Chapter 7

Conclusions

7.1 Invasion sequence

To successfully manage introduced species it is essential to understand how a species will interact in a new environment (Hulme 2006; Sakai *et al.* 2001; Tobin *et al.* 2007). By reconstructing the invasion sequence (Chapter 2), the common myna invasion of Canberra was observed to closely follow the sequence predicted by invasion process theory. This was the first study to estimate spreading rate, population growth rate and maximum population size for the common myna. Additionally, this study provided estimates for lag periods before population growth and spreading. This information on the invasion sequence can provide the foundation for any management plan aimed at the control of the common myna (Hulme 2006; Sakai *et al.* 2001; Tobin *et al.* 2007).

7.2 Impact

Prior to this thesis there was limited understanding of the impact the common myna had on the abundance of native species. Chapter 3 used long-term data and an integrated approach to provide the strongest evidence to date for the impact of the common myna on the population abundance of some cavity-nesting and small bird species. These findings were further supported by evidence from Chapter 4, which indicated that, in combination with habitat change, some cavity-nesting and small bird species were negatively associated with common myna abundance. Despite this, Chapter 4 revealed that the common myna is primarily a passenger of habitat change. The abundance of the common myna was strongly influenced by tree density and the species was far more abundant in urban areas than nature reserves. There were no negative associations between common myna abundance and total species abundance and richness, native cavity-nester abundance and richness or large native bird abundance and richness.

Chapter 5 also demonstrated the strong influence of habitat on the abundance and nesting success of the common myna, crimson rosella and eastern rosella. At low tree density sites the common myna occupied a high number of nest boxes (up to 90%) and built 'fake' nests that further reduced cavity availability. Common myna nest box occupancy had a negative influence on crimson rosella and eastern rosella abundance at low tree density sites. However, this study revealed that common myna nest box occupancy may have a more severe impact on crimson rosella abundance at high tree density sites than low or medium tree density sites.

7.3 Gaps, limitations and future directions

Canberra Ornithologists Group Garden Bird Survey data was used in Chapters 2, 3 and 6, providing an invaluable resource. However, the limitations of this voluntary community survey must be accounted for. Therefore, in the analysis I resolved this potential variability by grouping survey sites to ensure continuity of survey effort over regions and year. Transect bird survey data was used in Chapters 4, 5 and 6. Detectability issues can occur across different bird surveyors, habitat types and bird species. However, in Chapters 4 and 5, I did not attempt to quantify the exact number of individuals present at each site, rather I examined the general trends in bird abundance in relation to the common myna and habitat. Additionally, surveys were replicated and undertaken by experienced bird surveyors, reducing the chance of detectability issues. In Chapter 5 the rate of natural cavity nesting was not quantified due to the difficulty of locating and surveying natural cavities. However, significant correlations between nest box use and abundance were observed, indicating that nest boxes in the study area were representative of natural cavity nest use for the common myna and crimson rosella.

Models used throughout this thesis are only simple representations of a complex natural system. Therefore, I acknowledge that not all causal variables have been incorporated into these models. However, no model will capture the complete complexities of the natural environment and I encourage future refinement and investigations into the introduction, impact and control of the common myna. Examples of potential un-modelled causal variables include the effect of other territorial species, nest predators and cavity nesters. For example, the noisy miner (*Manorina melanocephala*) and bell miner (*Manorina melanophrys*) are two native bird species that are territorially aggressive and have been linked to reductions in native bird diversity and abundance (Clarke and Schedvin 1999; Grey 2008; Kemmerer *et al*. 2008; Mac Nally *et al*. 2012; Maron *et al*. 2011; Montague-Drake *et al*. 2011; Piper and Catterall 2003). Other species in the study site that may impact native bird species include the pied currawong (*Strepera graculina*), the introduced domestic cat (*Felis catus*) and the European honey bee (*Apis mellifera*). Additionally, the cavity nesting sulphur crested cockatoo (*Cacatua galerita*) increased in abundance throughout the survey period. However, this species is much larger and would be unable to occupy smaller hollows available to the common myna, crimson rosella and eastern rosella.

