Guardian dogs for livestock protection in Australia

by

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MSc

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Preface & declarations by author

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The following people and institutions contributed to the publication of research undertaken as part of this thesis:

Linda van Bommel: Contributed to ideas and study design, collected data, carried out analysis and wrote the manuscripts.

Chris Johnson: Contributed to ideas and study design, assisted with analysis and edited the manuscripts.

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Abstract

Wild predators can form a threat to livestock production all over the world. Lethal methods are often used to control predators, however, lethal control has many disadvantages. Livestock Guardian Dogs (LGDs) offer a non-lethal alternative to lethal predator control. There is increasing evidence that LGDs can be highly effective for stock protection, and are able to protect many types of livestock from many different types of predators.

In Australia, wild dogs (including dingoes and hybrids) cause the most damage to the livestock industry. LGDs are a relatively new predator control method in Australia, and little research has been done on their use. In this PhD project, the effectiveness of LGDs for stock protection in Australia was investigated. In particular, I examined the effects of scale of management – the size of property and number of livestock – on LGD effectiveness, movements and behaviour.

A critical evaluation of existing literature on non-lethal predator control methods showed that, of all existing methods, LGDs are likely the most suitable method for Australian farm conditions. A telephone survey among 150 users of LGDs further showed that these dogs are apparently highly effective in Australia, with 66% of respondents stating LGDs had eliminated all predation, and an additional 30% stating the LGDs significantly decreased predation. Scale of management did not influence their effectiveness; the main factor influencing LGD effectiveness was the number of stock per LGD.

In order to investigate LGD movements and behaviour, GPS collars were deployed on Maremma Sheepdogs on three research properties, where the dogs were free-ranging over large areas with their livestock. The results show that LGDs spend between 82% and 100% of their time with their livestock, but movements away from stock do occur. On two properties, simulated wild dog incursions were used to test the Maremmas' response to a predator challenge. These experiments showed that LGDs exhibit territorial behaviour, and suggest that free ranging LGDs can use territorial exclusion of predators to protect their livestock. Movements away from livestock are then to be expected, as the LGDs need to spend some time away from stock to patrol and maintain territorial boundaries.

LGDs can be a very effective predator control method in Australia, on both small properties and extensive livestock operations, as long as the appropriate number of dogs is used for the property situation. On extensive livestock operations, LGDs are often free-ranging, and can set up and maintain territories around stock. This is likely a highly effective method of predator control because it creates a buffer zone around livestock from which predators are repelled. By reducing or eliminating predation, LGDs have great potential in reducing conflict between livestock producers and predators. In Australia this can benefit dingo conservation and biodiversity, if lethal predator control is reduced when LGDs are used.

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Chapter 1: General introduction: effectiveness and management of livestock guardian dogs world-wide

"While staying at this estancia, I was amused with what I saw and heard of the shepherd-dogs of the country. When riding, it is a common thing to meet a large flock of sheep guarded by one or two dogs, at the distance of some miles from any house or man. I often wondered how so firm a friendship had been established."

(Charles Darwin, *The Voyage of the Beagle*, New York: P.F. Collier and Son, 1909, p. 163)

1.1 Introduction

Predation on livestock is a world-wide problem which can cause substantial financial losses for livestock producers, and recurring livestock predation can cause animosity towards predators by farmers and other rural groups that are affected by it (Kellert, 1999, Ericsson and Heberlein, 2003, Kaczensky et al., 2004, Davies and du Toit, 2004). As a result, lethal control, whether legal or illegal, is the primary tool used to manage predator populations and prevent livestock predation. Lethal control consists of killing predators in an attempt to reduce or eliminate their populations and impacts. However, lethal control is often expensive (Mech, 1998, McLeod and Norris, 2004) and at best it is only temporarily effective, because in most situations predator numbers quickly recover through immigration (Saunders et al., 1995, Musiani et al., 2005, Knowlton et al., 1999, Allen and Gonzalez, 1998). In addition, reducing the density of top predators in an ecosystem can lead to an increase in the density of mesopredators, which can in turn negatively affect prey and livestock populations and cause further human-wildlife conflict (Terborgh et al., 2001, Reynolds and Tapper, 1996). Lethal predator control can also contribute to the decline and extinction of populations of threatened predator species (Woodroffe, 2001, Woodroffe and Ginsberg, 1998, Breitenmoser, 1998, Treves and Naughton-Treves, 1999).

Non-lethal methods for predator control have the potential to prevent livestock predation, while allowing predators to persist in the environment, thereby preventing the unwanted effects of lethal control on ecosystems. Non-lethal control methods are generally also rated as more acceptable by the public than lethal control methods (Andelt, 1996, Reiter et al., 1999). Various non-lethal predator control methods exist, ranging from livestock husbandry methods such as confining livestock at night, to fertility control of predators (Andelt, 1996, Linnell et al., 1996, Shivik, 2006). One of the oldest non-lethal predator control methods is the use of special breeds of dogs (*Canis lupus familiaris*) to guard livestock (Coppinger and Coppinger, 2001). Livestock guardian dogs (LGDs) have been used for centuries by traditional pastoralists, and their use is increasing in Western societies (Rigg, 2001, Shivik, 2006).

1.2 Livestock guardian dogs

All over the world dogs have traditionally been kept with livestock, working alongside shepherds to protect sheep (*Ovis aries*) and goats (*Capra hircus*) from predation and theft (Coppinger and Coppinger, 2001). Often, these dogs do not belong to any specific type of breed, but are general village dogs (Coppinger and Coppinger, 2001). Their use goes back thousands of years, frequently appearing in ancient writings and art (Black and Green, 1985, Coppinger and Coppinger, 2001). For example, Job mentions the presence of a dog with its flock (Job 30:1), and in 347BC Aristotle wrote in *The History of Animals*:

> *"Of the Molossian breed of dogs, such as are employed in the chase are pretty much the same as those elsewhere; but sheepdogs of this breed are superior to the others in size, and in the courage with which they face the attacks of wild animals."*

(Artistotle, *The History of Animals*, IX, part I, ca. 347 BC)

The modern day breeds that are purposely bred for guarding livestock originated in Europe and Asia, but their exact origin and descent is unknown. One theory holds that the ancestor of most LGD breeds is the predecessor of all modern day Mastiffs, originating in Tibet in prehistoric times (Guardamagna and Breffort, 1997). These dogs probably spread from their native regions with nomadic tribes or merchants. However, DNA analysis in a number of studies has shown various levels of relatedness between Mastiffs and different LGD breeds, or even different lines of descent (see for example Parker et al., 2004, Pollinger et al., 2010) contradicting the mastiff hypothesis.

