The biology of the grassland Melomys (*Melomys burtoni*) (Rodentia: Muridae) in far north Queensland sugarcane crops

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ABSTRACT

Melomys burtoni and M. cervinipes naturally occur in habitats adjacent to sugarcane crops in north Queensland, have been trapped within sugarcane crops, and are potentially damaging to sugarcane crops. However, little is known about their biology and pest status in sugarcane crops and this information is needed by the industry for the development of a sustainable pest management programme for these rodents. Field studies were undertaken between Tully and Innisfail in far north Queensland, to determine the extent to which either or both *Melomys* species inhabit sugarcane crops and to examine the biology of *Melomys* within the crop. Field diagnostic approaches were developed which, when blind tested using molecular techniques, proved 100% accurate in-field discrimination of the two *Melomys* species. Based on field trapping, *M. cervinipes* proved to be rare in sugarcane and should not be regarded as a pest by the industry. In contrast, *M. burtoni* were recorded in significant numbers within cane, were found to feed on cane and, in crop stage 5 (canopy closure to harvest) were responsible for damage to ~5% of stalks. *Melomys burtoni* were found to colonise sugarcane at the later stages of crop development than the other major sugarcane rodent, *Rattus sordidus*. The highest proportion of *M. burtoni* reproduction and juvenile recruitment also occurs in the later stages of crop development. The late colonisation of the crop by *M. burtoni* means that the Integrated Pest Management (IPM) strategy already in place for *R. sordidus* is not directly transferable to *M. burtoni*. If an effective IPM strategy is to be developed, further research is required to examine the population

dynamics and dispersal of *M. burtoni* populations between the crop and the adjacent habitats within the sugarcane production system of far north Queensland.

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STATEMENT OF ORIGINALITY

The work presented in this thesis has not been previously submitted for a degree, either in whole or part, at any other higher education institution. To the best of my knowledge and belief, this thesis contains no material published or written by another person except where due reference is made.

All photographs and figures within this thesis are by the author except where acknowledged as otherwise.

Signed:

Date:

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Andrew Schalks is happy to be collecting live capture traps from the last sampling period in not so pleasant conditions post Cyclone Larry, April 2006.

Chapter 1 - Introduction

The Australian sugarcane industry

Sugar is a globally important agricultural commodity traded on the 'world sugar market' and is presently one of Australia's major export industries (Twine 2005). Sugarcane was introduced to Australia with the First Fleet in 1788, and Queensland's first plantation was established at Ormiston, south-east of Brisbane in 1862, producing commercial raw sugar by 1864. Industry expansion in the 1880s saw cane cropping develop along the eastern coast of Queensland and northern New South Wales (Griggs 1997). In the mid 1990s, a small industry was established in the Ord River area of northern Western Australia.

The industry currently has the capacity to produce more than 5 Mt of raw sugar annually, stemming from approximately 38 Mt of harvested sugarcane. Direct revenue varying between AU$1.5 billion and AU$2 billion is generated annually, 80-85% of which is realised from exports. Ninety-four percent of sugar is produced in Queensland, 5% in New South Wales and the remainder in Western Australia's Ord River Irrigation Area (Walker *et al.* 1997; CANEGROWERS 2006a). Given the importance of the sugarcane industry to Queensland, the remainder of this discussion focuses on Queensland.

Sugarcane in Queensland is grown from Rocky Point near Beenleigh (27°43.062'S, 153°12.156'E) in the south through to Mossman (16°27.69'S, 145°22.386'E) in the north. This range encompasses four regions; the

Southern, Central, Burdekin and Northern regions. While there has been a reduction in the number of growers within the industry in recent years, the area of sugarcane harvested in Queensland remains stable at approximately 380,000ha (CANEGROWERS 2006b). Australian Bureau of Statistics (2005) estimate a total of 2,694,000ha in Queensland is used for cropping, excluding crops harvested for seed, hay, pastures and grasses. Sugarcane thus represents 15% of the State's total cropping area, while accounting for 38% of the State's total gross value of cropping (EPA 1999). Given the industry's concentration in eastern coastal areas, sugarcane is the dominant component of the economics of many coastal communities.

Rodent pests as limiters of production

There are approximately 1700 rodent species worldwide (MacDonald and Fenn 1994; Stenseth *et al*. 2003), 5-10% of which are considered pests in agricultural and urban environments (Wood 1994; Chambers *et al*. 1999; MacDonald *et al*. 1999; Mills 1999; Aplin *et al*. 2003; Jacob *et al*. 2003; Liers 2003; Tobin & Fall 2004). Pest rodents inflict damage on a variety of crops worldwide, resulting in significant losses. Typical crops that are affected include cocoa, cereals, oil palms, nut and seed crops, broad-acre vegetables and root crops, fruit, rice and sugarcane (Wilson & Whisson 1993; Wood 1994; Buckle 1999; Makundi *et al*. 1999; Liers 2003; Brown *et al*. 2007).

The economic impact of rodents varies within agricultural systems, both temporally and regionally. For example, rodent-related losses in Indonesian rice production range between 10-20% of the annual crop (Geddes 1992;

Leung *et al*. 1999; Liers 2003), while in Malaysia rice losses may be as low as 2-5% of the crop (Liers 2003), or as high as 18% in some years (Hafidzi & Mohd 2003). In Tanzanian maize crops, rodents are responsible for damage to an estimated 5-15% (400,000 t) of the annual crop (Liers 2003), although in neighbouring Kenya rodents can out-break, resulting in losses of 30-90% to maize crops (Odhiambo & Oguge, 2003).

In Australia, rodents are regarded as a major pest of agricultural systems, where they out-break periodically resulting in serious economic damage to various crops. Ramsey and Wilson (2000) described three situations where periodic population outbreaks are of economic importance in Australia: (a) infestation of sugarcane by *Rattus sordidus* (the cane-field rat); (b) infestation of macadamia orchards by *Rattus rattus* (the roof rat or black rat); and (c) infestation of cereal and oilseed crops by *Mus domesticus* (the house mouse).

Mouse plagues have been recorded in the grain-growing areas of southern and eastern Australia since the early 1900s and occur, on average, every four years (Mutze 1989a; Kay *et al*. 1994; Caughley *et al*. 1998; Brown & Singleton 2000; Singleton *et al*. 2005; Brown 2005; Brown *et al*. 2007). Mouse plagues are characterised by rapid and widespread increases in mouse population densities to >800 mice/ha (Brown & Singleton 2000; Stenseth *et al*. 2003; Singleton *et al*. 2005; Brown *et al*. 2007). The most severe damage is caused to freshly sown seed and to maturing grain heads, although the intermediate vegetative growth stages may also experience

damage (Mutze 1993). Damage is not restricted just to in-field damage, but also includes post-harvest losses and damage to livestock and infrastructure (Mutze 1989b; Stenseth *et al*. 2003). Caughley (1994, cited in McLeod 2004) reported that '*in the case of the 1993 southern Australian plague, approximately 450 thousand hectares of crop were affected*' and '*despite the use of baiting, $58.9 million in losses were realised*'.

Significant crop losses have been caused by *R. rattus* to Australian and Hawaiian macadamia orchards (Tobin *et al*. 1997; White *et al*. 1997), with losses in Australian orchards having been estimated at up to 30% of total crop volume (Horskins *et al*. 1998). The Australian Macadamia Society (1997) estimated a crop yield of '*19 500 tonnes in 1996, with a value of $55.2 million*'. Given the afore-mentioned crop-loss estimate of 30%, this would equate to a potential AU$16.56 million loss to industry.

Rodents as pests of Queensland sugarcane (*Saccharum* hybrid)

Wherever it is grown, including Asia, Africa, Latin America, the Pacific region and Australia, ripening sugarcane is susceptible to extensive damage from rodents (Tobin *et al*. 1990; Tobin & Fall 2004). Damage from rodents has been recorded since the inception of the Queensland sugar industry. McDougall (1944a) stated that few detailed records were published prior to Gard (1935), but this does not mean that the pests were either absent or that they were neglected entirely, as there are various reports of sporadic rodent out-breaks in the early cane industry. For example, Anon (1946, cited in Plomley 1972) recorded that '*prior to 1884 rats must have begun to reach*

plague numbers in the cane fields, because in that year the mongoose was introduced unsuccessfully', while Anon (1900, cited in Plomley 1972) writes '*regarding a plague in 1890'*. Further reports and journal articles are cited by McDougall (1944a) on various rat out-breaks in different sugarcane-growing districts between 1910 and 1935. These include Kerr (1934) who stated '*A large percentage of the crop was damaged by rats, grubs and borers*' and Bell (1934) who recorded that '*damage to cane on account of the attack by rats has been considerably greater than in previous years and its aggregate has been greater than that caused by any other pest*'. Gard (1935) stated that from 1930 to 1934 the proportion of bitten stalks varied between 13 and 32.8%, and noted '*that the losses are purely in terms of cane and there is no complete data regarding the actual sugar losses*'. More recently, it has been reported that rodents are the second-most important pest (after canegrubs) in the Queensland sugarcane industry and may cause damage to over 50% of sugar-producing areas, resulting in estimated annual losses of between AU$2 and AU$4 million (Wilson & Whisson 1993; Whisson 1996). Smith *et al*. (2002) put the damage much higher, stating that rats destroyed approximately 825 000 t of sugarcane valued at AU$25 million during the 1999 and 2000 seasons combined.

Damage to sugarcane occurs when rodents gnaw at the internodes on the cane stalk, resulting in a loss in yield. This feeding and the resultant open wounds then pre-dispose the cane to micro-organism infection, causing a reduction in sugar quality (Hood *et al*. 1970; Wilson & Whisson 1993; Robertson *et al*. 1995; Smith *et al*. 2002; Tobin & Fall 2004). Hood *et al*.

(1970) concluded that '*the secondary losses are of far greater importance than the small amounts of cane the rats actually consume*'.

Rodent pest species in Queensland sugarcane

The common collective name 'rats' was used in early references to describe damage by pest rodents in Queensland sugarcane fields. Gard (1935) assessed the rat problem in sugarcane areas in northern Queensland and identified three species of rodent in cane fields, *Rattus culmorum* (now known as *Rattus tunneyi*), *Melomys littoralis* (now known as *Melomys burtoni*) and *R. rattus*. Gard described the rodents' general habits and concluded that the latter species should not be considered a pest. However, McDougall (1944b) found that the accepted identifications of some members of the Family Muridae (rats and mice) were not accurate and thus Gard's identifications were confused. McDougall's results showed that two species of *Melomys* (*Melomys littoralis* and *Melomys cervinipes*) damaged sugarcane in Queensland and that the species referred to by Gard as *R. culmorum* was actually *R. conatus* (now known as *Rattus sordidus*).

Eleven species of rodent were trapped by McDougall (1944b) in Central and Northern Queensland cane fields, five of which were associated with damage to sugarcane. While *R. conatus (= R. sordidus)* was considered the most serious economic pest and *M. littoralis (= M. burtoni)* second-most in importance, the pest status of *M. cervinipes* was described as indefinite: its real distribution in years of heavy rodent population was not known (McDougall 1944b). *Rattus rattus* and *R. culmorum (= R. tunneyi)* were

considered of little direct economic importance (McDougall 1944b; Redhead 1973; Watts & Aslin 1981). Henceforth, the current rodent taxonomic descriptions will be used in this review (Table 1.1).

Table 1.1: Rodents listed by McDougall (1944b) occurring in sugarcane and current nomenclature (following Story 1995).

McDougall's nomenclature	**Current nomenclature**
Rattus conatus Thomas	*R. sordidus* (Gould)
R. rattus Linnaeus	*R. rattus* Linnaeus
R. culmorum Troughton	*R. tunneyi* (Thomas)
Melomys littoralis Troughton & Le Souef	*M. burtoni* (Ramsay)
M. cervinipes pallidus Troughton & Le Souef	*M. cervinipes* (Gould)

It is now commonly accepted that the two main species responsible for damage to sugarcane are *R. sordidus* and *M. burtoni* (McDougall 1944b; Volp 1960; Redhead 1973; Hitchcock 1973; Hitchcock & Kerkwyk 1975, 1978; Redhead 1980; Redhead & Saunders 1980; Watts & Aslin 1981; Wilson & Whisson 1993; Wilson 1994; Robertson *et al*. 1995; Smith *et al*. 2002; Hunt *et al*. 2004). A third species was suspected by Volp (1960) where '*the fibrous residue left near bitten stalks in some areas was much coarser*', whilst Redhead (1973) stated '*the closed forest dwelling group* [of rodents]*, though occasionally trapped in or near cane fields, have not become pests, with the exception of* Melomys cervinipes *in isolated cases*'.

Investigations of rodent pest species in Queensland sugarcane

Many investigations have centred on the development of suitable rodenticides and the improvement of baiting strategies for the control of rodents in Queensland sugarcane (see Gard 1935; McDougall 1944c; Volp 1960; Hitchcock 1973; Hitchcock & Kerkwyk 1975, 1978; Redhead & Saunders 1980).

Rodenticide-based control techniques are described as direct 'organism based' strategies, which aim to increase mortality within a target population. While such strategies may prove successful in the short term, few studies can show their effectiveness in the long term (Putman 1989). In contrast to mortality-based strategies, control strategies that rely on a reduction in rodent reproduction rates and immigration into the crop can achieve increased, sustainable effectiveness. Therefore, an understanding of the population dynamics of the pest species is fundamental to the development of an effective management strategy (Stenseth 1981; Hussain *et al*. 2003; Tobin & Fall 2004).

The most extensive investigations of rodent pests in Queensland sugarcane have been undertaken by McDougall (1944a, b, 1946a, b, 1947), Wilson and Whisson (1993), and Whisson (1996), where the focus was on the ecology of, and ecologically based management strategies for, *R. sordidus.* Other incidental investigations addressed the breeding (Taylor & Horner 1973; Breed 1978) and diet (Harrison 1962; Woods 1966; Watts 1977) of *R. sordidus*.