Due to the focus of the thesis, limited budgets and time constraints I was unable to investigate the impact the above listed species on native species abundance and nesting. However, I would encourage future research into these areas.

Variations in weather such as rainfall and temperature were included in earlier analysis in Chapter 3 and 4. However, these variables were removed from the thesis due to their lack of significance and the desire for a concise manuscript. The apparent lack of influence of rainfall may be due to the study site being located in an urban area subject to watering of gardens and ovals.

Due to model limitations, safeguards were built into the analysis to ensure that observed impacts were correctly attributed to the common myna. Analysis was undertaken using replication to ensure observed patterns were not simply due to a unique set of circumstances at a particular site. For example, Chapter 2 and 3 used long-term data replicated over four regions, while Chapters 4 and 5 used data collected at 15 sites with five replicates per treatment (high, medium and low tree density). Furthermore, analysis in Chapter 3 focused on bird populations before and after specific time points for common myna establishment. I used the variable of years before and years after common myna establishment so that the analysis could be structured as a 'before and after' experiment. I wanted to investigate if bird populations in each region changed significantly after the arrival of the common myna at a specific time point for each region (when the common myna became established). It is highly unlikely that un-modelled variables, such as the noisy miner, would begin to impact on native bird species at these exact time points in each of the four regions. Structuring the analysis this way ensured that impacts were correctly attributed to the common myna. Additionally, I included non-cavity nesting large bird species in the analysis to assess if the model was working correctly (Chapter 3 and 4). Based on prior scientific findings the mechanisms for common myna impact (territorial exclusion of small birds and nest cavity competition) would not extend to non-cavity nesting large bird species. Therefore, if the models were working correctly there should be no impact of the common myna on non-cavity nesting large bird species, as was the case (Chapter 3 and 4).

Culling of the common myna was not included in the analysis for Chapters 2, 3, 4 and 5 as culling was not observed to influence common myna abundance at the regional scale (Chapter 6). Common myna numbers appeared to decrease across regions over the last 5-10 years (occurring prior to culling in some areas). This decline is likely to be caused by natural population limitation and regulation (Chapter 6). However, the exact cause of this decline would be a good area for future research as it may assist in the control of common myna populations.

Future research on the common myna should also look deeper into the prioritisation of management actions. Comparative studies to quantify the level common myna impact against other impacts such as habitat clearing or the noisy miner, would be of value. This could enable management resources to be allocated directly proportional to impact rather than a reaction to public perception or dislike of non-native species. Furthermore, reducing the impact of a species may *not* assist threatened species recovery if habitat destruction is the main driver of native species decline (Chiron et al. 2009). Therefore, further investigation into the passenger-driver model is recommended to quantify the impact of habitat restoration on both native species and common myna abundance.

If culling of the common myna is to continue, suitable management units and a target population size (where the species' impact is minimised) need to be defined. Movement studies and population genetics may be suitable tools to define management units where there is negligible immigration. Additionally, defining a target population size will enable managers to determine the number of individuals that need to be culled annually. Alternative control methods should also be investigated, specifically cull timing, duration, method and the impact of environmental manipulation.

The population model utilised in Chapter 6 could be further refined, if required, to include estimates of age structure, sex ratio, survival rates and reproduction rates. Additionally, more complex models exist that incorporate the links between life-history dynamics, culling rates and environmental variables.

7.4 The human element

Despite the findings of this thesis, many scientists may still question the seriousness of common myna impact and the type of management (if any) that is warranted. For example, one paper suggests that '…the substantial efforts currently directed towards culling of common mynas in heavily urbanised environments is misdirected, and resources would be better directed to improvement of natural habitat quality in these areas…[*sic*]' (Lowe *et al.* 2011).

