

*Responses of invasive birds to control:
the case of common mynas in Australia*

by

Ms Marie C. Diquelou, M.Sc.

supervisor: Dr. Andrea S. Griffin
co-supervisor: Dr. Geoff MacFarlane

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STATEMENT PAGE

1. Statement of Originality

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to the final version of my thesis being made available worldwide when deposited in the University's Digital Repository, subject to the provisions of the Copyright Act 1968.

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2. Statement of Authorship

I hereby certify that the work embodied in this thesis contains scholarly work of which I am the principal author.

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ABSTRACT

Wildlife harvesting is one of the first ways in which humans have influenced their environment. Effects of harvesting through hunting and fishing on target populations are now well recognised. However little attention has been directed at effects of other modalities of harvesting such as control of problem species. Using a predator-prey framework, I looked at what behavioural responses could be expected from controlling a population of invasive birds. The main predictions that arose were that control should lead to increased risk aversion and larger groups in target species.

To verify these predictions, I used the common myna (*Acridotheres tristis*), a very successful alien invasive species worldwide. Mynas were introduced in Australia at the end of the 19th century and have been spreading across the country. Due to concerns about effects on native wildlife, a number of control programs have appeared in the last two decades. Using questionnaires, I was able to localise trapping efforts, which allowed me to perform surveys of myna populations undergoing high and low control pressure. This showed that mynas undergoing trapping tended to be more risk-averse, less conspicuous and form smaller groups.

This in turn raised the question of what mechanism may be responsible for these changes. A captive study provided little support for the implication of selective removal of certain personalities through trapping. However a field study revealed the important impact of learning on responses towards stimuli related to trapping.

I suggest responses to control practices are divided into responses specific to the method in use, and general responses to the increased risk in the environment. I discuss theoretical and management-related implications of these two categories of responses. Additionally, based on integrated pest management theory and on information collected from questionnaires to the public and to organisations involved in control, I make recommendations for improving current myna control practices.

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GENERAL INTRODUCTION: PREDICTING RESPONSES TO CONTROL PRACTICES IN INVASIVE ALIEN SPECIES

1. Introduction

Archeological evidence of fishing and hunting suggests humans have exploited neighboring wildlife from very early on (Stiner et al. 1999; O'Connor et al. 2011; Ferraro et al. 2013). It hence seems that throughout their history, humans have collected non-human animals from their surroundings. This practice, which can be referred to as artificial predation (Glasgow 1953) or wildlife harvesting (Coltman et al. 2003), often aims to provide resources such as food and clothing, but can also occur for other motives (e.g. study, collections or trophies). Just like natural predation, wildlife harvesting has the potential to influence population dynamics and selection regimes of prey species.

There are several well known cases of wildlife harvesting influencing evolutionary processes. For example, trophy hunters that selectively target bighorn rams (*Ovis canadensis*), with the largest horns, have been shown to push populations towards the production of lighter rams with smaller horns (Coltman et al. 2003; Pigeon et al. 2016). Similarly, there is evidence for phenotypic changes associated with harvesting pressure from fisheries in a number of species (Law 2000; Conover and Munch 2002; Olsen et al. 2004; Biro and Sampson 2015; Heino et al. 2015). In fact, most cases of human exploitation of wild animal populations are expected to lead to “unnatural selection” because these organisms are almost systematically non-randomly harvested (Law 2001; Allendorf and Hard 2009). Additionally, phenotypic changes in response to human harvesting occur much faster than changes due to natural and other human-mediated causes (Darimont et al. 2009). Together this highlights the dramatic impacts that wildlife harvesting can have on prey populations.

While phenotypic changes related to fishing and hunting, albeit often overlooked, have long been recognized (Allendorf and Hard 2009; Heino et al. 2015), other types of wildlife harvesting have received far less attention. In particular, harvesting of invasive, pest and over-abundant species in order to control or eradicate their populations also has the potential to result in phenotypic changes of the target species. Two exceptions in which control-related phenotypic change is relatively well documented are antibiotic resistance in bacterial diseases and pesticide resistance in pest

insects which have caused substantial economical costs to human societies (Palumbi 2001). Invasive alien species are one of the most important threats to ecosystems around the world, following increasing human mobility worldwide. Species are more and more often transported to habitats to which they are not native and some have the potential to colonize entire ecosystems and overtake native species (Vitousek et al. 1996; Pimentel et al. 2000; Pimentel et al. 2005). As a consequence, these species demand from human societies the implementation of effective control strategies (Mack et al. 2000). In contrast to exploitation of wildlife for consumption, where one could argue phenotypic changes can allow a species to overcome over-exploitation and hence might be desirable (even though they often reduce population fitness, and decrease yields and profitability to exploiters), there is no doubt that phenotypic changes that make problem species better able to cope with control measures should be avoided wherever possible. It hence seems that measuring these changes is equally, if not more important in the context of animal control than in other cases of wildlife harvesting. The question then becomes, how likely are such changes to occur in this context?

Harvesting-induced phenotypic changes likely depend on high harvesting pressure and highly directional selection. Harvesting pressure applied in the context of control programs is highly variable. At one end of the spectrum, control programs based on high harvesting pressures can lead to eradication, usually in contexts where the target population(s) are in small delimited areas like islands (Zavaleta et al. 2001). While other programs implement maintenance control that aims at limiting populations numbers under some problematic threshold (Mack et al. 2000). Maintenance control, however, is not always successful in keeping populations under certain levels as the applied pressure is not always sufficient. Some kangaroo control programs are expected to have a reduced potential to elicit genetic phenotypic changes because their harvesting occurs on a limited spatial scale and removes only few individuals (Hale 2004). As is the case in the development of antibiotic and insecticide resistance (Palumbi 2001), high but sub-maximal and intermediate levels of pressure are most likely to lead to phenotypic changes in target populations.

The second reason for which wildlife harvesting in the context of control practices is likely to lead to phenotypic change is that there is increasing evidence that commonly used capture methods such as trapping are biased and preferentially remove certain types of personalities. For example more exploratory and higher risk-taking

collared flycatchers (*Ficedula albicollis*) are more likely to enter traps (Garamszegi et al. 2009). Selective removal of certain personality traits (e.g. low neophobia, high exploration) from populations increases the frequency of individuals that possess opposite traits to those being selected (e.g. high neophobia, low exploration). As a result these individuals will breed together, which if the trait is heritable, will lead to populations that have high occurrences of traits that are not easily removed by captured methods.

Here, I use the large empirical literature on how animal populations change in response to natural and artificial anthropic predation to argue that compensatory behavioural responses are likely to arise from most population reduction programs. While it can be expected that the main effect of predation and control programs is to reduce density of the target species, I focus on changes that are not density-dependent. Thus I focus on changes that arise from the presence of the predator, and not from the number of individuals it removes. I begin by considering the mechanisms by which both natural and human predators can change prey populations. I then focus on those programs that control invasive alien birds as a model system. The main objective is to predict the potential behavioural consequences of these measures on alien birds, while integrating considerations of underpinning mechanisms. Although most of the discussion is focused on trapping of alien birds, a widespread population control method, especially in areas where human population densities are high, other measures are also mentioned. Interestingly there is scope for the logic developed below to be applied to most pest control methods which is of particular interest since in many control programs several methods are used in conjunction with one another.

2. Can wildlife harvesting in the context of predator control be compared to natural predation?

Predation is the consumption of an organism (prey) by another (predator): true predation involving the death of the former shortly after the encounter and therefore characterized by the impossibility for a prey to further propagate its genes (Begon et al. 2006). Wildlife harvesting refers to all actions by which humans collect free-ranging animals from their habitat. The individuals that are removed, as a result, cannot participate in further reproduction. The impact of natural and artificial predation is hence the same on prey, the main difference being that one predator is a human while in

the other it is a non-human animal. Accordingly, as exposed above, when taking place on a large scale they can both lead to evolutionary responses.

Prey species have evolved together with their predators such that many have developed innate recognition and responses towards their predators. Accordingly, humans are likely to be innately recognized as predators by a number of species which have been hunted for thousands of years. Even for species that are not hunted, humans possess certain characteristics that could fit with some species' innate predator pattern such as their eye-pattern (Curio 1993; Caro 2005b), or carnivore-specific odors (Nolte et al. 1994; Ferrero et al. 2011). Additionally a number of studies show that human disturbance is perceived as analogous to predation risk (Frid and Dill 2002).

Beyond their similarities, wildlife harvesting and natural predation also have differences. One difference lies in the means by which prey are collected. While a fantastic diversity of predator strategies exists in non-human animals, in most cases predators have to approach in close range to their prey before catching them. On the other hand, ,in many cases humans use passive capture devices (i.e. trapping, gill-netting) such that they may not be present at the moment of collection. As a result, anti-predator responses directed at humans will not increase chances of survival. While there are few species that have evolved trap-like capture strategies (e.g. spider webs, ant-lion larva, see list in Bateman 2003), they target very small prey, often arthropods. These arthropods are hence the only ones with the potential to have evolved specific responses to passive capture strategies. As such, it is unlikely that birds and mammals have evolved innate recognition of such systems. Certain stimuli are recognized as threats by many species, for example any loud noise over a certain threshold and any rapidly approaching object (Frid and Dill 2002). However traps and nets do not seem to contain any of these generalized threatening stimuli. Hence experience-dependent mechanisms such as learning might hold the key to understanding responses to these structures. Yet it is important to note that many species are predisposed to learn about certain types of dangers (Caro 2005b). Thus, learning about artificial man-made structures may be more complex, or limited to fewer species, than learning about natural predators. Overall, this might favor species with high phenotypic plasticity that can develop responses to novel threats more easily, and be disadvantageous for those species that rely heavily on innate recognition and responses.

Even though there is scope for important differences between natural and artificial predation, in particular when the latter takes place with the help of man-made devices, I argue that using the natural predation literature can inform potential responses to control measures. In particular, similar responses may arise from natural predators, from wildlife harvesting for consumption and from control measures. Similar responses are likely to occur because the same mechanisms which underlie them are likely to apply. Likewise, anti-predator behaviours are also used as a conceptual basis to understand animal-vehicle collisions (Blackwell et al. 2016). Just like natural predation, escape from an approaching vehicle follows economic rules, and individuals with certain characteristics are more vulnerable than others (Blackwell et al. 2016). Overall the anti-predator framework provides a useful theoretical framework to understand and potentially mitigate responses to wildlife harvesting, and many other human activities (Frid and Dill 2002).

3. Potential mechanisms underpinning phenotypic changes in controlled populations

Both natural and artificial predators not only reduce prey densities, but also induce profound phenotypic changes in prey populations through the risk they represent (Lima 1998; Preisser et al. 2005; Creel and Christianson 2008; Cresswell 2008). Predator-induced phenotypic changes can arise via mechanisms ranging from evolutionary adaptation through to phenotypic plasticity, including developmental plasticity, as well as experience-dependent flexible adjustments such as learning. Some phenotypic changes are likely to be underpinned by combinations of these processes, but for the sake of simplicity I discuss each one separately.

Evolutionary adaptation to predation occurs in cases where individual prey vary in their expression of a heritable trait and variability confers a survival or reproductive advantage under predation pressure. Across generations, selective removal by predators of those individuals that do not express the beneficial trait, or express it to a lesser extent, increases the relative abundance of individuals carrying the genes that confer the beneficial trait within the prey population. There is abundant evidence for adaptive evolution in the context of predation. Long-term studies in guppy populations (*Poecilia reticulata*) have shown that predators can induce changes in coloration, behaviour, and life history that reduce predation risk to the individual (Reznick et al. 1990; Magurran et al. 1992; Endler 1995; Reznick et al. 1996; Reznick and Ghalambor 2005). For

example, when guppies live with predators that prey predominantly on large individuals, they mature at earlier ages (and hence at smaller sizes), invest more in reproduction especially early on, and produce more and smaller offspring (Reznick et al. 1990). Similarly, because fisheries target large individuals through the use of size-selective gillnets a number of fish species have evolved smaller sizes, slower growth rates and earlier maturation (Handford et al. 1977; Grift et al. 2003; Olsen et al. 2004).

In contrast to evolutionary adaptation, which requires multiple generations to arise, phenotypic plasticity, the production of multiple phenotypes from a single genotype depending on environmental influences (Miner et al. 2005; Sultan and Stearns 2005), enables prey to respond to predation within the timescale of their lifetime. Interestingly, it is often difficult to disentangle phenotypic plasticity from evolutionary changes observed in natural populations (Kuparinen and Merilä 2007; Fenberg and Roy 2008; Heino et al. 2015). For example early maturation in fish could also be related to smaller densities and reduced competition for resources or increasing water temperatures (Kuparinen and Merilä 2007).

Phenotypic plasticity is a complex concept that encompasses phenomena as varied as irreversible developmental plasticity and short term physiological responses (Sultan and Stearns 2005). Developmental plasticity derives from reception by the organism of certain environmental signals during ontogeny that will direct development of certain cells such that its phenotype at maturity is better suited to this specific environment. In waterfleas (*Daphnia cucullata*), predator-released kairomones induce increased morphological defenses, in the form of longer helmets, both through direct exposure of eggs and previous exposure of the mother (Agrawal et al. 1999). This example highlights one important source of developmental plasticity: non-genetic inheritance which is the result of parental transmission of factors other than DNA (Bonduriansky and Day 2008). For example in birds, offspring behavioural and physiological phenotype can be influenced by hormones contained in the egg (Henriksen et al. 2011; Adkins-Regan et al. 2013). Similarly, following high predation periods, snowshoe hares (*Lepus americanus*) transmit high levels of stress hormones to their offspring, which might explain slow recovery of reproduction rates, even after predation decreases (Sheriff et al. 2010).

Another pathway of non-genetic inheritance is through epigenetic regulation of genetic expression (e.g. DNA methylation) that allows individuals to be better suited to

a given environment at a given time (Jaenisch and Bird 2003; Angers et al. 2010). Although the role of epigenetic changes in mediating the emergence of adaptive responses to predation pressure has received little attention, there is some evidence that predators can induce epigenetically mediated phenotypic change in prey. For example under lab conditions, early stress in rats, in particular that mediated by maternal behaviour, leads to altered adult behaviour which in turn can be transmitted epigenetically to their offspring (Francis et al. 1999). In a more naturalistic context this could translate to predation risk undergone by parents influencing anti-predator behaviours in their offspring.

An alternative source of plasticity, more confined to the behavioural modality, is learning. Learning enables a dynamic and ongoing adjustment of behaviour in response to spatially and temporally fluctuating levels of predation risk within an animal's lifetime. It is well established that learning is triggered by the prey's own interactions with predators (Brown and Chivers 2005; Caro 2005a), but also by exposure to the interactions of other individuals with predators (Griffin 2004). Individual and social experiences can drive acquired recognition of novel predators whereby prey learn to recognize previously unfamiliar predator-related visual, chemical and/or auditory cues (Maloney and McLean 1995; Griffin et al. 2000; Brown and Chivers 2005; Magrath et al. 2015). Individual and social learning of cues associated with predation risk can also generate temporal and spatial adjustments of behaviour. For example, an animal might learn to avoid a location in which it previously escaped a predator attack or a location in which it observed predation of a conspecific (Griffin and Boyce 2009). Experience-dependent learning of novel predator cues, as well as places and times associated with predation risk, are underpinned by an associative learning process known as classical conditioning in which initially neutral stimuli that predict predation (e.g. sounds, smells, time of day and/or location) become associated with predator stimuli such as attacks on the individual or conspecifics and social alarm signals (Griffin 2008).

Learning about control pressure is not necessarily restricted to learning about the specific stimuli involved (e.g. location, predator and/or time), it can also be in the form of learning about the environment. When encountering predators and other threats animals can re-assess the overall danger of the environment in which they are located and adjust their perceived risk accordingly. Predator encounters in birds induce an increase in corticosterone levels, a transitory stress response (Cockrem and Silverin

2002; Jones et al. 2016). Hence multiple successive predator encounters could lead to chronic stress in prey species, which could participate in risk perception of the environment. Evidence is accumulating that encounters with predator and predator cues can have sustained long-lasting effects on prey such as reducing reproductive success (Clinchy et al. 2013). This underlying hormonal pathway may be one explanation to the fact that the presence of a threat, and the increase in perceived risk it elicits, lead to a range of behavioural changes that are not necessarily limited to defence and avoidance of this particular threat (e.g. decline in reproduction).

Together, evolutionary adaptation, developmental plasticity, associative learning and experience-dependent risk perception provide a temporally integrated set of mechanisms that enable prey to cope with both cross- and within-generation quantitative (e.g. increased predation pressure by familiar predators) and qualitative (i.e. new predators) fluctuations in predation risk.

4. Potential behavioural and life-history changes occurring in response to control

Phenotypic changes observed in controlled species will depend on the time frame, spatial scale and intensity with which measures are applied to them. The changes observed will be specific to certain individuals or persist across generations and populations depending on the mechanism involved. As a result, the mechanisms involved have important implications in terms of how to counteract these changes. However, it is often difficult to disentangle which of evolution, developmental plasticity, and learning causes which change in particular in the context of behavioural changes. Moreover the same apparent change in behaviour can be due to different mechanisms in different species and or contexts. This is why in this section I focus on what behavioural changes may occur in an invasive bird population in response to an increase in harvesting pressure without discussing the mechanisms involved.

4.1. Reproduction

When, where and how much to invest in reproduction are important decisions for birds. While they should aim to maximize their fitness by producing the greatest number of offspring that reach reproductive maturity, there are a number of costs associated with reproduction such as energetic costs of egg production and food provisioning. As a result birds need to engage in more food searching which is likely to

put them more at risk from predation. Additionally, they have to stay in the nest for extended periods of time, and sometimes engage in conspicuous courtship behaviours which are also likely to increase the chances of being detected by a predator. Overall, it seems reproduction increases predation risks for birds and there is a tradeoff between allocating resources to breeding and to anti-predator behaviours (Cresswell 2008).

Decrease in the level of investment in breeding is one of the most studied effects of predation on bird reproduction, whether this predation is directed at adults or nests (Lima 2009). In tropical stonechats (*Saxicola torquata axillaris*), pairs with fiscal shrikes (*Lanius collaris*), a predator of adults and fledglings, on their territory produce less broods than those pairs without (Scheuerlein et al. 2001). Nest predation events in song sparrows (*Melospiza melodia*) lead females to produce smaller clutches in subsequent attempts (Travers et al. 2010) and the threat of predation alone leads pairs to produce less eggs and hatchlings (Zanette et al. 2011). It hence seems that there is a general trend in birds living under high predation risk to invest less in reproduction. In the context of control programs this could be a substantially beneficial 'side effect'.

On the other hand, size-selective fishing benefits fish that mature early such that they can breed before being captured (Heino et al. 2015). This same bias is unlikely in birds as capture methods are rarely size-selective. However other biases are possible in particular related to age. Juvenile birds are generally regarded as more susceptible to predation (Van Den Hout et al. 2008), and this trend seems to extend to artificial predation in particular when using passive techniques such as mist-nets and traps (Pienkowski and Dick 1976; Insley and Etheridge 1997). One factor that might play a role in higher likelihood of capture of juveniles, in corvids at least, is that juveniles are less neophobic than adults (Miller et al. 2015). Increased mortality of offspring before maturity could lead to reduced investment in reproduction by adults, or inversely increased compensatory investment in breeding.

Predation has potential to impact every aspect of breeding, from nest choice location to food provisioning. Siberian jays (*Perisoreus infaustus*) choose to nest in denser vegetation when under predation risk (Eggers et al. 2006). Presence of predators that prey on adults or nestlings also reduce rates of food provisioning in pied flycatchers, *Ficedula hypoleuca* (Tilgar et al. 2011). Considering frequency and quality of food provisioning received by nestlings affects behavioural types at maturity (Carere

et al. 2005), predation and its perception by prey has the potential to influence offspring before they even experience predators themselves.

4.2. Vigilance and social aggregations

Vigilance relates to the collection of information in the vicinity of an animal, generally in the context of anti-predatory behaviours (Lind 2010). In particular, it often refers to scanning for predators, an activity that aims at detecting predators in the proximal environment in order to increase chances of escape and survival when under attack. In birds, the level of vigilance is often assessed by measuring “*scans*”, periods where birds are standing head up, which appear allocated to visual exploration of the surroundings (Pulliam et al. 1982; Devereux et al. 2006; Valcarcel and Fernández-Juricic 2009). The higher the predation risk, the more these vigilance scans are expected to be frequent and last long (Sirot and Pays 2011). Allenby’s gerbils, *Gerbillus andersoni allenbyi*, allocate more time to vigilance and less to foraging in the presence of predators (Embar et al. 2011). Overall, in response to predator cues, mammals generally suppress non-defensive behaviours (e.g. feeding, grooming), at the profit of defensive behaviours such as vigilance (Apfelbach et al. 2005). Many studies have focused on how birds allocate their time between vigilance and other fitness-enhancing behaviours (Pulliam et al. 1982; Sirot and Pays 2011). In particular, there is a trade-off between vigilance and foraging, an activity which requires the animal to localise, manipulate and ingest an item. However, although vigilance quality is lower while birds are feeding head down, these behaviours are not strictly exclusive (Lima and Bednekoff 1999; Beauchamp 2003). The visual system of starlings, for example, enables them to collect partial information about social partners and predators while feeding when the environment is not visually obstructed (Devereux et al. 2006). This incompatibility, despite being partial, is likely to influence how birds allocate their attention (Shuttleworth 2010).

Because of this trade-off between vigilance and foraging, under higher predation risk animals are likely to suffer from a decrease in energetic income. One strategy to oppose this reduction is to form social aggregations, which when they refer to birds are often called flocks. The term flock refers to any homogenous aggregation of birds, and might arise from individuals being attracted to a same localized resource as well as from mutual attraction between individuals (Emlen 1952). Social aggregations have several

advantages regarding predator avoidance, the most studied one is called collective detection or the many-eyes hypothesis (Pulliam 1973; Clark and Mangel 1984). This theory is based on the idea that as the size of a group increases, there are more eyes (and other senses) scanning the environment for predators, and it is therefore expected that any one individual may devote less time to vigilance and benefit from the anti-predator behaviour of its conspecifics (Lima 1995). As a result, larger groups (up to a certain limit) generally have lower individual scanning rates and higher probability of predator detection (Lima 1999). A classic study in yellow-eyed juncos (*Junco phaeonotus*) shows that birds tend to form larger groups in the presence of predator cues and that these larger groups allowed individuals to spend less time scanning for predators (Caraco et al. 1980).

A number of other advantages are expected of social aggregations. The dilution effect states that the mere presence of n individuals within a same area forces predators to make a choice between them, and dilutes predation risk, as the chances for any individual of surviving the attack is $(n-1)/n$ assuming random selection (Bednekoff and Lima 1998; Beauchamp 2003). While in some cases the relative importance of risk dilution compared to other advantages can be ascertained (Beauchamp and Ruxton 2008). In most cases, collective detection and dilution effects are entwined and interact such that birds benefit from both phenomena at once when aggregating (Bednekoff and Lima 1998). Another benefit from aggregations, although mainly very large ones, is the confusion effect in which predators suffer a loss of success because of the difficulty to single out a single prey individual (Krause and Ruxton 2002). This strategy is especially prevalent in fast and agile preys (Jeschke and Tollrian 2007). For example, peregrine falcons, *Falco peregrinus*, are more successful when targeting individual starlings, *Sturnus vulgaris*, than large swarms (Zoratto et al. 2010), and starlings tend to aggregate into swarms more frequently when predation risk is higher (Carere et al. 2009).

Overall, it should be expected that invasive alien birds under control pressure will increase their vigilance, as this seems a widespread response to increased risk. To reduce the energetic costs of increased vigilance, those species that form aggregations, may form larger groups hence also benefitting from the risk dilution effect. However, it is interesting to note that while these strategies could be efficient for active 'predators' (i.e. shooters), they are unlikely to lead to increased survival to passive 'predators' such as traps and poison. Increased tendency to aggregate may even be deleterious in these

cases as they might lead birds to attempt to join those inside traps or foraging on poisoned food. Whether maladaptive responses such as these may arise will depend on the specificity and plasticity of anti-predator responses: either there is one general anti-predator response, or these responses can be tailored to certain risks, even if these risks have only been present for a short time on the evolutionary timescale.

4.3. Temporal and spatial shifts

When predation is more likely to happen at certain times or in certain places, there is scope for preys to avoid, on a small or large scale, these places and times. For example, when hunting is taking place, willow ptarmigans (*Lagopus lagopus*) stop using the open areas in their territory and instead used dense shrubs which provide cover (Brøseth and Pedersen 2010). Similarly, during the hunting season Brown bears (*Ursus arctos*) switch from diurnal to nocturnal activity which has scope to limit the fat reserves stored before hibernation begins (Ordiz et al. 2012). These small scale shifts have also been observed in response to control measures applied to invasive lionfish (*Pterois volitans*). Hunting by spear-fishers has driven the fish to hide deeper in the reef, particularly during the day, when most of the hunting takes place (Côté et al. 2014). In a majority of habitats, one sub-category is likely to be less accessible to predators (e.g. dense cover for ptarmigan hunters, deep reefs for lionfish spear-hunters), as a result, increased use of those areas will lead to significant decrease of capture success. Thus, small-scale temporal and spatial shifts can have dramatic impacts on control programs.

At a larger scale, prey species may, in some cases, be able to emigrate away from their current habitat or territory to avoid predators. This strategy should be particularly relevant in the context of predators with relatively poor mobility (Wooster and Sih 1995). In stream systems, large predators are usually confined to certain pools while smaller prey have the opportunity to navigate from one pool to the other and usually emigrate away from risky pools (Lima 1998). Intriguingly, while emigration is expected in response to increased risk, immigration has been observed in a number of controlled pest species. For example in Martinique, removing over 70% of lionfish populations did not impact the population significantly because of rapid re-colonization and recruitment (Trégarot and Maréchal 2014). In Tasmania, control of feral cats, *Felis catus*, even led to an increase of up to 211% of the number of individual cats at

experimental sites, possibly because of the arrival of new individuals after dominant territory-holders were removed (Lazenby et al. 2015). It hence seems that successful invasive species under sufficiently favorable conditions can use localized control efforts as ecological opportunities.

While overall, it may be expected that animals should move away from danger and that controlled species should hence leave controlled areas, this has received mixed support. While in some cases (e.g. willow ptarmigan) perceived risk has clearly led to avoidance, in some other cases (e.g. Tasmanian cats) increased mortality, probably by lowering competition and freeing up resources, has led to immigration in controlled areas. This might rely on how properties of the specific situation (e.g. level of risk, amount of resources, amount of alternative resources) influence the trade-off between staying and leaving a risky area. As a result, predicting whether invasive alien birds will tend to emigrate from controlled areas seems difficult.

4.4. Risk-taking behaviours

For an outside observer, watching a predator approach a prey, the initial assumption is usually that the prey has not yet detected the predator, which is referred to as the perceptual limit hypothesis (Ydenberg and Dill 1986). However, the economic hypothesis points to an alternative reason for which prey may not have fled yet; the benefits from leaving the patch (e.g. increased chances of survival to attack) may be inferior to the costs (e.g. leaving a valuable food source) (Ydenberg and Dill 1986). This economical hypothesis is at origin of a large field of research on flight initiation distance (i.e. FID), the distance at which a prey allows a predator to approach before fleeing. One key prediction of the model is that FID will increase with the risk of capture. A number of empirical studies have supported this prediction, showing animals flee sooner when they are in a risky environment, especially from predators from which they have received attacks in the past and that a number of factors increase perceived risk such as directness of approach and number of predators approaching (Stankowich and Blumstein 2005; Cooper Jr 2010). In the context of wildlife control, this has strong implications especially for active methods which require to approach an individual as these individuals might will flee much earlier when approached.

Another behaviour which is often taken to indicate risk-taking is neophobia; the tendency to avoid novel objects (Greenberg 1990). The dangerous niche hypothesis

states that one of the functions of neophobia is to protect animals from unknown dangers which might be particularly useful in high risk environments (Greenberg 2003). In line with this hypothesis, guppies respond differently to unknown odors depending on the level of risk of the environment in which they live. Guppies from high predation streams avoid novel predator odors as if they were confronted with a known predator odor, while guppies from low-risk streams do not show any avoidance of the novel stimulus (Brown et al. 2013). This suggests neophobia is plastic and can be induced or at least amplified by risk. As such, one predator can affect the success of others. Control programs will often use several methods in order to capture those individuals that have come to avoid one of the methods. Yet, this suggests that the use of a first method can condition the success of the second. In particular, this has potential for passive methods such as traps and nets which might be approached by less individuals once heightened predation risk is perceived.

5. Conclusion

The threat-sensitivity hypothesis (Helfman 1989) states prey should align the intensity of their anti-predator responses to the threat predators pose. Accordingly, invasive alien bird species that are the target of control practices are expected to show a range of behavioural and life-history adjustments to this risk.

First, this risk is likely to lead to overall more risk-averse behaviours, including reduced tendency to approach novel objects, reduced tendency to let other species approach and increased vigilance. This all comes at a cost, since time spent on anti-predator behaviours is not spent on other fitness-enhancing behaviours such as foraging and reproduction. Hence, while at first sight it may seem that behavioural adjustments will allow controlled birds to lessen their susceptibility to harvesting and hence decrease its efficiency; some life-history costs associated with anti-predator behaviours might intensify the apparent effect of harvesting. This is the basis of the concept of "hunting for fear" developed in the field of overabundant ungulate management: instead of maximizing mortality, hunting is here designed to maximize risk perceived by prey in order to amplify compensatory responses and hence minimize the species' impact (Cromsigt et al. 2013; Le Saout et al. 2014). Responses to harvesting are likely to depend on the scale at which it is applied, including whether it allows re-colonization from neighboring territories or whether some micro-habitats are less at risk. Importantly, how the species perceives the threat by which it is targeted will be one of

the key determinants of the responses observed, and the more at risk individuals perceive themselves, the more extreme compensatory responses are likely to be.

Additionally to a generalized decrease in risk taking, increased harvesting risk is also likely to elicit specific responses towards elements of the capture set up (e.g. equipment, location, personnel). Such a response is likely to arise through learning which can allow recognition of the dangerous elements. This learning does require that the targeted birds are able to associate a negative unconditioned stimulus (e.g. being handled by a human, or seeing a conspecific being captured) with said elements of the capture set up. Once this condition is filled, birds are likely to avoid the stimuli they learned about, and potentially perform other anti-predator behaviours (e.g. mobbing).

Overall, while an increase in anti-predator behaviour is most likely, it seems difficult to predict exactly which behavioural and life-history responses will arise in birds undergoing control, which is why I argue that control programs should sample behaviour as the program progresses. Most of the responses detailed above can have significant cascading effects on control programs, in particular on their apparent outcome. For example movement towards more dense vegetation may lead the species to be more cryptic to observers, and hence exaggerate the observed decrease in population. Learnt avoidance of the capture apparatus clearly has scope to jeopardize future control efforts.

6. Aims and structure of the thesis

The aim of this body of work is to investigate the question of behavioural responses to control programs in the specific case of the common myna, *Acridotheres tristis*.

This species, its introduction history and control measures applied are described in detail in chapter 1 (p 24). I present results from a set of questionnaires exploring presence and prevalence of control among the public and organizations of Eastern Australia. I was able to see which members of the public were most likely to be involved in discouraging mynas from approaching their property, and which were most likely to be involved in active control of the species. Additionally, these surveys allowed me to see where control of mynas was taking place and with which intensity.

Having established that interest in common myna control is strong, I then ask whether this practice may have an effect on behaviour of common myna populations targeted. Building on estimates of trapping pressure from these questionnaires, I went to

areas undergoing high and low trapping pressure. In these areas, ranging across two different regions, I was able to observe behavioural differences between free-ranging populations undergoing high and low harvesting risk as detailed in chapter 2 (p80).

The second part of this thesis investigates potential mechanisms explaining the differences observed in chapter 2. The first mechanism tested is selection through biased harvesting. In particular, among other behavioural traits, birds that are captured during control programs may have to be bold and exploratory enough to approach and enter a large foreign structure such as a trap. Thus there is scope for personality biased harvesting to arise where individuals with certain personalities are harvested while others are left to reproduce. This hypothesis was tested in Chapter 3 (p122). While no evidence for such biases was found, I also argue that potential methodological issues might explain this result.

In chapter 4 (p155), I then investigated whether learning might explain behavioural differences observed between areas under high and low trapping pressure. Common myna learning has been the object of a number of studies in captivity. I here tested in the field whether these birds would learn to avoid a patch after witnessing a simulated capture event, typical of what would be observed during a control program. Common mynas readily learnt to avoid the place where the capture event took place, and interestingly there was also evidence that they recognized the specific human that had performed the capture.

A general discussion (p179) of behavioural changes observed in response to control pressure and the potential underlying mechanisms follows. Specificity of the response to the threat is discussed and in particular whether the observed response may be the result of two separate behavioural components. Implications of my findings on common myna control and invasive alien species control in general is then discussed.

7. References

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CHAPTER 1. THE COMMON MYNA IN AUSTRALIA: KNOWN IMPACTS AND PREVALENCE OF MANAGEMENT

Abstract

This chapter describes the historical introduction and invasion of the common myna, *Acridotheres tristis*, alongside the motivations for, and status of, current practices in myna management in Australia. First, introduction history and known impacts of common mynas on wildlife and human activities in Australia and throughout the world are summarised, along with potential control methods and their success in eradicating mynas from islands. Second, I present results from questionnaires investigating preponderance of control practices and attitudes towards common mynas.

Common mynas were considered an issue in most localities. Trapping was the most used control method, but trapping pressure varied greatly between localities. The public survey revealed that respondents saw mynas frequently and in small numbers. Mynas and their nests were most present in most human-modified habitats. Two-thirds of respondents with mynas in their backyards attempted by one means or another to discourage the birds from entering their gardens, and 15% were involved in active reduction. People living in less modified habitats and with higher birding skills were most likely to be involved in these activities. Interestingly, while many members of the public use non-lethal management, this practice received little attention from local governments.

Overall, these results provide a backdrop on the current status of human predation pressure on mynas against which to evaluate the effects of such practices on myna behaviour in subsequent chapters.

1. Introduction

1.1. Description of the species

Common mynas, also called ‘Indian mynahs’, are a medium sized bird from the Sturnidae family. The species’ scientific name has been under some controversy, but the current consensus is to refer to it as *Acridotheres tristis* (Lovette et al. 2008; Zuccon et al. 2008), even though some authors have suggested the genus *Acridotheres* and *Sturnus* should be merged under the name *Sturnus* (Christidis and Boles 2008). The species will be referred as ‘mynas’ and ‘common mynas’ in this text from hereon after.

The name of the genus, *Acridotheres*, means grasshopper hunter, and while the species feeds largely on insects, it has an omnivorous diet that includes a range of items ranging from fruits, to small reptiles and human waste (Moeed 1976; Feare and Craig 1999; Ahmad and Sahi 2012). They live mostly in open habitats such as grasslands and woodlands, but also thrive in human-modified environments, especially cities (Feare and Craig 1999).

1.2. Introduction and distribution of common mynas

1.2.1. *Distribution and introduction history in the world*

Common mynas are native to central and southern Asia with a widespread distribution that ranges from Iran and Afghanistan to Thailand and Vietnam (Feare and Craig 1999). Their native range seems to be extending westwards with populations as far as Russia and Turkey, and southwards with populations in Malaysia and Singapore, although it is unclear to what extent this is due to natural range expansion or introductions (Long 1981; Feare and Craig 1999).

The mynas’ current worldwide distribution goes far beyond that of its native range because of numerous accidental (e.g. release of pet birds) and deliberate introduction events around the world. Deliberate introductions took place either for aesthetic reasons, such as were commonly done by acclimatisation societies in the 19th century, or for agricultural reasons, attempting to take advantage of the insectivorous diet of the bird in order to control pest insects (Long 1981). As a consequence, common mynas are now thought to be present on every continent (except Antarctica and South-America) and on many islands around the world (Feare and Craig 1999).

Deliberate releases were the cause of many of the early introduction events. The earliest of these introductions took place in 1755 when mynas were brought by the governor to Réunion island to control locusts (Long 1981). In the 18th and 19th century, the species was taken to many islands to control a range of agricultural pests such as wasps in Polynesia, cattle ticks in St Helena, grasshoppers in Mauritius, army worm in Hawaii, and other various insects in Madagascar, Ascension and the Seychelles (Long 1981; Feare and Craig 1999). These deliberate introductions were not limited to islands however, and by the end of the 19th century, mynas were present in Australia, South Africa (Peacock et al. 2007) and New-Zealand (Baker and Moeed 1979).

In Europe, their presence in the pet trade (Carrete and Tella 2008) is believed to have been the source of several independent accidental introductions in the Iberian peninsula (Saavedra et al. 2015), the north of France (Hars 1991; Dubois 2007) and England (Long 1981), which did not result in established populations. The DAISIE platform (Delivering Alien Invasive Species Inventories for Europe) states that they are also present in Italy (www.europe-aliens.org). To this date, the only well documented established population in continental Europe is around Lisbon, Portugal (Saavedra et al. 2015). Mynas are also quickly colonising the middle east (Holzapfel et al. 2006) and are spreading in Florida, USA (Pranty 2008).

1.2.2. Introduction history in Australia

Common mynas were introduced in several locations in Australia. They were first introduced to Melbourne, Victoria in 1863 to control insects and keep the city clean (Ryan 1906). In 1883, a number of birds were transported to Queensland to help combat the cane beetle in sugar-cane plantations (Chisholm 1919). Introduction into New South Wales is less documented, but they were present in Sydney by 1900 and in Newcastle by 1970 (Hone 1978). Mynas started being released in the Australian Capital territory in 1968, although dispersing individuals might have reached Canberra a few months before the first introductions took place (Gregory-Smith 1985).

Although not all introduction events were successful, some of these initial populations adapted well to their new environment, particularly in Melbourne. In Sydney there is evidence the population struggled to establish itself (Chisholm 1926; Hone 1978). This might reflect a similar ‘lag’ in population spread as the one observed

in Canberra, and is representative of the invasion pattern of many introduced species (Grarock et al. 2013b). Mynas are now common and widespread in Eastern Australia (New South Wales, Victoria and Queensland), and much of the range expansion that was predicted twenty years ago (Martin 1996) is now realized (Figure 1).

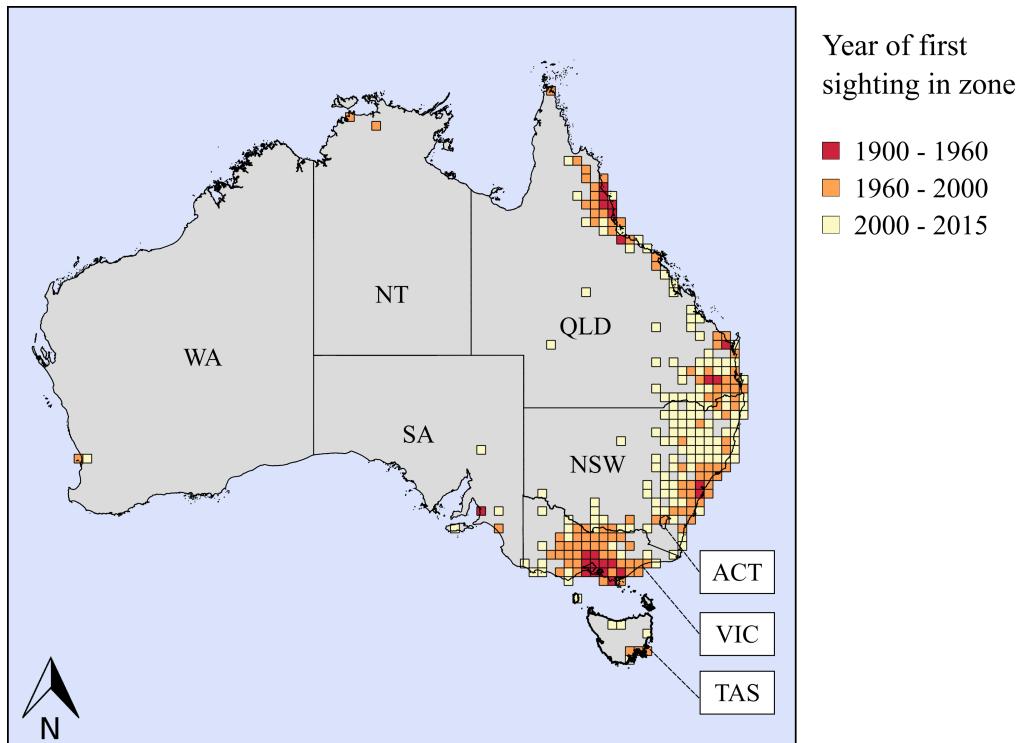


Figure 1 Map of the approximate time of arrival of common mynas in different regions of Australia. This map indicates the year of first sighting in each zone and hence shows spread from introduction points. Zones in which mynas have been present for longer appear in dark red. All sightings range from 1900 to 2015. Grey areas indicate no sighting was recorded in the database. Map created from a database including data from Bionet (www.bionet.nsw.gov.au) and from the Atlas of living Australia (www.ala.org.au).

1.3. Impacts of common mynas

1.3.1. Ecological impacts of common mynas in the world

The effects of common mynas depend strongly on the particular native wildlife present where they were introduced. On islands, mynas have had a particularly dramatic impact. There is evidence that they are capable of predating eggs of several species of sea birds: they are responsible for 25% of nest failures of sooty terns (*Onychoprion fuscata*) on Ascension island (Hughes et al. 2008), and for the destruction of 23% of wedge-tailed shearwater (*Puffinus pacificus*) eggs in Kauai, Hawaii (Byrd 1979). There

are also reports of myna predation of gull (*Larus*) eggs in New-Zealand and Noddie (*Anous*) eggs in the Seychelles (Feare and Craig 1999; Feare et al. 2015).

Egg predation is not the only means by which mynas affect bird populations. In French Polynesia, reproductive success of the endemic and endangered Tahiti Flycatcher (*Pomarea nigra*) is lower in territories where mynas are present (Blanvillain et al. 2003). The mechanism behind this phenomenon is unclear as there is no overlap in nesting sites and there is no evidence of nest predation (Thibault et al. 2002), it could hence be related to food competition or disturbance. In the Seychelles, mynas are presumed to be threats to a number of endangered and endemic species such as the magpie robin, *Copsychus sechellarum* (Komdeur 1996), and the Scops-owl, *Otus insularis* (Currie et al. 2004), mainly because of interference competition in terms of foraging and nesting. This goes to prove that mynas can have dramatic effects on islands.

In New-Zealand, control of common myna in a small island led to an increase in abundance of some species of native birds, suggesting mynas had been keeping their numbers at bay (Tindall et al. 2007). However, a later study showed that small garden birds on the mainland had no propensity to avoid common mynas (Borowske et al. 2012), which suggests the effect on native wildlife might not be through aggressive interactions but instead through interference competition or other mechanisms.

Mynas can also have effects beyond bird populations, and are believed to be involved in the dispersal of the introduced weed *Lantana camara* in Hawaii (Bomford and Sinclair 2002; Pimentel et al. 2005).

Altogether, this suggests that common mynas pose a significant threat to many island ecosystems. However, while non-native species are often reported to have dramatic ecological impacts on islands, this is much less often the case on continents (Bauer and Woog 2011). This bids the question of whether mynas are as much of a threat on continents than islands.

1.3.2. Threat to native wildlife in Australia

In Australia, concerns about impacts of common mynas on native wildlife, and birds in particular, are centred around competition for three resources: food, territory and nesting-hollows (Grarock et al. 2012). There have been suggestions that common mynas are not very good competitors when it comes to food. In Newcastle, they do not

perform more aggressive behaviors or succeed more in displacing other species around food patches than native species (Haythorpe et al. 2012; Sol et al. 2012). Similarly, in Melbourne (Crisp and Lill 2006) and Sydney (Lowe et al. 2011), aggression around food by mynas was not particularly high.

However competition is a complex phenomenon that cannot be solely measured by aggression. Instead, it is common practice to look at the co-occurrence of species where negative correlations can be taken to indicate avoidance and/or competition between species. Such studies show that in Sydney, common mynas were not negatively associated with native birds, suggesting they are not strong competitors (Parsons et al. 2006). Additionally, when long-term data are available, there is scope to compare occurrence and abundance of species before and after the species of interest is present or spreads. Such an approach was used by Grarock et al. (2012), in a study that showed that the increase in common myna numbers in Canberra was synchronous to a decrease in many small bird species. However, this does not necessarily indicate that mynas are outcompeting these small birds, instead both phenomena (i.e. increase in myna and decrease in small birds) could be a consequence of a third one. This idea is supported by a later study that found that both the increase in common myna numbers and the decrease of small bird numbers were driven by habitat modification, in particular urbanization and decrease in tree density (Grarock et al. 2014a).

Much of Australia's wildlife relies on tree cavities for breeding. It is estimated that over 15% of Australian birds use hollows for nesting which is more than in any other region in the world (Gibbons and Lindenmayer 2002). However, very few animals excavate these cavities (i.e. primary cavity nesters), which means a lot of animals are dependent on naturally occurring cavities that appear mainly in old trees (Gibbons and Lindenmayer 2002). The high dependence of the native fauna on this resource, coupled with the hollow nesting habits of common mynas, has led to much concern towards their potential to monopolise cavities. Particularly so, because cavity bearing trees are a decreasing resource in cities due to urban planning (Harper et al. 2005a) and in forests due to forestry practices and logging (Newton 1994; Politi et al. 2010).