Redhead (1973), in contrast, concentrated on the ecology of *M. burtoni* and found that *M. burtoni* was associated with tall grasses and fully developed cane that provided cover and protection, while offering suitable support for nests within the canopy (Figure 1.1). He observed that population numbers of *M. burtoni* increased following the presence of a high proportion of pregnant females in the trappable population, and that the highest period of reproductive activity extended from January to July. This corresponds with the crop providing the most cover. He also found that population numbers of *M. burtoni* in some sugarcane crops were equal to, if not greater than those of *R. sordidus*, and concluded that the importance of *M. burtoni* as a pest had been underestimated, at least north of Ingham. Redhead's studies however, were interrupted when growers insisted on baiting their crops and as such, became observations on the effects of baiting rather than observations on the fluctuations in *M. burtoni* population numbers.

Figure 1.1: A spherical *Melomys burtoni* nest of dry cane leaves, built within a stool of sugarcane almost one meter off the ground.

Wilson and Whisson (1993) stated '*Approximately 75% of land assigned to cane growing is in areas where the canefield rat (*R. sordidus*) is responsible for over 90% of total rodent damage, therefore damage caused by this species is of far greater economic significance to the sugar industry than damage caused by* M. burtoni*'*. For this reason, it is logical that the majority of previous investigations have focused on *R. sordidus* within the Queensland sugar industry.

Given life history characteristics such as early independence and sexual maturity, short gestation periods, large litter sizes and post-partum oestrus, *R. sordidus* has one of the highest reproductive potentials of any native Australian *Rattus* species (McDougall 1946a; Taylor & Horner 1973; Breed 1978; Wilson & Whisson 1993). *Rattus sordidus* were found by Gard (1935) and McDougall (1946a) to breed all year round. In contrast, Taylor and Horner (1973) found *R. sordidus* breeding between November and May, with the peak between March and May (71% of births), and Wilson and Whisson (1989, 1993) identified a peak in breeding where >95% of pregnancies occurred during the December - July period.

Many investigations considered rainfall as the stimulus for *R. sordidus* to commence breeding. This was attributed to an increase in both the quantity and quality of available food resources following rainfall in spring (Gard 1935; McDougall 1946a; Redhead 1973, 1980). Wilson and Whisson (1989, 1993) suggested the onset of breeding was associated with a flush of summer grass and weed growth in and around crops resulting from rainfall in the

November-January period, and that the onset of breeding was delayed if rainfall during this period was low.

Current management of rodents in Queensland sugarcane

By combining biological and chemical methods in sequence, Wilson and Whisson (1993) developed an Integrated Pest Management (IPM) strategy for *R. sordidus* in cane. This was based upon an understanding of the population cycle of *R. sordidus* in sugarcane growing areas and identifying the critical factors that determined the spatial and temporal distribution of rodent damage within districts.

Colonisation of the sugarcane crop by *R. sordidus* occurs each year, and as such, the population cycle of *R. sordidus* is closely related to the crop cycle. Wilson and Whisson (1993) divided the population dynamics of *R. sordidus* into three complete population phases. Firstly, as the crop canopy develops the environment becomes more favourable to *R. sordidus* and the majority of available crops are colonised over the November-January period by mature, non-breeding individuals from non-crop habitats (harbourage areas). Secondly, following colonisation, an annual breeding period (November-March) is associated with the first appearance of summer grasses in and around crops as a result of rainfall. Breeding intensity peaks 1-3 months after initial observed pregnancies and declines thereafter. The decline in breeding intensity coincides with a decrease in the availability of summer grass in crops, while the utilisation of sugarcane as a food source increases. Wilson and Whisson (1993) also suggested that this decline in breeding

could be considered as a result of increased population density leading to increased stress in *R. sordidus* populations. Thirdly, in the final phase of the cycle, *R. sordidus* populations disperse to non-crop harbourage areas as sugarcane crops are harvested. Re-colonisation the following season will occur in the November-January period.

In summary, Wilson and Whisson's (1993) study showed that the proximity of crop to the nearest harbourage and the extent and type of habitat connecting the harbourage to the crop influenced the level of colonisation. Similarly, spatial distribution of damage throughout a mill area was dependant on site characteristics that influence colonisation, breeding and survival. Breeding and survival were strongly associated with stomach content (i.e. non-cane vegetation provided the nutrition required during the breeding period). Crop damage intensified after the peak of breeding and the pattern of damage correlated with stomach content (i.e. there was a distinct diet switch to sugarcane following the breeding season). The strongest association was between weed cover and damage, where sites with high weed cover were associated with more damage than sites with low weed cover. However, the effect of available harbourage on crop damage was also linked, where sites with high weed cover were associated with high damage, provided there was harbourage available.

The IPM strategy developed by Wilson and Whisson (1993) involves:

- Rodent population monitoring (to predict the extent of the problem well in advance of its occurrence, so that appropriate management

options can be initiated at an appropriate stage of the population cycle);

- In-crop weed control (a reduction in grasses and weeds within the crop decreases breeding potential);
- Harbourage management (fewer grasses and weeds in adjacent non-crop areas decreases the potential for crop colonisation the following season);
- Manipulation of adjacent habitats or land use (not all adjacent habitats have the same potential to provide colonists);
- Strategic use of permitted rodenticides (prior to the onset of breeding).

Monitoring of *R. sordidus* population levels allows the potential for damage to be assessed prior to the problem occurring. A non-breeding *R. sordidus* population can be baited after colonisation but prior to the onset of breeding, thus resulting in a reduction in population level and the potential for crop damage. Similarly, the removal of weeds and grasses by herbicide application can result in the suppression of *R. sordidus* populations and a 60% reduction in damage to the harvested crop. Decreasing the area of harbourage available and thus reducing the level of colonists for the following season would result in a reduction in the potential for damage (Wilson and Whisson 1993).

In a later study, Whisson (1996) found that with the advent of 'green-cane trash blanketing' (GCTB), (where the green leaf top and dry leaf material is

left in the field as a trash blanket at time of harvest with minimum or zero tillage techniques used), weed cover was reduced by >75% compared with the conventional farming practice of burning prior to harvest. Although rodents can colonise a GCTB crop earlier than in conventional crops, the reduction in weeds resulted in a reduction in the proportion of breeding females and less rodent damage to the sugarcane crop.

The *Melomys* species Issue

As stated earlier, rodents were responsible for the destruction of approximately 825 000 t of sugarcane valued at AU$25 million in the 1999 and 2000 seasons (Smith *et al*. 2002). In mid to late 2000, extensive industry-wide extension campaigns were developed and undertaken to raise the knowledge, understanding and skills of growers with regard to rodent management in the Central and Northern regions of Queensland. Over 2500 growers attended these training workshops (BSES 2001). Nearly 3200 industry personnel participated in some form of training and awareness in contemporary rodent IPM during this period (Hunt *et al*. 2004).

Growers, millers and industry representatives (referred to hereafter as industry members) were given the opportunity through these workshops to raise and discuss any issues regarding general rodent management, and rodent damage, both at the farm and district level. Industry members demonstrated they were aware the current IPM strategy was developed for *R. sordidus* and agreed that the components of the strategy alleviated pressure from that species. There were concerns, however, as to the

effectiveness of the strategy in managing *M. burtoni* - industry consensus was resolute in that this species was emerging as an increasingly significant pest in the Central and Northern cane growing regions of Queensland. Furthermore, there was concern from industry members that a third species, *Melomys cervinipes*, was becoming a significant economic pest. The issue of *M. cervinipes* stems directly from the *R. sordidus* IPM strategy, specifically management of harbourage areas, and so it was of potentially great concern.

Unmaintained (grass and weed infested), non-crop areas on farm are harbourage for grassland species of rodent, providing food and shelter. Methods for managing these areas include slashing, spraying, fencing and grazing (Wilson and Whisson 1989, 1993; Robertson *et al*. 1995; BSES 2000). High rainfall and uneven and slippery ground on the edge of rivers, creeks and drains can, however, restrict the implementation of these options. Even if these methods are suitable for a site, they remain an ongoing cost and repetitive for the grower. In contrast, habitat manipulation is seen as a long-term method of maintaining harbourage areas. This involves the revegetation of non-crop areas with native rainforest trees that grow quickly to form a dense canopy, minimise light at ground level and shade out grasses and weeds. This approach has been adopted by the industry as part of the *R. sordidus* IPM strategy (Wilson and Whisson 1993; Land and Water Resources Research and Development Corporation 1999; Tucker *et al*. 2004).

Recently, industry members have questioned the effectiveness of revegetation because it may create a niche for a species that can utilise both the forest habitat and adjacent cane fields. *Melomys cervinipes* is one such animal, being virtually restricted to closed forests along the eastern coast of Queensland, but also found in cane fields where these are adjacent to forested areas (Watts and Aslin 1981). The pest status of *M. cervinipes* in sugarcane has never been clarified and, while considered a minor pest at worst by previous researchers (McDougall 1944b; Volp 1960; Redhead 1973), some industry members perceive it as a potential flow-on problem following habitat manipulation for *R. sordidus* management. There is, therefore, industry pressure to research the management of this second *Melomys* species. Given that there is presently little known about *M. burtoni* and *M. cervinipes* in the sugarcane production system, an understanding of the significance of these species as pests in sugarcane, and the damage potential to sugarcane from these species will foster the development of an effective and sustainable management strategy.

Conclusion

This review has highlighted what is known about the biology and ecology of *R. sordidus* in sugarcane crops, the damage associated with this species, and the past and current management of this species. Comparatively, very little is known about the biology of *M. burtoni* (Watts and Aslin 1981). In 1993, Wilson and Whisson developed an effective and sustainable IPM strategy for *R. sordidus* and industry supported this approach. More recently, industry members have questioned the effectiveness of the existing IPM

strategy in managing *M. burtoni* and the potential for a third species, *M. cervinipes*, to become a significant pest.

Sugarcane farming management practices have changed dramatically in recent times. *Melomys burtoni* and *M. cervinipes* are locally abundant in the northern regions of Queensland, both species have been found within sugarcane crops, and both are potentially damaging to sugarcane crops. Damage from *Melomys* species is often concentrated on the edge of sugarcane crops, thus making it highly visible and increasing its apparent importance (Robertson *et al*. 1995).

Research into the control of *Melomys* species in sugarcane crops has been limited and a separate management strategy for these rodents has not been developed (Allsopp *et al*. 1993). Given this limited knowledge on the biology and ecology of *Melomys* species within the present sugarcane industry, more research is needed on the importance of *Melomys* species in sugarcane.

Objectives

The objectives of this study are:

a) To use morphology and genetics to identify the *Melomys* species utilising the sugarcane crop;

b) To gain an understanding of the damage process; and

c) To understand the population dynamics and demography of *Melomys* species within sugarcane crops.

Each of the objectives is addressed in one or more subsequent chapters of this thesis. The general materials and methodology of this study, including a description of the study sites and the experimental and survey procedures, are outlined in Chapter 2.

In identifying the species utilising the sugarcane crop, readily measurable morphological characteristics are tested against DNA sequencing and phylogenetic reconstruction to ensure that the field identification of *Melomys* species corresponds with the true taxonomy of each species. This is covered in Chapter 3 – 'Diagnostics'. Having developed usable diagnostics, I assessed the population numbers of each species utilising the sugarcane crop at different stages of crop development and this is covered in Chapter 4 – 'Species in Sugarcane'.

In order to understand the damage process, it was necessary to determine whether the diet of *Melomys* species includes sugarcane to confirm whether *Melomys* species are indeed responsible for damage to sugarcane. It was also necessary to determine whether the diet of *Melomys* species consists of non-crop vegetation and seed and what, if any, the influence of non-crop vegetation may be having on the damage and population levels within the crop. These questions are covered in Chapter 5 – 'Diet and Damage'.

The population dynamics and demography of *Melomys* species within the sugarcane production system are covered in Chapter 6 – 'Population Dynamics'. Male-to-female ratios in each stage of crop development are investigated, along with the proportion of pregnant and non-pregnant females within the population, and adult to juvenile ratios.

The information in each of these chapters can contribute to the management of pest populations of *Melomys*. A better understanding of *Melomys* species as a whole within the sugarcane production system presents the potential to further develop an effective and sustainable management strategy that would be very useful to the sugarcane industry in Queensland.

Chapter 2 – Materials and Methodology

Study sites

Eight study sites, all in areas that *Melomys* species would potentially be encountered, were selected within the sugarcane production area around Tully, East Feluga, El Arish and Silkwood in far north Queensland (Table 2.1). Four sites had cane-fields adjacent to grassland (Figure 2.1), while the remaining four had cane-fields adjacent to closed forest (Figure 2.2). Each landholder/grower involved conducted normal farm-management practices (i.e. spraying/slashing) in-crop and on headlands (machinery access roads) for the duration of these studies, with the exception of rodenticide applications which were not made.

Surveys and Experimental Work

This project involved a number of studies and methodologies for each are listed separately below. The studies undertaken were:

(a) Capture-and-release study;

(b) Snap-trapping study;

(c) Weed-biomass study; and

(d) Damaged-stalks study.

All studies were initiated at all eight sites when the crop was fully developed with a closed canopy (crop stage 5, see Tables 2.2, 2.4). Data collection continued into and through the harvest period (from 23 to 43 weeks after first samples were taken) and then through all stages of crop development until full canopy closure was again reached. The total sampling period covered 15 months, from February 2005 to April 2006.

Table 2.1: Information on sampling sites within the sugarcane production area of far north Queensland.