Regardless of scientific evidence, many community members are passionate about controlling this species. Perhaps this strong community reaction to the common myna is due to the species being highly visible in urban areas. Individual observations of the common myna competing with native species, while at times is distressing, may not result in a widespread collapse in bird numbers. For example, in a paper on the cane toad (*Rhinella marina*), Shine and Doody (2010) suggest that community groups tend to view species 'impact as more severe, wide-ranging, and long-lasting than do scientists'. This problem is due partly to the lack of scientific studies available to the community (Shine and Doody 2010).

Community concern about introduced species can put significant pressure on government and land managers to take action (Newton 1998). At times this leads to unnecessary management actions that are unsustainable and take the focus and funding away from other management programs (Davis *et al.* 2011; Shine and Doody 2010). Therefore, the breakdown in communication between scientists and the community can be a barrier to effective species management (Sharp *et al.* 2011). We must not let community passion for common myna management cloud rational scientific judgment and the strategic allocation of pest management resources (Brown *et al.* 2011; Davis *et al.* 2011; Parker *et al.* 1999; Simberloff 2003; Townsend 2003).

The role of science communication cannot be overlooked in any successful management plan. Community group leaders have the freedom and ability to motivate individuals through emotive discussions about a species or issue. Scientists need to ensure their research is communicated effectively to people to ensure enthusiasm for conservation is harnessed into meaningful projects based on good science. Scientists need to actively engage with public debate on these issues to help inform interested community members.

7.5 How should we manage the common myna?

Community support is already very strong for common myna management in Australia. However, greater use of science in community-led projects could further enhance management outcomes.

The main priority should be to prevent the transport and establishment of new common myna populations as management complexity and costs increase significantly as a species moves through the invasion process (Mack *et al.* 2000; McNeely *et al.* 2003; Sakai *et al.* 2001). Due to the species' strong history of establishment, broad niche breadth and behavioural flexibility, it is likely to quickly establish in new areas and grow in population size (Duncan *et al.* 2003; Duncan *et al.* 2001; Feare and Craig 1998; Griffin 2008; Griffin and Boyce 2009; Kolar and Lodge 2001; Sol *et al.* 2011). Therefore, attempts to eradicate new introductions should also be a priority. For example, recent sightings of the species in Tasmania should be investigated and newly arrived individuals euthanised (Paine 2013).

Chapter 2 demonstrated that the common myna had both a short lag period before population growth (<3 years) and spreading (six years). This highlights the importance of a rapid response to new invasions before the population can grow in numbers and spread. Once a species becomes widespread and abundant, total eradication is highly unlikely; population control and impact mitigation are then the best management strategies (Hulme 2006; Mack *et al.* 2000; Sakai *et al.* 2001). If deemed necessary, population control should aim to reduce the population size to a pre-defined level where impacts are minimised. However, defining this level can be highly problematic (Hulme 2003; Hulme 2006).

Chapter 6 is the first study to assess the impact of community-led culling on common myna abundance. This study also modelled common myna populations to provide insight into their population dynamics and the influence of culling. Understanding population dynamics is essential to enable managers to create an informed and targeted strategy. This study revealed that high intensity community-led culling is reducing common myna abundance at a fine scale. However, current culling levels are too low to reduce common myna numbers across Canberra. A significant amount of effort is currently being directed to a program that may not be achieving the desired results. Natural reproduction, survival and/or immigration are probably replacing culled individuals. This study indicated that community-led culling would be more effective if the overall rate of culling was increased. Culls of at least 25 birds per km^2 per year are needed or alternative methods for controlling this species should be pursued.

The common myna is able to compensate for culling through rapid reproduction. Therefore, control programs need to be maintained year after year or the species will quickly recover. The population model in Chapter 6 demonstrated how culling rates should increase or decrease for different population densities. Additionally, as the population size decreases, it becomes more difficult to locate and cull individuals, potentially reducing the effectiveness of control measures (Newton 1998; Potts 1986; Shine and Doody 2010). Furthermore, the timing of culling can have a large impact on the effects of a control program. Currently the largest numbers of the common myna are culled just after the breeding season, when young birds are easily trapped. However, it would be more effective to cull prior to, and during, the breeding season, when culling is more likely to be additive to natural mortality. Culling in September to December also would be more likely to reduce the competitive pressure for nest cavities.

