and I. Watson, *Pasture Degradation and Recovery in Australia's Rangelands: Learning from History*, (Indooroopilly, Department of Natural Resources, Mines and Energy, 2004). The authors use July–December average SOI to match with April–March rainfall in bracketing of ENSO monthly values to define El Niño and La Niña periods.
[42] Joelle L. Gergis and Anthony M. Fowler, 'A history of ENSO events since AD 1525: implications for climate change', *Climatic Change*, 92 (2009), 343–387, Table 10, p. 375.

The grasshoppers of the 1840s were recognised as an annoying but short-lived annual pest rather than a major threat to agricultural development. This view changed by the 1860s. Swarms were worse in dry years, not only damaging the struggling crops, but consuming the squatters grass across several colonies. Many people saw the arrival of locust swarms in the 1870s as objects of fascination rather than fear, but within a year rural subscribers gave accounts of disastrous agricultural and domestic damage. The common question was whether they were the same destructive insects of European and Eastern myth, and whether they would become as bad as the incredible stories emanating from other countries. By the 1890s there was a general perception that the swarms were spreading and becoming more frequent. This was expressed in all states in the first half of the twentieth century, and the reconstruction of outbreaks suggests it was based in fact.

People lived and coped with the locusts and they came to represent just one among the many trials of the settler. The overwhelming challenges of 'droughts and flooding rains' featured in the creation of a national identity from experiences in rural Australia, but several other characteristics of life on the 'wide brown land' were missed from Dorothea Mackellar's iconic poem.[43] Locusts were such a familiar and concerning feature of agricultural life they were often mentioned with droughts, floods and bushfires. One comprehensive list from 1880 included 'floods, droughts, rust, pleuro, grasshoppers, burrs, thistles, inspectors and mice'.[44]

The outbreaks produced a cascade of political reactions. Politicians were expected to act and scientists to provide answers. Newspapers were used to mobilise landholders as part of attempts to collectively 'control' nature. The media and politicians were quick to adopt the metaphors of war for locust pests that were established after 1918 and amplified after 1945. The more humans battled against the insects and utilised wartime technologies, the more frequent those references became. When the investigations turned to the insects' ecology, it was construed as 'science declares war on grasshoppers'.[45]

There are aspects of the human historical experience of locusts the thesis has not examined, including the geographical inequalities of health risks involved in widespread pesticide use. The higher frequency of locust swarms occurring in certain regions, and regular control responses in agricultural districts, increased the likelihood of potential negative health effects for people in those areas. By the 1970s, farmers, agricultural workers and Pastures Protection Board staff in NSW had born the risks of

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[43] Dorothea Mackellar's 'My Country' was written in 1904 and published in 1908.

[44] *The Maitland Mercury and Hunter River General Advertiser*, 20 April 1880, p. 6.

[45] *Tweed Daily*, 8 October 1937, p. 4.

exposure from the repeated use of organochlorine insecticides for twenty years. Although the formulations changed, most spraying and baiting had been done with BHC and its derivatives.

The regions most affected by organochlorine insecticides were the same ones where arsenic baits and sprays were used most frequently from the 1920s to the 1940s. Exposures could occur during handling and use in baits or ground spray equipment, but also during government organised aircraft spraying campaigns. The use of aircraft introduced undetected contamination risks through spray drift.[46] People in the Central West and Riverina regions of NSW in particular were frequently mobilised to conduct locust control, whereas only brief campaigns were organised in the other states. In addition, farmers were already at greater risk of pesticide exposure, because of its increasing use in other agricultural applications.

Locusts were a spatially widespread and dynamically changing problem, and dealing with them was a challenge of political geography. French recognised this in the 1890s when he called for the cooperation of the NSW and South Australian governments. Each state however, had a different perspective on the scale of the problem and therefore how it should be addressed. In addition, there were different local political views. The willingness to accept and participate in state-run control programs diverged along occupational lines in the late nineteenth century. Pastoralists had less to lose and more country to cover than cereal farmers, who often depended on precarious seasons to harvest just one crop in three.

In recommending each in the sequence of internationally accepted insecticide solutions, the entomologists were entangled by their institutional positioning. Required to formulate scientific locust control policy, they faced criticism if they did not embrace the newest technology, and to question the progress or success of any strategy would have compromised their professional role. The coincidence of a multi-state locust plague with the wheat crisis of the early 1930s brought several states to enact legislation making reporting and controlling locusts compulsory in 1934. That same year, a conference of agriculture ministers created the AAC as the mechanism for Commonwealth–state cooperation on national agricultural issues, and it made locusts one of the first national issues. It also gave the new national science agency, the CSIR, a new direction for its entomological research.

The first attempts to plot the distributions of swarms on state maps came in the 1930s and maps became an increasingly important tool for understanding, explaining and distilling information on how plagues developed. However, state maps could not capture the wider view of migrations between states. When the importance of breeding in inland Queensland became apparent in the 1960s, the

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[46] Jill Lindsey Harrison, *Pesticide Drift and the Pursuit of Environmental Justice*, (Cambridge, MIT Press, 2011).

political challenge of engaging many states with different perspectives on the problem became more complex. This time it was the conjunction in the early 1970s of a major plague across four states, spiralling costs of controlling several locust species, the culmination of an intensive CSIRO ecological research project, and a different strategy for monitoring and controlling locusts that resulted in the creation of the Australian Plague Locust Commission. This joint governmental structure was seen as addressing the political difficulties of managing an ecosystem-wide environmental challenge.

