BIOLOGICAL CONTROL OF GORSE: AN EX-ANTE EVALUATION

by

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PREFACE

The incorporation of an economic input to the evaluation of the potential outcome of scientific research work is a relatively new development in New Zealand. This Research Report presents an analysis of the possible effect a research programme output may have on the New Zealand agricultural scene. The possible outcomes have been quantified and an estimation of the value of those outcomes has been provided. This can be used in an assessment of whether work should proceed on the research project, both in terms of the possible outcome values and the costs yet to be incurred carrying out the research.

The methodology used in this evaluation can be applied to many other similar problems. It is anticipated that such evaluations may become more common in future. The Agricultural Economics Research Unit has a continuing role to play in supporting work of this nature and wishes to promote greater effort in the evaluation of scientific research programmes. This can be of considerable value to both the scientist, the potential beneficiaries of scientific research and to the nation through assisting in achieving the best allocation of research resources.

This particular piece of economic research was funded by the Department of Scientific and Industrial Research. We would like to commend the Department for its recognition of the value of such evaluation processes and urge other research institutions to seriously consider the value of this approach to the research activities they undertake.

R.G. Lattimore
Director

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This report was commissioned by the Department of Scientific and Industrial Research. Dr Richard Hill, Entomology Division, DSIR, provided ready co-operation throughout this study, and particularly on the technical aspects of biological control.

My thanks to the beekeepers of New Zealand. The questions asked in the survey were not easy to answer but a good response rate was obtained. John Smith and Murray Reid, MAF Apicultural Advisory Officers, assisted by providing information on the beekeeping industry and helping to design the survey form used. A special thanks is due to them both.

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Several other people have contributed to the research report. My thanks to those people, and I trust the pers com acknowledgements in the appropriate places is enough. A special thanks to my colleagues Lyn Toovey and Ron Sheppard for helping design the questionnaire.

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Finally, thanks to my wife Nancy Stirgwolt for support and editorial comments on the study.

SUMMARY

Gorse has become a major scrubweed problem to farmers and forestry since being introduced to New Zealand by the early European settlers. This has led to research being carried out to find biological agents capable of naturally regulating the plant.

However, while this may be of benefit to farmers and foresters, beekeepers are concerned about the possible introduction of these agents. Gorse is a major spring and autumn pollen source for honeybees, and a reduction in flowers may impose costs to the beekeeping industry.

The objective of this report is to estimate the benefits and costs to New Zealand if agents were introduced to naturally regulate gorse. The costs of gorse include both the direct costs of control and indirect costs in the form of the opportunity cost of lost production.

Next, the benefits and potential benefits of gorse are examined. These benefits include shelter hedges, animal fodder, and gorse as a nursery and erosion control plant as well as the pollen source to beekeepers. A theoretical framework is developed to enable these costs and benefits to be compared and a set of decision rules adopted to advise on the question of the introduction of biological agents. Several theoretical issues are discussed, and examples are provided where the compensation criteria has been used.

In order to quantify the costs to New Zealand beekeepers, a survey was conducted of all beekeepers with over 50 hives.

Results confirm that gorse is the major pollen source in both spring and autumn. Cost estimates to beekeepers should biological control be "successful" are obtained.

Estimates of the benefits to farming and forestry are calculated. These are shown to be substantial should the agents establish.

Comparison of the costs and benefits lead to the recommendation that, provided all reasonable steps are taken to ensure the agents are host specific, the introduction of these agents is economically efficient. The potential benefits outweigh the costs. Reduction in the spread and vigour of gorse would provide large net benefits to New Zealand.

Several limitations of the study are noted, and these must be kept in mind. The report concludes by discussing these limitations and suggesting directions for future research.

CHAPTER 1

INTRODUCTION

Gorse (Ulex europaeus) was introduced into New Zealand in the early days of European settlement to provide an inexpensive and rapidly growing hedging plant. So successfully did the plant adapt to New Zealand conditions that it was declared a noxious weed in 1900 (MacCarter and Gaynor, 1980). The plant grows from sea level to an altitude of 800 metres throughout the country and in 1984 had become the most serious scrub weed in New Zealand (Monsanto, 1984, Bascand and Jowett, 1982). A map showing the distribution of gorse in New Zealand is contained in Appendix C. Conventional control measures are both expensive and meet with limited success. This is supported by the Monsanto report:

> "The trend is reflected by the anecdotal (but supported by statistics) report that every year enough 2,4,5-T is sprayed to kill one quarter of New Zealand's gorse crop. Spraying has been going on for about 30 years while the amount of cover has not decreased significantly." (p.9)

Exotic afforestation development costs are increased greatly by the need to initially control gorse, and the invasion of pasture lands by gorse is known to result in substantial economic costs. In 1983 the annual cost of gorse control measures was estimated to be 14 million dollars (Hill, 1983(a)). When carried out effectively, current methods of gorse control can be profitable, but the extreme vigour and competitive ability of the weed makes it difficult to control. It has been estimated that gorse infested land in New Zealand has a potential production of some $150 million annually (Monsanto, 1984). These estimates may be high because of the assumptions made regarding product returns and also the question of complementary weed infestation. However, it remains that gorse is an extremely widespread and costly weed to New Zealand.

In the current economic climate with increasing costs, high interest rates, and decreasing returns, very little development of gorse infested land is likely and much gorse prone pasture is likely to revert to gorse and other weeds. Entomology Division of the Department of Scientific and Industrial Research (DSIR) is developing a programme aimed at biological control (natural regulation) of gorse which it is hoped will improve the effectiveness of current control procedures and reduce both farmers and foresters costs.

However, gorse flowers are a major source of pollen for beekeepers in New Zealand (Walsh, 1978). Beekeepers are concerned that introduction of biological agents to control gorse will result in serious losses. These may occur to both the beekeeping industry from increased costs and possibly New Zealand's agricultural and horticultural industries from lack of pollination services should the beekeepers be seriously affected. The objective of this study is to estimate the cost and benefits to New Zealand of the introduction of agents for the biological control of gorse. Emphasis will be given to identifying and, where possible, quantifying costs of introduction to the beekeeping industry.

As an illustration of how biological weed control works, let us consider the most famous and successful project undertaken to date. In 1920 two species of prickly pear cactus occupied 25 million hectares of Queensland rangeland. Most descriptions of this project simply say that the prickly pear moth Cactoblastis cactorum was introduced, and prickly pear quickly disappeared. In fact, as with all such work this was a slow and complicated project. Exploration for potential control agents began in North and South America in 1912. In the following 20 years, 150 insect species were tested and 52 were selected for introduction to Australia. Of these, 19 were successfully reared and released in large numbers, but only 9 (including the moth) established successfully. The project ended in 1939, 27 years after the initial research, with prickly pear under sufficient control so that farming and grazing could be resumed on the affected land. In the following 44 years the weeds have remained in balance with their natural enemies at a low population density. This is not to say that any of the prickly pears are necessarily rare or even uncommon in Queensland. They are probably still amongst the commonest introduced plants in Queensland, occurring throughout the landscape at 1-15 plants per hectare.

This example illustrates three important features of biological weed control:

1. Such control is a long and gradual process. The Queensland example referred to above took 27 years to complete.

2. Biological control has a zero percent likelihood of obtaining total eradication of a weed, so it can only be expected to lower its density.

3. Successful control results in decreased awareness of the weed so that it is no longer regarded as a problem.

Biological control of gorse is not a new concept. In 1931 the Cawthron Institute released the gorse seed weevil (Apion ulicis F.) into New Zealand for gorse control. This insect attacks the seeds of the plant, as it was considered that gorse was too important as a shelter hedge to attack directly. Although this weevil has become one of New Zealand's commonest insects, it has not controlled the spread of gorse. Amongst other reasons, this is because the weevil is winter dormant so pods escape damage then (MacCarter and Gaynor, 1980, Syrett et al.1985).

Since the introduction of the seed weevil, gorse has declined in importance as a shelter hedge, with a corresponding increase in interest in biological control which will affect the plant directly. In 1977 the DSIR requested a report overseas to update available information on insects which attack gorse. This report (Girling, 1977) considered 94 species which attack gorse in Europe and recommended 9 species for further consideration by the DSIR. The safety and suitability of 3 of these for introduction to New Zealand has been examined more closely.

The caterpillars of the gorse shoot moth, Agonopterix ulicetella St., feed on the shoot tips of gorse. In sufficient numbers they can cause significant reduction in gorse growth. Final trials are underway in England to see if this species is safe to introduce here.

Gorse lace bug, Dictyonota strichnocera Fieb., sucks plant juices from the stems and spines of gorse. The damage it can cause is not very obvious, but in sufficient numbers gorse lace bug should reduce plant vigour. The safety of this species is also being checked in final trials in England.

The gorse mite, Tetranychus lintearius Dufour, is the most damaging species attacking gorse. It forms large colonies which move about the bush causing severe bronzing. Heavy infestations cause the death of whole branches, produce very heavy webbing over the remainder of the bush, and on occasions kill whole gorse plants. It is closely related to the two-spotted mite which is a serious pest of apple trees in New Zealand and causes similar damage to gorse. Gorse mite is the only potential control agent known to kill gorse plants. Last year detailed studies by DSIR showed that this species is suitable for introduction into New Zealand, and releases could begin in late 1985.

Several other species are likely to be suitable control agents, but have not been assessed yet. These include two species which should reduce the annual seed crop of gorse even lower than the present attacks by gorse seed weevil.

The general aim of DSIR's programmes is to gain biological control over the weed by reducing its vigour and hence its aggressiveness. This would be a slow process and significant immediate impact on existing gorse stands would be unlikely.

CHAPTER 2

CURRENT COSTS OF GORSE CONTROL

2.1 Costs to the Farmers

Two authoritative pieces of research have been documented on the scrubweed and vegetation cover. Both of these investigations show gorse to be a major problem weed. The major New Zealand inventory has been produced by the Ministry of Works and Development on behalf of the National Water and Soil Conservation Organisation (NWASCO, 1975-79). This survey recorded vegetation in homogeneous land inventory map units and is summarised in Blaschke et al,[1] 1981. The second authoritative source is a major postal survey conducted by the Ministry of Agriculture and Fisheries in the South Island between 1972 and 1978. The resultant distribution of scrubweeds in agricultural and pastoral land below 1220 metres altitude is reported in Bascand and Jowett (1981). A discussion on this second survey and the importance of scrubweeds and other herbaceous weeds to South Island farmers is reported in Bascand and Jowett (1982).

Some idea of the extent of gorse in New Zealand's major islands is shown in Table 2.1, with 3.56 percent of the New Zealand land area classified as having some gorse cover.

TABLE 2.1

Vegetation Cover Class (ha) Containing Gorse

Land Type	South Island	North Island	Total
Scrubweed and Fernland	18,500	34,500	53,000
Grassland and Scrub	201,600	455,000	656,600
Grassland including Crops and Scrub	32,800	198,900	231,700
Total	252,900	688,400	941,300
As a % of Total New Zealand Land Area	2.2	4.58	3.56

Source: Blaschke et al, 1981. See Appendix C for a detailed breakdown of the vegetation cover.

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[1] The NWASCO survey excludes shingle type land such as riverbeds, and consequently may understate the gorse area. This should be kept in mind for subsequent discussions on gorse as a pollen source for bees.

A more detailed estimate of the "farmable" land of the South Island covered by scrubweed is shown in Table 2.2. Gorse ranks third by area behind bracken and matagouri.

TABLE 2.2

Estimated Area (km^2) of Farmable Land in the South Island Covered by Scrubweed

Scrubweed	South Island	Cant.	Marl.	Nel.	Otago	South.	West.
Bracken	1881	426	207	284	499	316	50
Matagouri	1756	795	105	-	606	249	-
Gorse	1214	532	100	129	189	156	106
Kanuka/Manuka	812	258	120	105	196	89	42
Broom	607	256	37	34	155	122	-
Sweet Brier	581	97	175	14	267	27	-

Source: Bascand and Jowett, 1981.

As a "Serious Problem" weed, gorse is ranked second behind barley grass in the Bascand and Jowett postal survey. These results are shown in Table 2.3 for the South Island.

TABLE 2.3

Plant Importance as a "Serious Problem" for South Island Farmers (% of Responses)

Plant	Serious	Minor	No Problem
Barley Grass	38.8	39.3	14.7
Gorse	34.3	39.7	19.8
Nodding Thistle	25.6	39.5	23.3
Broom	25.5	46.4	21.3
Sweet Brier	20.9	30.8	36.3
Other Thistle	20.9	51.3	19.5

Source: Bascand and Jowett, 1982.

An extension of Table 2.3, providing a regional breakdown, is presented in Table 2.4.

TABLE 2.4

Noxious Plants Ranked as a "Serious Problem" by South Island Farmers

Plant	Cant.	Marl.	Nel.	Otago	Sthld	West.
Barley Grass	2	4	4	1	3	-
Gorse	3	1	1	3	2	1
Nodding Thistle	1	6	10	7	5	10
Broom	4	2	5	4	4	9
Sweet Brier	6	3	19	2	7	-
Other Thistle	5	13	7	5	1	3

Source: Bascand and Jowett, 1982

The adaptability of gorse to New Zealand conditions make it a particularly important and costly scrubweed to a wide range of farming systems. A recent survey of high country farms in the South Island recorded some 25 percent of runs reporting gorse to be of concern (Table 2.5).

TABLE 2.5

Weeds of Major Economic Significance

Weed	Percent of Runs Reporting Weeds of Concern
Brier	52
Matagouri	34
Broom	29
Hawkweed	25
Gorse	25
Nodding Thistle	9

Source: Kerr and Lefever, 1984.

In a similar type of survey on "traditional" farms in Ashburton, Ellesmere, and Strathallan Counties (Canterbury), and Southland County (Southland) Mumford (1980) asked farmers about chemical usage. The results, Table 2.6, show gorse as being an important weed in both Southland and Canterbury. Thus gorse is perceived as being a major problem over a range of farming situations.

TABLE 2.6

Weeds Treated on Farms

Weed	Canterbury	Southland
	Percentage of Farmers Reporting Each Weed	
Gorse	18	23
Thistles (unspecified)	20	18
Fat Hen	29	16
Nodding Thistle	24	3
Californian Thistle	18	23
Broom	5	5

Source: Mumford, 1980, p.9.

To obtain an idea of the historical importance of gorse it is interesting to look at a survey of farmers published almost 70 years ago. The Board of Agriculture distributed circulars to farmers "for the purpose of obtaining a definite expression of opinion as to which were the most serious weeds of both arable and pastoral land" (Cockayne, 1917). Results, shown in Table 2.7, indicate that gorse was a major problem weed, although more so in the North Island.

TABLE 2.7

Main Weeds Reported in Order of Importance

Weed	Times Reported
	North Island (341 Replies)
Blackberry	304
Californian Thistle	249
Gorse	179
Ragwort	162
	South Island (328 Replies)
Californian Thistle	262
Couch-Grass	150
Fat-Hen	133
Yarr	130
Sorrel	99
Sweetbrier	94
Gorse	93

Source: Cockayne, 1917, p.343.

An estimate of the direct costs of gorse control over the last few years can be obtained from the Noxious Plants Control Scheme data.

This scheme subsidised farmers to the extent of 50 percent of chemical costs for noxious plant control. A summary of subsidy expenditure is given in Table 2.8 by region. The percentage of the subsidy spent on gorse increased from 56 percent in 1979/80 to 87 percent in 1984/85. Regionally, the Christchurch and Invercargill Districts have received the largest amounts of subsidy, suggesting that more gorse control expenditure is occuring in these districts.

TABLE 2.8

Noxious Plant Control Scheme Expenditure on Gorse ($000's)

District	1980	1981	1982	1983	1984	1985
Auckland	878	839	757	573	487	321
Hamilton	803	661	625	617	356	646
Palmerston North	632	654	679	844	523	423
Hastings	265	309	240	499	786	870
Christchurch	719	841	754	1,053	988	1,215
Nelson	512	393	472	499	346	316
Dunedin	832	900	804	808	626	533
Invercargill	481	372	396	470	433	1,022
Total New Zealand	5,124	4,967	4,727	5,363	4,535	5,345
Gorse as % of Total	56	70	74	78	80	87

Source: Noxious Plants Council Annual Reports for 1980 to 1983, 1984-85, Graham Strickett, South Island Field Officer for Noxious Plant Council, pers com.

Total costs of gorse control to farmers in the 1984-85 year are estimated from data in Table 2.8 and presented in Table 2.9. Chemical costs and estimates of application costs and costs incurred outside of the scheme bring the total estimated costs to New Zealand farmers for gorse control to almost 18 million dollars.

A recent paper by Reid (1985) shows that 5,042 hectares of gorse were treated in 1984-85 based on a farm survey. Multiplying this figure by 46[1] provides a national estimate of 232,000 hectares treated for gorse in 1984-85. This represents an average cost of $76.80/ha (from Table 2.8), but the average cost and area treated are misleading because the degree of spot-spraying is unknown. Herbicides represented 15 percent of the total market share for chemicals in 1984-85, with fertilisers (75 percent), insecticides (6.3 percent), and fungicides (3.8 percent) comprising the rest (Reid, 1985).

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[1] The figure of 46 was given to the author by Fergus Reid as being the multiplier to convert the survey estimate to a national estimate.

TABLE 2.9

Total Cost of Gorse Control to Farmers and the Nation, 1984-85 Year

	$
Noxious Plants Council Subsidy (a) (at 50 percent of chemical) (Cost to Taxpayers)	5,345,000
Non-Subsidy Cost from Above (a) (Cost to Farmers)	5,345,000
Estimated Application Cost (b) (Cost to Farmers)	3,565,000
Estimates of Costs from Non-Subsidy Control (b)	3,563,000
Total Cost to New Zealand Farmers and the Nation	17,818,000

Source: (a) From Table 2.8
(b) Graham Strickett, Noxious Plants Council, pers com. This includes spraying not subsidised, such as Local Body spraying and others not eligible for the subsidy.

An alternative approach to estimating the cost of gorse to farmers in New Zealand can be obtained from the Monsanto (1984) report. In discussing the economics of gorse clearing, the report takes 18 sets of development budgets in three land type categories and adjusts all figures to 1982 dollars. The cost of developing 520,000 ha (the area of scrub cover in the South Island with grazing potential) is calculated at $408 million. These costs are then compared to a return of $153.2 million based on FOB prices. The report claims this equates to a payback period of 2.6 years. While providing a crude estimate, there results are deficient for the following reasons:

a) the returns are gross and not net figures,
b) the demand elasticities are not taken into consideration,
c) no discounting is allowed for (in real terms), and
d) complementary weed infestation costs are ignored.

The true cost of gorse to New Zealand farmers would be intermediate between the two estimates of spraying costs of $17.8 million and the Monsanto estimates of $150 million. Spraying costs will provide a lower bound of estimates. Farmers can be expected to spend money on spray to the level they consider profitable in a development budget. Thus a cost may well be borne in the form of lost production where, although positive returns would result from development, the costs outweigh benefits. The exception to this is the amount of money spent on "compulsory" spraying under the Noxious Plants Act - farmers are obliged to spray regardless of expected returns. A block of solid gorse is not considered to be a "noxious plant", other than boundary containment, and therefore operates on a market type system - develop if profitable. A final word of caution should be sounded about Table 2.9 - March 1985 was the last date for subsidy of chemicals. Next years (85/86) expenditure can be expected to be lower for two reasons. Chemical costs will be higher to the farmer because of subsidy withdrawal, and expected returns from farming for the 1985/86 season are lower.