Site	Landholder	Mill area Farm number (block)	Address	Location (Latitude/Longitude)	Cane cultivar	Adjacent habitat hype
1	Maccarone	South Johnstone 05004 (23A)	-Walter Lever Estate, Silkwood.	17°43.644'S 145°57.814'E	Q138	Large grassland knoll dominated by blady grass (*Imperata cylindrica*) adjacent to cane blocks.
2	Boustead	South Johnstone 04028 (3A, 19B)	-No. 4 Branch Rd, Silkwood.	17°46.519'S 145°58.133'E	Q187[A]	Terraced grassland dominated by guinea grass (*Panicum maximum*) surrounding cane blocks.
3	Blennerhassett	Tully F1812A (12A & B)	-Dargin Rd, El Arish.	17°49.184'S 146°02.969'E	Q181[A] Q186[A]	Unmanaged neighbouring block dominated with molasses grass (*Melinis minutiflora*).
4	Benn	Tully F1062 (01B, 02)	-Dargin Rd, El Arish.	17°49.286'S 146°02.988'E	Q166[A] Q200[A]	Unmanaged neighbouring block dominated with molasses grass (*Melinis minutiflora*)
5	Pietrobon	Tully F1118A (28A)	-Mission Beach Rd, El Arish.	17°48.695'S 146°01.574'E	Q166[A]	Contiguous lowland rainforest bordering Walter Hill State Forest.
6	BSES Limited	Tully F5717 (23, 25A)	-Dallachy Rd, Tully.	17°58.944'S 145°55.473'E	Q187[A]	Lowland rainforest remnant bordering the Tully River
7	BSES Limited	Tully F5717 (35A, 35C)	-Dallachy Rd, Tully.	17°58.703'S 145°55.778'E	Q181[A] Q200[A]	Lowland rainforest remnant bordering the Tully River
8	Cuddihy	Tully F3228 (12, 13)	-East Feluga Rd, East Feluga.	17°52.967'S 146°00.633'E	Q152	Contiguous rainforest bordering Walter Hill Range State Forest.

A denotes Plant Breeders Rights for BSES Limited protected varieties.

Figure 2.1: Typical sugarcane site with adjacent grassland, separated by a grassed headland.

Figure 2.2: Typical sugarcane site with adjacent closed forest, separated by a partially grassed headland.

Table 2.2: Crop stage (0-5*) at each monthly sampling event for the eight sites sampled in this study.

Sampling event	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Site 1	5	5	5	5	5	5	5	5	1	2	3	4	4	5	n/a
Site 2	5	5	5	5	5	5	5	5	5	1	2	3	3	4	5
Site 3	5	5	5	5	5	5	5	0	1	2	3	4	4	5	5
Site 4	n/a	5	5	5	5	1	2	3	3	4	4	4	4	5	5
Site 5	5	5	5	5	5	5	5	5	5	5	1	2	3	n/a	5
Site 6	5	5	5	5	5	5	5	5	1	2	3	4	4	5	5
Site 7	5	5	5	5	5	5	5	1	2	2	3	4	4	5	5
Site 8	n/a	5	5	5	5	5	5	5	1	2	3	4	4	5	n/a
Month	Feb 2005	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr 2006

N.B. n/a indicates that either no site was chosen at that time or that a site had no access due to flooding and/or cyclone.

*0= Harvest underway, no trapping
1= Recently harvested/trash blanket
2= Individual plants
3= Individual rows <1.5 m
4= >1.5 m in height
5= Closed canopy >2 m in height

(a) Capture-and-release study

Each month, for the duration of the study, every site was live trapped using Elliott Type 'A' folding mammal traps (100x100x330 mm) (Elliott Scientific Equipment, Upwey, Victoria). Two transects which lay parallel to the adjacent habitat, were placed at 2.5 and 10m into the crop. Each transect consisted of 25 traps placed at 5 m intervals (total transect length 125 m). At each site for each month, trapping was conducted over four nights, resulting in 200 trap nights per month, a total across all sites of 1600 trap nights per month. All traps were baited with a piece of plain cardboard approximately 25 mm², previously soaked in raw linseed oil. This bait has proven to be attractive in previous studies (Wilson and Whisson 1993; Whisson 1996; Ruscoe *et al.* 1998). No alternative food or bedding was placed inside traps, but traps were covered with cane trash to prevent excessive heat from sunlight when the crop canopy was open and low.

Non-target species, including *Rattus sordidus,* were recorded and released at point of capture. *Melomys* species were all handled live, were not anaesthetised and were identified using morphological characteristics. Each individual trapped for the first time was permanently marked by injecting a uniquely numbered 4D-ISO microchip (2x12 mm) (Veterinary Marketing Network, Wahroonga, NSW). Microchips were scanned and read using a Destron Technologies Pocket Reader™ (Lifechip, Baulkam Hills, NSW). Given that *M. burtoni* and *M. cervinipes* have similar body form and overlapping ranges, a 2 mm² tissue sample was taken from the ear of each animal for DNA examination (see Chapter 3). The capture location, recapture

status, sex, reproductive condition, weight and tail length were recorded for each capture. All animals were released at point of capture. It was assumed that trappability of male and female *Melomys* species was equal.

Following Wilson (1994), reproductive condition was assessed as:

- Males: -Testes abdominal (no scrotal sac) - immature
  -Testes scrotal (scrotal sac present) - mature
- Females: -Vagina imperforate- immature
  -Vagina perforate- mature
  - Pregnant (by palpation)

(b) Snap-trapping study

The design (both in placement of traps and sampling occasions) for this study was identical to that of study (a), with the exception that Supreme snap traps were used instead of Elliot traps. Transects for study (b) were situated no closer than 50 m to those run for study (a). Snap traps were baited with cardboard soaked in linseed oil. On clearing snap traps in the morning, a rat caught live would be euthanized by cervical dislocation.

All target and non-target captures were recorded. Different species of *Melomys* were identified using morphological characteristics and a 2 mm^2 tissue sample was taken for DNA examination. The capture location, sex, weight and tail length were recorded for each capture. Specimens were micro-chip scanned to determine if they had been captured previously in

study (a), and, if so, data-sheets for study (a) were modified accordingly. Dissections on all *Melomys* species captured were undertaken in the field to assess reproductive condition for females (litter size per pregnant female) and stomach contents for all specimens. A visual estimation of the volume percentage of cane-fibre, seed, non-cane vegetation and other material of the total stomach content to the nearest 10% was recorded against each capture.

(c) Weed-biomass study

At each site, five 100 m long transects were laid parallel to the adjacent habitat at 1.0, 2.5, 8.5, 13.0 and 20.5 m into the crop. These transects were in the same location as the trapping undertaken in study (a). Five quadrats, each of 0.5 m² were chosen at random (using random numbers generated prior to going to the field) on each transect (i.e. total n = 25), on every sampling event in studies (a) and (b). Non-cane vegetation within each quadrat was harvested and total wet weight of biomass (g) and dominant weed species were recorded.

A simple coded system (Table 2.3) for rapid, in-field recording of weed biomass cover and height was used in conjunction with biomass sampling. A weed-score was developed by multiplying the cover scale by the height scale and recorded alongside biomass weight. For example, based on the codes in Table 2.3, a quadrat in which approximately 60% of the ground surface was covered with non-cane vegetation and at an average height of 15 cm was recorded as 3 * 2 and would result in a weed-score of 6.

Weed-scores versus wet biomass weight were analysed with a Pearson correlation to verify that weed-score was indeed correlated with wet biomass weight. For the correlation analysis, a sample of 100 weed-scores, each with their corresponding wet biomass weight, were chosen in a stratified manner to ensure that all weed-scores were represented (but individual score/biomass pairs were randomly selected within strata). Results of the analysis showed weed-score and weed biomass to be highly correlated ($r=0.86$, $p<0.001$) and so for simplicity of reporting, weed-scores only are used in data analysis in Chapter 5 – Diet and Damage.

Table 2.3: Scale used for cover (%) and height of non-cane vegetation in field vegetation surveys

Code	Biomass cover	Biomass height
0	0%	0 cm
1	1-25%	<10 cm
2	26-50%	11-30 cm
3	51-75%	31-50 cm
4	76-100%	>50 cm

(d) Damaged-stalks study

Five transects, 100 m in length, were established parallel to the weed biomass transects and spaced at 1.5, 3.0, 9.0, 13.5 and 21.0 m into the crop at each site. The total number of cane stalks within each transect was counted and inspected thoroughly for rodent damage. A sugarcane stalk was recorded as damaged regardless of whether it had one rodent gnaw or many, i.e. degree of damage for an individual stalk was not recorded. The number of damaged stalks per total number of stalks in each transect was

recorded and converted to a damage percentage. Stalk counts were undertaken during every sampling event where the crop had developed to the point where harvestable stalk was present.

Given the presence of *R. sordidus* in sugarcane crops, a method of eliminating the damage caused by this species from damage caused by *Melomys* species was required. Watts and Aslin (1981) described *R. sordidus* as a poor climber, and that damage to cane is confined to those parts which the rat can reach from the ground. Although *Melomys* species can damage cane at ground level, they are agile climbers (Figure 2.3). Thus, for this thesis, a conservative approach was adopted by considering only damage on the stalk at a height greater than 50 cm (Figure 2.4) to be that caused by *Melomys* species, while ground-level damage (Figure 2.5) was attributed to *R. sordidus*. This will have lead to an underestimation in total *Melomys* damage.

Figure 2.3: *Melomys burtoni* climbing through the canopy of a developed sugarcane crop.

Figure 2.4: Damage caused by *Melomys burtoni,* at a height greater than 50cm on sugarcane stalk.

Figure 2.5: Damage on sugarcane caused by *Rattus sordidus* at ground level.

Crop stages

As stated above, all studies were conducted within the crop for more than one full crop cycle. For analysis, the crop cycle was split into different growth stages based on percentage canopy cover, following Ward and Wilson (in prep.) (Table 2.4).

Table 2.4: Approximate canopy cover % and age at different crop stages.

Crop Stage	Canopy Cover %	Age of Crop (months)
0 = Harvest underway	0	0
1 = Recently harvested	0	0-1
2 = Individual plants	5	1-3
3 = Individual rows	24	2-4
4 = Crop > 1.5 m	33	4-7
5 = Crop > 2.0 m	84	6- Harvest

Chapter 3 – Diagnostics

Introduction

Central to the understanding of any pest management problem is the accurate identification of the pest species concerned. Because different species are generally recognised based on morphological dissimilarities, morphologically similar, but biologically distinct species, may be incorrectly lumped within cryptic species complexes (Paterson 1991). Biologically distinct species within cryptic species complexes may look identical, but are likely to present different problems, demands and opportunities for pest management. A failure to detect the existence of different species within a research study can have serious implications for pest management practice (Walter 2003).

Two species of *Melomys*, *M. burtoni* and *M. cervinipes*, may be encountered within the sugarcane production area of north Queensland. In many parts of their range, *M. burtoni* and *M. cervinipes* are sympatric, although they generally occupy different habitats (Taylor and Horner 1970; Baverstock *et al*. 1980; Smith 1985). In Queensland, *M. burtoni* prefers grasslands along the coast, sedgelands, open forest, woodlands and grassy patches within rainforests (Kerle, 1995). In contrast, *M. cervinipes* is known to inhabit rainforest in northern Queensland, extending its habitat in the south to include wet sclerophyll and coastal mangrove forest (Redhead 1995). Both species have been found in cane fields (McDougall 1944b; Watts and Aslin 1981).

Further to this overlapping range, body form in *M. burtoni* is similar to that of *M. cervinipes.* *Melomys burtoni* (Figure 3.1) is described as a small, rat-sized species, variable in colour from grey-brown to a reddish brown above, while the belly may be white, grey or cream. The ears are pale grey or brown and the tail may be dark grey, brown or black, sometimes lighter on the underside. The tail also tends to be slightly shorter than the combined head and body length (Watts and Aslin, 1981).

Figure 3.1: *Melomys burtoni*.

The back colour of *M. cervinipes* (Figure 3.2) ranges from light orange to dark-grey-brown in adults, with a white, cream or grey belly. Juveniles are often grey on both the back and belly. The ears and tail are dark grey to almost black, although the tail is occasionally lighter on the underside. The tail length is usually equal to the combined head and body length (Watts and Aslin 1981).

Although *M. burtoni* is on average smaller than *M. cervinipes*, both species overlap in their morphological measurements and both have four teats (Table 3.1). This creates difficulties in identifying live specimens of both species in the field.

Figure 3.2: *Melomys cervinipes*. Photo: D. Elmouttie

Table 3.1: External diagnostic characteristics of adult *Melomys burtoni* and *Melomys cervinipes* (following Watts and Aslin, 1981)

Diagnostic Characteristics	***Melomys burtoni***	***Melomys cervinipes***
Head/Body length (mm)	85-130	110-160
Tail length (mm)	90-150	115-180
Hind foot (mm)	20-29	23-31
Ear length (mm)	13-19	16-22
Weight (g)	25-80	35-150
No of teats	4	4

Knox (1978) found a character on alveolar pattern of the upper molars that consistently separated *M. cervinipes* and *M. burtoni*. *Melomys burtoni* have

smaller skulls and shorter molar rows than *M. cervinipes*, and the molar rows in *M. cervinipes* tend to diverge toward the back of the skull, while remaining parallel in *M. burtoni*. There are four roots to the first and second molars in *M. cervinipes*, whereas *M. burtoni* has five (Watts and Aslin 1981). While these techniques may have the ability to distinguish between species, they require the examination of dead specimens using laboratory equipment such as a microscope. This is clearly inappropriate for a field situation.

Frost (in press) developed a field-based method for distinguishing *M. burtoni* from *M. cervinipes* by measuring the pes length, pes pad lengths and head/body lengths of 41 voucher specimens from the Queensland Museum. She found that all pes pads on *M. burtoni* were smaller than those of *M. cervinipes* and concluded that the thenar pad in *M. burtoni* was consistently less than 2.3 mm long, whilst in *M. cervinipes* it was longer than 2.3 mm, irrespective of pes length. This approach requires considerable precision and would most likely prove difficult to use in the field with live specimens.

Given the overlap in range and habitat, similarities in body form and the difficulties associated with the field identification of the two *Melomys* species outlined above, the first objective of the current study was to examine whether the readily measurable characteristics of weight and tail length could be used as diagnostic traits for field identification.

Taxonomic and evolutionary relationships of organisms can be determined by comparing the various characteristics shared by organisms. Patterns of

shared characteristics are generally depicted using a phylogenetic tree. Early phylogenies and taxonomy were based upon observable morphological, physiological, and phenotypic similarities (Avise 1994), but, in the last few decades, molecular data has been used increasingly more for taxonomic assessment (Hillis 1987).

Phylogenetic reconstruction based on morphological data is limited in taxa that exhibit low levels of morphological differentiation (i.e. cryptic species). Molecular data, however, offer large character sets that are only limited by the number of nucleotide pairs in the DNA (Hillis 1987). Thus, molecular investigations can be particularly useful in detecting cryptic species and for recovering phylogenies of morphologically similar organisms. The second objective of the current study was, therefore, to confirm that the field identification of *Melomys* species based upon weight and tail measurements corresponded with that of the 'true' taxonomy assessed using DNA sequencing and phylogenetic reconstruction.