In 2000 Stephen Dovers challenged environmental history to make itself relevant to public policy.[47] We have seen that both of the southern locust species changed along with environmental changes in historical times. Perceptions of them also changed in line with the accumulation of environmental and scientific knowledge. Unstable and often denuded landscapes characterised their population peaks. Future environmental changes could cause both to change again, and there are other species that could also respond in unpredictable ways. Although an increase in swarming is identified in both species, their distinct ecologies produced responses to different seasonal climatic conditions. The rise and decline of *A. cruciata* was direct, rapid and persistent; for the locust the response was lagged and spatially unpredictable. With the agriculturally important Murray–Darling Basin falling within the range of both species, future land use changes could alter their pest status again.[48]

As the scope of environmental history expands to address many issues of current relevance it has also been called on to engage with the social sciences.[49] There is a renewed interest in approaching locust problems with integrated social and scientific research, and in finding different ways of managing their ongoing environmental challenge. Integrated approaches involving knowledge of landscape ecology as well as insect ecology are reminiscent of Uvarov's hope for ecological modification of habitats to manage populations. Knowledge of the long historical relationship between scientific research and government engagement might bring different perspectives, including the socio-environmental, to ideas and policies about the way that this and other environmental challenges are dealt with in the political and public arenas.

[47] Stephen R. Dovers, 'On the contribution of environmental history to current debate and policy', *Environment and History*, 6 (2), (2000), 131–150.

[48] As politicians also return to 'developing northern Australia', locusts are a reminder of possible environmental challenges. The yellow-winged locust, *Gastrimargus musicus*, which has affected northern agricultural enterprises in the past, is currently a pest in northwest WA where pastures are being irrigated through the dry season.

[49] Sverker Sörlin and Paul Warde, 'The problem of the problem of environmental history: a re-reading of the field', *Environmental History*, 12 (1), (2007), 107–130.

Appendix 1. Sample of my summaries of newspaper reports, South Australia 1873

(red highlights diagnostic descriptions, blue natural enemies)

1873

6.1.73 — GULNARE — myriads, quarter to half inch (second gen)

6.1.73 — NEALES PLAINS, AUBURN, new hatchings, holes 1” apart (24 Dec)

6.1.73 — PT ELLIOT, PT VICTOR, considerable numbers but no damage

6.1.73 — BURRA, little damage

13.1.73 — WATERVALE, thousands of young commencing to hop

15.1.73 — ADELAIDE, now in the streets

15.1.73 — PT LINCOLN, now disappeared

15.1.73 — BUSCHFELDE, swarms young gh in our fields

17.1.73 — WAKEFEILD PLAINS, injured some crops, but at AUBUURN,1/8th in hopper thick in patches

17.1.73 — BUSCHFELDE, young seen

24.1.73 — AUBURN, still millions of young to be seen

25.1.73 — PENOLA, locusts eating everything green, thistles included

27.1.73 — MT GAMBIER damage to gardens

3.2.73 — HARVEST of 72–73: STOCKPORT, the locust pest seems to have been more imaginary than real, ANGASTON, half oats lost to locusts (Register)

11.2.73 — (Kapunda Herald, p.2) We believe much good has been found to result at Anlaby from the introduction of a large number of cats which are turned loose on the run, and which make sad havoc amongst the young bunnies. It is, however, somewhat problematical whether on a sheep run the cure may not ultimately prove almost as hurtful in its results as the evil sought to be remedied, inasmuch as in the course of two or three generations the domestic cat will have degenerated into the wild species, by which the safety of the young lambs will be greatly imperilled.

11.2.73 — (Register) Harvest: mostly not damaged, but MT BRYAN and H. Inkerman, Balaklava, Nairne, some damage reported

11.2.73 — BORDERTOWN, covered with locusts

28.2.73 — NARRACOORTE — eating everything green

1.3.73 — DRY CREEK — present swarms hatched from eggs laid a month or 2 ago.

3.3.73 — ADELAIDE, Cricket Assoc intercolonial match cancelled because of locusts.

4.3.73 — TARLEE, locust eaten all the grass

4.3.73 — ADELAIDE, swarming in gardens

5.3.73 — HAMLEY BRIDGE, eaten grass (25 Feb), MELROSE & PT AUGUSTA, swarms

6.3.73 — McDONNELL BAY, beach for 8 miles a bank of dead locusts up to a foot deep (SA Adv, p2) fear stench of vast amount of dead matter will cause some epidemic

6.3.73 — MT REMARKABLE, just returned, crops not affected (Register, p.3.)

7.3.73 — KANGAROO ISLAND, (Kingscote) paying a visit and polishing off everything green (Register,7)

7.3.73 — STOCKPORT, (E Kapunda) millions locusts eating everything green (Kapunda Herald,3)

7.3.73 — ENCOUNTER BAY (West Island) myriads locusts floating on water, great number of snappers leaping to get them, caught 20–30 fish and they were found to be crammed full of locusts, now lying on beach, drayloads of them washed up by the sea (Register,5)

7.3.73 — LANGHORNES BRIDGE, passed through (MULGUNDAWA) locusts attacking sheaok — fear unless some means can be devised to materially lessen number, damage to crops next season if they come as they did last year before crops were thoroughly ripe (Sthn Argus, 3)

7.3.73 — PT AUGUSTA, air filled as far as the eye could see (3 Mar) travelling N (Register, 7)

7.3.73 — MANOORA, busy on gardens

7.3.73 — PT ELLIOT, large swarms infesting — all along beach lying dead in heaps (Register, 4)

7.3.73 — LAKE PLAINS (Pt Elliot) such clouds as to completely obscure the scenery … the scene baffles description, the insects being so numerous as to resemble at a distance thick clouds (Sthn Argus, p. 2.) on p. 3, all Wednesday morning (5 march) a fierce hot north wind

13.3.73 — GREENOCH, eaten everything

12.3.73 — (CURIOUS) parasites, can anyone throw light on parasites … I have found a great many on taking off the head to contain maggots … curious dispensation of providence (Register, 5).

13.3.73 — detailed method of sweeping large nets, stout wire hoops among the ‘clumsy’ nymphs best method (Robert Bruce) (Reg, 5)

14.3.73 — AUBURN, very destructive here last fortnight — more than ever before

15.3.73 — CALLINGTON, CLARENDON, TEMPLERS, immense swarms

17.3.73 — KANMANTOO, visited by swarms

17.3.73 — WELLINGTON, plentiful

17.3.73 — RIVERTON, all veg matter gone, except cockspur (SA Adv, 3)

17.3.73 — SANDERGROVE, eaglehawks, locusts destructive

22.3.73 — MT BARKER, swarms arrived 17 Mar.