In summary, the $17.82 million (Table 2.9) estimates of spraying costs is a minimum of the costs of gorse to New Zealand taxpayers and agriculture, while the $150 million from Monsanto would be an upper bound. Considering all the factors involved, the true cost is between the two estimates. These costs are widely spread between farming systems, but tend to concentrate in the South Island.

2.2 Costs to Foresters

As is the case in farming, gorse control represents two major costs to foresters. These are the direct increased costs of land clearance and gorse control and the indirect costs of a longer rotation period and/or lowered production and/or reduced quality.

Few first rotation pine plantations in New Zealand are established on clear sites. Most areas require a considerable preparation programme to clear the ground of native shrubs or weed species such as gorse, broom, or bracken. Gorse is a particularly bad scrubweed because of the residual seed pools which survive an initial firing of the site and the difficulties associated with pruning and cultivating trees once they are established in gorse. The present trend to lower the density of tree stockings, together with thinning, pruning, and fertiliser treatment of tree crops, can create an understory of gorse that will persist throughout the entire rotation (Zabkiewicz and Balneaves, 1984). This gorse can severely restrict growth as well as hindering pruning operations.

Balneaves (1981, p.241) cites an earlier study in the Ashley Forest where a weed free stand of radiata pine recorded a 123 percent increase in bulk index over a gorse infested stand at nine years of age. Additionally, the costs of pruning were double that of a clean block (15.5 man-hours/ha versus 7.8 man-hours/ha) and thinning cost also increased. Where a policy of using close plantings to enable canopy closing to kill gorse and delaying pruning and thinning is employed nominal costs can be lowered. However, a real cost is incurred in lost production and quality reduction of the final crop. Additionally, gorse presents a fire hazard to foresters.

No cost-effective means of eradicating gorse after tree planting has been devised. Even where chemical application appears to be successful, tree damage is common. Thus the only time to tackle gorse is during site preparation. Current Forest Service recommendations are to crush and burn mature gorse, followed by a 2,4,5-Trichlorophenoxy Acetic Acid (2,4,5-T) spray some 4-6 weeks later. This is followed by a second spraying some 12 months later, with planting a month or so after the second spraying (Forest Research Institute, 1981). The extra cost of controlling gorse to "ensure" a 3 lift pruning regime in the Nelson area is calculated at $530/ha (H. Rautjoki, pers com). This figure takes no account of the opportunity cost of time - a delay of almost two years is incurred between the initial burning and planting of the radiata pines.

Forest Service estimates of the area of gorse-infested land that they planted in trees for the 1984 year are shown in Table 2.10.

TABLE 2.10

Forest Service Plantings in Gorse Areas for 1984 (ha)

Region	ha
Auckland	350
Rotorua	400
Nelson	1,950
Westland	220
Canterbury	1,145
Southland	1,200
Wellington	411
Total	5,676

Source: Forest Service data, J. Balneaves, pers com.

Taking the earlier quoted figure of $530/ha as increased costs resulting from gorse, the direct preparation costs over 5,676 hectares are some $3 million annually. Extra pruning and thinning costs of 26-32 hours/ha (Balneaves, 1981) at $6 per hour amounts to a further $156-$192/ha. Taking a mid-point of $174/ha (29 hours at $6/hour) over the 5,676 ha from Table 2.10 adds another $1 million, giving direct costs of $4 million annually. John Balneaves (Forest Research Institute, Rangiora) further estimates that the 5,676 hectares of gorse land planted by the Forest Service would represent about 50 percent of total plantings in gorse prone land in New Zealand. This implies the direct costs would double, assuming the same management system as the Forest Service, and a figure of $8 million annually should be used.

Zabkiewicz and Balneaves (1984, p.262) cite a Forest Research Institute calculation of 476 m /ha timber yield from a multiple spray regime compared to the standard regime calculations of 368 m /ha. These increases, are "a direct result of eliminating gorse from the site." Balneaves (pers com) estimated that a correct gorse control programme in the Ashley Forest of Canterbury would result in a $300 million increase in output value over a 20 year period. While this figure is a gross figure, and includes the cost of not handling gorse correctly as well as gorse per se, it does indicate the magnitude of potential lost opportunity costs to the forestry industry. One must be careful not to double-count the control costs with opportunity costs, though.

2.3 Costs to the Nation

Many of the direct costs to farmers and foresters estimated in Sections 2.1 and 2.2 do not apply to the nation. For example, costs to the farmer and forester of sprays are higher than costs to the nation for the same sprays - many of the costs are transfer payments. Similarly, extra labour costs of pruning and thinning of trees should be costed at the opportunity cost of labour, and not total wages.

Opportunity costs of lost production are, on the other hand, valid costs to the nation, with some provisos. These are mainly elasticity effects of increased supply, opportunity costs of resources used in producing this extra supply, and the supplementary weed problems which would occur if gorse didn't exist. Care must also be taken not to value a dollar in overseas funds higher than a dollar generated internally. This weighting is not valid under a floating exchange regime.

Costs borne by persons other than farmers and foresters have not been addressed. These include organisations such as Catchment Boards and Local Counties. No non-market benefits have been addressed - for example, recreationists, conservationists, and environmentalists who dislike an introduced species replacing native flora and fauna.

Subsidy costs of $5.35 million have been included in costs to farmers and farming (Table 2.8, 2.9). Strictly speaking, these should be included in this section under "costs to the nation". Second round effects have also been ignored in the analysis.

2.4 Summary of the Costs of Gorse

Estimates of the total annual costs of gorse to New Zealand are shown in Table 2.11.

TABLE 2.11

Annual Costs of Gorse ($000's)

	Direct Costs	Indirect Costs
To Farmers and Farming	17,818 [a]	Up to 150,000 [b] Opportunity cost of gorse covered land
To Foresters and Forestry	8,000 [c]	Unknown, but large [d] Opportunity costs of extra time in rotation, lost production, and decreases in product quality product
To the Nation	Others concerned with gorse clearance	The above opportunity costs, nett of expenditures, elasticities effects, and complementary weed infestation

a. From Table 2.9. Includes subsidy payments on chemicals as well
b. Monsanto (1984) estimates of lost production
c. From Chapter 2.2.
d. Chapter 2.2 references and estimate of $300 million over 20 years from Ashley Forest

These include both direct and indirect costs. The direct costs of $22 million can be regarded as a minimum annual cost. Some transfer payments are included in these estimates and complementary weed infestation is ignored. These direct costs do not include the opportunity costs of lost production.

CHAPTER 3

THE BENEFITS OF GORSE

3.1 The Beekeeping Industry

The rich pasture lands of New Zealand and some of its bush areas are favourable for agriculture and produce high quality honey. Much of this honey is obtained from the nectar of white clover. Recent statistics for honey production and export are given below.

TABLE 3.1

New Zealand Honey Production and Export

	YEAR					
	1980	1981	1982	1983	1984	1985
Production (tonnes)	7489	6931	6495	5053	5818	10314[a]
Export (tonnes)	2044	1310	1161	940	825	
Export ($,000 fob)	3695	2853	3414	2557	2568	

a Estimated (Murray Reid, MAF, pers com)

Source: Ministry of Agriculture and Fisheries 1984 (a)

Gorse does not produce nectar for honey but is considered to be a major source of pollen for the beekeeping industry. The maintenance of brood rearing in honeybee colonies is dependent almost entirely upon the bees receiving adequate supplies of the protein, vitamins and minerals that are essential for the production of royal jelly (this is produced within the glands of honeybees as a larval nutrient). In nature, these nutrients are obtained from pollen, and in undisturbed colonies the rate of brood-rearing varies throughout the year according to the amount of pollen available (Doull, 1975). To achieve maximum populations at nectar flow time is the major management problem facing beekeepers, as shown in Figure 3.1.

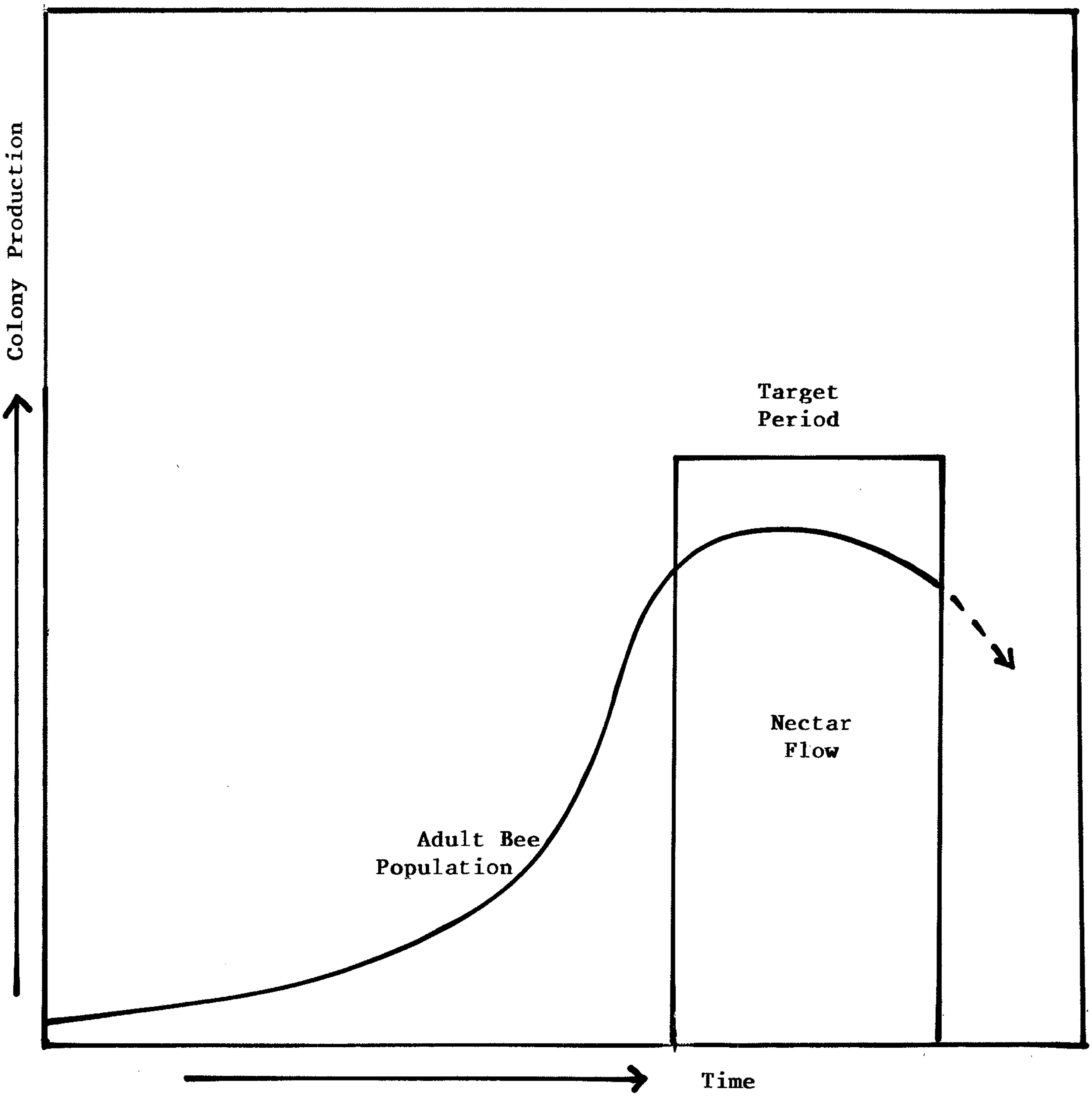
Gorse is considered to be extremely valuable as a pollen source because of the almost year-long availability and the quality of the pollen. This timing of the availability of gorse flowers is important. White clover, for example, provides pollen as well as nectar, but the need for pollen is to build hives to harvest the white clover nectar.

Thus the usefulness of white clover as a pollen source may be limited because of the timing of the flowering. Not all pollens are of equal value because of differing protein contents. Generally, the higher the crude protein the greater the breeding rate and longevity of bees. Bryant (1982) provides the following categories for pollen in New Zealand:

Excellent - clovers, tree fruits, willows, heather.
Good - dandelion, gorse
Poor - pine, birch, poplar
Toxic - karaka

FIGURE 3.1

Relationship Between Colony Build Up and Nectar Flow
(from Bryant, 1982)



Wells (1983) contains a listing of common Victorian (Australia) plants with their pollen protein levels. This table is edited below in Table 3.2 to give an idea of the relevant New Zealand pollen sources.

TABLE 3.2

Protein Concentration (percent of dry matter) of the Pollen of Some Victorian Plants

Pollen Source	Protein
White Clover	17.0 - 25.5
Thistle (*Cirsium vulgare*)	18.3
Paterson's curse (*Vipers bugloss*)	32.0
Gorse	16.5
Willow	19.0
Pine	9.0
Gum	17.9 - 24.3

Pollen shortage at the critical late spring build-up stage is an age old problem for beekeepers. Johnansson and Johnansson (1977) state that in 1655 Samuel Hartlib recommended that dry meal or bean flour be added to 'tostes of bread sopped in strong ale' as a cheap winter feed for bees, and wondered whether it would be better if first 'maulted'. By 1900 beekeepers in Europe routinely used feeds composed of sugar, pea flour, and egg white to stimulate breeding in the spring. Commenting on Samuel Hartlib's recommendation, Matheson (1982) suggests that modern practice is to reserve the ale for the beekeepers, and feed the bees with something which has been formulated a little more scientifically.

However, despite modern science, there still appear to be problems in the availability of substitutes to natural pollen, although these substitutes can supplement natural pollen for a period of time. The best protein source for bees is pollen, hence the value of gorse flowers.

Given a shortage of natural pollen, beekeepers can intervene in the following ways:

(a) shift hives to a pollen source;
(b) trap natural pollen to feed during critical times;
(c) feed pollen substitutes; and
(d) combinations of the above.

Forster (1966) considered it difficult to make a general recommendation as to when and where to feed pollen supplements in New Zealand. Shortages are not easy to forsee, and the effects of deficiencies are difficult to anticipate. Even 20 years ago he regarded that "the effective use of pollen supplement must be treated as another skill in the art of beekeeping which requires considerable study if worthwhile practical results are to be obtained."

Current recommendations are to feed the Beltsville diet, which consists of the following ingredients:

12 kg Lactalbumin (ALATAC 560) protein
24 kg Brewer's yeast [1]
65 kg Sugar
Water

An additional 10 - 20 percent of natural pollen may be added to improve the acceptability of the mix. The ingredients are moulded into patties of about 500 - 600 gms. Each pattie is sufficient to feed one colony of honey bees for 2-3 weeks, depending on hive strength and the availability of natural pollen. Feeding could begin in late August and continue until October/November, although consumption may decrease after 8 - 10 weeks as the bees tire of the substitute (MAF, 1984 (b)).

Lactalbumin is currently selling for $2.80 kg ex factory, with free delivery anywhere in New Zealand for tonne lots. The estimated cost of the Beltsville mixture is about $1200 tonne, with labour and travelling costs associated with feeding extra. Hives need a total of some 20 - 30 kg of pollen annually, so feeding at the Dairy Board recommendations is only likely to provide some 10 -15 per cent of requirements, at a mixture cost of around $3-$5 per hive. Labour and travelling costs are extra, but beekeepers regularly inspect hives during this period anyway.

An estimate of artificial feed costs is provided by Oldroyd (1985), for Australian conditions. Total cost is $26.25 (Aust) per hive, with 2 kg of pollen supplement at $6/kg and 15 kg of sugar at 75 cents/kg making up the bulk of the costs. Labour at $3.00 per hive makes up the rest. These estimates are higher than the quoted New Zealand supplement costing. The Australian pollen supplement is presumably natural pollen, and at $6/kg would compare to the market value of New Zealand pollen (Tony Cleveland, Beekeeper, Nelson, pers com.) However the Lactalbumin at $2.80/kg is cheaper, and the Beltsville diet contains less sugar. Additionally, the Australian estimates of Oldroyd appear to refer to a complete artificial feeding situation in the spring, while the Beltsville diet is considered as a supplement for the spring. Other natural pollen sources, either stored autumn pollen or spring pollen from alternative plants, are presumed to be available as well.

Problems of substitute and supplementary feeding include:

a) the direct monetary cost;

b) associated disease risk, especially when natural pollen is added to encourage bees to eat the mix;

c) some problems on enticing the bees to eat the diet;

d) effect on the hive of trapping pollen (reduces honey production); and

---

[1] Currently (September 1985) very difficult to obtain (John Smith, pers com)

e) opportunity cost from not selling the pollen (although this may involve some double counting from (d)).

These problems and costs must be balanced against the current costs involved in shifting hives to alternative pollen sources, including gorse. The crucial problem facing beekeepers is potential impacts of a reduction in the availability of gorse as a pollen source. As Moar (1983) considers, it is worth remembering that what may be accepted as a typical pollen spectrum today, may not be typical tomorrow. Kennaway (1881) is cited as raising bees over a 30 year period in an area notable for the absence of trees "over a great distance", flax swamps, and later, as settlement proceeded, by miles of gorse hedges. Moar then concludes by wondering what will replace gorse, as it is "being destroyed so rapidly that it may not be long before gorse pollen ceases to be a characteristic component of South Island clover honey".

The crucial question of this study is the potential additional reduction in gorse pollen availability should biological control be introduced, and the costs of this to the beekeeping industry. To find some indication of this cost, a survey of all beekeepers in New Zealand with over 50 hives was conducted. Results and discussions form the basis of Chapter 6.

3.2 Benefits as a Shelter Source

Gorse was originally introduced by the early European settlers as an inexpensive, quick growing hedge for stock fences and shelter. By the 1920's, as outlined in Chapter 1, gorse had become a problem and serious attempts were made to find a biological control. Even then a conflict of interest existed, and prospective biological control agents were restricted to flower and seed feeders so that established gorse hedges would not be damaged (Syrett et al, 1985). Since that period, gorse hedges have declined in importance as the use of wire fences and trees has become more prevalent. However, gorse still provides some economic benefits as a stock containment and shelter hedge.

In the early 1970's Sturrock (1972) conducted a survey of hedge and tree shelter in two sample areas, each of 13.4 square kilometres, on the Canterbury Plains. One area (Area A) between Lincoln and Rolleston, was sparsely wooded, while Area B, near Methven, contained more shelterbelts for north-west gale protection. Part of the work of this study was the "Estimation of shelter benefits" (Sturrock, op cit, p.107), but these estimates are not provided. However, some information is given about the relative importance of gorse as a shelter source, and details of hedges and shelters for the two areas are summarised in Table 4.3. The conclusions from the study were that in Area A the proportion of sheltered land is "insignificant", but that Area B is relatively well sheltered. Gorse represents some 79 percent of the shelter by length in Area A, but only a minor 9 percent in Area B. Since this survey, the North Canterbury Catchment Board has subsidised about 80 km of new shelter per year, and some 10 percent of this is replacing or adjacent to existing gorse hedges (Mr McGuigan, North Canterbury Catchment Board, pers com.)

TABLE 3.3

Details of Hedge and Shelter Area in Two Canterbury Regions

	Total Length (km)	Percentage of Land Area
Area A		
Gorse Hedges	48.96	0.366
Other Hedges	3.47	0.055
Shelter Belts	9.51	0.33
Total	61.94	0.75
Gorse as % Total	79.0	49.0
Area B		
Gorse Hedges	3.16	0.024
Other Hedges	3.10	0.064
Shelter Belts	27.59	1.20
Total	33.84	1.29
Gorse as % Total	9.0	2.0

Source: Sturrock, 1972

The economic value of gorse shelter and fencing benefits have not been calculated. They are apparently declining, but still must be considered as providing positive nett values and at least recognised in any benefit-cost analysis for the introduction of biological control.