Materials and Methodology

Morphological Characteristics

Weight (g) and tail length (mm) measurements were taken on initial capture of each *Melomys* individual during field surveys, and then on recapture in any subsequent sampling event. Other possible measurements (listed in Table 3.1) were not taken. Watts and Aslin (1981) outlined the difficulties in obtaining 'other' measurements which '*in the case of living animals, generally requires two people and is subject to considerable inaccuracy, particularly in*

the case of the head and body measurement'. Individuals were weighed with a Pesola® (300g) scale and tail length was measured from the beginning of the mosaic tile pattern on the underside near the base of the tail to the tip using a 150mm stainless-steel ruler.

DNA Examination

Small ear-tissue samples (2 mm²) were taken from live and snap trapped *Melomys* species in the field, labelled and stored in 100% ethanol. DNA was extracted from 40 *Melomys* tissue samples using the salt-extraction methodology of Miller *et al.* (1988). Samples consisted of 20 field-identified *M. burtoni* and 20 field-identified *M. cervinipes* chosen from a total collection of 215 animals, and were stratified to ensure that all age classes from both sexes were represented. Laboratory analysis was outsourced and samples were analysed 'blind'. A fragment of the mitochondrial 16SrRNA gene of approximately 500 bp was amplified using primers (16Sar-L and 16Sbr-H) and polymerase chain reaction (PCR) conditions as outlined in Palumbi *et al.* (1991). PCR products were purified using a QIA-quick® PCR purification kit (Qiagen) and directly sequenced using ABI PRISM® Big Dye Terminators Version 3.1 Cycle Sequencing Kit on an ABI PRISM® 3700 DNA Analyser. Sequences were edited using BioEdit Version 5.0.9 (Hall 1999). A phylogenetic tree was constructed using the Neighbour-Joining methodology (Saitou and Nei 1987) and 1000 bootstrap pseudo-replicates in MEGA Version 2.1 (Kumar *et al.* 2001). *Rattus norvegicus* was included in the analysis as an outgroup (Genbank Accession number: NC_001665).

Results

Morphological Characteristics

Independent sample t-tests were used in data analysis. Individuals recaptured in separate sampling periods were treated as independent measures due to the opportunity for growth. Mean weight (Figure 3.3) and tail length (Figure 3.4) of *M. burtoni* and *M. cervinipes* for both sexes in each age class varied (Table 3.2).

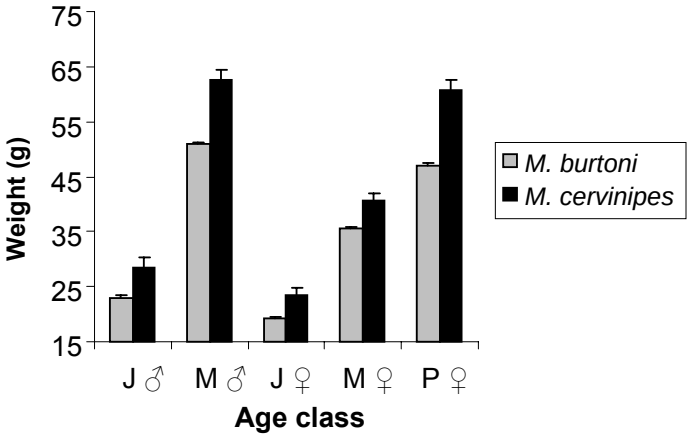

Figure 3.3: Mean (+SE) weight of the different age classes of *Melomys burtoni* (n=1695) and *Melomys cervinipes* (n=202). [J = Juvenile, M = Mature; P = Pregnant]

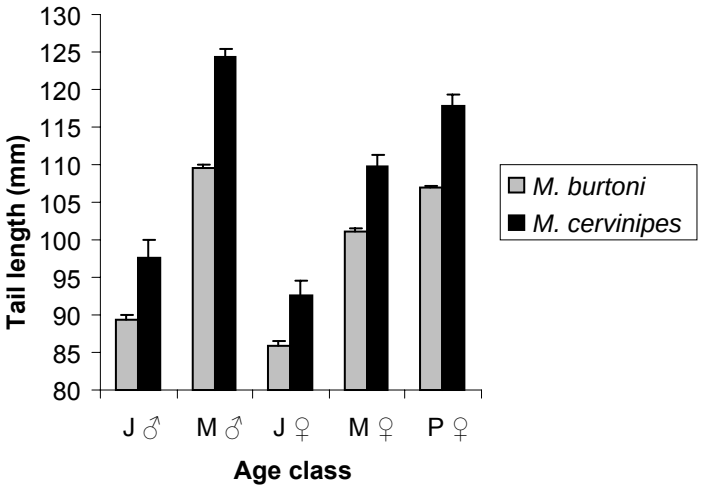

Figure 3.4: Mean (+SE) tail length of the different age classes of *Melomys burtoni* (n=1695) and *Melomys cervinipes* (n=202). [J = Juvenile, M = Mature and P = Pregnant]

Table 3.2: Weight and tail length ranges for *Melomys burtoni* and *Melomys cervinipes* of all age classes.

Age Class	*Melomys burtoni* measurement range (n)	*Melomys cervinipes* measurement range (n)	t value	df	p value
Juvenile ♂ weight	22.4 – 23.4 g (246)	26.7 – 30.3 g (34)	-4.014	278	p<0.001
Juvenile ♂ tail	88.8 – 90.0 mm (246)	95.1 – 100.0 mm (34)	-4.254	278	p<0.001
Mature ♂ weight	50.4 – 51.2 g (647)	60.6 – 64.6 g (65)	-8.293	710	p<0.001
Mature ♂ tail	109.4 – 109.9 mm (647)	123.1 – 125.4 mm (65)	-16.870	710	p<0.001
Juvenile ♀ weight	18.8 – 19.6 g (172)	22.1 – 24.8 g (22)	-3.691	192	p<0.001
Juvenile ♀ tail	85.3 – 86.4 mm (172)	90.5 – 94.7 mm (22)	-3.708	192	p<0.001
Mature ♀ weight	35.0 – 36.0 g (279)	39.5 – 41.0 g (44)	-4.003	321	p<0.001
Mature ♀ tail	100.6 – 101.5 mm (279)	108.5 – 111.2 mm (44)	-7.364	321	p<0.001
Pregnant ♀ weight	46.4 – 47.6 g (351)	58.9 – 62.6 g (37)	-8.625	386	p<0.001
Pregnant ♀ tail	106.6 – 107.2 mm (351)	116.1 – 119.4 mm (37)	-9.772	386	p<0.001

DNA Examination

Polymerase chain reaction (PCR) products were obtained for 39 of the 40 samples. The phylogenetic analysis clearly identified two clades (Figure 3.5). Blind samples within each clade always agreed with their field identification as either *M. burtoni* or *M. cervinipes*.

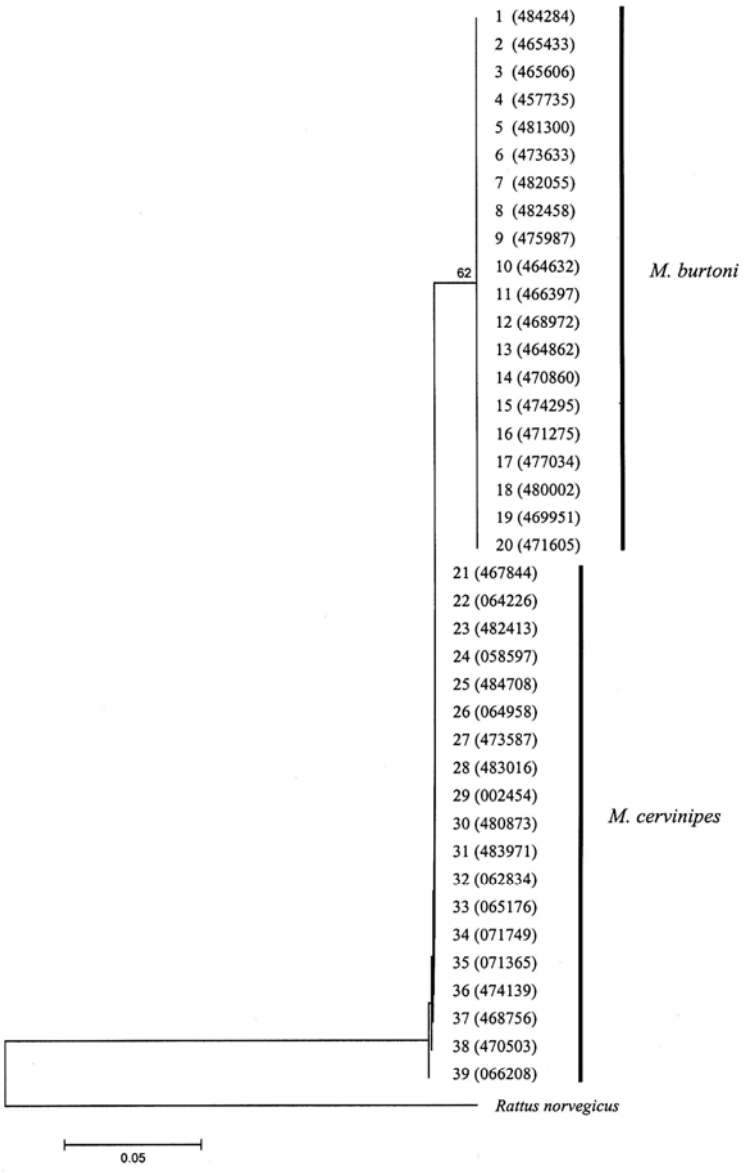

Figure 3.5: Neighbour-Joining Tree of 16S rRNA sequence data (1000 bootstraps) showing the two divergent clades corresponding to the field identified *Melomys burtoni* and *Melomys cervinipes*. Bracketed numbers correspond to the unique microchip number.

Discussion

As populations of *M. burtoni* and *M. cervinipes* within the sugarcane production area of north Queensland are sympatric and individuals of both species exhibit overlapping morphological characteristics, the first objective of this chapter was to ensure that field identification of *Melomys* species utilising the crop was accurate. As live specimens had to be retained in the field, it was important to determine whether morphological measurements taken in the field provided a diagnostic identification of species that corresponded with the 'true' taxonomy.

Results have shown that the morphological characteristics of weight and tail length used in field identification are different when comparing individual species of both sexes and across all age classes (Table 3.2). *Melomys cervinipes* of all age classes were heavier and had longer tails than *M. burtoni*. For example, a mature male *M. cervinipes* weighing 45g would in general have a longer tail than its *M. burtoni* counterpart of the same weight. This finding for the juvenile age class is important as it has long been accepted that distinction between *Melomys* species as juveniles is particularly difficult (Redhead 1973, Knox 1978, Watts & Aslin 1981). The combined characteristics of weight and tail length are simple enough for an animal biologist with field experience to use and have confidence in the identification of the *Melomys* species. Interestingly, while it is understandable that females of both species would have higher weights during pregnancy; it is unexplainable pregnant individuals of both species have longer tails than females that are not pregnant (Table 3.2). This cannot

be attributed to sample size differences, as sample sizes were approximately equivalent (non-pregnant (n=279) and pregnant (n=351) female *M. burtoni* and non-pregnant (n=44) and pregnant (n=37) female *M. cervinipes*).

DNA examination of tissue samples confirmed that field identification based upon weight and tail measurements corresponded to the 'true' taxonomy of both species. Therefore, the morphological identification of *Melomys* species in the field using weight and tail measurements results in a reliable method of distinguishing between species.

Chapter 4 – Species in Sugarcane

Introduction

Damage to sugarcane crops by pest rodents has been recorded since the inception of the industry in Queensland in the late 1800s. Research since then has focused largely on the ecology and impact of one pest species, *Rattus sordidus*, and its control using rodenticides and/or habitat manipulation (McDougall 1944a, b; 1946a, b; 1947; Hitchcock 1973; Hitchcock and Kerkwyk 1975, 1978; Redhead & Saunders 1980; Wilson and Whisson 1993, Whisson 1996). This focus on only one pest species is at odds with current industry perceptions, where industry members are advocating research and possible management options for *Melomys burtoni* and *M. cervinipes*.

The only extensive study of the biology of *M. burtoni* in sugarcane was conducted by Redhead (1973) in the Cairns/Babinda region of far northern Queensland. He investigated the reproduction and growth of *M. burtoni* in laboratory studies and also recorded changes in population density and composition of *M. burtoni* in the field within sugarcane and surrounding areas. He found that, in far north Queensland, population numbers of *M. burtoni* were equal to, if not greater than, those of *R. sordidus* after a steady population increase in the April/May period in fully developed sugarcane crops. It was inferred that this increase resulted from the recruitment of young individuals from surrounding areas.

With the exception of Redhead's study, no other work in sugarcane has dealt with the biology of *Melomys* species. It is thus unclear if Redhead's results for *M. burtoni* were typical or atypical, and there is no formal knowledge at all of how prevalent *M. cervinipes* may be within sugarcane crops. Given this situation, the first objective of this chapter is to identify which species of rodent are utilising the crop. Given that there is a tested and reliable method for distinguishing *M. burtoni* from *M. cervinipes* (previous chapter), we can be confident that the identification of *Melomys* species in the field corresponds with that of the 'true' taxonomy of each *Melomys* species. McDougall (1944b, see Table 1.1) also recorded a number of species other than the two target *Melomys* and *R. sordidus* in sugarcane, but this information is now over 60 years old and sugarcane management is now very different. As such, an updated list of other rodent and small mammal species found within the sugarcane crop is also warranted.

The second objective of the current study is to quantify the number of *Melomys* species within the crop and to determine the stage/s of crop development that favour any increase in population numbers of *Melomys* species. Similar information was essential to the successful development of an IPM program for *R. sordidus* (Wilson and Whisson 1993).

Methodology

Live and snap-trapping studies were carried out over eight sites within the sugarcane production area in far north Queensland (refer Chapter 2 (a) Capture-and-release study; and (b) Snap-trapping study). Trapping was

undertaken over a 15-month period covering more than one entire crop cycle. The number of all rodent species captured was recorded, but emphasis is centred on the presentation of data for *R. sordidus*, *M. burtoni* and *M. cervinipes*.