25.4.73 — WATERVALE, end of March & April, noticed maggots in these pests, never heard the matter fully explained — some say they will become caterpillars, some ½” long and thick in proportion (Nthn Argus, 3)

31.3.73 — THE MEADOWS, damaged young barley

31.3.73 — ALDINGA, MT BRYAN, bad

22.3.73 — MT BARKER, swarms arrived

29.3.73 — AUBURN, still swarms

31.3.73 — (Border Watch — very destructive , where?)

4.4.73 — ADELAIDE HILLS, HAHNDORF (Kapunda Herald, 2) Some of the gardeners have lost from 3,000 to 20,000 cabbage plants, besides young turnips and potatoes. In the neighbourhood of Handorf the locusts have consumed the young barley sown for early feed, and the lucerne, also the mangold-wurtzel, which is grown extensively by our German friends. What the upshot of this calamity will be it is hard to conjecture. Should the plague continue, it is feared by some people that tbe young corn, in its season, will suffer; but we have never known the locusts do much mischief in the winter time in this country.

4.4.73 — ADELAIDE (Sthn Argus, 2), locusts are still numerous. The fly which attacks them and deposits a maggot in them is busy at work, and may occasionally be seen striking its prey to the ground.

4.4.73 — KANMANTOO, damage to vines

7.4.73 — SALISBURY, gravel strewn with dead after frost

11.4.73 — COOKES PLAINS, eating all green grass.

12.4.73 — MELRSOE, MENINGEE, NAVAN, millions, but dying out, some peculiar maggot has attacked them (SA Adv, 3)

15.3.73 — RIVERTON, FREELING

17.4.73 — NARACOORTE — plentiful

18.4.73 — CLARE, CLARENDON, HOYLESTON

19.4.73 — KAPUNDA, locusts thick for miles together, up to 400 miles to the north, heading E.

22.4.73 — BUNGAREE — 2/3 barley taken

25.4.73 — TOTHILLS BELT, gh have not left a blade of grass (Kapunda Herald, 3)

7.5.73 — KOORINGA, no feed but plenty of gh

8.5.73 — DRY CREEK (Pt Augusta), great nuisance past 2 or 3 months, we have had 4 generations, no question worse than last year. (SA Adv, p. 3.)

23.5.73 — MT BARKER, several sharp frosts, have completely destroyed the locusts (Sthn Agus, 3)

26.5.73 — BLINMAN — locusts all dying, some from maggots.

5.9.73 — NAIRNE, few appeared some weeks ago, but soon disappeared?

12.9.73 — KOORINGA, locusts appeared a short time since?

20.9.73 — NEALES PLAINS, so far none, last year swarming at this time

2.10.73 — WALLAROO, numbers of locusts seen, acreage lower but the dung cart is at work all year round (Register)

3.10.73 — NAIRNE — locusts too late

3.10.73 — KOORINGA, beginning to appear in large numbers

3.10.73 — TUNGKILLO, BORDERTOWN, STRATHALBYN, immense numbers (nymphs)

3.10.73 — BLINMAN, (29 Sep) millions just hatched, 1/8th inch long

4.10.73 — WALLARAOO, appeared

10.10.73 — KOORINGA, disturbed myriads, in great numbers, all very young, only not on wing (SA Chron, 10)

11.10.73 — birds (saved)

11.10.73 — WELLINGTON, methods of killing, E.C. Hughes

17.10.73 — ULOOLOO, appearing, too small to do damage

18.10.73 — THE HUMMOCKS, myriads as yet very small

18.10.73 — BLINMAN, acres of young locusts everywhere

18.10.73 — YORKE PEN, KALPARA, appearing thickly

27.10.73 — WELLINGTON, now showing in myriads

22.10.73 — STRATHJALBYN (Clare||Kapunda) swarming myriads (nymphs?)

22.10.73 — REYNELLA, bag young locusts

23.10.73 — NATIVE VALLEY, awful quantities of small gh (21 Oct)

24.10.73 — MT BRYAN EAST, innumerable in patches, KAPUNDA, KOORINGA, CALTOWIE, MELROSE, JAMESTOWEN, (hatching)

27.10.73 — KANMANTOO, MT TEMPLETON, ¼ inch long, thick

27.10.73 — JAMESTOWN, locusts insignificant scale, (no rain for 6 weeks)

30.10.73 — locusts in nearly every district, but as yet very small incapable of doing damage for a few weeks

29.10.73 — WILLUNGA, 1/8 inch, thousands, RC Hughes has already shown how can be killed at this stage

31.10.73 — STRATHALBYN, BORDERTWON, TUNGKILLO — gh the size of flies, hatching

31.10.73 — COROMANDEL VALLEY — young half inch

1.11.73 — TRURO, YORKE VALLEY, making appearance

1.11.73 — HANSON, here in myriads but no damage

7.11.73 — MORPHETT VALE,WOODSIDE,NARRIDY, young, ground covered in places

8.11.73 — BROUGHTON EXT, never before seen in 34 years, compared to what I see here, backward crops literally black with locusts. (SA Chron & Weekly Mail, 7)

8.11.73 — MORPHETT VALE, ground covered young grasshoppers, WOODSIDE, not much damage, NARRIDY, GULNARE, beginning to appear (Ad Obs, 6)

8.11.73 — YORKE VALLEY — thousands of young appeared

15.11.73 — PORT ELLIOT, BULLS CK, NEALES PLAINS

21.11.73 — along valley of Murray myriads, and at VIC locations

21.11.73 — mentions France and rewards (SA Adv, 3)

21.11.73 — LANGHORNES BRIDGE, appears to be the birthplace of myriads locusts. There is Legisl. for Scotch Thistles, but gh worse if they increase in next 2 y as they have the last (Sthn Argus, 3)

21.11.73 — PT ELLIOT, (Sthn Argus, 2) Mr Lamshed brought in several bags weighing 5 cwt, he bagged in an hour.