Most studies estimating impact of mynas on other hollow-nesting species are based on monitoring of nest occupancy to estimate resource monopolisation. Nest-box occupancy by mynas is high in urban vegetation remnants in Canberra (Pell and Tidemann 1997) and Melbourne (Harper et al. 2005b). However the extent to which this

represents a threat to native wildlife is unclear. First, high monopolisation of nesting sites by mynas is mostly restricted to low tree-density zones which might be a less preferred habitat for native animals (Grarock et al. 2013a). Second, this trend of high monopolisation rates is not found in natural hollows. In Sydney, few natural hollows are occupied by mynas and those that are, are restricted to residential areas (Lowe et al. 2011; Davis et al. 2013). A lack of studies in natural hollows in Canberra and in nest-boxes in the Sydney region is apparent and needs to be addressed in order to investigate whether there are regional differences in the impact of common mynas, which could be due to differences in dominant vegetation types (Lowe et al. 2011), or whether their effect is particularly high in human provided nest-boxes. Overall, such diverging patterns command further investigation on the effect of common mynas (Baker et al. 2014).

While resource monopolisation studies assume that the use of nesting hollows by mynas prevent their use by other species, it is rarely proven. There are anecdotal observations reporting evictions of native species from nesting hollows by mynas (Wright and Wright 1991), which confirm the use of hollows by mynas can be at the expense of native species. Moreover, in Canberra, two studies have found native parrot nests replaced by myna nests in a timeframe that suggest takeovers (Pell and Tidemann 1997; Grarock et al. 2013a). Altogether common mynas seem capable of outcompeting certain native species for nesting hollows. In support of this idea, long-term bird-surveys in Canberra suggest that mynas have a negative impact on the long-term abundance of some, but not all, avian cavity nesters (Grarock et al. 2012).

Overall, it seems that mynas are capable of outcompeting at least a subset of Australian native cavity-nesters. However, there is scope for region and type of cavity (i.e. manmade or natural) to influence the level of threat mynas cause which warrants further investigation. More importantly, the potential of rampant habitat modification to be in part responsible for the decrease in native cavity-nesters (Grarock et al. 2013a) needs to be systematically assessed in studies of common myna impacts.

Mynas could present risks to the native fauna that go beyond those of outcompeting them for resources. Common mynas are known to carry two malarial blood parasites: *Plasmodium* spp. (50% prevalence in the introduced range, 0 to 80% depending on country) and *Haemoproteus* spp. (8% prevalence in the introduced range, 0 to 19% depending on country) (Ishtiaq et al. 2006). In Australia, mynas have a 22%

prevalence of *Plasmodium* and a 2% prevalence of *Haemoproteus*, which means they carry more *Plasmodium* but less *Haemoproteus* than Australian natives (Clark et al. 2015). This brings concerns that mynas may act as a reservoir of potentially dangerous lineages of *Plasmodium* that can infect native species (Clark et al. 2015). In Hawaii, mynas are one of the potential original hosts of *Plasmodium relictum* which has been implicated in the decline of many native birds (Beadell et al. 2006). It is important to note that although common mynas are hosts to a number of parasites, they are often not the only introduced species to carry them in a certain area (Beadell et al. 2006). Moreover, the effective rate of parasite transmission to native species is difficult to establish and hence the impact of the species in terms of health hazard, although potentially devastating, is hard to quantify.

1.3.3. Impacts on agriculture

In many countries where mynas were introduced to control agricultural pests, they have ironically become a pest themselves by eating the crops, often fruits, they were meant to protect (Feare and Craig 1999). In Australia and New Zealand they are particularly problematic regarding grapes, berries, figs and pears (Dawson and Bull 1970; Tracey et al. 2007). They can also feed on certain cereals crops when these are close to urban areas (Tracey et al. 2007).

1.3.4. Nuisance to Humans

Common mynas often live in close association with humans hence increasing the likelihood of human-wildlife conflict. Their habit of communal roosting in particular is an important source of nuisance as up to several hundred individuals assemble in trees in the evening to spend the night. During this process, mynas are particularly vocal (Counsilman 1971), and the noise produced along with the large quantities of dropping is a source of inconvenience for residents (Yap et al. 2002; Yap and Sodhi 2004). Additionally to sound and visual nuisance, there are concerns that fouling around roost locations presents a health hazard, such as histoplasmosis (i.e. a fungal infection), to the surrounding residents (Yap et al. 2002; Adams et al. 2005).

Across their range they commonly nest under roofs and in various cavities on human constructions (Long 1981) which can damage buildings and block gutters (Bomford and Sinclair 2002). This habit of nesting in proximity to humans also presents

a health hazard as mynas carry a bird mite, *Ornithonyssus bursia*. There have been cases of this mite spreading into houses from nests, causing irritations to occupants through bites (Zimmerman 1944; Leong and Grace 2008).

Overall, there has been very little effort to quantify the level of nuisance and health hazard represented by mynas to humans. This is of particular importance as setting a level of acceptable damage and nuisance is a key step in any maintenance control program.

1.3.5. The need for more research on myna impact in Australia

Overall, despite a lot of attention directed at the species, few studies have examined in depth the impact of common mynas on Australian wildlife. In 2014, the Australian invasive animal cooperative research centre stated that "the perceived impacts of the common myna are often based on unreliable information, and there is a lack of scientific research that confirms the birds actual impacts" (Invasive Animals CRC 2014).

Invasive, and introduced species in general, have bad press. They are often the target of management based on the solely on their origin, despite the fact this does not entail that they have a negative impact on the environment (Davis et al. 2011). Some scientists suggest that native species, such as the noisy miner (*Manorina melanocephala*), which has profound deleterious effects on the avifaunal communities across Eastern Australia (Mac Nally et al. 2012; Maron et al. 2013), could be a greater threat to native biodiversity than common mynas (Haythorpe et al. 2013). Interestingly, not only do noisy miners have a number of shared morphological attributes with the common myna (e.g. similar size, yellow eye patch, black head), they also have very similar sounding names. This makes the two species very likely to be confused with one another and has lead some authors to suggest that the perceived high level of aggression of common mynas by the community might be caused by misidentifications (Lowe et al. 2011).

Common mynas can be considered a synanthrope species (*sensu* Johnston 2001), which means they live in close association with, and to some extent rely on, humans. Accordingly, a number of studies have found that they are more common, and sometimes limited to, urbanised habitats (Wood 1996; White, Antos, et al. 2005; Crisp and Lill 2006; van Rensburg et al. 2009; Lowe et al. 2011; Sol et al. 2012; Grarock et

al. 2014a; Old et al. 2014), where traditionally bird biomass is high but not very diverse (Clergeau et al. 1998; Chace and Walsh 2006). This has important implications as it could mean risks to native wildlife from myna invasion are mostly limited to a few urban adapters. Moreover, the fact that they occur mainly in urbanised habitats, makes it difficult to disentangle effects due to common myna from those due to the anthropisation of the habitat. In line with this, a recent study found that the negative correlation between the presence of nesting mynas and native parrots was mostly explained by strong differences in habitat preferences, where mynas preferred sparse tree cover while natives preferred dense tree cover (Grarock et al. 2013a).

1.4. Common myna management

1.4.1. Official international status of common mynas

The invasive species specialist group (ISSG), a specialist group of the world conservation union (IUCN), has listed a hundred of the world's worst invasive alien species based on their impact on biodiversity and human activities and their ability to illustrate important aspects of the invasive species problem (Lowe et al. 2000). This list included only three bird species among which the common myna (and its close relative, the European starling) was present, revealing the international importance of the species. Additionally, further analysis of this list revealed that common mynas, by virtue of having extremely high impact in a large type of environmental and economic impact categories (e.g. competition, wildlife diseases, agriculture, infrastructures...), was the bird species most deserving to be present in the list (Kumschick et al. 2015). However, not all regions in the world are treating the threat with the same importance. Thus far, it looks like the common myna is absent from reports preparing the official 'list of species of concern' that will be announced in 2016 by the European Commission (Roy and Scalera 2015).

1.4.2. Official status of common mynas in Australia

Governments have an important role in pest species management. By adopting certain schemes and policies, they can fund control programs and/or incentivise private landholders to participate in management practices (Olsen 1998; Myers et al. 2000). Australia is a federal country and states can differ in the status they give to a species. For example, the rainbow lorikeet (*Trichoglossus haematodus*) is native to coastal

regions across Northern and Eastern Australia, but following recent introductions, it has been declared a high priority pest in Western Australia and Tasmania (Latitude 42 2011).

Table 1 Establishment status and official pest status of the common myna in each Australian state as of December 2015. Note that I here report status for a single government agency, yet several can be implicated in dealing with pest species. For a list of all agencies that can have a role in pest bird management see Tracey et al. (2007, p 226-237).

State / Territory	Established	Official status (actions undertaken)	Source of information
Federal (Australia)	yes	'low interest species', class3*	www.environment.gov.au
Australian Capital territory (ACT)	yes	'pest animal'	http://www.environment.act.gov.au
New South Wales (NSW)	yes	'non-indigenous animal category 4'**	www.dpi.nsw.gov.au
Northern Territory (NT)	Not established	'prohibited entrants'	www.parksandwildlife.nt.gov.au
Queensland (QLD)	yes	'not a declared pest species'	www.daf.qld.gov.au
South Australia (SA)	not established, a few incursions	'alert animal pest' (exclusion, alert on entry)	http://pir.sa.gov.au
Tasmania (TAS)	not established, a few incursions	'restricted' (exclusion, alert on entry)	http://dpipwe.tas.gov.au
Victoria (VIC)	yes	'not a Declared Pest Animal'	http://agriculture.vic.gov.au
Western Australia (WA)	not established, a few incursions	'prohibited' (exclusion, alert on entry)	www.agric.wa.gov.au

* All exotic birds in Australia have been classified as either 'high interest' or 'low interest' based on their pest and disease risk and the potential for illegal trade.

** category 4: animals that would be unlikely to present a threat to the environment, agriculture or persons or greatly worsen an existing threat if they escaped into the wild, the importation and keeping of which are not restricted

In Australia, there are no federal guidelines as to how to deal with the question of mynas. At the state level, only states in which the myna is not established have a clear strategy concerning the species, mostly focused around preventing intrusions (Table 1). In states in which the bird is established, they are not listed as a pest or species that represents an important threat (Table 1).

1.4.3. Perception by the public

While government agencies have an important role in guiding control programs, public understanding and acceptance is also key to their success (Olsen 1998; Myers et al. 2000). There is overall a strong negative public perception of common mynas in Australia, in 2005 they were elected 'worst pest of Australia' by viewers of a popular TV channel (ABC 2005), and they are the bird that people are most unhappy to see in their garden according to a survey in Victoria (Shaw 2014). On the other hand, mynas

were not given a high importance among pest species in the upper Hunter Valley, a rural area of NSW (Fitzgerald and Wilkinson 2009).

It seems there is also a lot of uncertainty around the question of common mynas. In Victoria, 38% of people considered the common myna to be a pest while 20% considered it was not, leaving 42% undecided (Johnston and Marks 1997). Overall, in this survey a large proportion of respondents remained undecided regarding questions about pest birds reflecting a high uncertainty about the topic. This could be linked to the fact that birds are one of the taxonomic groups for which people are least likely to support control programs (Bremner and Park 2007). In Victoria, eradication was deemed the most appropriate level of management for common mynas, followed by controlling population numbers and no action at all, and preferred control techniques for the species were biological control, trapping, poisoning and shooting (Johnston and Marks 1997). As discussed in the section below however, with our current knowledge, eradication of common mynas in mainland Australia is not a realistic goal. This, along with the public uncertainty around pest birds, suggests there is a need for more information on common mynas. This is an important issue as people that have better knowledge and awareness of conservation issues and control programs are the most likely to support control programs (Bremner and Park 2007).

1.5. Methods available for common myna management

1.5.1. *Non-lethal methods*

Exclusion and scaring methods

Exclusion and scaring do not contribute to control of populations *per se* but can be used in the context of localised problems in particular in the agricultural context (Tracey et al. 2007; Tracey 2012). These methods aim to exclude birds from a particular area through chemical repellents, scaring devices and mechanic barriers (e.g. nets), and are usually considered specifically for damage reduction. These methods are also used in an urban context to displace certain bird aggregations that cause particular problems. For example urban passerines often form large and noisy roosts that can be scared away by the use of alarm call playbacks or explosion noises (Adams et al. 2005).

Habitat management

Habitat management has a lot of potential for common myna control, in particular targeting their foraging and nesting habits. Reduction of the availability of human waste, through increased protection of bins and more regular cleaning showed promising results in Singapore (Yap et al. 2002). The reduction of available nest opportunities through blocking of access to cavities in man-made structures (e.g. eaves, gutters) is recommended by several control programs across Australia although its efficiency remains to be tested.

Another avenue for habitat modifications directed at common mynas is to target roosts that disturb local residents. For example trimming and pruning of roost trees was successful in displacing a few communal roosting species including starlings in Texas (Good and Johnson 1976) and mynas in Singapore (Yap et al. 2002). While this not a practical strategy to use on a broad scale, it has a lot of potential for displacing birds from a few problematic roosts in cities in the short term, in particular in combination with bio-acoustic scaring techniques, and encouragement to plant tree species in which birds are less likely to roost (Yap and Sodhi 2004).

Overall, vegetation management could play an important role in myna control. Remnants of native vegetation support much of the indigenous fauna in urban Australia (White, Antos, et al. 2005) and there is evidence that cities containing more native vegetation retain more native birds (Chace and Walsh 2006). This suggests there is scope for urban planners to influence bird communities present in the city, and hence for habitat management to influence suitability of habitat for common mynas. For example, mynas show a strong preference for areas with low tree density (Grarock et al. 2013a), and it is suggested that limiting the presence of mown grass might limit feeding resources and improve control efficiency (Feare et al. 2016).

Fertility control

Bird fertility can be controlled either through the ingestion of oral contraceptives or destruction of eggs (Tracey et al. 2007). Destruction of eggs is likely to elicit production of a new clutch, hence methods that prevent hatching without removing the egg (such as oil applications) are preferred. Overall, fertility control through contraceptives is difficult because chemicals used are rarely specific to the target species and often require doses to be regularly administered to each individual

(Olsen 1998; Tracey et al. 2007). Research is currently underway to establish a reliable delivery mechanism that targets common mynas (Griffin and Rodger, pers. com.).

Achievement of fertility control of pest species is a highly desirable goal as there is strong community pressure against lethal techniques (Bomford and O'Brien 1992). The main risks are due to difficulty to find a target-specific drug and delivery mechanism, hence presenting important potential effects on non-target species, additionally there can be side-effects of the used chemical (Bomford and O'Brien 1992).

1.5.2. Short note on ethical considerations of lethal control

Conservation science is based on the moral and ethical assumption that species, communities and ecosystems should be conserved. Often if a vulnerable species is negatively affected by another species, the latter will be the target of lethal management. Some authors have made efforts to remind conservationists that, beyond the population or ecosystem to which they belong, individual animals lives have an intrinsic value and that sentient animals should only be killed if benefits to the ecosystem are, as much as ecological uncertainty allows it, assured (Vucetich and Nelson 2007; Ramp and Bekoff 2015; Wallach et al. 2015). On the other hand, others caution that the decision not to act on an identified threat to a vulnerable species, and hence letting them die, also raises ethical issues (Russell et al. 2015). Thus, although the importance of conservation science is well recognized, there are opposing views as to whether the welfare of species should systematically put above that of individuals that highlight the difficulty of critically integrating ethical issues and wildlife conservation.

These same considerations also apply in the case of species that interfere with human goals or safety causing human-wildlife conflicts such as agricultural pests (Madden 2004). One example of such a conflict takes place in suburbia across Australia, where during the breeding season Australian magpies (*Gymnorhina tibicen*) attack pedestrians and cyclists who pass in proximity of their nest (Jones and Thomas 1999). Most common management activities are information campaigns and punctual shooting of aggressive birds (Jones and Thomas 1999). Yet the ethical issue of culling magpies should be carefully weighted against costs and risks, as well as public perception associated with culling and its alternatives.

In the context of invasive species, preventing species from arriving in novel locations is the most effective, economical and ethical strategy (Henderson et al. 2011).

However, conservation practitioners and scientists often have to deal with situations in later stages of the invasion process, when species are already established. In this case ethical issues are mostly related to justification (“why should this be done?”) and outcomes (“what happens if the goal is not achieved?”), but there is also scope to apply the “precautionary principle” in cases where sufficient scientific evidence has not yet been gathered (Cowan and Warburton 2011). The general rule is that benefits have to outweigh the harms (Yeates 2010), therefore acceptable methods depend on the objectives. For example, although eradication have been achieved on islands, this has rarely been the case on continents, especially for well established species (Bomford and O'Brien 1995). This means that under those conditions, long-term maintenance control of populations is the norm, which is likely to involve different ethical considerations than when eradication is possible. In particular, gathering evidence that reduced abundance can elicit significant benefits should condition implementation of such programs.

1.5.3. Live traps

Cage traps

The most widely used control method for common mynas is trapping with walk-in baited cage traps. Mynas are attracted to bait placed on the floor of the trap and enter this 'foraging cage' by walking through a funnel-shaped entrance (Tidemann 2005). Birds then fly into a 'holding cage', through puzzle-valves that prevent exits. The holding cage often serves to contain live decoys or 'caller birds' which are captive held common mynas used to attract their free ranging conspecifics, a simpler alternative is sometimes to use mirrors to mimic conspecific presence in the cage. The trap achieves relatively high target-specificity through size of entrance, choice of bait and overall design (Tidemann 2005). Multiple variations around this design are commonly used around the world (Saavedra 2010). Other designs are also used, such as a walk-in cage traps that are activated remotely by the trapper pulling on a string (Canning 2011).

All traps used in common myna control are live traps that birds enter without getting injured. Sudden confinement can however lead to distress and there is a risk of injury for birds trying to escape, there is also a risk of harm from other captured birds and predators outside the trap, all underlying the need for regular monitoring of traps (Sharp 2012b). In the case of non-target birds being captured, a careful inspection

should take place to ensure birds are released in good condition (Sharp 2012b). Welfare of birds in traps is usually acceptable as long as they are left in the trap for a minimal period of time and the holding area provides sufficient space, protection from elements (sun, wind and rain), food and water (RSPCA 2014). Most traps used for myna control will contain caller birds such that social isolation is seldom an issue.

Once captured, euthanasia can be performed using three methods: cervical dislocation, inhalation of lethal doses of carbon dioxide (CO_2) or overdose of barbiturate (Sharp 2012b). All methods are only humane if performed by competent trained operators and should be done according to Australian standard operating procedures (Sharp 2012b). The use of carbon monoxide (CO) from petrol engine exhaust is more controversial, while it is viewed as a cheap, practical and humane method by some (Tidemann and King 2009), there are concerns in particular due to variability of age and condition of engines used (Sharp 2012b; RSPCA 2014).

One challenge of live traps in urban environments, where mynas are often present, is the fact that habitat is fragmented into small privately owned parcels and time must hence be spent seeking permission to use that land (Adams et al. 2005). Additionally these environments present risks for the equipment in terms of theft and vandalism which must be minimised by careful location selection and time of operation (Adams et al. 2005). Despite these challenges, most people engaging in myna control for wildlife protection, find trapping to be the most efficient method (Saavedra 2010; Canning 2011; Feare et al. 2016). In the context of crop protection however, trapping seems to have poor efficiency removing birds and preventing damage, although this could be related to poor operator skill (Tracey et al. 2007).

Whoosh nets

‘Whoosh nests’, also called ‘pull nets’, are a type of net trap that attempts to take advantage of the tendency of certain bird species to flock such that entire groups of birds can be caught at once. Birds are attracted to a target area by bait. A net is laid on the ground, attached to two stretched elastics such that once the operator activates the trigger mechanism, the elastics pull the net to cover the target area, hence capturing the group of birds feeding on the bait. Smaller ‘self-contained’ versions with solid frames and springs can also be used.

This method is quite time consuming as it requires a period of pre-baiting and extremely regular monitoring (if the trap has a self-trigger mechanism) or constant presence (if the trap must be triggered manually). Target animals are unlikely to sustain important injuries as they are restrained by soft material (Sharp and McLeod 2012); however, there are risks related to entanglement in the net. Mynas are small birds particularly sensitive to over-heating, and it is hence recommended that the operator be present at all times so that target birds can be euthanatized rapidly and non-target species released immediately. Welfare considerations regarding euthanasia are the same as for traps (see above).

Other traps

An attempt to use the mynas' roosting behaviour in order to capture and then put down large numbers has been trialled in the past (Tidemann 2010). The set up consisted of two 15 m high masts, mounted on trailers that supported a large net that could be released onto a tree. However testing revealed the set up was impractical mainly because it had considerable wind load and was very difficult to operate.

1.5.4. Poison

Poisoning has the potential to eliminate a large number of individuals with very little effort. However it presents high risks to non-target species, through direct consumption and secondary effects in the food chain, and hence requires careful preparation. In particular choosing the bait, the chemical concentration and the placement of the bait are very important steps (Olsen 1998). An additional concern is that there is often little public support to the use of poison (Fraser 2006; Bremner and Park 2007).

Mynas can be poisoned using starlicide® (DRC-1339, 3-chloro-p-toluidine hydrochloride) which was originally developed to kill European starlings, *Sturnus vulgaris*, in North America (Feare 2010). This poison has been used effectively in some control programs (Millett et al. 2004). But there are questions around the sustainability of this method in particular because of concerns around bait aversion (Feare 2010).

Starlicide has the advantage of presenting low toxicity towards a range of non-target birds and mammals, and being metabolized quickly such that consumption of poisoned individuals by predators poses few risks (Tracey et al. 2007). Humaneness of poisons is based on behavioural, biochemical and pathological criteria (Sharp and

Saunders 2011). Birds display few signs of distress after starlicide ingestion, and show no signs of pathology, however poisons can have symptoms that conceal behavioural and physiological distress indicators making their humaneness particularly difficult to assess (Tracey et al. 2007).

Another poison available to control mynas is alpha-chloralose which is a sedative. Although high doses can be lethal, it is possible to use small doses so that non-targets can be revived while target species are collected to be put down (Tracey et al. 2007). This technique was successfully used in 2004 in South-Australia, where mynas are not yet established, to capture a family group (Tracey et al. 2007). Other poisons used on birds exist (Tracey et al. 2007) but to my knowledge have not been trialled or used on common mynas.

1.5.5. Capture at nest boxes

Capture of pairs at nest boxes took place in the Seychelles by fitting fishing-line nooses above the entry of boxes known to be occupied by mynas (Millett et al. 2004; Canning 2011). When birds attempted to enter the box, the noose would fit around their neck and get more tight as they pulled on the string and attempted to escape. While great care must be taken with such a technique that nooses are only set up once occupant species has clearly been established, this method requires little effort and often captures both mates.

Another nest-box capture methodology was trialled in Australia in which the entrance of the nest was blocked while cooled gas from a small engine (carbon monoxide) was introduced (Tidemann et al. 2011). This method allows for nest occupant species to be determined on the spot and hence presents little risk to non target species. Trials were performed during the night such that the sitting female was reluctant to fly, but could hence only lead to the death of one parent along with the clutch.

Strangulation of mynas on nooses is likely to elicit high levels of distress, and time between capture and death can vary greatly. As time to death is the key criterion to determine humaneness of ‘kill traps’ (Sharp and Saunders 2011), it is unlikely that this method can be considered as humane. Euthanasia in nest boxes by introduction of gas seemed to elicit few distress responses and time to immobility in adults was around 1.5 minutes (Tidemann et al. 2011). Time to immobility was longer for fledglings,

reflecting their high tolerance to hypoxia, and they hence had to be euthanized manually (Tidemann et al. 2011). Concerns about the type of gas used are the same as for traps (see above). Eggs should preferably be destroyed by cooling or freezing them to under 4°C for at least 4 hours (Sharp 2012b).

1.5.6. Shooting

Shooting has been used in several programs (Saavedra 2010; Canning 2011; Feare et al. 2016) and it is usually recommended as a supplement once another method has already lowered numbers, in particular because mynas have the potential to become wary. It can also be used as a scaring strategy to disperse birds congregated in certain area (Sharp 2012a).

Shooting has high target-specificity and presents little risks to non-target species, except in the case of multi-species flocks. There are welfare concerns associated with shooting, especially in cases where injured animals cannot be found and death ascertained (Olsen 1998). This is why shooting is only considered humane when carried out by highly trained personnel with appropriate equipment, such that few birds are injured instead of killed. Shooting is considered more humane than cage-trapping and net-trapping, particularly when the latter requires handling (Fraser 2006; Sharp and Saunders 2011).

1.5.7. Integrative pest management

The various methods listed above differ in their ease of use and effort required. Most successful programs (see section below) however, advocate the use of several methods so that birds that develop an aversion for one method can be caught or killed using another (Saavedra 2010; Canning 2011). This is in line with the principles of integrative pest management (IPM) which advocate for a careful and reasoned selection and combination of control methods that maximize benefits to society and the environment (Wittenberg and Cock 2001; Dhawan and Peshin 2009).

IPM does not only focus on optimally combining control techniques with each other, it also stresses the need to take into account the whole ecosystem (Wittenberg and Cock 2001; Dhawan and Peshin 2009). Once in a new environment, invasive species interact with other species, native and invasive alike. These complex and dynamic interactions shape the ecosystem. As such, simply removing one 'troublesome' species

can have cascading effects on the rest of the ecosystem. These can include a fast recovery from native threatened populations, but in some cases can result in increased damage to the ecosystem (Zavaleta et al. 2001; Courchamp et al. 2003). For example, control of rabbits (*Oryctolagus cuniculus*) in New-Zealand is suspected to have caused prey-switching of predators that used to hunt rabbits, such as cats (*Felis catus*), towards vulnerable shorebirds (Dowding and Murphy 2001). Therefore, scientists increasingly recommend that managers take into account the fact that ecosystems are under multiple, often interacting, threats which all need to be integrated in management plans (Doherty et al. 2015). In order to account for such processes, managers need to engage in careful monitoring of their system. Such monitoring is not only vital to predict potential side-effects of the methods used, it is essential to assess success of the program (Courchamp et al. 2003).

Overall, the role of IPM is to encourage managers to include compatible methods into a cohesive strategy that takes into account the whole ecosystem. Such an approach is likely to benefit common myna control as the species is mostly present in habitats that are under significant anthropic pressure, such that the impact of the bird on the ecosystem is likely to co-occur with other threats such as increased noisy miner abundance. Additionally, this approach would lead control programs to set clear objectives in terms of target abundance which to date is mostly lacking (Grarock et al. 2014b), despite the fact that setting clear goals is an essential aspect of sustained bird control (Tracey et al. 2007).

1.6. How successful are control and eradication attempts ?

There is a general consensus that eradication is only possible under some specific circumstances such as small localized populations (Bomford and O'Brien 1995; Myers et al. 2000; Zavaleta et al. 2001). Factors such as mobility, wide distribution, high breeding rates and costs of operation mean that often eradication of pest birds an unrealistic goal (Tracey et al. 2007). As such, in Australia the target of myna control is to keep numbers at levels where their undesirable effects are deemed ‘acceptable’ (even though this acceptable level is yet to be clearly defined) and to prevent its spread to new areas. The CIMAG (Canberra Indian Myna Action Group) is a community-led group that formed in 2006 with the objective of reducing myna abundance in Canberra. The group has captured over 53,000 birds in the nine years since their creation (CIMAG

2015). This was mainly achieved through the use of walk-in baited traps by volunteers, and has been supplemented over the last two years by nest destruction (CIMAG 2015). There has been a decrease in abundance of the myna in the Canberra region during the time this program has been active, however there is evidence that the impact of trapping on abundance is mostly limited to fine spatial scales (1km^2) and is not significant at larger scales (Grarock et al. 2014b). While the CIMAG was the first control program of importance to take place in Australia, a number of community-led groups and council-led groups are now active within the distribution area of common mynas.

Table 2 Common myna control efforts on islands and outcomes achieved

Island (year)	Surface (ha)	methods	birds culled (initial population)	outcome
<i>Control efforts in Seychelles, Indian Ocean (Millett et al. 2004)</i>				
Cousine (1995)	23	trapping, shooting	NA	reduction
Cousin (2000-2002)	27	nest trapping, shooting	5 (6-10)	eradication
Aride (1993-1994)	63	shooting	16 (NA)	eradication
Denis (2001)	143	poisoning, shooting	40-60 rem. ^a (300-350)	reduction
Fregate (1993-2002)	219	nest trapping, shooting	1015 ^b (400-600)	reduction
<i>Control efforts in Seychelles, Indian Ocean (Canning 2011)</i>				
Fregate (2010-2011)	219	trapping, shooting, nest trapping	745 (NA)	eradication
<i>Control efforts in Seychelles, Indian Ocean (Feare et al. 2016)</i>				
Denis (2010-2015)	143	trapping, shooting	1186 (921) ^b	eradication
<i>Control efforts in Coastal islands of New-Zealand (Tindall et al. 2007)</i>				
Moturoa (1995)	162	trapping, poisoning	457 (NA)	reduction
<i>Control efforts in Atlantic and Mediterranean islands (Saavedra 2010)</i>				
Ascension (2009)	9,100	trapping	623 (1,100)	reduction
St Helena (2009)	12,100	trapping, poisoning	351 (8-10,000)	reduction
Mallorca (2006)	20,800	trapping	10 (12)	eradication
Gran Canaria (2006)	156,000	trapping	3 (3)	eradication
Fuertaventura (2008)	165,900	trapping	24 (30)	reduction
Tenerife (1999-2000)	203,400	trapping, shooting	10 (12)	eradication

^a because poisoning was used and only a fraction of bodies were recovered number of birds culled is uncertain, hence number of birds remaining is presented

^b note that estimated population is at start of control, because control took place over several years, birds had time to produce offspring.

Several attempts have been made to eradicate mynas from islands around the world (Table 2). With two exceptions, only small populations (under 50 birds) have been successfully eradicated. Eradication of the larger populations (over 100 birds) was possible thanks to strong sustained efforts during the period of the program and use of

various methods to complement each other (Canning 2011; Feare et al. 2016). Overall poisoning seems to be the least inefficient method, as none of the programs that used it were successful, while those using at least trapping and shooting together were successful 3 out of 4 times (Table 2).

1.7. Aim of the chapter

The number of control programs described above comes to show that there is significant interest in managing common mynas. Yet these can arise from different levels of organisations, and even from individuals. Overall, in Eastern Australia, control efforts against common mynas are on the rise but have so far been uncoordinated. Thus, these efforts are likely to vary locally depending on a number of factors such as available resources and community interest. To date, little has been done to document the intensity of these control efforts across the zone in which they occur.

In mainland Australia, where eradication is unlikely to be achievable, programs have to engage in long-term maintenance control of the species. These types of programs have to be active over long durations and hence require substantial support whether financial, or in terms of volunteers or both. This means that the general rule that involvement and understanding of the situation by government agencies and the public are key to the success of control programs (Olsen 1998), is even more important in these cases where such support is required for long periods of time. Because there is little focus on mynas as a pest species of importance at the state and at the federal level in Australia (see section 1.4.2), in addition to that of the public, the support must come from smaller government agencies.

In this study, I undertook a series of public and government surveys. My first aim was to investigate to what extent local government agencies, community groups and private individuals are (1) confronted with the issue of common mynas and (2) engaging in common myna control. This allowed me to characterize and estimate current efforts directed at common myna control in Eastern Australia and to determine which aspects might warrant more investment in the future. My second aim was to identify geographic areas that varied in levels of control effort and could be used in subsequent studies to quantify changes in behaviour associated with control (Chapter 2).

2. Prevalence of common myna management among local government areas in Eastern Australia.

2.1. Aim / introduction

2.1.1. Aim of survey

I decided to undertake a large-scale survey to estimate the amount of effort directed at controlling common mynas across Eastern Australia, focusing on NSW and the ACT, in which the bulk of the Australian common myna population is suspected to be. To do this, I contacted three types of organisations involved in myna control: local councils, community volunteer groups and capture device retail shops. This constitutes all potential sources of traps beyond self-built traps, which will be addressed in the second part of this chapter, and hence should provide almost complete census of control efforts.

I decided to estimate control efforts at the local government area level. In Australia, local government areas (LGAs) are the third highest level of government after the federal and the state level. LGAs can have extremely different sizes (1.5 km^2 to $380,000 \text{ km}^2$) and populations, with often small densely populated ones in proximity to city centres and large sparsely populated ones in rural areas. There are 152 LGAs in NSW but none in ACT that is instead divided in seven districts. These districts have no administrative function but were used for planning of the ACT and hence reflect its structure. In order to use a consistent vocabulary, both units are from hereon after referred to as localities (to represent the fact that they are both local administrative units).

2.2. Survey strategy and contents

While there are four potential sources of control effort in a locality: private efforts with self-made devices, private efforts with purchased devices, council lead programs, and community volunteer group-driven efforts, this section focuses on efforts driven by organizations and hence focused on the last three groups. Note that they are not necessarily independent, indeed in some cases councils and government agencies (e.g. Landcare) encourage, supervise and/or fund volunteer groups. Likewise both council-led programs and volunteer groups can purchase traps from retailers.

2.2.1. Survey to retailers

Very few retailers answered to our survey, which asked for the postcodes of clients who had bought traps in order to localize trapping effort. For most resellers that information proved to be impossible to gather. I hence do not discuss or present results from that survey.

2.2.2. Survey to councils

The survey comprised 11 questions regarding the level of concern and involvement towards common mynas, as well as their control in the council. The questionnaire also contained a table that requested number of mynas trapped and culled within the council, as well as a section for open-ended comments. The questionnaire can be found in annex 1.1 and 1.2 (p190-194).

Questionnaires were sent out to all councils across the potential distribution of common mynas, as a general rule this consisted of LGAs in which mynas were known to be present in 2012 (from data from BIONET and the ALA) and adjoining LGAs. The survey was sent as a written questionnaire by email directed at either the general enquiries of the council or when available, directly at the environmental officer. Initial surveys were sent between 11/04/2012 and 23/05/2012 followed by a reminder approximately three weeks later to those councils that had not answered by then. The initial dispatch and the following reminder represented all efforts to obtain replies from councils, no attempt to examine non-response bias was made. Replies were received between 12/04/2012 and 18/06/2012.

2.2.3. Survey to volunteer groups

The Canberra Indian Myna action group (CIMAG) offered their help for this study and kindly granted me permission to access their records which covers trapping in the whole ACT and surrounding localities. Contacting other volunteer groups was essential to the rest of the study and I hence tried to contact as many groups as possible. Contact details for volunteer groups were gathered from several sources: 1) a list provided by the CIMAG, 2) web searches, 3) responses of the survey to councils. The surveys were sent on the 30/04/12 and 23/05/12. The questionnaire can be found in annex 1.3 and 1.4 (p198-202).

Table 3. Number of organisations contacted and replies received

	Councils	Volunteer groups
Surveys sent	130	>5*
Responses received	39 (30%)	3

* information on the exact number of surveys sent to volunteer groups could not be recovered, but I can ascertain that at least 5 were sent of an approximate total of 12.

2.2.4. Analysis

Data collected from survey to councils and to volunteer groups was grouped into a single dataset upon reception of answers. Descriptive qualitative results are presented below as the sample size and response rate was deemed insufficient for statistical testing.

2.2.5. Ethical note

All questionnaires were sent with the approval of the Human Ethics committee of Newcastle (approval H-2012-0248). The ethics protocol under which this survey took place included a confidentiality clause which is why individual councils are not identifiable in this thesis.

2.3. Results of survey to councils

2.3.1. Are common mynas an issue?

Out of 130 surveys sent, 39 replies from local government areas in NSW were received (30% response rate). Of those, 95% declared common mynas were present within their LGA, and some of them were even able to provide the year of arrival of the species (Figure 2), showing in many cases the presence of mynas is a recent phenomenon.

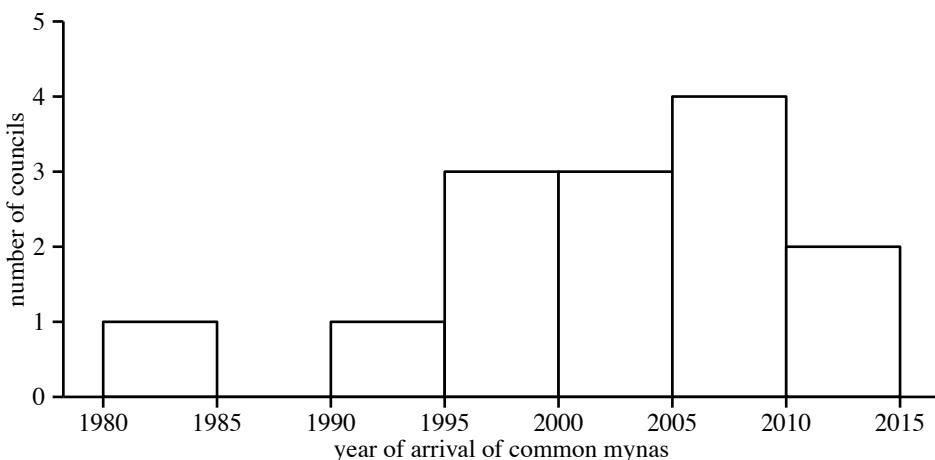


Figure 2. Year of arrival of common mynas in localities.

2.3.2. Actions undertaken against common mynas

Among those LGAs where common mynas were present, 34 (92%) considered the presence of the bird was of concern and constituted an issue. This in turn led a number of councils to take certain measures (Figure 3). In particular, a majority of councils encouraged “individual action by providing information on how to get traps and/or a guide on best practices”. Councils recommended that their constituents obtain traps through: the council (n=10), volunteer groups (n=5), self-made (n=4), the men’s shed (n=3), online resellers (n=2), pest control companies (n=2), and local environment and agricultural organizations (n=2).

On the other hand, only two councils (5%) had a clear position against trapping, suggesting that although it is uncommon, some councils do reject this practice. A little less than half of councils encouraged alternatives to trapping in order to manage mynas (note that which specific alternatives were encouraged was not investigated in this survey).

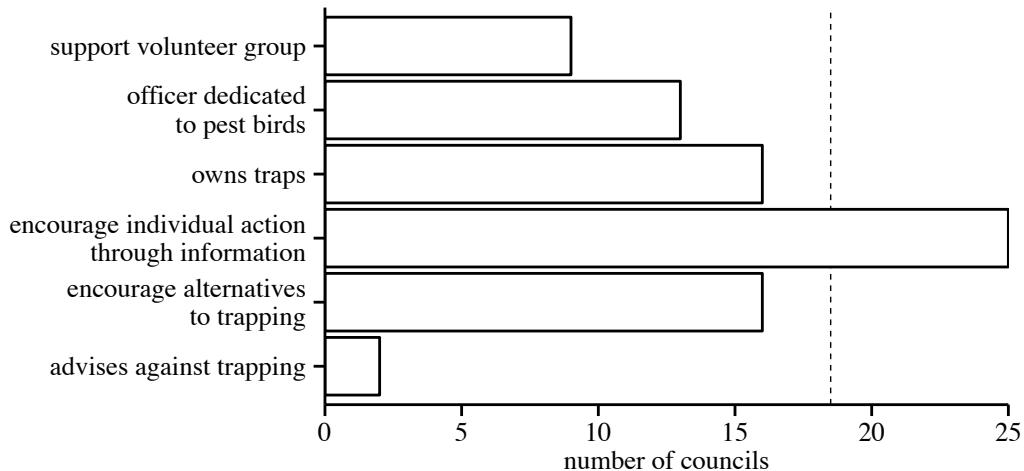


Figure 3. Number of councils that have certain positions or are engaging in certain practices regarding the presence of common mynas in their locality, out of the 37 that have mynas present on their territory. The dashed line represents 50% of the councils. Factors are respectively from question q7, q9, q8, q5, q6, q4, see annex 1.2, p194.

A large number of councils owned traps (43%) and had officers dedicated to the question of pest birds (35%), suggesting pest birds are a high priority issue in NSW.

75% of councils that owned traps kept records of myna trapped within their territory, however only two (12%) had additional strategies to assess effectiveness of measures in place (resident feedback/surveys, and ground monitoring).

2.4. Levels of common myna management across NSW and ACT

2.4.1. Specificity of dataset

For this section, results from the survey to council and information from volunteer groups are pooled in order to have as much information as possible to estimate management efforts across localities in NSW and ACT. Because only three volunteer groups responded to the survey, the data they provided were considered unlikely to be representative of volunteer groups as a whole and did not give rise to a specific section.

In two localities, information from both the council and the local volunteer group was received. To avoid having several data-points representing the same locality, I chose to keep the most detailed data in this dataset (in both cases from the volunteer group). Note that the same volunteer group can be active in several councils, such that the number of localities for which information was available for this analysis increased to 51.

2.4.2. Intensity of myna management across localities

The number of new common myna management programs being created, whether they include only an information campaign, or a trapping program, peaked between 2006 and 2010.

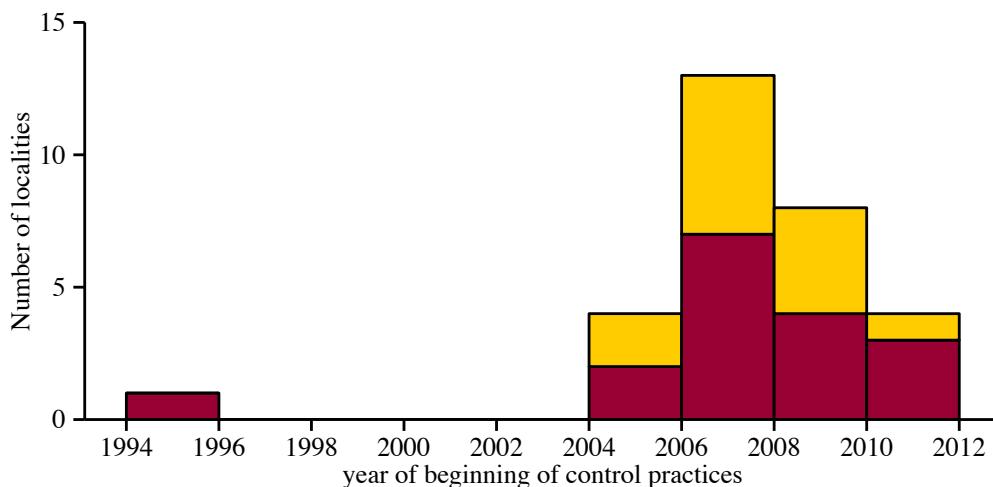


Figure 4. Number of localities in which myna control actions (e.g. information campaigns, trapping programs...) were started as a function of the year in which they were started. In yellow, number of programs started by volunteer groups, in red, programs started by councils.

Many localities are undergoing trapping programs but resources and efforts allocated to the task can vary greatly. For example the number of traps owned by organizations (councils or volunteer groups) ranged from 1 to 478. Accordingly the number of birds captured also varied greatly and, within localities could go from 0 to 4000 mynas caught per year. In total in this survey, 83,531 common mynas were reported to have been euthanized between 2004 and 2012 in NSW and ACT.

2.4.3. Trapping pressure index

In view of planned work on compensatory responses to trapping (chapter 2), I used the data collected from this survey to develop an index of trapping pressure. While it might seem intuitively that the number of traps deployed reliably estimates capture levels, it is important to note that operating traps is not a straightforward activity. Trapping requires experience and skill in order to be successful, mistakes related to inadequate baiting and trap placement are common (Gorenzel et al. 2000). Because it was difficult to know under which conditions traps were being used, I chose to estimate trapping pressure from its most direct result: the number of birds caught. Regardless of

these considerations, it is important to note that these two proxies (number of traps and number of birds captured) are highly and significantly correlated (Pearson's $r=0.84$, $df=49$, $p<0.001$, Figure 5).

Yet it is also important to note that this value also has its caveats, such as the fact that trapping is less likely to work in areas where there are few targets (i.e. low bird abundance), and that there are often issues with reporting and recording of trapping success. The abundance of birds may have an effect at multiple levels in this context. Not only is trapping more likely to yield large numbers if abundance is high, it might also be more likely that traps are applied to zones that carry more birds. However, in very few cases have control programs estimated abundances before and even during trapping was taking place. As such I argue that the number of birds caught is likely to be the best proxy available.

In addition to varying in their level of control effort, localities varied in their characteristics. Responses were, for example, received from localities as small as 6 km^2 to areas larger than $10,000\text{ km}^2$. In large geographic areas, control effort is unlikely to be spread evenly, first, because common mynas are much more likely to be present in areas where humans live, and second, because one of the reasons why mynas are considered problematic is related to their interactions with humans (e.g. defecating on buildings); consequently, management efforts are likely to be concentrated in areas with higher density human populations. To account for this likely preferential association of mynas and trapping with humans, I decided against expressing the number of birds captured as a function of locality surface area, but instead, to express the number of birds captured as a function of human population.

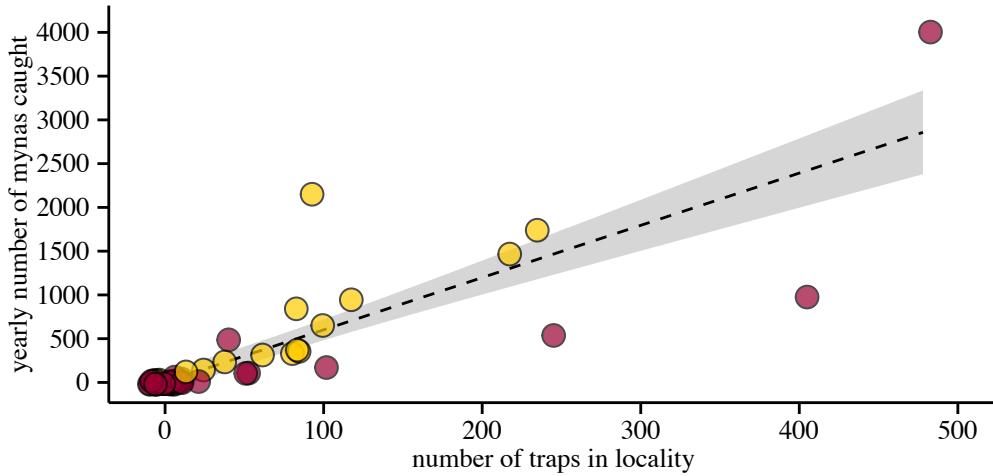


Figure 5. Yearly number of mynas caught in locality as a function of the number of traps available. Dots in yellow represent localities where trapping is a result from volunteer programs and points in red represent localities where trapping is handled by the council. The dashed line represents the best fitting linear regression line and confidence interval.