3.3 Gorse as a Fodder Plant

A recent publication (Krause et al., 1984) looks at the relative profitability of using goats to control gorse infestation on hill country. The study concludes that given 1984 prices and technology, the use of goats is a viable alternative to the chemical method of gorse control. Goats are more profitable for two main reasons. Firstly, the capital outlay can be recouped once development is complete, and secondly, goats generate income during the development phase. With the recent increased interest being shown in goat production, an obvious question to ask is "Can gorse be used as a fodder source for goats as an alternative to a traditional pasture system?" This is an extension of the goats-to-control gorse issue, and is raised by Krause et al (p78) as an area for future research.

Trials by the Ministry of Agriculture and Fisheries show the potential dry matter production from gorse (Radcliffe, 1985, pers com). Twenty seven tonnes of dry matter per hectare (dm/ha) has been recorded at Loburn, followed by 11.5 tonnes dm/ha in the next season from cages placed in a gorse paddock set-stocked by goats. An estimated 15 tonnes and 11 tonnes of green dm/ha was recorded for the two seasons, with 12 to 16 tonnes of total dm/ha (7 to 10 tonnes green dm/ha) consumed each year. Radcliffe attributed the decline in dm/ha over time to silver leaf fungus, which depresses yields in woody scrubs under grazing. Note however that green dm/ha was reasonably consistent between the two seasons. The above dm/ha yields should be compared to an estimated 6 to 9 tonnes dm/ha from a conventional pasture sward in the same location, although nutrient values may be different. Gorse is low in most minerals, including nitrogen.

3.4 Gorse as a Nursery Plant and Erosion Control

One of the beneficial features of gorse is that the plant is a legume, and therefore fixes its own nitrogen supply. This has led to the suggestion that gorse would provide a valuable nursery plant for the regeneration of native forest. The evidence on this appears to be mixed at best, and contradictory at worst. For example:

> ".... gorse, as an early pioneer plant that colonises disturbed soils and abandoned pastures, fulfils a very valuable ecological role. It not only has a beneficial effect on the soil, but it also acts as an excellent nurse plant for the regeneration of native scrub, which in turn acts as a nurse for the re-establishment of native forest trees." (Hackwell, 1980, p.28).
>
> In contrast,
>
> "In Hoon Hay Valley, gorse lives for at least 20 years and probably up to above 30 years, whereas broom has only half this life. Gorse is evergreen, whereas broom is leafless from late summer until early spring, allowing more light to reach seedlings of later successional species. Moreover, gorse produces a massive amount of litter that has a relatively low nitrogen concentration compared with the sparse readily decomposable broom litter. Gorse litter, therefore, tends to accumulate above the mineral soil where it tends to acidify the upper soil horizons. These differences suggest conditions for establishment of broad-leaved shrubs would be more favourable under broom stands than gorse stands of a similar age." (Williams, 1983, p.246).

Additionally, gorse constitutes a considerable fire hazard, and this is one of the costs of gorse to the Forest Service (John Balneaves, pers com). Consequently, I would find it difficult to assign any value to gorse as a nurse plant unless some further evidence is presented. Also, any value that gorse may have as a nitrogen fixer is likely to be less than that of a clover sward.

This leaves the issue of erosion control, and any benefits which gorse may have in lessening the effects of erosion. Recent literature concerned with erosion in the high country appears to be reappraising the long held views on its causes. For example, recent studies suggest, *inter alia,* that most erosion in the Southern Alps occurs during high intensity storms and earthquakes, and that some erosion features attributed to vegetation depletion following early European pastoral management do not result from this cause (Whitehouse, 1984). For the purpose of this study, it may be sufficient to assign a positive benefit to gorse for erosion control, but suggest that the absolute sum is not great.

3.5 Summary

Although gorse is legally a noxious plant in New Zealand, it does have several redeeming beneficial features. The major factor is it provides a considerable amount of quality pollen to the beekeeping industry. This industry produces honey from nectar and provides pollination services. The timing of gorse flowering makes it very valuable in the spring during colony build-up. A survey to find the value of gorse and possible losses to the beekeeping industry should biological control be introduced will be discussed in Chapter 6.

Artificial pollen substitutes and stored pollen supplements are possible ways of overcoming potential losses of gorse pollen, but they involve costs. These costs include the direct costs, for example, artificial substitutes and increased transport and labour costs, and indirect costs such as disease risk from pollen supplements.

Early British settlers introduced gorse as a shelter and stock containment hedge, and although the benefits appear to be reducing, they are still positive. Recent interest in goat farming has stimulated discussion on the value of gorse as a fodder source, and it is shown that gorse can produce higher green dry matter yields per hectare than grass, but at a lower quality.

Finally, the possible values of gorse as a nursery plant and erosion control agent are discussed. Little evidence is found to support either the nursery plant or the erosion control benefits having significant positive net values.

CHAPTER 4

PROBABLE IMPACTS OF BIOLOGICAL CONTROL

Gorse occurs commonly in the British Isles and on the Western European seaboard. It is a minor problem in North-West Spain but elsewhere is not aggressive and is valued as a wildflower. Natural regulation is maintained in part by the invertebrate herbivore fauna which attacks the plant, and the aim of biological control is to establish that sort of control in New Zealand.

Though difficult to establish, history shows that this method can provide stable, long-term control of weed problems. Sixty years ago insects were introduced into Queensland to control 25 million hectares of rangeland totally infested by prickly pear (Chapter 1). Today prickly pear is still common on this land, occurring at 1-15 plants per hectare (Hill, 1983). More recent examples of successful biological control include St Johns Wort control in California, *Lantana* control in Hawaii, Skeleton weed control in Australian wheat fields, and many others. In the most recent case, the aquatic weed *Salvinia molesta* has been controlled in Queensland and Papua New Guinea by insects imported from South America in 1980 by CSIRO. In New Zealand, three South American insects have been introduced to control the aquatic alligator weed *Alternanthera philoxeroides*. The level of success achieved has been encouraging, and it is considered that "biological control may have a substantial long-term effect on alligator weed in New Zealand." (Roberts et al, 1984).

Establishment of an equally successful programme against gorse would take many years. If control agents were to be released in New Zealand in 1985, it is unlikely that they could have any impact on gorse vigour and density nationally before 1990 or 1995. In fact, it may prove impossible to re-establish gorse insects in New Zealand at all. Assuming that a complex of different control agents did establish widely here, what impact could DSIR hope to have on the gorse problem?

There are two distinct facets to gorse control in New Zealand :

1. Reduction in plant density in mature gorse stands; and
2. Suppression of gorse regeneration and spread.

It is very difficult to predict the impact of biological control on either situation because of uncertainties in:

a) Establishment of control agents;

b) Population responses of control agents in New Zealand without their natural enemies;

c) The impact of native parasites and predators on the introduced control agents;

d) The role of other plants (eg. grasses) as competitors with weakened gorse;

e) The impact of New Zealand climate on control agent performance.

In mature stands control means reduction in gorse density to a level where the land can be managed. Mature plants are highly resilient to all forms of attack and so the probability of a high degree of control is small. Gorse mite can kill mature plants so the likelihood of some reduction in plant density is significant. One consequence of a moderate reduction in the density of gorse in mature stands could be up to a fourfold increase in the number of flowers, as flowers could form on the sides of bushes as well as the tops (R.Hill, pers.comm)

In developing gorse stands control can be equated to reduction in plant vigour and aggressiveness. Immature plants have much less capacity to compensate for damage than mature plants. Even low densities of control agents could therefore reduce plant vigour. The greater the reduction, the more susceptible gorse plants would be to additional grazing, competition, climatic stress and herbicides.

The likelihood of achieving a particular degree of control over a weed by biological means is inversely related to that degree of control, and is impossible to predict for an individual case. Dr M.J. Crawley (pers. comm.) has summarised the history of biological weed control worldwide. Based on all previous weed projects the likelihood of establishing a single control agent in a new habitat is 60 percent. The likelihoods of that newly established agent then giving differing degrees of control are:

0% control	25%	50%	75%	100% removal
79% likelihood	11%	5%	5%	0% likelihood

Four to six potential control agents are known for gorse. Additional agents would achieve better results but their effects would not necessarily be strictly additive, i.e. 4 agents might achieve the same control as 6.

The benefits of successful biological control vary according to the end use of the land. In forestry successful control might make alternative planting strategies such as line-cutting more economic, and would remove the need for release spraying during the first years of tree growth. In pastoral farming successful biological control might make the development of existing gorse stands economic, would slow or stop regeneration in existing or renovated pasture, and would certainly reduce farmer costs by making herbicide applications more effective in the long-term. These points are treated more vigorously in Chapter 7.

CHAPTER 5

THE ISSUES INVOLVED: THEORY AND MEASUREMENT

5.1 Technological Change

The introduction of biological agents to control gorse is, by definition, a technological change. Although the impact of a new technology may generally be beneficial to society, these changes are often achieved at a cost to some sectors of the community. Usually the group enjoying benefits will not be the group bearing the cost, and many questions must be answered before the new technology can be unambiguously "good" or "bad". This section will look at the concept of technological change with reference to the introduction of biological control and discuss how the impacts may be quantified. Decision rules to evaluate the desirability of introduction will be formulated.

We do not, as Stoneman (1983) laments, have a neat, completely general definition of the concept of technological change. Indeed, Yotopoulas and Nugent (1976) consider that "a great deal of the confusion surrounding the discussion of technological change is no doubt due to the ambiguity that shrouds the term in its conventional usage". It would seem imperative that some common ground can be reached for a definition of technological change before we can move on to discussing its impact.

Technology is considered to be the body of knowledge which can be applied to a production process. This is defined in neoclassic literature as being represented by a production function;

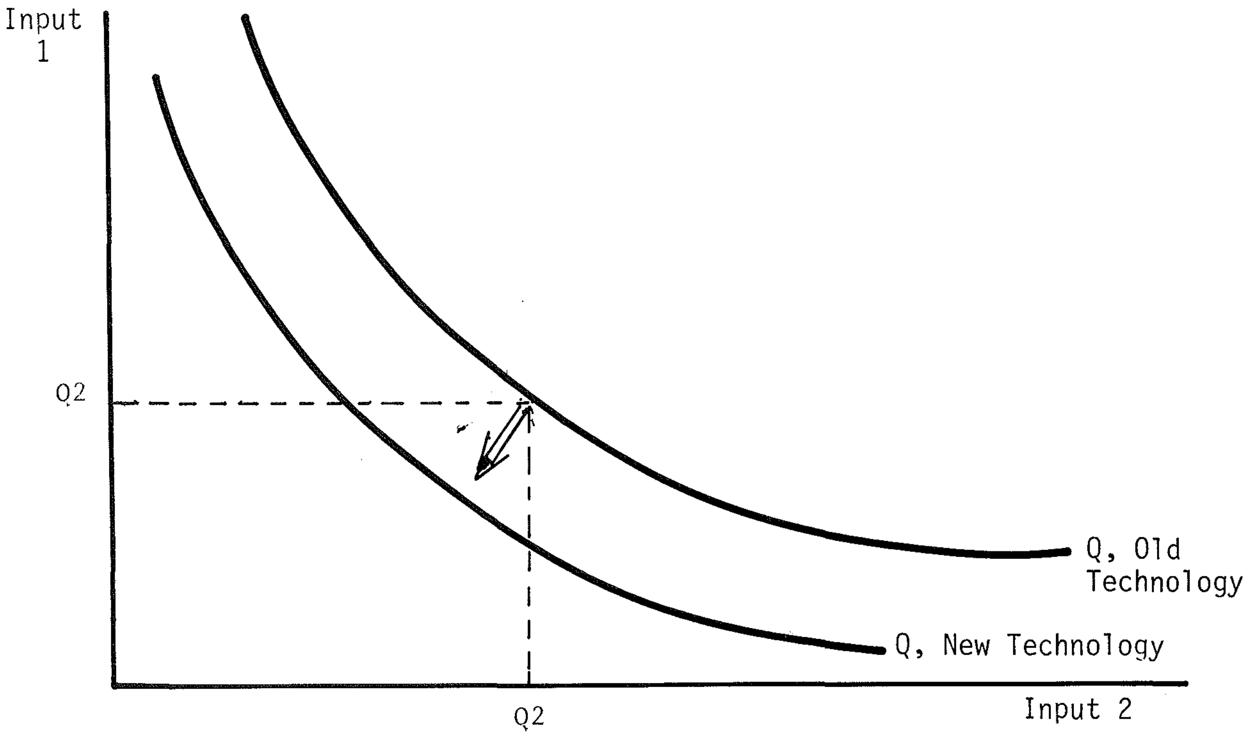
$$Q = f(t,k,c,)$$

where Q is output, t is time, k and c are capital and labour respectively, and f is some functional relationship. Technological change is represented by the cover-all term t in this production function. One initial problem of estimation using this residual approach is that several other factors may also be changing over time, including factor prices.

The production function approach can be represented as an isoquant movement towards the origin (as shown in Figure 5.1), implying that a given amount of output can be produced with fewer inputs. This is purely a physical relationship, and can be related to economic reality by the Schumpeterian concept of latent and economically feasible technology. Latent technology is invention, and before a new technology is introduced some distinct advantage to the entrepreneur has to be shown. Thus an invention may require some exogenous force such as a change in either output or factor prices or an adjustment of the risk level before being introduced. Once introduced a quantum shift in the isoquant should result (ie. a discrete change), as opposed to a continuous change resulting from improvements in technical efficiency from using the old production process. Following the Hayami and Ruttan (1971) approach, much of this technological change is "induced" by changes in relative factor scarcities.

FIGURE 5.1

Change in Inputs needed to produce Q between Old and New Technology

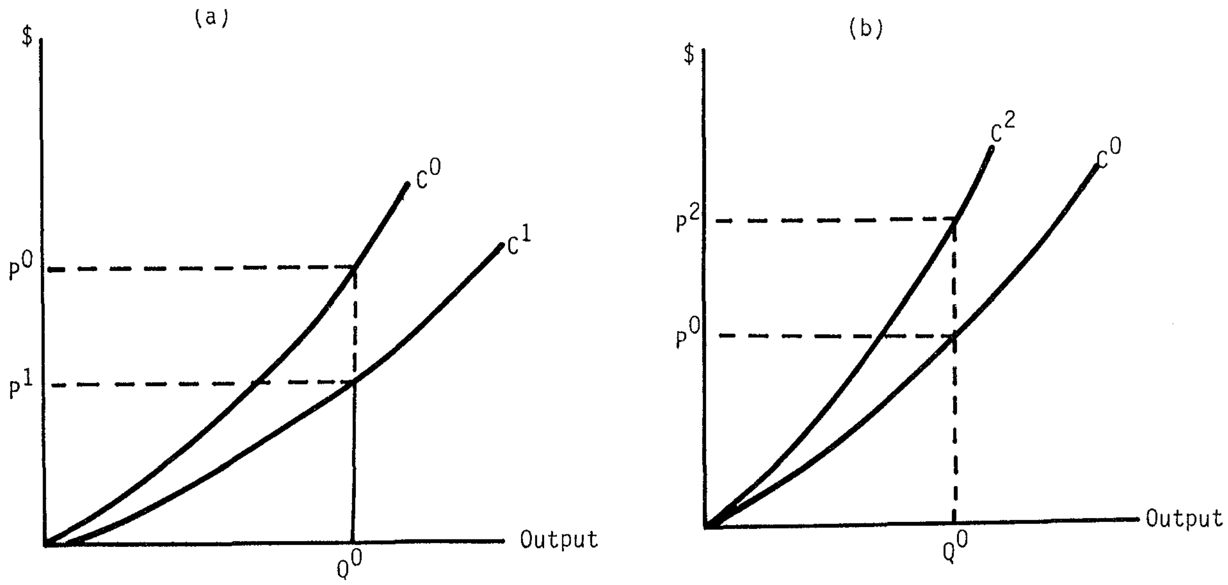


A further distinction is made between embodied and disembodied technical change. Technological advance is disembodied if, independent of any changes in the factor inputs, the isoquant contours of the production function shift towards the origin (Figure 5.1) (Stoneman, 1983). This is the "mana from heaven" type of technological change with a resultant rightward shift in the cost curve (from C to C^1, Figure 5.2(a)). Embodied technological change requires an investment in new skills and equipment, and may involve retraining labour. Thus embodied change has an associated cost, while a disembodied change can be thought of as costless! Changes facing beekeepers are an example of induced embodied technological change. Induced because input factors have changed in availability and price, embodied because new skills must be learnt to use the technology. Disembodied technology (lowering of gorse clearing costs) is automatic, embodied (pollen substitute feeding) is not.

Two distinctly different concepts are simultaneously occurring with the introduction of biological control of gorse. A reduction in the vigour of the plant lowers the cost structure for those who regard gorse as a weed. This makes areas which may have previously been marginal to clear now become viable to clear. Additionally, less cost may be involved in follow-up control once the area has been cleared. This reinforces the shift in the cost curve, with the net result being a rightward shift in the cost curve as shown in Figure 5.2(a).

FIGURE 5.2

Cost Curve Analyses



where

C^0 = original cost curve

C^1 = rightward shift - less cost of produce the original output, Q^0 $(P^a - P^1)$ is the decrease in cost.

C^2 = leftward shift - greater cost to produce the original output, Q^0 $(P^2 - P^0)$ is the increase in cost.

However, the second effect is that less gorse flowers could be expected to be available as a pollen source. Under these situations beekeepers must use the new pollen substitutes to maintain bee health and subsequent honey production with its associated by-product of plant pollination. This will move a beekeeper's cost curve to the left, as shown in Figure 5.2(b). Thus some framework needs to be formulated to both quantify these alternative effects and to weight the distribution of gains and losses. Welfare economics provides such a framework. Gains and losses can be aggregated and the compensation criterion applied. This involves the following test - everyone is better off under the new scheme if gainers can potentially compensate the losers so that everyone prefers the change to the original position. If the losers are, in fact, compensated then the change will be acceptable to all. Problems arise when the change is potentially beneficial to all, as it is then only possible for winners to compensate losers. Thus the compensation criterion is only concerned with allocative efficiency, and cannot handle the question of income redistribution. Economists usually absolve themselves from judgements on the proper distribution of gains from a change and hide behind the compensation criterion. Cost - benefit analysis is deficient from this perspective. Who benefits and who loses from the technology within the social distribution of income is a key question (Kingma, 1985), and this issue is addressed in Tisdell et al. (1984) with specific reference to biological control of weeds. The Industries Assistance Commission (1985) considers "Adjustment schemes may be justified if: desirable changes in policy can only be achieved if people adversely affected are compensated" (p.8.4). This appears to be a step past the normal compensation criterion framework, which usually includes the "potentially able to compensate" clause, but recognises income distribution problems.