The concept of a dog breed is relatively modern, and most breeds have existed for less than 400 years (Crowley and Adelman, 1998, Rogers and Brace, 1995, Fogel, 1995). Intensive selective breeding, through sexual isolation of individuals in favour of particular breed characteristics, did not take place on a large scale before that, and these dogs were never isolated from the larger populations of which they were part. Shepherds simply provided more care for dogs that had physical or behavioural attributes that made them good at their job, thereby increasing the fitness of these individuals and their chances of breeding successfully (Gehring et al., 2010a, Coppinger and Coppinger, 2001). One attribute that shepherds often favoured was close physical resemblance of dogs to the sheep they were guarding, perhaps in the belief that this would be less disturbing to the sheep. Coppinger and Coppinger (2001) hypothesize that the regionally similar groups of dogs that are found today occur due to convergence in appearance of individuals over time, under the combined influence of founder effects, natural selection and favourable treatment by owners of the most useful dogs. Today's LGD breeds have their origins in these regionally similar groups. Even now, selective breeding by sexually isolating individuals is predominantly done by dog breeding associations, not by the shepherds in the traditional systems from which the dogs originated and where they are still in use today (Gehring et al., 2010a, Coppinger and Coppinger, 2001).

In modern European societies knowledge of guardian dogs was lost where large predators had been eradicated. As a result, this knowledge was not imparted to the majority of cultures colonised by Europeans, with the exception of some Spanish colonies in South America. Spain had retained its large predators, and LGDs were still in use there. In the U.S.A. LGDs were initially only used on a small scale by some individuals familiar with the concept, but large scale interest developed in the 1970's, after a Presidential ban on the use of predator toxicants (e.g. strychnine, compound 1080) on federal lands in 1972 (Moehrenschlager et al., 2004, Pfeifer and Goos, 1982, McGrew and Blakesley, 1982). Everywhere where predators persisted in Europe, so did the tradition of using dogs to guard livestock, and from there several breeds of LGDs were imported into the U.S.A. (Coppinger and Coppinger, 2001). From the U.S.A., LGDs have recently spread to Canada, parts of South America, Africa, Australia and back to Europe as the need for them has returned with the restoration of large predators to parts of their former ranges (Gehring et al., 2010a, Rigg, 2001, Landry, 1999).

LGDs are raised from an early age with the livestock they are to protect. This is thought to thoroughly socialise them with that stock, and to create a strong bond between the dog and its charges (Coppinger and Coppinger, 2007, Coppinger et al., 1983). The livestock become the LGD's social companions, and the dogs choose to remain with their stock and display strongly affiliative and protective behaviour towards them for the rest of their lives. The raising of a LGD can require a considerable time-input from its owner. Most LGDs go through a boisterous juvenile phase, in which they can display unwanted behaviour, requiring supervision to learn which behaviours are appropriate (Green and Woodruff, 1990a, Lorenz and Coppinger, 1986, van Bommel, 2010). However, the time and financial input associated with raising, training and maintaining LGDs is offset by the reduction in predation they can achieve (next section).

1.3 Effectiveness of livestock guardian dogs in preventing predation on livestock

The earliest published research on the effectiveness of LGDs comes from the 1980s and 1990s in the U.S.A. following their importation in the 1970's. Most of this early research was based on reports from surveys, either from users who had adopted the use of LGDs themselves, or who had received a LGD as part of a research program investigating their effectiveness. Both types of surveys can lead to biased results. If only current users of LGDs are included, the sample could be skewed towards people that have a higher than average likelihood of implementing the method successfully. This could be due to a number of reasons, such as their specific property situation or the predator pressure in their area. If producers receive a LGD as part of a research project, they might not be fully motivated to make the method succeed. In addition, when conducting surveys the researcher often cannot control for confounding factors (for example variations in stock management, predator density, livestock vulnerability), and producer estimates of livestock predation are often unreliable (Green and Woodruff, 1983b). The results from these surveys could therefore be biased and uncertain. Nevertheless, the results can at least provide an indication of how satisfied the users were with their LGDs.

In these surveys, LGDs are generally rated as effective for predator control by most users (Table 1.1). The percentage by which LGDs are able to decrease predation was found to potentially be large. Table 1.2 summarises the decrease in predation that was reported in the various producer surveys in the U.S.A. The research by Coppinger et al. (Coppinger et al., 1988) is the only study that did not only report on the average decrease of predation, but also reported that 54% of respondents indicated that predation had not only decreased, but had been fully eliminated. Outside of the U.S.A., a producer survey was also conducted in Namibia, where the Cheetah Conservation Fund has placed Anatolian Shepherds with farmers on both communal and commercial farmland, in order to decrease predation on livestock by cheetah (*Acinonyx jubatus*). It was found 73% of the owners of 117 LGDs reported that their dog had greatly reduced predation rates on livestock (Marker et al., 2005a). Farmer satisfaction with their dogs was high, with 93% willing to recommend the program to others (Marker et al., 2005a). Therefore, despite potential limitations to the studies, initial research suggested that the use of LGDs was effective.

One of the first published field trials that tested the effectiveness of LGDs was by done by Linhart et al. (1979). They found that the presence of Komondor LGDs significantly reduced predation by coyotes (*Canis latrans)* on sheep, over a 20 day period on three ranches. This effect persisted for at least 20 days after the dogs were removed, possibly due to a displacement effect of the coyotes (Linhart et al., 1979). O'Gara et al. (1983) reported that on a ranch in Montana the use of LGDs was the only control method to succeed in stopping coyote predation. In Norway, 13 Pyrenean Mountain Dogs were used to guard sheep from bears (*Ursus arctos*), in three different working regimes: free range in a large area without supervision, free range in a large area with supervision, and in a fenced area (Hansen and Smith, 1999). Unsupervised free range dogs were unsuccessful, but in the other two working regimes sheep predation was lower

Table 1.1 The effectiveness of LGDs as reported by users.

The percentage represents the percentage of respondents that rated their dog as effective in reducing predation. In the questionnaire surveys the respondents had adopted the use of LGDs independent of the research efforts. In the producer surveys, the LGDs were received as part of the research program. These programs were aimed specifically at testing LGDs effectiveness as a predator control method, although some studies had additional goals such as investigating LGDs behaviour.

Effectiveness	Area	No of respondents	Reference
Questionnaire surveys, LGDs adopted independent of research efforts			
97%	Colorado, U.S.A.	160	Andelt and Hopper (2000)
94%	Kansas, U.S.A.	33	Andelt (1985)
92%	Whole of U.S.A., parts of Canada	399	Green and Woodruff (1988)
90%	Colorado, U.S.A.	22	Andelt (1992)
86%	Navaho LGDs in Arizona	72	Black and Green (1985)
91% (Komondor)	12 states of U.S.A., 4 Canadian provinces	54	Green and Woodruff (1980)
94% (Great Pyrenees)	25 states of U.S.A., 1 Canadian province	63	
Producer surveys, LGDs received as part of the research program			
77%	37 states of U.S.A.	217	Coppinger et al. (1988)
90%	Idaho, Oregon, Washington and Whyoming	60	Green and Woodruff (1990a)
85%	Idaho, Oregon, Washington and Whyoming	93	Green (1989a)
80% (3 separate studies)	16 states of U.S.A., 2 Canadian provinces	24	Green and Woodruff (1983a)
		27	Green, Woodruff and Tueller (1984b)
		70	Green and Woodruff (1985)

in the areas containing LGDs than the areas without the dogs, and predation started earlier outside the test areas (Hansen and Smith, 1999). In a second trial, four LGDs were taken to patrol large areas under human supervision in order to protect sheep from bears, wolverines (*Gulo gulo*) and golden eagles (*Aquila chrysaetos*) (Hansen et al., 2002). The trials involved eight sheep flocks in two separate areas; significant reductions in sheep losses were achieved in one area, but not the other (Hansen et al., 2002), which the authors attributed to the size of the area that needed to be covered, and the qualities of the dogs used. However, as in the Linhart et al. (1979), O'Gara et al. (1983) and Hansen and Smith (1999) studies, these studies suffered from small sample sizes and/or poor study design, which could have significantly influenced the results.