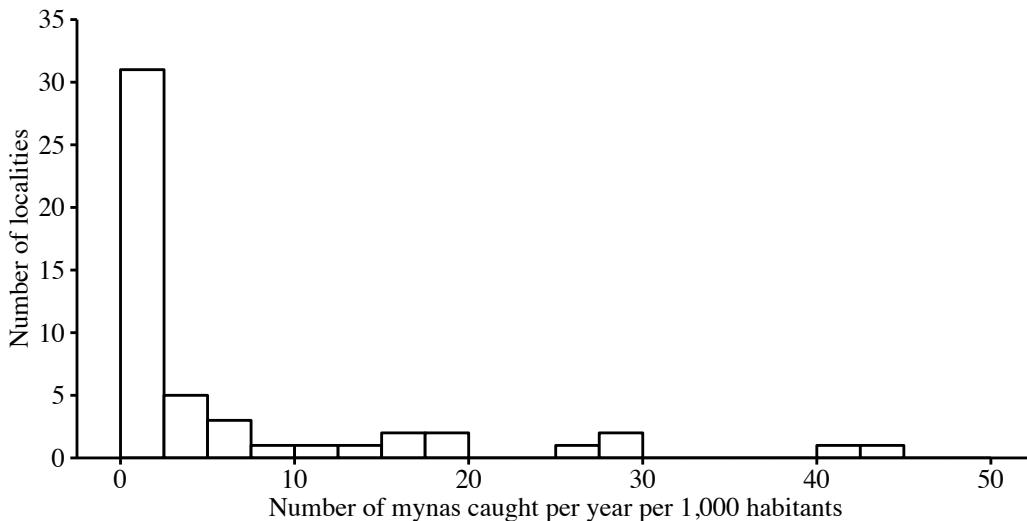


Figure 6. Number of localities in which different trapping pressures are applied. Trapping pressure is here defined as the number of common mynas caught per year and per 1,000 habitants.

Although the number of mynas captured per year per 1,000 inhabitants displayed a very wide range of values, most councils only applied a low trapping pressure (<10 mynas per year per 1,000 habitants) (Figure 6). It is worth noting that many councils encourage individual private action which is a type of effort not accounted for in this survey, and hence the estimates above are likely to under-estimate local trapping effort. I address the question of trapping by private individuals in the next section of this chapter.

2.5. Discussion

Results from the surveys to councils indicate that there is an overall agreement on the fact that common mynas are an issue in NSW and ACT. However, while surveys were sent to all organizations for which the issue was relevant (i.e. those present within the range of common mynas), results suffer from a low response rate (30%). This is of concern here as low response rates can indicate low interest in the topic (White, Jennings, et al. 2005). This suggests there is a bias and that respondents might have tended to be those for which mynas are indeed an important issue. Such a trend was found in fruit growers, where those most likely to respond to a survey about bird-related damage were those that suffered most from such damage (Dawson and Bull 1970). Here, no attempt beyond sending reminders about the survey was made to survey non-respondents, which means this potential bias was not quantified (White, Jennings, et al. 2005).

Despite this potential bias, results of this survey remain as investigating what councils that do consider mynas an issue do about it. There is large variability in terms of what measures these councils choose to address the issue. The most widely employed method was to encourage private action by providing information. This measure presents two main benefits. First it provides information to the public hence favoring acceptance of measures (Olsen 1998). Second, it increases the likelihood of measures being implemented with minimal costs from the council.

Most often trapping was the favored mode of action whether councils supported it by providing information on this practice, supporting volunteer groups or owning traps. Pooling data from councils and action groups revealed that there is substantial variation in trapping pressure, measured as the number of mynas caught per year per 1,000 inhabitants, among localities. Despite this variation, most localities had low (<10) trapping pressure. Because the number of birds caught is correlated with the number of traps present, this might come from the fact that often few traps (<50) were available in localities. One alternative or additional explanation is that localities where a high number of traps are available are those that invest most in trapping, not only financially but also in terms of informing constituents, devoting time and respecting trapping procedures. At the other end of the spectrum, 5% of councils had a position strictly opposed to trapping of common mynas. This shows that low trapping pressure does not

always reflect a lack of investment, but can also reflect an active decision not to control mynas.

The large variations in trapping pressure noted here do not account for all the trapping activity that takes places within localities. Not only do 25% of councils not record the number of mynas caught within their traps, several councils encourage constituents to buy or make traps on their own, leading to the presence of more traps for which catches are not recorded. Even for those councils that do record catches, and those that advise against trapping, it is possible for private individuals within these localities to acquire a trap and use it. This means the trapping pressure estimates in this section are likely to underestimate real values. However, I see no reason for the ratio of private trapping to be stronger in some localities than others, I hence argue that the above estimates are useful for comparing localities between each other. Additionally the next section seeks to estimate the amount of private trapping that takes place in eastern Australia and will confirm the lack of geographical bias of this practice.

While many councils promoted trapping, less than half of councils encouraged alternative measures to trapping. While this could suggest alternatives are logically more complex to implement, it could also suggest councils might have limited awareness of their existence and utility. Often programs that have been successful in eradicating common mynas from islands (see section 1.6, p42) advise for the use of several methods integrated together (Saavedra 2010; Canning 2011). This is in accordance with one of the principles of integrated pest management (see section 1.5.7, p41) which recommends combining different methods into a coherent strategy to deal with problematic species (Wittenberg and Cock 2001; Dhawan and Peshin 2009). Councils often have to deal with plethora of problems and can only dedicate so much effort to investigate the best strategy for the issue of common mynas. It is possible that the lack of encouragement to trapping alternatives by councils reflects the scarcity of information available on the subject.

3. Prevalence of common myna management by private individuals

3.1. Survey aim and methodology

3.1.1. Aim of survey

While the first survey directed at councils and action groups allowed to form a global view of efforts directed at myna management in Australia, it omitted the fact that private individuals could also by themselves decide to engage in myna control. The aim of my second survey was twofold. First, it aimed to estimate to what extent the general public engages in common myna management and the factors that might influence engagement. Second, it aimed to identify participants for an in-situ experiment in the Newcastle - Central coast area.

3.1.2. Strategy

To achieve the above aims, I targeted the present survey towards two slightly different populations: all people living within the common myna range in Australia, and in particular those within the Newcastle - Central coast area. Advertisement methods were hence chosen with these two populations in mind.

The survey was hosted on the birds in backyards (BiB) website (www.birdsinbackyards.net) between the 25/09/2012 and the 1/02/2014. BiB is part of Birdlife Australia, it is a conservation and education program that focuses on birds that live alongside people. This was hence an ideal media to investigate a species associated to humans such as common mynas.

The survey was regularly advertised in the BiB newsletter, but it was also punctually advertised by the Wyong shire council and the School of Psychology of the University of Newcastle. Hence, most respondents would have been BiB members or users and inhabitants of the Central Coast – Newcastle area and were expected to be over-represented among survey participants. Most members and users of birds in backyards are likely to have a high interest and potentially knowledge of Australian wildlife and birdlife in particular. As such, they might have been particularly sensitive to the problem of invasive bird species. No particular biases were expected from the specific Central coast population regarding the question of common mynas. In addition, the title of the survey directly referred to common mynas, it is likely that people with interest or knowledge of the problem might have been more likely to answer.

3.1.3. Content

Survey questions and the accompanying information statement are presented in appendix 1.5 and 1.6 (p206-209). Questions were divided into several sections that focused on different aspects: (a) demographic and garden characteristics, (b1) presence of common mynas and starlings in the garden, (b2) actions against common mynas and European starlings in the garden, (c) presence of common myna breeding in the neighbourhood, (d) additional comments, and (e) possibilities for involvement in an in-situ experiment in the Newcastle-central coast area.

3.2. Results

3.2.1. Characteristics of respondents and gardens

Table 4. Number of respondents to survey from each state and territory.

State / Territory	ACT	NSW	QLD	SA	TAS	VIC	WA
Respondents	15	562	177	12	7	261	1

1035 people responded to the web-survey between September 2012 and February 2014. As expected most respondents were from states within the common myna range (NSW, QLD and VIC), although surprisingly few were from the Australian Capital Territory (Table 4). For the remainder of the analysis respondents from states outside common myna range (SA, TAS, and WA) were excluded.

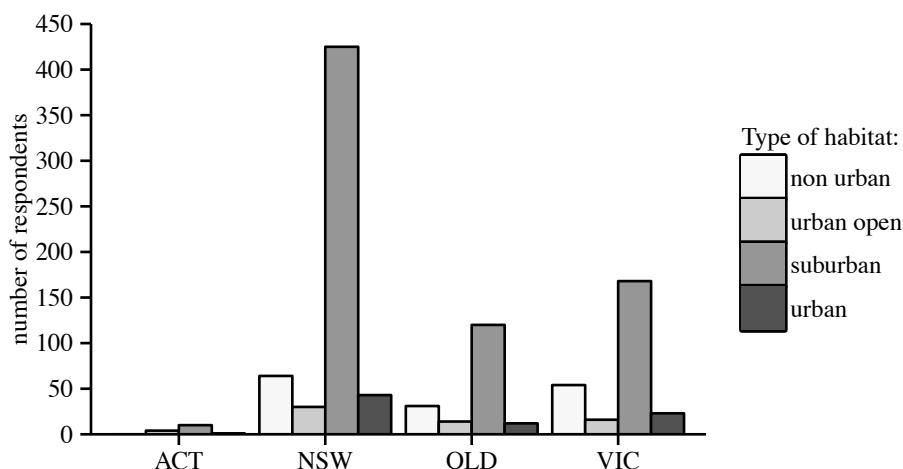


Figure 7. Number of respondents per state per habitat category

Respondents mostly lived in residential suburban areas (Figure 7) as could be expected from users of a website such as birds in backyards. Gardens of respondents varied in the composition of their vegetation although most, with the exception of urban

gardens, were clearly dominated by Australian native plants or a mix of natives and exotic plants (Figure 8). Similarly lawn coverage was highly variable and patterns were similar across habitats (few gardens with 'no lawn', between 20 and 40% for all other categories: 'less than 25%', 'between 25 and 50%' and 'more than 50%'), the only exception was urban residential gardens which had over 40% of gardens with no or trivial amounts of lawn.

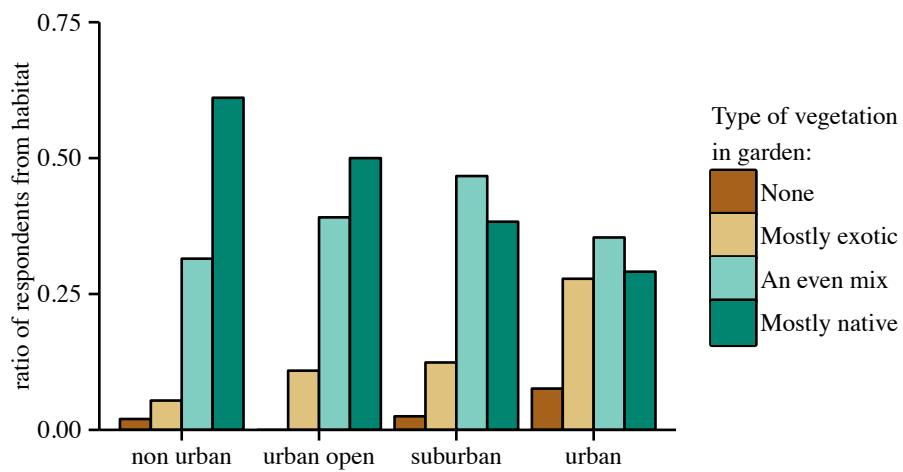


Figure 8. Types of plants present in gardens of different habitats.

The distance to bush at which gardens were located reflected their habitat: most non-urban gardens were close to a bush reserve while urban gardens were mostly far from bushland and suburban gardens were intermediate. Surprisingly most urban open spaces were also close to a bush reserve.

74% of gardens were frequently visited by pets (dogs, cats, aviary birds, etc), and pet feeding took place in 30% of gardens. Most respondents had at least an intermediate bird identification ability, meaning they could identify all birds that visit their garden (Figure 9).

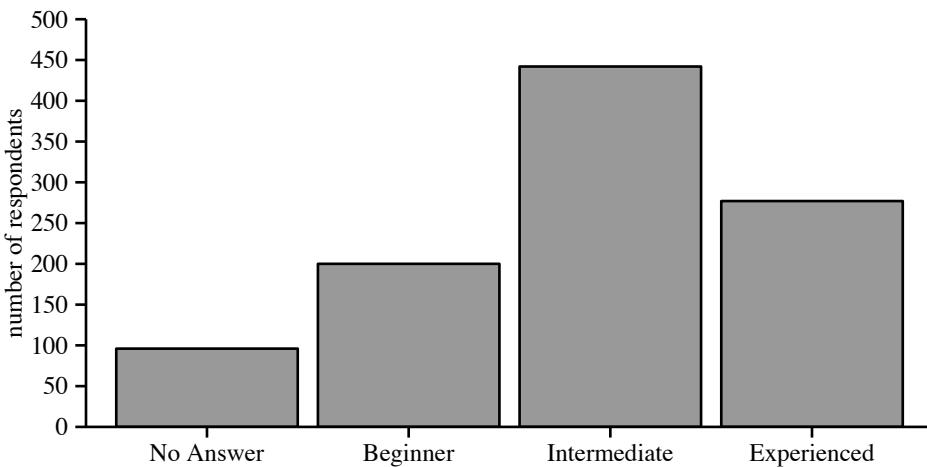


Figure 9. Number of participants by bird identification level

3.2.2. Factors increasing likelihood of presence of mynas in garden

As expected by the fact that people regularly confronted by mynas were more likely to answer a survey on the topic, a large majority of respondents (mean: 86%, range: 78% in QLD to 90% in Victoria) reported mynas to be present in their backyard.

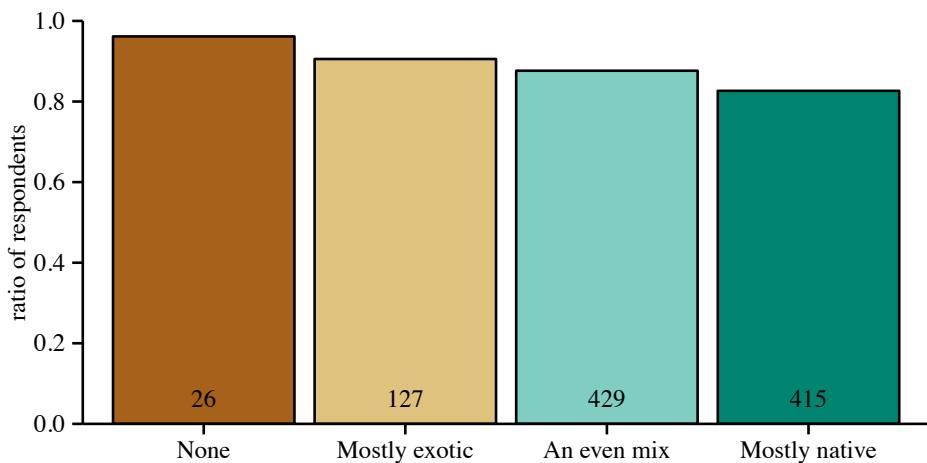


Figure 10. Ratio of gardens, within each vegetation category, in which mynas were present. Numbers at the bottom of the bars represent the sample size.

Mynas were scarcer in non-urban habitats such as bushland and farmland (present in 75% of gardens) than in other habitats such as suburban habitats (present in 87% of gardens) and urban open habitats (present in 94% of gardens). Accordingly, gardens closer to bushland, composed of more native plants (Figure 10), and with less lawn cover, were less likely to contain mynas. This all suggests common mynas prefer more modified habitats.

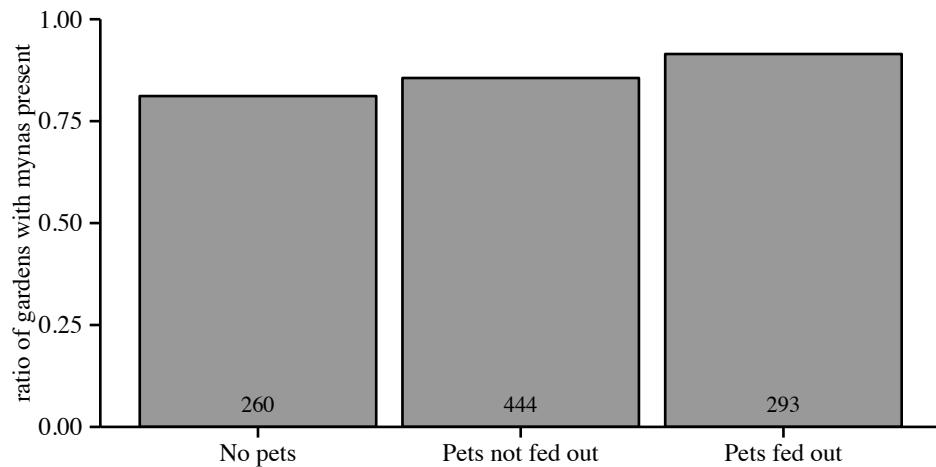


Figure 11. Ratio of gardens in which common mynas are present depending on whether pets are present, and if they are fed outside. Numbers at the bottom of the bars represent the sample size.

Mynas were more likely to be present in gardens in which pets were present, particularly if they were fed outside (Figure 11).

3.2.3. Most recent common myna sightings

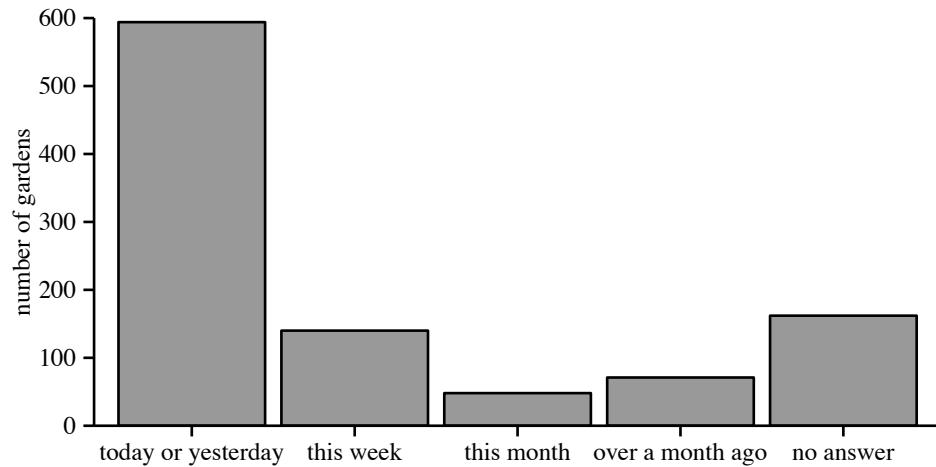


Figure 12. Time of the most recent common myna sighting in the respondent's garden.

Most respondents who saw common mynas in their garden saw them within the last two days (Figure 12). Moreover, respondents tended to see small (<5) groups of birds (Figure 13). Overall mynas appeared to be seen very frequently but in small numbers.

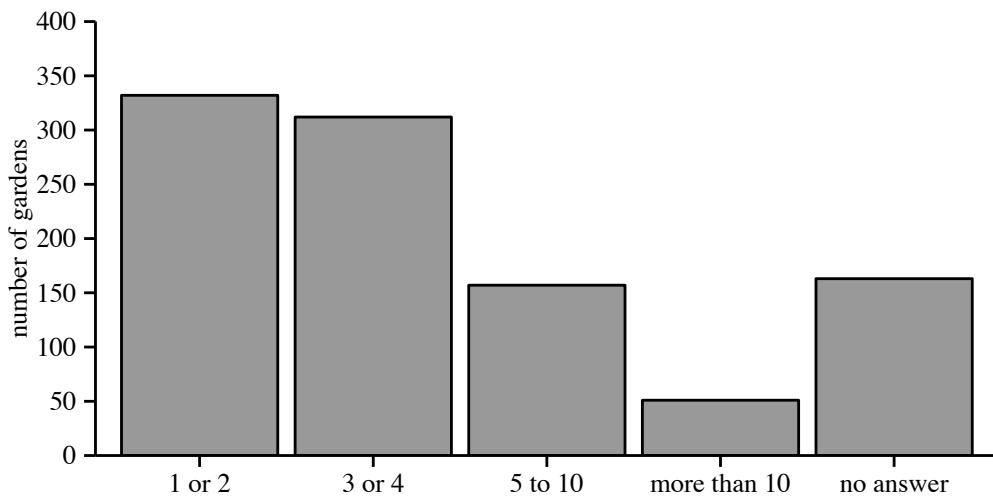


Figure 13. Number of common mynas seen in the most recent sighting of respondents.

3.2.4. Common myna breeding

About half of the respondents of this survey (47.6%) reported common mynas to be breeding in their neighborhood. Nests were more common further away from bushland (Figure 14). Respondents reported knowing birds were breeding from the fact that (a) they repeatedly saw a pair (36%), (b) they saw the nest (33%), and that (c) they saw adults feeding juveniles (31%). Detection of breeding increased with the bird watching ability of the respondents (from beginner: 36%, to experienced: 54%).

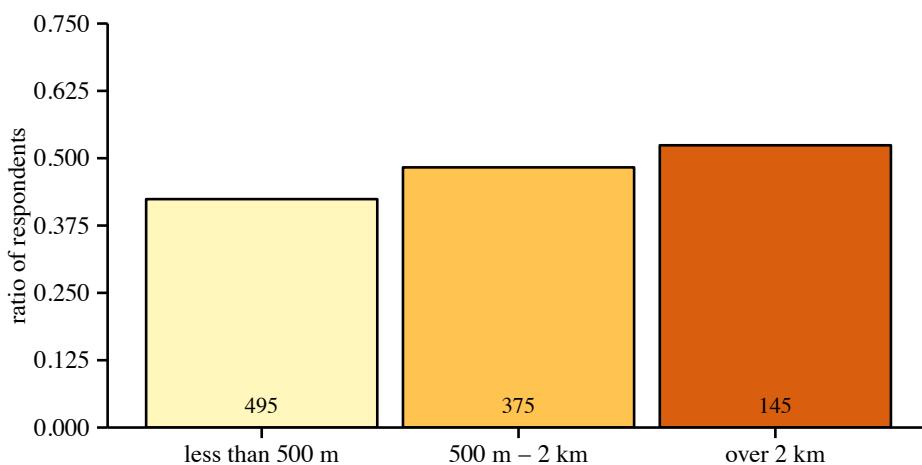


Figure 14. Ratio of respondents declaring to have mynas breeding in their neighborhood as a function of the distance to bushland.

Most nests detected by respondents were in man-made structures (79%, Table 5). Overall, this trend was similar across all states: Queensland (71%), New South Wales (78%) and Victoria (82%) (only 3 nests were reported in the Australian Capital

Territory). As has been found in previous studies in Australia and worldwide, the trend for nesting in man-made structures found in this study was very high (Table 5), and included structures such as art installations and barbecues.

Table 5. Number (percentage) of nests seen by respondents by structure category. I include the results from the present survey along side those of others to allow a comparison.

	Eastern Australia, this study	Sydney (Lowe et al. 2011)	Florida (Pranty 2008)	New Zealand (Counsilman 1974)	India Dhanda and Dhindsa (1996)
<i>Man-made structure</i>	118 (79)	29 (81)	32 (97)	60 (90)	Y
Hole in house wall/roof	86 (57)		-		Y
Commercial buildings and signage	9 (6)	29 (81)	21 (64)	53 (79)	-
Nest box	17 (11)	1 (2)	-	-	-
Public equipment	3 (2)	-	11 (33)	2 (3)	-
Outdoor equipment	3 (2)	-	-	5 (7)	-
<i>'Natural' structure</i>	32 (21)	7 (19)	1 (3)	7 (10)	Y
Tree, Tree hollow	24 (16)	4 (11)	1 (3)	7 (10)	Y
Palm tree	6 (4)	2 (5)	-		-
Other species' nest*	2 (1)	-	-	-	Y
Vertical earth banks*	-	-	-	-	Y
Total	150 (100)	36 (100)	33 (100)	67 (100)	NA

* indicates an answer not proposed in the survey, but provided by respondents in an open comment section of the survey.

3.2.5. Types of management practices

To investigate the characteristics of respondents involved in management practices, all respondents that did not have mynas present on their property were excluded which left a sample of 859 respondents.

Over 72% of people who had mynas on their property were attempting to discourage them by one way or another (Figure 7). The most frequent activity to discourage the birds from coming on the property was to chase them away or install scaring devices (49%), followed by practices designed to encourage native birds, such as installing feeders or planting specific trees (40%), and reducing the presence of freely available food by, for example, feeding pets indoors (29%). Interestingly, these three practices were quite strongly associated as indicated by the fact that persons engaging in one were likely to engage in another.

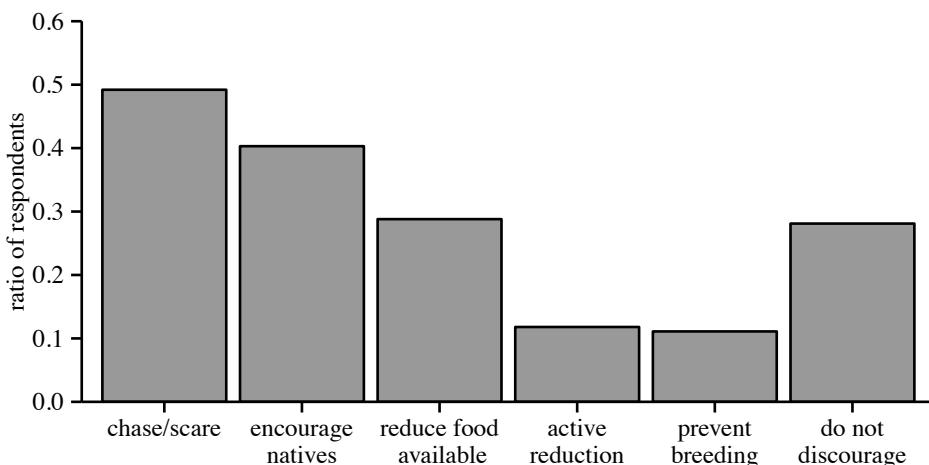


Figure 15. Ratio of respondents that try to discourage common mynas (and starlings) to be present on their property by using different methods. Methods were not mutually exclusive and hence several could be used by the same respondent.

Although a large majority of respondents were involved in some kind of action against mynas, only 12% of people were involved in ‘active reduction’ of local population (Figure 15), mainly through trapping (83%) and shooting (12%) (note that 4% used both these methods). A few respondents used poison, sticky traps and ‘manual dispatching’ (often following capture of a bird that got caught in a room by accident).

Some respondents had been trapping for several years while others only for a few days. Trapping success was highly variable, and number of mynas caught ranged from zero to 600, accordingly, trapping success per month ranged from zero to 60 mynas caught. Traps were mostly made by respondents or purchased from a reseller (Figure 16). Only 18% of traps were provided by community groups and local councils, but they had the highest mean number of mynas caught per month (5.90 ± 2.10 se), closely followed by traps purchased from re-sellers (5.42 ± 2.35 se) although this latter value was strongly inflated by two extremely large values.

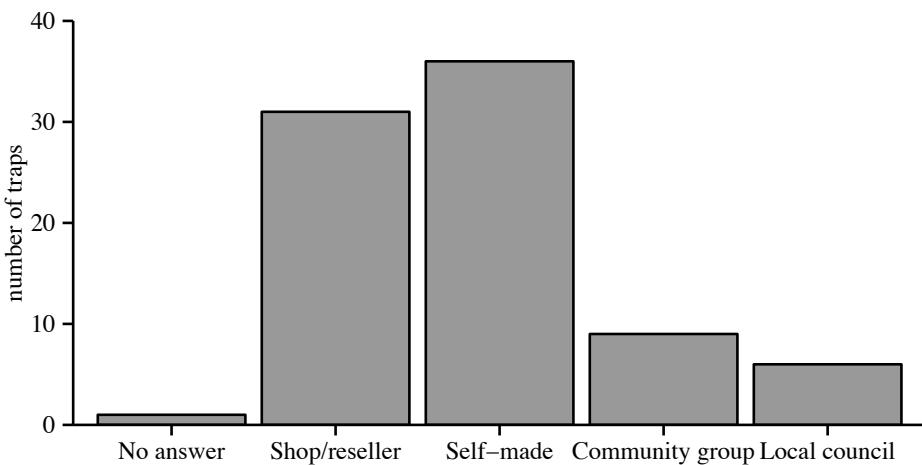


Figure 16. Origin of traps used by respondents.

3.2.6. Factors influencing likelihood of engagement

A large majority of respondents who had mynas present on their property (70%) had tried to discourage mynas from using their garden by one means or another. I attempted to determine which factors were associated with the likelihood of engaging in these activities. Urban residents were less likely to engage in discouraging mynas (53%) than people living in other habitats (non-urban: 76%, urban open-space: 74%, suburban: 73%). Overall, the higher the ratio of native plants in the garden, the more people tended to be involved in discouraging mynas (Figure 17), suggesting that a ‘love of natives’ might be one of the driving forces behind the motivation to reduce the presence of mynas. Participants’ level of birding was also associated with engagement, with beginner birders (64%) tending to be less involved in reduction strategies than birders with more advanced skills (range: 73%-75%), suggesting information and knowledge about birdlife is important for potential action.

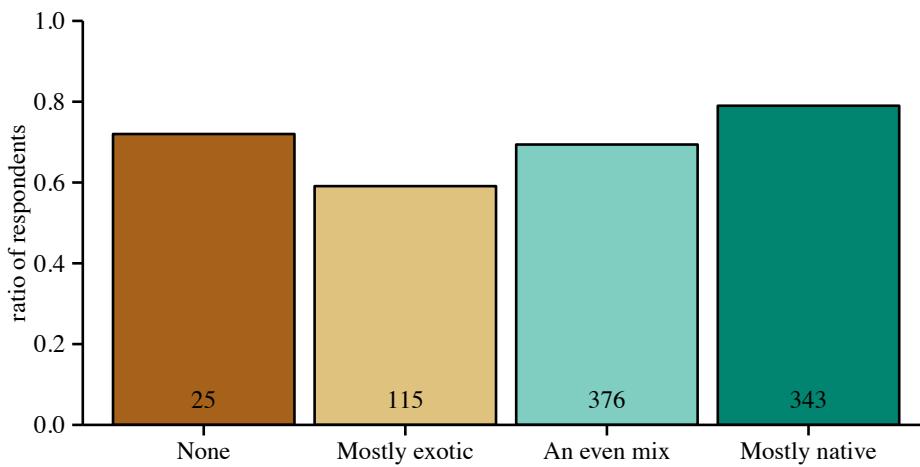


Figure 17. Ratio of respondents that discourage mynas to come on their property by one way or another. Numbers at the bottom of the bars indicate the sample size of that category.

About a tenth of respondents were involved in active removal of mynas, in the sense of taking part in activities that led birds to be killed. As with involvement in discouraging mynas, likelihood to be involved in active reduction increased from “mostly exotic vegetation” (6%) to “mostly native vegetation” (14%), with a large value also for people that have no vegetation in their garden (16%). The strongest effect seemed to be habitat, with many people from non-urban habitat, including farmland, involved in active reduction (Figure 18). Involvement also increased with birding level (beginner: 6% to experienced: 19%), and decreased with pet ownership (pets: 10%, no pets: 16%).

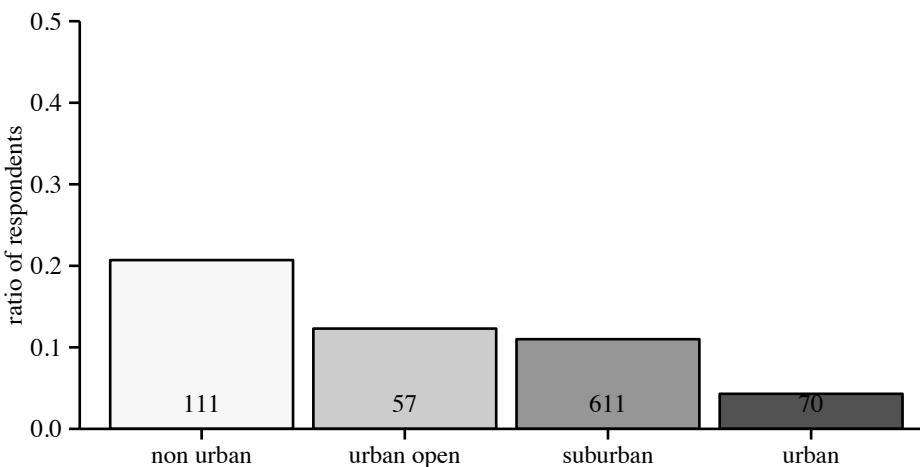


Figure 18. Ratio of respondents, among those that have mynas present in their garden, that practice active removal of mynas (mostly trapping and shooting). Numbers at the bottom of the bars indicate the sample size of that category.

3.3. Discussion

Results of this survey to the public confirm common mynas are widespread in eastern Australia. The species was present in 86% of gardens where they were seen frequently even though most of the time in small numbers. Although it was expected that myna presence would be high because the survey likely sampled preferentially people with mynas in their garden, this level of myna presence is comparable to that found in previous studies. For example, mynas were present in 80% of gardens in the greater Sydney region (Parsons et al. 2006). It is worth noting that the majority of participants sampled in both the present and previous surveys lived in suburban houses in New South Wales and overlapping study populations might explain why the outcomes of the two studies match so closely.

Presence of mynas in gardens was influenced by a range of factors. In particular, the species occurred less often in gardens that had more native plants, less lawn cover and those that were closer to bushland. Accordingly, previous studies in Sydney gardens have shown that mynas are associated with high lawn cover and negatively associated with tree cover (Parsons et al. 2006). Exotic vegetation in urban areas (Chace and Walsh 2006) and human-modified habitats in general (Case 1996) are often taken to favor invasive species. It is hence not surprising that an invasive species that is often referred to as commensal (Chace and Walsh 2006; Peacock et al. 2007) and hence relies on its proximity to humans, would flourish in such human-modified habitats.

Another factor that seemed to increase occurrence of mynas was the presence of pets in the garden, in particular if they were fed outside. It is possible that pets provide resources to mynas. Pet dogs can leave food residues around their bowl, which, as suggested by the fact that captive-held mynas feed willingly on dog pellets (personal observation), might be a valued food for mynas. Some authors have also observed the birds feeding on dog fecal matter (Ahmad and Sahi 2012), potentially searching for insects and larvae. Recent data suggests that common mynas living in urban areas are deficient in proteins (Machovsky-Capuska et al. 2015), and both behaviours might reflect their search for this nutrient. On the other hand it is also possible that pet ownership is more likely by residents living in environments that already favor mynas. More research is certainly needed in this domain to estimate how much pets and their food participate in resources consumed by mynas. Interestingly, mynas also interact with cattle by foraging on the insects disturbed during their locomotion or by foraging

on their skin parasites (Ahmad and Sahi 2012), suggesting mynas could profit from all domestic animals, cattle and pets alike.

Although a large majority (86%) of respondents had common mynas present in their backyard, less than half saw the birds breeding in their neighborhood. One factor that could explain this relative ‘scarcity’ of nests is that they can be hard to detect, and breeding activity difficult to identify. Fittingly, more experienced birders detected more breeding activity indicating birding knowledge and skill is perhaps important in view of quantifying breeding. Another factor that could participate in the apparent ‘scarcity’ of breeding is that appropriate breeding habitat for the species might be more limited than suitable foraging grounds. Myna nests were more commonly seen further away from bushland, suggesting that very much like factors predicting their presence, occurrence of nesting was more likely in more modified habitats. Accordingly, low tree density has been shown to harbor high myna and myna nest abundance (Grarock et al. 2013a).

Common mynas are a hollow-nesting species, however they are extremely versatile in their nest choice in their native range (Dhanda and Dhindsa 1996) as well as their invasive range (Feare and Craig 1999; Pranty 2008; Canning 2011) (Table 5). A large majority of nests observed in this survey were found in man-made structures, mostly in cavities on walls and under roofs of houses, but sometimes in more unusual locations such as unused barbecues and art installations. The tendency of mynas to use man-made structures is a consistent finding across several studies worldwide (Table 5) and is probably an important factor in allowing the species to live in such close association with humans and thus in the ecological success of this species.

Less than a third of respondents who had mynas on their property did not attempt to discourage their presence by one means or another, leaving a large majority of people reluctant to have the species close to their home. In a study of discouragement of birds around Berlin, Germany, and around Seattle, USA, between 10 and 20% of respondents declared they tried to keep crows away from their home (Clucas et al. 2011). These results are much lower than those found here for mynas. In fact, even if the percentage of people involved in myna discouragement was calculated using the entire respondent population (rather than only those respondents with mynas on their property), as was done in the crow survey, the level still rises to 60%. This highlights that mynas are the target of significant discouragement effort, even though the comparison with crows has limits since the species have different ecologies and the

study did not take place on the same continents. Accordingly, mynas have been voted ‘the worst Australian pest’ (ABC 2005) and they are the most unwelcome medium size bird in Victorian backyards, in line with a general trend for introduced species to be unwelcome (Shaw 2014). This suggests that the public attitude towards common mynas is extremely negative.

The level of contempt towards common mynas found here is extremely high. One factor that could explain the prominence of negative attitudes is that our participant recruitment process might have favoured a certain sub-class of the population. In particular, most respondents were recruited from birds in backyards newsletters, which are likely to be received mostly by people who already have a significant interest in wildlife. One of the main draws to the BIB website is their well designed bird identification tool. Considering in some countries only between 15 and 50% of people sometimes try to identify birds (Clergeau et al. 2001), then the present sample is probably skewed towards those people that do attempt to identify the birdlife they observe and hence have a strong interest in wildlife.

People surrounded by more native wildlife tended to be more engaged in myna discouragement. Indeed, respondents who had most native plants in their garden and had the most knowledge about birds were the ones most likely to be engaged in some level of management activities. In New-Zealand, people who planted trees for native fauna were more likely to have positive attitudes towards native birds and this positive attitude persisted even if they encountered bird problems (Charles and Linklater 2015). Based on the idea that behaviors are influenced by values and attitudes (Miller 2000), this suggests there is a factor of biodiversity awareness that could underlie positive attitudes towards native birds and drive negative attitudes and actions towards introduced birds.

Discouragement of mynas most often took the form of scaring and chasing, reduction of available food and encouragement of natives. Each of these activities encompassed a range of actions. For example, chasing mynas ranged from people throwing objects at the birds to people staring at them insistently. These discouragement methods did not impact abundance of crows in Seattle and Berlin (Clucas et al. 2011); however, they did affect the birds’ behaviour (Clucas and Marzluff 2012). Crows and starlings undergoing chasing and scaring by the public in Berlin and Seattle were more risk-averse than the others (Clucas and Marzluff 2012). Another human practice that has

important ramifications for urban birdlife is supplemental feeding which constitutes a significant resource for some species to the point where abundance is affected (Fuller et al. 2012). Altogether, this comes to show the strong impact that behaviours directed by humans at wildlife can have on wildlife behaviour.

The author of the Melbourne survey noted that there were some issues with spelling that made it unclear whether people were referring to noisy miners or common mynas (Shaw 2014). This is particularly interesting as there is some suspicion that the public sometimes confuses one species with the other because of similar names and morphological features and hence misattributes observations of noisy miner aggressions to common mynas (Lowe et al. 2011). The present results cannot be used to determine whether confusion occurs, although I did note the frequent misspelling of "common mynas" in the open comment section of the survey (e.g. "common miner", "common minors", "minahs"). Future work should aim to compare public attitudes towards the two species directly and estimate how much of the negative attitudes towards common mynas are driven by misidentification.

I defined active reduction as any method that would lead to the death of fledged mynas (in some cases, nest removal could include destruction of eggs or hatchlings). These were assumed to be one of the practices that would require the highest level of involvement as often people are reluctant to kill animals themselves. Just under 15% of respondents who had common mynas on their property were involved in active reduction, mainly through trapping and shooting. Involvement in active reduction was most common in non-urban habitats, followed by open urban and suburban habitat. People who had a high level of birding skills and those who had a higher percentage of native plants in their garden were also more likely to be engaged in active reduction. Altogether this suggests that likelihood of engaging in lethal control is higher for people with high awareness of native fauna and flora and live in more open habitats.

The control methods preferred by the public in a previous study (Johnston and Marks 1997) were biological control (18%), trapping (9%), poisoning (7%) and shooting (6%). Not surprisingly, not all of these methods were reported in the present survey, presumably because biological control cannot be practiced by the public, and poisoning entails risks to non-target animals. Overall rates of acceptance of trapping and shooting in Johnston and Marks (1997) approach performance rates in the present study. However, it is unlikely that all people who deem a practice acceptable will actually

actively take part in it. This hints to the fact that the sample of respondents of this study might have been biased towards those most likely to take part in common myna control.

4. General discussion

The surveys presented above show that a majority of sampled councils in NSW (95%) and private individuals in Eastern Australia (72%) are involved in some level of common myna management. This brings the idea that councils might be overall more in support of managing the species than the public. It is also possible part of the public deems it is not its role to partake in such activities. Overall, this is important as public understanding of pest management is often poor, yet public acceptance of management programs is often key in determining their success (Olsen 1998). A striking example of this is the case of feral pigeons in Switzerland. While culling did not reduce populations, changing the attitudes of residents towards feeding pigeons along with complimentary measures lead to long lasting population reduction in one city (Haag-Wackernagel 1993, 1995). Discrepancies between the attitudes of different stakeholders can present a risk to the success of management programs (Miller and McGee 2001). This risk can be reduced by considering human dimensions of wildlife management when making environmental decisions (Miller and McGee 2001).

While for councils, trapping was the prevalent control practice used, it constituted only a small fraction of what the public chose to do. The public engaged in multiple activities such as scaring mynas away, encouraging the presence of native birds or reducing food available and preventing breeding. This is interesting, as there is evidence that attitudes of the public, expressed through behaviours such as chasing birds away, can impact birds' behaviour and increase wariness levels (Clucas and Marzluff 2012), suggesting the behaviour of mynas could be affected by that of the public. On the other hand, although the survey to councils did not collect details about alternatives to trapping used by councils, it did highlight the fact that these alternatives were used and/or encouraged by less than half of councils. Overall, the public seems to favor non-lethal methods of myna control which is at odds with the position of councils which mainly encourage or engage in trapping. Non-lethal aspects of common myna control receive far less attention, by the governing bodies but also by the scientific community, than lethal methods, and trapping in particular. Yet, these non-lethal alternatives are the most predominant practices used the public, this gap shows that more research in this area is clearly needed to assess their efficiency and in turn, encourage their use by councils.

Only 15% of private individuals were implicated in lethal control of mynas. This suggests the public might only marginally influence the overall harvesting pressure that mynas undergo in Eastern Australia. Additionally, of those performing trapping, it appears 18% of traps were provided by community groups and local councils, and hence are already accounted for in the initial survey to those organizations. Thus councils and community groups represent the bulk of the control efforts against mynas. The fact that the trapping pressure index I extracted from these surveys did not account for private efforts should hence only lead to a small under-estimation of real trapping pressure. Moreover traps provided by local councils had the highest mean number of mynas caught per month such that even if they did not represent the largest number of traps present, they might still on the other hand represent a large part of the mynas removed. This supports the use of council and community group data to estimate trapping pressure in localities, as this index is likely to approach true trapping and only slightly under-estimate it.

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CHAPTER 2. COMPARISON OF COMMON MYNA BEHAVIOUR ACROSS ZONES OF VARYING TRAPPING PRESSURE

Abstract

Harvesting of wildlife by humans is commonly known to impact target species' demography, life history and behaviour. Yet in the context of alien and pest species control, behavioural shifts have received very little attention. The introduced common myna is undergoing intensive control efforts in some areas of its Australian distribution. In order to investigate whether myna populations respond to harvesting, I compared the behaviour of free-ranging common mynas, *Acridotheres tristis*, in areas of high and low trapping pressure.

Behavioural analyses revealed that mynas in high predation risk areas stayed closer to refuges, and tended to form smaller groups and be overall less detectable. On the other hand, there was no effect of trapping pressure on abundance and response to conspecific alarm calls. Overall, these results suggest that common mynas adjust their behaviour to the level of anthropic risk in the environment. Behavioural shifts in invasive alien species have the potential to modify their ecological impact and may interfere not only with the effectiveness of control measures but also how this effectiveness is assessed.

1. Introduction

Humans collect individuals from populations of wild animals in many contexts such as hunting and fishing. Although it does not necessarily take place with the aim of consumption (e.g. trophy hunting, insect collectors), it is similar to natural predation, inflicted upon prey by non-human animals, in that it removes certain individuals from the prey population permanently. This phenomenon, sometimes called “artificial predation” (Glasgow 1953), is now more commonly referred to as wildlife exploitation (Mace and Reynolds 2001) or wildlife harvesting (Coltman et al. 2003; Olson 2009).

Another similarity between wildlife harvesting and natural predation is that both phenomena tend to display a bias towards harvesting some types and sub-types of prey preferentially (Curio 1976; Law 2001). However these selection biases can be very different between natural predation and wildlife harvesting. In Minnesota, both wolves and humans hunt deer, but they do not select the same animals: wolf kills contain a high proportion of old individuals with many presenting pathologies and abnormalities while these trends do not appear in prey taken by hunters (Mech and Frenzel 1971). On the other hand, in trophy-hunting, preference for game with larger antlers is well documented (Coltman et al. 2003), and in industrial fisheries, fish with larger body-size are harvested preferentially (Law 2001; Fenberg and Roy 2008). Fossil records of mollusks and tortoise suggest that such prey size selectivity by humans has been going on for a very long time (Stiner et al. 1999; Klein et al. 2004).