The compensation criterion has been applied to a situation involving beekeepers. In examining the case of Tulare County (California) citrus Siebert (1980) shows that substantial net benefits (US $722,810 annually) arise from mandatory requirements to protect bees from pesticide sprays. In this particular case study, bee keepers suffered substantial financial losses when their bees where damaged by pesticides sprayed on citrus trees while bees where gathering nectar. The 1975 losses equaled more than 4 percent of Californian beekeepers' income. Regulation was then introduced requiring citrus fruit owners to change both the type of spray and time of application (to early morning) to protect bees. This raised costs on average by $8 per treated acre. Taking the difference between the amount that beekeepers save and the extra amount that growers spend enabled the net gain to be calculated. In this particular case study, property rights were assigned to the beekeepers - legislation was passed to force orchardists to protect the bees. However, should the legislation be changed to assign property rights to orchardists, the same net benefits would result. The distribution of these net benefits would be different, and Siebert calculated that a nectar gathering fee of $1.51 per hive would compensate growers for the extra costs involved. This highlights the issue that property rights is concerned with the distribution of gains, and not the gains themselves in most cases. The exception to this is where the income effects facing any particular individual are a "large" percentage of his/her income.

5.2 Property Rights

Many of the issues involved with the introduction of biological control arise from a lack of full property rights. Imagine a situation whereby farmers and others who "own" gorse could charge beekeepers for the pollen from that gorse, and beekeepers could, in turn, charge for fertilisation services. Owners of gorse would have an incentive to maintain gorse plants and a market would operate to ensure that pollen was available to beekeepers up to the cost of providing a satisfactory alternative such as artificial pollen. Beekeepers would charge farmers and horticulturalists for fertilisation services, thus the question of losses from lack of bee activity could be measured (Cheung, 1973). Scarcity values would push up prices in both markets and the pricing mechanism would allocate gorse efficiently (Siebert, 1980). A set of non-attenuated property rights to achieve such an efficient solution would need to be completely specified, exclusive, transferable, and enforceable (Randall, 1983). Complete specification of those rights would include rights about ownership, the restrictions upon those rights, and a system of penalties for violation of rights. Exclusive means that all rewards would accrue to owners of the rights, and transferability would ensure the rights would move to their best use in society.

It is easy to see, however, that the allocation of property rights to gorse pollen and bee fertilisation services is limited. Pollen is a "free" good in the sense that it is available to bees and fertilisation is a by-product of the honey industry. A market does operate to the extent that many owners of gorse are also benefiting from fertilisation of their clover and fruit crops. Many other owners of gorse (river beds, waste land) are neither potentially able to benefit from providing pollen nor gain from fertilisation of other crops. As Cheung (1973, p19) states, the reciprocal situation in which a beekeeper is able to extract honey from the same farm to which he renders pollination services is an interesting theoretical riddle. Thus the property rights concept is not able to effectively allocate gorse to its best use.

A market can and does operate to provide pollination services. The first recorded renting of bees for pollination purposes occured in the United States in 1910 (Johnston, 1973, p43), and the same author considers the beekeeping industry as competitive as any industry in the United States. Pollinating bees are an extremely mobile factor of production, with many hives being moved thousands of miles to service growers and take advantage of seasonal weather changes. Beekeepers in the United States generally receive more of their income from paid pollination services than from honey collection (Industries Assistance Commissions, 1985).

A very good example of the market system operating to provide services can be found in New Zealand. Kiwifruit production has increased drammatically in the Bay of Plenty and other areas in the last few years. During a period of 2 to 3 weeks in mid to late November it is critical to ensure pollination of the vines. This requires from 1 to 12 hives per hectare, depending on the age of the vines, with a district average of around 5 hives per hectare. An estimated 26,000 hives were involved in pollination services in the Bay of Plenty in 1984, with $65 per hive being the accepted rental fee. During this period little or no nectar is gathered, and with an increased concentration of hives in the area, late spring pollen is critical. It is no coincidence that more interest in pollen substitutes is shown in the Tauranga area. Property rights operate to the extent that bees do not operate very far from a hive, and by strategic placing of the hives an orchardist can encourage bees to pollinate the "right" vines, and not the neighbours.

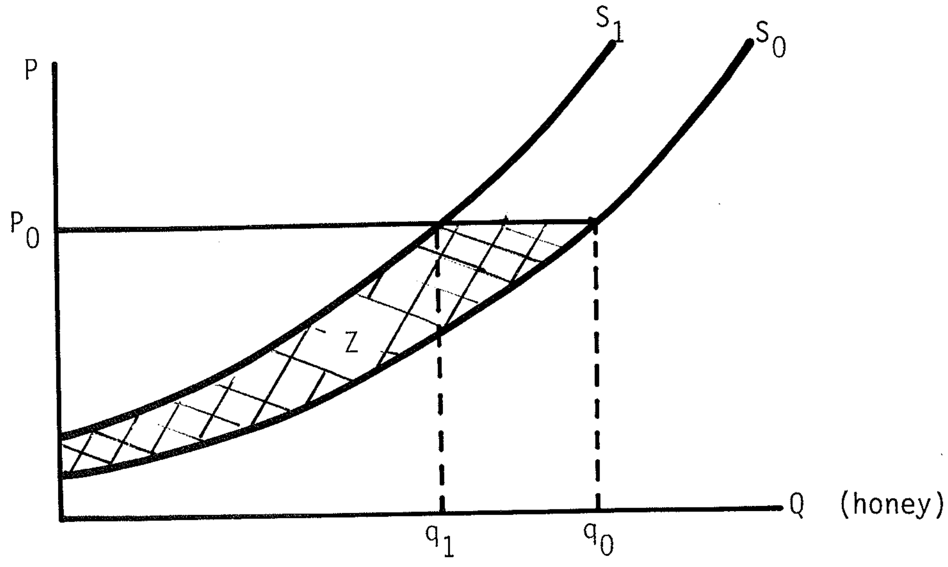
The other important issue is that once introduced, the control agent will not differentiate between "undesirable" gorse to attack and "desirable" gorse to leave. This is a classic externality - the welfare of beekeepers is affected by the actions of others (Meade, 1952) who seek to control gorse. Selective control such as current methods would leave areas of "desirable" gorse, biological control may accentuate the problem of beekeepers in two separate but related ways. More "undesirable" gorse is cleared as the cost of clearing is reduced, and much of the "desirable" gorse may also become unavailable as a pollen source.

5.3 Measurement of Welfare Change

The associated welfare measurement problem can be given "willingness to pay" interpretations. Benefits of introduction can be measured by the maximum amount that a person would be willing to pay for the change. This is known as compensating variation - the amount of money which, when taken away from an individual after an economic change, leaves the person just as well off as before the change (Just, Hueth and Schmitz, 1982). For risk neutral persons, discounting the future income stream expected to result from introduction will provide a lower bound estimate of benefits. This of course abstracts from reality and assumes an analytical "representative" person. Since the seminal work of Griliches (1958) measurement of the benefits to research have been undertaken by numerous authors (Scobie, 1976, Lindner and Jarrett, 1978, Ruttan 1982, and Wise 1984) using this cost - benefit approach. Examples where benefits of the control of weeds and pests in agriculture have been quantified include Vere et al (1982) for serrated tussock control in Australia, Marsden et al (1980) for skeleton weed (Chondrilla juncear) in Australia, Ritchie et al (1978) for soldier fly in New Zealand, Johnston (1975) for Australian cattle tick, Johnston and Vere (undated) for sheep lice control in Australia, Hartley and James (1979) for New Zealand Californian thistle in pasture, Hartley and Atkinson (1978) for barley grass control in pasture, and Industries Assistance Commission (1985) for Echium species in Australia.

FIGURE 5.3

Welfare Change in Output Market



The costs of introduction are harder to qualify. However, the net welfare effect on the producer (beekeeper) of an input (pollen) price change can be measured accurately in the output (honey) market (Just, Hueth, and Schmitz, 1982). Thus, suppose that the shift in marginal cost brought about by the change in pollen "prices" is represented by the movement from So to S1 in Figure 5.3. The resulting change in producer surplus is then given by the shaded area z, with an output change from, qo to q1. The compensatory variation associated with the price increase is the sum of money that, when taken away from the producing firm, leaves it just as well off as if the price did not change. The sum in this case is negative. Compensation takes place after the change in prices (Varian, 1984). The correct measure of the welfare change facing beekeepers before possible introduction of biological agents is equivalent variation - how much would beekeepers collectively be willing to pay to avoid the change. The two welfare measures, equivalent and compensatory variation are measured before and after the change respectively, and will differ to the extent that income effects are important. Expected changes in the profits of producers (beekeepers) is also an exact measure of the compensatory variation.

Estimates of changes in other markets are needed if more than one price change is considered (Edwards and Freebairn, 1982). Supply shifts may be large enough to cause a slight fall in commodity prices in other sections of the market. Estimates of elasticities would be needed to calculate these effects.

A further problem associated with biological control is that the time period is uncertain. Possible reduction in natural pollen may be able to be compensated for with artificial pollen substitutes. However, some degree of uncertainty is associated with the technical acceptance of this relatively new product. Thus the amount spent on artificial pollen may not be a complete measure of the costs. The time frame involved in any change in the availability of gorse as a pollen source is important. Difficulties will be less severe if a number of years are required before any impact is apparent, as beekeepers will be able to adjust to new technologies. As outlined in Chapter 4, it appears as though a medium to long term period is likely before major impacts are felt. The Industries Assistance Commission (1985) considers that it could be 10 years or more after release before introduced agents reduce *Echium* to a "significant level" (p.8.1), and a similar time span would appear realistic in the gorse case (Hill, 1983).

Loss of the pollination services of bees could potentially amount to a major (ie. non-marginal) cost to agricultural and horticultural industries. Increasing beekeeping costs to the extent of forcing operators out of the industry would cause these losses to occur. The producer surplus approach has no way of measuring these second round effects, and thus may be substantially underestimating costs of introduction. However, despite some beekeepers claims to the contrary, it is extremely unlikely that any major loss will occur to either the agricultural of horticultural industry. The demonstrated ability of a market system operating for pollination services in the Bay of Plenty is a clear contradiction to the arguement that substantial losses will occur.

5.4 Uncertainty

Uncertainty has many perverse effects when considering the introduction of biological agents to control gorse. The first and probably the most important uncertain state is the degree to which the biological control will be "successful". This will obviously depend upon the time frame used, and could range from no effect at all to almost complete eradication of gorse. Beekeepers are, however, interested in gorse as a pollen bearing plant. It is conceivable that reduced vigour of a plant may, in fact, increase its flowering, thus increasing pollen availability. Conversely, eradication of gorse would completely remove a prime source of pollen for beekeepers. Reality would suggest an effect somewhat intermediate between these two extremes, as Crawley assigned a zero likelihood to the possibility of eradication (Chapter 4).

Secondly, the threshold where a reduction in gorse pollen availability becomes critical is unknown. Major differences may occur between geographical regions and also between seasons. Effects of this reduction in pollen availability are complicated by the uncertainty surrounding artificial substitutes. As outlined earlier, beekeeper's and the nations costs will be greater should a substantial reduction in gorse flowering occur and should the artificial pollens prove to be unsatisfactory.

It is easy to see the complication caused by uncertainty - beekeepers can only be advised on possible medium to long term impacts of biological control, and they are uncertain as to the effectiveness of pollen substitutes in replacing natural pollen. Asking the question "If gorse flowers were reduced by 50 percent, what would the estimated cost of feeding pollen to your hives be?" (Chapter 6) is not a willingness to pay question. To the extent that beekeepers are risk averse, answers to this question will understate compensatory variation. The correct willingness to pay (equivalent variation) question is "how much would you be willing to pay rather than have have gorse flowers reduced by 50 percent". What is relevant to the analysis is beekeepers response to a change in perceived risk (Mishan, 1982, p331).

Any decision to change the natural environment raises the issue of irreversibility - once introduced, can the biological agent be eradicated should anything go wrong? There are numerous examples of plants, animals, and insects being introduced which have proved either impossible or extremely expensive to eradicate - to wit, gorse. Society may have a collective willingness to pay to avoid introducing another species which may have some unanticipated long term consequences (what happens when all the gorse is eaten). Conversely, society may also have a willingness to pay to reduce possible externalities caused by current methods of gorse control. New Zealand is still engaged in widespread use of 2,4,5 -T for gorse control - remember Agent Orange?.

5.5 Summary

The problem of biological introduction has many facets. Firstly, the physical impacts of the technological changes must be identified. This involves two distinct issues - the impact on gorse of the biological control, including the effect on pollen availability, and the substitutibility of artificial pollen for natural pollen. Uncertainly is involved in each of these issues.

Secondly, welfare measurements of the change are needed before total costs and benefits can be aggregated. Given a set of nonattenuated property rights, an allocatively optimal solution could be obtained by using the market system. This is impracticable for several reasons, thus the compensation criterion, with its associated shortcomings, must be employed. The introduction of biological control is economically efficient if winners can potentially compensate the losers and still be better off with the change. All costs and benefits must be included in the aggregation, and many of these welfare changes are difficult to even identify, let alone quantify.

CHAPTER 6

COSTS OF INTRODUCTION

6.1 Potential Costs to the Beekeeping Industry

A census was conducted of all registered beekeepers owning over 50 hives to obtain an estimate of potential costs to the beekeeping industry of the introduction of biological agents to control gorse. A copy of the survey form is shown in Appendix A.

The objectives of this survey were:

1) to find some estimation of the value of gorse flowers as a pollen source;

2) to find indications of the impact of reductions in available gorse flowers; and

3) to estimate the likely cost of a possible reduction in gorse flowers.

A total of 561 forms were posted, and 268 usable replies were included in the analysis of results. Some 10 or 12 forms returned were not usable for various reasons. The usable returns represented a 48 percent response rate, with Table 6.1 providing a regional breakdown of the returns.

TABLE 6.1

Usable Returns by Apiary District

Apiary District	Usable Returns	Percent Usable of Those Posted
North Auck	21	43
Auck	19	47
Taur	29	32
Ham	26	38
Palm North	26	62
Nel	31	62
ChCh	50	60
Oam	33	42
Gore	30	80
Total	268	48

The average number of hives per respondent was 601. A breakdown of the hive numbers is presented in Table 6.2, along with a comparison with the New Zealand figures. The percentage of usable returns is higher for the larger operators.[1] The percentage of New Zealand beekeepers included in the survey results ranges from 37 percent at 51-250 hives/beekeeper to 86 percent at over 1000 hives/beekeeper. The total forms posted of 561 can be compared to the yearbook figures of 545 operators, although some operators with exactly 50 hives would have received survey forms but would not be included in the Yearbook's "above 50 hives" total. Thus we may conclude that results are biased towards the larger operators, and those in the Palmerston North, Nelson, Christchurch, and Gore apiary districts.

TABLE 6.2

Beekeepers by Hive Numbers

	Hive Numbers					
Number of Response	1-50[b]	51-100	101-250	251-500	501-1000	1000+
Survey	13	50	52	52	53	44
New Zealand[a]	5,900	(275)		129	90	51
Survey Response as a Percentage of Beekeepers		(37)		40	59	86

a Source: New Zealand Yearbook, 1984
b Beekeepers with under 50 hives were not included in the survey posting

Question 1 asked respondents to list up to 5 major spring and autumn pollen bearing plants (including gorse if applicable). The perceived importance of gorse as a pollen source can be seen from the next two tables (Tables 6.3 and 6.4).

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[1] In collecting primary data some 8 types of error can reduce the accuracy of research data. These errors are sampling, population specification, frame, selection, non-response, surrogate information, measurements, and experimental. A study using a census, be definition, contains no sampling, population specification, selection or frame error and reduces non-response bias to those who did not reply rather than those not contacted. However, error may still arise from non-response, surrogate information, and measurement error (Tull and Hawkins, 1976). These are discussed later in the report.

TABLE 6.3

Major Spring Pollen Plants
(Five Responses)

Plant	1st	2nd	3rd	4th	5th	Total
Gorse	141	35	16	10	10	212
Willow	78	76	39	10	4	206
Broom	1	39	31	7	5	83
Dandelion	4	12	14	28	14	32
Acacia	5	9	11	10	5	40
Barberry	2	10	12	8	6	38
Clovers	2	4	3	11	12	32
Hawthorn	-	4	11	10	3	28
Manuka	-	6	6	6	6	24
Five-Finger	7	7	7	-	1	22
No Response	10	20	46	92	136	

Gorse and willow dominated the spring responses, followed by broom and dandelion. Gorse and dandelion are the major autumn sources of pollen, followed by clovers.

TABLE 6.4

Major Autumn Pollen Sources
(Two Responses)

Plant	1st	2nd	Total
Gorse	125	12	137
Dandelion	15	43	58
Clovers	28	16	44
Thistle	8	15	23
Broom	-	11	11
Natives	6	5	11
Willow	1	1	2
No Response	56	101	

Respondents were then asked when gorse is the most value to the hives. Results are presented by apiary district in Table 6.5.

TABLE 6.5

When is Gorse the MOST Value?

	North Auck	Auck	Taur	Ham	Palm North	Nelson	ChCh	Oamaru	Gore
Spring	11	8	13	13	11	14	14	16	22
Autumn	2	2	2	1	2	5	1	2	0
Both Spring and Autumn	8	5	8	7	4	10	34	10	6
Never	-	3	6	4	9	1	-	5	2

The Christchurch district had a much higher (and statistically different) number of beekeepers regarding gorse as important in both spring and autumn. This is also confirmed by Table 6.6, which looks at the first response to major pollen plant by apiary district. A probable reason for the importance of gorse to the Christchurch district may be the honeydew honey industry in Canterbury. This will be discussed later.

TABLE 6.6

Importance of Pollen Plants By Region
Number of Beekeepers (1st Response)

	National	North Auck	Auck	Taur	Ham	Palm North	Nel	ChCh	Oam	Gore
Spring										
Gorse	141	13	7	10	7	6	16	42	18	21
Willow	78	3	6	13	11	10	11	5	12	7
Autumn										
Gorse	125	14	10	7	4	5	18	38	13	15
Clover	28	-	1	5	4	5	2	1	8	3

The importance of gorse was confirmed by asking the proportion of hives that would:

a) gather some gorse pollen;
b) gather the bulk of pollen needs from gorse; and
c) gather only gorse pollen

at some stage during both spring and autumn. As expected, the numbers in each "box" decline as respondents answered a, b, and c above (Table 6.7).

TABLE 6.7

Percentage of Hives Gathering Gorse Pollen
(Expressed in Numbers of Beekeepers)

		0	1-20%	21-49%	50-75%	76-99%	100%
Spring	Some	40	30	22	47	39	90
	Bulk	62	41	28	49	31	57
	Only	108	34	22	40	18	46
Autumn	Some	83	29	15	42	32	68
	Bulk	105	29	18	48	20	47
	Only	138	27	15	27	27	34

The next series of questions was designed to find if a lack of pollen is currently a problem, and if so, what steps beekeepers are taking to overcome this problem. The question of pollen substitutes and supplements has been discussed and several important changes appear to be occurring with these products. Answers to question 4(a) "Have you hives that can/do suffer from lack of natural pollen" are shown in Table 6.8.

TABLE 6.8

Lack of Natural Pollen
(Number of Responses)

	National	North Auck	Auck	Taur	Ham	Palm North	Nel	ChCh	Oam	Gore
a) Spring										
Yes	162	11	5	22	17	16	16	34	20	20
No	96	10	3	5	8	10	15	13	11	9
No Response	10	0	1	2	1	0	0	3	2	1
Chi-square = 25										
b) Autumn										
Yes	84	4	5	11	1	2	10	30	11	9
No	132	14	13	9	15	18	20	15	15	11
No Response	52	3	1	9	10	6	1	5	7	10
Chi-square = 59										

An early source of natural pollen is shown to be more of a problem in the Tauranga district, where build-up for the kiwifruit pollination is a major concern. For pollination services the hives must be up to an agreed standard by early November, whereas honey production hives have another 6-8 weeks for colony build up. Christchurch is the only other district to differ much from the national pattern in the spring. However, the autumn pollen question shows that statistically significant differences exist in the apiary districts.