Table 1.2 Decrease in predation as reported by users.

In the questionnaire surveys the respondents had adopted the use of LGDs independent of the research efforts. In the producer surveys, the LGDs were received as part of the research program. These programs were aimed specifically at testing LGDs effectiveness as a predator control method, although some studies had additional goals such as investigating LGDs behaviour.

Decrease in predation	Area	Sample size	Reference
Questionnaire surveys, LGDs adopted independent of research efforts			
93%	North Dakota, U.S.A.	36	Pfeifer and Goos (1982)
76% (Komondor) 77% (Great Pyrenees)	12 states of U.S.A., 4 Canadian provinces	54	Green and Woodruff (1980)
	25 states of U.S.A., 1 Canadian province	63	
40%-67% (ewes) 0%-33% (lambs)	Colorado, U.S.A.	178	Andelt (1999)
Without LGDs 5.9 and 2.1 times more losses of lambs in 2 years	Colorado, U.S.A.	160	Andelt and Hopper (2000)
Producer surveys, LGDs received as part of the research program			
Fenced: 90% Open range: 78%	Several western states of U.S.A.	70	Green and Woodruff (1985)
77%	37 states of U.S.A.	217	Coppinger et al. (1988)

In a larger field trial in Slovakia, Rigg et al. (2011) placed 68 LGDs on farms, to guard sheep from bears, wolves (*Canis lupus*) and lynx (*Lynx lynx*). They found that the presence of LGDs was associated with lower levels of predation, particularly in flocks that previously suffered from predation (median loss of 1.5 in trial flocks versus 5.0 in control flocks) (Rigg et al., 2011). In addition, surplus killing was greatly reduced, with the maximum number of stock taken at once being five, versus 10-35 in control flocks (Rigg et al., 2011). Similarly, Gehring et al. (2010b) placed LGDs with cattle (*Bos primigenius*) on six farms in Michigan, U.S.A., to evaluate their effectiveness in excluding predators (i.e. wolves and coyotes), mesopredators (i.e. raccoons *Procyon lotor*, opossums *Didelphis virginiana*, foxes *Vulpes vulpes* and skunks *Mephitis mephitis*) and white-tailed deer (*Odocoileus virginianus*) from paddocks. They found that all species used areas with LGDs less than control areas, and there was no predation on livestock in paddocks with LGDs, even though predation did occur on neighbouring properties (Gehring et al., 2010b). A potential added benefit of spatially segregating deer from cattle is a reduction of disease transmission (Gehring et al., 2010b).

A range of studies show that LGDs seem to be able to defend livestock from a range of predator species. The majority of research has dealt with their effectiveness against coyote predation, but there is also evidence that they can be effective against wolves, bears and cheetah (Table 1.3). In addition, there are many anecdotal reports of LGDs being used to protect stock from a wide range of other predators, from foxes and wolverines to mountain lions (*Puma concolor*) and bobcats (*Lynx rufus*) (Rigg, 2001). Therefore, they seem to be an effective method for minimizing the impact of predators on livestock, with potentially widespread applications.

1.4 How LGDs are thought to work

The exact mechanism by which LGDs protect their livestock is not well understood. There are three ways in which LGDs can potentially deal with predators that are threatening their livestock: by confrontation, disruption and territorial exclusion (van Bommel, 2010).

Confrontation involves a LGD directly confronting a predator that is attacking, chasing or otherwise threatening livestock. The dog will approach the predator, and use intimidation or force to cause it to withdraw. There are many anecdotal reports of LGDs confronting a predator and chasing it away, which has been also been documented in a number of studies. Both McGrew and Blakesley (1982) and Black and Green (1985) reported that Komondorok and Navaho LGDs confronting and chasing coyotes, similar to Green and Woodruff (1983b) who documented confrontation of both coyotes and bears by LGDs. Direct confrontation of bears that were killing sheep were also reported by Hansen and Smith (1999), and LGDs have beenrecorded confronting wolves (Coppinger and Coppinger, 1995, Coppinger et al., 1988). Direct confrontation potentially leads to fights between LGDs and predators, but this seems to

Table 1.3 Literature referring to different predator species against which LGDs can provide protection.

Guardian dogs protecting livestock from:	References
Coyotes	Andelt (1985), Andelt (1992), Andelt (1996), Andelt and Hopper (2000), Black and Green (1985), Coppinger et al. (1988), Green and Woodruff (1980), Green and Woodruff (1983a), Green and Woodruff (1988), Green et al. (1984a), Gehring et al. (2010b), Linhart et al. (1979), McGrew and Blakesley (1982), Pfeifer and Goos (1982)
Bears	Green and Woodruff (1993), Hansen and Bakken (1999), Hansen and Smith (1999)
Wolves	Bangs et al. (2005b), Coppinger and Coppinger (1995), Coppinger and Coppinger (1996), Coppinger et al. (1988), Gehring et al. (2006), Gehring et al. (2010b), Ribeiro and Petrucci-Fonseca (2004), Ribeiro and Petrucci-Fonseca (2005), Rigg et al. (2011)
Cheetah	Marker et al. (2005a)

be rare However, LGDs have been reported to be injured or killed by wolves (Bangs et al., 2005a).

Disruption is caused by the presence and behaviour of the LGD interrupting the hunting behaviour of the predator, without a direct confrontation. LGDs usually become noisy and active when any unfamiliar animal or person approaches the livestock. The effect of their obvious presence can cause predators to withdraw, and seek prey elsewhere. Green and Woodruff (1983b) recorded that LGDs sometimes barked and made a lot of noise at the approach of a predator in their field trials, which was often enough to drive the predator away without confrontation. Coppinger et al. (1988) argue that LGDs disrupt predatory behaviour by entering into social interactions with the predators, including behaviours such as aggression, dominance display, scent-marking, exploratory behaviour, greeting and play, or it could lead to the predator avoiding the LGD (Coppinger et al., 1988). Aggression and avoidance are most often documented, although more friendly interactions do seem to occur sometimes (Bangs et al., 2005a).