21.11.73 — AUBURN, few, YORK VALLEY, numerous in places but not general, PT ELLIOT, destroyed green feed, but not crops. MT BRYAN, first day swarming in air, innumerable on ground. Numbers dying, dozens under tufts of grass (Register, 3)

27.11.73 — MT BARKER, appeared, THE MEADOWS, STRATHALBYN, NARRIDY, BROUGHTON, BELALIE — burning partly developed insects

27.11.73 — BLINMAN, locusts disappeared (22 Nov)

28.11.73 — MELROSE, not as many as last year, NARRIDY, numerous, now on wing (25 Nov)

29.11.73 — DRY CREEK, TOTHILLS CK, BURRA, thriving, muster in great forces in places

29.11.73 — ADELAIDE, all over road at Penfield, scarcely able to fly (laying, parasite or fledgling?)

29.11.73 — STRATHALBYN, ground black with them (Ad Obs,3)

29.11.73 — STIRLING NTH, appeared clouds like heavy snow, coming from N, PT AUGUSTA, great influx, like clouds of dust, crossed Gulf on 23 Nov, NARRIDY, now on wing, MELROSE, MT BARKER, numerous, BUNGAREE RUN (Hawker's) almost entirely confined to grass paddocks.

29.11.73 — STRATHALBYN, head eaten off wheat (SA Chron, 10)

5.12.73 — 'Engineer' (from 7.7.71) Anti-locust machine USA, and blacksmith Salt Lake USA (scraper)

5.12.73 — HALLETT, damage, KOORINGA locusts

5.12.73 — AUBURN, not shown themselves here

5.12.73 — MT BRYAN, came in swarms, damage to wheat, places not left an ear for yards, yield will be light

5.12.73 — CANOWIE, locusts damage to late crops

5.12.73 — WELLINGTON, damaging fruit trees

5.12.73 — STRATHALBYN, description

6.12.73 — ANGASTON, no crop damage at present, MOCULTA, swarms in millions

6.12.73 — NOARLUNGA, CLARENDON, appearing but small, APILLA, MEADOWS, millions

8.12.73 — MT BRYAN — swarms

12.12.73 — KOORINGA, damage to crops

13.12.73 — STRATHALBYN, surrounded, patches yards, surface alive, RIVER ANGUS, piled thickly, heaped together, incessant sound as they jump against windows like pattering of rain.

19.12.73 — STIRLING NORTH (20 Nov) swarms, PT AUGUSTA crossed Gulf 23 Nov

23.12.73 — CALLINGTON, plentiful, but not much damage

27.12.73 — MELTON, when first appeared as detached patches 30–40 ft, where they were a couple of inches thick

Appendix 2. Journals of explorers and settlers

List of early explorers' and settlers' journals checked for records of locusts or grasshoppers. Several of those were available as digitised files, allowing keyword searches:

Explorers:

Thomas L. Mitchell 1836, *Three Expeditions into the Interior of Eastern Australia*, Volume 1, (London, 1838), http://gutenberg.net.au/ebooks/e00035.html , on January 27, noticed a black insect nearly as large as a bird carrying something like a grasshopper; *Three Expeditions into the Interior of Eastern Australia*, Volume 2, (London, 1838), http://gutenberg.net.au/ebooks/e00036.html

George William Evans 1813–15, *Two Journals of Early Exploration in New South Wales*, (Sydney, 1916), http://gutenberg.net.au/ebooks13/1300271h.html

John Oxley, 1817–18. *Journals of Two Expeditions into the Interior of New South Wales*, http://gutenberg.net.au/ebooks/e00037.txt

William H. Hovell and Hamilton Hume, 1824 — *Journey of Discovery to Port Phillip*, http://gutenberg.net.au/ebooks04/0400371.txt

Edward J. Eyre, 1840–41, *Journals of Expeditions of Discovery into Central Australia, and Overland from Adelaide to King George's Sound in the Years 1840–1* (London, 1845), https://ebooks.adelaide.edu.au/e/eyre/edward_john/e98j/

Charles Sturt, 1844–46 — *An account of the sea coast and interior of South Australia*, (1847), https://ebooks.adelaide.edu.au/s/sturt/charles/s93a/; *Narrative of an Expedition into Central Australia*, http://gutenberg.net.au/ebooks/e00058.html, 'There are in South Australia two periods of the year which are equally deceptive to the stranger. The one is when the country is burnt up and suffering under the effects of summer heat--when the earth is almost herbless, and the ground swarms with grasshoppers--when a dry heat prevails in a calm still air. The other when vegetation is springing up under the early rains and every thing is green' …. Ground Grauculus. There were not more than six or seven of this bird seen during the progress of the Expedition, and that only at the Depot. They were exceedingly wild and wary, keeping in the centre of open plains and feeding on locusts and grasshoppers.

Ludwig Leichardt, 1844–45, *Journal of an Overland Expedition in Australia, 1844–45*, https://ebooks.adelaide.edu.au/s/sturt/charles/s93a/

George Goyder, 1857, *Explorations in South Australia 1856–1882,* (Adelaide, South Australian Parliament, 1857–1882)

Stephen Hack, 1857 — S. Hack, 'Explorations by Mr S. Hack', No. 156 in *Explorations in South Australia 1856–1882,* (Adelaide, South Australian Parliament, 1857–1882)

A. H. Freeling 1857 — No. 193 in *Explorations in South Australia 1856–1882,* (Adelaide, South Australian Parliament, 1857–1882)

Benjamin Babbage, 1856, in *Explorations in South Australia 1856–1882,* (Adelaide, South Australian Parliament, 1857–1882).

John McKinlay, 1861–66, *McKinlay's Journal of Exploration in the Interior of Australia*, (Adelaide, South Australian Parliament, 1857–1882).