Size-selective harvesting has strong impacts on prey demography and ecology (Fenberg and Roy 2008). For example, bighorn sheep populations that undergo trophy hunting show morphological changes, such as a reduction in ram size (Coltman et al. 2003), and heavily harvested fish display changes in life-history traits, such as earlier maturation (Olsen et al. 2004; Kuparinen and Merilä 2007). It is often difficult to disentangle the mechanisms causing these changes, in particular the influence from phenotypic plasticity and that of evolution (Law 2001; Fenberg and Roy 2008). Phenotypic plasticity corresponds to changes induced by the environment within the lifetime of the individual and can be reversible at the scale of the population, for example reduction of antler size in some cervids could be related to the reduction of available feeding grounds (Law 2001). Similarly, earlier maturation in fish species could be favored by rising sea temperatures (Grift et al. 2003). In some cases however, there is clear evidence that these changes are due to selection on traits that make

animals less susceptible to exploitation, and hence represent human-induced evolution (Festa-Bianchet 2003; Allendorf and Hard 2009). This has brought support to the idea that wildlife harvesting is the main selection force acting on prey populations in the wild (Darimont et al. 2009).

The effect of wildlife harvesting on prey populations is not limited to morphological and life-history traits and extends to behaviour as well. In particular, many species adjust to harvesting by performing more risk averse behaviours. During the hunting season, brown bears (*Ursus arctos*) change their activity patterns to be more nocturnal (Ordiz et al. 2012), while willow ptarmigans (*Lagopus lagopus*) switch from using open areas to using more forested areas of their territories (Brøseth and Pedersen 2010). Under high pressure of recreational angling, some species of fish become more avoidant of fishing gear (Alós et al. 2014). Although they are rarely explicitly tested, most authors invoke learning and selection as potential mechanisms underlying observed behavioral changes (Alós et al. 2014; Côté et al. 2014). Regardless of the mechanisms, this suggests that some species are capable of changing their behaviour to cope with the increase in risk represented by harvesting.

The study of wildlife harvesting focuses mainly on demographic effects, as well as, to a lesser extent, morphological and life-history traits. However the idea that species can change their behaviour in response to capture risk has received little attention in this field. This is particularly true for one type of wildlife harvesting: control of invasive and pest species. The goal of biological control is to contain, reduce or eradicate a target population and there is hence a large focus on demographic effects. Behavioral changes in response to control have only recently started to get some attention. For example, Côté and colleagues (2014) showed that invasive lionfish (*Pterois volitans*) undergoing culling efforts became more wary from humans and modified the spatial and temporal distribution of their activity in such a way that encounters with spear-fishers were less common. Because eradication is seldom a realistic objective for control programs, managers have to deal with the population in the long-term. This means behavioural responses to control measures, particularly those that could reduce susceptibility to such measures, as in the case of lionfish, could have profound consequences for control programs. Beyond the possibility that the behavioural changes in the population could hinder sustainability of management programs, there is also scope for these changes to modify, for better or for worse, the

problematic behaviours that caused the species to be managed in the first place. It hence seems paramount to actively track behavioral adjustments and adaptations that could appear in species targeted by control measures.

In this study, I investigate behavioral differences between heavily harvested populations and lightly harvested populations, in the common myna (*Acridotheres tristis*). This species is a highly successful worldwide invader (Lowe et al. 2000; Peacock et al. 2007). Although in Australia the species is currently mostly limited to the East coast, it is extending its range westwards (Martin 1996). There is evidence that it competes with native species for nesting hollows (Pell and Tidemann 1997b; Grarock et al. 2012). The species is also highly disliked by the Australian people as shown by the results of a national survey (ABC 2005). Consequently, the species is now the target of substantial control efforts across its Australian range, mainly through trapping programs. Preliminary observations have suggested that the species is changing its behaviour in areas where it is undergoing heavy trapping pressure by avoiding trapping locations, forming smaller groups and becoming less conspicuous (King 2010), which hints towards the idea that the common mynas might be able to adjust to harvesting by humans.

After locating zones in which mynas were undergoing different trapping pressures (see Chapter 1), I compared a range of behavioral variables between highly and lowly harvested areas in two regions of Australia. Based on findings from other predatory contexts, both natural and anthropic, mynas from riskier areas were expected to be more risk-averse and show stronger anti-predator behaviour. More specifically, I predicted that mynas in risky areas would (1) form larger groups (Cresswell 1994), (2) spend less time foraging away from refuges (Slotow and Coumi 2000; Kavaliers and Choleris 2001; Caro 2005), (3) be less active to reduce chances of encounter with a trap (Alós et al. 2012), (4) be more vigilant while foraging (Devereux et al. 2006), (5) be more responsive to conspecific distress calls (Griffin 2008) and (6) become less detectable (King 2010; Côté et al. 2014). Abundance was also estimated in each sampled area to determine to what extent differences in population density contributed to differences in behaviour between high trapping pressure and low trapping pressure locations.

2. Methods

2.1. Sampling strategy

Sampling took place from June 2012 to October 2012 in New South Wales (NSW) and the Australian Capital Territory (ACT), in Australia.

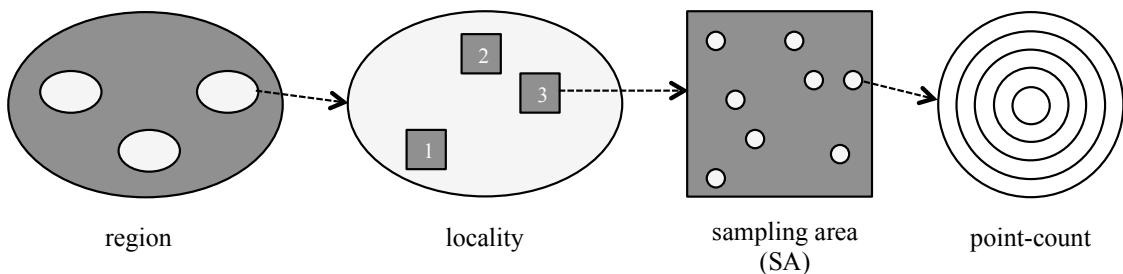


Figure 19. Diagram of sampling hierarchy going from the first level, region, to individual point-count plots. Region and Locality shape are approximations. In our sampling there were a total of two regions and nine localities. Between two and five SA's were selected in each locality, leading to a total of 32. In each SA, eight point count plots were randomly selected. The point-count plot is represented with its five concentric 10 m distance bins (see text for more details).

2.1.1. *Region*

I used trapping estimates from the survey to councils and volunteer groups (presented in Chapter 1) to select zones with high and low trapping pressure. A large portion of the data received for this survey came from around Canberra and Sydney, which are the two principal urban zones in the target geographic area. It was hence decided to focus on these two regions.

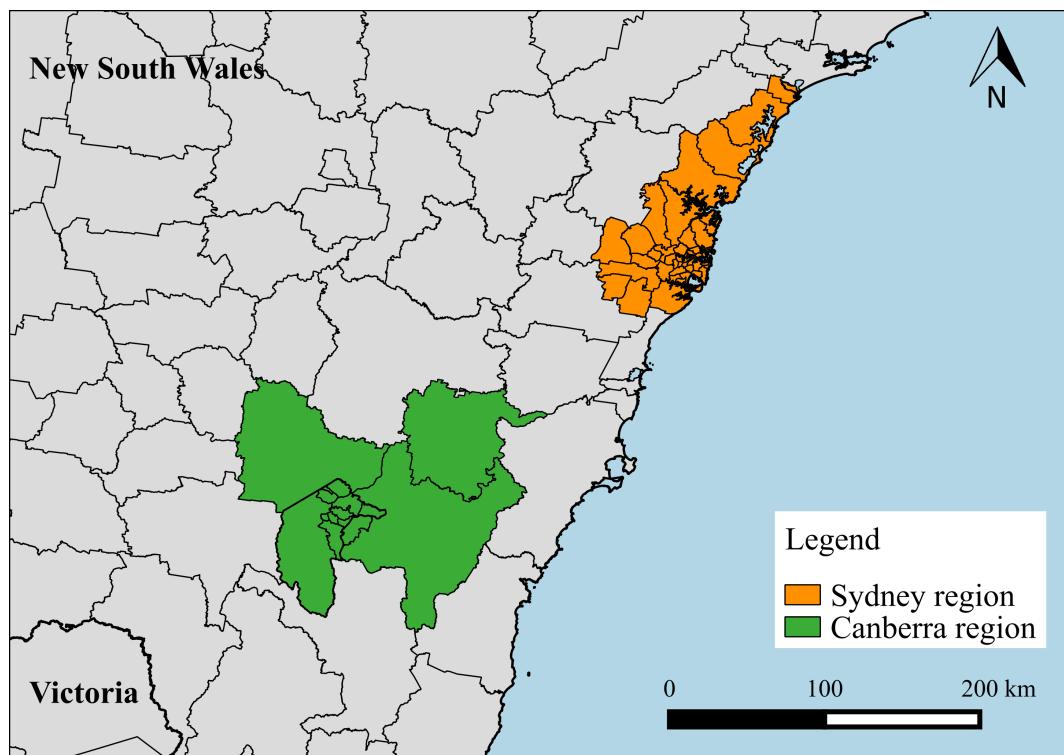


Figure 20. Localization of the two sampled regions on a map of south-eastern NSW. Small lines indicate division of localities (see details below) while thick lines indicate shoreline and state borders. Specific localities sampled cannot be provided due to privacy reasons.

The designation Sydney region and Canberra region are not based on any administrative or otherwise pre-existing categories. Instead, I refer to large areas, where the ‘Sydney region’ is a coastal region centered around the city of Sydney, and the ‘Canberra region’ is an inland region (every point at least 80 km from the sea) (see Figure 20). These two regions belong to different bioregions (Australian Department of the Environment 2015). Canberra lies at over 500 m above sea level and has a continental climate with overall lower temperatures (yearly mean minimum and maximum temperature: 7.1-20°C) than Sydney (13.8-21.7°C). Sydney has a more temperate climate, in particular during winter (Australian Bureau of Meteorology 2015). As a result, vegetation communities in these regions vary. The Sydney region is part of the ‘Sydney basin bioregion’ and is surrounded primarily by eucalypt open forest and tall open forest, while the Canberra region lies on the ‘south eastern highlands’ and ‘Australian alps’ bioregions and is surrounded primarily by eucalypt open forest and eucalypt woodland (Atlas of living Australia 2015).

2.1.2. Localities

Information collected in our survey to councils and volunteer groups was gathered at the scale of small administrative units: local government areas (in NSW) and districts (in ACT), both hereon after referred to as localities. In each region I selected localities with high (more than 10 mynas removed per 1,000 inhabitants per year) and low (less than 10 mynas removed per 1,000 inhabitants per year) trapping pressure (Table 6, see Chapter 1). A total of nine localities were selected across the two study regions, four with high trapping pressure and five with low trapping pressure. Details are indicated in Table 6. The specific localities sampled in this study cannot be revealed because of a privacy clause contained in the survey

2.1.3. Sampling areas (SA)

Within each locality, sampling areas (SA) of 2 x 2 km were determined randomly. SAs were restricted mostly to suburban habitats and were designed to contain no more than 15% bushland or parkland habitat. The number of SAs in a locality depended on its size, with more SAs in larger localities (mean: 3.5, range: 2-5). A total of 32 SAs were sampled in this study, 15 in high trapping pressure localities and 17 within low trapping pressure localities. Details are indicated in Table 6.

Table 6. Distribution of sampled localities and sampling areas (in brackets) across the two study regions

	High pressure (>10 per yr per khab)	Low pressure (<10 per yr per khab)
Sydney Region	1 (4)	2 (8)
Canberra Region	3 (11)	3 (9)
Total sample	4 (15)	5 (17)

2.2. Abundance estimates

2.2.1. Point-counts

In order to account for differences in behaviour that might have been attributable to differences in myna density, I undertook to measure the abundance of the species in each of the 32 SAs. As it was predicted that mynas would be less conspicuous in areas undergoing high levels of trapping, it was critically important that abundance surveys maximize myna detection. Following recommendations that sampling smaller areas with greater sampling effort better accounts for low detectability (Bibby et al. 1998), I elected to undertake point-counts to estimate abundance.

Plots in which point-counts took place consisted of an area of 50 m radius and were always at least 300 m apart. In each SA, the location of eight point-count plots were all selected randomly except one, which one was arbitrarily set to be in a commercial habitat. This is because mynas typically congregate to feed in areas around commercial buildings (e.g. supermarket/fast food outlets) so abundances can be very high (personal observation). These surveys were always conducted during the 3 h prior to sunset, during the dusk peak activity period (Bibby et al. 1998), and lasted 5 min (Bonthoux and Balent 2012). Two experimenters conducted the surveys and one experimenter, always the same (MD), undertook the observations, while the other (NH) took notes. All mynas seen and heard were recorded but those flying high overhead (when neither the takeoff point nor the landing point could be seen) were excluded. Although vocalizations were recorded, they are not used in abundance estimates (see methods section 2.3.2, below). Overall, birds were included in the count conservatively in order to avoid any double counting.

Distance to the experimenter was measured by locating birds on maps marked with five concentric circles of 10, 20, 30, 40 and 50 m radius. Birds outside of the 50 m boundary were noted as “beyond 50 m”. For the purpose of the analysis, an arbitrary maximum distance of 100 m at which birds could be seen was selected. During the analysis involving distance to experimenter, either the median distance of each distance bin (5, 15, 25, 35, 45, 75 respectively) or an ordinal ranking (0, 1, 2, 3, 4, 5, respectively) was used. Experimenters remained in the 10-m central zone during the entire duration of the point-count.

2.2.2. *Transects*

The sampling areas (SAs) were additionally surveyed during the four hours following sunrise on the day following the point-count. During this time the experimenters walked through the SA at a constant slow pace, looking for mynas without following a predefined path. This survey is from hereon after referred to as the transect and there was hence one per SA. The main goal of these transects was to make as many observations of mynas as possible in order to collect data on their behaviour. Hence transect path and location were selected to maximize the likelihood of finding mynas (based on information collected during and in-between point-counts as well as the daily experience of the experimenters).

Not the whole four-hour period was spent walking and recording sightings as the experimenters occasionally drove from one part to another of the SA (mean time spent in the car: $20.12 \text{ min} \pm 1.27 \text{ SE}$). This meant that despite walking at a constant pace, and spending the same duration each morning, transects could vary in their length. The distance walked was hence carefully recorded on a map. All mynas sighted within 25 m from the experimenters were recorded, creating a 50 m-wide transect. The combination of width of transect and its length allowed to calculate the surface surveyed (average surface surveyed by SA: $37 \text{ ha} \pm 1.20 \text{ SE}$, which represents approx. 9% of the total SA surface).

The experimenters never walked twice in the same place during these surveys. All mynas sighted were recorded (once again, conservatively to avoid counting the same bird more than once). In this way, transects provided additional estimates of abundance that complemented those obtained from point counts.

2.3. Detectability

2.3.1. *Comparison of density estimates from point-counts and transects*

Non-random selection of transects in order to maximize the number of mynas encountered (see methods section 2.2.2) had the consequence that abundance estimates based on transects would likely be greater than those obtained from point-counts. However, this overestimation could be predicted to differ among sampling areas (SA). Specifically, I expected the level of overestimation to vary as a function of the trapping pressure experienced by birds in each SA.

My reasoning for this prediction was as follows. Bibby and co-authors (1998) argue that point-counts are more likely to lead to the detection of cryptic birds than transects because points counts require spending a greater amount of time in the same area. Transects, on the other hand, cover more ground in less time and are hence more likely to lead to more sightings simply due to sampling a larger area, making them better suited to counting conspicuous birds. This suggests that, were my transects to have led to an overestimation of densities compared to point-counts, then this overestimation should have been more important where birds were very conspicuous. Based on the assumption that trapping pressure causes mynas to become shier, I made the following prediction: in low trapping pressure SAs, where birds should be

conspicuous, transect density estimates were expected to be much higher than those obtained from point counts. In contrast, in high trapping pressure SAs, where mynas should be shier, I expected abundance estimates based on transects to be only slightly higher than those based on point counts.

Conspicuousness of birds is not the only factor expected to influence differences between density estimates from point-counts and transects. In particular absolute rarity of birds could have an effect. Because transects allow one to search larger surfaces, birds that are rare (in the sense that they are at very low density) are more likely to be encountered during transects than point-counts. Hence if birds become less conspicuous as a result of a decrease in density, the main gain from point-counts (better detection of shy birds) might be outweighed by its limitation (poorer detection of rare birds), in areas where these two phenomena co-occur.

Table 7. Predicted relative tendency of transects to over-estimate density found in point-counts depending on conspicuity and absolute rarity of birds.

Myna behaviour		Conspicuous	Shy / discreet
Rarity	low	moderate	low
	high	high	moderate

I hence expected that overestimation of density by transects would be larger when 1) birds were conspicuous, and 2) when birds were rare. Further, I expected these effects to be cumulative; in other words overestimation would be highest in areas where birds were conspicuous *and* rare. These predictions regarding the tendency that transect-densities will over-estimate point-count-densities are presented in Table 7.

2.3.2. Comparing visual and auditory detections

Another approach to investigating differences in detectability is to estimate the likelihood of seeing birds in places where their presence can be established with certainty. I took advantage of the fact that common mynas are very vocal throughout the year (Counsilman 1971; Feare and Craig 1999) to estimate that they were present in the vicinity of a point-count plot. This then allowed me to investigate the factors underpinning the likelihood of visually detecting mynas in plots where mynas had been detected acoustically and were therefore known to be present.

In a subset of 227 point-count plots (out of 253 total), I noted whether mynas were heard or not, this could include any type of vocalization (see Counsilman 1971 for exhaustive list of vocalisations), but was in practice limited to singing, contact calls (i.e.

flight calls) and alarm calls. Mynas were heard in 97 out of 227 point-counts surveys (43%), while only seen in 20% of plots. Auditory detections were hence much more common than visual detections, which validates the approach taken here, especially since there were extremely few cases ($n=3$) where mynas were seen in plots in which they were not heard.

2.4. Characterization of sites

2.4.1. *Habitat*

For each point-count plot, the percentage covered by each land use category (Table 8) within the 50 m-boundary was determined from satellite images (Google earth). The category that covered the greatest proportion of the plot was used to characterize its habitat. A plot covered with 70% of residential housing and 30% of open parkland was hence referred to as a ‘residential plot’. The fact that ‘wooded parkland’ and ‘urban area’ were infrequent (Table 8) lead to statistical abnormalities. To overcome this issue, both types of parkland (i.e. wooded and open) were grouped subsequently into a single habitat category referred to as ‘park’. Similarly, both highly modified categories were grouped into a habitat category referred to as ‘urban’. As the study focused on suburban habitat, residential habitat was unsurprisingly the most frequently encountered habitat.

Table 8. List of the three habitats employed to characterise habitat of sampled birds in this study and description of the five land use categories they include. Depending on the land use category that covered the greatest ratio of a plot (road and water bodies excluded), it was attributed one of three habitat types. %PC shows the percentage of point counts for which each category was the main habitat (see text for details).

Habitat	Main land use category	Description	% PC
PARK	Wooded Parkland	Remnant bushland and woodland, vegetation dominated by woody plants, most often with leaf litter substrate.	4.7
	Open Parkland	Open grassy area with scarce or fringing trees, includes parks and sport grounds	17.4
RESID	Residential Area	Low-rise buildings with large gardens and often front lawns, mostly surrounded by grassy or vegetated areas.	62.8
URBAN	Urban Area	High density housing with limited vegetation, high-rise housing, mostly surrounded by sealed surfaces.	2.4
	Commercial and industrial Area	Buildings and parking used for commercial and industrial purposes: Shopping centre, warehouse...	12.6

2.5. Season, temperature and weather

This study took place over the span of five months (June 2012 to October 2012). This period was divided into two seasons: winter (field sessions: mid-June to end-June,

end-July to beginning of August) and spring (field session: mid-September to mid-October). Overall this distinction corresponds to the breeding status of common mynas (non-breeding in winter and breeding in spring), however, although the onset of the breeding season is often set in September (Pell and Tidemann 1997a; Grarock et al. 2014), it is sometimes set as late as October (Counsilman 1974; Grarock et al. 2013a).

Temperature was recorded once at the beginning of every point-count and every hour during transects. Surveys were only carried out in clement weather, avoiding high winds (over 30 km/h) and rain.

2.5.1. Time of day

Two types of survey took place during this study: transects, which were performed during the 4-h time period after sunrise (i.e. in the morning) and point-counts, which were performed during the 3-h time period before sunset (i.e. in the afternoon). This has important implications for the way in which I elected to measure time of day.

In those components of the analyses that used abundance data from point-counts, time of day was straightforward to determine: I used “time to sunset”, where zero is set at sunset (i.e. larger values therefore refer to times earlier in the afternoon).

In those components of the analyses that drew upon abundance data from both point-counts and transects, determining time of day was more complicated. As our surveys stretch over two seasons, variation in day length has a strong impact if all times are measured relative to sunset. Consequently, an alternative variable to measure time was required here. Based on the bimodal circadian activity pattern of birds (Aschoff 1966; Bednekoff and Houston 1994), and the tendency of mynas to form pre- and post-roosting aggregations (Counsilman 1971), I expected time from the closest period of dark to be the most biologically relevant. “Time to dark” in the morning refers to time from sunrise (zero set at sunrise), and in the afternoon refers to time to sunset (zero set at sunset), and in both cases larger values represent times closer to noon. The time to dark variable does not allow to discriminate between morning and afternoon. However this information appears in the variable “survey type” which distinguishes point-counts and transects.

2.6. Behavioral observations

All groups of mynas, whether of one or several individuals, seen during this study, whether during point-counts or transects, were considered an ‘observation’. The observations are considered independent because repeated sampling of the same individual is unlikely to have occurred. First, double-counting of birds was carefully avoided during point-counts and transects (see section 2.2). Second, point-count locations were at least 300 m apart and all took place in succession, making it unlikely for a same bird to be present at several plots.

For each observation, experimenters noted (1) the size of the group, (2) if the group was close to a refuge, and (3) its activity (see below). Additionally, measures were also carried to measure vigilance levels and response to alarm signals.

2.6.1. *Group-size*

In the literature, researchers generally rely on a combination of factors including proximity, time of association and similarity in behaviour to assess whether birds are part of a same group or flock (Randler 2005; Farley et al. 2008; Valcarcel and Fernández-Juricic 2009). Groups of common mynas are usually very variable in their number (pers. obs.). In this study, group size was measured as the number of mynas that were within 10 m of each other during at least 30 s. Groups could hence vary in size from a single individual, to tenths of individuals.

2.6.2. *Proximity to refuge*

As the focus of the present study was on trapping pressure, risk taking was mainly of interest in the context of human avoidance. A group of birds was considered close to a refuge when the center of the group was less than 2 m away from either a perching point (at least 2 m-high), or cover (such as a dense bush). In such positions, birds would be able to escape a ground predator, such as a human, rapidly.

2.6.3. *Activity*

Activity was allocated to five mutually exclusive categories: calling, foraging, ground locomotion, flying, standing still. Self-centered activities such as preening were rare and were included in the standing still category. The vast majority of the time, all

group members were observed to be performing the same activity. When this was not the case, the activity performed by the majority of the group was recorded.

2.6.4. Vigilance

During transects, experimenters video recorded mynas on the ground in order to score vigilance levels more precisely. Only individuals and groups present on grass and leaf litter, the most common foraging substrate of this species (Crisp and Lill 2006), were video recorded. Most mynas present on the ground are there to engage in foraging and this focus was intended to maximize similarity of foraging effort and food sources across samples. Highly vigilant and alarmed birds were not tested (Blumstein 2003). Sampled flocks had to contain at least 75% of common mynas. Groups and individuals that were recorded less than 300 m apart were considered to be part of the same sample. Experimenters remained at least 20 m away from the birds while video recording in order to minimize disturbance. Non-experimental-related sources of disturbance were quantified by counting the number of animals, pedestrians, cars, and bicycles that passed within 50 m of the focal group of birds.

Video recordings lasted a maximum of 90 s. Only videos where birds remained in sight for at least 30 s were analysed. They were scored using j-watcher (Blumstein et al. 2006) by an observer blind to the SA and locality of origin of the video. One random bird was chosen in the group and the position of the head (above or below shoulder) and its orientation (downwards, straight, and upwards) were recorded continuously.

Although birds can detect approaching predators while foraging head down, efficiency of vigilance is best when their heads are up (Lima and Bednekoff 1999). In this study, both head position (up, down) and head orientation (upwards, straight, downwards) were measured. I assumed vigilance efficiency, in the sense of ability to detect approaching predators, would be high when head position was up and head direction was upwards, and inversely would be low when head position was down and head orientation was downwards. I hence calculated a composite score that included both position and orientation where the proportion of time spent in each state was multiplied that by the estimated ‘vigilance efficiency’ of that state. This vigilance score (*vs*) was calculated based on the following formula:

$$vs = \sum_z p(t_z) \times i_z + \sum_y p(t_y) \times i_y$$

in which z is a head position and y is a head orientation and $p(t)$ is the proportion of time spent in that position or orientation and i is the estimated vigilance efficiency of that state ($i_{\text{down}}=0$, $i_{\text{str}}=1$, $i_{\text{up}}=2$). Calculated in this way, the maximum vigilance score (vs) possible was 4 and was achieved when a bird spent the entire observation period with its head in a position and orientation that had the maximum vigilance efficiency (i.e. $i_{\text{up}}=2$).

2.6.5. Response to distress calls

Sensibility to social risk signals was assessed by measuring the mynas' responses to distress call playbacks. Distress calls are high amplitude, broadband vocalizations that are produced by small birds in response to seizure by a predator, such as a human (Norris and Stamm 1965). Although it is not clear to what extent they function as an intra- or an inter-specific signal, it is quite clear that distress vocalisation are indicative of heightened predation risk (Conover 1994). Distress calls played back under free-ranging conditions are highly attractive to common mynas who respond to them by approaching the source of the sound (Griffin 2008).

Once the first 5-min point-count period was over (pre-playback survey), the experimenters initiated a second point count from the same position (playback survey). This second survey followed exactly the same protocol as the pre-playback point-count, except it started with a 1-min distress call playback. The playback point-count protocol was further modified in that experimenters noted whether the groups of mynas present responded to the playback. Responses were defined as any abrupt change in activity following the onset of the playback. As long as one individual in the group responded, the group was considered to have responded to the playback. Common responses included interrupting the ongoing activity, flying to a perch and freezing, and approaching the speaker. Myna responses were recorded as soon as the 1-min playback began and for four minutes after it ended. In this way, pre-playback and playback surveys had the same duration.

The specific acoustic stimulus used in the present study was created by concatenating sequences of calls from three different mynas recorded during handling (Griffin 2008). The frequency of the distress calls in the playback was approximated to that observed naturally (mean 86 ± 15 SE calls/min, measured from recorded sequences

of calls). The signal was played back using a Pignose 7-100 portable amplifier at approximately 75 dB (measured at 1 m with a sound level meter).

2.7. Analysis

All analyses were undertaken using R version 3.2.2 (R Core Team 2015).

2.7.1. *Abundance*

Distance analysis (Buckland et al. 2001) allows for variation in detectability to be accounted for when estimating abundance. This is achieved by estimating a detectability function based on the recorded distances between the experimenter and the birds, under the assumption that birds closer to the experimenter are more likely to be detected. In order to perform this analysis, I truncated the data at the limit of the last distance-bin. In doing so, I excluded arbitrarily all birds seen beyond 50 m as it was not clear what the maximum detection distance might have been beyond 50 m. In addition, distance bins were pooled in order to improve the fit between the data and the detection function. Overall, despite the great ecological tool this method represents, these restrictions meant that a substantial amount of data was being disregarded. For this reason, I do not report further on this analysis other than to point out that using abundance estimates calculated using Distance (Miller 2015) did not change any of my conclusions.

Number of birds detected at each point-count plot was used to estimate abundance. All birds seen both within and beyond the 50 m plot edge were recorded. I used a zero-inflated model to account for the high proportion of plots in which no birds were seen (80%). Zero-inflated models are a mixture model where a discrete probability distribution is used to explain the count data and is combined with an additional binomial process that explains excess zeros (Zuur et al. 2009). The negative-binomial distribution was chosen over the Poisson distribution because over-dispersion was present over and above the zero-inflation.

I fitted zero-inflated negative binomial GLMM with the glmmADMB package (Fournier et al. 2012; Skaug et al. 2015). The initial model included trapping pressure, region, the interaction of trapping pressure and region, habitat, season, temperature and time to sunset. Non-significant predictors were removed successively until only significant predictors were left in order to obtain a minimum adequate model (MAM).

Because trapping pressure was a key variable of interest in the present work, trapping pressure was always left in the model regardless of whether it was a significant predictor or not. I then verified that this model was an improvement over simpler and more complex models using likelihood ratio statistic (Zuur et al. 2009). All models were validated by visual inspection of plots of residuals to ensure the absence of any pattern.

The full nested random-intercept structure of the data collection (region/locality/SA) could not be used because region had too few levels to be incorporated as a random variable ($N=2$). The (locality/SA) nested structure elicited model failures when entered into the model alongside the zero-inflation. For these reasons, I only included locality as a random factor. It is worth noting however, that in the model without zero-inflation, SA explained very little of the variance of the MAM (locality:SA : variance= $2.33 \times 10^{-9} \pm 4.83 \times 10^{-5}$) and that the MAM revealed the same significant predictors whether zero-inflation was accounted for or not.

In order to incorporate myna abundance as a predictor in models explaining behavioral variables (see below), I determined a mean abundance for each SA. This was calculated by averaging the number of birds seen in each point-count plot across that SA.

2.7.2. Detectability

Comparison of density estimates from point-counts and transects

In each of the 32 sampling areas (SA), 8 point-count surveys took place. By considering only birds within the 50 m point-count plot boundary, I was able to calculate a density estimate that could then be compared to the one obtained from the transect surveys.

To evaluate to what extent transects overestimated density found in point-counts, I calculated an overestimation index by extracting residuals from a linear regression of the two density estimates. As discussed previously, I expected this overestimation index 1) to be higher in low-trapping areas if trapping influences conspicuousness of birds, and 2) to be higher in areas where mynas were rare because under such circumstances transects are more likely to lead to sightings than point-counts. To account for rarity, all SAs with an average point-count density of 0.5 or below were categorised as “low density” (i.e rare mynas), while all those with higher

densities were categorised as “high density”. I tested whether the indexes differed in such ways by using an ANOVA and testing for an effect of trapping pressure and rarity.

Comparing visual and auditory detections

For this analysis, I used only pre-playback point count data. I used the subset of 97 plots where mynas were heard to investigate the likelihood of seeing mynas when mynas were heard. The rare cases in which mynas were seen without being heard ($n=3$) were excluded from this analysis. The likelihood of seeing at least one myna was modeled using a binomial GLMM with the lme4 package (Bates et al. 2015) with a nested random-intercept structure (Locality/SA).

Model selection was done through a stepwise backward procedure for which the initial model contained the following terms: trapping pressure, region, the interaction of trapping pressure and region, habitat, season, temperature and time to sunset. Once again, trapping pressure was retained in the model throughout the backward elimination process as it constituted a key variable of interest.

2.7.3. Behaviour

To model the effects of trapping pressure on behaviour, I used a stepwise backward model selection procedure, retaining my key variable of interest, namely trapping pressure, throughout the process. Other predictor variables included in the full-model prior to simplification were: region, the interaction of trapping pressure and region, survey type, season, time to dark and abundance, as well a nested random-intercept effect (locality/SA). Temperature caused collinearity issues with season, region and survey type, hence could not be included as a factor in the full model.

Group size

Group size was analyzed using a zero-truncated negative binomial GLMM with the glmmADMB package (Fournier et al. 2012; Skaug et al. 2015).

Proximity to refuge

Likelihood of birds to be close to a refuge was analyzed with a binomial GLMM (LME4 package).

Activity

Activity was analyzed using a multinomial log-linear model with the five categories as the outcome variable and the “standing still” category as the reference category. This was done with the nnet package (Venables and Ripley 2002) following method suggested by Agresti (2002). The initial model contained all factors listed above except the interaction term. A follow-up Wald test was then performed to identify more precisely which activities were affected by the significant factors.

Vigilance

Due to the way in which it was calculated, the vigilance score was bounded between zero and four. However, observed values rarely approached those bounds and it was hence deemed acceptable to use a Linear Mixed model with a Gaussian error distribution. Models were fitted in a Bayesian framework with the MCMCglmm package (Hadfield 2010) such that confidence intervals could be obtained. A non-informative proper prior was used (see annex 2.1.2 for details). The model included region, trapping pressure, group size, time to dark, season, disturbance and the interaction of trapping pressure and region as fixed factors. The full model is presented. There were mixing issues when locality was included in the random effects. For this reason, it was removed and the final random structure retained was sample (i.e. all recordings that took place within 300m from each other) nested in SA. Autocorrelation of successively stored iterations was checked to ensure that it was under 0.1, and convergence was assessed visually from diagnostic plots.

Response to distress calls

Comparison of abundance (i.e. the number of birds seen during point counts) before and after the playback was undertaken following the same methodology as described for abundance (see section 2.7.1). The data from the pre-playback and playback point counts were combined such that each plot had two counts (one before and one after the playback) which necessitated the addition of a random factor to account for repeated measures on the same point-count plot. The full random structure (locality/SA/plot) was used in this model. A variable called “stage” which referred to whether the count took place before or after the playback was added to investigate whether the playback significantly predicted the number of birds seen.

Likelihood of groups of birds to respond to playbacks was analysed using a binomial GLMM in order to determine whether groups of mynas present after the playback responded to the distress calls or not. Initial model included trapping pressure, region, the interaction of trapping pressure and region, time to sunset, temperature, distance to experimenter/speaker (median of distance bin) and group size. The nested random-intercept structure (locality/SA) was included.

2.8. Ethical statement

Observations for this experiment were done under a NSW national park scientific license #12304 and an ACT animal use research license granted to Andrea Griffin on September 20th 2011.

All procedures were approved by the University of Newcastle Animal Ethics Committee (protocol #A-2011-129).

3. Results

3.1. Differences in abundance

Point-count surveys were performed in the afternoon, and the number of mynas detected increased as sunset approached (Table 9). More birds were seen in the Sydney region (mean= 1.23 ± 0.26 SE birds per plot) than in the Canberra region (mean= 0.41 ± 0.10 SE birds per plot) and less birds were seen in highly modified urban habitats than residential ones (Table 9, Figure 21). Surprisingly, trapping pressure of localities did not predict abundance (Table 9).

Table 9. Parameter estimates from minimal adequate zero-inflated negative binomial mixed model of the number of mynas seen per point-count

<i>Fixed coefficients</i>	estimate	std. error	z-value	p
(Intercept)	1.383	0.450	3.075	0.002
Trapping pressure (low)*	0.381	0.301	1.267	0.205
Region (Sydney)*	0.590	0.292	2.017	0.044
Habitat (Park)*	-0.649	0.482	-1.346	0.178
Habitat (Urban)*	-0.794	0.383	-2.071	0.038
Time to sunset	-0.584	0.175	-3.330	0.001
<i>Random effects</i>	Variance	std. dev.		
Locality	2.061×10^{-9}	2.219×10^{-8}		

* categorical variables in the table are compared to a reference category, Region: Canberra, Trapping pressure: high, Habitat: residential. When a variable contains more than two categories, all are compared to the same reference category.

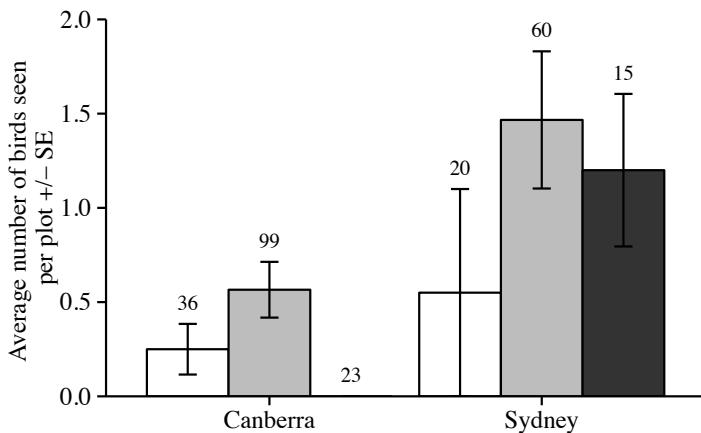


Figure 21. Average number of birds seen per point-count plot (\pm standard error) as a function of region and habitat, parks in white, residential in light grey and urban in dark grey. Numbers above bars indicate the sample size (i.e. number of point-count plots of each type surveyed).

3.2. Differences in detectability

3.2.1. Comparison of density estimates from point-counts and transects

Density estimates from point-counts and transects were significantly, but not highly correlated (Pearson's $r=0.51$, $p=0.03$, Figure 22a). As discussed in the methods, I expected differences in overall density estimates yielded by the two methods. In line with my predictions, I found that transects had higher estimates (mean= $1.27 \pm 0.19\text{SE}$ bird per ha) than point-counts (mean= $0.66 \pm 0.12\text{SE}$ bird per ha) (ANOVA, $F(1,62)=7.52$, $p=0.008$).

In order to estimate how much density estimates from transects overestimated those from point-counts, I calculated an overestimation index by extracting residuals from linear regressions between density estimates from the two survey types for each sampling area (Figure 22a). Because of the effect of region on abundances, one regression line per region was fitted and residuals were extracted. In line with my prediction that overestimation of abundances by transects should be reduced in high trapping areas relative to low trapping areas because birds should be more shy, I found that low trapping areas tended to have higher overestimation indexes than high trapping areas (Figure 22b). This difference fell just short of significance, however (two-way ANOVA, $F(1,29)=3.71$, $p=0.064$).

Although it was expected that transects were more efficient at recording rare species, this was not supported by the data: high and low density areas did not differ in their overestimation indexes (two-way ANOVA, $F(1,29)=1.12$, $p=0.299$).

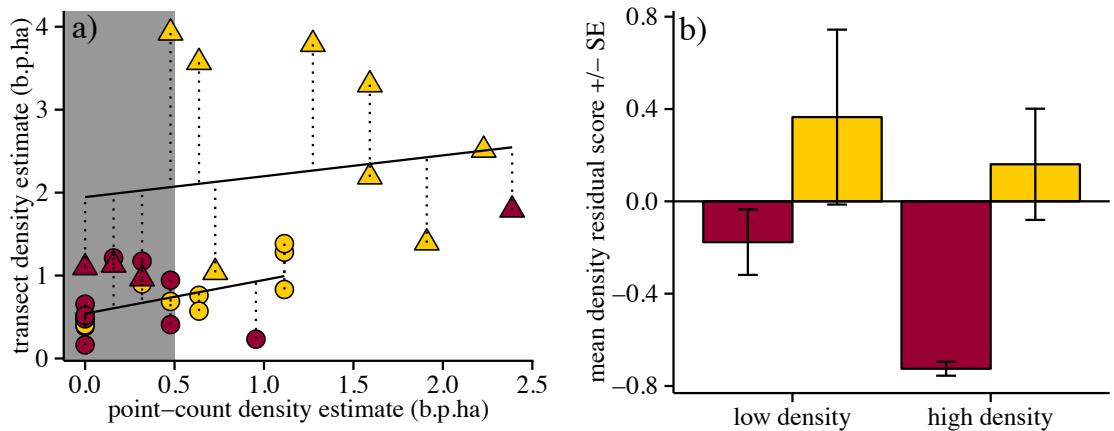


Figure 22. a) Linear regression of point-count density estimates (birds per hectare) against transect density estimates (birds per hectare) for each sampling area. One regression line was fitted per region because of large regional differences, Sydney represented by triangles (line at the top) and Canberra represented by circles (line at the bottom). High trapping SAs in red, low trapping SAs in yellow. A point-count density of 0.5 was chosen as a cut point for low density (grey area in plot). b) Mean overestimation indexes (i.e. residuals from density estimate regression) and standard error among high and low trapping pressure SAs and high and low density SAs.

Based on the assumption that transects have a reduced tendency to over-estimate density in areas where mynas are shy (see methods section 2.3.1), this result suggests that there is a trend for mynas in high trapping areas to be less conspicuous than their conspecifics living in low trapping areas. This is in line with my predictions and previous anecdotal observations (King 2010).

3.2.2. Comparing visual and auditory detections

Trapping pressure was not a significant predictor of the likelihood of seeing mynas in plots where they were heard (Table 10). However, the likelihood of detecting mynas visually in plots where mynas were heard was higher in the Sydney region than in the Canberra region (Table 10). This indicates either that mynas in these two regions differ in their behaviour such that they are more likely to be seen in Sydney than in Canberra, or alternatively that the two regions differ in some aspect that makes mynas easier to see in Sydney than in Canberra (see discussion).

Table 10. Parameter estimates from best fitting binomial GLMM on the likelihood of seeing at least one myna in a point count where mynas were heard vocalizing.

<i>Fixed effects</i>	estimate	std. error	z-value	p
(Intercept)	-1.135	0.421	-2.699	0.007
region (Sydney)*	1.352	0.438	3.088	0.002
Trapping pressure (low)*	0.577	0.463	1.247	0.212
<i>Random effects</i>				
variance				
Locality:SA	0.00	0.00		
Locality	0.00	0.00		

* categorical variables are compared to reference category which is not indicated above. Region: Canberra, Trapping pressure: high.

3.3. Behavioral observations

3.3.1. Group size

The number of individuals within groups varied substantially (mean: 1.86, range: 1-18) over the 914 observations that were made during this study. However, a vast majority of groups consisted of one or two individuals (n=794, 87%).

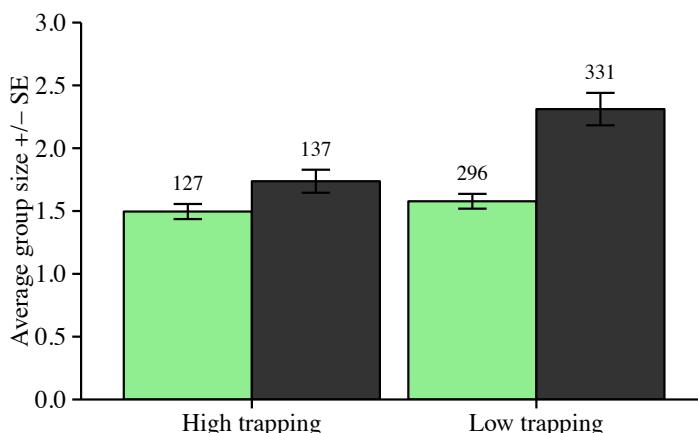


Figure 23. Mean group size observed among mynas in high and low trapping pressure environments as a function of season, with spring in light green and winter in dark grey and spring in light green. Numbers above bars indicate sample size.

Group size was, on average, smaller in spring than in winter (Table 11, Figure 23) and observations of larger groups were made more often at times closer to dark (early in the morning and late in the evening) (Table 11). There was also a strong trend for smaller groups under high trapping pressure (Table 11), particularly in winter (Figure 23). Note that I retained trapping pressure in the final model, but the incorporation of this variable only marginally improved the model fit (log likelihood = -1104.6, p=0.06, ΔAIC=1.4).

Table 11. Parameter estimates from minimum adequate zero-truncated negative-binomial mixed model on the number of individuals in a group.

<i>Fixed effects</i>	estimate	std. error	z-value	p
(Intercept)	-0.543	0.206	-2.638	0.008
Trapping pressure (low)*	0.322	0.165	1.950	0.051
Season (winter)*	0.588	0.158	3.722	<0.001
Time to dark	-0.159	0.063	-2.537	0.011
<i>Random effects</i>	variance	Std. deviation		
Locality:SA	0.083	0.288		
Locality	8.66x10 ⁻⁹	9.31x10 ⁻⁵		

* categorical variables are compared to reference category which is not indicated above. Trapping pressure: high, Season: spring

3.3.2. Proximity to refuge

In accordance with my predictions, tendency to be close to a refuge was higher in areas under high trapping pressure, and this was particularly true in Canberra as suggested by the significant interaction (Table 12), suggesting risk taking is higher in safer localities (with low trapping pressure).

Table 12. Parameter estimates from minimum adequate binomial mixed model on the likelihood of mynas of being close to a refuge. A bird was considered close to a refuge when it was less than 2 m away from either a perching point (at least 2 m-high), or cover (such as a dense bush).

<i>Fixed effects</i>	estimate	std. error	z-value	p
(Intercept)	1.660	0.227	7.299	<0.001
Trapping pressure (low)*	-0.816	0.279	-2.925	0.003
Region (Sydney)*	-0.773	0.303	-2.547	0.011
Trapping pressure : Region	0.758	0.359	2.112	0.035
<i>Random effects</i>	variance	std. deviation		
Locality:SA	3.88x10 ⁻¹⁵	6.23x10 ⁻⁸		
Locality	0.00	0.00		

* categorical variables are compared to reference category which is not indicated above. Region: Canberra, Trapping pressure: high.

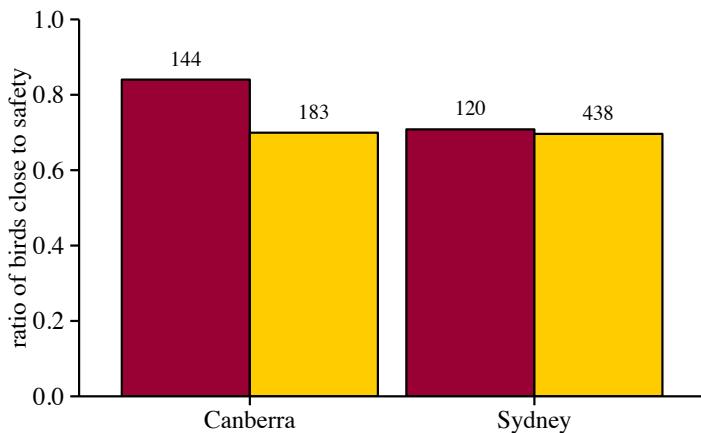


Figure 24. Ratio of birds close to a refuge as a function of region and trapping pressure, with high trapping pressures represented in red and low trapping pressures represented in yellow. Numbers above bars indicate the sample size.