Territorial exclusion happens when a predator recognises the area used by the LGD as the territory of another predator. The predator can then avoid entering the LGD's territory, or if it does enter, modify its behaviour to avoid detection, such as by travelling through the area more quickly, remaining alert and spending less time hunting. All these behaviours reduce the probability of livestock within the LGD's territory being killed. Territorial exclusion would be most effective against other Canids, as members of the same or closely related species are likely to recognise each other's territorial signals. Territorial boundaries can be maintained in a number of ways. Apart from confronting trespassers, signals such as scent-marking and vocalisations can signal the occupation of a territory to conspecifics (Peters and Mech, 1975, Harrington and Mech, 1979, Thomson, 1992b, Gese and Ruff, 1997, Sillero-Zubiri and Macdonald, 1998). No research has shown that LGDs deter predators through territorial exclusion, although a number of studies have reported scent-marking, regular barking and patrolling by LGDs (Black and Green, 1985, Green and Woodruff, 1983b, Linhart et al., 1979, Hansen and Smith, 1999, McGrew and Blakesley, 1982, Parker, 2010). Therefore, while it looks like territorial exclusion is possible, it has yet to be definitively demonstrated.

1.5 Effect of spatial scale on management and effectiveness of LGDs

There are a variety of different management systems for LGDs. Traditionally, LGDs were (and in some areas still are) used in groups and work together with a shepherd who keeps the flock together and provides backup for the dogs in case of predator attack (Gehring et al., 2010a, Rigg, 2001, Coppinger and Coppinger, 2001). Flocks and shepherds often lead a nomadic or semi-nomadic existence for at least part of the year, and the LGDs follow the flock. In some cases LGDs are kept in villages close to people in winter, while in summer they range with the livestock. In other cases they spend nights (or days) in villages, while going out with livestock during the day (or night). But in all cases they work closely with a shepherd (Landry, 1999, Coppinger and Coppinger, 2001).

In most Western societies, livestock management, and therefore dog management, is different. Livestock are kept in paddocks, or are allowed to roam through an area without a shepherd, and LGDs are expected to remain with the livestock unsupervised. If livestock are kept in paddocks, LGDs can be fence-trained so they will remain in the paddock in which they are deployed (Gehring et al., 2011), but they can also be allowed to cross stock fences and thereby given the freedom to roam more freely. When LGDs are confined to fenced paddocks, their general location is always known. But if they are free-ranging, either in an un-fenced area, or when they are allowed to cross stock fences, they can leave their livestock and potentially roam over large areas. This can cause concern about the dogs' safety, as roaming dogs have a higher mortality rate due to causes such as vehicular accidents, accidental poisoning or trapping, or shooting during trespassing (Gehring et al., 2011, van Bommel, 2010). It can also cause concern over the effectiveness of the LGDs, as a dog that roams is not with its livestock. In addition, LGDs can influence wildlife and other livestock they encounter while roaming (Gehring et al., 2011).

In Norway, Hansen and Smith (1999) found that LGDs that were working unsupervised over large unfenced areas were not as effective in reducing predation on sheep by bears, wolverines, lynx and wolves as dogs that worked under supervision, or in fenced areas. In unfenced areas the dogs had the tendency to roam far, and they caused problems with nearby settlements, wildlife and with other livestock. Their recommendation for Norwegian conditions was to keep livestock in fenced paddocks for optimal effectiveness. Conversely in Colorado, U.S.A., LGDs working on open range were more effective in protecting sheep from bear and mountain lion predation than LGDs working in fenced paddocks (Andelt and Hopper, 2000). However, confounding factors were that sizes of the flocks on open ranges were larger than in fenced paddocks, and predation by these predators on fenced livestock was very low to start with (Andelt and Hopper, 2000), which may explain the greater effectiveness of LGDs on open range for bear and mountain lion predation. Other studies did not find a difference in the effectiveness of LGDs between open range and fenced paddocks, in their research in several States across the U.S.A. (Green and Woodruff, 1990a, Coppinger et al., 1988). Instead, LGDs were found to be less effective when sheep were scattered widely over a very large area, and did not flock, and when producers did not spend more than a minimal amount of time with the flock (Coppinger et al., 1988).

Apart from keeping predators away from livestock, LGDs also influence wildlife other than predators. Various studies report that LGDs will chase large and small mammals, and in some cases kill them (Black and Green, 1985, Black, 1981, Green et al., 1984b, Timm and Schmidtz, 1989). In their producer survey, Coppinger et al. (Coppinger et al., 1988) reported that 40% of working LGDs harassed wildlife other than predators, or other domestic species. White-tailed deer are deterred from using both pasture and concentrated cattle feed by LGDs (Gehring et al., 2010b, Vercauteren et al., 2008). Similarly, on the Golan Heights cattle are kept in predator-free enclosures for part of the year, some with LGDs, and mountain gazelles (*Gazella gazella*) can be present in these enclosures. Gazelles spent more time being vigilant and running, and did not approach the cattle as closely in enclosures with LGDs, and the presence of LGDs had a significant negative effect on gazelle reproduction (Gingold et al., 2009). LGDs have not only been documented to affect larger herbivore species. In Norway, during LGD trials 50% of Lapland marmots (*Marmota spp*) that LGDs encountered were attacked and killed, and LGDs also chased or followed other wildlife they encountered in 85% of cases (Hansen and Smith, 1999). Gehring, VerCauteren and Landry (2010a) report that in addition to lower use of paddocks by white tailed deer, there were lower numbers of small mammals (deer mice *Peromyscus maniculatus* and meadow voles *Microtus pennsylvanicus*) in paddocks with cattle guarded by LGDs, compared to control paddocks with cattle not guarded by LGDs.

The risk of LGDs encountering domestic animals of species other than those they are used to is greater if they roam large distances. LGDs are generally raised and bonded to the animals they will guard later in life, and farmers often do not include other species of domestic animals in this process. Problems can arise if LGDs that are socially bonded to one species display predatory or defensive behaviour towards other species of livestock (Coppinger et al., 1988). If they do, this behaviour can cause problems with livestock they encounter if they roam.

Therefore, the way LGDs are socialised and deployed can potentially influence their effectiveness and the unintended impacts on non-target species.

1.6 Livestock and guardian dogs in Australia

In Australia, the livestock industry is an important part of the economy. This is particularly so for the sheep and cattle industries. Livestock growing operations are often large. The average farm size for sheep operations in the whole of Australia in 2012 was 3,738 ha, for cattle it was 11,446 ha (ABARE, 2013). In the rangelands, grazing properties can be much larger than these averages, for both sheep and cattle, and flocks or herds are usually managed with low input and low-intensity monitoring by livestock managers. Wild dogs (*Canis lupus familiaris* including dingoes *Canis lupus dingo*) cause the greatest damage to the livestock industries, mainly to sheep and cattle (Fleming et al., 2001, Lightfoot, 2011). Smaller predators include red foxes and wedge tailed eagles (*Aquila audax*), although due to their smaller size they target smaller livestock and therefore do not cause the same amount of damage as wild dogs. Lethal control and exclusion fencing are the most common methods of controlling the impact of predator populations (Allen and Fleming, 2004, Allen and Sparkes, 2001, Fleming et al., 2001).