Peter E. Warburton 1857, 1860–64. — *Explorations in South Australia 1856–1882, No. 177,* (Adelaide, South Australian Parliament, 1857–1882); *Journey across the Western Interior of Australia* (London, 1875), http://gutenberg.net.au/ebooks12/1202821h.html

John McDouall Stuart, 1858–62 — *The Journals of John McDouall Stuart during the years 1858,1859,1860,1861 & 1862*, http://ebooks.adelaide.edu.au/s/stuart/john_mcdouall/journals/complete.html ; second expedition 20 May 1861 – Lawsons Ck, Sturt Plain, grasshoppers in myriads on plains (this is north of Elliott in the NT)

Augustus C. Gregory and Francis T. Gregory, 1846–48 — *Journals of Australian Explorations*, (Brisbane, 1884), http://gutenberg.net.au/ebooks/e00029.html

William Landsborough, 1862, 1866 – *Journal of Landsborough's Expedition form Carpentaria, in Search of Burke and Wills*, (Melbourne 1862), http://gutenberg.net.au/ebooks/e00029.html, 29 March 1862–Landsborough Creek –22 deg. 27' (near Muttaburra), Fisherman believed grass eaten off by grasshoppers.

William John Wills, 1981 — *Successful Exploration through the Interior of Australia, from Melbourne to the Gulf of Carpentaria*, (London, 1863), http://gutenberg.net.au/ebooks/e00060.html

List of early settler's journals:

James Atkinson, *An Account of Agriculture and Grazing in New South Wales*, (London, 1829), 'locusts are abundant in summer, but have never been known to do damage'.

James Backhouse, *A Narrative of a Visit to the Australian Colonies*, (London, 1853), p. 22, described *Gastrimargus* at Hobart in 1837, 'grasshoppers with wings of black and yellow were very numerous, so as to be injurious to the vegetation'.

Hermann Beckler, *A Journey to Cooper's Creek*, (translation by Stephen Jeffries), (Melbourne, Miegunyah Press, 1989).

John Wrathall Bull, Early Experiences of life in South Australia and an Extended Colonial History (Adelaide, 1884).

Robert H. Croll, *I Recall: Collections and Recollections*, (Melbourne, Robertson and Mullens, 1939).

Peter M. Cunningham, 1823–1827, P. M. Cunningham, *Two Years in New South Wales: a Series of Letters, Comprising Sketches of the Actual State of Society in that Colony; of its Peculiar Advantages to Emigrants; of its Topography, Natural History, etc., etc.*, 2 volumes, (London, Henry Colburn, 1827), https://archive.org/stream/twoyearsinnewso01cunngoog/twoyearsinnewso01cunngoog_djvu.txt

Alice M. Duncan-Kemp, *Our Sandhill Country: Man and Nature in South-west Queensland*, (Sydney, Angus and Robertson, 1933), p. 118, 'plague of giant crickets one night … fat yellow bodies, long pointed wings, eaten by men'.

Mary Durack, *Kings in Grass Castles*, (London, 1981), p. 137, after rain and floods in November 1872, locust nymphs destroyed gardens at Thylungra in Southwest Queensland.

Finney Eldershaw, *Australia as it Really Is*, (London, 1854), p. 46, 'the locust is prolific... a serious inconvenience to the settler. Eldershaw was referring to 1842–44, when he travelled to the Darling Downs in southern Qld (p. 142.), possibly encountering the swarms reported on the Liverpool Plains NSW.

Mrs James Foote, *Sketches of life in the bush, or Ten Years in the Interior*, (London 1872).

Joseph Hawdon, *Joseph Hawdon's Journal of his Overland Journey by tandem from Port Phillip to Adelaide with Alfred Mundey: with accounts of earlier journeys of Charles Bonney, 1839, and Foley, Stone and Stanley, 1837*, (Adelaide, Sullivan's Cove, 1984).

Willian Howitt, *A Boy's Adventures in the Wilds of Australia, or Herbert's Notebook*, (Boston, 1854).

John Lewis, *Fought and Won*: *autobiography of a South Australian*, (Adelaide, 1922), pp .68–69. In February 1872, locusts were numerous at Pekina Creek, Moolooloo, My Lyndhurst, Mundowdna,

between Lake Phipps and Lake Eyre…. country covered with grass as far north as Mt Margaret in Queensland

Louisa A. Meredith, *Notes and Sketches of New South Wales*, (London, 1844), p. 62, describes ‘grasshoppers’ making an ‘indescribable’ noise, in the Bathurst area found them to be insects of the true grasshopper shape, with small wings, and about an inch long ; but these colonies swarm with an immense variety of these long-legged insects of all sizes, from a quarter of an inch to two inches in length, and of all colours ; brown in every hade (particularly the tints of withered grass and dead gum-leaves), green of the brightest hues, grey, black, reddish, and purple. Many of the large ones are very handsome and curious creatures’.

Edward Snell, *The Life and Adventures of Edward Snell*, (North Ryde NSW, 1988), p. 165, No. 57, in 1850 in South Australia, Among several ‘locusts’ sketched, one is likely to be *A. cruciata*, particularly as it was described as green and yellow in colour.

William Westgarth, *Australia Felix; or, a Historical and Descriptive Account of the Settlement of Port Phillip, New South Wales’*, (Edinburgh, 1848).

Appendix 3. Publications during PhD candidacy

In producing this interdisciplinary thesis I was able to engage in some of the relevant disciplines from which it draws. They include the history of science, environmental history, ecological science, quantitative natural history, ecological modelling and even an overview of policy. Not all are about locusts, but insects feature in all of them. The research proved valuable to the development of the thesis, and ideas presented in some chapters are drawn from these publications.

E. D. Deveson, 'The search for a solution to Australian locust outbreaks: how developments in ecology and government responses influenced scientific research', *Historical Records of Australian Science*, 22 (2011), 1–31.