3.3.3. Activity

Of all five possible activities, standing still was the most common activity category recorded ($N=301/891$). When looking at what factors predicted the probability of mynas of engaging in an alternative activity to standing still, group size, region, season and trapping pressure remained in the minimum model while survey type, abundance and time to dark did not. Predictors of whether mynas were more likely to be observed moving, vocalizing, foraging or flying than standing (baseline category) are indicated in Table 13. Trends expected by common myna ecology appeared. For example, in line with a large literature on group size effects on foraging, mynas in larger groups were significantly more likely to be observed foraging relative to standing still (Table 13). Moreover, vocalizations were less common during winter, outside the breeding season (Table 13).

Trapping pressure influenced activity of mynas, such that mynas were significantly less likely to be observed engaged in locomotion under low, rather than high, trapping pressure (Table 13). Mynas were also significantly more likely to be observed moving in Sydney than in Canberra (Table 13).

Table 13. Minimum adequate model coefficients with log odds (p-value of z-test) from Wald test indicating differences in probability. Because multiple comparison are taking place, the significance threshold was lowered to 0.005, significant factors are indicated in bold.

Activity*	(Intercept)	Trapping pressure (low)	Region (Sydney)	Group size	Season (winter)
locomotion	-1.25 (0.002)	-1.32 (0.001)^a	1.53 (0.001)	-0.02 (0.864)	-1.65 (<0.001)
calling	0.86 (<0.001)	-0.25 (0.225)	-0.47 (0.018)	-0.25 (0.010)	-0.58 (0.003)
foraging	-1.87 (<0.001)	0.16 (0.624)	0.55 (0.076)	0.20 (0.001)	-0.63 (0.022)
flying	0.15 (0.504)	-0.21(0.298)	-0.09 (0.663)	0.02 (0.729)	-0.38 (0.047)

* activity baseline category : standing still

^a sample interpretation of table: the log odds of mynas engaging in locomotion rather than standing still decreases by 1.32 under low trapping pressure compared to high trapping pressure. In other words, birds are less likely to be locomoting in low trapping areas than in high trapping areas.

3.3.4. Vigilance

Analysis of the 51 feeding bouts recorded showed that mynas were more vigilant in spring than in winter, and were more vigilant earlier in the morning (Table 14, Figure 25). The effect of time of day seemed particularly pronounced in winter (Figure 25), although this was not tested in the model presented (Table 14). Statistical modeling did not reveal evidence of a significant effect of trapping pressure on the vigilance scores of mynas (Table 14).

Table 14 Coefficients from full MCMC linear mixed model on vigilance scores

Fixed effects	posterior mean	lower 95% CI	upper 95% CI	pMCMC
(Intercept)	2.779	2.242	3.224	0.001
Trapping pressure (low)*	-0.164	-0.651	0.413	0.562
Region (Sydney)*	0.102	-0.499	0.711	0.738
Trapping pressure : Region	0.166	-0.516	0.833	0.620
Time to dark	-0.004	-0.008	-0.001	0.022
Season (winter)*	-0.490	-0.811	-0.087	0.014
Group-size	0.004	-0.034	0.040	0.852
Disturbance	-0.006	-0.095	0.067	0.906
Random effects				
SA	0.020	1.94x10 ⁻⁴	0.076	
SA:sample	0.019	2.47x10 ⁻⁴	0.071	

* categorical variables are compared to reference category which is not indicated above. Region: Canberra, Trapping pressure: high, Season: spring.

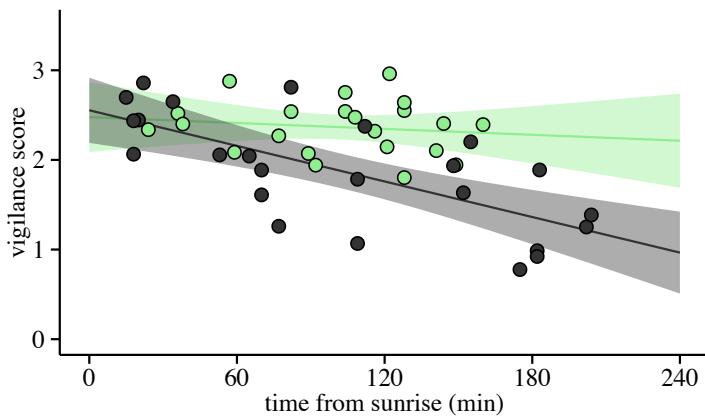


Figure 25. Vigilance score as a function of time to dark (here, time from sunrise as vigilance was measured only in the morning) and season with winter in dark grey and spring in light green. Lines represent linear regression lines for each season with 95%CI.

3.4. Response to distress calls

As expected, the sound of myna distress calls increased the number of mynas detected (Table 15). However, stage (before vs. after playback) was not a significant predictor in a GLMM modeling the number of birds seen (negative binomial GLMM with zero inflation, $\text{estimate}_{\text{stage}}=0.063\pm 0.154\text{SE}$, $p=0.69$). Instead, factors predicting the number of birds seen at a point count (Table 16) were the same than when only pre-playback counts were considered (see results section 3.1).

Table 15. Number of detections of common mynas during point-counts, before and after the playback of distress calls (i.e. the two stages).

Stage	Total number of mynas seen (mean per point-count)	Number of plots where mynas were seen (percentage)	Number of plots where mynas were heard (percentage*)	Total number of plots
Before playback	182 (0.72)	51 (20%)	97 (43%)	253
After playback	210 (0.83)	65 (26%)	100 (44%)	253

* note that auditory detections were only recorded for 227 point count plots

Table 16. Parameter estimates from minimal adequate zero-inflated negative binomial mixed model of the number of mynas seen per point-count

Fixed coefficients	estimate	std. error	z-value	p
(Intercept)	0.386	0.599	0.644	0.519
Trapping pressure (low)*	0.232	0.413	0.562	0.574
Region (Sydney)*	1.073	0.361	2.974	0.003
Habitat (Park)*	-1.471	0.402	-3.658	<0.001
Habitat (Urban)*	-0.368	0.409	-0.900	0.368
Time to sunset	-0.609	0.210	-2.899	0.004
Random effects	Variance	std. dev.		
Locality	4.49×10^{-6}	0.002		
Plot/Locality	1.071	1.035		

* categorical variables in the table are compared to a reference category, Region: Canberra, Trapping pressure: high, Habitat: residential. When a variable contains more than two categories, all are compared to the same reference category.

If at least one bird in a group of mynas suddenly changed its behaviour at the onset of the distress call playback, the group was considered to have responded to the playback. Of 107 observations on groups or individual mynas, 56 responded to the sound of myna distress calls. The level of trapping pressure did not influence likelihood of responding to the playback (Table 17), but birds closer to the experimenter and the speaker were significantly more likely to respond to the playback (Figure 26, Table 17). Most commonly observed responses included freezing and flying towards the speaker and sometimes culminated in groups performing alarm calls around the speaker.

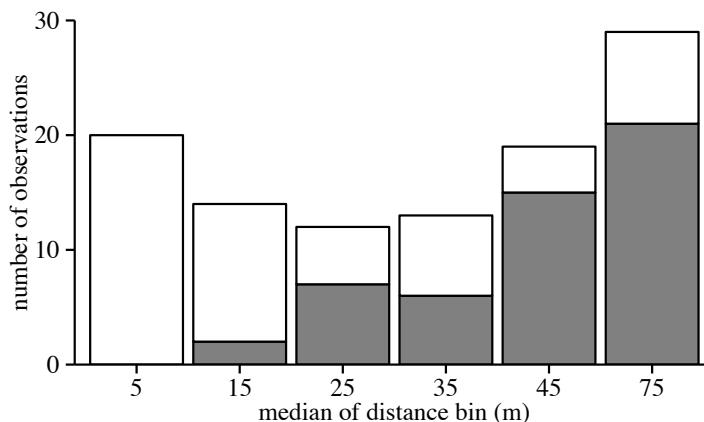


Figure 26. Number of observations of groups of birds responding to playback (in white) or not responding to playback (in grey) as a function of the distance bin from the speaker at which birds were detected.

There are two possible non-mutually exclusive explanations for why mynas closer to the speaker were more likely to respond (Table 8). First, it is possible that birds that were closer to the speaker were more likely to hear and respond to the stimulus. Alternatively, response to playbacks might have incited the birds to approach the speaker. In support of the first explanation rather than the second, even though

mynas were often seen approaching the speaker, responses were most often recorded before hand. In other words, mynas approached the speaker, but did so after they had already been detected by the experimenter. In line with this suggestion, there was no difference in the average distance to speaker (calculated from bin medians) between the two stages of the point-counts (before versus after the playback), confirming that experimenters were successful in recording presence and behaviour prior to approach (ANOVA, $F(1,211)=0.363$, $p=0.548$).

Table 17. Parameter estimates from minimum adequate binomial GLMM on the likelihood of a group of mynas responding to the distress call playback

Fixed effects	estimate	std. error	z-value	p
(Intercept)	1.817	0.560	3.247	0.001
Trapping pressure (low)	0.179	0.511	0.351	0.726
Distance to speaker *	-0.048	0.011	-4.522	<0.001
Random effects	variance		Std. deviation	
Area : Locality	0.067	0.260		
Locality	0.000	0.000		

* Distance to speaker is a continuous variable which takes for value the median distance within the bin (e.g. any group of bird recorded in the 20 to 30m bin were given a value of 25m).

4. Discussion

Common myna populations living under high and low trapping pressure displayed differences in behaviour. Specifically, I found evidence that under high trapping risk, mynas tended to form smaller groups, were more likely to stay close to refuges, and also tended to be less conspicuous. On the other hand, I found no evidence that trapping pressure affected abundance, leading to two important conclusions. First, myna removal does not appear to be reducing myna population levels, or at the very least, not at the spatial scale targeted by my analyses. Second, observed differences in behaviour were not a consequence of differences in myna abundance.

Trapping pressure influenced the size of myna groups encountered. On average, groups observed in this study were small ($1.86 \text{ individuals} \pm 1.66 \text{ se}$) and very similar to groups found in India ($1.7 \pm 0.1\text{se}$) (Burger and Gochfeld 1991). But mynas tended to be encountered in larger groups more frequently in areas with low trapping pressure. One explanation for this could come from the fact that group sizes in birds is sometimes shown to vary with density. For example, urban houses finches (*Carpodacus mexicanus*) have a tendency to form larger groups at higher densities (Valcarcel and Fernández-Juricic 2009). Therefore, high trapping pressure might lead to smaller groups

by the mere fact that trapping reduces bird abundance. This is unlikely to have been the case in the present study, however, because local abundance did not predict group size. On the other hand, a large literature on anti-predator strategies shows that the typical response to increased perceived predation risk involves forming larger groups. Benefits attributed to these social aggregations include earlier threat detection, increased information transfer and risk dilution (Caro 2005). However these anti-predator strategies have most often been described in the context of actively hunting predators. Risks associated with human traps, on the other hand, are more similar to a “sit-and-wait” predator that can favor different anti-predator responses than active predators (Preisser et al. 2007; Miller et al. 2014). Hence, the smaller group sizes observed in high-trapping environments could reflect a strategy specific to bird traps. One reason for this could be that, as conspecifics inside traps are attractive to mynas, a reduced tendency to aggregate could lessen the likelihood of entering traps.

Under high trapping pressure, not only were groups smaller, mynas also tended to be seen more often close to refuges. In general, many species prefer feeding close to a refuge if given the choice, presumably to limit predation risk (Slotow and Coumi 2000; Kavaliers and Choleris 2001; Caro 2005). In this study, mynas present in zones undergoing high trapping pressure were less often seen away from a refuge such as a high perch or a dense bush. This suggests birds tended to be more risk-averse in these high-risk environments.

In zones undergoing high trapping pressures, mynas also showed a higher tendency to perform ground locomotion. Although it is expected that animals confronted with passive capture methods should decrease locomotion such that encounter with the capture apparatus is less likely (Alós et al. 2012), in mynas, increased locomotion has been associated with dangerous situations (Griffin and Boyce 2009). This could suggest that high trapping areas are perceived by mynas as risky environments.

Although I found that trapping pressure has an effect on group-size and the tendency to stay close to refuges and activity, I found no effect on the tendency of birds to be vigilant while on the ground. I expected mynas living in high-risk areas to demonstrate less risk-taking and, as a result, be more vigilant as is observed in starlings (Devereux et al. 2006). However mynas were seldom observed on the ground through this study, leading to only 51 recordings of sufficient length to be explored. It is hence

unclear whether results reveal a lack of difference or whether the sample collected was insufficient to find an effect of trapping pressure.

I also found no effect of trapping pressure on response to distress call playbacks. Because zones undergoing high trapping levels represent places of increased risk for mynas, I expected that birds from high and low trapping areas would differ in their response to conspecific risk signals. Although a lot of birds sampled responded to the distress call, no effect of trapping pressure was found, suggesting risk level of the environment does not influence likelihood of responding to risk cues in common mynas.

Distress calls are often attractive to birds who respond by approaching and inspecting the emitter (Stefanski and Falls 1972; Conover 1994). In this study, however, playbacks did not significantly increase the number of birds seen. It is possible that: (a) our playback was not loud enough to elicit approaches from birds far away, or (b) our point-count survey was very good at detecting birds (i.e. all birds in the area were seen before the playback). The fact that responses to playback were highly dependent on distance to playback suggests that the sound of the playback may not have been loud enough to be heard beyond 40m. By reducing the number of birds that were exposed to the stimuli, this might have limited my ability to find differences between birds undergoing different trapping pressures.

The fact that mynas differ between trapping pressures on several behavioural traits could lead to further differences. In particular, I investigated whether there might also be differences in detectability. For example, the tendency to remain close to refuges under high trapping pressure also meant that these birds were closer to visual obstacles and hence harder to see for human observers. This could reflect one way in which risk-taking influences detectability. A phenomenon that is apparent in game hunting, where more risk-averse pheasants tend to be less likely to be flushed from cover and hence seen and shot by hunters (Madden and Whiteside 2014). Similarly, smaller groups, as they appeared in localities under high trapping pressure, could be harder to detect for observers (Marques et al. 2007). Overall, this suggests there is scope for behaviour to affect detection of birds.

This hypothesis is also substantiated by the fact that control programs can lead to a reduction in numbers that goes beyond the number of birds caught. In a study of the efficiency of common myna trapping programs, Grarock et al. (2014) compared the

number of birds trapped by a community group in Canberra to surveys estimating myna density before and after the captures took place. The study showed that removal of 10 to 15 bird per km^2 could be associated with decreases of birds observed ranging from 20 to 50 birds per km^2 . Although other factors are likely to be playing a role here, such as emigration and unreported catches, I suggest a change in behavioural conspicuousness of birds may also be taking place.

In order to investigate this possibility, I attempted to measure detectability of mynas by analyzing the likelihood of visual detection of mynas in areas where they were known to be present. Mynas are a highly vocal species (Feare and Craig 1999), which suggests that hearing them is a good way to ascertain their presence. I found no effect of trapping pressure on this variable, instead the main predictor was region, showing that birds are more easily seen when they are heard in Sydney. There are several ways in which regional differences in this detectability index can be explained. The higher detectability of birds heard in Sydney might reflect: (1) that birds are more conspicuous in Sydney, for example, they spend a lot of time in places where they are easily visible such as rooftops or ground foraging, (2) that birds are as likely to be seen in the two regions but that they are much more likely to be vocal in Canberra, (3) that the environment is more noisy in Sydney, such that only birds that were close to the experimenter were heard. Overall, it is unclear if mynas differ in their behaviour between regions, or if the two regions are different in their environment, and the experimental design makes it impossible to disentangle the role of these mechanisms.

Another way in which I investigated detectability was by comparing density estimates from point-count surveys and transect surveys. Density measures taken from transects were higher than those from point-counts. This was expected from differences in methodology, in particular transect location was not random, but instead selected to maximize the number of mynas seen. I had predicted that the amount by which transects would over-estimate abundance when compared to point-counts would depend on conspicuousness and rarity of birds (see section 2.3.1). While I found no effect of rarity, there was a trend for birds in zones of high trapping pressure to have a smaller overestimation index than those undergoing low trapping pressure. In other words, in safe areas, transects revealed far larger density estimates than point-counts, while this trend was far less pronounced in high-risk areas. I suggest that this effect is mainly due to a decrease in conspicuousness in response to high trapping pressure such that was

reported previously (King 2010). Similarly, lionfish populations that undergo control by spear-fishing shift their activity pattern such that they spend more time deeper in the reef and less time active during the day. Additionally, the fish also have high levels of concealment and avoidance of humans (Côté et al. 2014). These changes are likely to make the species difficult to find and could hence hinder further control efforts (Côté et al. 2014). The trend towards less conspicuous birds in areas with high control pressure in common mynas is the first evidence that a similar phenomenon could be taking place in a bird species.

The fact that detectability of a bird species can be impacted by control pressure has important consequences for the way in which the success of these management programs is assessed. In North America, many migratory shorebird species have been declining since the 1980's, while raptors on the other hand have been on the rise. There is evidence that increased predation risk from raptors has caused shorebirds to alter their behaviour and spend less time at each stop-over. Because abundance estimates are dependent on the duration of stay at each site, some authors argue that the perceived decline in shorebird populations does not reflect a true population decline but instead is due to changes in behaviour (Ydenberg et al. 2004; Ydenberg and Prins 2012). Similarly, a decrease in detectability in response to trapping would be of paramount importance in the context of pest bird control. In particular, because despite damage estimation being essential, abundance estimates are often the only tool used to measure effectiveness of management (Olsen 1998; Wittenberg and Cock 2001). This suggests that, where change in conspicuousness occurs, there is scope for measured effectiveness of control to be exaggerated if specific survey methods that account for these types of effects are not implemented.

The present study found no effect of trapping pressure on common myna abundance. I used a coarse locality-scale trapping pressure estimate (i.e. high and low) because the data originated from different sources, which meant small differences could very well be due to diverging data collection modalities (see chapter 1). These locality-scale trapping estimates were used to predict the number of birds seen at plots within sampling areas (SAs), but failed to do so in a significant manner, suggesting this practice has little effect at the local scale. In a study investigating the effects of trapping pressure (estimated in a similar fashion as here) on myna populations in Canberra, Grarock et al. (2014) found diverging results depending on the scale of focus. Broad-

scale abundance (which approximates what has been called the locality-scale in this manuscript) was not predicted by broad-scale culling levels, while on the other hand, fine-scale abundance (which corresponds to the SA-scale here) was predicted by fine-scale culling levels. Together with the current results, this suggests broad-scale trapping pressure is a poor predictor of myna abundance at a broad and local scale, indicating the effect of trapping might be small or restricted to a fine scale. This restriction to fine-scale effects could be linked to potential mechanisms underlying responses to trapping such as spatial avoidance or short distance emigration. For example, if birds avoid a small area within a locality, overall locality abundance will remain the same.

While abundance was not predicted by trapping pressure, results showed that it was predicted by region. Common mynas were much more abundant in the Sydney region than in the Canberra region. As this study is the first to experimentally measure common myna abundance across several regions of Australia, and I found important differences between the regions studied, I found it useful to compare my results to those previously found in each region (see Table 42 and Table 43 in appendix 2.2, page 216). Although a number of studies have measured myna relative abundance in the Sydney region (see Table 42 in appendix 2.2, page 216), to my knowledge this study is the first to explicitly estimate densities in this region. I was able to calculate density estimates from the data available in one article (Haythorpe et al. 2013) and results found with point-counts here (111 ± 24 birds per km^2) sat in between what was found previously for suburban areas (196 birds per km^2) and suburban-bush edges (8.5 birds per km^2) with a hybrid of transect and point-count survey methods. On the other hand, a large number of studies have reported density estimates for the Canberra region (see Table 43 in appendix 2.2, page 216) and results show large variations (King 2010; Grarock et al. 2013b). My results (39 mynas per km^2) lie in between the range of densities found by King (2010) (i.e. 6 to 16 mynas per km^2) and those found in streetscapes by Pell and Tidemann (1997a) (i.e. 43 to 124 mynas per km^2). It is important to note here that contrary to most previous studies, the present one is not restricted to Canberra city, but instead extends over a wider Canberra region. Inclusion of zones further away from the city center might have lowered these estimates, as there is evidence that these areas carry lower myna abundances (Sol et al. 2012; Broms et al. 2016). Overall, I found that myna densities were higher in the Sydney region than in the Canberra region, and

although there was high variability among studies, I found that my results fell within the range of previous studies for each region.

A number of factors could explain regional differences in common myna abundance, amongst which differences in environmental characteristics are a likely candidate. Canberra region has a less temperate climate, with colder winters than the Sydney region (Australian Bureau of Meteorology 2015). Considering minimum temperatures are thought to be an important limiting factor of common myna range expansion, among other things preventing expansion into Tasmania and Southern New-Zealand (Martin 1996), it is possible that low temperatures limit their reproduction or survival rates in certain areas. Moreover, the greater Canberra urban area is much less populated than the greater Sydney urban areas: in 2013, the Australian Capital territory had a population of over 381,000 while the greater Sydney area had a population of over 4,757,000 (Australian Bureau of Statistics 2015). Considering the highly commensal habits of common mynas and their tendency to benefit from their association with humans, one could expect that they would perform better in zones with higher populations. It seems as if the Sydney region is overall better suited for the species, despite the fact that the eucalypt woodlands situated around Canberra (Atlas of living Australia 2015) are rather similar in terms of tree density and vegetation structure to the myna's native habitat (Feare and Craig 1999).

Other reasons for which common myna density might differ between the Canberra and the Sydney region include introduction history and control history. Common mynas were introduced to Sydney much earlier than in Canberra (Long 1981, also see Chapter 1), this means they have had a longer time to acclimatise, adapt and expand in the Sydney region. This is also important in regard to their response to management practices, because mynas have a wider distribution around Sydney city, there is more scope for re-colonization to occur, and hence abundance to remain high despite control efforts. Moreover, at a regional scale management histories likely differ. Although both regions contain localities with high and low trapping pressure, Canberra has benefited from the presence of one of the first and most active community volunteer groups in Australia (i.e. the CIMAG) whose action expands beyond the boundaries of Canberra city, while most actions in the Sydney region are undertaken at the scale of local councils. Interestingly, this brings to light the possibility that region, as another scale of trapping pressure beyond sampling areas and localities, might be an interesting

topic for future research. Overall, it is possible that regional-scale introduction and regional-scale control history participated in explaining higher abundance in the Sydney region.

Common myna abundance was not only predicted by region in this study, habitat and time of day also played an important role. I found that mynas were more abundant in residential than highly urbanized habitats. Residential habitats are more likely to contain both lawn patches from which to extract insects as well as human and pet refuse, which seems like an ideal habitat for an omnivorous species that relies on insects to feed their juveniles (Feare and Craig 1999). However, this result is at odds with previous findings that mynas are more abundant in more highly modified habitats such as urban habitats (White et al. 2005; Lowe et al. 2011; Sol et al. 2012). This discrepancy between the preferred habitats found in this study, and those found in previous studies, can be largely attributed to a methodological issue, in particular to the way habitats were defined. Ecological habitat terminology, in urban landscapes in particular, can be confusing and make cross-studies comparisons difficult (Marzluff et al. 2001). In this study, habitat was measured on a very fine scale (point-count plots: 50m radius circle), however, on a wider scale (SAs: 4km²) all data collection can be considered to have taken place in residential areas. The question of scale is paramount in defining habitats, as the same parameter (e.g. housing density) can lead to the same location to be classified as different habitats because of differing scale choices (Marzluff et al. 2001). Despite the importance of detailing scale choice, the common myna literature often directs little effort at making explicit the scale used to measure the features that define habitats (White et al. 2005; Sol et al. 2012; Haythorpe et al. 2013; Old et al. 2014), making comparisons between studies difficult, and potentially explaining contrasting results.

This study showed the first evidence of differences in common myna populations undergoing different trapping pressures. Although the specific mechanism taking place cannot be ascertained in this study, I suggest that under high trapping pressure birds become less detectable, which seems driven, at least in part, by a decrease in risk-taking and the formation of smaller groups. Such behavioural shifts in response to control practices are starting to get attention. In lionfish (*Pterois volitans/miles*), decreased risk-taking along with shifts in daily foraging patterns and micro-habitat used were associated with increased risk from culling programs (Côté et

al. 2014). These shifts are of tremendous importance as they can impact the sustainability of the control programs by making the target species less susceptible to them. Moreover, shifts in behaviour of an invasive species could change its potential impact. For example, the switch in temporal and spatial activity patterns of lionfish, not only can make them less susceptible to spear-fishing, it also leads to interactions with other prey species that might not have been at risk from lionfish predation otherwise (Côté et al. 2014).

It is hence important that these behavioural changes are taken into consideration in management programs. Not only should they be monitored, but attention should also be taken that they do not affect measures of efficiency, such as abundance estimates. Considering the important conservation implications of this phenomenon, I suggest it is also of key importance to investigate the mechanisms underlying these changes such that they can be better managed.

5. References

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CHAPTER 3. INVESTIGATING POTENTIAL CAPTURE BIASES ACROSS CAPTURE METHODS IN COMMON MYNAS

Abstract

In the previous chapter, I found evidence that behavioural modifications occur in common myna (*Acridotheres tristis*) populations undergoing high levels of harvesting by humans. In this study, I investigate whether selective removal might be the mechanism underlying the observed changes. This would imply that traps are biased towards capturing individuals with certain traits or personalities, leaving behind individuals without those traits in the population.

In this study, I explored whether selective removal of individuals with more potentially ‘trap-friendly’ personalities, including a high propensity for exploration and boldness, might explain why populations are overall becoming more difficult to trap. 50 common mynas were captured using one of two methods: 1. a widely-used walk-in baited trap which required the birds to enter a large cage-like structure; 2. a woosh-net which was placed in the grass in proximity of a large feeding patch. Under the assumption that the more discreet woosh-net would be less selective in terms of behaviour of birds captured, netted and trapped birds were tested under captive conditions on a range of personality tests to identify differences in exploration, boldness, fearfulness, social behaviour, anti-predator responses and innovation.

No behavioural differences were found between the two groups of birds, suggesting selective removal is not taking place in the context of common trapping. However, an alternative explanation for this negative finding is that both capture methods produced the same biases. While this study remains inconclusive as to which explanation is true, I discuss why the second seems most likely in the present context.

1. Introduction

Scientists have observed that in a wide range of species, across contexts, individuals differ consistently in terms of behavioural traits or suites of traits. These inter-individual differences have been referred to as temperament (Réale et al. 2007), behavioural profiles (Groothuis and Carere 2005), behavioural syndromes (Sih, Bell and Johnson 2004) and animal personalities (Wolf and Weissing 2012; van Oers and Naguib 2013). There has been growing interest in how personality, as a source of within-population variation, influences the ecology and evolution of a species (Sih, Bell, Johnson, et al. 2004; Wolf and Weissing 2012). In particular, because repeatable inter-individual variation is presumed to have a genetic basis, personality traits provide a potential substrate for evolution when environmental change leads to certain personalities being selected against (Wolf and Weissing 2012).

While animal personality provides a wealth of opportunities for research, some scientists have warned that it could also be a source of issues. There are concerns that studies based on sampling of individuals from a population might be undermined by personality-related sampling bias (Biro and Dingemanse 2009; Garamszegi et al. 2009; Stuber et al. 2013). This phenomenon refers to the fact that certain capture methods sample a non-random subset of the original population. For example, in red squirrels (*Tamiasciurus hudsonicus*), more active individuals are more likely to be trapped (Boon et al. 2008). This means that data collected from these individuals might not represent the whole population accurately, thus violating the assumption that experimental conclusions draw upon data that is collected from a random sample of the original population.

The importance of personality-related sampling bias goes beyond that of sampling of populations by scientists. It can be extended to the context of wildlife harvesting by humans in general. Systematic selective removal of individuals with certain traits can lead to selection against those traits and hence to directional evolution. This is of particular concern in the case of animals sampled for human consumption. In fisheries, evidence is accumulating that selective removal of larger individuals leads to selection against late-maturing, fast-growing, bold fish (Law 2000; Olsen et al. 2004; Biro and Post 2008; Heino et al. 2015). Additionally different fishing gear and methods seem to each target preferentially a certain subset of personalities (Wilson et al. 2011; Alós et al. 2012; Häkkinen et al. 2014; Diaz Pauli et al. 2015).

Such issues are likely to appear in all cases of wildlife harvesting including control of pest species. For example personality-related sampling bias could explain behavioural differences observed between common myna (*Acridotheres tristis*) populations undergoing heavy and low predation pressure (see chapter 2). This species is the target of increasing control efforts in Eastern Australia which mainly involve the use of walk-in baited traps. This method has scope to select for certain personalities, for example by preferentially catching birds that are bold enough to approach a novel structure such as a trap. Similarly, some researchers have suggested that selective removal of bolder and more active personalities could explain shifts in behaviour observed following control periods of invasive lionfish, *Pterois volitans* (Côté et al. 2014). In order to investigate whether control is leading to selective removal of certain behavioural types in common mynas, I captured individuals using two distinct methods. The first, a classic walk-in baited cage trap, is a passive method used in most occurrences of control in this species. The second method was a whoosh net, a method that allows capture of birds present in a certain target area and is considered more active, in that it does not solely rely on the approach of the target species. Birds were transported into captivity where they underwent a range of behavioural tests to assess their personality. This is particularly relevant as it is already established in this species that individual mynas differ consistently across time and/or contexts on a variety of behavioural traits, including for example, the propensity to innovate and motor flexibility (Griffin and Diquelou 2015).

I expected that a walk-in cage trap, which requires approaching a large foreign structure, would selectively capture birds that were bold enough to approach it, whereas I expected no such trend for birds caught with the whoosh net as the bulk of the elements are hidden in the grass. I measured several behaviours related to the general boldness/risk-taking axis: neophobia (Greenberg and Mettke-Hoffman 2001), fearfulness (Edelaar et al. 2012), response to predatory stimulus (Godin and Dugatkin 1996), docility during handling (Möller and Ibañez-Álamo 2012) and ease of capture (Guillette et al. 2010). The traps also require that birds find the entrance within the structure. I hence expected that birds caught with this method would present a high tendency to explore and to innovate. Moreover, traps contained live lure birds to entice free-ranging mynas to approach. Hence, individuals caught with this method could be

biased towards more social individuals. This was tested by measuring behavioural responses towards social stimuli (Carvalho et al. 2013).

2. Methods

2.1. Capture methods

Fifty common mynas were caught in the Newcastle area (Newcastle, NSW, Australia) between June 2013 and November 2014, using one of two methods: a walk-in baited cage trap and, a whoosh-net. Captures took place in four suburbs localised in two areas of Newcastle (Table 18).

Table 18. Location of capture sites, including localization within the Newcastle area, name of suburb and number of bird captured using each method.

Location in Newcastle	Suburb	Whoosh-net	Cage trap
North-West	Jesmond	6	8
	Mayfield	0	3
South-East	Broadmeadow	16	14
	Merewether	0	3

2.1.1. *Walk-in baited cage trap*

The trap used in this study was designed specifically for this species (Tidemann 2009). It consists of a 'foraging cage' which contains food and that birds enter through funnels, and on top, a 'holding cage', which is entered by flying through one-way puzzle-valves (Griffin 2008; Tidemann 2009; see figure 1.a). The holding cage contains ample perches, shade, water and food, and mynas can be comfortably kept in it for a few days. Most often the experimenter put two captive held mynas as decoys or lure birds in the holding cage that emit social calls and attract free-ranging mynas to the foraging location.

Small dog pellets were used as bait. Food and water was changed daily. Birds were typically removed the day of their capture but could be left for up to five days, when the weather permitted (no extreme heat, cold or wind), in order to attract more surrounding birds. Birds were caught from within the trap with a small net, they were then put into individual cotton bags and immediately transported to the University in an air-conditioned vehicle. This apparatus is from here onwards referred to as *the trap*, and birds caught with it as *trapped birds*.

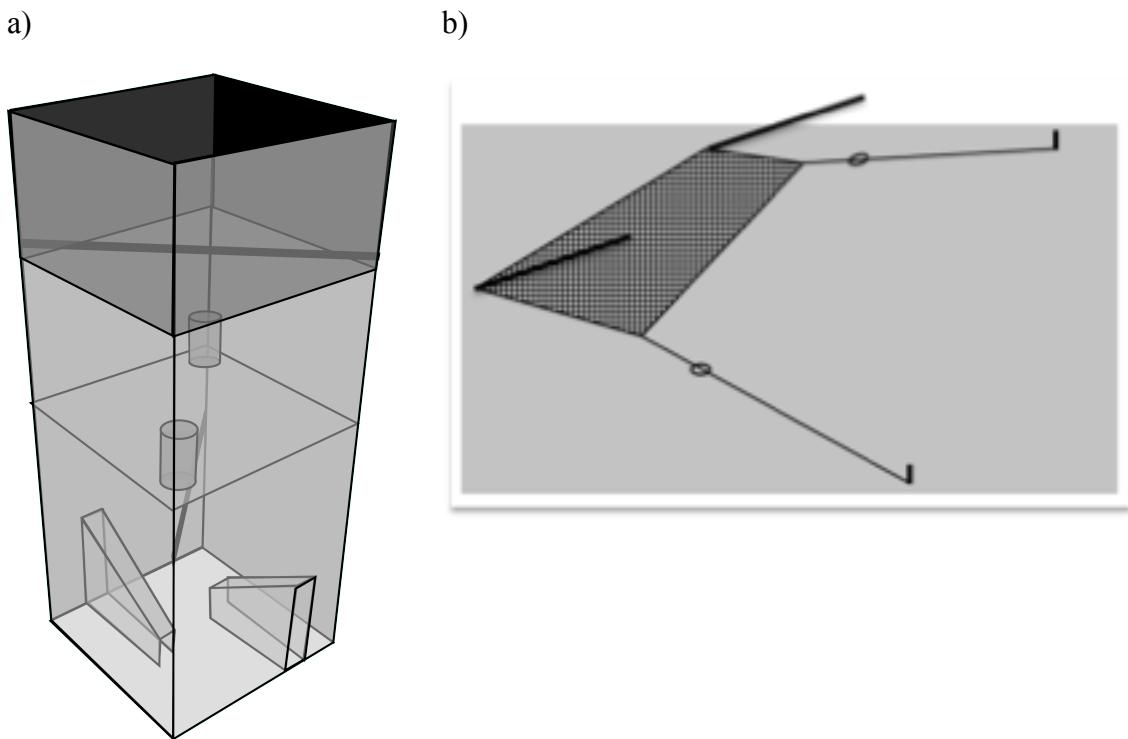


Figure 27. Illustration of the two capture apparatuses used in this study. a) The walk-in baited trap with at the bottom, the 'foraging cage' and at the top the 'holding cage'. The top part of the holding cage is covered by opaque material to offer a shelter to birds. b) The woosh-net which is here represented after it has been activated, the net is spread on the ground, covering the target area. Note that the two illustrations are not at the same scale, the trap has a height of 1.8m while the net measures 4.2x5.1m.

2.1.2. Woosh-net

Whoosh-nets consist of a large net, two thick elastic bands and two lead poles (Figure 27.b). The net is initially rolled up between the base of the poles, with two ends each attached to one elastic, but secured in place by the trigger mechanism. Once the trigger mechanism is released by the experimenter, the two ends of the net that are attached to the elastics are quickly thrown over the target zone, following the lead poles, such that the net entirely covers the target zone (Gosler 2004). All birds that were present in the target zone become trapped under the net. This method is usually employed to target birds that feed on the ground in large groups (Gosler 2004).

Following a period where the site was pre-baited with small dog pellets and pieces of bread, the experimenter stayed in a hide approximately 5 m away from the set up. Once a group of mynas came into the target zone, the experimenter manually triggered the apparatus with an electrical device. The net was immediately covered by a lightweight opaque fabric to decrease bird movement and entanglement in the net. Birds

were then removed from the net and immediately transported to the University in cotton bags in an air-conditioned vehicle

Captures were only performed during the early or late hours of the day and never in strong heat, wind or rain. As much as possible the experimenter avoided triggering the apparatus when other species were present in the target zone, only one other species was caught (European starling, *Sturnus vulgaris*) and when this happened they were removed and released from the net immediately. This apparatus is from hereon after referred to as *the net*, and birds caught with it as *netted birds*.

2.2. Subjects and Husbandry

Upon capture, common mynas were transported to the animal house of the University of Newcastle, where their morphometric measurements were taken (wing length, tarsus length, beak length, weight), and they were banded for individual identification before being released into aviaries. Birds were first held for ten days in small groups in outdoor quarantine aviaries (length x width x height: 2 x 1 x 2.2m), in which they were left undisturbed to adjust to captivity. Birds were then moved to large outdoor group aviaries (4.4 x 1.25 x 2.25m) while waiting for behavioural tests to take place. During this period mynas had access to ad libitum water and food. Time in captivity before tests took place varied from 6 to 237 days (mean: 82), and was balanced across the two types of birds.

For testing, five randomly selected birds were moved from large outdoor group aviaries to individual cages (0.8 x 0.4 x 1.3m) in a semi-outdoor holding room. With the exception of two cohorts that consisted solely of individuals caught with a single method, all cohorts contained at least two individuals caught with each method. All cages were in acoustic contact and each cage was in visual contact with at least one other. Birds were left to habituate to this setting for two days before testing began. Mynas had access to ad-libitum pellets and were presented daily with 3-to-6 mealworms in a plexiglass container, which were then used for the innovation task (see below). Birds were checked daily and weighed twice a week. Mynas typically loose some weight when moved to individual housing, mainly due to muscle loss from reduced flight opportunities; however no bird lost more than 10% of its weight during the experiment.

Fifty birds participated in this study, 28 were trapped and 22 birds were captured with the net. All individuals but three were adults, as determined by head colouring, at the time of testing. Sex was determined either from post-mortem examination or through DNA testing of feathers. For three birds, neither technique could be used and sex was determined by comparing their morphological measurements to a database of 178 mynas sexed between 2013 and 2015. For this I relied on the fact that although there is no visually explicit sexual dimorphism in the species, males tend to be larger than females. The sample used in this study was composed of 28 females and 22 males.

At the end of the experiments birds were returned to the group aviaries. Mynas are classified as a pest species in Australia and it is therefore forbidden to re-release them into the wild. For this reason, once birds were no longer required for research they were euthanized by exposing them to a lethal dose of CO₂ (Griffin 2008). Care was taken to re-allocate mynas when possible to other experiments before euthanasia to reduce sampling of birds from the wild. All animal care and experimental procedures were in accordance with the Australian Code of Practice for the Care and Use of Animals for Scientific Purposes and were approved by the University of Newcastle Animal Ethics Committee (protocol A-2011-129).

2.3. Behavioural tests

Two tests were run in the individual's cages, in the holding room, while three others were run in an adjacent testing room. In the latter case, loud-speakers played white noise to guarantee acoustic isolation from birds in the holding room. During these tests, access to the nest-boxes was denied so that birds would remain in sight. Experiments are described below in the order in which they occurred unless stated otherwise.

2.3.1. *Exploration*

The individual cages were rolled from the holding room into the testing room (**2.8 x 1.7 x 2.7m**), which contained five artificial trees each bearing five perches. Birds were left to habituate 10 min to this environment before the door of their cage was opened remotely by the experimenter. The bird was given a 15-min period to exit its home cage, if it had not departed from the cage by the end of that period, the experimenter approached the cage to induce it to fly out. The room was divided into 29

zones: four same-sized zones were delimited on the ground, and the 25 perches available. Once the bird had exited its home-cage, I recorded the number of times it would land in each zone and the latency to do so for the first time during a period of 15 min.

2.3.2. Response to social and predatory stimuli

Subjects were moved to the testing room and left to habituate to this setting for 10 min; all behaviours and spatial location within the cage were then video-recorded for 5 min. At the end of this period, a stimulus located within 1 m of the cage was unveiled and the cage was filmed for a further 5 min.

This test was run on two successive days, on the first day, the stimulus was a large mirror, while on the following day it was a taxidermy mount of a domestic cat (*Felis catus*). Stimuli were presented in this order to reduce stress in case birds learnt to associate the room with the predator mount.

Each bird's position (three possible zones in the cage; Figure 28) and behaviours were scored continuously from video-recordings using j-watcher (Blumstein et al. 2006). A number of behavioural variables were also measured. Behaviours of interest included movements, calls, self-centred behaviours (preening, scratching, stretching) and bowing. Bowing is a ritualized social display which consists of rapid succession of head lowerings and raisings (Counsilman 1977). Mynas perform a variety of calls (Feare and Craig 1999). I grouped flight calls, contact calls and song into a category called 'social calls' while distress calls and alarm-calls were grouped under the denomination of 'non-social calls'. These names do not reflect the function of the calls instead they merely reflect the fact that non-social calls are usually produced when mynas are confronted with a distressing situation (being held in hand, seeing a predator).



Figure 28. Photograph of cage used for testing showing localization of the three zones (z1, z2, z3). All zones are the same size and z1 is the closest to the stimulus.

2.3.3. Innovation

After being food deprived overnight, subjects were presented with five mealworms, a highly preferred food, inside a closed puzzle box consisting of a small plexiglass box with a lid (see annex 3.1 p221). Mynas were habituated to the box beforehand to reduce neophobia towards it (see section 2.2). Most mynas solved the task by pulling at the small handle on top of the lid; however a few birds managed to open it by pecking vigorously at the edges of the lid. I measured whether birds accessed the food reward during a two-hour trial and how long it took them to do so. Birds that failed to open the task were given a capped latency of 121 min.

2.3.4. Neophobia

Neophobia, the aversion to approach novel objects (Greenberg 2003), is often considered a measure of risk-taking (e.g. Cole and Quinn 2014). Neophobia was evaluated by measuring the latency (test latency) of the focal bird to approach a familiar food dish in the presence of a novel object, and comparing it with the latency (baseline latency) to approach that same food dish in the absence of any novel object. To obtain the baseline approach latency, the experimenter placed the opened puzzle box containing three mealworms in the focal bird's aviary. Latency to consume the first food item from the dish was then measured. The experimenter introduced the same container with three mealworms in the cage 30 min later, this time placing the novel object next to it (black cup of 7 cm diameter at the base and 8 cm high, with blue and green straws attached to the side). Latency to approach the dish and consume a food item was measured once again, and capped at 7201 sec (i.e. 120 min) if the bird failed

to approach within two hours. A neophobia score was calculated for each bird by subtracting the baseline latency from the test latency. Hence large scores represent birds that were reluctant to approach food once a new unfamiliar object was placed next to it.

2.3.5. Tonic immobility

In order to assess levels of fearfulness, tonic immobility tests were performed. Birds were taken out of their cage and laid on their back on a small cradle in a quiet empty room (Jones and Faure 1981; Suzuki et al. 2013). They were maintained in this position by gently pressing on their breast for twenty seconds. The experimenter then remained about 60 cm away from the bird, while continuously looking at it, and measured the time birds remained in tonic immobility before righting themselves and flying away. If the bird stayed on its back for less than 10 sec, it was considered that tonic immobility had not been induced and the trial was re-started immediately, up to a maximum of five times (Suzuki et al. 2013). If mynas had not righted themselves 15 minutes after the induction, they were given a maximum latency of 901 sec. The first two cohorts tested were given a shorter latency to exit tonic immobility (8 and 10 minutes) and maximum latencies were adjusted accordingly (respectively: 481 and 601 sec). In some cases a loud noise coming from outdoors 'awoke' the birds, in which case test latencies were censored at the time of the noise. Three birds never entered the tonic immobility state across the five attempts and were hence excluded from analysis of this variable. Tonic immobility tests were performed once at the end of the sequence of behavioral tests.

2.3.6. Docility

When they were brought into captivity from the wild, and once again when they were moved from group-housing to individual cages, mynas underwent morphological measurements. While collecting morphological measurement, I recorded the birds' responses to being handled by counting all struggles, distress calls, biting and clawing during a 10-min period (Möller and Ibañez-Álamo 2012; Carvalho et al. 2013). Struggles were defined as a series of quick body movements ("wriggles") seemingly performed to get out of the holding grip of the experimenter. Clawing and bites were recorded whether they were targeted at the experimenter or at pieces of equipment. The

tally of all these behaviours provides a docility score where birds with high scores were those that were most reluctant to being handled.

2.3.7. *Capture order*

Each time mynas had to be caught from group aviaries, regardless of the reason, the order in which the birds were captured was recorded (Guillette et al. 2010). Identities of birds in groups contained in aviaries changed over time. Hence the number and identity of birds contained within an aviary from one capture event to the next could change.

The experimenter consistently used the same strategy to catch birds: she entered the aviary and walked towards the opposite side in which the birds grouped to avoid her. As she did so, birds tried to reach the side of the aviary she was not facing by flying over her head, which is when she would catch them with a large bird net. Generally birds were caught one by one with the net but on a few occasions, several (up to three) birds entered the net at once.

For each capture event, birds were attributed a score which was calculated from their capture order divided by the number of birds in the aviary. The last bird caught received a score of 1, representing the fact it was the last to be netted. The score of the first bird caught varied with the size of the group, the larger the group, the smaller the score showing these birds were particularly fast to catch. Birds that were captured simultaneously in the net were allocated a tied score. Only aviary catch-ups where five or more birds were caught were used for the analysis. This approach generated an average of 6.5 capture scores per bird (range=2-13).