Question 5 asked about current feeding patterns. Some 181 beekeepers indicated that they are not feeding natural or substitute pollen to their bees. Very few responses were recorded to the question asking about amounts of either natural or substitute pollen being fed to bees. These replies are recorded in Table 6.9.

TABLE 6.9

Amount of Natural and Substitute Pollen Feed
(Number of Responses)

Amount (kg/hive)	Natural Pollen	Substitute Pollen
1	3	8
2	1	1
3	1	2
5		2
7	1	1
	6	14

Answers were rounded to the nearest integer, so replies to question 5(a) may have excluded some respondents who are currently feeding less than one half of a kg per hive. Additionally, some beekeepers may not have filled out this question accurately, as a very low response was recorded. The next question asked about costs involved in feeding pollen, and a slightly higher response rate was recorded to this question (Table 6.10).

As discussed elsewhere in the report, the feeding of pollen substitutes is perceived by the industry to be in a state of technological change. To find beekeepers attitudes towards pollen feeding, question 5(c) and (d) asked if beekeepers felt that their bees would perform better with more feeding, and if so, why this was not being done. It was considered that if biological control of gorse was to seriously affect the beekeeping industry, reasons for not feeding more pollen under present conditions may be valuable information. Results are presented in Table 6.11. The apiary district break-down is given, as the results are statistically different. Tauranga and Christchurch districts have a greater percentage answering "Yes".

TABLE 6.10

Costs of Feeding Natural and Substitute Pollen
(Number of Beekeepers)

Cost ($/hive)	Natural Pollen (Christchurch)	 (National)	Substitute Pollen (National)
1	2	5	11
2	1	3	5
3	1	2	1
4	1	2	
5			1
7		1	
9	1	1	
10	1	1	
13	1	1	
20		1	
21		1	1
40		1	
50		1	

TABLE 6.11

Would Your Hives Perform Better if You Fed More Pollen?

	National	North Auck	Auck	Taur	Ham	Palm North	Nel	ChCh	Oam	Gore
Yes	131	5	8	19	13	9	12	33	13	18
No	59	2	6	5	8	7	12	7	5	6
Don't Know	64	11	4	4	4	9	5	8	13	5
No Response	14	3	1	1	1	1	2	2	2	1

Beekeepers where then asked for their reason(s) for not feeding any or not feeding more pollen. This question was left open, and groups of responses shown in Table 6.12 where received.

The preceding questions were designed to find the importance of gorse to beekeepers, the extent and timing of a pollen deficiency, measures being taken to overcome any deficiencies, and reasons for not feeding pollen where a perceived deficiency exists. Answers to these questions are important, but the critical issue addressed in the survey is the effect of the introduction of biological control. This was the purpose of Question 6. Given the degree of uncertainty associated with the effects upon gorse of biological control, beekeepers were asked to consider impacts of a reduction in available gorse flowers of 10, 25 and 50 percent.

TABLE 6.12

Reasons for Not Feeding (or Not Feeding More) Pollen

Reason	1st Response	2nd Response
	(Beekeepers)	
1. Too expensive	28	7
2. Unable to obtain enough natural pollen	23	8
3. No suitable product	18	9
4. Better to shift hives instead	17	5
5. Lack of time	16	9
6. Disease problem	8	3
7. Don't know enough about substitute pollen	7	

As discussed in Chapter 4, two separate issues are involved with the effects of biological control. Firstly, the degree of biological control as measured by a reduction in vigour, and secondly, the question asked here of the reduction in gorse flowers. These may not, and indeed, probably will not, be the same.

Beekeepers were first asked if they would need to feed pollen if available gorse flowers were reduced by the different percentages. This was followed by asking the percentage of hives, the number of days, and finally, the estimated cost. Questions on the estimated cost of possible reductions in available gorse pollen were expected to be difficult for beekeepers to answer. This proved to be the case. However, most beekeepers could be expected to have a reasonable idea of the need to feed compensatory pollen.

One of the major problems in conducting a census of this nature is the problem of bias in the results. Two major sources of potential bias exist in this census. Firstly, the non-response bias, and secondly, the strategic bias. Non-response bias has been discussed, but the issue of strategic bias remains. This occurs when respondents feel they have a vested interest in the issue involved, and that by answering the questions in a particular manner they may be able to influence possible outcomes of any event. Question 6 is vulnerable to strategic bias. Results suggest that beekeepers answered the question to the best of their knowledge,[2] and these results are summarised in Tables 6.13 to 6.16.

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[2] A check was conducted by cross-tabulating the "Lack of Natural Pollen" by "Would your hives perform better if Pollen was Fed". Results are shown in Table 6.18, and would suggest that responses are consistent.

TABLE 6.13

Numbers of Beekeepers Needing to Feed Pollen to Bees with 10, 25 and 50 Percent Reduction in Gorse Flowers (Number of Responses)

Need to Feed	Percent Reduction in Flowers 10	25	50
Yes	57	99	145
No	136	93	50
Don't Know	62	66	61
No Response	13	10	12
	268	268	268

Tables 6.14 to 6.16 apply only to those beekeepers who answered "yes" in Table 6.13.

TABLE 6.14

Proportion of Hives to Compensate (Number of Responses)

Percent of Hives Affected	Percent Reduction in Flowers 10	25	50
1-20	8	11	7
21-49	12	19	15
50-75	13	19	53
76-98	3	11	18
100	16	20	33

Regional differences were apparent in answers to the need to feed pollen at selected reductions in gorse flowers, with the Christchurch district once again showing a different response to other districts, probably because of honeydew honey.[3] Auckland, Hamilton, and Palmerston North districts were less concerned with the reductions in gorse flowers. Both Hamilton and Palmerston North districts indicated concern about lack of spring pollen in an earlier question (Table 6.8).

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[3] Additionally, gorse may be one of the few reliable sources of early pollen on the Canterbury Plains.

TABLE 6.15

Number of Days to Compensate

Days	Percent Reduction in Flowers 10	25	50
1-7	2	2	1
8-14	1	1	
15-21	1	2	4
22-29	2	2	3
30	5	11	17
31-59	5	8	9
60	8	14	31
61-89	1	1	
90	3	10	13
90+	7	9	17
No Specific Number of Days	19	32	47

TABLE 6.16

Cost of Feeding to Compensate

$/Hive	Percent Reduction in Flowers 10	25	50
1	4 (1)	8	10
2		3 (2)	4
3	6 (3)	2 (1)	10 (2)
4	1	4	6 (1)
5	5 (3)	5 (3)	2 (1)
6		2 (1)	2 (1)
7		2 (1)	5
9	1 (1)	1 (1)	1 (1)
10	2 (1)	1	3 (2)
12			2
13		1	
14	1 (1)	2 (2)	4 (3)
16	1	1	
18			1 (1)
20			2 (1)
35			1 (1)
Responses	21	32	43

a Numbers in parentheses represent responses from beekeepers in honeydew areas

The regional breakdown of Table 6.13 is shown in Table 6.17. Chi-square values of 55 to 57 were recorded for the three categories, indicating that the districts are statistically different in their responses.

TABLE 6.17

Number of Beekeepers Needing to Feed Pollen to Bees with 10, 25 and 50 Percent Reduction in Gorse Flowers, By District

	National	North Auck	Auck	Taur	Ham	Palm North	Nel	ChCh	Oam	Gore
10% Reduction										
Yes	57	4	3	5	3	1	6	22	6	7
No	136	7	12	14	16	20	21	13	19	13
Don't Know	62	6	4	7	6	4	4	14	7	9
25% Reduction										
Yes	99	8	4	11	3	3	7	32	15	15
No	93	7	9	7	15	16	16	8	7	7
Don't Know	66	4	6	8	7	6	8	9	9	8
50% Reduction										
Yes	145	12	8	15	7	10	13	38	20	21
No	50	2	4	5	11	11	5	4	4	3
Don't Know	61	4	7	6	7	4	13	7	7	5

Use of the cross-tabulation technique enables some consistency checks to be made on beekeeper's answers. For example, if a beekeeper considered that lack of pollen was a problem in the spring, then it would be consistent to reply "yes" to the question "Do you consider any of your hives would perform better if you fed more pollen?" Results of this cross-tabulation are given in Table 6.18, and suggest results are consistent.

TABLE 6.18

Cross-Tabulation, Lack of Pollen in Spring by Increase Performance by Feeding

Increase Performance By Feeding Pollen	Lack of Natural Pollen in Spring Yes	No
Yes	113	15
No	19	38
Don't Know	25	37

A cross-tabulation of the "Need to Feed Pollen with Reduction in Gorse" by "Lack of Pollen in Spring" is shown in Table 6.19. Results show that several Beekeepers who currently consider they have a spring pollen problem would not need to feed with a reduction in gorse flowers (64, 38, and 24 for the 10, 25, and 50 percent reductions respectively). This could still be consistent if gorse was not a major pollen source to these Beekeepers.

TABLE 6.19

Cross-Tabulation, Need to Feed Pollen with Reduction in Gorse By Lack of Pollen in the Spring

Need to Feed Pollen With	Lack of Natural Pollen in Spring Yes	No
10 percent reduction in Gorse		
Yes	48	6
No	64	69
Don't Know	41	19
25 percent reduction in Gorse		
Yes	83	12
No	38	53
Don't Know	35	30
50 percent reduction in Gorse		
Yes	104	35
No	24	24
Don't Know	25	35

Independent of any possible reduction in gorse flowers from the possible introduction of biological control is the question of the effects that current methods of gorse control may be having on beekeepers. This issue was addressed in Question 7, with results presented in Table 6.20.

TABLE 6.20

Are Current Methods of Gorse Control Affecting Your Hives?

	National	North Auck	Auck	Taur	Ham	Palm North	Nel	ChCh	Oam	Gore
Yes	104	9	4	11	4	3	11	29	18	14
No	120	8	12	15	15	18	16	15	10	10
Don't Know	38	3	3	2	6	4	4	5	5	5
No Response	6	1	0	1	1	1	0	1	0	1

When asked about the cost to the beekeepers of current methods of gorse control the following responses were obtained (Table 6.21).

TABLE 6.21

Cost of Current Methods of Gorse Control

$/Hive	Responses	Apiary District
1	5	
2	7	
3	2	
4	4	
5	2	
6	3	
8	1	Nelson
10	1	Gore
11	1	ChCh
12	1	ChCh
17	1	Palm. North
20	1	Taur
25	1	ChCh
29	2	ChCh Auck
33	1	Gore
36	1	ChCh
45	1	ChCh
	35	

If current methods of gorse control were affecting beekeepers, they were asked to say in what way was the enterprise affected. This is shown in Table 6.22.

TABLE 6.22

Effects of Current Methods of Gorse Control

	1st Response	2nd Response
1. Reducing pollen collecting areas	50	2
2. Forced to shift hives	20	3
3. Health/vigour of bees affected	30	12
4. Cost	2	4

In order to overcome spring pollen shortages and effects of current methods of gorse control Ministry of Agriculture and Fisheries Advisers and others have been trying to encourage plantings of alternative pollen bearing trees. Beekeepers were asked if these plantings will have any effect, with the following results (Table 6.23).

TABLE 6.23

Possible Effects of Recent Plantings

	Responses
Great effect	19
Some effect	84
Little effect	74
No effect	39
You must be joking	34
No response	18

If alternative plantings are having some effect, Table 6.24 lists the plants.

TABLE 6.24

Alternative Planting Species Having Some Effect

	Responses
1. Willows	62
2. Tree Lucerne (Tagasaste)	17
3. Acacia	10
4. Gums	9
5. Others	16

The 1984 New Zealand Yearbook (p.454) considers that "fewer than 300 beekeepers are completely dependent on honey production and beekeeping for their livelihood." One could assume from the yearbook comment that 250 hives is considered an "economic unit", as 270 beekeepers are listed in the yearbook as having greater than 250 hives, and presumably they represent "fewer than 300".[4] To test the hypothesis that "full-time" beekeepers may have a different response to the "need to feed pollen at 10, 20 and 50 percent reduction in gorse pollen" questions, a cross tabulation was obtained. The results, presented in

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[4] the yearbook definition of "full-time" beekeepers is supported by survey data. Some 25 respondents in the 50-250 hives range indicated at least one full-time person employed, with 13 respondents in the above 250 category indicating no full-time employees. Overall, the "fewer than 300" would appear to be a reasonable number, although perhaps the 251 hive numbers may be an arbitrary cut-off point. However, in a review of this report Murray Reid, MAF Apicultural Advisory Officer, considers the 250 hives may be misleading, and that 450 hives is a minimum full time economic unit. Notwithstanding this comment, the 250 hives has been used as an abitrary figure.

Table 6.25, indicate a significantly different pattern. A greater proportion of beekeepers with more than 250 hives answered "yes" in each of the 10, 25 and 50 percent reduction categories.

TABLE 6.25

Cross-Tabulation, Number of Hives by Need to Feed with 10, 25 and 50 Percent Reduction in Gorse Pollen

	Number of Hives				
	51-100	101-250	251-500	501-1000	1000+
	(No. of Responses)				
Need to Feed at 10% Reduction in Gorse Pollen					
Yes	8	3	12	19	14
No	33	34	29	14	20
Don't Know	8	12	9	18	5
Chi-square = 46					
Need to Feed at 25% Reduction in Gorse Pollen					
Yes	9	9	22	31	24
No	23	29	18	8	9
Don't Know	16	12	10	14	7
Chi-square = 49					
Need to Feed at 50% Reduction in Gorse Pollen					
Yes	17	25	35	35	28
No	16	15	5	6	5
Don't Know	16	11	11	8	7
Chi-square = 37					

The importance of these "full-time" operators is that they operate 74 percent of the hives in New Zealand (N.Z. Yearbook, 1984). Greater reliance can also be placed upon the returns from larger operators, as a return rate of above 50 percent was obtained (Table 6.2). Summarising Table 6.25, the importance of gorse as a pollen source can be seen in Table 6.26. Only beekeepers with more than 250 hives are shown in this summary - i.e. the "full-time" operators. Some 74 percent felt they would need to feed with a 50 percent reduction in gorse flowers, compared to 54 percent from the survey (Table 6.13).

A further cross-tabulation of selected questions (Table 6.27) also shows a different response pattern to "full-time" operators. A higher percentage of "full-time" operators view gorse as being the most important pollen plant in both the spring and autumn. More "full-time" beekeepers perceive pollen problems in both the spring and autumn and consider the hives would perform better with pollen feeding. Most of the responses to Table 6.15 (some 66-74 percent), the cost of feeding with selected reductions in gorse flowers, was from "full-time" beekeepers. In the same way some 75 percent of replies used in Table

6.21, the cost of current methods of control, were from "full-time" operators.

TABLE 6.26

Need to Feed Pollen with 10, 25 and 50 Percent Reduction in Gorse Flowers
(Beekeepers with more than 250 Hives)

Need to Feed at	Yes		No	Don't Know
		%		
10	45	32	63	32
25	77	54	35	31
50	90	70	16	26
Percent Reduction In Gorse Flowers				

Two hypothesis could be put forward for the different responses to questions from the "full-time" beekeepers. The first is that "full-time" operators are more critically aware of costings and possible impacts, while the second is that they are operating closer to total pollen source capacity. The two hypothesis are not mutually exclusive, and possibly both reasons are valid.

TABLE 6.27

Percentage of "Yes" Responses

Issue	Survey	Operators with 250 or More Hives
	%	%
Lack of Natural Pollen in Spring	60	75
Lack of Natural Pollen in Autumn	31	38
Would Increase Performance of Bees by Feeding Pollen	50	64
Spring Pollen Plant, 1st Response Gorse	49	64
Autumn Pollen Plant, 1st Response Gorse	47	53

It is worth noting that an average cost of $10.11/hive was obtained from Table 6.21, costs of current control measures. This can be compared to average costs of $5.24/hive, $5.10/hive and $7.93/hive from a 10, 25 and 50 percent reduction in gorse pollen plants (Table 6.16). However, both the low response rate and general uncertainty as to possible costs needed to substitute for gorse pollen caution against too much reliance being placed on the findings that average costs of current methods of control are greater than a possible 50 percent decrease in gorse flowers from biological control.

6.2 Potential Costs to the Honeydew Honey Producers

New Zealand beech honeydew is a dark coloured syrup excreted by a soft scale insect which occurs on the trunks and branches of beech trees. This honeydew occurs commercially mainly in the low to moderate rainfall areas of the northern half of the South Island. Honeybees collect the honeydew and transform it into honeydew honey. Early beekeepers used beech honeydew for feeding bees, but since 1968 honeydew honey has become accepted as a human food, particularly for export (Crozier, 1981). This season (1985-86) it is expected that about $1.5 million worth of honeydew honey will be exported (G.L. Jeffery, Beech Honey Producer's Association (Inc.), pers com).

Special concern has been expressed by the honeydew producers about the proposed introduction of biological agents to control gorse. Many of the hives remain in the area all the time, with some 25 percent being introduced for the autumn gathering only. Honeydew hives actually require more supervision than conventional hives, so accessibility and inspection of hives to supplement pollen need not be a serious problem (John Smith, pers com). Spring honeydew honey is gathered from September to early December, with the autumn harvest from late January to April in most years. One interesting development in the beekeeping industry is the possibility of combining Nelson kiwifruit pollination, Canterbury clover nectar gathering, and beech honeydew collection. Jasper Bray, a leading Christchurch beekeeper considers it may be feasible to use the same hives for the three operations in one season and intended to experiment in the 1985-86 season.

A question was included in the Survey (question 9.0), to enable the effects of biological control on honeydew honey producers to be analysed separately. Forty seven beekeepers indicated that they had hives in honeydew areas, with a total of 15,616 hives being used to gather honeydew. Details are given in Table 6.28.

TABLE 6.28

Hives Numbers Kept in Honeydew Areas

Number of Hives	Responses
25-50	7
51-100	6
101-250	10
251-500	15
501+	9
	47

Many honeydew honey producers considered that pollen shortage was a problem in autumn (29 "Yes", 14 "No"), and this would account for much of the statistically different responses regionally given in Tables 6.5 and 6.8. Gorse is perceived as being extremely important as a pollen source, especially in the autumn. The responses given in Table 6.29 can be compared to Table 6.3 for all beekeepers.

TABLE 6.29

Major Pollen Sources (1st Response) for Honeydew Producers

Plants	Number of Responses Spring	Autumn
Gorse	39	35
Willow	6	1
Clover		3
Fuschias	1	
Thistle		1
Dandelion		2
Broom	1	

Two apiary districts, Tauranga and Christchurch, stand out in Table 6.11 as having more beekeepers answering "Yes" to the Question "Would your hives perform better if you fed more pollen?" Tauranga district is the major kiwifruit pollination area, and Christchurch district represents nearly all of the honeydew honey producers. A potential bias in the postal survey may be coming from honeydew honey producers. Of the 47 replies with hives in honeydew areas, 45 are from the Christchurch district. However, a total of 50 replies were received from the Christchurch district beekeepers, for a response rate of 60 percent. Thus almost all of the honeydew honey producers may have replied, as it is considered by John Smith, MAF Advisory Officer, Christchurch, that some 50 percent of the regions beekeepers would have hives in the honeydew areas. Many of the responses obtained in Table 6.16 regarding costs to producers from a 10, 25 and 50 percent reduction in available gorse flowers were obtained from honeydew honey producers. Similarly, honeydew honey producers are concerned with current methods of gorse control. One honeydew honey producer considers current methods of gorse control are costing the operation $29/hive (with over 500 hives in honeydew areas), another, $36/hive, while a 3rd at $45/hive has over 250 hives in the honeydew areas. It is very difficult to conceive of costs due to biological control being additional to costs from current methods of control at perceived costs of this magnitude. A majority of honeydew honey producers considered that they needed to feed pollen with the three categories of available gorse flower reductions (Table 6.30).