M. P. Chapuis, J. A. Popple, K. Berthier, S. J. Simpson, E. Deveson, P. Spurgin, M. J. Steinbauer and G. A. Sword, 'Challenges to assessing connectivity between massive populations of the Australian plague locust', *Proceedings of the Royal Society B*. 278 (2011), 3152–3160.

E. D. Deveson, '*Naturae Amator* and the grasshopper infestations of South Australia's early years', *Transactions of the Royal Society of South Australia*, 136 (1), (2012), 1–15.

D. Eagles, T. Deveson, P. J. Walker, M. P. Zalucki and P. Durr, 'Evaluation of long-distance dispersal of *Culicoides* midges into northern Australia using a migration model', *Medical and Veterinary Entomology*, 26 (3), (2012), 334–40.

E. D. Deveson, 'Satellite normalised difference vegetation index data used in managing Australian plague locusts', *Journal of Applied Remote Sensing*, 7 (2013), (075096), 1–21.

T. Deveson and J. D. Woodman, 'Longevity relative to temperature of *Scelio fulgidus* (Hymenoptera: Platygastridae) emerging from Australian plague locust (*Chortoicetes terminifera*) eggs', *Australian Journal of Entomology*, 52 (2013), 277–281.

E. D. Deveson, 'The Adelaide Philosophical Society and the early accommodation of the Darwin-Wallace theory of Natural Selection', *Transactions of the Royal Society of South Australia*, 137 (2), (2013), 151–167.

T. Deveson and J. D. Woodman, 'Observations of *Scelio fulgidus* (Hymenoptera: Platygastridae) parasitism and development in southern NSW during the 2010 *Chortoicetes terminifera* (Orthoptera: Acrididae) locust plague', *Austral Entomology*, 53 (2014), 133–137.

E. D. Deveson and J. D. Woodman, 'Embryonic diapause in the Australian plague locust relative to parental experience of cumulative photophase decline', *Journal of Insect Physiology*, 70 (2014), 1–7.

S. Veran, S. J. Simpson, G. A. Sword, E. Deveson, S. Piry, J. E. Hines, and K. Berthier, 'Modeling spatiotemporal dynamics of outbreaking species: influence of environment and migration in a locust', *Ecology*, 96 (2015), 737–748.

C. Adriaansen, J. D. Woodman, E. Deveson and V. A. Drake, 'The Australian Plague Locust—Risk and Response', in eds. J. F. Shroder and, R. Sivanpillai, *Biological and Environmental Hazards, Risks, and Disasters*, (The Netherlands, Elsevier, 2016), pp. 67–86.

E. D. Deveson, ‘Parasites, politics and public science: the promotion of biological control in Western Australia, 1900–1910’, *British Journal for the History of Science*, 49 (2016), 231–258.

E. Deveson and A. Martinez, ‘Locusts in Southern Settler societies: Argentine and Australian Experience and Responses, 1880–1940’, in eds. E. Vaz, C. Joanoz de Melo, C. Pinto and M. Ligia, *Environmental History in the Making. Vol 1. Explaining*, (Switzerland, Springer, 2017), pp. 259–286.

Appendix 4. How bad were the locusts?

South Australia's informal network of rural agricultural reporting allowed for rapid wheat planting and yield statistics to be calculated by the official statist Josiah Boothby. In 1872 there was little cultivated land north of Jamestown, but then rapidly expansion to the north. Despite grasshoppers having damaged crops for many years, the plague was called 'almost a new one' as the locusts 'were so very destructive on their first appearance'.[1]

The total and average figures published in 1873 and 1875 show yields alternated during the plague, despite a steady increase in area planted. The considerable drop in wheat yield for 1871–72 over the previous year (from 150,000 to 99,000 tons*), despite an increase in area sown, was attributed to red rust and the locusts. However, separating the impact of the locusts from weather and other factors is not possible.

	1869–70	**1870–71**	**1871–72**	**1872–73**	**1873–74**	**1874–75**
Total yield (bushells)	3,652,320	5,981,154	3,967,069*	8,735,912	6,178,816	9,862,693
Total (tons)	91,308	149,529	99,177	218,398	154,470	246,568
Average yield per acre (bushells)	5.7	11.5	5.7	11.5	7.9	11.8
Total area (acres)	532,135	604,761	692,508	759,811	784,784	839,638

The values are for crops taken-in at the end of the second year (i.e. 1871–72 is for crops harvested at the end of 1872). *NOTE: *Register*, 10 April 1873, p. 5, 1871–72 yield given as 4,768,833 bushels or 119,220 tons.

In January 1872 *The South Australian Register* began a series of harvest return questionnaires for each agricultural district, which included estimates of yield, area planted, crop varieties and of damage from various sources, such as rust, hot winds, frost, storms and locusts. Wheat varieties of the time grew to 5 feet, so hot winds were a threat, and crops cut for hay to avoid threatened losses from locusts. These records offer a chance to trace regional impacts of locusts through time, and some comparison of the effects of locusts with those of grasshoppers in later years. In the 1870s, crops yields were also being affected by a new and increasing pest — the rabbit. From 1872 rabbits were mentioned in local estimates of yield losses, although their numbers and extent had been increasing for several years.

Most detail on damage from locusts was reported for the 1871–72 harvest. Locusts and red rust combined to reduce expected yield by up to two-thirds in places. Some reports were by settlement district, others by hundreds. Some locust damage was reported from Angaston, Nuriootpa, Truro,

[1] *South Australian Advertiser*, 2 Jan 1873, p. 2; *South Australian Chronicle and Weekly Mail*, 3 April 1875, p. 8.

Williamstown, Grace Plains, Kapunda, Auburn, Farrells Flat and Penwortham. Between one third and two thirds of the crop was estimated lost from Mintaro, Booborowie, Steelton, Manoora, Black Springs, Marrabel, Springfield, Gulnare, Port Wakefield, Kooringa and, in its first year of cropping, Belalie.[2]

For the 1872–73 harvest estimates of loss were given as bushells/acre from some localities. There were general comments that locusts appeared too late to do much damage and that grass was so plentiful, 'it no doubt saved the crops'.[3] At Stockport it was said 'they were more imaginary than real'.[4] However, local crop damages of one-third were reported at Mt Bryan, Parrot Hill (Angaston), Murray Flats, Marrabel, Burra, Kallington, Balaklava and Port Lincoln.