The use of dogs to guard livestock is relatively unknown in Australia (Jenkins, 2003), but interest in the method is increasing. The first LGDs in Australia were Pyrenean Mountain Dogs, which were imported in 1843 to protect sheep from dingo predation (Fetherstonhaugh, 1917). However, once sheep were confined in paddocks and dingo numbers were severely reduced in many areas, there was no longer a need for LGDs, and the breed died out in Australia. The next Pyrenean Mountain Dogs were imported in 1936, and from that time onwards LGD numbers and breeds have slowly increased (Crago, 1991). Currently 11 LGD breeds are registered with the Australian National Kennel Council, but the majority of breeds occur in low numbers only, with less than 50 registrations annually (ANKC, 2012). The most common breed is the Maremma Sheepdog (ANKC, 2012).

1.7 Study Aims

This study will attempt to address some of the questions, and gaps in knowledge related to the use of LGDs as a non-lethal predator control method, particularly in Australia. Non-lethal predator control is relatively uncommon in Australia, apart from the use of exclusion fencing. It is currently unknown which non-lethal predator control methods would be suitable for the Australian environment, and likely effective in protecting livestock. LGDs have been used by some livestock producers in Australia to protect their animals, and Jenkins (2003) reported anecdotal evidence of LGDs being effective against predation by wild dogs and foxes, but he did not report the size of the properties on which these dogs were used, nor how they were managed. Apart from this brief survey, no research had been published on LGDs in Australia before I began this PhD. In Australia, livestock properties tend to be large, with low-input management. If LGDs are used on such properties, they are likely to be allowed to cross stock fences, and range freely with their livestock. The findings by Hansen and Smith (1999) suggest that LGDs might be less effective when working free-range over large areas, and Coppinger et al. (Coppinger et al., 1988) suggest that LGDs might be less effective when sheep scatter widely over a very large area, and when producers do not spend more than a minimal amount of time with the flock. This raises the question of how effective LGDs would be in preventing predation on livestock on large grazing properties under Australian conditions. In particular, we need to know whether effectiveness declines with increasing spatial scale, and, if so, at what property size LGDs cease to become a viable approach for controlling predation.

In order to understand how spatial scale affects the ability of LGDs to protect stock from predators, we need a better understanding of the mechanisms they use when protecting livestock. No research has ever looked in detail at the movements of free-ranging LGDs, and how allowing them to roam freely influences their behaviour. For example, direct confrontation of predators has been documented in various studies (see section 1.4). If direct confrontation is the main mechanism by which LGDs protect their stock, then the effectiveness of LGDs relies on the dogs being close to their stock in order to deter any predator that approaches. This could lead to low LGD effectiveness on larger scales, because in such situations LGDs or stock will roam over large areas, and flocks or herds are likely to be scattered. However, if LGDs work through territorial exclusion of other Canids, their constant presence with livestock is not absolutely necessary. With territorial exclusion, scale of operation does not necessarily lead to a decrease in effectiveness, provided the LGD can maintain a large enough territory or multiple LGD groups operate in adjoining territories. Scattered livestock would not be an issue provided they remain within the territorial boundaries of the LGD. Furthermore, roaming of LGDs away from livestock may not always be cause for concern, since patrolling territorial boundaries requires the LGD to spend some time away from its stock.

This has led to the following key questions in this research: 1) given the large scale of most livestock operations in Australia, can LGDs be an effective non-lethal predator control method in this country? 2) If LGDs are used in large areas in a free range situation, how does this affect their movements and the way they work?

To address these questions, the objectives of this study were:

1. To review currently existing non-lethal predator control methods, their suitability to the Australian conditions, and how LGDs compare to other non-lethal methods (Chapter 2).

2. To determine how well LGDs perform under Australian conditions, and if there is a difference in their ability to prevent predation on livestock on large enterprises compared to smaller ones (Chapter 3).

3. To track free-ranging LGDs on large grazing properties to find out their movement patterns (Chapter 4).

4. To determine in what way free-ranging LGDs work to protect their livestock from predators (Chapter 5).

1.8 Thesis Outline

Chapter 1 is a general introduction to LGDs. It gives background information on the history of the method as a predator control technique and reviews studies done in other parts of the world with regard to their effectiveness. In addition, it gives an overview of current theories about how LGDs work and different management types of the dogs.

Chapter 2 presents a critical evaluation of existing non-lethal predator control methods based on published studies, and assesses their potential suitability for use in Australia. The most suitable methods are identified.

In chapter 3 the effectiveness of LGDs for stock protection in Australia is investigated and the factors that influence that effectiveness, in particular scale of management, are identified and quantified. In addition, the different management systems for LGDs in Australia are documented, their cost-effectiveness for livestock producers is evaluated and the factors that determine the number of dogs required for different property situations are identified.

In chapter 4 the effect of scale of management on LGD movements is investigated. If LGDs are restricted to small areas only, their movements and behaviour are easy to observe. However, on large scale livestock operations where dogs are free ranging over large distances their movements and behaviour are unknown. The aim of this chapter is to document range sizes of free ranging LGDs, and to determine which time of the day they are most active. In addition, the activity of LGDs is investigated relative to location in their range. Fast movement suggests a different type of behaviour than slow movement, and was hypothesized to be more likely to occur at the edge of their range. The time that LGDs spent in livestock areas is determined, and a multivariate analysis is done to investigate which factors most influence the distribution of LGDs.

Chapter 5 tests how free-ranging LGDs work to protect their livestock. If LGDs solely rely on direct confrontation to deter predators, then LGDs effectiveness probably declines with increasing scale of deployment. However, if LGDs are territorial and can use territorial exclusion to deter predators from stock, than scale of management is less important. In chapter 5 simulated wild dog incursions were used to determine whether the LGDs response to these incursions is consistent with territorial behaviour, or more consistent with the dogs relying on direct confrontation to deal with predators.

Finally in chapter 6 a general discussion evaluates the findings of the study, and makes recommendations for the use of LGDs in Australia.

1.9 Comments on thesis structure

All data chapters (chapters 2-5) were prepared as stand-alone manuscripts suitable for publication. These chapters have been re-formatted to fit into the thesis conforming to the overall style used throughout this manuscript. However, due to the stand-alone style of each chapter, there is some degree of overlap in content of each chapter, mainly their introductions, with the content of the general introduction to this thesis. References have been consolidated in one reference list at the end of the document. At the time of writing, chapter 2 has been accepted for publication in the book ‘Carnivores of Australia, Past, Present and Future’, and chapter 3 has been published in the scientific journal Wildlife Research. Chapter 4 and 5 have both been submitted to scientific journals, chapter 4 to Wildlife Research, and chapter 5 to Agriculture, Ecosystems and Environment. All manuscripts were written and prepared by the author of this thesis, but where co-authors contributed to the content, acknowledgement is given at the start of the chapter.

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Chapter 2

Protecting livestock while conserving ecosystem function: nonlethal management of wild predators

This chapter constitutes a published chapter in a book: (in press)

van Bommel, L., Johnson, C.N. Protecting livestock while conserving ecosystem function: non-lethal management of wild predators. In Glen, A. S. and Dickman, C. R. (eds) *Carnivores of Australia: Past, Present and Future.* (CSIRO Publishing: Collingwood).