Potential costs to the beekeeping industry from increased costs to honeydew honey producers are difficult to calculate. Average costs of $6.45, $6.90 and $11.43 per hive for a 10, 25, and 50 percent reduction in gorse flowers were obtained from honeydew honey producers, but only one third of producers responded to this question. An extreme possibility would, of course, be cessation of the honeydew honey production. This would appear unlikely, as honeydew honey production can be obtained after normal nectar flows. Taking the $11.43/hive figure for increased costs at a 50 percent reduction and extrapolating this to all honeydew honey hives would amount to around $180,000 annually. Adding this cost to estimates from the beekeeping industry would entail double counting. Any costs to the honeydew honey industry will be included in the next section on beekeepers costs.

TABLE 6.30

Honeydew Honey Producers Responses to Need to Feed with 10, 25 and 50 Percent Reduction in Gorse Flowers

	Yes	No	Don't Know
Need to Feed at		(Responses)	
10	23	13	10
25	30	9	7
50	35	4	7

Percent Reduction in
Gorse Flowers

6.3 Implications of the Beekeepers Survey

As outlined in 6.1, the objectives of the beekeeper's survey were:

a) to find some estimation of the value of gorse as a pollen source;
b) to find indications of the impacts of reductions in available gorse flower;, and
c) to estimate the likely cost of a possible reduction in gorse flowers.

There can be little doubt that New Zealand beekeepers perceive gorse as a valuable source of pollen during both spring and autumn. Most beekeepers considered more than 50 percent of their hives gathered some gorse pollen during the spring. One hundred and fourteen beekeepers replied that more than 50 percent of their hives gathered only gorse pollen during some stage of the spring.

By a margin of 2 to 1 beekeepers consider they have hives which can or do suffer currently from a lack of spring pollen, although the ratios were reversed for autumn pollen shortages. Tauranga district with the kiwifruit and Christchurch district with the honeydew, were more concerned with spring and autumn shortages respectively. One half of all beekeepers thought their hives would perform better if they fed pollen substitutes or supplements but only 20 beekeepers indicated that they were currently feeding an average of one half kg/hive or more of either natural or substitute pollen to their hives. Too expensive and unable to obtain enough natural pollen were the major reasons for not feeding more pollen.

The important answers to objective b are contained in Table 6.13 - the number of beekeepers needing to feed pollen at a 10, 25 and

50 percent reduction in gorse flowers. Over one half of all beekeepers felt they would need to feed pollen with a 50 percent reduction in gorse flowers. In the 3 categories of potential reductions in gorse flowers, the percentage of "full-time" beekeepers needing to feed was higher than the total survey results. Responses were mixed to a question asking if recent plantings of other pollen bearing plants would have any effect, with willow and tree lucerne (tagasaste) being the important alternative species being planted.

For each of the 10, 25, and 50 percent reduction in available gorse flowers beekeepers were asked to estimate the cost in dollar terms. Few responded to this question, probably because most beekeepers found it very difficult to answer precisely. Responses of those who did answer show an average cost of $5.24, $5.10, and $7.93 per hive for the 3 reduction categories.

Taking these perceived cost figures as an indication enables estimates for the total cost to the beekeeping industry to be calculated. The following assumptions are made:

1. those beekeepers who replied with dollar figures provide the best estimates of the costs;

2. these costs can be used for all beekeepers;

3. the percentage of beekeepers answering "yes" compared to those answering "no" to the need to feed pollen question give the correct percentages for those who did not know or did not reply to the question; and

4. the survey is representative of all New Zealand beekeepers.

Using these assumptions enables cost estimates of $417,778, $704,801, and $1,559,547 to be calculated for the 10, 25, and 50 percent reduction in gorse flowers respectively (Table 6.31).

Several potential sources of bias exist. Non-response bias may come from both within the survey for those not responding to some questions and those who did not participate in the survey. As outlined in Section 6.2, many of the cost figures are supplied by Christchurch district honeydew honey producers, and this may represent an upward bias. One response of an estimated cost of $35/hive was received from a honeydew honey producer. This estimate increases the total cost figures by some 12 percent at a 50 percent reduction in flowers. Conversely, "full-time" operators are more concerned about reductions in gorse flowers. Given the importance of these larger operators to the industry, there may be a bias in the survey from smaller operators. Using Table 6.26 estimates instead of Table 6.13 for "Yes" as a percentage needing to feed pollen gives an indication of the amount of the bias. The total estimates presented above would have to be adjusted upwards by 29, 32 and 15 percent for the 10, 25 and 50 percent reductions respectively.

TABLE 6.31

Potential Cost to the Beekeeping Industry - Survey Costs

	Percentage Reduction in Gorse Flowers		
	10	25	50
Average estimated cost ($ per hive)	5.24	5.10	7.93
Percentage answering "Yes" to need to feed pollen (%)	30	52	74
Expected cost per hive ($)	1.57	2.65	5.87
Times survey average of hives (601) ($)	945	1,594	3,527
Total for the survey (times 268) ($)	253,199	427,152	945,180
Total for New Zealand (times 1.65) ($)	417,778	704,801	1,559,547

a. From Table 6.16.
b. From Table 6.13.
c. The survey represents 161,068 hives, compared to Yearbook figures of 265,042 hives in New Zealand.

An alternative approach to estimating the potential costs to beekeepers is to cost artificial pollen supplementary feeding. Recommendations for a Beltsville diet mixture would cost some $3-$5/hive for materials plus an estimated $3/hive for labour and transportation. This gives a total estimated cost of $8/hive for a 6-8 week period. Using similar assumptions listed above for survey costings enables total costs of $637,830, $1,105,571, and $1,573,312[5] for the 10, 25, and 50 percent flower reductions respectively to be calculated (Table 6.32). An additional assumption is made to feed for 6-8 weeks in the 3 categories, and an inspection of Table 6.15 shows this to be reasonable. Comparisons of these estimates and the estimates obtained directly from the survey costs are shown in Table 6.33. The same comments about potential bias apply to both sets of estimates.

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[5] These estimates overstate the costs because the assumption is made that 100 percent of the hives are fed if the beekeepers answers "Yes". Table 6.14 shows this is not the case, and the overestimation of costs would be highest for the 10 percent reduction in gorse flowers.

TABLE 6.32

Potential Costs to the Beekeeping Industry - Supplementary Feeding Approach

	Percentage Reduction in Gorse Flowers		
	10	25	50
Percentage answering "Yes" to need to feed pollen (%) [a]	30	52	74
Expected costs per hive ($) [b]	2.4	4.16	5.92
Expected costs per beekeeper ($) [c]	1,442	2,500	3,558
Total costs from survey ($) [d]	386,563	670,043	953,523
Total New Zealand Costs ($) [e]	637,830	1,105,571	1,573,312

a. From Table 6.13.
b. Using Beltsville costing of $8/hive.
c. With a sample average of 601 hives.
d. From 268 responses.
e. Multiplying by 1.65, as shown in Table 6.31, footnote (c).

Very similar figures are obtained from the 50 percent reduction in gorse flowers from both approaches. The approaches are different, with the only common calculation used from a per-hive comparison is the ratio of beekeepers indicating they would need to feed pollen. These figures will be used as the best available estimates of the costs to beekeepers of the introduction of biological agents to control gorse.

TABLE 6.33

Comparison of Costs from the Alternative Approaches

	Percentage Reduction in Gorse Flowers		
	10	25	50
A. Table 6.31 from survey costs directly	417,778	704,801	1,559,547
B. Table 6.32 from Beltsville diet costs	637,830	1,105,571	1,573,312

As a final comment, the total estimated cost of current methods of gorse control from survey figures is $1,235,954. This represents a cost of $4.65/hive, and an average cost to each beekeeper of $2,795.

These costs are estimated from an average cost of $10.11/hive for those who supplied an estimate if current methods of control were effecting the operation, weighted by 46 percent of the survey effected by current methods of control. The beekeeper who responded with an estimated cost of $45/hive raised this estimate by some 15 percent. The same proviso about assumptions used, and potential bias also apply to these estimates.

6.4 Additional Costs of Introduction

Chapter 3 discussed the benefits currently derived from gorse. The major "user" of gorse is the beekeeping industry for pollen, and estimates of costs to this industry should biological control be effective have been provided. Other potential costs may come from the deterioration of gorse hedges and a loss of gorse as a potential fodder crop.

Benefits from gorse hedges were not quantified, but considered to be positive and declining. Changes in the Noxious Plants Act have removed sub-section 4, section 49, which allowed gorse to be planted as a hedge (Graham Strickett, pers com). This may not have much effect, as it is doubtful that many new hedges would be planted in any case. Introduction of biological control may well hasten the replacement of existing gorse hedges with wire fences and shelter belts. Costs from this will be incurred to beekeepers from loss of another pollen source and extra costs to farmers in replacement of the hedges. Beekeepers costs have already been estimated - to include them again here is double counting. The important issue is the costs over and above those which would occur without the introduction of biological agents. The steady replacement from a declining absolute amount of gorse hedges suggests the costs may not be great. They are, however, positive costs to at least be recognised.

Gorse and goats have both been with us for a long time without any direct association between the two. Using goats to control gorse is a different issue from providing gorse to sustain a goat enterprise. The current interest in goat farming is driven by the medium-term objective of using feral goats to breed pure mohair from angora animals. Once the industry obtains an equilibrium number of pure bred goats, present values of ferals may revert back to the levels of a few years ago - i.e. almost "noxious animal" status. The pure bred animals can thrive on a wide range of alternative fodders, so the reduction in gorse as a fodder source may not be serious.

Another possibility does exist for gorse as a fodder source, and this is to develop a genetically superior plant for grazing. Prospects for this appear to be slim, but it does present an example of option value. Successful introduction of biological agents may well close this potential benefit, thus imposing a cost in the form of a lost "option".

Unless some further evidence can be presented from scientists, there appears to be limited potential costs from losing gorse as a nursery plant and erosion control agent (Section 3.4).

These costs are considered to be minor compared to the beekeeper's costs.

One of the original briefs of the study was to look at potential costs from loss of pollination should the beekeeping industry be severely effected. As pointed out in Section 5.3, the theoretical issue involved in the study is the compensatory variation. Expected changes in the incomes of beekeepers provide the compensatory variation, and these have been presented in Section 6.3. The Australian study on Echium (Industries Assistance Commission, 1985, p3.31) adopts the same approach as used in the present gorse study. If output (number of bees) is kept at the same level but with increased costs, then there is no loss of pollination services. Should the losses occur very quickly or should the costs be high enough to force beekeepers out of business, then costs may occur from lack of pollination. As demonstrated in the Bay of Plenty, the market system can and does overcome any potential problems in this area. Producers will pay pollination fees to the level of marginal benefits obtained - i.e., the "market" works. Thus to include potential loss of pollination services is double counting and will not be included, with the reservation that hive numbers will not be reduced. Expected increases in the kiwifruit crop in New Zealand are likely to act as a stimulus to the technological changes in artificial pollen feeding.

Finally, there is the issue of costs incurred in the introduction of the agents themselves. The DSIR have supplied estimates of total costs of the gorse control project from 1961 to 1990. These have been adjusted to 1985 dollar figures, and amount to some $650,000. However, the relevant sum is the costs from now on should the project proceed. Most of the DSIR's costs are in the form of "sunk" costs - they have already been spent. Salaries make up the major component of the "sunk" costs, but these salaries include training costs which can be transferred to other projects as benefits. Should the gorse project be halted at the end of 1985, the expected savings would be in the order of $150,000 in salaries and overheads. Even this figure may over-estimate the marginal costs of introduction, as biological control research must be regarded as an on-going program. The introduction of agents would, in itself, provide benefits in the form of genuine applied research in monitoring the results. Chapter 4 showed the need for more information to be obtained in this area!

Costs from deterioration of gorse hedges (farmers additional costs only), option values from gorse as a fodder plant, and some marginal costs to the program for DSIR expenses are recognised. These are considered to be minor. In the absence of evidence to support benefits from gorse as a nursery plant or erosion control agent, no costs can be assigned from these sections.

CHAPTER 7

BENEFITS OF INTRODUCTION

7.1 Potential Benefits to Farmers and Farming

Chapter 2 contained a detailed analysis of the amount of gorse vegetation cover in New Zealand. The direct costs of gorse control to farmers and some published estimates of the cost borne in the form of lost production were discussed. The issue involved in this report is the potential change in gorse and the subsequent benefits to agriculture should natural regulation be successful.

To obtain some check on the potential lost production from gorse more information was obtained from the NWASCO inventory of land in New Zealand from Dr John Russell, Ministry of Works and Development. The total area of land with a greater than 40 percent gorse cover is 166,141 hectares. A breakdown by land class is shown in Table 7.1. The stocking potential of this land ranges from zero in the Class VIII land to 18 stock units per hectare in the case of North Island Class II land. Tabulation of land class by stocking potential (Table 7.2) shows that 956,304 stock units are foregone annually from gorse infestation. At $23 gross margin per stock unit[6] (McGregor, 1983) this translates to lost income to farmers of $22 million annually.

TABLE 7.1

Area of Gorse in New Zealand by Land Class (ha >40%)

	Land Class							
	I	II	III	IV	V	VI	VII	VIII
South Island	-	135	1,152	13,378	1,453	75,429	40,050	2,054
Sub Total = 133,851								
North Island	-	-	-	1,559	-	21,660	8,892	179
Sub Total = 32,290								
Total	-	135	1,152	15,137	1,453	97,089	49,942	2,233
Overall Total = 166,141								

Source: NWASCO 1975-79

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[6] The 1985-86 schedule prices for sheep meats have been announced as this report goes to press. These figures will reduce the gross margin values and consequently the lost income figures.

This ignores elasticity and second round effects, but is an approximation. Note that this figure is 15 percent of the Monsanto estimate reported earlier, and suggests the Monsanto estimate is unrealistically high.

TABLE 7.2

Area of Gorse[7] in New Zealand by Land Class (ha) and Potential Stocking Rate (E.E./ha)

	Land Class						
Stocking Rate	II	III	IV	V	VI	VII	VIII
			South Island				
0.0						1,926	2,054
0.2						244	
0.5					362	5,694	
1					1,419	14,547	
2					22,561	968	
3					2,295	1,640	
4					5,157	886	
5		120			1,527	4,245	
6			1,457		6,297		
7					14,508	9,203	
8			2,230		11,204	697	
9		179		770	9,989		
10		87	3,012	683	567		
11		182	973				
12	135	434	5,858				
13			38				
15		150					
			North Island				
0						211	179
5					910	3,868	
6					2,958		
7					4,142		
8					1,877		
9					3,275		
10			476		4,385		
11					857		
12			92		676		
13			919		1,660		
14					618		
15					80		
18			72				

Source: NWASCO, 1975-79.

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[7] Both Tables 7.1 and 7.2 refer to land with 40 percent or more of gorse cover. This gives total estimates considerably lower than the estimates in Appendix C.

How much of this land would be brought into production if natural regulation occured is speculation. Farmers can be expected to be operating rationally and developing this land when benefits to them exceed their costs - Ricardian theory of land. Faced with depressed farm prices and reduced subsidies on chemicals, it is difficult to envisage much short to medium term development of gorse land without a technological change. Table 7.2 shows that much of this land has a very low potential carrying capacity, and is unlikely to be brought into production under any scenario.

One approach to finding the real opportunity cost to individual farmers of gorse covered land is to look at the market. Estimates of land values both with and without gorse were obtained for Banks Peninsula farmland and adjusted for time of sale. Two sales, \$636 and \$626 per hectare land values, both with gorse problems sold for forestry. Land with scattered gorse patches sold for land values of \$779 and \$768 per hectare. Other factors were similar, and the presence of gorse accounted for the difference. Sales in slightly better locations of slightly better soils and/or aspects showed land values of \$1,009 and \$1,004 per hectare. The market indicated a range of \$170 to \$200 per hectare in 1982 to 1984, with a similar difference in 1985 values.[8]

Analysis of Table 7.2 shows 52,373 hectares of gorse covered New Zealand farmland with a potential of 7 to 10 stock units per hectare. Taking the land value estimate of \$200/hectare as the difference between "gorse problem" and "clear" land on Banks Peninsula as an indication of the markets valuation over both the South and North Islands of New Zealand enables an estimate to be made of the "cost" of gorse. This "cost", with 52,373 hectares at \$200/hectare, amounts to around \$10.5 million. Using a 10 percent real discount rate would suggest a net income of only around \$1.05 million annually to the owners of this land. However, the \$10.5 million can be considered as being a real cost to the present owners of the land, but refers only to that land with greater than 40 percent gorse cover and between 7 and 10 stock units potential. Additionally, questions of land ownership and owner's objectives are not taken into account.

Natural regulation of gorse could enable the plant to be removed from the Noxious Plants Act. The degree of control may be critical to whether or not gorse is removed. If gorse was removed from the Act, then the direct costs of control to farmers may decrease. Given the gorse seed weevil is very common but meets with limited success in controlling gorse, it is unlikely that any change would occur to the status of gorse with a 10 percent reduction in vigour. However, definite benefits are possible from reduced vigour. From the discussion in Chapter 2 and this section, an arbitrary estimate of \$500,000 will be used as the benefits to farmers and farming from a 10 percent reduction in gorse vigour.

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[8] Mr Cedric Croft, Lecturer, Department of Farm Management and Rural Valuation, Lincoln College, pers com.

If a 50 percent reduction in vigour occured this would change the entire status of gorse as an economically important weed to New Zealand farmers. Many of the direct current costs from gorse control would be reduced in time, although a period of increased activity in gorse control may occur. This could result because land clearing has become less costly, i.e. an example of disembodied technology, Figure 5.1. Consequently, much of the opportunity cost now attributed to lost production from gorse would disappear. The problem of complementary weed infestations remains. Graham Strickett, Noxious Plants Council Field Officer for the South Island, suggests broom may occupy the niche and that broom was more difficult than gorse to control.

What is a realistic figure to place on the value of a 25 and 50 percent reduction in gorse vigour? The extremely high percentage of the total Noxious Plants Subsidy spent on gorse (Table 2.8) suggests direct benefits must be high. A figure of $10 million annually would not seem to be too high for a 50 percent reduction. This estimate will be used. For the 25 percent reduction, the assumption will be made that gorse remains a Noxious Plant, and that benefits amount to a reduction of $2.5 million annually. I must emphasis that these are little more than "guesstimates".

Expected annual direct benefits to farmers and farming from the introduction of agents are thus $500,000 for the 10 percent example, $2.5 million for 25 percent, and $10 million for the 50 percent reduction in vigour scenario.

7.2 Potential Benefits to Foresters and Forestry

The following comments on likely effects of biological control were received from Dr David Preest, Forest Research Institute, and have been used as the best estimates of benefits to foresters.