Valve traps used by the community for trapping may have only limited use as there are reports that the common myna can become trap shy (King 2010). These traps may target the young or weak in a population leaving individuals that cause the most damage and/or are strong breeders. Valve trapping at low densities, and in food-rich environments, also may limit the effectiveness of this control method. The common myna is capable of recognising aspects of the trapping process as dangerous and adapting its behaviour to avoid being trapped (Griffin 2008; Griffin and Boyce 2009; King 2010; Tidemann 2010). Similarly, the common myna has been observed to avoid areas controlled by shooting (Dhami and Nagle 2009). Perhaps trapping with decoy birds could enhance trapping of the common myna in valve traps, especially in areas where food is readily available (Tidemann 2010). Alternative methods for common myna control also may be required, such as nest box trapping (Appendix 9) and roost trapping (Tidemann 2010; Tidemann *et al.* 2011).

Several methods of controlling the common myna will likely be required, due to its adaptable nature (Tidemann 2010). A multifaceted approach could include reducing food availability (e.g. dog food), limiting nesting sites (e.g. in roof cavities), habitat manipulation (e.g. tree planting and revegetation) and culling in sensitive areas. Modifying current practices (e.g. timing of cull) or utilising alternative and/or complementary culling methods may also be required (Parkes 2013). For a detailed review into the best practice for the management of the common myna see Parkes (2013).

7.5.1 An Alternative method for control

Chapter 4 and Chapter 5 highlighted the importance of including both habitat variables and introduced species impact into analysis to disentangle the different impacts on native species. This method will also help determine if the impact of an introduced species is more severe in particular habitats. Understanding impact will enable targeted management and mitigation. For example, the impact of the common myna might be more severe in areas that represent 'high quality' habitat for native species (Chapter 5). Perhaps culling should be restricted to localised areas where the species is deemed to have the greatest impact. For example, management of the common myna could be focused near threatened species breeding areas, such as the superb parrot (*Polytelis swainsonii*). Simply providing nest boxes to alleviate competition for cavities may be counterproductive if the nest boxes are not actively managed to remove nesting common myna (Appendix 4 and 9). Chapter 5 and other research (Lowe *et al.*

2011) indicates the common myna may prefer using nest boxes to natural cavities. Therefore, the provision of nest boxes could lead to an increase in common myna nesting and abundance.

Habitat plays a critical role in species abundance. Species are highly vulnerable to habitat manipulation and many species extinctions can be linked to human habitat modification, while many eradication attempts have failed (Caughley 1977). Therefore, habitat manipulation could be a highly effective tool for the control of introduced species. The common myna occurs in greater abundance in cities and towns, and in areas with low densities of native trees (Chapter 4 and Chapter 5). Human habitat modification can reduce the 'quality' of habitat for native species; this modification can then lead to an increase in common myna abundance. Low tree density, or fragmentation of native vegetation, may enhance habitat quality for the common myna enabling the species to spread into new areas and compete for resources with native species (Lowe *et al.* 2011; Tracey *et al.* 2007). Therefore, in combination, habitat modification and the introduction of invasive species, can have significant negative impacts on native species (Gibbons and Lindenmayer 2002; Lindenmayer *et al.* 2009). For example, housing developments that are built adjoining threatened species habitat would be of significant concern. This type of habitat modification would drive an increase in the abundance of the common myna in sensitive areas, greatly increasing the likelihood of negative impacts on threatened species.

Given the influence of habitat on species abundance, habitat restoration and tree planting may be useful tools to both control common myna abundance and to aid native bird species recovery. This will not only increase habitat quality for native species (including cavity availability in the longer term), but it is also likely to make the habitat less suitable for the common myna, reducing its abundance. Without restoring habitat and making these areas 'less suitable' for the common myna, attempts to control species numbers are only likely to succeed over the short term, with the species reinvading once control actions are eased.