For 1873–74, again some districts reported the locusts came too late and more damage was done to the grass than crops (Gulnare, Narridy), but some was reported from Melrose, Clarendon, Woodside, Mt Bryan, Port Elliot, Kapunda, Caltowie, Laura, Kooringa, Angaston, Canowie, Hallett and Broughton.[5]

The following year, 1874–75, very little damage was reported, with only 1 bushell/acre loss at Booborowie.[6] One correspondent thought the farmers were 'more frightened of locusts than hurt' and another that 'harm arises from exaggerated damages or excessive acreage estimates', first to credit and storekeepers and second, an expectation of abundant crop.[7] Locusts and rabbits were mentioned only at Mt Bryan for 1875–76, and in the following two years it was lack of rain that reduced yields.[8]

There is a case for locusts having significantly impacted on South Australian wheat yield for 1871–72. Rainfall records show 1870–72 were wet years in the wheat growing districts around Burra, Kapunda, Strathalbyn, Bungaree and Auburn.[9] For later years however, these records would suggest that the overall effect was minimal.

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[2] *South Australian Register*, 29 December 1871, p. 5; 12 January 1872, p. 6; 27 January 1872, p. 7.

[3] *Register*, 11 Feb 1873, p. 6; *Register*, 6 December 1872, p. 5.

[4] *Register*, 3 February 1873, p. 6.

[5] *Register*, 14 November 1873, p. 5; 28 November 1873, p. 5; 7 November 1873, p. 7; 21 November 1873, p. 3; 13 February 1874, p. 7.

[6] *Register*, 4 December 1874, p. 6; 16 March 1875, p. 7.

[7] *Register*, 21 December 1874, p. 5.

[8] *Register*, 30 December 1875, p. 5; 9 February 1877, p. 6; 20 February 1877, p. 6; 7 November 1877, p. 5.

[9] H. A. Hunt, *Results of rainfall observations made in South Australia and the Northern Territory for all years of record up to 1917,* (Commonwealth of Australia, Bureau of Meteorology, 1918), pp. 201–203.

Appendix 5. 1850s grasshoppers in Western Australia

In Western Australia, swarms of 'grasshoppers' appeared in the first decades of agricultural expansion. South of Perth in the Vasse River district around Busselton, swarms became an almost annual spring pest for twenty years from the early 1850s. Concerned about the grasshoppers getting continually worse, residents wrote to the Britain Royal Agricultural Society in 1857 hoping for a remedy. The 'highest entomological authorities' were consulted, including John Curtis and John Westwood. Curtis thought the 'employment of poultry' was the best answer despite the unknown 'economy' of the Australian species. Westwood may have been sent Charles Wilson's descriptions of the Adelaide locusts in 1845, as he 'knew' they belonged to 'the same group as the migratory locust'. He therefore suggested the methods tried against locusts in France.[1]

Infestations of the district in the late twentieth century have been caused by the 'wingless grasshopper, *Phaulacridium vittatum*.

[1] *Sydney Morning Herald*, 21 January 1855, p. 3; *The Enquirer & Commercial News,* 4 February 1856, p. 3; 14 October 1857, pp. 3–4.

Appendix 6. Locusts and grasshoppers 1930–32

The complexity of the events during 1930–32 highlights the difficulty of interpreting reports, particularly during spring.

Even when locusts were recorded in the previous autumn, or before the appearance of any swarms in January, grasshoppers could have been present and formed spring swarms in the same locations. Key found evidence that both species were active during 1930–32 and newspaper reports accord with his conclusions.

Swarms appeared suddenly in the Central West in late November and December, laying eggs at numerous locations as they migrated eastwards to Wellington, Dunedoo and Mudgee, and southwards to Parkes, Grenfell, Forbes and Cootamundra.[1] Bands of nymphs were reported at several locations in January 1931, indicating the species was *C. terminifera* and the following swarm generation penetrated further east to Eugowra, Young, Binalong, Yass, Gundagai, Junee and Tumut, where it was compared to the 1908 plague, reaching Wagga and Coolamon in late February 1931. The infestation continued in the following spring and summer, finally contracting to the eastern districts of Mudgee, Cowra, Boorowa, Cootamundra, Wagga, Albury and Jindera by February 1932.[2]

Gurney's report from Mathoura in October 1932 identified the nymphs in widely scattered patches as 'probably the smaller species of plague grasshopper'. Locust specimens were even collected near Canberra in 1931.[3]

In contrast to swarms increasing in summer in the eastern districts, by early December 1930 another plague in the southern Riverina and northern Victoria was subsiding.[4] In October, thousands of acres between Echuca and Deniliquin were affected by swarms. Crops were cut for hay in the Bunnaloo–Womboota district and at Mathoura sheep were sold off, one report commenting that it was 'strange this area has had the lightest rainfall'.[5] Further north there were reports at Jerilderie, Hay and Leeton, and in November grasshoppers were reported at Rochester and Castlemaine in Victoria and settled on the tennis courts in Echuca.[6] Despite heavy rainfall in December, there were no subsequent hatching

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[1] *Sydney Morning Herald*, 27 November 1930, p. 9, laying eggs at Narromine; *Narromine News*, 5 December 1930, p. 4, laid eggs at Trangie. Reports also laid eggs Dubbo and Denman in December.

[2] However, in late May 1932, trains were held up near Nyngan and Gilgandra, by dense patches of 'grasshoppers'. This was also noted by Key, suggesting he or his informants used newspaper sources.

[3] *Sydney Morning Herald*, 29 October 1932, p. 11.

[4] *Albury Banner*, 12 December 1930, p. 43, 'plague has subsided at Finley'.

[5] *Age*, 30 October 1930, p. 12.