"As of course you have recognised, assessing the effect of reductions in gorse vigour on the establishment and tending costs of growing trees (radiata pine) on gorse-infected country is fraught with uncertainty. Firstly, we do not know what compounding effects there might be consequent on it. Even a modest reduction in gorse vigour coupled with enhanced competition from the crop, could have a significant effect. Secondly, we have done no research on the crop response, if any, to such reductions as you propose. The following comments should therefore be accepted for what they are - informed guesses!

10 Percent Reduction in Gorse Vigour

I would not consider that this would be of significant practical benefit in the context of site preparation, tree establishment, stand productivity or silvicultural costs (access for pruning and thinning).

25 Percent Reduction in Gorse Vigour

This would not, I believe, have a significant effect on site preparation costs, but on some already low-vigour gorse sites, and with good radiata pine growth rates, it could well obviate the need for release treatments. However, stand access for silviculture would still be a problem - unless, as already suggested above, there was some interaction with the crop which held the gorse back further or killed it off.

50 Percent Reduction in Gorse Vigour

This could well reduce the cost of mechanical clearing, or crushing preparatory to burning by up to 1/3, but I cannot see that it would markedly affect our recommended 2-hit spray regime for long-term gorse control, unless reduced vigour made the gorse more susceptible to our herbicide sprays in some way. The 2-hit spray regime is largely aimed at exhausting the gorse seed bank within germinable distance of the soil surface and fostering vegetation, such as grasses, which will successfully compete with young gorse seedlings. On the other hand a 50 percent reduction in regrowth and seedling gorse vigour could well be sufficient to render long-term gorse control no longer an essential requirement, i.e., such gorse might no longer be an obstacle to establishment.

Work by Balneaves (FRI, Rangiora) at Ashley has shown that a normal gorse understorey can reduce tree height growth by 1/3 and volume growth by more than 1/2. Presumably gorse of reduced vigour would make less demands on the site′s resources and compete less successfully with the trees for these. However, I am unable to quantify the effect of a 50 percent reduction in gorse vigour on tree growth. I would guess such gorse would be no worse than other minor understorey vegetation types.

Currently gorse offers formidable hindrance to silvicultural operations in many areas. A 50 percent reduction in gorse vigour coupled with a possible greater suppressive effect from the tree crop, could render the hindrance problem of little concern.

In summary:

- 10 percent reduction would not excite us greatly.
- 25 percent reduction could be of some limited value.
- 50 percent reduction could well remove gorse as a major obstacle to radiata pine establishment and tending, or as a serious competitor for site resources.

Costs

1. 10 percent reduction in gorse vigour - a significant reduction in direct or indirect costs is unlikely.

2. 25 percent reduction in gorse vigour - no effect on pre-plant spraying or mechanical clearing or crushing costs. If the 2-hit spray regime is used post plant, release should be unnecessary anyhow. If 2-hit spray regime is not used, then a 25 percent reduction may avoid the need for release spraying on limited areas where gorse vigour is already low.

	Savings (ha)
1.5 litres Tordon Brushkiller DS	$47
Flying	$50-$60
Total	$97-$107

Savings in silvicultural costs must be considered unlikely at this point.

3. 50 percent reduction in gorse vigour - unlikely to affect the cost of pre-burn dessicant sprays but could reduce the cost of mechanical clearing or crushing[9].

2-hit spray regime:	Savings (ha)
7.5-1 litres Tordon Brushkiller DS	$232-$310
Flying	$50- $60
	$282-$370 x 2 $564-$740

Savings in silvicultural costs due to better stand access could be of the order of $156-$192/ha[10] (Dr David Preest, pers com)."

TABLE 7.3

Potential Benefits to the New Zealand Forest Service (Direct Costs)

	Reduction in Gorse Vigour 10	25	50
Reduction in Costs ($/ha)	-	100	750
Total Over Estimated Plantings of 5,676 ha in Gorse (Table 2.10)	-	567,600	4,257,000

These estimates of the potential benefits to the Forest Service are brought together in Table 7.3 and applied over 5,676 ha, the 1984 plantings of pinus radiata in gorse infested land. Savings are

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[9] Balneaves, pers com, suggested a cost reduction of $60-$70/ha would be realistic. This represents a 20 percent reduction in costs.

[10] Based on $6/hour wage rate, and 26-32 hours/ha savings. This is from 8 hours pruning and 18-24 hours thinning saved (Balneaves, 1981).

negligible for the 10 percent reduction in vigour, but amount to over 4 million dollars for a 50 percent reduction. As in Chapter 2, these estimates include only the Forest Service plantings, so they are again a lower bound estimate. This estimate of $4 million is similar to Chapter 2.2 costs of $4 million to the Forest Service. The estimates were obtained by different approaches and are the same because "50% reduction could well remove gorse as a major obstacle in radiata pine establishment and tending" (Dr D. Preest, in the above Section).

However, as discussed in Chapter 2.2 and shown in Table 2.11, the Forest Service represents about 50 percent of total gorse area plantings in New Zealand. This implies the actual estimates would be around twice as much as shown in Table 7.3, and the final totals are presented in Table 7.4.

TABLE 7.4

Potential Benefits to Forestry (Direct Costs)

	Reduction in Gorse Vigour 10	25	50
Total Estimated Plantings of 11,350 ha in Gorse ($)	-	1,135,000	8,514,000

These estimates will be used in the next section as the best estimates available of potential benefits to Forestry should biological control of gorse be successful. Note that these estimates are reductions in direct costs, and do not contain an opportunity costs such as the improvements in quantity and/or quality which may occur from a reduction in the vigour of gorse. To count these indirect benefits is to double count the cost of gorse if the direct costs from Table 7.4 do, in fact, control gorse.

CHAPTER 8

COMPENSATION CRITERIA

8.1 Benefits and Costs

Preceding Chapters have discussed, and where possible quantified, the costs and benefits of the introduction of biological agents to naturally regulate gorse. Direct costs and benefits are brought together in Table 8.1 and a benefit to cost ratio calculated. At a 10 percent reduction the direct annual benefits are very similar to costs, but at a 50 percent reduction the benefits substantially outweigh the costs to the beekeeping industry. Additional benefits and costs which should be considered are listed in Table 8.2. With the exception of the DSIR's costs these have not been quantified.

The DSIR costs are included with the additional and not annual costs because of the uncertainty of time spans. Two major assumptions are made in Table 8.1. Firstly, a given percentage reduction in available gorse flowers is equated to the same reduction in the vigour of gorse plants. Unless these are similar, we may be comparing apples and oranges. Secondly, the time sequence is the same. These two assumptions are interelated, but are essential to enable a comparison to be made and avoid the need to discount.

If the time sequence is not the same, a very difficult discounting exercise would be needed. However, it is almost certain that a symmetry between the time sequence of costs and benefits would exist. When, or even if, these changes occur doesn't matter in calculating a benefit to cost ratio if this assumption is made. The only discounting is the DSIR's costs, which are relatively minor.

TABLE 8.1

Annual Costs and Benefits from the Introduction of Biological Agents ($000's) Direct, Measurable

	Percent Reduction 10	 25	 50
Direct Costs			
Beekeeping Industry (Table 6.31)	418	705	1,560
Direct Benefits			
To Farmers and Farming	500	2,500	10,000
To Foresters and Forestry	-	1,135	8,514
Net Direct Benefits	82	3,635	18,514
Direct Benefit to Cost Ratio	1.2:1	5:1	12.1

The ratios calculated in Table 8.1 are deficient to the additional extent that the non-measurable costs and benefits have not been included. These are listed to recognise them. A sensitivity analysis can be conducted by estimating these costs and benefits and including them in the analysis.

It must be stressed that the net direct benefit estimates presented in Table 8.1 are not expected values. The expected value is the sum of the products of the possible outcome of an event multiplied by the probability of that outcome. Problems arise in attempting to calculate expected values for the Table 8.1 estimates. While the probabilities of success presented in Chapter 4 are obtained from a world-wide survey of biological control attempts, there is still too much uncertainty to enable an expected value to be presented which is meaningful. For example, the likelihood estimates from Chapter 4 refer to single agents, and it is stressed that multiple releases of different agents is not additive in the degree of probability. Additionally, if multiple releases are contemplated the sequence of releases may well alter the outcome. Accordingly, expected values will not be presented as they may well be misleading. This in no way alters the benefit to cost ratios of the different scenarios, though. These ratios are not dependent on any probability of outcomes.

TABLE 8.2

Additional Costs and Benefits from the Introduction of Biological Agents

	Direct, Measurable ($000's)
Costs	
DSIR	150 Total additional
	Indirect, Non Measurable
Costs (Actual and/or Potential)	
Possible loss from pollination services	
Gorse as a fodder source	
Deterioration of shelter hedges	
Gorse as a nursery plant	
Gorse as an erosion control	
Irreversible introduction of biological agents (risk of non host specificity)	
Losses to chemical companies and spray operators	
Replacement by other weeds	
Elasticity effects of increased production	
Reduction in habitat for other biota - bumble bees, pheasants	
Benefits	
Indirect Benefits to Farming	
Employment multiplier effects from increased production	
Contribution to entomology from the experience	
Non-market values from a reduction in gorse (e.g. access for recreation)	
Reduced fire hazard to forestry	
Reduced use of 2,4,5-T - i.e. "clean" control (should 2,4,5-T be banned direct benefits would increase, as alternative chemicals are more costly)	

8.2 Adjustment Assistance

Although outside of a cost-benefit study, the issue of adjustment assistance to those suffering losses needs to be addressed. The legal aspect of gorse as a "noxious" plant raises some interesting questions regarding the redistribution of income following a possible successful introduction of biological control. Even though gorse is gazetted as a noxious plant, dense stands, hedges, and general waste areas such as riverbeds are currently not required to be cleared. These sources of pollen may decrease following introduction of agents, which is the major concern of beekeepers. Should beekeepers be compensated? The compensation criterion absolves the analyst from this issue - potential benefits over costs, to whoever they accrue, is the decision vehicle. When addressing this issue with respect to *Echium* (Patterson's Curse), the Australian Industries Commission (1985, p.9.7) considers this question might be better determined after the introduction when impacts can be known with more certainty. The review considers adjustment assistance justified if, and only if, a very fast reduction in *Echium* is achieved. Otherwise, given a 10 year period, normal market adjustments should be able to operate. A similar situation could well apply to New Zealand with gorse. However, research and extension work into supplementary pollen feeding and encouragement of alternative pollen bearing trees and shrubs would probably be cost effective programmes, as well as politically desirable exercises.

CHAPTER 9

RECOMMENDATIONS, LIMITATIONS OF THE STUDY, DIRECTIONS FOR FUTURE RESEARCH, AND CONCLUSIONS

9.1 Recommendations

The ex ante results from this study are quite clear. Provided that all reasonable steps are taken to ensure the agents are host specific the introduction of these agents is economically efficient. The potential benefits outweigh the costs, and should natural regulation prove successful the benefits are substantial. While gorse does provide a valuable source of pollen to beekeepers, this pollen can be replaced at a measurable cost. Gorse is a very major scrubweed in New Zealand and reduction in the vigour and spread of gorse would provide substantial benefits to both farming and forestry.

From an equity perspective, the gainers and the losers are different groups in society. However, the gainers can potentially afford to compensate the losers and still be better off. The compensation criteria is satisfied, and any further decisions on either the introduction of biological agents or possible redistribution of gains become political and not economical.

Two areas have been identified where gorse is of considerable value. These are the Christchurch and Tauranga districts. Consideration could be given to not using these two areas as initial release sites for biological agents. This would provide a longer lead time for adjustments to pollen sources should the agents successfully establish in New Zealand. The Wellington hills may be an alternative release site, although it is recognised that additional monitoring costs would be borne by the Entomology Division of DSIR.

Additionally, as suggested in the previous Chapter, some more research and extension work into supplementary and substitute pollen feeding should be considered. The planting of alternative pollen bearing trees and shrubs should also be encouraged.

One further issue has been highlighted by the study, and this is the issue of land cost to the New Zealand Forest Service for tree planting sites. Currently the Forest Service is regarded as a buyer of last resort, and is restricted by law in the type of land that can be purchased (H. Rautjoki, pers com). With the current downturn in land prices, it may be economically optimal for the Forest Service to purchase "clean" sites for exotic plantings, thus avoiding the cost of gorse control.

9.2 Limitations of the Study

There are several limitations of this study. These range from the degree of uncertainty associated with the introduction of biological agents through to limitations of the techniques of the compensation criteria. Discussion of these problems may assist future research in the economics of biological control. The order of listing does not imply any particular order of importance.

A section in Chapter 5 dealt specifically with the uncertainties involved with the introduction of agents naturally regulating gorse. Will the agents establish in New Zealand? What effects will biological control have on mature and seedling gorse, and especially what will be the effect on gorse flowers?

Several sources of potential bias exist with any survey. These have been fully discussed in the paper, and any assumptions made are explicitly stated.

The compensation criteria has been criticized from several viewpoints. Meister (1985) contains an excellent review of the use and misuse of the Cost-Benefit Analysis in New Zealand. One of the major shortcomings of the technique is the inability to weight income redistribution without making value judgements. This weighting has not been attempted in the present study, and the study is deficient as a result. Additionally, neither economic efficiency nor income redistribution (equity) look at the political realities faced by decision makers.

A sensitivity analysis has not been attempted. Any assumptions made in arriving at the estimates used have been stated. This should enable interested readers to both question the assumptions and conduct a sensitivity analysis if these assumptions are rejected.

The questions asked in the beekeepers' survey are not willingness to pay questions, but rather how much it would cost the enterprise. This would be a lower bound estimate of willingness to pay. Parallel supply shifts have been assumed in both the beekeepers' costs and foresters' benefits, and this assumption may overstate both sets of estimates.

The role of discounting has been ignored, and only a benefit to cost ratio calculated. No problems are presented if the costs and benefits are symmetrical - i.e. a 25 percent reduction in gorse flowers occurs about the same time as a 25 percent reduction in gorse vigour. However, should the time frame be different or the physical impacts different, then a more detailed analysis may be needed. This would involve discounting, and estimating the present value over the relevant time period.

Indirect costs and benefits are difficult to quantify. Several assumptions must be made in order to arrive at the estimates given in the study. Problems of supplementary weed infestation - what would occupy the gorse niche, elasticity effects and the quality-quantity relationship in forestry are examples. Also, a major assumption has been made that pollination services will not be reduced. Estimates of beekeepers' costs are the costs to restore output (bees) to their original level. Pollination services will only suffer if these bees are not kept at their original levels. Should this happen, transfer payments between farmers and orchardists and beekeepers will maintain pollination levels. No "second round" effects have been incorporated into the study, and where possible, subsidies and transfer payments have been identified.

Non-market values have been ignored - do tourists and city folk find our colourful yellow hillsides attractive? On a more serious note, the concept of irreversibility has been discussed but not followed up. Thus it is accepted as an act of faith that the agents, if introduced, will be host specific.

Some lingering doubts remain over the potential for goats in New Zealand. Should this livestock industry increase to one of substantial proportions, the issue of gorse may well be reduced considerably.

Finally, some interesting questions about possible effects of natural regulation on the gorse plants remain. The interactions between chemicals and natural regulation have not been looked at. Intuitively one might expect that a plant weakened by biological agents would be more susceptible to chemical control. However, recent research and Darwinism suggests that changes in the plant may occur.

> "Research into the mechanism and causes of fluctuations in population numbers of herbivores has been hampered by the general assumption that plants play a passive role in the interaction. We now know that plants actively defend themselves, and these defenses are sensitive to physical stress to the plants and that they can be increased by the plants in response to attack" (Rhoades, 1983, p.204).

9.3 Directions for Future Research and Conclusions

Evolution teaches us that the environment is constantly changing and the battle against weeds and pests is an ongoing campaign. The demise of one weed may only change the relative rankings on the ladder of economic importance. Natural regulation promises an ecologically desirable way of controlling weeds, provided care is taken to ensure host specificity. Research in this area is a continuing process, and this study shows that potential benefits from success are substantial. Chapter 4 suggests the probabilities of success are large enough to justify research being conducted.

This study should provide both a basis for further discussion on the gorse issue and a framework for a similar analysis on any other "noxious" weed in New Zealand. Natural regulation of weeds is a good example of disembodied technological change.

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APPENDIX A

Form Used in Beekeeper Survey

APPENDIX A

COVERING LETTER SENT TO BEEKEEPERS WITH SURVEY

Lincoln College

UNIVERSITY COLLEGE OF AGRICULTURE

Lincoln College
Canterbury
New Zealand

Telephone: Christchurch 252 811

2 May 1985

Gorse if probably the most costly weed problem affecting forestry and agricultural land in New Zealand today. Entomology Division of D.S.I.R. hopes to reduce the impact of the weed by controlling it biologically using insects introduced from Europe. Exhaustive tests show that these insects damage gorse only.

The aim of this project is to reduce the vigour of gorse in New Zealand and so cut down its capacity to regenerate and spread. Successful biological control would result in some reduction in gorse density in New Zealand but it is very unlikely that the amount of gorse flower would be reduced by more than 50%.

The importance of gorse as a pollen source to many New Zealand beekeepers is well known. D.S.I.R. has asked the Agricultural Economics Research Unit of Lincoln College to report on the benefits and disadvantages of this project before the insects are introduced. This analysis will determine whether such a biological control project is in the country's best interests.

It would be appreciated if you would please complete the enclosed questionnaire and return it as soon as possible in the reply paid envelope. Please note that this survey is considered by the M.A.F., Apicultural Advisory Service, and members of the N.B.A. executive as URGENT and they are asking all beekeepers to treat it as such. The report for this part of the study has to be prepared by the end of May, 1985. We therefore need your urgent action.

Your individual replies will be kept strictly confidential.

Ron Sandrey

Ron Sandrey (Dr)
Lecturer
Department of Agricultural Economics
and Marketing

SURVEY OF NEW ZEALAND BEEKEEPERS

1. Please list in order up to five major spring/autumn pollen plants in your district, including gorse if applicable.
(1 = most important)

	SPRING	AUTUMN	
1	____________________	____________________	1
2	____________________	____________________	2
3	____________________	____________________	3
4	____________________	____________________	4
5	____________________	____________________	5

☐ ☐ ☐
☐ ☐
☐ ☐ ☐
☐ ☐

2. When is gorse pollen of most value to your hives (please tick one box).

Spring ☐ 1
Autumn ☐ 2
Both ☐ 3
Never ☐ 4

☐

If NEVER please go to question 4.

3. (a) Please estimate the proportion of your hives that would gather gorse pollen as a pollen source during:

Spring __________ percentage ☐ ☐
Autumn __________ percentage ☐ ☐

(b) Please estimate the proportion of your hives that would gather the bulk of their pollen needs from gorse during the:

Spring __________ percentage ☐ ☐
Autumn __________ percentage ☐ ☐

3. (c) Please estimate the proportion of your hives that would have only gorse as a pollen source at some stage of the year:

Spring __________ percentage ☐ ☐
Autumn __________ percentage ☐ ☐

4. (a) Have you any hives that can/do suffer from lack of natural pollen:

Spring Yes ☐ No ☐ ☐

Autumn Yes ☐ No ☐ ☐

(b) If yes, please estimate the proportion:

Spring __________ percentage ☐ ☐

Autumn __________ percentage ☐ ☐

(c) If yes, please also estimate the years that hives suffer (tick one)

Every year ☐ 1

Most years ☐ 2 ☐

Some years ☐ 3

Very occasional years ☐ 4

5. (a) What amounts of natural pollen or pollen substitutes do you presently feed to your bees:

Natural Pollen kg ______ ☐ ☐ ☐

☐ ☐

Pollen Substitute kg _____ ☐ ☐ ☐

☐ ☐

None (please tick) ☐ ☐

5. (b) If possible, could you please estimate your costs involved in feeding either natural pollen or pollen substitute.