Results

Total captures

Over the duration of these studies, in 43600 trap nights from February 2005 to April 2006, 1792 *R. sordidus*, 1187 *M. burtoni* and 122 *M. cervinipes* were caught in sugarcane crops, representing 57.79%, 38.28% and 3.93% of the total capture rate for these species, respectively. *Rattus sordidus* was the dominant species captured in crop stages 1 – 4, representing 68.18%, 87.23%, 76.65% and 71.20% of total captures, respectively. *Melomys burtoni* occurred in relatively low proportions initially, but increased to 28.37% of the captures in crop stage 4 and was trapped equally to *R. sordidus* in crop stage 5. Catch rate for *M. cervinipes* remained below 10% in all crop stages, but, as for *M. burtoni*, was most trapped in crop stage 5 (Table 4.1).

Table 4.1: Proportion (and numbers) of each species captured in different crop stages.

Crop Stage	*R. sordidus*	*M. burtoni*	*M. cervinipes*	Totals
1	68.18% (15)	22.73% (5)	9.09% (2)	0.71% (22)
2	87.23% (198)	10.57% (24)	2.20% (5)	7.32% (227)
3	76.65% (174)	21.59% (49)	1.76% (4)	7.32% (227)
4	71.20% (497)	28.37% (198)	0.43% (3)	22.51% (698)
5	47.12% (908)	47.28% (911)	5.60% (108)	62.14% (1927)
Overall	57.79% (1792)	38.28% (1187)	3.93% (122)	100% (3101)

Captures within crop stage

Differences between population captures for each species within each crop stage were analysed by One-way-ANOVA, with a *post hoc* Tukey's test run when the ANOVA identified a significant difference. There was no significant difference among any species at crop stage 1 ($F=1.0$, $df=2$, $p=0.385$), where very few captures were made. There were differences among species captures in crop stage 2 ($F=4.883$, $df=2$, $p=0.017$) where the *post hoc* test identified that captures of *R. sordidus* were significantly greater than both *M. burtoni* and *M. cervinipes*, which did not differ from each other. In crop stage 3 ($F=3.803$, $df=2$, $p=0.035$), the *post hoc* test revealed that captures of *R. sordidus* were significantly higher from *M. cervinipes*, but not from *M. burtoni*, while the two *Melomys* species again, did not differ from each other. For crop stage 4, *R. sordidus* population numbers were significantly greater than *M. burtoni*, and *M. burtoni* numbers were significantly greater than *M. cervinipes* ($F=12.205$, $df=2$, $p<0.001$). In crop stage 5, there was no significant difference between numbers of *R. sordidus* and *M. burtoni*, while captures of both these species were significantly greater than those of *M. cervinipes* ($F=24.790$, $df=2$, $p<0.001$) (Figure 4.1).

Other captures

Incidental captures of other native species in the sugarcane crop were *Rattus fuscipes* (n=40), *Isoodon macrourus* (n=39), *Perameles nasuta* (n=11), *Sminthopsis virginiae* (n=6), *Uromys caudimaculatus* (n=3) and *Hydromys chrysogaster* (n=2). The introduced *Mus domesticus* was trapped in-field on 65 occasions.

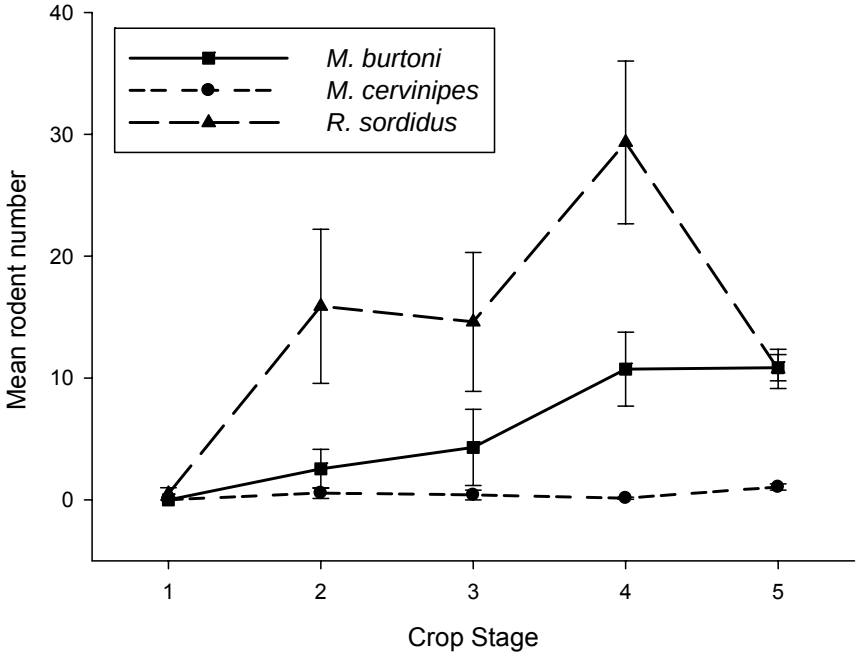

Figure 4.1: Mean (±SE) captures of *Melomys burtoni*, *Melomys cervinipes* and *Rattus sordidus* across all eight sampling sites, at each crop stage (1-5), corrected for sampling effort.

Discussion

The first objective of this chapter was to identify the species of rodents that utilise the sugarcane crop. The results outlined above confirm the finding of Wilson and Whisson (1993) that crop colonisation by *R. sordidus* occurs early within the development of the crop and continues to increase during crop development.

Numbers of *M. burtoni* remain relatively low for crop stages 1-3, but an increase in numbers occurs in crop stage 4 and remains relatively stable in crop stage 5 (Figure 4.1). Actual numbers of *M. burtoni* are much higher in crop stage 5 than in crop stage 4 (Table 4.1), however, trapping effort was much greater in crop stage 5 due to the length of time at this stage of crop

development (Table 2.2). This sampling bias is accounted for in Figure 4.1, so comparing the rate of catch between crop stages 4 and 5 is best judged from Figure 4.1, rather than comparing the absolute catches as shown in the Table 4.1. The vast majority of the earlier research into pest rodents in Queensland sugarcane had focused upon *R. sordidus*, but it is interesting to note that in the present study, *M. burtoni* population numbers are comparable to *R. sordidus* numbers in crop stage 5. This is comparable to the findings of Redhead (1973), who found *M. burtoni* population numbers to be equal to, if not greater than those of *R. sordidus* in sugarcane crops with a developed canopy.

At crop stage 5, movement through the field is restricted due to the high density of the sugarcane crop. It is therefore unreasonable to suggest that in-crop management techniques could be applied at this stage. Under current management strategies, growers may have, prior to crop stage 5, applied rodenticides in order to manage colonising *R. sordidus* populations. Growers do not, however, usually enter crops after canopy closure because of the physical difficulties. This poses a potential problem for the control of *M. burtoni* damage, as the application of rodenticides earlier than crop stage 4, in anticipation of damaging *Melomys* populations in crop stage 5, would be compromised due to poor bait longevity. This would only result in an economically unviable process to the cane grower.

Numbers of *M. cervinipes* remained low throughout all stages of crop development. A small increase in population size occurred within crop stage

5, however, overall numbers were not considered to be significant when compared with *M. burtoni* or *R. sordidus* population numbers. It would not be in the best interest of cane growers to consider management of *M. cervinipes* due to their very low population numbers and therefore, are not considered a pest of sugarcane. Other non-target species were present in the crop only in very low numbers (when compared with *M. burtoni* and *R. sordidus*) and this minimises the need to consider non-target bait mortality problems when managing the pest species.

Having identified that *M. burtoni* is the only *Melomys* species likely to be occurring in sugarcane in damaging numbers, this thesis will consider only *M. burtoni* in following chapters. Given the significant population size of *M. burtoni* in the field in crop stages 4 and 5, an investigation of the diet of *M. burtoni* is required to, firstly, confirm that this species is indeed responsible for causing damage to the sugarcane crop and, secondly, to identify whether non-cane vegetation levels within the diet of *M. burtoni* has any influence on population growth. This is addressed in the next chapter – 'Diet and Damage'.

Chapter 5 – Diet and Damage

Introduction

After having identified high population numbers of *M. burtoni* within sugarcane crop stages 4 and 5 (Chapter 4), it is important to investigate the diet of these animals. Specifically, are they feeding exclusively or predominantly on sugarcane, are they simply sheltering in the crop and feeding on non-cane vegetation, or is a combination of both happening?

Few specific studies on the diet of *M. burtoni* have been undertaken. An incidental study on the stomach content of 12 *M. burtoni* captured in open woodland, found their diet to consist mainly of grass vegetation and the testa and endosperm of dicot seeds (Watts 1977). The stomach contents of 213 *M. burtoni* captured in and around cane fields were examined by Woods (1966) and the diet was found to consist mainly of grass shoots (30.9%), grass seed (8.3%), cane fibre (9.7%), miscellaneous vegetation (41.8%), and small proportions of other seed, insects, hair, fruit and fungi. Based on this latter study, at least, there may be reason to suspect that the simple presence *of M. burtoni* is not sufficient evidence to regard them as important cane pests.

Wilson and Whisson (1993) analysed the stomach contents of *R. sordidus* and found that sugarcane, seed and non-cane vegetation were the major components (≥50%) of stomach content. Sugarcane was utilised as a food source throughout the year, but there was an increase in non-cane vegetation and seed within the diet over the December – April period, which

corresponded with the period that summer grasses were available in sugarcane crops. This availability of summer grass coincided with the breeding period for *R. sordidus* and it was inferred that summer grass provided the high level of nutrition required for breeding. A decrease in the breeding intensity of *R. sordidus* then occurred with the decline in the availability (and possibly nutritional quality) of summer grass, resulting in a distinct switch to sugarcane as a food source. In their study, over 60% of mature *R. sordidus* in the Herbert River district, and approximately 50% of *R. sordidus* in the Mackay district contained ≥50% of sugarcane in their stomach contents.

Given these findings for *R. sordidus*, it is necessary to put Woods' (1966) study into a temporal context. Was the low amount of cane fibre in the stomachs of *M. burtoni* sampled in his study due to a true non-preference for cane, or was it simply that preferred food sources were more available or that a diet switch was made based on the breeding cycle?

A very strong association between weed cover in-crop and *R. sordidus* damage has been identified previously. Wilson and Whisson (1993) found that rodent damage was highest in sugarcane crops with prominent weed cover and lowest in crops with minimal weed cover. In their study, they examined the difference between a site sprayed with herbicide and a site not treated with herbicide application. Both sites had similar *R. sordidus* population levels prior to the herbicide treatment, but there was a reduction in the utilisation of the weeded site by *R. sordidus* immediately after herbicide

application and this continued for the duration of the study. The lower *R. sordidus* numbers corresponded with a reduction in damage to sugarcane at harvest, where an average of 9.1% of stalks was damaged in the untreated site, compared with only 3.5% in the herbicide-treated site. This equates to a decline in damage of approximately 60%.

Further to direct weed management (i.e. by herbicide application), Whisson (1996) found a >75% reduction in weed cover when green-cane trash blanketing (GCTB) was used instead of the conventional practice of burning sugarcane prior to harvest. In GCTB crops, the sugarcane is cut green (i.e. not burnt before harvest) and the cane trash (live and dead leaf material) is left as mulch in the field. This, amongst other agricultural benefits, suppresses weed growth. Despite the major reduction in weed cover, *R. sordidus* stomach contents over time were found by Whisson (1996) to be similar to those reported by Wilson and Whisson (1993), i.e. an increase in non-cane vegetation and seed within the diet over the December – April period (the rodent's breeding period), with a distinct switch to a sugarcane dominant diet following this period. Although no significant difference in the diet of individuals (either GCTB or conventional) was found, much greater breeding of *R. sordidus* did occur in conventional crops, where 45.2% (of 104) of captured mature females were pregnant, compared with only 9.2% (of 76) of females in GCTB crops. Overall, Whisson's study observed *R. sordidus* population levels to be significantly lower in the relatively weed free GCTB crops than in conventional crops.

Given this strong link between in-crop weeds, *R. sordidus* diet, and cane damage, it is critical to gain a similar understanding of the relationship among weeds, damage and diet for *M. burtoni*. Thus, the first objective of this chapter is to determine whether *M. burtoni* utilises cane-fibre in its diet, thereby confirming if this species is responsible for damage to sugarcane. The second objective of this chapter is to determine the relationships among the weed-score, the damage-score and *M. burtoni* population levels.

Methodology

Snap trapping was carried out over eight sites within the sugarcane production area of far north Queensland (refer Chapter 2 (b) Snap-trapping study). Dissections were performed on all *M. burtoni* captures to assess stomach content. A visual estimation of the volume percentage of sugarcane, weed and grass seed, non-cane vegetation and other (unidentified) material of the total stomach content to the nearest 10% was recorded for each capture.

Weed biomass was harvested from 25 randomly chosen, non-cane vegetation quadrats (0.25 m^2) per site on every sampling event over the duration of the study. In addition to wet weight of biomass (g), a weed-score and dominant weed species were recorded for each quadrat. Refer to Chapter 2, section (c) 'Weed-biomass study', for further details.

Sugarcane stalks were counted at each sampling period where harvestable stalk was present (refer Chapter 2 (d) 'Damaged-stalks study'), and

inspected thoroughly for rodent damage. As discussed in Chapter 2, the conservative approach was taken that only rodent damage at heights greater than 50 cm up the stalk was attributed to *M. burtoni*. The number of damaged stalks per total number of stalks was recorded and converted to a percentage (damage score).

Results

Number of Individuals Sampled

During this study, 183 *M. burtoni* (male = 107, female = 76) were dissected and stomach contents assessed for diet. The proportion of *M. burtoni* captured in snap trapping was very similar to the proportions found in live trapping (Chapter 4). Nearly all individuals were caught in either crop stage 4 or 5 (Table 5.1).

Table 5.1: Number and proportion of *Melomys burtoni* dissected and assessed for stomach content in each sugarcane crop stage (1-5).