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Chapter 3

Good dog! Using livestock guardian dogs to protect livestock from predators in Australia's extensive grazing systems

Published in:

http://www.publish.csiro.au/?act=view_file&file_id=WR11135.pdf

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http://dx.doi.org/10.1071/WR11135

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Chapter 4

Where do Livestock Guardian Dogs go? Movement patterns of free ranging Maremma sheepdogs

This chapter has been submitted to Journal of Wildlife Research for publication and therefore has been removed.

van Bommel, L., Johnson, C.N. (submitted). Where do livestock guardian dogs go? Movement patterns of free-ranging Maremma sheepdogs. *Journal of Wildlife Research*.

This chapter has been removed for copyright or proprietary reasons.

Chapter 5

How guardian dogs protect livestock from predators: territorial enforcement by Maremma sheepdogs

This chapter has been submitted for publication and therefore has been removed.

van Bommel, L., Johnson, C.N. (submitted) How guardian dogs protect livestock from predators: territorial enforcement by Maremma sheepdogs. *Journal of Agriculture, Ecology and Environment.*

Chapter 6: Discussion and Conclusions: LGDs in Australia

"[Samual Pratt]Winter told me that when the diggings broke out in 1851 [in Australia], and labour was not to be had, he put all his sheep into two flocks, and two magnificent [Pyrenean Mountain Dogs] used to take the sheep out all day and look after them and keep them apart, and then at night these grand dogs used to sleep between the two flocks and guard them."

(Cuthbert Fetherstonhaugh, *After Many Days: being the reminiscences of Cuthbert Fetherstonhaugh*, 1917, pp 94)

6.1 Introduction

Predation on livestock causes severe financial losses to the livestock industry in Australia. Wild dogs/ dingoes (*Canis lupus familiaris* and *Canis lupus dingo*) in particular cause large losses to the sheep and cattle industries (Fleming et al., 2001, Lightfoot, 2011). The use of LGDs (*Canis lupus familiaris*) as a non-lethal predator control method is relatively unknown in Australia, but its popularity is increasing (Jenkins, 2003, van Bommel, 2010). The applicability of this method for large rangeland properties has been questioned, as the effectiveness of LGDs is thought to decrease when the dogs range over large areas, low-input management systems are used or when stock does not stay together very well (Hansen and Smith, 1999, Coppinger et al., 1988). These descriptions characterise many Australian livestock operations, and therefore in this thesis the use of LGDs for stock protection in Australia was researched, in particular the effect of scale of management. If we can understand the effects of scale of management on the effectiveness and behaviour of LGDs, we will be in a better position to make recommendations on how LGDs can be used in Australia for optimal effectiveness. On the other hand possible limitations of the method could be identified.

6.2 Research synthesis and conclusions

The first key question posed in this research was*: given the large scale of most livestock operations in Australia, can LGDs be an effective non-lethal predator control method in this country?*

This question was answered in Chapter 2: and Chapter 3:. Of all non-lethal predator control methods, LGDs are probably the most suitable for all Australian conditions (Chapter 2:). A survey of producers that were already using LGDs indicates that they can be highly effective, irrespective of property size or management system (free-range vs. restricted in movement) (Chapter 3:). The results from Chapter 2: and Chapter 3: indicate that LGDs can be a very effective predator control method in Australia, in spite of the large scale of most livestock operations.

The second key question posed in this research was: *if LGDs are used in large areas in a free-range situation, how does this affect their movements and the way they work?*

This question was answered in Chapter 4: and Chapter 5:. Chapter 4: shows that when allowed to range freely, LGDs spend the majority of their time with livestock, and the presence of livestock is an important factor predicting the distribution of LGDs in their range. However, movements away from livestock do occur, probably for a variety of reasons. In Chapter 5: simulated wild dog incursions showed that the response of LGD to intruders is consistent with territorial behaviour. The overall conclusion of these two chapters is that free-ranging LGDs display territorial behaviour, and their movement patterns reflect this. They spend the majority of their time with livestock, but also make excursions away from them, which could be related to territorial boundary patrolling. Territorial exclusion of predators is likely to be a highly effective method of livestock protection, as the protection against predators is extended to the areas beyond the immediate location of the livestock. It is probably most effective against other canid predators, as members of the same species are more likely to recognise each other's territorial signals.

To summarise, the main conclusions from this research are:

- LGDs are an effective non-lethal predator control method in Australia.
- Property size does not influence LGDs' effectiveness, as long as an appropriate number of dogs is used for the number of stock that needs protection.
- Having LGDs free-ranging is the preferred management system on large Australian grazing enterprises.
- Free-ranging LGDs spend the majority of their time with their livestock.
- Free-ranging LGDs display territorial behaviour. Some movements away from livestock will therefore occur, as the dogs patrol and maintain territorial boundaries.

6.3 Management implications

The main factor that influences how effective LGDs will be on a property is the number of stock per LGD. This suggests that in a situation where existing LGDs are not sufficiently effective, this can often be remedied simply by adding more dogs until predation levels are suppressed to the required level. Predation does not always have to be fully eliminated in order to bring large benefits to a producer. In some cases a reduction in predation can still make the difference between the livestock operation being unviable and running a profit.

Territorial exclusion of predators by LGDs is likely to be most effective if LGDs are allowed to roam freely around their livestock. Free-ranging livestock guardian dogs are able to demarcate their territorial boundaries some distance outside the range of the stock, which creates a buffer zone that gives the LGDs more opportunity to confront predators, and remove them from their territory before they reach the livestock. This makes it a highly effective method of predator control. In order to patrol and maintain territorial boundaries, LGDs will need to spend some time away from their stock. This does not have to be a cause for concern for the owner, as long as the movements do not become too extensive.

If LGDs are restricted in their movements to one particular paddock or area, they will probably still be territorial. However, in that situation the dogs will be unable to create a buffer zone around the livestock as they would in a free-range situation, making the method less effective. Therefore, in order to fully benefit from territorial exclusion of predators, LGDs should be allowed to range freely with livestock if the property situation allows for this. Obviously on smaller properties, and particularly in more densely populated areas, this management system might not be feasible. When deciding whether the method is safe to implement, the range of the dogs should be taken into consideration: the mean 95% kernel isopleth area was 316 ha in this study, the maximum size (a dog on Heatherlie) was 1438 ha. A minimum area of that size should be available for a LGD to safely use before the free-range system should be considered.

Within a group of LGDs working together, it seems that each dog has a consistent role to play. These individual roles of the dogs complement each other, and the group as a whole is an effective unit. It is therefore recommended to have multiple dogs working together for optimal effectiveness in livestock protection.

6.4 Multiple uses of LGDs

Apart from reducing or eliminating predation, and influencing the movements and behaviour of predators, LGDs could potentially provide other benefits for livestock, livestock production and biodiversity conservation. In the next sections three areas are identified where LGDs could provide further benefits, two mainly applying to livestock and livestock production, and a third mainly applying to biodiversity. Little research has been done on these additional benefits from the use of LGDs, and more research is needed on these topics.