Natural pollen $ per year __________ ☐ ☐ ☐

☐ ☐

Pollen substitute $ per year __________ ☐ ☐ ☐

☐ ☐

(c) Do you consider any of your hives would perform better if you fed more pollen?

Yes ☐ 1 No ☐ 2 Don't know ☐ 3 ☐

(d) If yes, please give your reason(a) for not feeding any or not feeding more pollen.

____

____

____

☐ ☐
☐ ☐

Now let us consider the introduction of the biological control of gorse. As outlined earlier, this control is unlikely to eradicate gorse. We will consider the effects upon your enterprise of a 10, 25 and 50 percent reduction in gorse flowers.

6. (a) If gorse flowers were reduced by 10 percent, would you need to feed pollen to your bees?

Yes ☐ 1 No ☐ 2 Don't know ☐ 3

If Yes, what proportion of your hives: ________ percentage

for how many days ____________________

and at an estimated cost of $_______________

☐
☐ ☐
☐ ☐
☐ ☐ ☐
☐ ☐

(b) If gorse flowers were reduced by 25 percent, would you need to feed pollen to your hives?

Yes ☐ 1 No ☐ 2 Don't know ☐ 3

If yes what proportion of your hives __________ percentage

for how many days _______________

and at an estimated cost of $ __________

☐
☐ ☐
☐ ☐
☐ ☐ ☐
☐ ☐

(c) If gorse flowers were reduced by 50 percent, would you need to feed pollen to your hives?

Yes ☐ 1 No ☐ 2 Don't know ☐ 3

If yes what proportion of your hives _________ percentage

for how many days _______________

and at an estimated cost of $_______________

☐
☐ ☐
☐ ☐
☐ ☐ ☐
☐ ☐

Now could you please estimate the effect that current methods of gorse control may be having upon your enterprise.

7. (a) Are current methods affecting your hives?

Yes ☐ 1 No ☐ 2 Don't know ☐ 3

if yes what proportion of your hives ______ percentage

for how many days ____________

and at an estimated cost of $______________

☐
☐ ☐
☐ ☐
☐ ☐ ☐
☐ ☐

(b) If the answer to the above question is <u>Yes</u>, in what way is your enterprise affected?

____

____

____

☐ ☐ ☐

8. Do you consider that any recent planting of other pollen bearing trees in your area will have any effect?

Great effect ☐ 1 Little effect ☐ 3

Some effect ☐ 2 No effect ☐ 4

You must be joking ☐ 5

☐

If alternate plantings are having some effect please list plants

____

____

____

☐ ☐
☐ ☐
☐ ☐

9. (a) Please mark the M.A.F. Apiary district in which you keep the <u>bulk</u> of your hives.

North Auckland ☐ 1 Auckland ☐ 2 Tauranga ☐ 3

Hamilton ☐ 4 Palmerston North ☐ 5

Nelson ☐ 6 Christchurch ☐ 7 Oamaru ☐ 8 Gore ☐ 9

☐

(b) If Christchurch district please indicate the number of hives kept in Honeydew areas.

Number ________________

☐ ☐
☐ ☐

10. (a) Please give the number of hives owned or operated by your enterprise

Number ________________

☐ ☐
☐ ☐
☐

(b) Please indicate number of people employed in your beekeeping enterprise (including yourself, family.

Full time ____________

Part time ____________

☐ ☐
☐ ☐

Thank you for your co-operation in completing the questionnaire.

Please return by using the reply paid envelope.

APPENDIX B

SELECTED COMMENTS FROM BEEKEEPERS

These comments were not solicited and indicate the wide range of feelings of New Zealand beekeepers on the introduction of a biological control agent for gorse. These comments are reproduced as received.

1. Our industry is actively engaged in promoting the planting of alternative nectar and pollen bearing plant species in rural areas, but this has proved very difficult in some regions.

2. As an alternative to gorse, we have planted Grevillea Rosmarini Folia and Ceanothus Var. The Grevillea starts flowering in April and continues in flower till approx. November. They are extremely useful for nectar. The Ceanothus Flower in October and have pollen in abundance. Both these plants would also give shelter for sheep. Any self sown seedlings where they are not wanted would not a be a worry as sheep would eat them.

3. Just as beekeepers must come to terms with fact that gorse is a noxious plant, and therefore under a control program, research must also take note that the pollen it produces is of the highest quality in protein value. Although plantings of alternative sources are of great assistance, the value of the pollen to bees is not as good as gorse.

4. I hope "Trees for Bees" persuades some farmers to plant something.

5. From my observations our bees work gorse for pollen reluctantly. My impressions are that the biological control would not make much difference if only 50% was affected.

6. Unfortunately there is not much gorse about Hawkes Bay. If gorse was allowed to spread throughout Hawkes Bay it would be of great benefit to beekeeping but a real problem to other land users.

7. I have been around for a while, I am 83, a beekeeper for 59 years and in my opinion gorse is not a problem except as a harbour for rabbits where they will stay warm, dry and will multiply like "rabbits".

8. Without gorse I would be out of beekeeping.

9. We feel to reduce gorse will be a total disaster to the Bee Farming industry; because I don't know of any other plant, tree or shrub, which will flower for such a long winter period.

10. If insects were released which reduced the amount of gorse available, bee keeping on honey dew may still be possible but only with a drastic reduction in hive stocking rates and consequently major reduction in bee keepers.

11. More spray - less gorse - less pollen - less bees - less honey and wax etc. - less profit.

12. Gorse gets the hives off to a good start for the season. I consider this the greatest value of gorse.

13. There is no substitute for natural pollen.

14. "New World" Pollens appear to be of little or no value in brood rearing, where pollens are top quality.

15. Pollen substitutes have been tried with no apparent success.

16. In my efforts to use pollen substitutes in the past, I have found that they are not particularly successful in the absence of natural good quality pollen.

17. Will definitely feed pollen substitute when a suitable product appears on the market.

18. Can't you breed a gorse plant that produces nectar?

19. Many hives with marginal pollen supplies are becoming deficient. Hives where surplus was available to crop are now self sufficient.

20. Present methods of gorse control cause temporary shortages in specific areas which are alleviated as regrowth occurs. These shortages are serious and unpredictable for the bee keeper and are occurring on an increasing scale.

21. I would point out that I do not deny the farmer's right to eradicate gorse from his land, but this is being effected through sprays and land clearing. What is of great concern to me is that biological control will effect waste areas inaccessible gullies, steep terraces and riverbeds, areas which are essentially never likely to be productive to a farmer. To reduce these areas further would be serious indeed.

22. In certain sites where spraying of gorse by helicopter has been carried out most other pollen sources are wiped out too.

23. Chemical control on a much reduced scale plus biological control would be acceptable to me long term as the unpredictable nature of the present situation would largely disappear, making it easier for the bee keeper to plan alternative tactics.

24. I am particularly wary of spraying 245T for gorse control due to possible contamination of honey and especially pollen, not to neglect the possible environmental and definite human risks in spraying. Would prefer biological control but PLEASE not both.

25. On districts such as mine where gorse is mainly confined to river beds the biological control could totally eradicate gorse.

26. Personally I consider biological control is preferable means to control noxious weeds and the usage of artificial methods: herbicides in mechanical clearing. These methods are non selective, and also eliminate many other equally important pollen - bearing plants.

27. Our major concern is not just the gorse eradication programme currently in use, 245T Tordon etc, but the fact that so many farmers are trying to convert pasture to - 100% ryegrass - clover and eliminate the dozens of "weed"varieties.

28. You can bet your false teeth that the kind loving insect that you are thinking of importing, if it does clean up the gorse, will not then die but will turn its attention to perhaps roses, or fruit trees or some other means or sustenance. It will very easily adapt to its new environment.

29. As a gorse contractor, it is my conservative estimate that a 20% better kill can be achieved on gorse simply by making it a requirement that all spray used on gorse has a dye in it.

30. Some combs have been coated in dye marker. I have had to destroy these contaminated combs and are worried about burning the dioxin.

31. What else do these bugs like to eat if they get fed up with gorse or even find that there were pleasant things to eat?

32. If gorse was eradicated or badly affected I would have to sell out but who would buy a bee keeping business in a pollen deficient area?

33. Considerable change in farmers attitudes would be necessary for the survival of bee keepers in gorse pollen dependent areas. This means a massive reduction of farmers in many parts of N.Z.

34. I have told the farmers, no gorse means no bees, no pollination, no clover, so some are taking notice and are refraining from spraying all their gorse.

35. Present methods of gorse control plus biological control would seriously inflame the present situation.

36. What we do know as bee keepers is that hives without ready access to high quality pollen in the Spring and the Autumn simply fail to thrive, hence their development is impaired and they fail to carry out their required tasks of honey gathering to support the bee keepers needs, or of pollination of legumes which meets the far greater needs in agriculture in New Zealand.

38. I was only a bee keeper for a short time. I don't think I could answer the questions accurately.

39. I am against the eradication of gorse, in any shape or form except where normal pasture is required, and this can easily be controlled by the good old hand grubber and slasher. Please leave our gorse alone, and please don't import any Foreign Insects to this country.

40. As a bee keeper my main weed is rye grass. Do you know of any insects that may be introduced to deplete it?

41. Sorry can't answer, controlling the spread of gorse would be good.

42. None (gorse) in my area.

43. A lot of these questions are beyond my knowledge - but have done my best.

44. As a younger man in another time I spent a considerable while shooting "noxious" animals??? I shed a tear for I.W.D. at your proposal. This year gorse - next year?

APPENDIX C

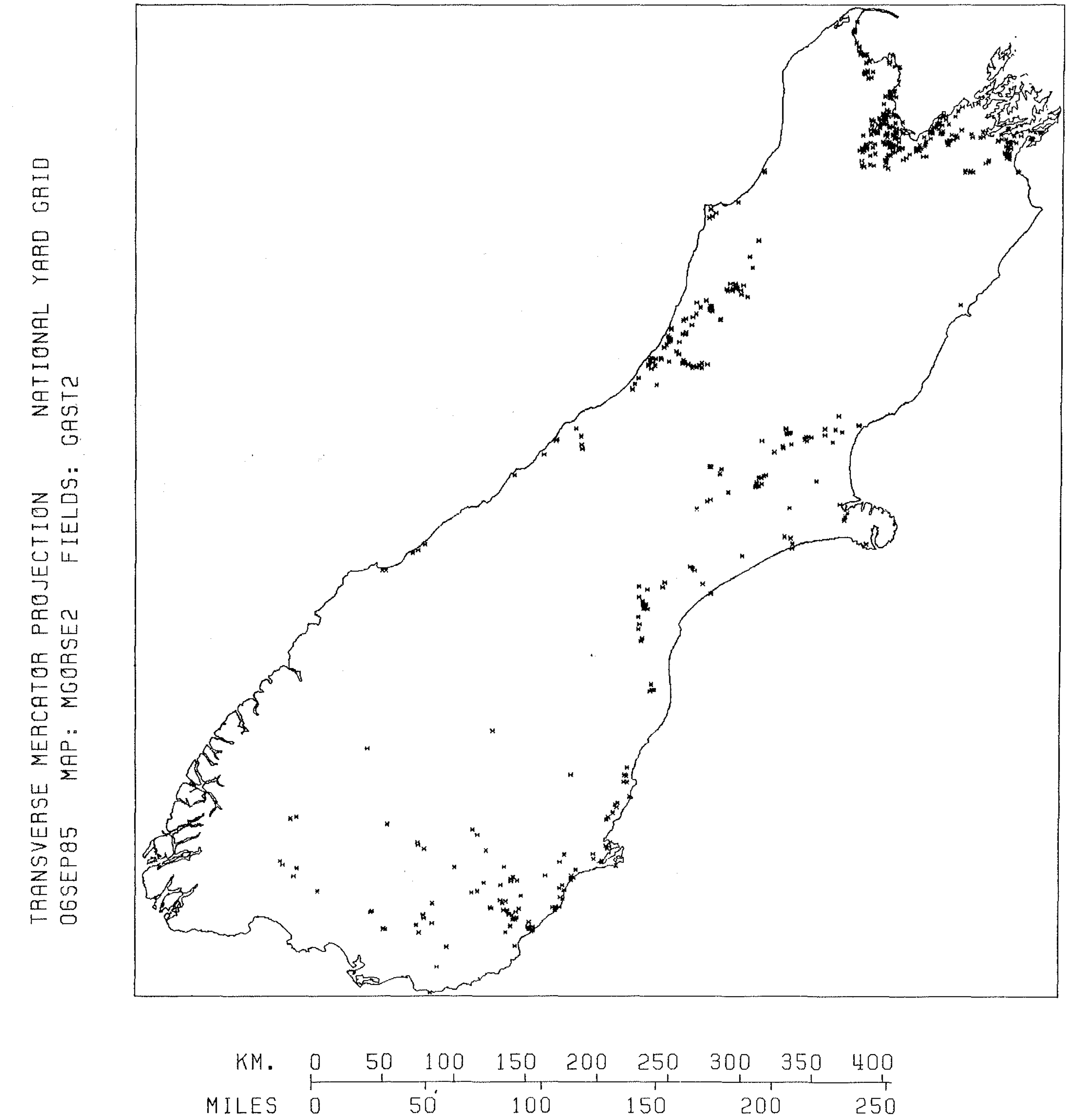
VEGETATION COVER CLASS (ha)

		North Island	South Island	Total
1	Scrubland and Fernland			
	- gorse and mixed indigenous scrub	3,300	2,800	6,100
	- gorse and Leptospermum	11,200	4,500	15,700
	- gorse and fern	1,500	10,000	11,500
	- gorse, fern, and Leptospermum	1,400	13,900	15,300
	- other gorse dominated scrub	1,100	3,300	4,400
	Sub Total	18,500	34,500	53,000
2	Grassland and Scrub Containing Gorse			
	- pasture and gorse	62,800	135,800	198,600
	- tussock and gorse	-	3,500	3,500
	- tussock, pasture and gorse	-	36,700	36,700
	- pasture, gorse, and mixed scrub	31,400	54,900	86,300
	- tussock, gorse, and mixed scrub	-	9.500	9,500
	- pasture, gorse and leptospermum	88,200	72,400	160,600
	- tussock, gorse and leptospermum	200	4,600	4,800
	- pasture, gorse and fern	11,700	71,400	83,100
	- tussock, gorse and fern	-	7,200	7,200
	- grassland, broom and gorse	500	48,800	49,300
	- pasture, gorse, and scrub	6,800	6,600	13,400
	- tussock, gorse, and scrub	-	3,600	3,600
	Sub Total	201,600	455,000	656,600
3	Grasslands Inc. Crops and Scrub			
	- pasture, gorse and crops	3,200	124,000	127,200
	- other grasslands, crops and scrub	29,600	74,900	104,500
	Sub Total	32,800	198,900	231,700
Grand Total		252,900	688,400	941,300

Source: Blaschke et al, 1981.

APPENDIX D

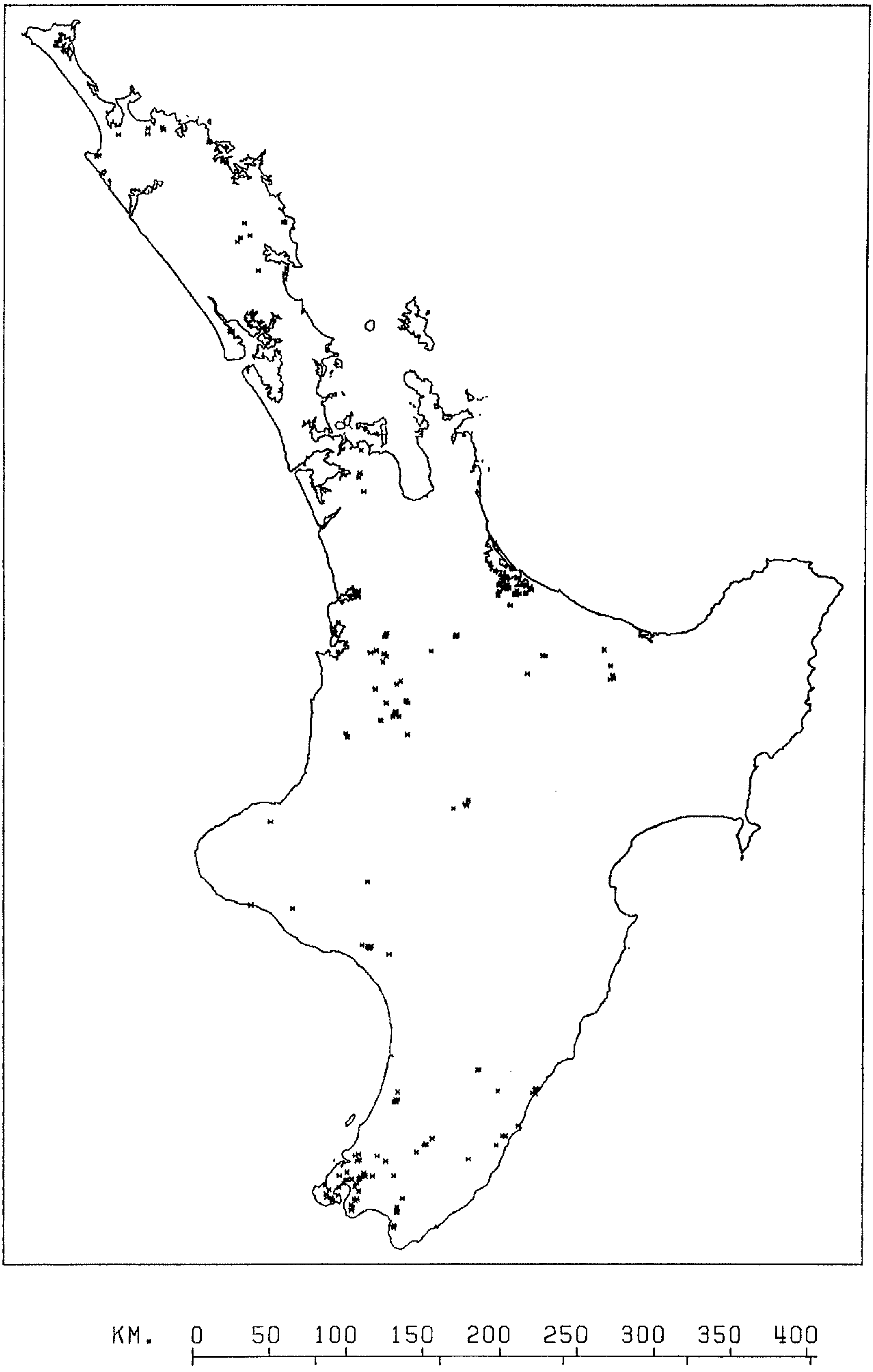
GORSE, SOUTH ISLAND (>40% VEG COVER)



SCALE 1: 4000000 RESOLUTION: 0.5 MM
FRAME 1 ACROSS 1 DOWN. ORIGIN 64000 169000
DATA FROM NWASCO NZ LAND RESOURCE INVENTORY USING LADEDA

GORSE, NORTH ISLAND (>40% VEG COVER)

TRANSVERSE MERCATOR PROJECTION NATIONAL YARD GRID
09SEP85 MAP: MGORSE3 FIELDS: GAST2



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