It was assumed that birds netted first were those that were most willing to take the risk of flying past the experimenter holding the net to join the side of the aviary located behind her. Symmetrically, it was assumed that those who were netted last were those that were least willing to take the risk of flying past the threatening experimenter. Hence, low scores were considered to reflect a bird willing to take risks, whereas a bird with a high score was considered less willing to take risks.

2.4. Analysis

The main interest of the study was to uncover potential behavioral differences between mynas caught using two different capture methods. As a consequence capture

mode was retained in all models whether it was significant or not. Additionally to capture method, I also checked for an effect of sex, morphometric measurement, time in captivity, and season of testing (summer: October to March, winter: April to September) on the data collected from our behavioral tests.

I had originally intended to enter suburb as a random factor in all models in order to control for a possible effect of capture location. However, in two suburbs birds were caught in small numbers and only using one method (Table 18). To avoid any ensuing numerical complications, I entered localization within the Newcastle area (North-West vs. South-East) instead. In addition, localization had to be entered as a fixed factor rather than a random factor because of its small number of levels (i.e. 2).

Integration of inter-individual variation in bird morphology into subsequent behavioural analyses required creation of a morphological index. I performed a Principal Components Analysis on a matrix of all measures. The matrix was appropriate for use in a PCA ($KMO=0.73$). Cattel's scree plot revealed a single component should be interpreted. The first axis explained 63% of the variance in the data and was considered to be a good summary of the data (Budaev 2010). It mostly reflected wing length (loading=0.53), tarsus length (0.57) and weight at capture (0.57), such that birds with high scores on this axis were overall larger. This score is from hereon after referred to as the morphometric index.

Several variables collected during exploration tests were aggregated into a Principal Component Analysis (number of movements, number of zones visited, number of floor-zones visited, latency to land on first tree, log of latency to exit home cage and time spent in home cage during trial). The KMO test suggested the matrix was appropriate for use in a PCA ($KMO=0.67$). Cattel's scree plot clearly suggested a single component should be kept for analysis. The first axis explained 47.1% of the variance in the data and was considered to be a good summary of the data (Budaev 2010), values on this axis were used as the exploration score of each individual. This axis was mainly explained by the total number of movements (loading: 0.52) and the total number of zones visited (loading: 0.56), high scores hence indicate high tendency to explore.

Morphology and exploration PCAs produced normally distributed scores. These were analyzed using linear regression models. Model selection was based on stepwise deletion of non-significant factors from the full model. The full model of morphometric index contained capture method, sex and locality of capture. The full model of

exploration contained capture method, locality of capture, sex, morphometric index, time in captivity and season of testing. The same best fitting models were extracted with stepwise addition of factors.

For those tests in which the variable of interest was the latency to occurrence of a certain event, survival analysis was used. More specifically, I used Cox regressions, a semi-parametric approach designed to analyze time-to-event variables that include censored times. As recommended in cases where multiple factors are under investigation for their potential influence on the occurrence of a certain event, the model was reduced by successively removing non-significant covariates (Bradburn et al. 2003). The proportional hazards assumption were checked by the scaled Schoenfeld residual test (Grambsch and Therneau 1994) and fit was assessed visually from plots of the residuals.

The neophobia score of a bird was calculated by subtracting its baseline latency to approach a food dish (novel object absent) from its test latency (novel object present). Although this score is not *stricto sensu* a latency, it was treated as such because baseline latencies were very short (mean=24 s +/- 3SE) compared to test latencies (mean=39 min +/- 6.2 SE).

Response to stimuli was analysed using count of relevant behaviours and position of bird in the cage. The zones of the cage in which birds were present (Figure 28) were used to estimate average position in the cage during the trial. Stimuli were always placed on the left of the cage, hence birds in zone 1 (z1) were close to the stimulus while birds in zone 3 (z3) were far away. An index of average position in the cage was hence calculated with the following formula:

$$\text{position index} = (t_{z1}x1 + t_{z2}x2 + t_{z3}x3) / t_{\text{trial}};$$

where t_z is the time spent in zone z and t_{trial} is the total duration of the trial. Overall position index represents the average position of the bird in the cage throughout the trial with a minimum of 1 indicating the bird spent all the trial in zone 1 (i.e. close to the stimulus when it was present), and a maximum of 3 (i.e. all time spent in zone 3, the zone furthest to the stimulus). This index was used to compare position in cage during baseline periods and test periods, when the stimulus was present. Because the response to social stimulus test took place before the response to predatory stimulus test, and that I anticipated the first test could have an impact on the second, I also checked that position in cage was similar during both baseline tests.

For those tests in which repeated measures were recorded for each individual, such as position index of the bird during baseline and test period, generalized mixed models were used. These models were fitted in a Bayesian framework with the MCMCglmm package (Hadfield 2010) with individual identity of birds as a random effect. Gaussian families were chosen throughout except for models of counts of behaviours in which the Poisson family was selected.

A weakly informative proper prior was used (see annex 3.2 p221). No attempt to simplify the model took place, instead the full model is presented such that results presented are conservative (Bolker et al. 2009). Autocorrelation of successively stored iterations was checked to ensure that it was under 0.1, and convergence was assessed visually from diagnostic plots.

All tests were performed in R (version 3.2.4, R Core Team 2016).

3. Results

3.1. Sex ratio and morphology

There were slightly more females than males in the sample of birds caught (F:28, M:22), but the sex ratio did not differ significantly from the expected 50% whether considering the full sample (Binomial Exact Test, male ratio=0.44, CI= 0.30-0.59, $p=0.480$), only trapped birds (BET, male ratio= 0.43, CI=0.24-0.63, $p=0.572$) and only netted birds (BET, male ratio= 0.45, CI=0.24-0.68, $p=0.832$).

All morphological measurements (wing length, tarsus length, weight) were highly and significantly correlated except beak length, which was not correlated with any other morphological variable (Table 19).

Table 19. Correlation matrix of four morphological variables. Scores indicate Pearson's correlation coefficient, stars indicate significance level (see below table).

	weight	wing	tarsus
wing	0.67 ***		
tarsus	0.80 ***	0.63 ***	
beak	0.24	0.22	0.27

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

As expected from the table above, the first axis of the PCA reflected the correlation between wing, tarsus length and weight. Capture method did not predict inter-individual variation in this morphometric index; instead, only sex was a significant predictor, showing males tended to be larger than females (Table 20).

Table 20. Best fitting linear model of morphometric index containing capture method. Reference categories of variables are noted between brackets beside the variable name.

	estimate	std. error	t value	p
intercept	-0.54	0.323	-1.676	0.10
capture method (trap)	-0.470	0.369	-1.272	0.21
sex (male)	1.830	0.369	4.954	9.83x10 ⁻⁶

other variables tested, but not included in the best fitting model: localization

3.2. Exploration

Exploration scores were extracted from the first axis of the PCA, which mainly reflected the number of movements and the number of zones visited. Mynas tested varied in terms of their exploration score (Figure 29), yet none of the variables of interest (capture method, sex, localization, morphometric index, time in captivity and date of test) improved the baseline model (Table 21).

Table 21. Best fitting linear model of exploration score including capture method. Reference categories of variables are noted between brackets beside the variable name.

	estimate	std. error	t value	p
intercept	-0.082	0.362	-0.227	0.821
capture method (trap)	0.147	0.484	0.304	0.763

other variables tested, but not included in the best fitting model: localization, sex, morphometric index, time in captivity, season of test).

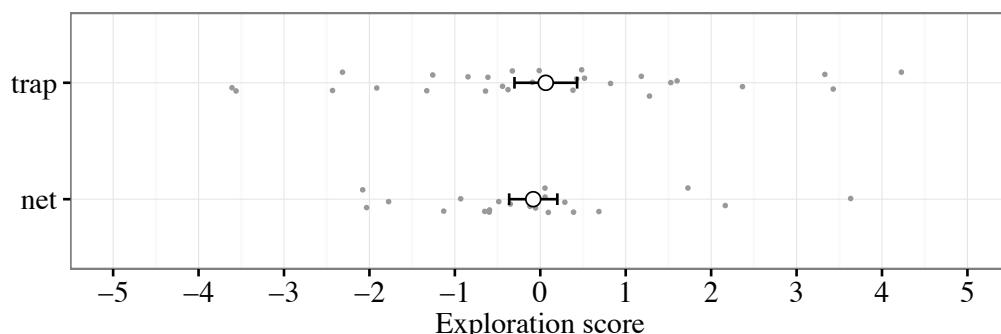


Figure 29. Average exploration score of birds captured with the trap and the whoosh net (large open circle) with standard error. Small grey dots show score of each individual.

3.3. Innovation

Most birds tested solved the puzzle-box in a short time. Twenty nine (58%) had solved the task in less than 5 min and only six (12%) failed to solve the task at all within the 120 minutes available (Figure 30). None of the factors tested, including capture method, explained the ability of mynas to solve the task (Table 22).

Table 22. Minimum adequate Cox regression model on the latency to open the puzzle box. Reference categories of variables are noted between brackets beside the variable name.

	estimate	exp(coef)	se(coef)	z	p
capture method (trap)	0.06	1.062	0.304	0.198	0.843

other variables tested, but not included in the best fitting model: localization, sex, morphometric index, time in captivity, season of test.

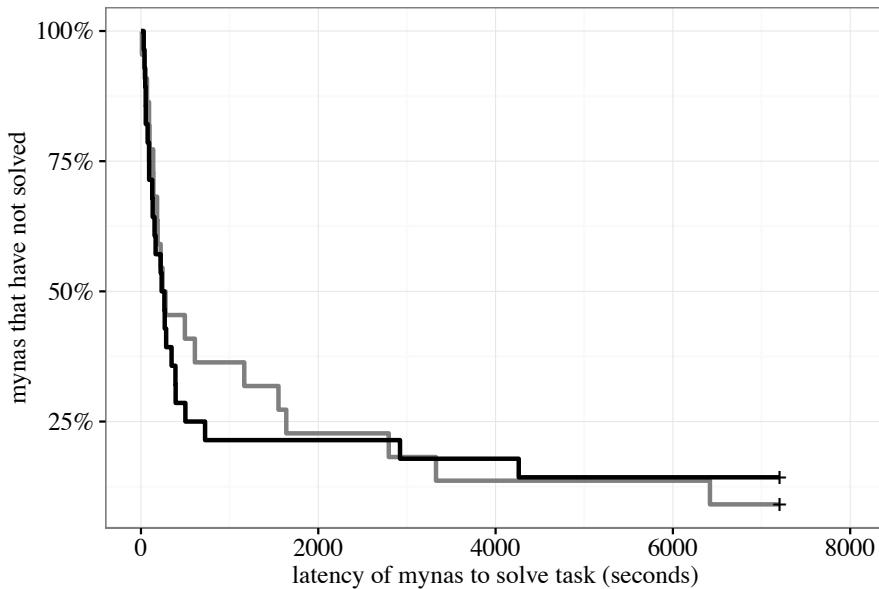


Figure 30. Kaplan-Meier survival curves of the latency of mynas to solve the task. Curve of trapped birds (black) and netted birds (grey). Ticks along the curve indicate censoring time (end of trial).

3.4. Neophobia

On average, mynas took 24 s +/- 3 SE to approach a food dish during the baseline trial. When the novel object was introduced next to the dish, this latency increased up to 2359 s (i.e. 39.3 min) +/- 327 SE, showing the strong reluctance of common mynas to approach novelty.

Survival analyses revealed that none of the variables tested, including capture method, influenced neophobia (Table 23, Figure 31).

Table 23. Minimum adequate Cox regression model on the Neophobia score. Reference categories of variables are noted between brackets beside the variable name.

	estimate	exp(coef)	se(coef)	z	p
capture method (trap)	0.112	1.118	0.299	0.373	0.709

other variables tested, but not included in the best fitting model: localization, sex, time in captivity, season of test. The morphometric index did not fit proportional hazards assumptions and was hence excluded from the initial full model.

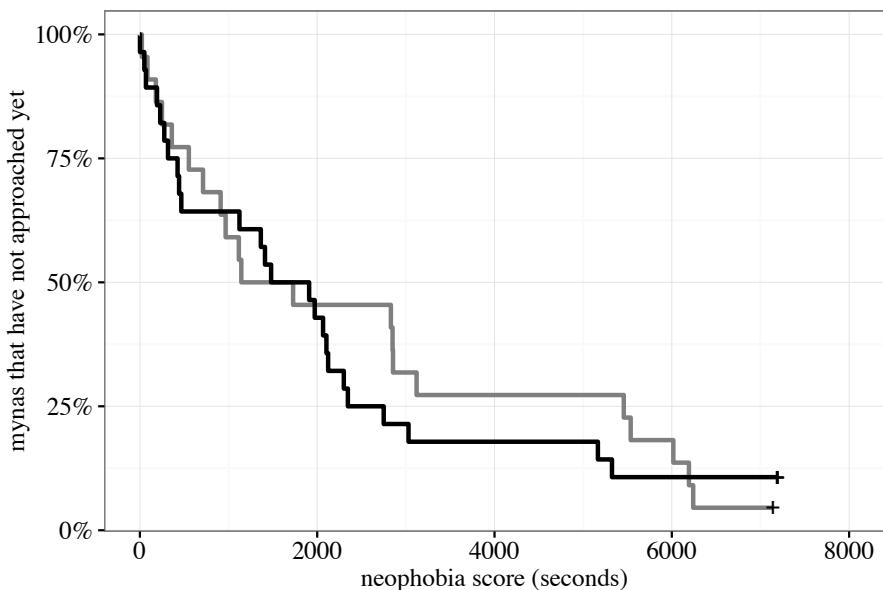


Figure 31. Kaplan-Meier survival curves of neophobia scores (latency of mynas to approach food when a novel object is present to which is subtracted the same latency without the object). Curve of trapped birds (black) and netted birds (grey). Ticks along the curve indicate censoring time (end of trial).

3.5. Tonic immobility

On average mynas remained 4.49 ± 0.55 SE minutes in a state of tonic immobility however this duration varied greatly among individuals (Figure 32). For three birds, this state was never induced during the five trials. None of the variables tested, including capture method, predicted the time bird spent in tonic immobility (Table 24).

Table 24. Minimum adequate Cox regression model on latency to exit a state of tonic immobility. Reference categories of variables are noted between brackets beside the variable name.

	estimate	exp(coef)	se(coef)	z	p
capture method (trap)	-0.122	0.885	0.369	-0.331	0.741

other variables tested, but not included in the best fitting model: localization, sex, morphometric index, time in captivity. Season of test did not fit proportional hazards assumptions and was hence excluded from initial full model.

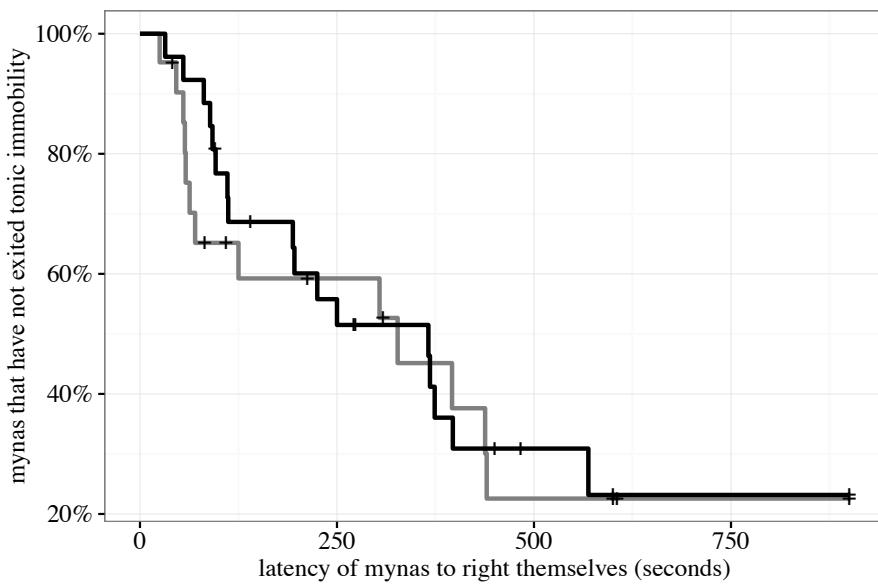


Figure 32. Kaplan-Meier survival curves of the latency of mynas to right themselves after induction of tonic immobility. Curve of trapped birds (black) and netted birds (grey). Ticks along the curve indicate censoring times (end of trial or interruption).

3.6. Response to social and predatory stimuli

3.6.1. *Position in cage during baseline periods*

During the baseline period, when no stimulus was present, birds tended to remain in the middle of the cage: they stayed in zone 2 on average 70% of the time during the baseline of the social stimuli test, and 72% of the time during the baseline of the predator stimuli test.

However, comparisons of position index during baseline periods of both tests indicated that birds tended to be closer to zone 1 (i.e. the left of the cage, close to where the stimuli are unveiled) during the baseline of the predatory stimulus test than the social stimulus test (Figure 33, Table 25).

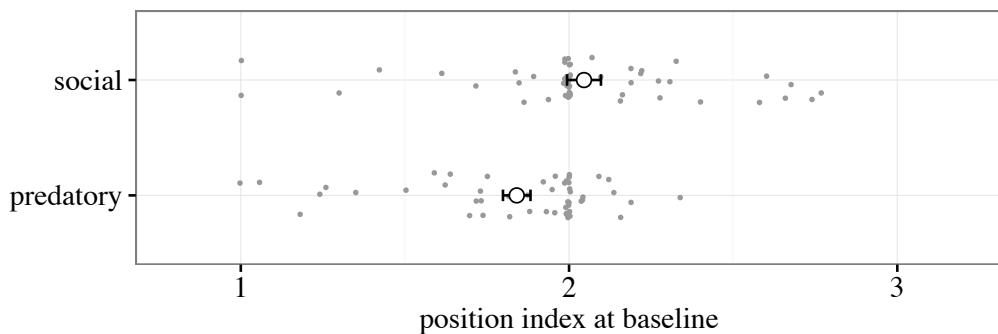


Figure 33. Average position index in cage during the baseline period of each of two different stimulus presentations (large open circle) with standard error. Small grey dots show position index of each individual during baseline of both tests. Position index represents position in cage, values close to 1 indicate birds that spent most of their time in zone 1 (i.e. the left of the cage).

Table 25. Gaussian MCMCglmm on position index during baseline period accounting for repeated measurements of individuals across both stimulus presentations.

<i>fixed effects</i>	posterior mean	1.95..CI	u.95..CI	effective sample	pMCMC
(Intercept)	1.783	1.609	1.981	1123	0.001
stimulus (social)	0.208	0.087	0.328	1000	0.001
capture method (trap)	-0.116	-0.269	0.033	1000	0.106
localization (NW)	0.027	-0.230	0.314	1241	0.806
sex (males)	-0.040	-0.251	0.140	1000	0.734
morphometric index	-0.013	-0.074	0.046	1000	0.674
time in captivity	0.001	-0.001	0.003	1289	0.328
season (winter)	0.100	-0.077	0.264	1000	0.260
<i>random effects</i>					
individual	0.018	0.0003	0.047	1000	

Reference categories of categorical variables are noted between brackets beside the variable name.

3.6.2. Response to a social stimulus

Common mynas responded strongly to the presentation of the social stimulus. When the mirror was unveiled they shifted their use of the space from mainly staying in the middle of the cage to remaining close to their reflection (Figure 34, Table 26)

Additionally, birds also increased the number of social behaviours (sum of all social calls and head bobbing) performed once the mirror was unveiled (Table 27): going from an average of 2.16 +/- 0.90 se social behaviours during the test to 42.62 +/- 6.01 se. Birds also seemed to perform more social behaviours in winter (mean: 25.16 +/- 4.73se) than in summer (mean: 19.62 +/- 5.57se). This analysis also revealed a small but significant effect of time in captivity, suggesting that birds that remained in captivity for longer before being tested tended to perform more social behaviours (Table 27).

I found no significant effect of capture method on either position in the cage or the number of social behaviours performed in response to the presentation of the social stimulus (Table 26, Table 27).

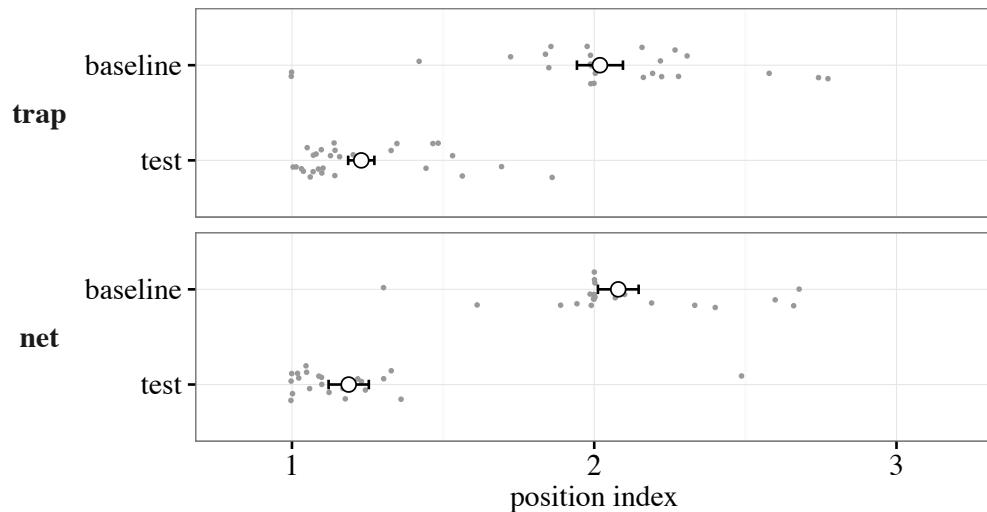


Figure 34. Average position index of trapped and netted birds during the baseline and the test phase of the social stimulus presentation (large open circle) with standard error. Small grey dots show position index of each individual during each phase. The stimulus was presented at the left of the cage, next to zone 1.

Table 26. Gaussian MCMCglmm on position index during baseline and test phase of social stimulus presentation, accounting for repeated measurements of individuals across both phases.

<i>fixed effects</i>	posterior mean	lower 95% CI	upper 95* CI	effective sample	pMCMC
(Intercept)	1.983	1.817	2.161	1000	0.001
phase (test)	-0.834	-0.949	-0.709	1000	0.001
capture method (trap)	-0.013	-0.158	0.126	1000	0.866
localization (NW)	-0.068	-0.335	0.206	1000	0.644
sex (males)	-0.027	-0.231	0.149	1663	0.788
morphometric index	0.031	-0.019	0.093	1150	0.258
time in captivity	0.001	-0.001	0.003	1000	0.416
season (winter)	0.088	-0.084	0.255	1000	0.286
<i>random effects</i>					
individual	0.007	0.0002	0.022	1122	

Reference categories of categorical variables are noted between brackets beside the variable name.

Table 27. Poisson MCMCglmm on number of social behaviours performed during baseline and test phase of social stimulus presentation, accounting for repeated measurement of individuals across both phases.

<i>fixed effects</i>	posterior mean	lower 95% CI	upper 95* CI	effective sample	pMCMC
(Intercept)	-4.093	-5.738	-2.487	1004	0.001
phase (test)	4.533	3.739	5.568	908	0.001
capture method (trap)	0.118	-0.999	1.183	1000	0.840
localization (NW)	0.320	-1.592	1.973	1122	0.722
sex (males)	0.058	-1.316	1.375	1000	0.960
morphometric index	-0.056	-0.491	0.347	1117	0.800
time in captivity	0.012	0.000	0.025	944	0.036
season (winter)	2.300	0.940	3.615	1000	0.002
<i>random effects</i>					
individual	1.098	0.141	2.498	1000	

Reference categories of categorical variables are noted between brackets beside the variable name.

3.6.3. Response to a predatory stimulus

Mynas showed a strong response to the predatory stimulus. Mynas moved away from the cat model after it was revealed (Figure 35, Table 28). Additionally, the birds increased the number of movements performed during the test phase (mean= 95.76 +/- 7.44 SE) compared to the baseline phase (15.86 +/- 3.62 SE) (Table 29) which is a typical anti-predator response in this species (Griffin et al. 2010; Griffin and Haythorpe 2011). These responses to the predatory stimulus did not depend on capture method, sex, morphometric index, time in captivity and season.

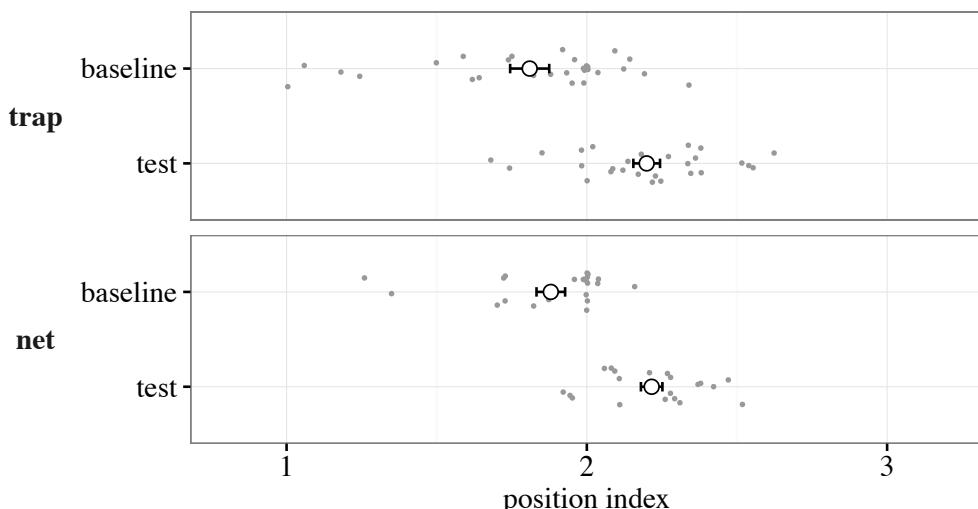


Figure 35. Average position index of trapped and netted birds during the baseline and the test phase of the predatory stimulus presentation (large open circle) with standard error. Small grey dots show position index of each individual during each phase. The stimulus was presented at the left of the cage, next to zone 1.

Table 28. Gaussian MCMCglmm on position index during baseline and test phase of predatory stimulus presentation, accounting for repeated measurements of individuals across both phases.

<i>fixed effects</i>	posterior mean	lower 95% CI	upper 95* CI	effective sample	pMCMC
(Intercept)	1.901	1.760	2.037	906	0.001
phase (test)	0.364	0.275	0.457	1000	0.001
capture method (trap)	-0.061	-0.175	0.058	1000	0.320
localization (NW)	0.059	-0.166	0.270	1000	0.592
sex (males)	-0.073	-0.222	0.085	1000	0.348
morphometric index	-0.015	-0.063	0.035	1000	0.540
time in captivity	0.0001	-0.001	0.002	1000	0.896
season (winter)	-0.046	-0.181	0.081	1000	0.482
<i>random effects</i>					
individual	0.010	0.0003	0.027	1000	

Reference categories of categorical variables are noted between brackets beside the variable name.

Table 29. Poisson MCMCglmm on number of movements performed during baseline and test phase of social stimulus presentation, accounting for repeated measurement of individuals across both phases.

<i>fixed effects</i>	posterior mean	lower 95% CI	upper 95* CI	effective sample	pMCMC
(Intercept)	0.881	-0.217	1.845	1000	0.116
phase (test)	2.948	2.344	3.478	1000	0.001
capture method (trap)	0.148	-0.689	0.909	897	0.708
localization (NW)	0.303	-1.053	1.734	1078	0.700
sex (males)	-0.361	-1.449	0.692	1256	0.492
morphometric index	0.133	-0.188	0.462	1034	0.392
time in captivity	0.002	-0.008	0.012	856	0.620
season (winter)	0.442	-0.480	1.372	1000	0.336
<i>random effects</i>					
individual	0.690	0.130	1.393	974	

Reference categories of categorical variables are noted between brackets beside the variable name.

3.7. Docility

Each bird underwent two handling tests during this study, during which they produced between 1 and 51 evasive behaviours (mean=11.03). Neither capture method nor any of the other variables tested explained the number of evasive behaviours observed during handling (Table 30).

Table 30. Poisson MCMCglmm on the docility score accounting for repeated measurement on each individual.

<i>fixed effects</i>	posterior mean	lower 95% CI	upper 95* CI	effective sample	pMCMC
(Intercept)	1.940	1.336	2.523	1000	0.001
capture method (trap)	0.003	-0.381	0.383	1000	0.976
localization (NW)	-0.087	-0.470	0.336	1000	0.682
sex (males)	0.134	-0.350	0.580	1000	0.594
morphometric index	-0.030	-0.177	0.117	1000	0.684
time in captivity	0.001	-0.002	0.004	1000	0.522
season (winter)	-0.024	-0.363	0.301	1000	0.850
trial number	0.141	-0.133	0.444	1000	0.342
<i>random effects</i>					
individual	0.260	0.099	0.440	1000	

Reference categories of categorical variables are noted between brackets beside the variable name.

3.8. Ease of capture

I found no evidence that the order in which birds were caught in their aviaries was related to capture method or any other measured trait (Table 31).

Table 31. Gaussian MCMCglmm on the docility score accounting for repeated measurement on each individual.

<i>fixed effects</i>	posterior mean	lower 95% CI	upper 95* CI	effective sample	pMCMC
(Intercept)	0.567	0.470	0.650	1096	0.001
capture method (trap)	-0.042	-0.121	0.041	1000	0.308
localization (NW)	0.030	-0.080	0.133	1000	0.564
sex (males)	0.020	-0.091	0.116	702	0.718
morphometric index	0.006	-0.029	0.037	841	0.736
time in captivity	-0.0002	-0.001	0.0002	1193	0.282
season (winter)	0.027	-0.035	0.103	1000	0.458
<i>random effects</i>					
individual	0.009	0.0005	0.017	1000	

Reference categories of categorical variables are noted between brackets beside the variable name.

4. Discussion

Capture method did not influence any of the traits measured in this study. Despite the presence of substantial inter-individual variation, morphology, behaviours related to boldness (neophobia, fearfulness, ease of capture, docility in hand, response to predators), sociality and exploration tendencies (innovativeness, exploration) were not explained by the type of method by which mynas were captured.

Morphological and behavioural trends corresponded to what was expected in this species. As predicted (Counsilman et al. 1994), males were on average larger than

females but did not differ in terms of innovation and neophobia (Griffin et al. 2014; Griffin and Diquelou 2015). Common mynas were highly innovative, 88% of birds solved the innovation task presented in this study, which is in line with a previous study using a similar task where 87% of birds were able to innovate (Griffin et al. 2014). Tonic immobility, docility and ease of capture had never been measured in this species before this study. The duration of tonic immobility in common mynas (mean: 4.49 minutes +/- 0.55 SE) was relatively close to that of wild white backed munias, *Lonchura striata* (mean: 5.35 minutes +/- 0.76 SE, Suzuki et al. 2013) and tree sparrows, *Passer montanus* (mean: 3.68 minutes, Edelaar et al. 2012). Docility in this study was more precisely measured than in previous studies of other species where the tendency of a bird to produce evasive behaviors was measured in broad categories (e.g. birds moves rarely in hand) (Möller and Ibañez-Álamo 2012; Carvalho et al. 2013), as a result between-studies comparisons are difficult to make. The fact that I was unable to find a method which allowed to account for the identity of all birds present inside the aviaries during capture events meant that different events might have taken place in different contexts (e.g. group of birds difficult to catch) and hence might be an unreliable measure. In contrast, other studies that investigated ease of capture kept group sizes and identity of birds within those groups constant throughout testing (Mills and Faure 2000; Guillette et al. 2010), meaning accounting for identity in groups was unnecessary. Measurements regarding morphology, innovation, neophobia, tonic immobility and docility aligned with expectations and previous findings

Responses to stimuli were also in line with expectations. Mynas seem to have perceived their reflection in the mirror as a conspecific. Unveiling the stimulus clearly attracted the birds towards the mirror and led to an increased production of social behaviours. The number of social behaviours also increased in winter, suggesting that during the period when mynas aggregate into large flocks (Feare and Craig 1999), they are more prone to producing these behaviours. Response to the predatory stimulus was also clear as mynas stayed further away from the stimulus and performed more movements, a typical anti-predator response in the species (Griffin et al. 2010; Griffin and Haythorpe 2011). Spatial avoidance of the predatory stimulus was less marked than attraction to the social stimulus because of the increase in movements which made birds switch zones regularly. During baseline trials, birds mostly remained in the middle of the cage, however they tended to be closer to the hidden stimulus during the predator-

stimulus test. This might reflect the fact that during the first test (i.e. the social stimulus test) this side of the cage was associated with a positive social stimulus. Overall, the fact that tests gave results in accordance with expectations suggests that there were methodologically valid and sampled ecologically relevant aspects of personality in common mynas.

Results of behavioural tests did not show any differences between trapped and netted birds. If we assume that the woosh net captured a random sample of mynas, then these results suggest that trapping does not submit common myna populations to personality-biased sampling. Lack of sampling-bias has been shown recently in a population of invasive delicate skinks (*Lampropholis delicata*) where three capture methods did not reveal any substantial bias across 63 individuals (Michelangeli et al. 2016). Similarly, no behavioural, morphological or physiological differences were found between black-capped chickadees (*Poecile atricapillus*) caught with mist-nets and potter walk-in baited traps (Burns 2015). This supports the idea that bias-free methods are available to catch birds and reptiles.

Despite findings suggesting bias-free live capture methods exist, a majority of studies seem to detect evidence for such biases. For example, out of a population of 26 wild male collared flycatchers, *Ficedula albicollis*, those that were caught in nest-box traps tended to be those that were most exploratory and risk-prone (Garamszegi et al. 2009). Similar sampling biases have also been found in wild great tit, *Parus major*, populations (Stuber et al. 2013), wild Namibian agama lizards, *Agama planiceps* (Carter et al. 2012), and wild red squirrels, *Tamiasciurus hudsonicus* (Boon et al. 2008). Interestingly, studies that show sampling biases in terrestrial vertebrates have measured personality in the wild, before individuals were captured and hence compare data from individuals that were captured to those that were not. This is quite different from the protocols, like the present study, where individuals were first captured and then underwent behavioural testing. This suggests there could be scope for some methodologies to be better able than others to reveal sampling biases.

One reason for which studies comparing several capture methods may fail to find evidence of sampling bias is that most sampling techniques are likely to be biased (Biro and Dingemanse 2009). This implies that the lack of difference in personality between animals captured with different methods might not reveal that these methods are unbiased but instead that these methods in fact carry the same biases. Sampling

biases are expected to be particularly strong with passive methods such as traps that require birds to approach a novel structure (Gosler 2004; Biro and Dingemanse 2009), I hence expected the whoosh net, a more active (in that it in part relies on being triggered by the experimenter) and camouflaged capture device (at least to the human eye) to reduce any capture bias. However a number of factors might have in fact produced similar biases between the two methods.

Because mynas are highly sociable (Feare and Craig 1999), lure or decoy birds generally facilitate the approach of free-ranging individuals from traps and are widely known within common myna management circles to improve capture success. As a result, common mynas captured using traps were expected to be highly sociable. However, netting methodology might have resulted in a similar bias. Indeed, the whoosh net was only triggered once a group of birds was reliably seen using the foraging site and therefore netted birds were always caught in groups. The reason for this was that it was quite clear from preliminary tests that once the net had been triggered once and birds handled in the net, the number of free-ranging birds willing to forage at the site was dramatically suppressed. Hence, I only triggered the net when the number of birds captured could be maximized given the time invested in attracting birds to the site. Unfortunately, the downside is that this capture method might have sampled individuals that were more likely to use conspecifics as cues for foraging opportunities. Hence, the lack of difference in response to social stimuli between groups could reflect the fact that neither method captured solitary and asocial individuals.

Another aspect in which the two capture methods used here showed similarities was the presence of food to attract birds. The fact that both methods relied on food baits had the potential to particularly attract hungry birds. Food-baited traps tend to capture individuals in poorer body condition than nets that do not rely on baits, as shown in mountain hares, *Lepus timidus* (Bisi et al. 2011) and Levant sparrowhawks, *Accipiter brevipes* (Gorney et al. 1999). This reflects the fact that individuals in poorer condition are more likely to engage in risky foraging situations. While I had initially intended to include 'baitless' capture methods in this study, the options were scarce (see chapter 1) and proved to be technically unfeasible. However it is worth noting that birds caught in this study covered the span of what is usually observed in terms of weight for the species (i.e. some very small birds <100g and some very large birds >130g). This suggests birds caught were not all in poor body condition, even though it does not

exclude the possibility that the frequency of small birds may be more important than in wild populations. Overall, the fact that both methods relied on food baits might have caused a similar bias towards birds in poor body condition, potentially overriding other potential existing biases in this study.

Mynas tested were overall reluctant to approach novel objects as is commonly observed in this species (Sol et al. 2012; Griffin and Diquelou 2015) but this tendency did not differ between trapped and netted mynas. Similarly, exploration was not affected by capture method. Neophobia and exploration are expected to be important factors of bias for passive methods; indeed only exploratory individuals come across the capture gear and only non-neophobic individuals dare approach it (Biro and Dingemanse 2009). Although whoosh-nets are a less passive method than walk-in traps they are still stationary, hence it is not surprising to have a similar bias in terms of exploration between the two methods. On the other hand, much of the structure of the whoosh net is hidden in the grass, as such I expected neophobic mynas to approach it more easily than the trap. However, during testing birds exhibited reluctance to approach, even with the elastic cables laying on the ground, showing that this species presents extremely high levels of neophobia. As a result, both methods are likely to have captured mostly exploratory and non-neophobic individuals.

Although comparing several capture methods has potential to reveal personality based sampling bias, it cannot elucidate whether there is a bias in the reference category or whether a fraction of the population remains out of reach of all methods used (Simons et al. 2015). I have highlighted potential reasons for which both methods used here might have elicited similar biases in terms of hunger, neophobia and sociality in particular, suggesting the choice of methods might not have been optimal. Even though the whoosh net was chosen based on reasonable assumptions including it being a more active method, less dependent on birds approaching and entering a large and obvious foreign structure, it appears it might not have been an ideal reference method. This highlights the difficulty of choosing a good, unbiased, reference group, and potentially explains why studies based on using wild population are better able to detect capture biases. An important advantage of these studies is that the reference category to which animals captured with a certain method are compared is the wild population. However, this does not completely exclude the potential presence of a bias in the reference category. Indeed, these wild individuals are those that tolerate the presence of humans

either capturing them for marking (Boon et al. 2008), or remaining in close proximity to allow for personality testing (Carter et al. 2012).

Capture biases related to life history traits and behaviour have been the subject of much research in fish where they may present important economical and ecological consequences for fisheries (Law 2001; Enberg et al. 2012; Heino et al. 2015). Large artificial fish populations can relatively easily be established in whole lake experiments where all individuals are known. These set-ups have enabled a number of studies on susceptibility to harvest methods which found that individuals that possess certain traits such as high activity rates or boldness are more likely to be caught than others (Biro and Post 2008; Biro 2013; Häkkinen et al. 2014). Contrary to studies with terrestrial animals, comparison of personality of fish caught with different methods also tend to find evidence of personality driven sampling bias (Wilson et al. 1993; Diaz Pauli et al. 2015; Wilson et al. 2015). Considering the importance of sampling biases in this taxa, it may come as no surprise that it is where the first study investigating the importance of this phenomenon for pest species management emerged (Côté et al. 2014).

Overall the issue of personality-related sampling bias is of critical importance not only to live captures for fundamental research and wildlife harvesting for human consumption, but to all forms of wildlife harvesting, including pest species management. Pest species are often considered as such because of one or more key problematic behaviours, if control measures were to select for, or against, some behaviours, then there is scope to worsen the situation. While this study remains inconclusive as to whether the lack of group differences observed reflects the fact that none of the capture methods present a personality sampling-bias, or whether both methods presented the same bias, I argue that considering the behaviours that could impact both methods, the second option is most likely. More generally, personality driven capture biases have received very little attention in the context of invasive and pest species, yet accounting for them is likely to improve efficiency and sustainability of most management programs.

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CHAPTER 4. INVESTIGATING THE ROLE OF LEARNING IN THE EMERGENCE OF TRAP AVOIDANCE IN COMMON MYNAS

Abstract

Common mynas, *Acridotheres tristis*, found in areas undergoing different levels of trapping pressure vary in their behaviour. Additionally, anecdotal evidence suggests trapping success drops once trapping is initiated in an area. One prime candidate mechanism in explaining these population-level changes in response to trapping is learning, particularly because there is substantial existing evidence for high learning capabilities in this species.

In this study, I tested whether common mynas learned to recognise and avoid stimuli associated with trapping activities. After training groups of free-ranging birds to feed from an experimental station, I measured bird attendance and behaviour at this station before and after a simulated trapping event took place. Mynas came in smaller numbers and took longer to feed from the patch following the trapping demonstration suggesting they learnt that the place or situation had become risky. Additionally the production of alarm calls following the demonstration was particularly high in the presence of the experimenter who performed the demonstration, suggesting mynas recognized the specific human involved.

Overall, these results suggest mynas learn quickly to recognise and avoid stimuli such as places and people, or combinations of stimuli, associated with dangerous situations. Learning is hence very likely to be involved in population-level behavioural differences observed in response to trapping pressure.

1. Introduction

The adaptive function of learning is reflected by its taxonomic prevalence. Indeed, the ability to alter behaviour as a function of experience plays a fundamental role in survival and reproduction of many animal species. Research in a broad array of model systems has made it clear that both vertebrates and invertebrates can learn predictive relationships between novel cues and biologically important outcomes, as well as between their motor actions and resultant environmental consequences (Kroodsma et al. 1984; Hammer and Menzel 1995; Brems 2003; Dukas 2008). Phenotypic expression of such prediction learning, referred to as classical conditioning and operant conditioning respectively, has been shown to represent adaptive changes in behaviour and increase fitness (Hollis 1984; Dukas 2004; Domjan 2005; Morand-Ferron et al. 2015).

One could expect that anti-predator recognition and behaviours are innate, such that they protect animals as early as their first encounter with the predator. However, in many cases, learning exerts a strong influence on anti-predator behaviour by allowing species to deal with novel and changing threats (Brown and Chivers 2005). When exposed to pairings of unfamiliar predator cues and predator risk or direct attacks, animals can learn to recognize the features of novel predators (Curio et al. 1978; Griffin 2008a), the contextual cues that predict the appearance of predators (Fanselow 2000) and the place and times at which they encounter predators (O'Brien and Sutherland 2007; Ferrari and Chivers 2009). One can assume that relying on other more informed individuals to learn about threats, rather than relying on ones own direct interactions with predators, is evolutionarily adaptive (Griffin 2004). And indeed, in many cases learning of predator-related information does not require direct observations of predatory events, but can emerge from social alarm signals of conspecifics (Mathis et al. 1996; Griffin 2008b; Griffin and Boyce 2009) and even from heterospecifics (Mathis et al. 1996; Griffin 2004; Magrath et al. 2015). Such social learning of predator-related information ensures horizontal and also potentially vertical (i.e. parent to offspring) transfer of predator recognition and avoidance.

Predator cue learning can vary in its specificity. On the one hand, classic work has demonstrated that prey acquire responses that are specific to trained cues (Chivers and Smith 1994). On the other hand, prey species often show adaptive patterns of generalization to related cues without further pairings of these cues with risk or attack.

For example, captive-born, fox-naïve wallabies that experience pairings of one predator species (fox) and an aversive human, acquire a fear response to that predator, which generalizes to another predator species (cat), but not to a similar size non-predator species (goat) (Griffin et al. 2001). Similarly, juvenile rainbow trout conditioned to respond to predator scents via pairings with conspecific olfactory alarm signals acquire anti-predator responses to trained predators but also generalize their acquired response to taxonomically closely, but not distantly, related predators (Brown et al. 2011). How much prey generalize (i.e. breadth of the generalization window) seems to depend on the level of risk associated with the known predator (Ferrari et al. 2008) and its certainty (Ferrari et al. 2016). Together, this large body of empirical work demonstrates the exquisite fine-tuning of animal anti-predator systems to deal with variability in predation risk.

It is therefore perhaps surprising that the capacity for such learning has received little attention in the context of wildlife management of overabundant species, despite the potential for such learning to affect management success quite dramatically. Management of overabundant species often includes poisoning, trapping and shooting animals. Because these situations pose direct survival threats to animals, they are highly likely to trigger avoidance learning with dire consequences for management if such learning translates into increased management avoidance. Even more concerning is that horizontal and vertical social transfer of avoidance could accelerate the rates at which animals develop avoidance strategies and therefore accelerate repercussions on effectiveness of management. Hence, it is important that such learning be quantified, its content identified and its consequences on management characterised. It is also critically important to identify the stimuli that trigger learning so that the occurrence of such stimuli can be minimized.

One example of widespread management practice is live-trapping, which is particularly common for the control of problem bird species. Trapping is a multidimensional experience in terms of its stimulus content and what predictors are learnt cannot be known *a-priori*. The place, the trap or the human manipulating it; each of these items might be learnt as an exemplar “avoid this place, avoid this trap, avoid this human”. Additionally, birds might be able to generalize to other members of the trap, human, or place categories and hence avoid management practices on a wider scale.

The common myna, *Acridotheres tristis*, is the target of heavy trapping pressures in Australia where it was introduced in the 1860's. Interestingly evidence is accumulating that mynas change their behaviour in response to trapping (King 2010, but see chapter 2). However the mechanism behind this modification is unclear. Captive studies have shown that the species is readily able to learn to avoid stimuli such as places and taxidermy mounts of non-predators associated with cues of predation (Griffin 2008b; Griffin and Boyce 2009; Griffin et al. 2010; Griffin and Haythorpe 2011). Learning is hence a prime candidate mechanism in the emergence of adjustments to trapping pressure.