6.4.1 Stress management in livestock

Constant threat of predator attack can lead to chronic stress in livestock. Chronic stress can negatively affect the immune system, and therefore lead to susceptibility to disease (Blecha, 2000, Padgett and Glaser, 2003). However, stress can also have less direct impacts on livestock production. In sheep (*Ovies aries*), chronic stress can cause reduced wool growth, reduced fibre strength and breaks in the wool (Lindner and Ferguson, 1956, Chapman and Bassett, 1970, Thwaites, 1972). Chronic stress can also potentially lead to reduced growth rates of livestock (Hemsworth et al., 1987, Ruckerbusch and Malbert, 1986, Colditz, 2002).Chronic stress can suppress reproductive efficiency and maternal abilities of livestock, leading to fewer offspring (Moberg, 1991, Von Borell et al., 2007, Dobson and Smith, 2000). In dairy cattle (*Bos spp.)* this can also lead to reduced milk production, and in hens (*Gallus domesticus*) to reduced egg production (Downing and Bryden, 2008, Dobson and Smith, 2000, Von Borell et al., 2007).

LGDs can take the constant threat of predation away from livestock, which could lead to reduced stress levels in the animals. Other predator control methods could have the same effect, however, compared to other methods, the bond that is formed between LGDs and their stock can lead to an increased sense of security for the stock, potentially reducing stress levels further than other predator control methods would. The LGDs are always physically present, and the livestock learn to rely on the dogs for protection, which does not occur with most other predator control methods. In the producer survey in Chapter 3:, many livestock producers mentioned that after they obtained LGDs, their livestock became much calmer as a result of the constant presence of the dogs. This made them and less aggressive and flighty and in general easier to handle, which could be an indication of reduced stress in the livestock.

Reduced stress levels do not only increase animal welfare, but can potentially lead to increased productivity of the livestock, and therefore a better return for the producer. However, the exact mechanism by which stress influences various aspects of animal productivity is complicated, and predator threat is not the only stressor in the environment for livestock. Therefore, the mechanism through which LGDs can influence stress in livestock through removal of the threat of predation and an increased sense of security, and the resulting effect on productivity is likely complicated, and would perhaps not always be clear. More research is needed on this topic. During this PhD project data were collected on stress levels in sheep, both with and without LGDs in similar ecological environments. However, due to a delay in the data collection that part of the research was not included in this PhD thesis, and will be published separately at a later stage.

6.4.2 Large herbivores

Three studies have identified the potential for LGDs to influence the movements and behaviour of large herbivores. White-tailed deer (*Odocoileus virginianus*) can be deterred from cattle paddocks and concentrated cattle feed by LGDs (Gehring et al., 2010b, Vercauteren et al., 2008), and the behaviour of Mountain gazelles (*Gazella gazella*) is significantly influenced by the presence of LGDs (Gingold et al., 2009).

In Australia, the main large herbivore species that have an effect on livestock grazing are kangaroos (red kangaroos *Macropus rufus* and grey kangaroos *Macropus giganteus*), wombats (mostly the common wombat *Vombatus ursinus*), and, increasingly, several introduced species of deer (chital *Axis axis*, red deer *Cervus elaphus*, hog deer *Axis porcinus*, Sambar *Cervus unicolor*, fallow deer *Dama dama*, and rusa *Cervus timorensis*). Kangaroos can compete with livestock for pasture, reducing the amount of feed available for stock (Edwards et al., 1996, Edwards et al., 1995, Fennessy, 1966). Wombats do not directly compete with stock over feed, but inflict damage to river beds, paddocks and fencing (Borchard and Wright, 2010). Deer numbers have not increased to the extent that they are in competition with livestock over feed on a large scale in Australia, but this might well happen in the future, if their populations keep expanding. However, an increasing problem that especially cattle producers are experiencing in deer areas is that rutting deer will harass cattle, often causing them to stampede and driving them through stock fences (Andrew Bowran and Mac Fraser, pers. comm.). Another potential problem with the presence of deer close to stock is the transmission of disease. In Australia Johne's disease could be a problem, as the disease is already well established in the country (Sergeant, 2001, Kennedy and Allworth, 2000). Deer can be affected by the bovine form of this disease, which they can subsequently pass on to cattle, goats, alpacas and llamas through their faeces (Kennedy and Allworth, 2000). Other diseases that deer can transmit to livestock are bovine tuberculosis and avian tuberculosis, both of which can affect a range of livestock species (Mackintosh et al., 2004). Both diseases are uncommon in Australia, however bovine tuberculosis has been detected in fallow deer in South Australia (Robinson et al., 1989). If feral deer became infected with any of these diseases, controlling the outbreak would be very hard, and it would affect livestock production in Australia.

If LGDs are able to deter white-tailed deer from cattle paddocks in the U.S.A., they could potentially also influence the behaviour of Australia's large herbivores. They could reduce competition between kangaroos and livestock over feed, and perhaps even reduce wombat damage to fences. In addition, they could potentially significantly reduce the rate of disease transmission between deer and livestock in Australia. There is anecdotal evidence that LGDs can influence kangaroo populations (van Bommel, 2010). Many participants in the producer survey of chapter 3 indicated that their LGDs limited kangaroo access to livestock paddocks, and two producers (not included in the survey results chapter) had specifically obtained their LGDs to work in cattle paddocks for kangaroo control. The property owner of the case study property Case study: Dunluce in north Queensland (Chapter 3:) also indicated that his LGDs kept kangaroos out of his sheep paddocks. In addition, on Case study: Dunluce the presence of the LGDs facilitated efficient pasture management, as even paddocks that were left to rest remained relatively free of kangaroos after sheep and dogs were removed.

More research is needed on this topic. During this PhD project data was collected on the presence of large herbivores on the research properties and ecologically similar neighbouring properties without LGDs. However, due to time-constraints these data do not form part of this thesis, and will be published separately at a later stage.

6.4.3 Biodiversity benefits

LGDs have great potential for the reconciliation of conflict between livestock producers and predators. This can greatly benefit predator conservation if it results in a cessation, or reduction, in the use of lethal control methods. In some parts of the world LGDs are already used for this. For example, in Namibia LGDs are placed with producers in an ongoing project which aims to protect livestock from cheetah (*Acinonyx jubatus*) predation (Marker et al., 2005a). In Switzerland and France the use of LGDs is encouraged as a method to protect stock from bear (*Ursus arctos*), wolf (*Canis lupus*) and lynx (*Lynx lynx*) predation now that these predators are returning to their former ranges and are legally protected (Landry, 1999). In the U.S.A., LGDs are used in areas where wolves occur in order to minimise predation on livestock (Urbigkit and Urbigkit, 2010). It seems likely that in Australia LGDs can also facilitate the coexistence of people with predators. If livestock are no longer threatened, producers might develop a more positive attitude towards predators. This could lead to a reduction or cessation of lethal control on livestock properties, as was reported in the case of the property Case study: Dunluce in north Queensland (Chapter 3:). Reduced lethal control could greatly benefit dingo conservation in Australia. In turn, this could provide more general benefits for biodiversity conservation in Australia, as there is increasing evidence that dingoes, as Australia's top predator, play a keystone role in the Australian environment (Corbett, 2001b, O'Neill, 2002, Johnson, 2006, Glen et al., 2007a, Johnson and VanDerWal, 2009, Johnson et al., 2007, Letnic et al., 2009a, Letnic et al., 2009b, Letnic and Koch, 2010, Ritchie and Johnson, 2009, Wallach et al., 2009a, Wallach et al., 2009b, Wallach et al., 2010).