7.6 References

Brown GP, Phillips BL Shine R (2011) The ecological impact of invasive cane toads on tropical snakes: Field data do not support laboratory-based predictions. *Ecology* 92(2), 422-431.

Caughley G (1977) Analysis of vertebrate populations. John Wiley and Sons, New York.

Chiron F, Shirley S, Kark S (2009) Human-related processes drive the richness of exotic birds in Europe. *Prococeedings of the royal society B* 276(1), 47–53.

Choquenot D Parkes J (2001) Setting thresholds for pest control: how does pest density affect resource viability? *Biological Conservation* 99(1), 29-46.

Clarke MF Schedvin N (1999) Removal of bell miners *Manorina melanophrys* from *Eucalyptus radiata* forest and its effect on avian diversity, psyllids and tree health. *Biological Conservation* 88(1), 111-120.

Davis MA, Chew MK, Hobbs RJ, Lugo AE, Ewel JJ, Vermeij GJ, Brown JH, Rosenzweig ML, Gardener MR, Carroll SP, Thompson K, Pickett STA, Stromberg JC, Tredici PD, Suding KN, Ehrenfeld JG, Philip Grime J, Mascaro J Briggs JC (2011) Don't judge species on their origins. *Nature* 474(7350), 153-154.

Dhami MK Nagle B (2009) Review of the Biology and Ecology of the common myna (*Acridotheres tristis*) and some implications for management of this invasive species. The University of Auckland, Auckland.

Duncan RP, Blackburn TM Sol D (2003) The ecology of bird introductions. *Annual Review of Ecology, Evolution, and Systematics* 34, 71-98.

Duncan RP, Bomford M, Forsyth DM Conibear L (2001) High predictability in introduction outcomes and the geographical range size of introduced Australian birds: A role for climate. *Journal of Animal Ecology* 70(4), 621-632.

Feare C Craig A (1998) Starlings and Mynas. Helm, London.

Gibbons P Lindenmayer DB (2002) Tree hollows and wildlife conservation in Australia. CSIRO Publishing, Collingwood.

Grey M (2008) The impact of the Noisy Miner *Manorina melanocephala* on avian diversity and insect-induced dieback in eucalypt remnants [PhD]. Melbourne: La Trobe University.

Griffin AS (2008) Social learning in Indian mynahs, *Acridotheres tristis*: the role of distress calls. *Animal Behaviour* 75(1), 79-89.

Griffin AS Boyce HM (2009) Indian mynahs, *Acridotheres tristis*, learn about dangerous places by observing the fate of others. *Animal Behaviour* 78(1), 79-84.

Hulme PE (2003) Biological invasions: Winning the science battles but losing the conservation war? *ORYX* 37(2), 178-193.

Hulme PE (2006) Beyond control: wider implications for the management of biological invasions. *Journal of Applied Ecology* 43(5), 835-847.

Kemmerer EP, Shields JM Tidemann CR (2008) High densities of bell miners *Manorina melanophrys* associated with reduced diversity of other birds in wet eucalypt forest: Potential for adaptive management. *Forest Ecology and Management* 255(7), 2094-2102.

King DH (2010) The effect of trapping pressure on trap avoidance, and the role of foraging strategies in anti-predator behaviour of common mynas (*Sturnus tristis*). *Canberra Bird* 35(2), 85-108

Kolar CS Lodge DM (2001) Progress in invasion biology: predicting invaders. *Trends in Ecology and Evolution* 16(4), 199-204.

Lindenmayer DB, Welsh A, Donnelly C, Crane M, Michael D, Macgregor C, McBurney L, Montague-Drake R Gibbons P (2009) Are nest boxes a viable alternative source of cavities for hollow-dependent animals? Long-term monitoring of nest box occupancy, pest use and attrition. *Biological Conservation* 142(1), 33-42.

Lowe K, Taylor C Major R (2011) Do common mynas significantly compete with native birds in urban environments? *Journal of Ornithology* 152(4), 909-921.