The aim of this study was to investigate whether free-ranging common mynas would acquire an avoidance response after witnessing a simulated trapping event. In particular the protocol was designed in order to tease apart whether the birds would learn about the location where the event took place or about the particular human that performed the trapping simulation. I predicted that mynas were capable of place avoidance learning as has been demonstrated in an anti-predator context in captivity (Griffin et al. 2010). But I also suspected that, as a number of urban birds that live in close proximity to humans (Levey et al. 2009; Marzluff et al. 2010; Belguermi et al. 2011), common mynas possess the ability to tell apart dangerous from safe humans.

2. Methods

2.1. Study sites

The ability of common mynas to learn about a dangerous location and/or threatening person was evaluated by establishing 14 experimental feeding stations at which the experience of free-ranging birds could be manipulated. All stations were located in the Newcastle and Wyong local government areas in the state of New South Wales, Australia. Feeding stations were situated at least 750 m apart to minimize chances of re-sampling the same birds at different stations.

In order to establish an experimental feeding station, free-ranging birds were trained to respond to food provisioning. In order to do so, an experimenter walked across rural and suburban areas within 4 h of sunset or sunrise. As soon as a group of common mynas was sighted feeding on the ground in a relatively undisturbed area (i.e. with minimal passage of pedestrians and vehicles nearby), the experimenter placed an assortment of foods (white bread, dog pellets and mealworms) in proximity of the birds

in an attempt to entice them to respond to food provisioning. Food was distributed in such a way that it was contained approximately within a 50-cm diameter circle. The experimenter then watched the food patch for 10 minutes to determine whether any mynas approached the food.

Thereafter, the experimenter returned to this site at the same time each day. Once birds fed from the patch within 30 min on at least three successive days, the feeding station was considered established and experimental feeding trials were initiated. Thirty-three sites were used for preliminary feeding, but only 14 reached this threshold.

2.2. Experimental feeding trials: overview

Experimental feeding trials included three successive types of trial, pre-demonstration trials, demonstration trials and post-demonstration trials. The demonstration trials staged an aversive human-myna interaction typical of the kind that occurs during myna trapping activities. Specifically, an experimenter pretended to remove two live decoy mynas from inside a trap. Pre- and post-demonstration trials allowed behavioural measurements in free-ranging mynas at the feeding sites before and after they had watched the aversive demonstration in order to detect changes in behaviour indicative of learning.

In order to determine whether mynas can learn to discriminate between aversive and non aversive humans, the experimenter alternated between two different visual appearances ('appearance treatments'), referred to as 'mask' and 'face'. During the mask treatment, the experimenter wore a blank mask, a white lab coat and a black hat, whereas during the face treatment, the experimenter wore a dark jacket, but neither a hat, nor a mask. All preliminary feeding (i.e. site establishment phase) involved an experimenter in face appearance. During pre- and post-demonstration trials, the experimenter alternated between face and mask treatments on successive days. During the demonstration trials, each experimental site was allocated to either the face or mask treatment (Table 32).

Table 32. Description of the successive stages of the experimental protocol. Appearance treatments used during each stage along with the procedures involved are listed. Note that, at each site, one of the two appearances (face or mask) was randomly selected to be used during the demonstration trial. This appearance is then referred to as the 'aversive' appearance for this site, while the other one is the 'neutral' appearance.

Stage	feeding station establishment	pre-demonstration trials	demonstration trial	post-demonstration trials
Experimenter appearance	face	face <i>and</i> mask alternate	face <i>or</i> mask (random)	face <i>and</i> mask alternate
Experimental procedure	• feeding	• feeding • continuous observation	• feeding • continuous observation • staged aversive demonstration	• feeding • continuous observation

2.3. Pre-demonstration trial procedure

Once a feeding site had been established, the experimenter visited the location at the same time each day and placed food at the patch as in the site establishment phase. The experimenter then watched the site from at least 12 m away and remained in the same position throughout the trial.

Starting as soon as the first bird began feeding, myna behaviour at and around the food was recorded for 30 min. The number of mynas present at the feeding station and in the surroundings (i.e. within a 50 m radius of the food patch) was recorded every 5 min. In addition, the maximum number of birds present at the station and in the surroundings was tracked continuously for later data analysis. A video-recording of the food station was also collected for later behavioural analysis (see section 2.6.1, p161).

Latency of the first myna to feed from the patch after food had been placed there was recorded. Birds were given a maximum latency of 30 min (i.e. 1800 s) to feed from the patch; if they failed to do so, they were attributed a maximum latency of 1801 s.

Across pre-demonstration trials, experimenters alternated between mask and face appearances on successive feeding days. The order of appearances was counterbalanced across sites, such that if one appearance was used on the first pre-demonstration trial at a given site, the alternative appearance was used on the first pre-demonstration trial at the next established feeding station. The procedure involved conducting two trials with each appearance at each feeding station, such that the pre-demonstration phase lasted four days if mynas fed from the patch each day. For logistic reasons, the first two sites of this experiment contained only two pre-demonstration trials both of which were conducted with the face appearance.

Trials on which no birds landed at the feeding location, from hereon after referred to as *empty trials*, might have occurred for stochastic reasons unrelated to the experiment (e.g. disturbance before the arrival of the experimenter). To account for such events, for each *empty trial*, an *additional trial* was conducted on the following day using the same appearance treatment (face or mask). As a result, if birds failed to return feeding during all four trials, four *additional trials* were run during that stage, adding up to a maximum of eight trials within a stage. *Empty trials* had missing values for all variables collected except latency to feed from patch (which was recorded as 1801 s) and maximum number of birds at patch (which was recorded as zero).

2.4. Demonstration trial procedure

The demonstration trial started in a similar way as pre-demonstration trials. An experimenter placed food at the patch and then waited until the first free-ranging myna began to feed. The experimenter then waited 20-40 s which provided most birds in the vicinity the opportunity to approach and begin feeding. The staged aversive demonstration was then initiated.

The experimenter walked slowly towards the food patch, carrying a portable speaker and a small portable cage (84 x 40.5 x 44.5 cm) covered with opaque material. Mynas typically responded to the slow approaching human by leaving the food patch but remaining in the vicinity from where they observed the subsequent events. The researcher placed both the cage and the loud speaker next to the food. She then removed the cage cover and started a 1-min playback of myna distress calls, which operates as a strong attractor social signal in mynas (Griffin 2008b). She then began waving a small net inside the cage using motions similar to those performed when birds are removed from myna traps and known to produce place aversion learning under captive conditions in mynas (Griffin and Boyce 2009). Decoy mynas exhibited a strong escape response involving flying rapidly from one side of the cage to the other. The 5-min aversive demonstration was terminated by covering the cage, collecting the equipment and walking away from the food patch. The cage was shielded from the sight of mynas by placing it in a nearby vehicle. The experimenter then continued to record behaviour of mynas at the food patch until 30 min from the first bird feeding had passed.

The distress call sequence was created by concatenating sequences of calls from three different mynas recorded during handling (Griffin 2008b). The signal was played

back using a pignose 7-100 portable amplifier at approximately 75 db (measured at 1 m with a sound level meter).

The experimenter's appearance (face vs. mask) used during the demonstration trial was selected randomly. The appearance used during the aversive social demonstration is referred to as 'aversive', whereas the alternative appearance, which was only ever associated with feeding, is referred to as 'neutral'.

2.5. Post-demonstration trial procedure

The procedure for the post-demonstration trials was identical to that of the pre-demonstration trials and the same behavioural measures were sampled. Whereas mynas rarely failed to feed at the patch during pre-demonstration trials, *Empty trials* were much more common during post-demonstration trials. As a result, several post-demonstration trials had the maximum value for approach latency (30 min) and the minimum value for the maximum number of birds sighted (zero).

2.6. Data analysis

2.6.1. Video analysis

Video recordings of field trials were scored in a random order by an observer blind to the timing of the trial (pre/post-demonstration) and to the treatment (neutral/aversive). To quantify the vigilance levels of birds at the food patch, the observer scanned the number of birds that had their heads up (i.e. above shoulder level), their heads down and for which head position could not be determined at one minute time intervals after the first bird began feeding at the food patch. This resulted in 31 data points for each trial given a trial duration of 30 min. Head position could not be determined for only a very small number of birds (<5%) and these were hence not included in calculations. The proportion of birds with their heads up was determined by dividing number of birds head up by the sum of head up and head down birds.

2.6.2. Dataset

Generally, mynas reliably fed at the food patch within 30 min of placing the food on the ground during the 4 pre-demonstration trials at each site. However this was less often the case during post-demonstration trials during which mynas often failed to feed from the patch within the given time. This led to a number of *empty trials* which in

turn resulted in *additional trials* in an attempt to obtain trials where birds were present (see pre-demonstration trial procedure). *Empty trials* were discarded from the dataset, unless mynas also failed to return to the patch in the corresponding *additional trials*, in which case the last *additional trial* was retained. Overall, 17 *additional trials* were run and 5 *empty trials* remained in the final dataset, indicating most *additional trials* succeeded in providing trials where birds were present. My reasoning behind disregarding part of the empty trials was twofold. First, it excluded days on which, for unknown reasons, birds did not come to the feeding station (which were rare). Second, including all trials in which no birds fed might have lead to oversampling of sites at which mynas had become wary post-demonstration (because additional feeding trials were conducted when no birds fed). Using this approach, I obtained four pre-demonstration and four post-demonstration trials for each experimental feeding site, except the two first sites where only two pre-demonstration trials were conducted. In total, the final dataset contained 108 trials.

2.6.3. Statistical analysis

Common mynas' latency to feed from the station once food had been put down was analyzed using survival analysis. Cox regressions are a semi-parametric approach designed to analyze time-to-event variables that include censored times (Bradburn et al. 2003). The proportional hazards assumption was checked by the scaled Schoenfeld residual test (Grambsch and Therneau 1994) and fit was assessed visually from plots of the residuals.

I first investigated whether birds responded differently to the two appearance treatments (face/mask) during the pre-demonstration trials. I ran a Cox regression model on latencies to come to the patch during the pre-demonstration which included only appearance treatment as an explanatory variable. I then analyzed the latency to come to the patch during all trials which included stage (pre/post-demonstration), the stimulus treatment (neutral/aversive) and the interaction of these two terms.

Count data were analyzed with Poisson Markov chain Monte Carlo generalized linear mixed models (MCMCglmm). These models allowed to integrate random variables such as site and trial, as well as account for over-dispersion of some of these variables (Hadfield 2010). These models were run with the MCMCglmm package (Hadfield 2010). Full models are presented for which a weakly informative proper prior

was used (see annex 4.1, p223). Autocorrelation of successively stored iterations was checked to ensure that it was under 0.1, and convergence was assessed visually from diagnostic plots.

I first investigated whether appearance treatments (face/mask) had an effect on the number of birds present at each scan during pre-demonstration phases. Several data points for each site and trial were analyzed such that these were entered as random variables. Only appearance treatment was entered as a fixed explanatory variable.

The number of mynas at the station and its surroundings as well as the number of alarm calls emitted were analysed with this same approach and included site and trial as random variables, and stage, stimulus treatment and the interaction of these two variables as fixed effects.

The ratio of birds that were seen head up during trials was analyzed with Gaussian MCMCglmm, following the same procedure as Poisson MCMCglmms. Because this ratio was calculated at the whole trial level, only site was included as a random effect while stage, stimulus treatment and the interaction of these variables were entered as fixed effects.

No attempts to apply transformations to the data were made. All statistical analysis were performed in R (version 3.2.4, R Core Team 2016).

2.7. Ethical note

During the demonstration, the researcher was careful not to stress the decoy birds excessively by regularly pausing the chase motions.

It was possible that for some members of the public viewing masked humans and bird captures could cause alarm. Hence at experimental sites located close to dwellings, experimenters letter-box dropped an explanatory leaflet before undertaking any pre-demonstration trials. Additionally, during experiments, in the vicinity of the site, the experimenter set up a small safety panel explaining a bird behaviour experiment was taking place.

All experimental procedures were in accordance with the Australian Code of Practice for the Care and Use of Animals for Scientific Purposes and were approved by the University of Newcastle Animal Ethics Committee (protocol A-2011-129).

3. Results

3.1. Effect of appearance treatment on pre-demonstration trials

Appearance treatment did not influence the latency of birds to arrive at the feeding station (Table 33), nor the number of birds present at each trial (Table 34). It hence appeared that birds behaved similarly during pre-demonstration trials whether these were performed by experimenters wearing the face or the mask appearance.

Table 33. Minimum adequate Cox regression model on latency to arrive at the feeding patch after food was put down during pre-demonstration trials. Reference categories of variables are noted between brackets beside the variable name.

	estimate	exp(coef)	se(coef)	z	p
appearance (face)	-0.192	0.826	0.290	-0.686	0.403

Table 34. Poisson MCMCglmm on number of mynas at feeding station at each scan during pre-demonstration trials.

<i>fixed effects</i>	posterior mean	lower 95% CI	upper 95% CI	effective sample	pMCMC
(Intercept)	-0.894	-1.385	-0.309	1000	0.001
appearance (face)	0.128	-0.326	0.571	1000	0.602
<i>random effects</i>					
site	0.452	0.014	0.988	1000	
trial	0.033	0.0002	0.135	828	

Reference categories of categorical variables are noted between brackets beside the variable name.

3.2. Number of mynas at feeding station

Myna attendance at the feeding station was highest at the point in time when the first bird began to feed from the station (i.e. scan 0) and decreased thereafter (Figure 36, Table 35). Since in most cases food remained at the end of the trial, this was most likely due to a decrease in motivation perhaps related to satiation.

Scans that took place after the demonstration contained less common mynas than during the pre-demonstration phase (Figure 36, Table 35), showing a lower attendance rate following the demonstration.

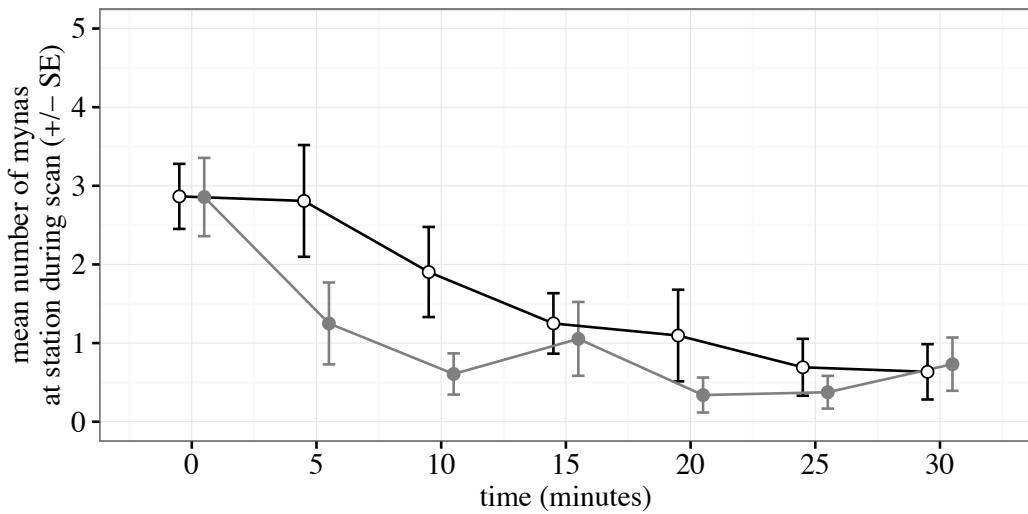


Figure 36. Mean number of birds at feeding station during seven successive scans separated by 5-min sample intervals. Open circles: pre-demonstration trials; filled grey circles: post-demonstration trials

Table 35. Poisson MCMCglmm on number of mynas at feeding station during each scan.

fixed effects	posterior mean	lower 95% CI	upper 95% CI	effective sample	pMCMC
(Intercept)	0.527	-0.141	1.156	1000	0.120
time of scan	-0.098	-0.117	-0.08	755	0.001
stage (post-demo)	-1.085	-1.625	-0.573	1000	0.001
stimulus (neutral)	-0.143	-0.677	0.301	1000	0.588
stage : stimulus	0.190	-0.547	0.908	1000	0.596
<i>random effects</i>					
site	0.926	0.199	1.885	1064	
trial	0.132	0.0003	0.377	394	

Reference categories of categorical variables are indicated in brackets beside the variable name.

The model displayed here (Table 35) showed strong significant effects of stage and time of scan. However, there were mixing issues with the trial variable, potentially related to the fact that several post-demonstration trials contained one or zero birds during every scan. While this issue is unlikely to affect the strong main effects found here, another model was run to confirm the effect of stage. Instead of focusing on the number of birds present during each scan, the outcome variable of the second model was the maximum number of birds present during a trial. Hence, this model no longer tested for an effect of time.

This second model confirmed the strong effect of stage on the number of birds attending the station. Fewer mynas came to the station after the demonstration than before (Figure 37, Table 36).

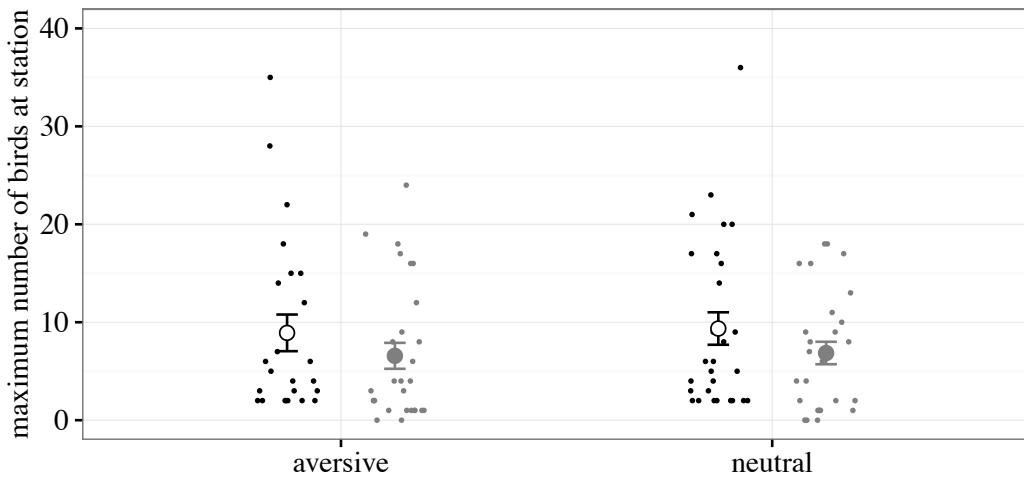


Figure 37. Mean (+/- SE) maximum number of common mynas at a feeding station during pre-demonstration trials (open circles) and during post-demonstration trials (closed circles) as a function of the stimulus (i.e. aversive: paired with aversive human, or neutral: not paired with aversive human). Small dots represent the maximum number of mynas present during each pre-demonstration (black) and post-demonstration (grey) trial.

Table 36. Poisson MCMCglmm on the maximum number of mynas at feeding station during each trial.

<i>fixed effects</i>	posterior mean	lower 95% CI	upper 95% CI	effective sample	pMCMC
(Intercept)	1.942	1.357	2.590	1071	0.001
stage (post-demo)	-0.523	-0.857	-0.216	1000	0.001
stimulus (neutral)	-0.136	-0.462	0.164	1000	0.378
stage : stimulus	0.224	-0.232	0.636	1332	0.318
<i>random effects</i>					
site	1.118	0.402	2.229	1000	

Reference categories of categorical variables are indicated in brackets beside the variable name.

3.3. Number of mynas within the surroundings of feeding station

The number of mynas in the surroundings of the station was not recorded during trials in which no mynas visited the station (contrary to the number of mynas at the feeding station which was determined to be zero). Hence, number of mynas in the surroundings had fewer trials (103 vs. 108 trials) and scans (721 vs. 756) than number of mynas at the feeding station, and, more importantly, fewer scans containing zeros.

Like the number of individuals at the feeding station, the number of individuals within 50 m of the feeding station, also decreased as time passed within trials, as well as after the demonstration (Figure 38, Table 37). However, posterior means suggested that the effect of these explanatory variables on the number of birds in proximity of the stations (Table 35) were smaller than their effect on the number of mynas at the feeding station itself (Table 37).

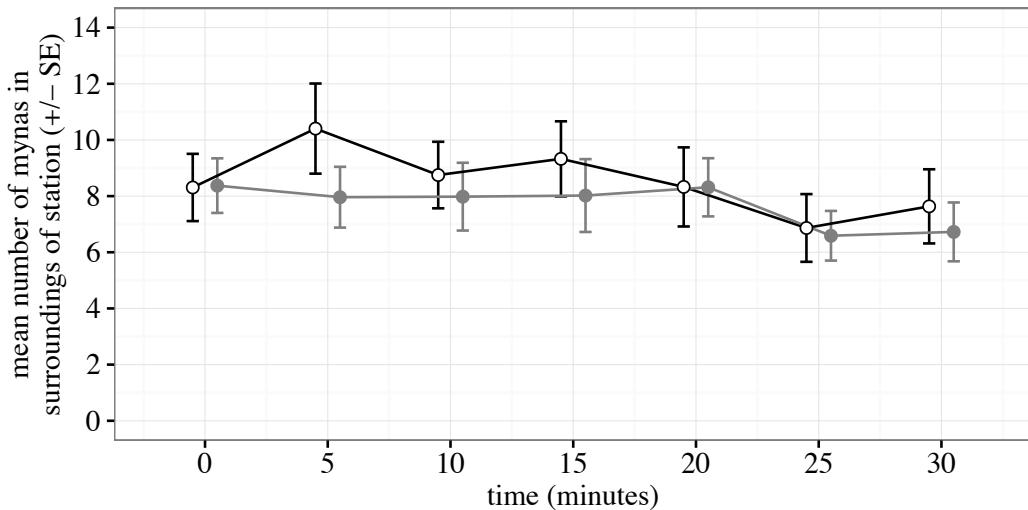


Figure 38. Mean +/- SE number of common mynas present in the surroundings (within 50m) of the feeding station during seven successive scans separated by 5-min sample intervals. Open circles: pre-demonstration trials; filled grey circles: post-demonstration trials.

Table 37. Poisson MCMCglmm on number of mynas in the surroundings of feeding stations at each scan.

fixed effects	posterior mean	lower 95% CI	upper 95% CI	effective sample	pMCMC
(Intercept)	1.864	1.350	2.471	1000	0.001
time of scan	-0.009	-0.014	-0.004	949	0.001
stage (post-demo)	-0.297	-0.540	-0.045	1000	0.018
stimulus (neutral)	-0.037	-0.286	0.192	1000	0.774
stage : stimulus	0.125	-0.205	0.459	1000	0.460
<i>random effects</i>					
site	0.909	0.276	1.713	1239	
trial	0.123	0.070	0.182	1000	

Reference categories of categorical variables are indicated in brackets beside the variable name.

3.4. Latency to feed from station

On average, common mynas took just under 6 min (350.3 s +/- 47.4 SE) to come to the station once food had been placed there. The Cox regression model revealed a strong effect of stage on this latency (Figure 39, Table 38), showing that birds took longer to come to the food after the demonstration had taken place. Surprisingly, however, tests revealed that the stage variable did not follow proportional hazards assumptions (Schoenfeld residuals test; $\rho_{\text{stage}}=0.27$, $X^2_{\text{stage}}=12.3$, $p<0.001$). Since only five trials contained capped values, I deemed acceptable to use a model that did not account specifically for them. A Gaussian MCMCglmm was conducted and revealed an

identical stage effect to the Cox regression (Table 38). Latency to arrive at the station was longer after the demonstration had taken place (Table 39)

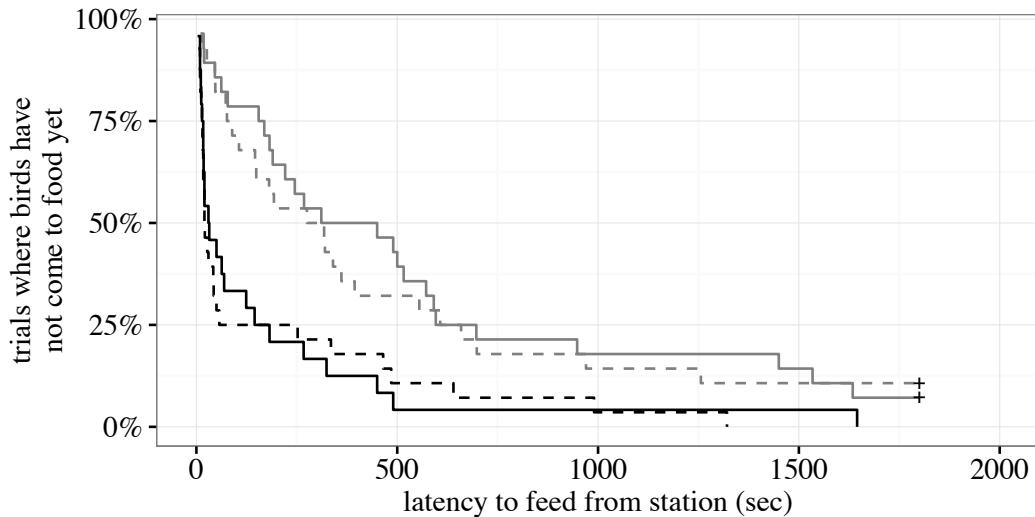


Figure 39. Kaplan-Meier survival curves of the latency of mynas to feed from the station during each trial. Pre-demonstration trials (black) and post-demonstration trials (grey) are presented, as well as trials with the aversive stimulus (solid line) and the neutral stimulus (dashed line).

Table 38. Cox regression model on the latency to feed from the feeding station. Reference categories of categorical variables are noted between brackets beside the variable name.

	estimate	exp(coef)	se(coef)	z	p
stage (post-demo)	-0.959	0.383	0.288	-3.077	0.002
stimulus (neutral)	-0.001	0.999	0.281	-0.005	0.996
stage : stimulus	0.062	1.064	0.397	0.268	0.789

Table 39. Gaussian MCMCglmm on the latency of mynas to arrive at the feeding station at each trial.

fixed effects	posterior mean	lower 95% CI	upper 95% CI	effective sample	pMCMC
(Intercept)	168.3	-31.5	406.9	1077	0.128
stage (post-demo)	378.0	141.8	595.8	974	0.006
stimulus (neutral)	7.0	-202.7	267.1	911	0.952
stage : stimulus	-82.3	-375.4	250.4	896	0.630
random effects					
site	63039.1	0.005	142238.5	1000	

Reference categories of categorical variables are indicated in brackets beside the variable name.

3.5. Number of alarm calls

Overall it was common for mynas to produce a few alarm calls during trials, often due to a bird of prey or a cat passing by. Only 30% of trials did not contain any calls (i.e. 26 of the 87 trials for which alarm calls were recorded). The number of alarm calls emitted after the demonstration tended to be higher than before, but this was

mostly true when the aversive stimulus, the appearance with which the experimenter had performed the demonstration, was present (Figure 40, Table 40).

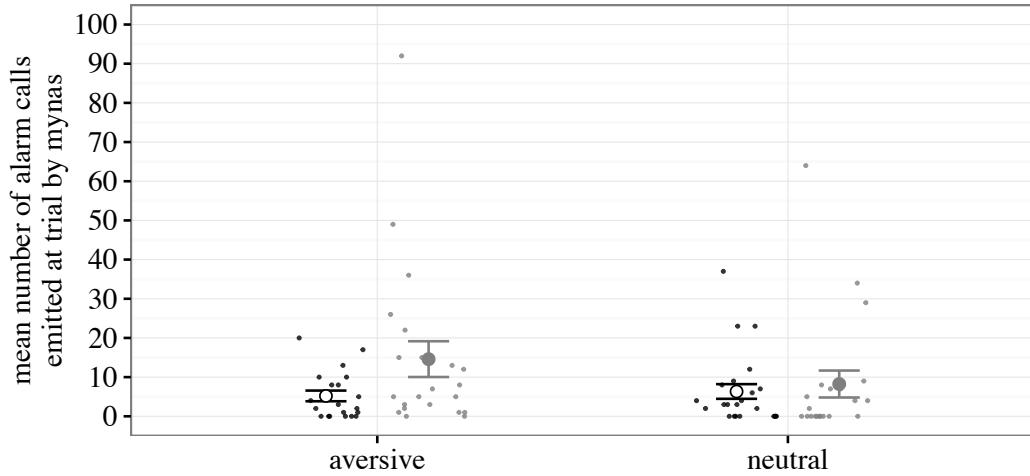


Figure 40. Mean (+/- SE) number of alarm calls emitted by common mynas during pre-demonstration trials (large open circle) and during post-demonstration trials (large grey closed circle) as a function of the stimulus (i.e. aversive or neutral). Small dots represent the number of calls emitted at each pre-demonstration (black) and post-demonstration (grey) trial.

Table 40. Poisson MCMCglmm on the number of common myna alarm calls emitted at each trial.

<i>fixed effects</i>	posterior mean	lower 95% CI	upper 95% CI	effective sample	pMCMC
(Intercept)	0.661	-0.402	1.539	1008	0.158
stage (post-demo)	1.041	0.087	2.002	1140	0.032
stimulus (neutral)	0.195	-0.718	1.217	1667	0.668
stage : stimulus	-1.447	-2.817	-0.099	1000	0.036
<i>random effects</i>					
site	1.384	0.095	3.308	1000	

Reference categories of categorical variables are indicated in brackets beside the variable name.

3.6. Vigilance rate

On average, 61% +/- 0.03SE of mynas were vigilant during trials. Vigilance rate during feeding trials was not influenced by either stage or stimulus (Table 41).

Table 41. Gaussian MCMCglmm on the ratio of mynas seen head up during trials.

<i>fixed effects</i>	posterior mean	lower 95% CI	upper 95% CI	effective sample	pMCMC
(Intercept)	0.638	0.521	0.746	1000	0.001
stage (post-demo)	-0.026	-0.164	0.124	990	0.716
stimulus (neutral)	-0.073	-0.214	0.057	1000	0.306
stage : stimulus	0.091	-0.123	0.281	1000	0.376
<i>random effects</i>					
site	0.006	0.0002	0.017	931	

Reference categories of categorical variables are indicated in brackets beside the variable name.

4. Discussion

Common mynas responded strongly to the trapping simulation performed in this experiment. After just one demonstration of an aversive human-myna interaction, of the kind that would take place during any trapping activity, birds took longer to land at experimental feedings stations and their surroundings, and landed in smaller numbers. Additionally, more anti-predator calls were emitted during post-demonstration visits, particularly when the experimenter wore the appearance used during the staged aversive demonstration. This discriminatory response indicates that mynas differentiated the human who had provided food but then interacted aversively with conspecifics from the human who had only provided food. Overall this study suggests common mynas have the ability to quickly learn to avoid a dangerous situation as well as details of the stimuli involved.

The fact that mynas were reluctant to approach the feeding station during all post-demonstration trials suggests that they learnt to avoid the place where they observed an alarming human-myna interaction. By demonstrating such learning in free-ranging birds, this result extends significantly the established finding that place learning can be triggered by a similar human-myna interaction under captive conditions (Griffin and Boyce 2009). In this earlier work, a series of three studies demonstrated together that learning only occurred if observers viewed both alarmed conspecifics and the cause of their alarm (Griffin and Boyce 2009; Griffin et al. 2010; Griffin and Haythorpe 2011). In the current experiment, as in any trapping situation, social alarm cues (e.g. from decoy birds) and their causal (human) and spatial (location of the trap) context were available to observing birds, providing all necessary information for place avoidance learning to occur.

Analysis of alarm calls indicated that common mynas were able to distinguish the human appearance that had been paired with the social alarm cues and the one that

had not, confirming what King (2010) suspected, when he proposed that he was being recognized and avoided by mynas in the surroundings of his trapping areas. While common mynas learnt to differentiate the aversive experimenter appearance from the neutral one, the protocol does not disentangle whether these birds are capable of human face recognition. Indeed, faces varied with other features (i.e. hat and clothes) such that the experimenters were physically different overall. Face recognition has been shown in several avian species, some of which are taxonomically relatively distant from mynas, including Antarctic brown skuas, *Stercorarius antarcticus* (Lee et al. 2016), feral pigeons, *Columba livia* (Belguermi et al. 2011; Stephan et al. 2012), Eurasian magpies, *Pica pica* (Lee et al. 2011), jackdaws, *Corvus monedula* (Davidson et al. 2015) and American crows, *Corvus brachyrhynchos* (Cornell et al. 2011), and others that are more closely related to mynas, including house sparrows, *Passer domesticus* (Vincze et al. 2015) and Northern Mockingbirds, *Mimus polyglottos* (Levey et al. 2009). Considering that common mynas are a highly commensal species, it is more than likely that this species possesses the capacity to recognize faces. Hence, it is most likely that the same discrimination effects would have been observed here, had I only manipulated face, rather than both face and other attributes of the two humans.

Whereas increases in alarm calling specific to the aversive human demonstrated human-recognition learning, reduced patch visitation during post-demonstration trials with both the aversive and the neutral faces revealed that mynas generalized their acquired avoidance behaviour from a human experienced during a simulated trapping event to one not associated with simulated trapping. Generalization of acquired responses from trained stimuli to further non-trained, but similar looking stimuli is a very well established phenomenon in basic learning research (Mackintosh 1974). Within a wildlife conservation and management setting, generalization of trained responses has been demonstrated in a variety of species (Mason et al. 1991; Davis et al. 2012). For example, tammar wallabies, *Macropus eugenii*, trained to respond fearfully to a model fox by pairing it with an aversive human later exhibited a similar fear response to a model cat (Griffin et al. 2001; Griffin and Evans 2003). In the present study, mynas not only generalized acquired avoidance across dangerous humans, they also displayed the capacity to generalize acquired approach responses across desirable humans. Indeed, despite undergoing several days of preliminary feeding during the site establishment phase with the face appearance and none with the mask appearance,

mynas behaved similarly during pre-demonstration trials towards both appearances. Broad generalization gradients might be adaptive in an invasive species like the myna because they would allow learning of a broad range of stimuli based on experience with just a few.

Classic learning experimental protocols designed to demonstrate associative learning in laboratory settings typically include not only a group that receives an initially neutral stimulus (conditioned stimulus, CS+) together with an aversive event (unconditioned stimulus, US), but also a group that receives both these stimuli separately. Alternatively, a within-subject design is used, where each subject receives one stimulus that is paired with an aversive event (CS+) and one that is not (CS-). These designs enable the experimenter to disentangle changes in behaviour post-conditioning attributable to associative learning from those attributable to non-associative learning processes, including sensitization due to repeated exposure to an aversive US (Shettleworth 2010). Implementing such designs is not possible under field conditions because it is not possible to reveal the CS+ (human/place) and US (staged alarm responses of conspecifics) to free-ranging observers separately. Hence, it might be argued that non-associative learning mechanisms contributed to increased caution even though my training protocol was designed to facilitate the formation of neutral/aversive event associations (Shettleworth 2010).

On the one hand, place avoidance learning triggered by a staged aversive human-myna interaction in captive-held mynas has been demonstrated to rely upon a purely associative learning process (Griffin and Boyce 2009; Griffin et al. 2010; Griffin and Haythorpe 2011) making associative learning a likely candidate mechanism in the present study. On the other hand, previous research has found evidence for generalized changes in risk taking behaviour governed by, amongst other factors, the perceived threat level of the environment. For example, fish that have experienced predators exhibit less risky behaviours overall regardless of the presence of the predator (Lönnstedt et al. 2012). In tropical stonechats (*Saxicola torquata axillaris*), the presence of predators on the breeding territory leads to lower body condition and lower breeding rates. In addition, these birds have higher corticosterone levels, suggesting the other effects could be mediated by chronic stress due to the presence of the predator (Scheuerlein et al. 2001). This body of work on perceived predation risk makes it possible that increased caution of mynas towards experimental food patches found here

might reflect a general, non associative, decrease in willingness to take risks. The possibility that aversive human/myna interactions observed during trapping facilitate general changes in risk-taking behaviour is supported by the finding that mynas from heavily trapped populations show changes in general risk-taking behaviour compared with those that have not undergone trapping (Chapter 2). These changes are not strictly restricted to responses to traps but include behaviours related to other aspects of risk taking such as group size and conspicuousness (Chapter 2). Hence, aversive human/myna interactions might well be the source of increased perceived risk in the environment.

One cannot overlook the possibility that aversive human/myna interactions trigger both learning about specific trapping cues and generalized changes in risk-taking behaviour simultaneously. There is evidence that both avoidance learning and risk taking are linked through common stress hormonal pathways. Indeed, inhibiting acute corticosterone elevation in response to a threat can prevent both the anti-predator response and aversive learning of that threat (Thaker et al. 2010). According to the threat-sensitivity hypothesis (Helfman 1989), intensity of the response to a predator corresponds to the threat level perceived by the prey and the willingness of the prey to withstand, or not, certain levels of risk. Hence, anti-predator response depends on risk taking, suggesting that both these mechanisms - which are suspected to take place in this study - could be underpinned by the same hormonal pathway. This underlines the interest of studies integrating cognitive sciences, behavioural ecology and physiology together (Kavaliers and Choleris 2001).

Common mynas showed an ability to learn about specific dangerous humans through production of alarm calls. Such production of alarm calls in the presence of a predator has the potential to be involved in social transmission of recognition of this predator. American crows have been shown to recognize and elicit scolding of specific humans that caught them for at least 2.7 years following the capture event (Marzluff et al. 2010). Interestingly, further research showed that this scolding behaviour then occurs even in the absence of any of the birds that were originally caught, suggesting scolding by captured individuals led to social learning (Cornell et al. 2011). Common myna alarm calls have been described as harsh scolding calls emitted when encountering predators (Feare and Craig 1999). These calls might hence serve a function analogous to crow scolding calls and could allow social learning about threatening stimuli.

Considering distress calls have been implicated in social transmission of threat avoidance in this study and in previous studies (Griffin 2008b, 2009), the potential for other common myna vocalizations, such as alarm calls, to enable social learning needs to be taken into account. Social transmission of threat recognition would be of great importance in our understanding of common myna populations, in particular in the context of controlling of these populations. The spread of trap-avoidance across populations (i.e. horizontal transmission) and potentially generations (i.e. vertical transmission) of mynas could multiply the effects of individual learning and hence seriously jeopardize future efforts.

Ultimately, it will be extremely important to understand the psychological processes that underpin avoidance learning in mynas. If avoidance comes from a purely associative mechanism, then ensuring that pairings of human and alarmed conspecifics do not occur, or at least are not visible to free-ranging birds, is paramount. In line with this, most groups involved with common myna control, recommend that traps are only approached at night such that other mynas cannot observe technicians approaching or removing distressed conspecifics (Dhami and Nagle 2009; Tidemann 2009; Copsey and Parkes 2013). In contrast, if acquired avoidance reflects a general change in risk-taking behaviour triggered by trapped, alarmed conspecifics then controlling these cues during trapping becomes very difficult. It will also be critical to determine the exact content of learning. This is because the degree of learning specificity will determine the impact of trapping on future trapping success. At one extreme, if aversive human/myna interactions inculcate avoidance responses that are specific to the exact human and/or exact place associated with trapping, then learning is unlikely to reduce future trapability. At the other extreme, if human/myna interactions inculcate non-associative generalized changes in risk-taking behaviour, which in turn affect the likelihood of mynas approaching traps, then the detrimental consequences of trapping are significantly more far-reaching.

This study revealed the ease with which mynas can learn to avoid a dangerous situation. Results point to the potential influence of learning and perceived risk levels on response to threatening stimuli. This suggests that advantages for trapping efforts to be discreet could be twofold: (1) they would lower the likelihood of learning by making stimuli less salient and reducing the opportunities for birds to learn the dangers associated with trapping activity, (2) they would reduce the perceived risk level such

that birds do not adopt risk-averse behaviors that can make approaching capture devices more difficult (e.g neophobia). Additionally, evidence for recognition of specific humans means that certain people might become associated with danger and could hence by their presence next to different trapping apparatus or locations lead to avoidance of those by mynas. This is particularly true if social transmission through alarm calls is possible and individual birds equipped with the capacity to recognize trap-related cues can inculcate avoidance responses in trap-naïve mynas, such that they too avoid trapping-related cues.

5. References

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GENERAL DISCUSSION

1. Understanding the process of behavioural responses to control efforts

The research presented in this thesis provides the first in depth investigation of behavioural responses to control pressure in an invasive avian alien species. After undertaking a thorough literature review of my target species, the invasive common myna (*Acridotheres tristis*), I then undertook a large-scale, inter-regional field study in Australia to determine whether control efforts could be linked to behavioural shifts in common myna populations. Control effort was quantified on the basis of an inter-regional survey of government and community management activities. I was able to detect behavioural differences between populations of mynas undergoing high and low trapping pressures beyond behavioural differences attributable to density differences. In particular, birds were more risk averse and tended to be less conspicuous in risky environments. I subsequently undertook two experimental studies, one in captivity and one in the field, to identify potential mechanisms by which behavioural change could arise. I found no evidence supporting the hypothesis that these changes could arise from selective removal of certain personalities within the population. I did, however, find strong evidence that learning was a key mechanism involved in behavioural changes in response to control.

The shift in behaviour observed under high control pressure was overall in line with predictions extracted from the anti-predator framework (see general introduction). The decrease in risk-taking is indeed a typical response to increased risk. On the other hand, birds were expected to form larger groups under high risk, while I observed the opposite trend. One reason for this may be that the classical assumption that larger groups favor predator detection and risk dilution (Caro 2005a) may be limited to the context of actively hunting predators. The dynamic of trap harvesting may be more akin to "sit-and-wait" predators which are likely to induce different defenses (Miller et al. 2014). Attraction to social companions is likely to increase vulnerability to trapping because more social birds might be more likely to enter traps with decoy birds or previously trapped birds. This suggests the decrease in group size observed could be adaptive in this context. At least some components of compensatory responses to trapping may be shaped by the properties of traps *per se*, rather than birds' pre-existing predator avoidance systems which have been shaped by their evolutionary predators.

Common mynas show a behavioural shift towards increased anti-predator behaviours in response to control activity, as they appear to become more wary in areas with high harvesting pressure from humans. This finding begs the question as to how mynas are able to recognize an environment with heavy human predation as risky. In turn, this brings the corollary question of how mynas can identify traps as threats. Modern traps are unlikely to have been present for long enough in the birds' evolutionary history to elicit innate recognition and responses. Additionally, the threat posed by traps is likely to be quite different to natural threats and predators they encounter. Specifically, traps do not contain features such as olfactory compounds or frontally placed eyes known to elicit anti-predator avoidance in a broad range of taxonomic species (Coss 1978, 1979; Nolte et al. 1994; Ferrero et al. 2011). Traps are also devoid of well-established generalized threatening features such as loud sounds and fast approaching objects (Frid and Dill 2002). Natural predators fail to capture prey in a large majority of their attacks, leaving prey ample opportunity to learn to identify novel predators (Laundré et al. 2010), however escapes from traps are extremely rare (personal observation) such that learning from individual (i.e. personal) experience with traps is an unlikely process to explain recognition of traps as threats. So, how do common mynas identify environments containing a high density of traps as threatening? In captivity, mynas learn to avoid and be vigilant towards stimuli that have been associated with distressed conspecifics along with the cause of their alarm (Griffin and Boyce 2009; Griffin and Haythorpe 2011). In an experimental study, I was able to show that this same process could be applied in the field in the context of trapping events. It was clear that birds that witnessed even a single simulated capture event, changed their behaviour towards the location in which the simulated capture had been witnessed but also towards the human involved, revealing the fundamental role of associative learning in compensatory responses to trapping.

In areas undergoing high levels of common myna control, birds tended to be overall more risk averse, even in the absence of traps. While associative learning clearly explains how birds come to be wary specifically of traps, how does this translate into birds becoming overall more wary? One possible explanation is that after initially learning that the trapping equipment and the people involved in control are dangerous, future encounters with these stimuli may be perceived as predator encounters. The rate of encounter with a predator is suspected to be a key factor involved in how prey

estimate the risk of predation (Lima and Dill 1990; Fernández-Juricic et al. 2004). Hence as the encounter-rate with control-related stimuli increases in a certain area, then that area may come to be perceived as increasingly dangerous, and risk-taking behaviour may be adjusted accordingly (Lima and Dill 1990). Mynas can hence move from estimating an instantaneous predation risk after the initial encounter, to assessing a global, more generalized, predation risk that applies to the whole area where this predator can be encountered: a landscape of fear (Laundré et al. 2010).

However, does this mean all birds need to witness capture events to change their behaviour? The fact that behavioural shifts between controlled and non-controlled populations were observed on such a wide scale suggests that birds beyond those that directly witnessed capture events were reacting to increased risk. In particular, I suggest there is scope for behaviour of one individual to influence that of its conspecifics. Specifically, there are two ways in which the behavior of one myna might influence the behavior of another: 1) mynas socially transmit wariness of the trap, and/or 2) mynas are able to assess level of risk of the environment by observing the level of risk-taking displayed by conspecifics. These are quite different processes, with very different implications for management, as the first depends upon encounters with traps, while the second does not.