Crop Stage	*M. burtoni* ♂	*M. burtoni* ♀	Combined Proportion
1	0	3	2.7% (n=3)
2	1	0	0.5% (n=1)
3	4	2	3.2% (n=6)
4	20	16	19.4% (n=36)
5	82	55	74.2% (n=137)
Overall	58.5% (n=107)	41.5% (n=76)	100% (n=183)

Diet

Due to extremely low capture rates in crop stages 1-3, only individuals collected in crop stages 4 and 5 were statistically analysed for stomach

content. For the 10 individuals caught in crop stages 1-3, their stomach contents included proportions of predominantly cane-fibre and seed, with one animal having consumed only non-cane vegetation (100%). *Melomys burtoni* with cane-fibre present in their stomach in crop stages 1-3 may have moved from a nearby standing sugarcane crop, been forced from a crop under harvest, or may have consumed sugarcane while it was less than 50 cm in height (i.e. harvestable stalk was present but excluded from damage assessments due to its lack of height).

Mean stomach-content percentages for crop stages 4 and 5 were, respectively: 66 and 56% for seed, 21 and 37% for cane-fibre, and 13 and 6% for vegetation. There were differences among the percentages of different stomach contents within crop stage 4 ($F=37.085$, $df=3$, $p<0.001$), with a *post hoc* Tukey test identifying that the percentages of seed were significantly different from sugarcane, vegetation and 'other' (i.e. un-identified) material and while the quantity of sugarcane was significantly different to 'other' material, it was not significantly different to the quantity of vegetation (Figure 5.1).

In crop stage 5, there was again found to be differences among the percentages of different stomach contents ($F=108.5$, $df=3$, $p<0.001$). The *post hoc* Tukey test identified that again seed was found in greater amounts to sugarcane, vegetation and 'other' material. There was an increase in sugarcane use in this crop stage, and cane-fibre was found in greater

amounts to vegetation and 'other' material. There was no significant difference found between vegetation and 'other' material (Figure 5.2).

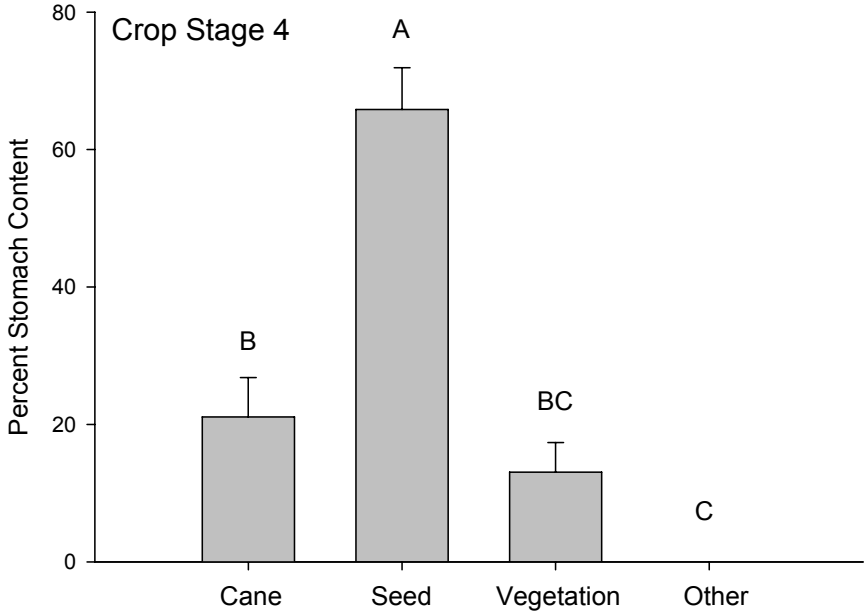

Figure 5.1: Mean (±SE) stomach content type in *Melomys burtoni* within crop stage 4. Columns headed by the same letter are not significantly different at p=0.05.

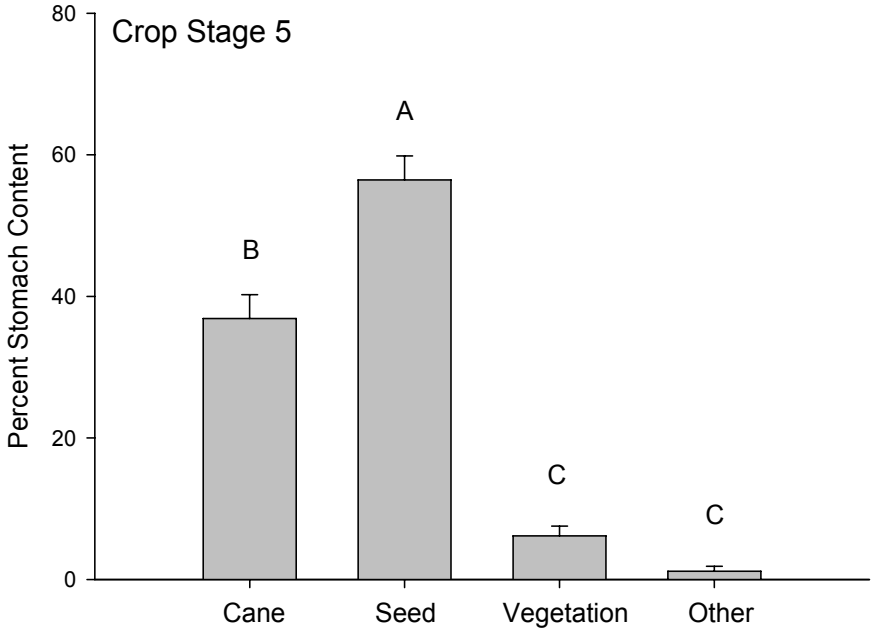

Figure 5.2: Mean (±SE) stomach content type in *Melomys burtoni* within crop stage 5. Columns headed by the same letter are not significantly different at p=0.05.

A Kruskal Wallis test was applied to examine the variation in the percentage of sugarcane and seed in stomach contents among *M. burtoni* age classes. There was no significant difference among age classes found for sugarcane (χ^2 =6.92, df=4, p=0.140) or seed content (χ^2 =8.46, df=4, p=0.076) (Table 5.2).

Table 5.2: Mean (±SE) proportion of cane and seed in *Melomys burtoni* according to age class.

Age Class	Ave % Cane ± SE	Ave % Seed ± SE
Juvenile Male	20 ± 8	74 ± 7
Adult Male	42 ± 4	48 ± 4
Juvenile Female	30 ± 13	62 ± 13
Adult Female	30 ± 8	57 ± 8
Pregnant	30 ± 5	63 ± 5

Sugarcane Damage

No harvestable sugarcane stalk >50 cm in height was available in crop stages 1 – 3, so no damage was recorded in these stages – only crop stages 4 and 5 are analysed. Damage attributable to *M. burtoni* became evident in crop stage 4 once harvestable stalk was present (0.4% of 35999 stalks), but increased in crop stage 5 (5.6% of 220,208 stalks). A Chi-square contingency test confirmed a difference in the proportion of damaged sugarcane stalk between crop stages 4 and 5 (χ^2 =1716, df=1, p<0.001).

Weed levels, cane damage and rodent numbers

A very weak, but positive linear relationship was found between the weed-score and the damage-score (r^2=0.060, p=0.024) (Figure 5.3). Similarly, there was a weak, but positive linear relationship between the weed-score and population numbers of *M. burtoni* (r^2=0.052, p=0.037) (Figure 5.4).

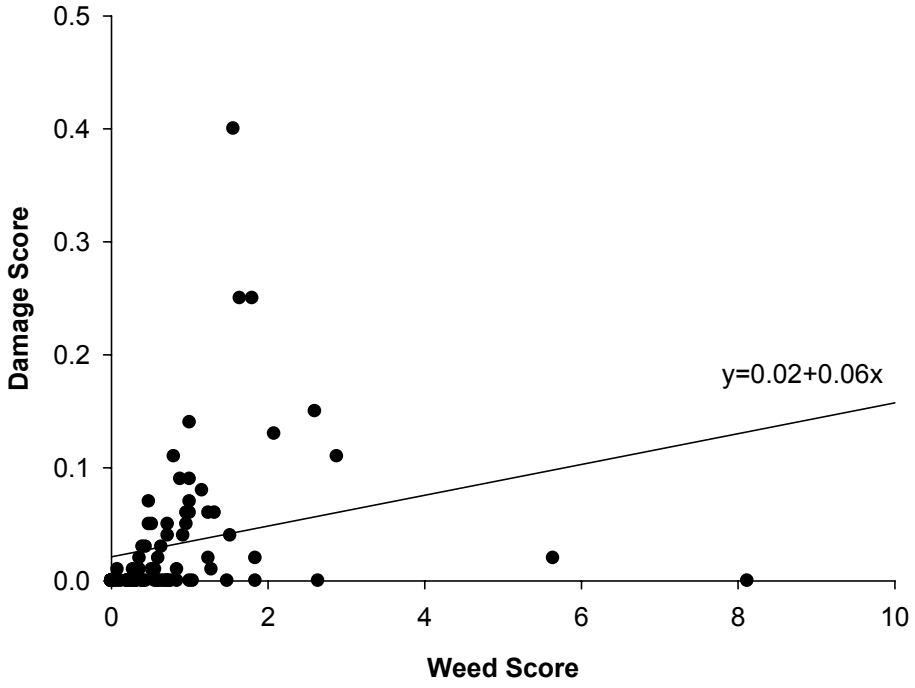

Figure 5.3: Relationship between weed-score and *Melomys burtoni* damage-score for sugarcane.

Not unexpectedly, there was also a significant, positive linear relationship (r^2=0.18, p<0.001) between the damage-score and *M. burtoni* population numbers (Figure 5.5). The regression was still positive (r^2=0.11, p=0.002) when a potentially outlying data point with high-leverage was removed from the analysis.

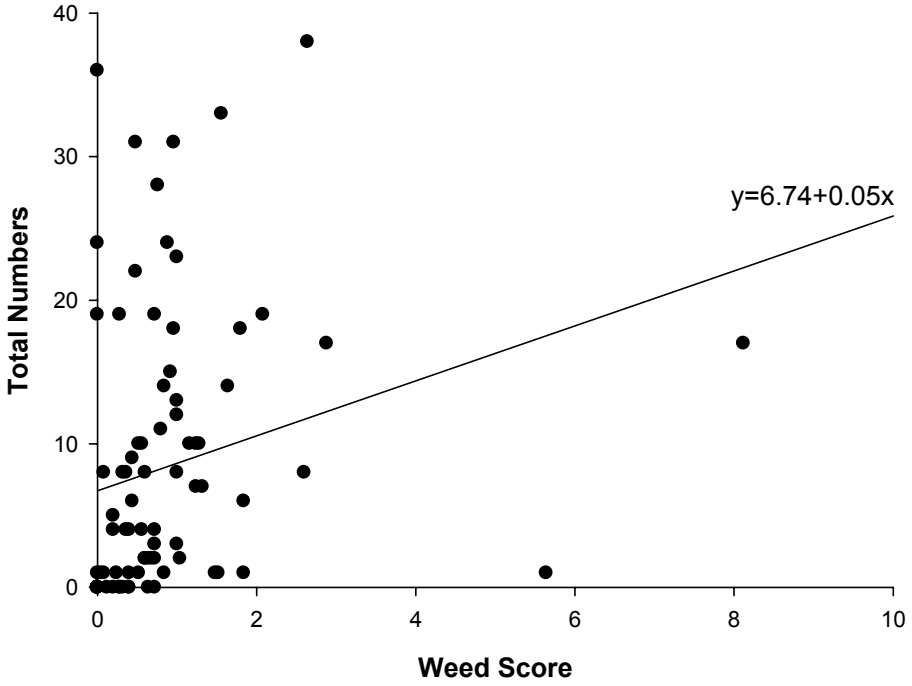

Figure 5.4: Relationship between weed-score and *Melomys burtoni* population numbers.

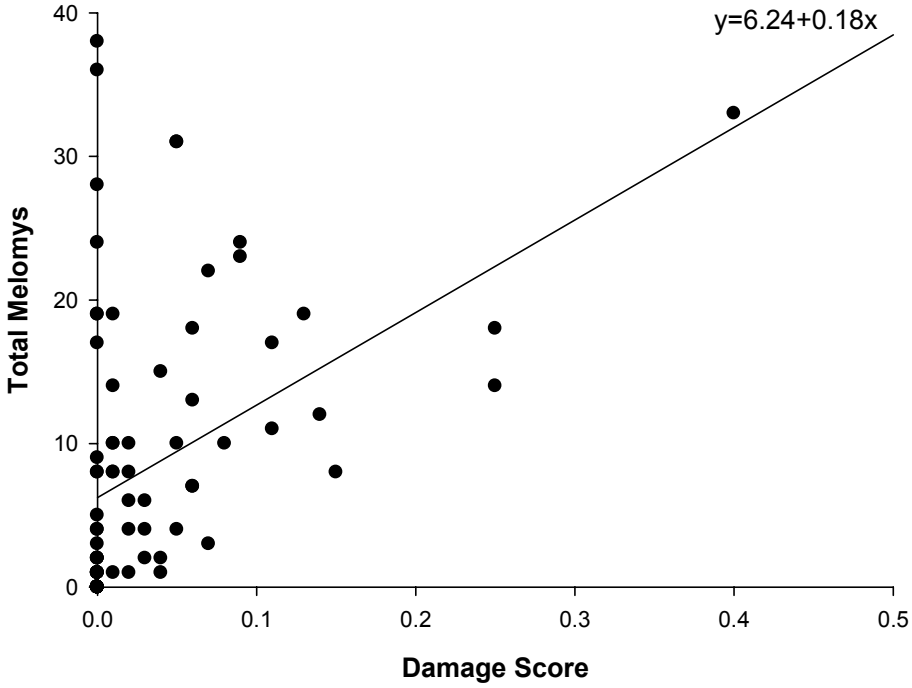

Figure 5.5: Relationship between sugarcane damage-score attributed to *Melomys burtoni* and *M. burtoni* population size.