[6] *Riverine Grazier*, 5 December 1930, p. 4.

reports in these areas until the following spring.[7] In September 1931, the Mathoura–Bunnaloo area was again infested, while in Victoria swarms were reported at Hopetoun, Ouyen and Warracknabeal in the Mallee district in mid-November, even appearing briefly further south at Stawell and Rupanyup.[8] Locusts would not have fledged until mid-November in the Riverina and early December in Victoria, making it fairly clear that the pest was an *A. cruciata*. Finley and Deniliquin in the Riverina were invaded at the end of September, and for the second year in succession grasshoppers swarmed through Hay, Narrandera and Leeton, where they had entered shops and the Roxy theatre to disrupt the film projection.[9] A feature of all these reports, in addition to the absence of known earlier nymph populations, was the nocturnal arrivals and the piles of dead left around the lights.[10] Again in September 1932, the same areas of the southern Riverina were infested, prompting the Department to despatch Gurney to investigate. At Deniliquin, it was the third year in a row they appeared, after many years free from their depredations.

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[7] Bureau of Meteorology, rainfall deciles monthly maps — Dec 1930, decile 10. http://www.bom.gov.au/jsp/awap/rain/archive.jsp?colour=colour&map=decile&period=month&area=nat&year=1932&month=4&day=30 , viewed 11 May 2016.

[8] *The Argus*, 18 November 1931, p. 12, Hopetoun; *Horsham Times*, 20 November 1932, p. 2, invaded Warracknabeal 9pm on 13 November; *The Age*, 12 November 1931, p.11, mild plague visits Stawell; 14 November, 1931, p. 13, Ouyen; 16 November 1931, p. 8. Rupanyup. Key, 1938, p. X, listed all these location in northwest Victoria, suggesting that Pescott had maintained newspaper clippings of grasshopper reports.

[9] Murrumbidgee Irrigator, 14 November 1930, p. 3, Narrandera Argus, 14 November 1930, p. 1. They flew through both towns on 10 November. Murrumbidgee irrigator, 10 Nov. 1931, p. 2. Invaded Leeton on night of 6 November.

[10] *Riverine Recorder*, 20 November 1931, p. 3. In addition to the towns mentioned, Barham and Koondrook reported grasshoppers pile inches thick under lights. Locusts were rarely described a dying in millions at night. A difficulty arises in separating the species in the central Riverina, as locusts spread at least far west as Coolamon and Wagga. The reports at Henty, Urana and Lockhart in spring could have been either, and even at Echuca in locusts some appeared in April 1930. The following October, grasshoppers were described as smaller than last season.

Appendix 7. Locust and grasshopper outbreaks and the Southern Oscillation Index

The graphic presentation of years in which swarms of *C. terminifera* and *A. cruciata* were identified in several regions from newspapers and official reports.
The year is given as representing the start of a spring–summer–autumn season. *A. cruciata* presence may have been overlooked during *C. terminifera* outbreaks. Because *A. cruciata* distribution is more restricted, outbreaks are identified by fewer regions being infested.

El Niño and La Niña years taken from several sources:

The Australian Bureau of Meteorology, http://www.bom.gov.au/climate/enso/lnlist/index.shtml and http://www.bom.gov.au/climate/enso/lnlist/index.shtml

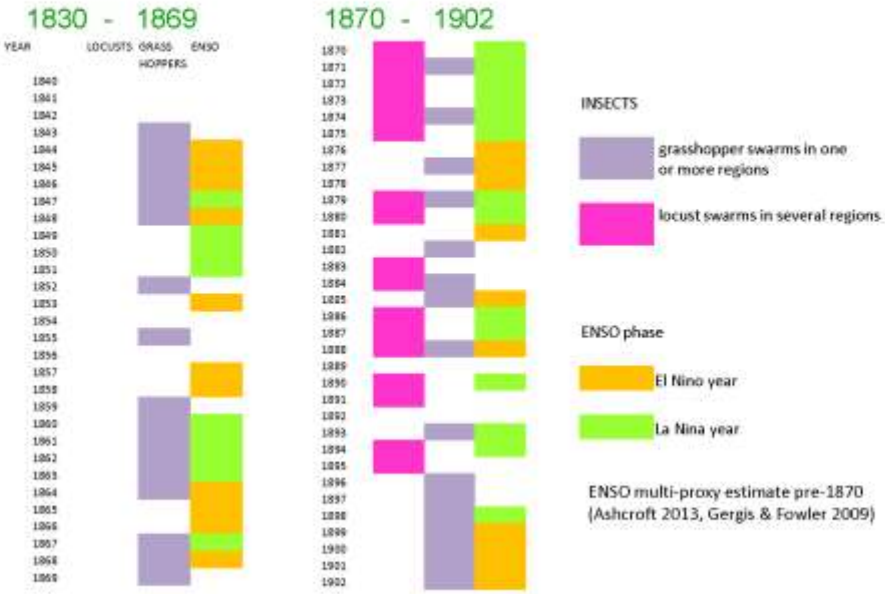
The Long Paddock, 'Australia's Variable rainfall', Queensland Government, https://www.longpaddock.qld.gov.au/products/australiasvariableclimate/

J. Gergis and A. M. Fowler, 'A history of ENSO events since A.D. 1525: implications for future climate change', *Climatic Change*, 92 (2009), 342–387, Table 9, pp. 367–69, Table 10, p. 375.

G. McKeon, W. Hall, B. Henry, G. Stone and I. Watson, *Pasture Degradation and Recovery in Australia's Rangelands: Learning from History*, (Indooroopilly, Department of Natural Resources, Mines and Energy, 2004).

L. Ashcroft, D. J. Karoly and J. Gergis, 'Southeastern Australian climate variability 1860–2009: a multivariate analysis', *International Journal of Climatology*, 34, (2014), 1928–1944.

Reconstructed grasshopper and locust outbreak years in south-east Australia with ENSO phase – 1830-1902



Reconstructed grasshopper and locust outbreak years in south-east Australia with ENSO phase – 1903-1975