Social transmission of trap aversion would entail that one myna that has already acquired wariness of the trap is able to transmit it to a conspecific without the need for a direct capture by a human to occur. Social learning in this species has been the object of a number of studies. Captive work has shown that the cause of the alarm (i.e. capture by human in the context of trap avoidance) is a crucial element of social transmission of place avoidance in mynas (Griffin and Boyce 2009; Griffin et al. 2010; Griffin and Haythorpe 2011). Hence the process through which mynas could participate in social transmission of trap wariness without the presence of the human experimenter is currently unclear but social vocalizations are likely candidates, especially considering the high awareness of mynas towards sound stimuli (Hubbard et al. 2015). A short pairing of distress vocalizations and a previously unfamiliar, and potentially dangerous avian taxidermy mount inculcates an acquired increase in visual exploration associated with increased alertness towards the novel stimulus (Griffin 2008). Given the low level of anti-predator response inculcated, distress calls might be insufficient on their own to produce trap avoidance. However by directing an individual's attention to potentially

dangerous stimuli in the environment, they could pave the way for future experiences to trigger acquisition of higher intensity anti-predator responses. Alarm call vocalizations may be an interesting avenue for future research in this topic as there is evidence these calls are more efficient in enabling social learning in a number of other species (Griffin 2004, 2008), in particular in the context of mobbing (Curio et al. 1978; Vieth et al. 1980; Griffin 2004). Interestingly, it is frequent that when experimenters manipulate traps, surrounding birds start alarm calling and mobbing, as was noted during the trapping simulation experiment (chapter 4). Considering, mynas continue to emit large numbers of alarm calls following trapping demonstrations, particularly towards the experimenter, it is extremely likely that these calls function as social signals of danger. Hence alarm calls could participate in two aspects of social transmission of trap wariness: 1) they attract birds to witness capture events and hence create opportunities for individual and social learning, and 2) there is scope for alarm calls to be an unconditioned stimulus that can hence mediate social learning *per se*. It is worth noting that whichever of these aspects of social transmission is favored through the occurrence of alarm calls, it will lead to specific learning about the trapping equipment or personnel. For this mechanism to lead to generalized increase in risk-aversion, birds that have socially learnt that traps are dangerous then would need to encounter multiple traps in order to integrate this information into a global risk assessment of the environment.

An alternative way through which generalized decreased in risk taking may spread through a common myna population is by individuals adjusting their risk taking to that of their conspecifics. This kind of information about the risk perceived is likely to be carried by inadvertent social information or cues (Danchin et al. 2004; Bonnie and Earley 2007), for example by displaying high levels of vigilance. One could even consider that the state of fear undergone by one individual could affect its neighbors and hence describe this phenomenon as direct emotional contagion (Špinka 2012). Overall, individuals observing cues or signals of fear in their conspecifics may be more likely to express a state of fear and risk-averse behaviours. In other words, birds may use behavioural cues from their conspecifics to assess the level of danger. Interestingly, this would allow risk-aversion to spread in populations without the need for each individual to encounter traps.

Another element that could influence behaviour of mynas on a wide scale is human behaviour towards them. In a thought-provoking study across Berlin, Germany

and Seattle, USA (Clucas et al. 2011; Clucas and Marzluff 2012), it was shown that attitudes of the public, positive and negative alike towards certain bird species affected their behaviour. The authors argue that this difference arises through human behaviour, species that receive additional feeding are more abundant while species that are discouraged (e.g. by throwing objects, yelling or using scaring devices) are extremely wary of humans. It is possible that this parameter also enters into account in the case of local differences in behaviour between myna populations. Places with high trapping pressures are likely to be so because they contain more people with strong negative attitudes towards mynas. Additionally, by advertising control programs in these places, more people are likely to become aware of the species and the issues associated with it and from there build a highly negative attitude. It is certainly possible this effect is present in this study. However the public opinion towards common mynas in Australia is overall extremely negative (ABC 2005; Shaw 2014), and one can wonder whether there is scope for attitudes to be *even more* negative in some areas. While I have not tested if this was the case in the surveys performed for this thesis, it is certainly a good avenue for future research.

Overall, these considerations suggest that there are two elements in the response of common mynas to control pressure demonstrated by my work: one is a specific avoidance response towards the threatening stimuli, while the other is a generalized decrease in risk taking presumably following from an increase in risk perception. Common mynas showed they were able to learn to recognize specific humans but also that being confronted with danger overall decreased their tendency to take risks. Under high trapping pressure mynas formed smaller groups, were more risk-averse and tended to be less conspicuous. This shift towards becoming less visible and taking less risks is likely to arise in response to a wide range of threats and is hence probably part of the generalized element of the response to threats. This generic response may potentially expand across predators and non-predator type threats alike. Interestingly, the dichotomy of the elements of responses to threats parallels the dichotomy of the two aspects of fear: the fear of an imminent visible danger, and the fear in anticipation of possibly upcoming threats (Laundré et al. 2010). The generalized response could hence correspond to a background level of apprehension that is used when no direct sign of danger is detected (Brown et al. 1999) but that is updated each time a threat or a cue of its presence is encountered. This explains that some changes observed were not specific

to the threat at hand (a trap), and might not necessarily improve likelihood to escape that threat. Instead it is likely that this generalized response includes mainly behaviours that reduce chances of encounters with predators.

Interestingly, generalized anti-predator behaviours have the potential to help species deal with threats that have not been present throughout the evolutionary history. The example of common mynas and control practices is a prime example of how this can be the case. Yet, these generalized responses may come at the risk of not being adaptive in some contexts. The potential to express anti-predator behaviours towards novel threats seems particularly useful in the context of invasive species. Indeed, these species, when transported into novel environments are likely to be confronted with a range of novel stimuli, resources and threats. Some categories of predators are widespread, for example most species of birds of prey across continents have a similar shape in flight, such that introduced small bird species might always be wary towards them based on their previous experience. Additionally, there is scope for these widespread patterns to be innately present in some species, for example snakes and objects of similar shape seems to be innately recognized by many species (Caro 2005b). However, beyond these familiar and potentially innate patterns, introduced species are also likely to encounter novel threats not taxonomically related to their native predators (e.g. possum). It is for these in particular that the ability to learn quickly about novel threats and to produce a generalized response when encountering these threats, are useful.

2. Implications for management programs

What consequences do these two aspects of myna responses towards control have on control practices? The first and most striking result in terms of its application is the ease with which mynas were able to learn to avoid the location of the trapping simulation, and the fact that the birds were able to recognize humans involved in this activity. In captivity, it had previously been shown that the association of a location, an experimenter and an alarmed myna could lead to social learning about the location (Griffin and Boyce 2009; Griffin et al. 2010; Griffin and Haythorpe 2011). The results presented here extend these findings by showing that these situations not only lead to learning about a place, but also about the person involved in the captures and, most importantly, that such learning occurs under free-ranging conditions. Common mynas are extremely fast learners and it is clear that opportunities for learning should be

minimized. Interactions between humans and traps containing common mynas should take place exclusively at night or after hiding the trap under a large opaque piece of fabric, such that free-ranging mynas cannot witness this interaction. This is particularly important if the same person is to operate several traps as his/her identity could allow mynas to become fearful of other traps. Varying trap appearance and location has the potential to reduce how easily birds can learn to categorize all traps together and hence avoid them (Greggor et al. 2014). Learning seems to be the key element in allowing mynas to perceive traps as threats. In turn, this identification as a threat is responsible for specific responses to the threat and also a generalized risk-aversion response. It hence seems that limiting learning is a major target of improvement for control programs.

Secondly, specific responses to control methods and generalized response to risk have different implications for control programs. If several methods are used to control mynas, compensatory responses induced by one control method might not influence an alternative control method, as long as the compensatory responses are specific (e.g. to traps). In contrast, there is scope for any generalized fear response to influence success of any type of control method. For example, common mynas that are undergoing trapping might become more difficult to shoot. One interesting avenue for testing this would be to compare the effort needed to shoot a bird on small populations that have undergone a trapping program to those that have not. While this would require a careful monitoring of abundance such that this important variable may be accounted for, I expect search times would be longer for mynas that have already undergone trapping. Particularly because my research has demonstrated that trapping programs tend to shift these birds towards being more risk averse and less detectable.

Another important consideration to keep in mind from this work is that non-lethal effects of trapping have scope to inflate any evaluation of management effectiveness in terms of number of birds removed. The first factor that influence this phenomenon is emigration from the controlled area due to the increase in perceived risk. While this in some ways corresponds to the objective of the control program, by decreasing the abundance of birds in the region of interest, it also has scope to push the birds into other areas or even novel habitats where they might not have been present. The second factor that is likely to have a strong impact here, is the reduction in detectability observed in highly controlled areas. I observed that in these areas mynas

formed smaller groups and tended to be less conspicuous. While this does not impact abundance *per se*, it does instead impact assessment of successfulness of control programs. Indeed, if the target of the control program is set in terms of population density, then by changing species detectability to observers, density could appear lower than it actually is and hence exaggerate the effect of the program. It thus appears important to measure emigration and reduction in detectability in response to control programs as these two phenomena have the potential to modify how successful the program actually is. Measuring abundance is already a key element of management programs, but I suggest that additional efforts should be made to ensure that survey techniques account for potential change in detectability. Furthermore, when possible, attempts to measure abundance around the area targeted by management should be made in order to estimate emigration.

Data from councils, community groups and the public provided interesting insights into motivations and interest towards common myna control. I recognize the potential for the sample of respondents to be biased towards people and groups that have strong interest and negative attitudes towards common mynas. However beyond this potential bias, the surveys presented in this thesis provide new insights into common myna control. For example, results highlighted an apparent link between knowledge and attachment to nature with the willingness to engage in common myna discouragement. A factor of biodiversity awareness could participate in positive attitudes and behaviours towards native wildlife and negative attitudes and behaviours towards invasive species. This suggests that promoting education not only about mynas but about wildlife in general could help foster interest in myna management. Planting of natives plant species, and trees specifically, has potential to negatively impact mynas, in particular since the species seems to prefer low tree-abundance areas (Grarock et al. 2013). But, by making people care about native species such an action also has potential to have a double impact on mynas: by directly acting on them, and by encouraging people to take action.

A survey of the literature about common myna effects on Australian wildlife revealed different results depending on the region in which they were done (see chapter 1). The bird surveys that took place for the experiment presented in chapter 2 were some of the first to take place across several regions. Interestingly, I found that birds varied in their behaviour across regions, suggesting some elements related to their

invasion history or habitat may lead to differences in behaviour. These differences in behaviour are extremely likely to be related to the differences in observed ecological effect. This could limit to what extent control methods can be generalised from one region to the other, but also may limit to what extent these programs are actually required in some regions. Understanding the factors that influence these regional differences in behaviour is an extremely important point in understanding the species as a whole and how to better manage it. I advocate for the more research to be done on this subject, and for future studies to include an even wider range of regions.

Additionally, there seems to be a gap between conservation theory, integrated pest management (IPM) in particular, and the way common myna control is currently performed. IPM states that one species should not be considered in isolation but that animals and plants, the whole ecosystem in fact, with which the target species interact should also be considered. Additionally IPM advocates for the use of several complementary control methods alongside careful monitoring before, and during, the program. On the other hand, our questionnaires revealed that little monitoring is done outside of counting birds captured and that little to no attention is given to other species with which mynas may interact. Additionally, most programs rely entirely on trapping and only a little under half of councils encourage alternatives to trapping. This shows a striking gap between theory and observed practices. While this gap could reflect that IPM-based practices entail more costs and are more difficult to apply, it may also reflect a lack of information available on these practices. Some of these measures might be relatively easy to apply, for example those councils that already have wildlife monitoring for native species could expand it to include invasive species such as common mynas.

Overall, the gap between observed myna control practices and those suggested based on IPM is quite perturbing as it raises the question of whether current control programs have the ability of reaching their goals. Especially considering these goals are often ill defined and often limited to reducing populations. Popularity of common management programs is clearly high, yet without clear goals and proper monitoring, whether these programs are viable and ethical is questionable. While current programs are based on valid environmental concerns and honorable intentions, without the insurance that they are led under best known practice and have a significant positive ecological or social impact, then the euthanasia of thousands of birds might not be

justified. On the other hand, resources may be more efficiently allocated to narrower, and potentially more realistic, goals such as preventing the spread of mynas to novel areas. Alternatively there may be scope to develop measures that have wider ecological benefits (e.g. urban park and tree management). Overall, there seems to be a need for better scientific management of common myna control programs in Australia. And I suggest my work, along with that by recent outstanding myna researchers, such as Dr Grarock and Dr Haythorpe provides a step in the right direction. Governments and other organizations should be encouraged to capitalize on these intense research efforts.

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ANNEXES

1. Chapter 1 Annexes

1.1. Information statement of survey sent to councils



THE UNIVERSITY OF
NEWCASTLE
AUSTRALIA

Dr Andrea Griffin
School of Psychology
Faculty of Sciences and Information Technology
University Drive, Callaghan
NSW 2308 Australia
Phone : +61 2 49217161
Or : +61 2 4348 4393
Fax : +61 2 4921 6980

Common Myna Control Research Project
Information Statement
Document version V1 – 20/02/2012

Dear Sir/Madam,

Your Council is invited to participate in the research project identified above. The research is part of Miss Marie Diquelou's doctoral studies at the university of Newcastle, supervised by Dr Andrea Griffin from the School of Psychology.

Why is Research being done?

The purpose of the research is to understand the consequences of control practices on common myna (or Indian mynah) behaviour. This highly invasive species is one of the most common birds along the East Coast of Australia and is rapidly extending its range. In some areas, a range of measures, in particular trapping, have been undertaken in an attempt to limit population numbers. However, there is preliminary evidence in areas where mynas have undergone intensive trapping, they might be starting to avoid traps. Acquired trap avoidance could jeopardize the long-term trapping efforts. The aim of this Research project is to determine whether trap avoidance is a widespread phenomenon, and if so, how to avoid its occurrence.

Who can participate?

All local councils across NSW and ACT are invited to participate. Your Council was selected on a map for its strategic localisation within the common myna range.

What choice do you have?

Participation in this research is entirely the choice of your Council. Only those organisations that give their informed consent will be included in the project. Whether or not it decides to

participate, the decision will not disadvantage the Council.

If your Council decides to participate, it may withdraw from the project at any time without giving a reason, with the option of withdrawing any data with which it can be identified.

What would you be asked to do?

If the Council agrees to participate, we would like a Council representative to answer the short questionnaire attached. If your Council has an environmental officer, we recommend that he/she answers the questionnaire.

How much time will it take?

The questionnaire should take from 10-15 minutes. Answers may be returned to the researchers by e-mail.

What are the risks and benefits of participating?

There are no direct benefits arising from participating in this research. However, indirectly you are assisting a very important research study that aims to evaluate the impact of trapping on myna populations to ensure that the approach is not having any unexpected and undesirable consequences. Such studies are critical to the development of best-practice myna management guidelines, potentially saving time and money for councils.

How will your privacy be protected?

Any information collected by the researchers which might identify your Council will be stored securely and only accessed by the researchers unless you consent otherwise, except as required by law. There are limits on assurances of confidentiality as research data/records may be subpoenaed by law.

Data will be retained for at least 5 years at the University of Newcastle.

How will the information collected be used?

All answers will be collated with other sources (other councils and community action groups) and used to map “trapping-pressure” across NSW and ACT. This will be used to select sites in which behavioural observations on free-ranging mynas will then be undertaken by the research team.

Specific organizations will not be identified in any reports arising from the project.

The results from our large study on the effects of trapping on myna behaviour will be submitted as part of a PhD thesis, published in scientific journals and presented in public and scientific conferences. If interested, participants may contact researchers to enquire about receiving a summary of the results at the end of the project (see questionnaire).

What do you need to participate?

Please read this information and be sure you understand its contents before you consent to participate. If there is anything you do not understand, or you have questions, contact the researcher.

If your organisation would like to participate, please complete and return the attached questionnaire directly by email.

Further information

If you would like further information please contact Miss Marie Diquelou (marie.diquelou@uon.edu.au) or Dr Andrea Griffin (Andrea.Griffin@newcastle.edu.au).

Thank you for considering this information.

Miss Marie Diquelou
PhD candidate

Dr. Andrea S. Griffin
Project supervisor

Complaints about this research

This project has been approved by the University's Human Research Ethics committee. Approval No. H-2012-0073.

Should you have concerns about your rights as a participant in this research, or you have a complaint about the manner in which the research is conducted, it may be given to the researcher, or, if an independent person is preferred, to the Human Research Ethics Officer, Research Office, The Chancellery, The University of Newcastle, University Drive, Callaghan NSW 2308, Australia, telephone (02) 49216333, email Human-Ethics@newcastle.edu.au.

1.2. Questionnaire sent to councils



THE UNIVERSITY OF
NEWCASTLE
AUSTRALIA

Dr Andrea Griffin
School of Psychology
Faculty of Sciences and Information Technology
University Drive, Callaghan
NSW 2308 Australia
Phone : +61 2 49217161
Or : +61 2 4348 4393
Fax : +61 2 4921 6980

Common Myna Control Research Project
Questionnaire.
Document version V1 – 20/02/2012

Please read the research statement attached before proceeding.

Completion of the survey will indicate consent of your organisation to participate in this study. Participation in this research is entirely the choice of your Council. Only organisations that complete the survey and give their consent will be included in the research. Whether or not your Council decides to participate, the decision will not disadvantage it in any way.

QUESTIONNAIRE

The following few questions concern the level of concern and involvement regarding the management of Common Mynas (Indian mynahs) within your Council. Please tick (X) one box ("Yes", "No" or "Do not know") for each question, or write your answer in the available space.

Question	YES	NO	DO NOT KNOW
1 - Are common mynas present in your Council?			
1a - If so, since when (year of first sighting)?			
2 - Does the Council consider the common myna as an issue or a concern?			
3 - Does your Council have an official position or line of conduct concerning the trapping of common mynas?			
4 - Does the Council discourage or advise against trapping of common mynas?			
5 - Does your Council encourage individual action by providing information on how to get traps and/or a guide on best practices?			

5a - If so, where/how do you recommend they obtain traps?			
6 - Does your Council encourage alternative control methods to trapping?			
7 - Does the council support (through advertisement, funding or other) a community action group?			

Question	YES	NO	DO NOT KNOW
8 - Does the Council own common myna traps?			
8a - If so, how many traps does it own?			
9 - Does the council have a dedicated officer to the question of pest birds?			
10 - In what year did your Council initiate any myna control actions (information campaign or making traps available etc...)?			
11 - Does your Council keep records of the number of mynas trapped			
11a - If so, how accurate do you think these records are?			
11b - If your Council does not keep records of the numbers of mynas trapped, do you have any other means of estimating how effective your efforts to control mynas are?			

In the table below, please write a number in the first box and specify if it is an estimate or a figure extracted from records by ticking (X) the "Estimate" or the "Record" box respectively. If you cannot estimate the number or if the question does not apply to your council, tick the "Do not know" box.

Please estimate the following	Number	Estimate	Record	Do not know
Geographical area over which your Council is attempting to control mynas (e.g. number of square kilometers undergoing trapping)				
Total number of common mynas trapped and culled in your council over the last 24 months				
Total number of mynas trapped and culled since your Council first started trapping mynas				
Total number of traps currently deployed on the ground in your Council				

COMMENTS

If you would like to give any additional details on one of your answers and/or give additional information that you may seem as relevant, please feel free to leave comments below.

.....
.....
.....
.....
.....

DETAILS

Date:

State:

Name of council:

Function of person who answered the questionnaire (optional):

.....
.....

FEEDBACK

Would you like to hear about the results of our long-term study?

YES

NO

If yes, please leave contact details where we can send you the information. Please note, these will not be available before mid-2013:

.....
.....

After completion, please save this file with your answers and send it back to one of the researchers of this project, Miss Marie Diquelou (marie.diquelou@uon.edu.au) or Dr Andrea Griffin (Andrea.Griffin@newcastle.edu.au).

Your help in this project is greatly appreciated.

Miss Marie Diquelou

PhD candidate

Dr. Andrea S. Griffin

Project supervisor

1.3. Information statement sent to community volunteer groups



THE UNIVERSITY OF
NEWCASTLE
AUSTRALIA

Dr Andrea Griffin
School of Psychology
Faculty of Sciences and Information Technology
University Drive, Callaghan
NSW 2308 Australia
Phone : +61 2 49217161
Or : +61 2 4348 4393
Fax : +61 2 4921 6980

Common Myna Control Research Project
Information Statement
Document version V1 – 20/02/2012

Dear Sir/Madam,

Your Group is invited to participate in the research project identified above. The research is part of Miss Marie Diquelou's doctoral studies at the university of Newcastle, supervised by Dr Andrea Griffin from the School of Psychology.

Why is Research being done?

The purpose of the research is to understand the consequences of control practices on common myna (or Indian mynah) behaviour. This highly invasive species is one of the most common birds along the East Coast of Australia and is rapidly extending its range. In some areas, a range of measures, in particular trapping, have been undertaken in an attempt to limit population numbers. However, there is preliminary evidence in one area where mynas have undergone intensive trapping, they might be starting to avoid traps. Acquired trap avoidance could jeopardize the long-term trapping efforts. The aim of this Research project is to determine whether trap avoidance is a widespread phenomenon, and if so, how to avoid its occurrence.

Who can participate?

All active community action groups in NSW and ACT are invited to participate.

What choice do you have?

Participation in this research is entirely the choice of your Group. Only those organisations that give their informed consent will be included in the project. Whether or not it decides to participate, the decision will not disadvantage your Group.

If your Group decides to participate, it may withdraw from the project at any time without giving

a reason, with the option of withdrawing any data with which it can be identified.

What would you be asked to do?

If you agree to participate, you will be asked to give information about efforts undertaken by your group in terms of common myna control by answering the short and simple questionnaire attached. If your group has a dedicated employee, we recommend that he/she answers the questionnaire.

How much time will it take?

The questionnaire should take from 10-15 minutes. Answers may be returned to the researchers by e-mail.

What are the risks and benefits of participating?

There are no direct benefits arising from participating in this research. However, indirectly you are assisting a very important research study that aims to evaluate the impact of trapping on myna populations to ensure that the approach is not having any unexpected and undesirable consequences. Such studies are critical to the development of best-practice myna management guidelines, potentially saving time and money for all those involved in myna control.

How will your privacy be protected?

Any information collected by the researchers which might identify your Group will be stored securely and only accessed by the researchers unless you consent otherwise, except as required by law. There are limits on assurances of confidentiality as research data/records may be subpoenaed by law.

Data will be retained for at least 5 years at the University of Newcastle.

How will the information collected be used?

All answers will be collated with other sources (other community action groups and councils) and used to map “trapping-pressure” across NSW and ACT. This will be used to select sites in which behavioural observations on free-ranging mynas will then be undertaken by the research team.

Specific organizations will not be identified in any reports arising from the project.

The results from our large study on the effects of trapping on myna behaviour will be submitted as part of a PhD thesis, published in scientific journals and presented in public and scientific conferences. If interested, participants may contact researchers to enquire about receiving a summary of the results at the end of the project (see questionnaire).

What do you need to participate?

Please read this information and be sure you understand its contents before you consent to participate. If there is anything you do not understand, or you have questions, contact a researcher.

If your organisation would like to participate, please complete and return the attached questionnaire directly by email.

Further information

If you would like further information please contact Miss Marie Diquelou (marie.diquelou@uon.edu.au) or Dr Andrea Griffin (Andrea.Griffin@newcastle.edu.au).

Thank you for considering this information.

Miss Marie Diquelou
PhD candidate

Dr. Andrea S. Griffin
Project supervisor

Complaints about this research

This project has been approved by the University's Human Research Ethics committee. Approval No. H-2012-0073.

Should you have concerns about your rights as a participant in this research, or you have a complaint about the manner in which the research is conducted, it may be given to the researcher, or, if an independent person is preferred, to the Human Research Ethics Officer, Research Office, The Chancellery, The University of Newcastle, University Drive, Callaghan NSW 2308, Australia, telephone (02) 49216333, email Human-Ethics@newcastle.edu.au.

1.4. Questionnaire sent to volunteer action groups



THE UNIVERSITY OF
NEWCASTLE
AUSTRALIA

Dr Andrea Griffin
School of Psychology
Faculty of Sciences and Information Technology
University Drive, Callaghan
NSW 2308 Australia
Phone : +61 2 49217161
Or : +61 2 4348 4393
Fax : +61 2 4921 6980

Common Myna Control Research Project

Questionnaire.

Document version V1 – 20/02/2012

Please read the research statement attached before proceeding.

Completion of each survey will indicate consent of your group/organisation to participate in this study. Participation in this research is entirely your choice and only organisations that complete the survey and give their consent will be included in the research. Whether or not your organization decides to participate, your decision will not disadvantage you in any way.

QUESTIONNAIRE

The following few questions are about your organization and the extent to which it is involved in, or encourages, efforts to control common mynas. Please write your answer for questions 1, 2, 5a, 5b and 6a in the space provided beside or below the question. Please tick (X) one box ("Yes", "No" or "Do not know") for questions 3, 4, 5 and 6.

Question	Answer
1 - In what year did your group/organisation start trapping mynas?	
2 - In which area(s) do you trap (list councils if possible)?	

Question	YES	NO	DO NOT KNOW
3 - Is there an employee dedicated to the group (full or part-time)?			

4 - Are you financially supported by local council(s)?			
Question	YES	NO	DO NOT KNOW
5 - Does your organization keep records of the number of mynas trapped?			
5a - If so, how accurate do you think these records are?			
5b - If your organization does not keep records of the numbers of mynas trapped, do you have any other means of estimating how effective your efforts to control mynas are?			
6 - Does your organization encourage alternative control methods to trapping?			
6a - If so, which one(s)?			

In the table below, please write a number in the first box ("Number") and specify if it is an estimate or a figure extracted from records by ticking (X) the "Estimate" or the "Record" box respectively. If it is impossible to estimate the number or if the question does not apply to your council, please tick the "Do not know" box.

Please estimate the following	Number	Estimate	Record	Do not know
Number of group members				
Geographical area over which your organization is attempting to control mynas (e.g. number of square kilometers undergoing trapping)				
Total number of traps owned by your group or your group members				
Total number of traps currently deployed on the ground				
Total number of mynas trapped and culled during the last 24 months				
Number of mynas trapped and culled since your group/organization first started trapping mynas				

COMMENTS

If you would like to give any additional details on one of your answers and/or give additional information that you may see as relevant, please feel free to leave comments below.

.....
.....
.....

FEEDBACK

Would you like to hear about the results of our long-term study?

YES **NO**

If yes, please leave contact details where we can send you the information. Please note, these will not be available before mid-2013:

.....
.....

After completion, please save this file with your answers and send it back to one of the researchers of this project, Miss Marie Diquelou (marie.diquelou@uon.edu.au) or Dr Andrea Griffin (Andrea.Griffin@newcastle.edu.au).

Your help in this project is greatly appreciated.

Miss Marie Diquelou
PhD candidate

Dr. Andrea S. Griffin
Project supervisor

1.5. Web-survey information statement

You are invited to participate in the following survey concerning Common mynas. This survey is part of Miss Marie Diquelou's doctoral studies at the School of Psychology of the University of Newcastle under the direction of Dr. Andrea Griffin.

Why is this Research being done?

Invasive birds are species that have been transported from their original native land and introduced to Australia. While some species do not adapt to the Australian environment and die off, others thrive, with populations spreading and moving into new areas year after year. A typical example is the common myna (i.e. Indian mynah, *Sturnus tristis*), which is now one of the most common birds on the Australian East Coast.

The aim of this study is to collect information on the ecology and distribution of common mynas. We also wish to know if and what people do to keep them away from their backyard.

Who can participate?

This survey is open to everyone. It requires that you register and create a Birds-in-Backyards account, which is completely free. This survey also provides Central Coast and Newcastle constituents the OPTION of participating in an on-site study.

What choice do you have?

Participation in this research is entirely your choice. Whether or not you decide to participate, the decision will not disadvantage you in any way.

What would you be asked to do?

To participate in this study, please answer to the questions of the following survey. If you live in the Newcastle or Central Coast area, you may additionally apply to receive more information about an upcoming on-site study.

How much time will it take?

This survey should take less than 15 minutes to complete.

What are the risks and benefits of participating?

There are no direct risks or benefits arising from this survey.

How will your privacy be protected?

Your answers to the following survey will be stored securely and separately from the personal information you have given to create your Birds in Backyards account. The information from your personal Birds in Backyards account is not accessible to Newcastle University researchers. If, in addition to participating in this survey, you wish to be contacted in view of participating in an on-site field study on mynas (see end of survey for details and conditions), please provide your contact details in the appropriate box at the end of the survey. If, and only if, you chose to provide your contact details, will Newcastle University researchers have access to personal data, but these will be strictly limited to the data entered in the contact details box.

How will the information be used?

Birds in Backyards and the Researchers from the University of Newcastle might use results arising from this survey in scientific or general audience publications. You will not be identified in any reports arising from this survey.

What do you need to participate?

Please read this information and be sure you understand its contents before you consent to participate. If there is anything you do not understand, or you have questions, contact the researcher.

Further Information

If you would like further information on this survey, please contact Miss Marie Diquelou (marie.diquelou@uon.edu.au) or Dr Andrea Griffin (Andrea.Griffin@newcastle.edu.au).

Thank you for considering this information.

Miss Marie Diquelou
PhD candidate

Dr. Andrea S. Griffin
Project supervisor

About the researchers



Miss Marie Diquelou is a PhD student at the University of Newcastle looking at the behaviour and cognition of Common mynas (*Sturnus tristis*), in particular their responses to control measures. She has been studying this introduced species in Australia since 2010.

Her current project aims to achieve a better understanding of the behaviour of this species in order to improve efficiency and sustainability of control practices.

Dr Andrea Griffin is a lecturer at the University of Newcastle. She has 16 years of experience in animal behaviour research and has been working on mynas and their remarkable adaptability since 2005.

1.6. List of questions in web-survey

1.6.1. Section A : My Garden

1. Please complete the demographic information below
 - What state or territory do you live in?
 - City/Town
 - ZIP/Postal Code:
2. Which option best describes your location?
 - Non-urban: farm, bushland, National Park
 - Suburban residential housing: area around the house is surrounded by vegetation (such as lawn or trees)
 - Urban housing: close proximity to urban centre, area around house is dominated by hard surfaces
 - Urban open space: parkland or grassy schoolground
3. What type of plants make up your garden? Note: your garden includes any vegetation within your property's boundaries (in most cases this is a front and backyard).
 - None
 - Mostly Australian native plants
 - Mostly exotic plants
 - Even mix of exotics and natives
4. If you looked at your garden from above what % of the garden would be covered by lawn?
 - none or a trivial amount
 - less than 25%
 - 25 to 50 %
 - over 50%
5. How far is your garden from a patch of native bushland > 1 ha (the area of two soccer fields)
 - less than 500m,

- 500m to 2 km,
- over 2 km

6. Do pets access your garden? Include your neighbours' if they visit frequently.

- Dog
- Cat
- Aviary birds
- Other, please specify...
- None

7. Are any dogs or cats fed in your backyard (at least once a week)?

- Yes
- No

*1.6.2. Section B1: Presence of common mynas and common starlings
in my backyard*

8. How do you rate your bird identification ability

- Beginner (I can identify some of the birds species that visit my garden)
- Intermediate (I can identify all of the bird species that visit my garden)
- Experienced (I can identify most of the bird species I encounter anywhere in my state)

9. Have you seen a Common myna in your garden? (include your front or backyard)

- Yes
- No

10. When did you last see a Common myna in your garden?

- today or yesterday
- this week
- this month
- over a month ago

11. How many Common mynas were present in your most recent sighting?

- 1-2
- 3-4

- 5-10
- over 10

12. Have you seen a Common starling in your garden?

- Yes
- No

13. When did you last see a Common starling in your garden?

- today or yesterday
- this week
- this month
- over a month ago

14. How many Common starlings were present in your most recent sighting?

- 1-2
- 3-4
- 5-10
- over 10

1.6.3. Section B2: Actions against common mynas and common starlings in my backyard

15. Do you try to discourage either the Common myna or Common starling from using your garden (front or backyard) using any of the methods below? (tick all that apply)

- I have never had either of these species in my garden
- I do not try to dissuade/exclude those species.
- I chase them away when I see them, or have installed scaring devices
- I remove/displace breeding pairs and/or block nesting hollows
- I try to reduce the food available to them (for example I feed my pets inside)
- I encourage native birds to come by putting specific food or planting specific trees.

16. Do you actively reduce the numbers of either the Common myna or Common starling by trapping or other methods?

- Yes
- No

17. How do you actively reduce numbers?

- Trapping
- Other, specify:

18. Please indicate the approximate date trapping/control commenced (MM/YYYY) and the approximate date trapping/control concluded (MM/YYYY). If trapping is ongoing, write 'ongoing'.

19. Approximately how many of each species have you trapped/culled?

20. If you have been trapping, was this trap:

- Purchased by yourself at store/reseller
- Made by yourself
- Borrowed from / lent by community group
- Borrowed from / lent by local council

1.6.4. Section C: Common myna nests, are mynas breeding in your neighbourhood

21. Have you seen Common mynas breeding and/or nesting in your neighbourhood?

- Yes
- No

22. When did you last see them breeding/nesting? (MM/YY)

23. How did you know they were breeding/nesting?

- I repeatedly saw a pair
- I saw a pair feeding a fledgling/juvenile (juveniles are recognisable with a characteristic brown head, whilst adults have a black one)
- I saw their nest
- Other, please specify...

24. Where was their nest?

- A tree hollow
- A palm tree

- A hole in a house wall/roof
- A nest-box
- A commercial building
- A public facility (bridge...)
- Public equipment (street light...)
- Other (please specify)

1.6.5. Section D: Additional comments

25. Use this space to specify any answers if needed or provide any interesting observations and details relevant to the survey.

1.6.6. Section E: Getting involved in a Central Coast – Newcastle study

This section is directed ONLY to people living in the Central Coast – Newcastle area, and who are interested in taking part into a scientific study (not an eradication program) that involves setting up traps in private backyards. All experiments have been approved by the University of Newcastle Animal Care and Ethics Committee (ACEC# A-2011-129) and the University of Newcastle Human Ethics Committee (approval # H-2012-0248). Particularly encouraged to reply to this call are people who have pairs nesting on their property. Please note that to be eligible to take part in the study you need a fenced backyard with no access to dogs and cats. If you are interested, please complete our survey and send us your contact details.

If you wish to be contacted and receive more information about how you can take part in our study, please insert your contact details here (e-mail address and/or phone number): _____

Researchers do not have access to personal information from your bird-in-backyards or Birds-Australia profile. Leaving your details is in no case considered as an engagement to take part in the experiment, and will just allow you to receive more information about the study. You are free to change your mind at any moment. Feel free

to contact Researchers if you have an enquiry (marie.diquelou@uon.edu.au). Please note this information will be stored with your survey responses.

Complaints about this research

This project has been approved by the University's Human Research Ethics committee. Approval No. H-2012-0248.

Should you have concerns about your rights as a participant in this research, or you have a complaint about the manner in which the research is conducted, it may be given to the researcher, or, if an independent person is preferred, to the Human Research Ethics Officer, Research Office, The Chancellery, The University of Newcastle, University Drive, Callaghan NSW 2308, Australia, telephone (02) 49216333, email Human-Ethics@newcastle.edu.au.

2. Chapter 2 Annexes

2.1. Statistical annex

2.1.1. List of R-packages used

Name	Version	Use in this chapter
lme4	1.1-9	Poisson and negative binomial GLMM
glmmADMB	0.8.1	Zero-inflated negative binomial GLMM Zero-truncated negative binomial GLMM
VGAM	0.9-8	Zero-truncated negative binomial GLM
Distance	0.9.4	Detectability adjusted abundance estimates
pscl	1.4.9	Zero-inflated Poisson and negative binomial GLM
MCMCglmm	2.22.1	MCMC linear mixed model
All packages used on R version 3.2.2		

2.1.2. Specifications of MCMCglmm on vigilance score

```
prior = list( R = list(V = 1, nu = 0.002),  
G = list(G1 = list(V = 1, nu = 0.002), G2 = list(V = 1, nu = 0.002)))
```

```
MCMCglmm(vigilance.score ~ trapping pressure + region + time to dark +  
disturbance + group size,  
random=~ area + area : sample, prior=prior,  
family="gaussian", nitt = 110000, burnin = 10000, thin = 100)
```

2.2. List of studies including estimation of common myna abundance or density

Table 42. Studies estimating common myna abundance in New South Wales, Australia

Reference	Location	Site distribution	Birds counted	Method	Results (Density in CM/km ²)
This study	Canberra and Sydney, Au.	WL, PL, SS, UR	All CM seen except flying overhead	5min PC Var*50m (3h)	110.84 ± 23.91 (PC) 224.47 ± 33.42 (TR)
Haythorpe et al. (2013)	Newcastle, NSW, Au.	SS, WL, edge	All birds seen or heard except flying overhead	200m*50m (20 min)	SS: 196^c Edge: 8.5^c WL: 0^c
Lowe et al. (2011)	Sydney NSW, Au.	WL, SS, UR	All birds seen or heard except flying overhead	40min PC 2ha / 20min transect	UR: 6.7 ± 7.9 per site SS: 4.9 ± 3.9 per site WL: 0.0 per site
Old et al. (2014)	Sydney NSW, Au.	UR, AG, PL, WL	All birds seen	30-35km and 2-6km (car transect)	Mean UR: 1.19 per km Mean AG: 0.83 per km Abundance: PL > UR > AG > WL
Parsons et al. (2003)	Sydney NSW, Au.	Distance to WL	All birds seen except flying overhead	1 km (1h)	CM present at 96% of suburban sites
Parsons et al. (2006)	Greater Sydney NSW, Au.	NA	NA	Var. (20 min*7 days)	CM present in 80% of gardens
Sol et al. (2012)	Newcastle NSW, Au.	UR, SS, WL	All birds seen (or heard)	50m (20 min)	UR: 189 sightings /24 transects SS: 19 sightings /24 transects WL: 0 sightings /24 transects
Wood (1996)	Wollongong NSW, Au.	PL, SS	All birds seen or heard except flying overhead	PL: 560*30m SS: 570*40m (± 20 min)	PL: 0 sightings /transect SS: 7.4 ± 0.6 sightings /transect CM is SS specialist

Abbreviations of site distribution: PL (parkland, including small urban reserves and sports grounds), WL (woodland or large bush remnant), SS (streetscape, suburbia, residential area), UR (highly urbanized or industrial area), AG (agricultural or rural land)

Other abbreviations in table: CM (common myna), Var. (Variable/varying), PC (point counts), TR (transect), Au (Australia), SG (Singapore), NA (not available)

Transects measured as: length* total bilateral width (duration).

^c indicates density estimates not provided in article but calculated from data contained in the article

Table 43. Studies estimating common myna abundance in the Australian Capital Territory and Victoria, Australia

Reference	Location	Site distribution	Birds counted	Method	Results (Density in CM/km ²)
This study	Canberra and Sydney, Au.	WL, PL, SS, UR	All CM seen except flying overhead	5min PC Var*50m (3h)	38.99 ± 9.34 (PC) 68.87 ± 7.92 (TR)
Crisp and Lill (2006)	Melbourne VIC, Au.	WL, PL, SS, UR	All CM seen except flying overhead	300*30m	Overall mean: 250 Open PL: 90 ± 60 SS: intermediate to open PL and wooded PL Wooded PL: 510 ± 160
Davey (1991)	Canberra ACT, Au.	SS	All CM seen	Var transects (3 min to 5h)	range: 0 to over 19
Grarock et al. (2013a)	Canberra ACT, Au.	PL	All CM seen and heard	1km*100m (20min)	low tree density: 101.9 ± 22.4 medium tree density: 45.4 ± 10.1 high tree density: 9.7 ± 3.6
Grarock et al. (2013b)	Canberra ACT, Au.	4 regions	All birds seen or heard	3.1ha during 7 days	South Canberra: 266.2 ± 10 North Canberra: 128.0 ± 4.2
King (2010)	Canberra ACT, Au.	In / Out trap catchment	All CM seen or heard	7.3km to 15.6km*100m	Minimum in catchment: 6.16 Maximum in catchment: 16.01
Pell & Tidemann (1997a)	Canberra ACT, Au.	SS / PL edge / PL interior / WL	All CM	PL: Var.*100m SS: 1km*60m	SS minimum: 43 ± 30 SS maximum: 124 ± 59 Increase in PL during breeding season.
Pell & Tidemann (1997b)	Canberra ACT, Au.	PL edge / PL interior / WL	2 exotic (CM or starling) and 2 native parrots	Var.* 100m	Exotic mainly in PL edge and interior / Natives in WL
White et al. (2005)	Melbourne VIC, Au	PL / SS (native, exotic, recent)	All birds seen or heard	200*50m (10 min)	PL: recorded at 5/9 sites Native SS: recorded at 7/9 sites Exotic SS: recorded at 9/9 sites Recent SS: recorded at 9/9 sites

Abbreviations of site distribution: PL (parkland, including small urban reserves and sports grounds), WL (woodland or large bush remnant), SS (streetscape, suburbia, residential area), UR (highly urbanized or industrial area), AG (agricultural or rural land)

Other abbreviations in table: CM (common myna), Var. (Variable/varying), PC (point counts), TR (transect), Au (Australia), Sg (Singapore), NA (not available)

Transects measured as: length * total bilateral width (duration)

^c indicates density estimates not provided in article but calculated from data contained in the article

Table 44. Studies estimating common myna abundance outside Australia

Reference	Location	Site distribution	Birds counted	Method	Results (Density in CM/km ²)
This study	Canberra and Sydney, Au.	WL, PL, SS, UR	All CM seen except flying overhead	5min PC Var*50m (3h)	Sydney 110.84 ± 23.91 (PC) 224.47 ± 33.42 (TR) Canberra 38.99 ± 9.34 (PC) 68.87 ± 7.92 (TR)
Lim et al. (2003)	Singapore	4 regions	All birds seen or heard except flying overhead	500*100m (20min)	<5 CM / transect Association: (+) with farmland, (-) with natural areas

Abbreviations of site distribution:

PL (parkland, including small urban reserves and sports grounds),

WL (woodland or large bush remnant),

SS (streetscape, suburbia, residential area),

UR (highly urbanized or industrial area),

AG (agricultural or rural land)

Other abbreviations in table:

CM (common myna),

Var (Variable/varying),

PC (point counts),

TR (transect),

Au (Australia),

Sg (Singapore),

NA (not available)

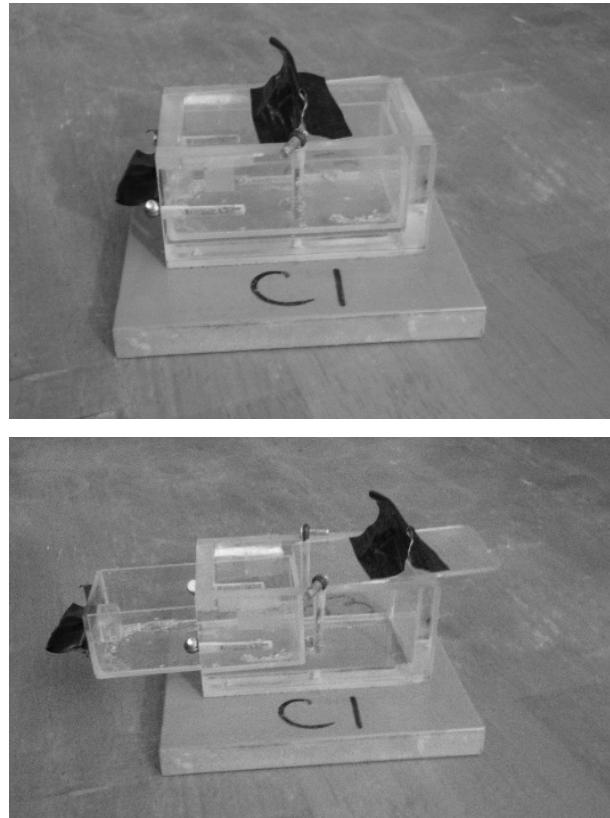
Transsects measured as: length * total bilateral width (duration).
e indicates density estimates not provided in article but calculated from data contained in the article

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3. Chapter 3 Annexes

3.1. Photography of apparatus used for captive innovation test



3.2. statistical annex: R-code of MCMCglmm in study

3.2.1. Distance index during stimulus presentation tests

```
priorA <- list( R = list(V = 1, nu = 0.002),
  G = list(G1 = list(V = 1, nu = 0.002)))
mcmcA <- MCMCglmm(distance index ~ phase + capture method +
  trap localization + sex + morphometric index +
  test date + time in captivity,
  random = ~ individual id,
  data = data, family = "gaussian", prior = priorA,
  verbose = FALSE,
  burnin= 10000, nitt= 110000, thin=100)
```

3.2.2. number of behaviours of interest performed during stimulus presentation tests

```
priorB <- list( R = list(V = 1, nu = 0.002),
                 G = list(G1 = list(V = 1, nu = 1, alpha.mu=0)))
mcmcB <- MCMCglmm( number of social behaviours ~ phase +
                     capture method + trap localization +
                     sex + morphometric index +
                     test date + time in captivity,
                     random = ~ individual id,
                     data = data, family = "poisson", prior = priorB, verbose = FALSE,
                     burnin= 10000, nitt= 110000, thin=100)
```

4. Chapter 4 Annexes

4.1. statistical annex: R code of MCMCglmms in study

4.1.1. *Number of birds feeding from patch*

```
prior1 <- list( R = list( V = 1, nu = 0.002),
                 G = list( G1 = list(V = 1, nu = 0.002),
                           G2 = list(V = 1, nu = 0.002)))
mcmc1 <- MCMCglmm( number ~ time.bin + stage * stimulus,
                     random = ~ site + trial,
                     data = data, family = "poisson",
                     prior = prior1, verbose = FALSE,
                     burnin= 10000, nitt= 110000, thin=100)
```

4.1.2. *Ratio of vigilant birds*

```
prior2 <- list( R = list( V = 1, nu = 0.002),
                 G = list( G1 = list(V = 1, nu = 0.002)))
mcmc2 <- MCMCglmm( ratio ~ stage * stimulus,
                     random = ~ site,
                     data = data, family = "gaussian",
                     prior = prior2, verbose = FALSE,
                     burnin= 10000, nitt= 110000, thin=100)
```

4.1.3. *Latency to feed from the patch*

```
prior3 <- list( R = list( V = 1, nu = 0.002),
                 G = list( G1 = list(V = 1, nu = 0.002)))
mcmc3<- MCMCglmm( lat ~ stimulus * stage,
                     random = ~ site,
                     family = "gaussian", data = data,
                     prior=prior3, verbose = FALSE,
                     burnin= 10000, nitt= 110000, thin=100)
```