Discussion

The first objective of this chapter was to determine whether *M. burtoni* utilises sugarcane in its diet, thereby proving that *M. burtoni* is responsible for damage to sugarcane crops. Cane fibre was present in *M. burtoni* stomach contents, at levels of approximately 21% of content in crop stage 4 (Figure 5.1), and this increased to approximately 37% in crop stage 5 (Figure 5.2). This is in contrast to the findings of Woods (1966) study where only 9.7% of cane-fibre was found in the stomach contents of *M. burtoni*. Interestingly, the greater quantities of cane-fibre found in the stomach contents of *M. burtoni* the present study are less than the percentages noted by Wilson and Whisson (1993) for mature *R. sordidus*. The level of the cane-fibre content in the stomachs of *M. burtoni* was relatively constant across all age classes (Table 5.2). This data confirms that sugarcane damage may be attributed to this species. In this study damage was very minor in crop stage 4, but 5.6% of cane was damaged in crop stage 5. This is lower than the 9% of *R. sordidus* damage described by Wilson and Whisson (1993).

The second objective of this chapter was to determine the relationships among weed-score, damage-score and *M. burtoni* population size. Wilson and Whisson (1993) and Whisson (1996) found strong relationships between the quantity of weed biomass in-crop and the level of *R. sordidus* damage, where crops with prominent weed cover had the highest damage levels. It was shown in both of these studies that the removal of in-crop weed biomass was critical in the management of *R. sordidus* by decreasing the breeding potential of *R. sordidus* populations.

The results of this chapter show that there is a relationship between increasing *M. burtoni* damage levels and the weed-score (Figure 5.3). The regression, however, explains only 6% of the variation in the dataset and, therefore, has low predictive ability. A positive regression between increasing *M. burtoni* numbers and weed-score also explains only 5% of the variation in the data and must be considered a weak relationship (Figure 5.4). The strongest relationship was found between the increasing damage-score and increasing *M. burtoni* population numbers (Figure 5.5), but such a relationship should be expected as the higher the number of individuals there are within a population the more feeding by that population you would expect. What is perhaps unusual is that the link between increasing *M. burtoni* numbers and increasing crop damage is not tighter.

The generally weak relationships between the weed-score and the damage-score and *M. burtoni* population numbers is in contrast to results for *R. sordidus*. While in-crop weeds provide the nutritional requirements needed for breeding in *R. sordidus*, it cannot be inferred that this is the case for *M. burtoni*. *Melomys burtoni* is a grassland animal and its natural diet has been found to include grass shoots and grass and weed seed (Woods 1966; Watts 1977). An increase in weed biomass in-crop could initially provide the preferred food type of *M. burtoni*, or extra cover, which is possibly a resource requirement for *M. burtoni*. This may prompt *M. burtoni* populations to colonise sugarcane crops by providing an alternative and extended habitat, rather than being what actually stimulates increased breeding from a few early colonists within the crop. Perhaps the level of damage in crop stage 5

is due to an increase in *M. burtoni* population numbers, and because of the length of time that the crop remains at crop stage 5, a reduction in the availability of in-crop weeds (competition for the preferred food type) may result, leading to the substitution of weed seed and vegetation with sugarcane in the diet of *M. burtoni*.

The data from this chapter suggests that in-crop weed control may still be of benefit in a *M. burtoni* management strategy. In-crop weed control may not be required to minimise the potential for breeding of *M. burtoni* as it does for *R. sordidus*, but perhaps it can reduce the potential of *M. burtoni* to colonise the crop, resulting in part of an effective management strategy. If in-crop management of *M. burtoni* by weed manipulation or baiting is to be initiated, it will be necessary to determine the population dynamics and demography of *M. burtoni* within sugarcane. This is covered in Chapter 6 – 'Population Dynamics'.

Chapter 6 – Population Dynamics

Introduction

In the previous chapter, the diet of *Melomys burtoni* was found to include grass and weed seed, sugarcane, small amounts of non-cane vegetation (grass and weed biomass) and un-identified material. The cane-fibre was found at mean percentage stomach content levels of 21% (crop stage 4) and 37% (crop stage 5), thereby confirming that *M. burtoni* is responsible for damage to sugarcane crops. In order to reduce damage levels to sugarcane, it is necessary to understand the population dynamics of *M. burtoni* within the crop, as this will provide an indication on when and how management of this species can best be achieved.

Rodents can thrive within agricultural crops and typically demonstrate annual variations in density and breeding effort and, occasionally, very high densities occur and are maintained for considerable time. Rodent management is often either inadequate, in that populations recover quickly, or poorly timed and applied after damage has occurred. Demographic characteristics such as the sex and age structure within rodent populations can help forecast the potential for population increases and subsequent damage, and can indicate the most effective times to apply control measures (Ramsey and Wilson 2000; Stenseth *et al*. 2003).

For example, past rodent pest management in Queensland sugarcane crops centred on the application of rodenticide in response to an increase in crop damage that occurred at the end of the breeding season of *R. sordidus*

(Wilson and Whisson 1993; Story 1995; Smith *et al*. 2003). This may temporarily control high numbers of *R. sordidus*, but it cannot manage the damage that has already occurred. Wilson and Whisson (1993) (outlined in Chapter 5 – Diet and Damage) developed an understanding of the ecology and population dynamics of *R. sordidus* in the sugarcane production system. From this, the importance was placed on weed management within the crop in the early stage of the breeding season for *R. sordidus*. A reduction in weed biomass resulted in a reduction in the breeding potential and, therefore, minimised the potential density of *R. sordidus* populations, minimising the level crop damage and reducing the reliance on rodenticide.

In contrast to a single, distinct breeding period within a crop, Tobin *et al*. (1994) found that in Hawaiian macadamia orchards, *R. rattus* reproduced throughout the year and caused considerable crop damage. This was because there was a prolonged flowering season resulting in the continuous availability of macadamia nuts. If this was the case for *M. burtoni*, control measures based on baiting may be required on a continual basis to keep crop damage at acceptable levels.

Melomys burtoni have been studied in their natural habitats in the Cooloola region of SE Queensland by Smith (1985), at Cobourg Peninsula, Northern Territory by Begg *et al*. (1983), and in the Kimberly region of Western Australia by Kemper *et al*. (1987). All studies found *M. burtoni* to breed throughout the year but with a marked decline in reproduction in mid-winter. Begg *et al*. (1983) noted that the highest proportion of pregnant *M. burtoni*

occurred during the wet season (December-March), and this was followed by a peak of juveniles entering the population. Kemper *et al*. (1987) found no statistical disparity in overall sex ratio, but there was bias toward females in April, while Smith (1985) and Begg *et al*. (1983) observed a male-biased sex ratio, the latter on 76% of the sampling occasions. Snap-trapped *M. burtoni* were investigated by Kemper *et al*. (1987) revealing a mean litter size of 2.4 ± 0.05 (range 2-3, n=25).

In sugarcane, Gard (1935) found that *M. burtoni* did not breed in a dry January and February, but recorded 87.5% of pregnancies (105 of 120 *M. burtoni*) following the commencement of sustained wet conditions. Gard also observed litter sizes to be less than that of *R. sordidus*, with a maximum of 4 pups and an average of 2.5 pups. McDougall (1946a) observed in incidental studies (in 1936) of *M. burtoni* in the Mackay district, that the species bred mainly in Autumn (March, April, May) with between 33 and 50% of captured individuals pregnant, with an overall average litter size of 2.9. In contrast, the same author found 39% of female *M. burtoni* in the Herbert River district and 45% of female *M. burtoni* in districts north of the Herbert River pregnant in September (1939) with an average litter size of 2.1 and 2.0 respectively. The highest proportion of pregnant *M. burtoni* in the Cairns-Babinda district was found in April and May coinciding with an increase in juveniles in the population (Redhead 1973). Redhead also noted that in this period a large proportion of young male *M. burtoni* were captured for the first time, with the sex ratio increasing from 30% male in March to 75% male in June.

Past research on the breeding patterns of *M. burtoni* in sugarcane crops has been mainly incidental (Gard 1935; McDougall 1946a; Redhead 1973). Given that *Melomys burtoni* are in significant population numbers in sugarcane in crop stages 4 and 5, and stomach content analysis confirms *M. burtoni* utilises cane-fibre in its diet, further detailed study of its phenology is warranted. Thus, the objective of this chapter is to determine the population dynamics and demographics of *M. burtoni* in sugarcane crops.

Methodology

Live trapping studies were carried out using Elliott Type 'A' folding mammal traps (refer Chapter 2 (a) Capture-and-release study). Each individual *M. burtoni* trapped for the first time was permanently marked by injecting a uniquely numbered 4D-ISO microchip (2x12 mm). The capture location, recapture status, sex, and reproductive condition were recorded for the initial capture of each *M. burtoni* in any sampling period. Following Wilson (1994), reproductive condition was assessed as:

- Males: - Testes abdominal (no scrotal sac) – immature
  - Testes scrotal (scrotal sac present) – mature
- Females - Vagina imperforate – immature
  - Vagina perforate – mature
  - Pregnant (by palpation).

Snap-trapping studies were undertaken using Supreme snap traps (refer Chapter 2 (b) Snap-trapping study). Dissections were undertaken in the field on all female *M. burtoni* captured to assess reproductive condition and litter size per pregnant female.

Results

Overall abundance

From 19,487 live trap nights, there were 996 captures of *M. burtoni*. Of these captures, 611 were initial captures within any sampling period (where individual details were recorded) and 385 were re-captures within any one sampling period and therefore released at point of capture with no further details recorded (Table 6.1). The overall proportion of traps filled in any sampling period averaged 4.6%, resulting in a high number of traps being available to *M. burtoni*. This indicates that the number of traps was not limiting the catch. Due to low capture rates of *M. burtoni* within crop stages 1-3, these sampling periods were pooled for subsequent analysis and discussion.

Table 6.1: Initial captures of *Melomys burtoni* in each sugarcane crop stage (1-5) where individual capture, sex, morphological characteristics and reproductive condition were recorded with the capture-and-release study.

Crop Stage	Juvenile ♂	Mature ♂	Juvenile ♀	Mature ♀	Total
1 - 3	2	22	3	7	34
4	5	52	10	19	86
5	95	175	50	171	491
Total	102	249	63	197	611

Breeding

The proportion of female *M. burtoni* pregnant varied across all crop stages (χ^2=7.059, df=2, p=0.029). Breeding was low in crop stages 1-3, but increased in crop stage 4, and again in crop stage 5 (Table 6.2).

Table 6.2: The proportion and number of pregnant and non-pregnant female *Melomys burtoni* across all crop stages (1-5) within the capture-and-release study.

Crop Stage	Proportion Pregnant ♀	Proportion Non pregnant ♀	Total (n)
1 to 3	0.29	0.71	7
4	0.42	0.58	19
5	0.65	0.35	171

Average Litter Size

Only one pregnant female was captured within the snap-trapping study. Mean litter sizes are shown for crop stages 4 (range 2-5, n=9) and 5 (range 1-3, n=26) (Table 6.3). The maximum litter size identified was five pups and was only encountered in one female in crop stage 4. Overall, 15 females were found to be carrying three pups, 19 were carrying two pups, and one female was carrying one pup. There was one incidental observation in crop stage 5 (within the capture-and-release study) of a female *M. burtoni* with two pups captured in an Elliott Type 'A' trap.

Table 6.3: Number of pregnant *Melomys burtoni* and mean (±SE) litter size across all sugarcane crop stages (1-5) within the snap-trapping study.

Crop Stage	Number Pregnant ♀	Mean (±SE) Litter Size
1 to 3	1	2
4	9	2.6 ± 0.3
5	26	2.5 ± 0.1

Sex Ratio

The proportion of adult (mature) male and female *M. burtoni* varied across the different crop stages (χ^2=17.315, df=2, p<0.001). The population was typified by a high proportion of males in crop stages 1-3 and crop stage 4, but with parity attained in crop stage 5 when the proportion of mature female *M. burtoni* increased (Table 6.4).

Table 6.4: Proportion and number of mature male and female *Melomys burtoni* across all sugarcane crop stages (1-5) within the capture-and-release study.

Crop Stage	Proportion ♀'s	Proportion ♂'s	Total (n)
1 to 3	0.24	0.76	29
4	0.27	0.73	71
5	0.49	0.51	346

Juvenile Recruitment

The proportion of *M. burtoni* juveniles varied across crop stages 1-5 (χ^2=8.189, df=2, p=0.017). The number of juveniles in the trappable population was stable at approximately 16% in crop stages 1-3 and crop

stage 4, prior to the peak in crop stage 5 when they comprised 30% of the total population (Table 6.5).

Table 6.5: Proportion and number of juvenile and mature *Melomys burtoni* across all sugarcane crop stages (1-5) within the capture-and-release study.

Crop Stage	Proportion juveniles	Proportion adults	Total (n)
1 to 3	0.15	0.85	34
4	0.17	0.83	86
5	0.30	0.70	491

Discussion

The objective of this chapter was to determine the population dynamics and demographics of *M. burtoni* within sugarcane crops. An understanding of population characteristics and changes in population structure over the development of the crop can indicate the most effective period/s for developing management options for pest species. An understanding of the demographic characteristics of *R. sordidus* populations in sugarcane enabled Wilson and Whisson (1993) to develop an integrated pest management strategy by identifying critical stages in the life cycle of *R. sordidus* when management options were best achieved.

The results of this and previous chapters show that population numbers of *M. burtoni* are low in crop stages 1-3, but increase in crop stage 4 and remain stable at that higher level in crop stage 5. The harvest of sugarcane crops in Queensland is staggered over 5-6 months, so that the age and size of crops

can vary both at the farm and district level. These studies were initiated at all eight sites when the crop was fully developed with a closed canopy (February 2005). Harvest of sugarcane crops began in July and all sites were harvested by December 2005. Data collection continued through the harvest period and then through all stages of crop development until canopy closure was again reached. Crop stage 5 is generally the longest stage in the development of sugarcane crops, and in this study, all crops were at crop stage 5 in February 2005, through to around September, and then again from March and April 2006 (see Table 2.2).