Apart from allowing dingoes to persist in the Australian environment, LGDs could potentially directly benefit biodiversity themselves. There is evidence that LGDs can protect livestock from fox (*Vulpes vulpes*) predation (Rigg, 2001, chapter 3), and during the survey of Chapter 3: anecdotal reports were recorded of LGDs chasing feral cats (*Felis catus*), and providing free-range chickens with protection from predation by cats. If LGDs can influence feral cat and fox populations, they might provide benefits for species that are threatened by fox and cat predation. This is, however, provided they do not threaten these species themselves. There is evidence in the literature that LGDs will harass and sometimes kill small mammals, if they have not been socialised with them (Hansen and Smith, 1999, Gehring et al., 2010a), although they can positively influence populations of ground-nesting birds (Gehring et al., 2010a). It is currently unknown how LGDs that are used for stock protection would react to small Australian mammals if they have not been socialised to them, and if the benefit of reduced fox and feral cat predation in areas used by LGDs could outweigh potential harm caused by LGDs themselves. More research is needed on this topic. However, one producer from the survey in Chapter 3:, who only had her LGDs for 2 years at the time of the survey, stated that she had had black swans (*Cygnus atratus*) nesting in her dam for years. They had only started to successfully raise chicks since she obtained the LGDs, as in the previous years the eggs had always been preyed on. Perhaps even if LGDs are unable to benefit small mammals, they could still have a positive influence on birds and reptiles that are threatened by foxes and feral cats.

The previous discussion of the potential benefits of LGDs for biodiversity in Australia refers to a side effect of the use of these dogs to protect livestock. However, benefit to biodiversity, and protection of wildlife, can also be the main aim of using LGDs. Two such projects already exist in Australia. In Warrnambool, Vic, Maremmas are used to guard a colony of little penguins (*Eudyptula minor*), and in Portland, Vic, Maremmas are used to guard a colony of Australasian gannets (*Morus serrator*) (van Bommel, 2010). In both cases the main predators are foxes, although in the case of the gannets, wallabies (*Macropus rufogriseus*) were also a cause for concern, as they can inflict great damage to nests and eggs if they move through the colony (van Bommel, 2010). In cases such as these nothing should be left to chance, and the LGDs should go through a raising and training schedule specifically aimed at getting them accustomed to the wildlife species they will have to protect. This is in order to prevent the LGDs from purposely harming the species.

There could be great potential in the use of LGDs to protect wildlife. Australia has a large number of threatened species, especially small and medium-sized mammals that are threatened by foxes and cats (Johnson, 2006). Various projects are attempting to re-introduce some of them to their former ranges, but these attempts often fail due to predation (Short et al., 1992, Moseby et al., 2011). The use of dingoes to control fox and feral cat populations for the protection of reintroduced threatened species is being investigated (Moseby et al., 2012). Perhaps LGDs could be used with a similar purpose. As long as their raising and training is aimed towards socialisation with the species of wildlife they have to protect, they will not harm them, and will likely be quite effective in reducing or preventing predation. In the majority of cases, the species they would have to protect would be small, and some would be burrowing. This could make the situation potentially very difficult for a LGD, as most of the time the species that we might wish them to protect would not be available for them to associate with. The species they guard are their social companions, so the LGDs could potentially become deprived of social interactions. A simple solution for this could be to add small numbers of sheep to the area where the reintroduction will take place. The LGDs could then be socialised with the stock and the wildlife, and protect both while still benefitting from the social company of the sheep. More research is needed on this topic.

6.5 Socio-cultural limits to the uptake of guardian dogs

Despite the fact that LGDs seem to work very well in reducing or eliminating predation problems in a range of situations, many livestock producers in Australia seem either unaware of this predator control method, or unwilling to use LGDs. Unawareness of the method is probably due to the fact that LGDs are a relatively new method in this country, and many people simply have not heard of the existence and/or effectiveness of LGDs. This seems to be slowly changing, and the popularity of the method is increasing (van Bommel, 2010). Their use mostly seems to spread through word-of-mouth; as one producer takes up the use of LGDs and they are effective on their property, neighbouring properties are likely take up LGDs as well. This effect was very clear in the areas surrounding the research properties that were used for the field work part of this project, and the Case study: Dunluce case study in Chapter 3:. In some cases the LGDs themselves facilitated uptake by numbers; some dogs guarded the neighbours' properties as well as their own, which in turn convinced these neighbours of their usefulness.

It is also relatively common for producers to be aware of LGDs, but being unwilling to use them. There might be a number of reasons for this. Many farmers in Australia are familiar only with herding type dogs to work with livestock. They do not understand that LGDs work very differently, and are therefore suspicious of the method, as the type of dogs they know could never be trusted with livestock unsupervised (Coppinger and Coppinger, 2007). Some people are discouraged by the time and effort it takes to raise a LGD, which can be substantial, especially for first-time LGD owners (van Bommel, 2010). In addition, some people have great difficulty understanding how a LGD can be cost-effective. They focus only on the extra expense associated with feeding and maintaining a LGD, without considering the profit derived from livestock saved from predation. In some cases, some producers are simply not 'dog people', and dislike the idea of using and being responsible for dogs for any reason.

However, Australia also seems to have a culture of farmers favouring traditional (usually lethal) predator control techniques to deal with predator problems, especially among traditional farming families who have owned and worked on their properties for a number of generations. If these techniques fail to achieve the desired outcome, a cry usually goes out for the government to fix the issue, instead of the affected farmers taking a pro-active approach and trying out new or different methods to control the problem. This reluctance to try new methods could stem from unawareness, or incomplete knowledge, of other predator control methods as described for LGDs earlier in this section. However, often it also seems to be caused by a refusal from producers to accept the fact that this country has predators that kill livestock, and that they will have to live with and operate their enterprise with these predators in the environment. In that case, blaming the government for not undertaking enough action to control predation is an easy way out.

Public education could help greatly in facilitating the uptake of LGDs in Australia. However, more research is also needed on the socio-cultural limitations to the use of LGDs in this country, and how to overcome these limits.

6.6 Concluding remarks

This study has greatly improved the understanding of the use of LGDs in Australia. It has shown that LGDs can be an effective predator control method in this country, and that the size of the livestock operation does not have to limit the effectiveness of LGDs. The results have contributed to the understanding of the behaviour of LGDs that are allowed to range freely over large areas with their livestock. In addition, through simulated predator incursions this study has greatly enhanced our understanding of how LGDs protect their livestock. It is the first research to experimentally prove that LGDs are territorial, and that territorial exclusion of predators could play a large part in livestock protection when these dogs are used.

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