Mack RN, Simberloff D, Lonsdale WM, Evans H, Clout M Bazzaz FA (2000) Biotic invasions: Causes, epidemiology, global consequences, and control. *Ecological applications* 10(3), 689-710.

Mac Nally R, Bowen M, Howes A, McAlpine CA, Maron M (2012). Despotic, high-impact species and the subcontinental scale control of avian assemblage structure. *Ecology* 93(3), 668-78.

McNeely J, Neville LE Rejmanek M (2003) When is eradication a sound investment. *Conservation Practices* 4(1), 30-31.

Maron M, Main A, Bowen M, Howes A, Kath J, Pillette C, McAlpine, CA (2011). Relative influence of habitat modification and interspecific competition on woodland bird assemblages in eastern Australia. *Emu* 111(1), 40-51.

Montague-Drake RM, Lindenmayer DB, Cunningham RB Stein JA (2011) A reverse keystone species affects the landscape distribution of woodland avifauna: A case study using the Noisy Miner (*Manorina melanocephala*) and other Australian birds. *Landscape Ecology* 26(10), 1383-1394.

Newton I (1998) Population limitation in birds. Academic Press, London.

Paine M (2013) 'Bird invaders spark alert', *The Mercury*, 26 May 2013, pp. 1.

Parker IM, Simberloff D, Lonsdale WM, Goodell K, Wonham M, Kareiva PM, Williamson MH, Von Holle B, Moyle PB, Byers JE Goldwasser L (1999) Impact: Toward a framework for understanding the ecological effects of invaders. *Biological Invasions* 1(1) 3-19.

Parkes J (2013) Review of best practice management of common mynas (*Acridotheres tristis*). In 'Institutional Capacity Building for Invasive Bird Management in the Pacific.' (Eds J Copsey and J Parkes) pp. 9-56. Critical Ecosystem Partnership Fund and Conservation International Pacific Islands, Apia.

Piper SD, Catterall CP (2003). A particular case and a general pattern: hyperaggressive behaviour of one species may mediate avifaunal decreases in fragmented Australian forests. *Oikos* 101(3), 602-614.

Potts GR (1986) The Partridge: Pesticides, Predation and Conservation. Collins Professional and Technical, London.

Sakai AK, Allendorf FW, Holt JS, Lodge DM, Molofsky J, With KA, Baughman S, Cabin RJ, Cohen JE Ellstrand NC (2001) The Population Biology of Invasive Specie. *Annual Review of Ecology and Systematics*, 305-332.

Sharp RL, Larson LR Green GT (2011) Factors influencing public preferences for invasive alien species management. *Biological Conservation* 144(8), 2097-2104.

Shine R Doody JS (2010) Invasive species control: understanding conflicts between researchers and the general community. *Frontiers in Ecology and the Environment* 9(7), 400-406.

Simberloff D (2003) How much information on population biology is needed to manage introduced species? *Conservation Biology* 17(1), 83-92.

Sol D, Griffin AS, Bartomeus I, Boyce H (2011) Exploring or avoiding novel food resources? The novelty conflict in an invasive bird. *PLoS One 6*(5):e19535. doi: 10.1371/journal.pone.0019535.

Tidemann CR (2010) Investigation into the potential for broad-scale control of mynas by trapping at communal roosts. Report to the Hermon Slade Foundation, the Australian Rainforest Foundation and the NSW Department of Environment, Climate Change and Water, The Australian National University, Canberra.

Tidemann CR, Grarock K King DH (2011) Euthanasia of pest sturnids in nestboxes. *Corella* 35(2), 49-51.

Tobin PC, Liebhold AM Anderson Roberts E (2007) Comparison of methods for estimating the spread of a non indigenous species. *Journal of biogeography* 34(2), 305-312.

Townsend CR (2003) Individual, population, community, and ecosystem consequences of a fish invader in New Zealand streams. *Conservation Biology* 17(1), 38-47.

Tracey J, Bomford M, Hart Q, Saunders G Sinclair R (2007) Managing Bird Damage to Fruit and Other Horticultural Crops. Bureau of Rural Sciences, Canberra.