Melomys burtoni were found to breed all year round in sugarcane, but, the proportion of *M. burtoni* breeding varied significantly across all crop stages. The highest proportion of pregnant females was in crop stage 5 (65%) and the lowest in crop stages 1-3 (29%) (Table 6.2). This generally agrees with the findings of Redhead (1973), and the incidental observations of Gard (1935) and McDougall (1946a), the only exception being McDougall's findings where approximately 40% of *M. burtoni* in, and north of, the Herbert River district were pregnant in September. This exception, however, may be the result of an extended breeding period due to favourable environmental conditions, such as a warmer than average winter. In non-cane habitats, *M. burtoni* have been found to breed throughout the year with a marked decline in the cooler months of winter (Begg *et al*. 1983; Smith 1985; Kemper *et al*. 1987). This is also in agreement with the findings of this study, but coincidentally this corresponds with the beginning of the annual harvest.

The recorded overall mean litter size of 2.5 ± 0.1 corresponds with the average litter sizes observed by Gard (1935), McDougall (1946a) and Kemper *et al*. (1987). This litter size is significantly less than that of *R. sordidus*, which has an average litter size of 6-7 pups (Gard 1935; McDougall 1946a). This demonstrates that *M. burtoni* are far less fecund than *R. sordidus*. It is interesting to note, however, that *M. burtoni* populations reach comparable numbers to *R. sordidus* in crop stage 5 (see Figure 4.1). Perhaps the high population numbers of *M. burtoni* in crop stages 4 and 5 result from immigration into the crop from adjacent habitat.

There was a significant variation in sex ratio of *M. burtoni* in sugarcane across the different crop stages, with a male bias in crop stages 1-3 and 4, but with an even sex ratio in crop stage 5 (Table 6.4). This is in stark contrast to the findings of Redhead (1973) where the sex ratio of *M. burtoni* increased from 30% male in March to 75% in June. In their natural habitat, Kemper *et al*. (1987) found no statistical disparity in overall sex ratio for *M. burtoni*, except in April where there was a bias toward females, coinciding with the last reproductive period prior to a decline in breeding in the cooler months of winter. Juveniles were found within the population in all crop stages, peaking at 30% of the total population in crop stage 5. The higher proportion of juveniles in crop stage 5 should be expected as this is the stage in the development of the crop where there is the highest proportion of mature, pregnant female *M. burtoni*.

In examining the population dynamics of *M. burtoni* within sugarcane crops, changes in the demographics of the population throughout the developing crop have been identified. The results of this chapter suggest that crop stage 5 is the most preferred stage in the development of the crop for *M. burtoni* reproduction. This information, coupled with the results of Chapter 4 – 'Species in Sugarcane' and Chapter 5 – 'Diet and Damage', have important implications for the management of *M. burtoni* populations in sugarcane crops. Numbers of *M. burtoni* build in crop stage 4, but it is crop stage 5 where females enter the population in greater proportions, the highest proportion of reproduction occurs and the greater proportion of juveniles enter the population. It is also crop stage 5 where significant levels of damage result from *M. burtoni* populations. Management efforts would most certainly need to be in place prior to crop stage 5. These are examined in more detail in Chapter 7 – 'Discussion and Management Implications'.

Chapter 7 – Discussion and Management Implications

Thesis summary

Integrated pest management of *R. sordidus* in Queensland sugarcane crops is effective, but may not be effective for other rodent species inhabiting the crop. *Melomys burtoni* and *M. cervinipes* are locally abundant in the northern regions of Queensland, both species have been found within sugarcane crops, and both are potentially damaging to sugarcane crops. Research into the control of *Melomys* species in sugarcane crops has been limited and there is no specific strategy for managing these species if such management is required.

Given limited knowledge on the biology and pest status of *Melomys* species within the sugarcane production system, the aims of this study were to: (i) identify and develop diagnostics for the *Melomys* species occurring within sugarcane; (ii) determine the extent to which the crop is utilised by *Melomys* and understand the damage process; and (iii) examine the population dynamics of *Melomys* to determine the population structure in the different stages of crop development. All such information is required for the development of sustainable management options.

Melomys burtoni and *M. cervinipes* have overlapping geographic ranges and share many morphological traits, making them difficult to distinguish in the field. My studies have shown that the measurements of weight and tail length of *Melomys* species provide an accurate identification in the field,

corresponding with the ‘true’ taxonomy of each species. This was confirmed by DNA examination.

Having demonstrated that my field identifications were accurate I could, with confidence, monitor the population dynamics of each species in sugarcane. Numbers of *M. burtoni* were found to be minimal in crop stages 1-3, but increased significantly in crop stage 4 and remained stable in crop stage 5. Numbers of *M. cervinipes* remained very low throughout crop development, and although a slight increase in numbers occurs in crop stage 5, the pest status of this species is considered insignificant. As identified in previous studies (Wilson and Whisson 1993; Whisson 1996), *R. sordidus* were observed to colonise sugarcane crops early in the development of the crop. It is important to note that numbers of *M. burtoni* within crop stage 5 are comparable to those of *R. sordidus*. Other species were present in the crop only in extremely low numbers.

An analysis of the diet of *M. burtoni* revealed that cane-fibre was present in the stomach contents at levels of approximately 21% and 37% in crop stages 4 and 5, respectively, and was relatively constant across all rodent age classes. Seed was the major component in stomach contents, accounting for approximately 60% of the diet. Cane stalk damage was very low in crop stage 4, but was 5.6% in crop stage 5, which is less than the 9% reported by Wilson and Whisson (1993) for *R. sordidus*. Nevertheless, with the average price of sugarcane for the grower valued at AU$25/t, and approximately 100 t/ha typically grown in the Tully district, and assuming *M. burtoni* as an edge

dweller may damage 25% of the crop, damage levels of 5.6% could equate to a potential AU$35/ha loss. Positive, but generally weak relationships were found between levels of weed in-crop and *M. burtoni* damage and population numbers. The strongest relationship was found between increasing damage levels and the increase in *M. burtoni* numbers.

The majority of overall *M. burtoni* captures occurred in crop stage 4 (14%) and crop stage 5 (80%). The greater percentage of captures in crop stage 5 was due to the greater period of time in which the crop is at this stage (ie closed canopy). Catch rate per unit effort was the same between crop stages 4 and 5. Breeding occurred all year round, but varied significantly over crop stage. The highest proportion of reproductive females occurred in crop stage 5 (65%), and average litter size was 2.5±0.1 pups/female. *Melomys burtoni* populations exhibited a male-biased sex ratio in crop stages 1-4 (75% male), but a 1:1 sex ratio was seen in crop stage 5. The proportion of juveniles was low in crop stages 1-4 (15-17%), but increased to 30% in crop stage 5, coinciding with an increase in mature and reproductive females in the same period.

Management Implications

The recommendations made in the following section stem not only from the data presented in this thesis, but also from personal observations made over eight years in the employ of BSES Limited as a rodent biologist within the Queensland sugar industry. Wherever possible conclusions are drawn from

data presented in the thesis, but I consider my professional experience also vital to placing specific research results into a wider industry context.

In developing an IPM strategy for *R. sordidus*, Wilson and Whisson (1993) examined *R. sordidus* in sugarcane crops to identify the critical organism-organism and the organism-environment interactions that determine the spatial and temporal distribution of rodent damage. In so doing, they divided the population dynamics of *R. sordidus* into three population phases - the colonising population, the breeding population, and the dispersing population. *Rattus sordidus* colonise sugarcane crops early in the crop development, but are non-breeding individuals. After establishment, *R. sordidus* will commence breeding if sufficient non-cane resources (weed and grass seed) are available. A distinct switch to sugarcane feeding occurs at the cessation of the breeding period and damage levels increase significantly. The majority of *R. sordidus* disperse during the harvest period and move either into unharvested crops or unmanaged non-crop harbourage.

Wilson and Whisson's (1993) IPM strategy sequentially combined biological and chemical control methods, the aim of which is to minimise *R. sordidus* population growth and therefore, crop damage. Given knowledge of how populations develop, monitoring *R. sordidus* population levels indicates the damage potential to be assessed prior to the problem occurring. Monitoring is conducted by snap-trapping of *R. sordidus* and can give an indication of male/female ratio, adult/juvenile ratio, and whether breeding has commenced. After colonisation, a non-breeding *R. sordidus* population may

be baited (if required) prior to the onset of breeding, thus resulting in a reduction in population level and subsequent crop damage. Breeding of *R. sordidus* populations can also be suppressed by the removal of in-crop weeds, further minimising the potential for crop damage. Similarly, a decrease in the area of non-crop harbourage available (by manipulating non-crop harbourage areas) will reduce the survival of dispersing *R. sordidus* populations and result in a reduction in the level of colonists the following season.

In the context of *M. burtoni*, the results of this study have shown that overall numbers of *M. burtoni* increased to significant levels in crop stages 4 and 5. The majority of mature *M. burtoni* in crop stages 1-4 were male, but mature females make up 50% of the population in crop stage 5. Breeding was observed all year round, but the highest proportion of reproductive females occurred within crop stage 5 and this corresponded directly with the highest proportion of juveniles in the population. Importantly, significant crop damage does not occur until crop stage 5. Therefore, it is important to have any management efforts in place prior to crop stage 5, and possibly prior to crop stage 4.

The fact that *M. burtoni* colonises the crop much later than *R. sordidus* may be the reason behind industry raising concerns as to the effectiveness of the existing IPM strategy in managing *M. burtoni*. For example, monitoring for *R. sordidus* numbers occurs in the early stages of crop development (October-December). If monitoring results indicate *R. sordidus* have colonised the

crop, a baiting strategy may be put in place in affected areas, prior to the breeding period for *R. sordidus*. This will reduce the potential for damage from *R. sordidus*.

Melomys burtoni, however, colonise the crop much later. Monitoring for *M. burtoni* in the early stages of crop development may yield mature males, but will do little to help predict the potential for population build up or crop damage. Monitoring in the later stages of crop development would be preferable to indicate the increase in the proportion of female *M. burtoni* and reproduction, but access to the crop at the later stages of development is physically difficult. A baiting strategy conducted earlier in the crop development, in anticipation of damage, would not be considered best management practice as, at such time, there would be neither direct damage nor indicative population build-up. Bait longevity may also be compromised if applied at an earlier stage.

Early monitoring for *R. sordidus* can also help identify the commencement of the breeding period. *Rattus sordidus* has one of the highest reproductive potentials of any native Australian *Rattus* species (McDougall 1946a; Taylor & Horner 1973; Breed 1978; Wilson & Whisson 1993). Where large proportions of pregnant *R. sordidus* are trapped, the population of *R. sordidus* would most likely require baiting to prevent breeding by individuals within that population, so preventing excess crop damage. Results from my study, combined with those of others, have shown that average litter sizes of *M. burtoni* are much lower than those of *R. sordidus*. With *M. burtoni* being

far less fecund *than R. sordidus*, it would be expected that population outbreaks of *M. burtoni* would not be as explosive as *R. sordidus.* However, numbers of *M. burtoni* are equal to numbers of *R. sordidus* in crop stage 5. This suggests that *M. burtoni* may be immigrating into the crop in crop stages 4 and 5.

The major components in the diet of *R. sordidus* are seed, vegetation and cane-fibre. Wilson and Whisson (1993) found that weed and grass seed provided the nutritional requirements for *R. sordidus* to successfully breed within the crop. A distinct diet switch to sugarcane was observed to coincide with the decline of the breeding period. By removing weeds from within the crop, the breeding potential of *R. sordidus* was minimised. This was not evident with *M. burtoni*. The major components in the diet of *M. burtoni* were similar to that of *R. sordidus* and included seed and cane-fibre. Seed was found in greater quantities than cane-fibre and, although the quantity of cane-fibre in *M. burtoni* stomach contents increased in crop stage 5, it never reached the proportions that were found in *R. sordidus*. Therefore, it appears that there is no distinct diet switch, such as has been reported for *R. sordidus*. This may explain why damage levels for *M. burtoni* (5.6%) are lower than the levels found by Wilson and Whisson for *R. sordidus* (9%). It is possible that sugarcane is only a secondary food source for *M. burtoni*, resulting from diminishing supplies of their preferred food resource, possibly due to population expansion and competition for this preferred food resource.

Both *M. burtoni* and *R. sordidus* are grassland animals, therefore it would be expected that grass and weed seed would be included in the diet of each species. However, the reason why seed is utilised in the diet may differ between the two pest species. Although *R. sordidus* may colonise the crop early, they cannot breed unless this resource is available, but even if breeding is suppressed, colonisation may still occur. Perhaps *M. burtoni* individuals move into sugarcane from their natural habitat in search of new territory and do not require in-crop weeds for breeding potential. This may explain the male bias in early crop stages. Population numbers of *M. burtoni* increase significantly in crop stage 4, but remained male biased until crop stage 5 when equal numbers of males and females are found. In addition to this, the largest proportion of juveniles is evident in crop stage 5, and it is possible that juveniles are migrating into the crop, rather than being the offspring of a population breeding within the crop.

Redhead (1973) found that *M. burtoni* were associated with the presence of tall grasses and fully developed sugarcane that provided cover and protection, while offering suitable support for nests within the canopy. He also suggested that movement of *M. burtoni* from grassland into sugarcane occurs over a long period of time (i.e. there is no '*en masse*' movement). This is in contrast to the results of the present study in that *M. burtoni* were not recorded in significant numbers in crop stages 1-3, but increased significantly in crop stage 4 and remained stable in crop stage 5. Crop stage 4 is, on average, only two months in length. This suggests that movement of *M. burtoni* occurs over a relatively short period of time. The movement into

the crop may perhaps be for utilisation of in-crop weed, not necessarily for providing seed-protein required for breeding, but for supplying cover and protection. As a result, weed control within sugarcane crops may be useful in controlling *M. burtoni*, as it is for *R. sordidus*.

Given that the population dynamics of *M. burtoni* indicate that management efforts should occur prior to crop stage 5 and, furthermore, control of *M. burtoni* at this stage in the development of the crop poses physical difficulties, it is suggested that one key management strategy for *M. burtoni* may be the management/manipulation of the adjacent habitat. To achieve this, research is needed to understand the population dynamics and dispersal of *M. burtoni* within the sugarcane production system and its adjacent habitats. Some elements of the existing IPM strategy for *R. sordidus* may be beneficial in managing *M. burtoni* populations within sugarcane, but since the movement of *M. burtoni* appears to occur later in the sugarcane crop-cycle, an understanding of the population dynamics and dispersal of *M. burtoni* between sugarcane and adjacent habitats is required.

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