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Landcare Research Manaaki Whenua

Wild ungulate impacts and management in lowland sites in Southland Region

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Summary

Project and Client

• The following report summarises the state of knowledge about the current ecological status of wild ungulates (wild deer, feral pigs, and feral goats) in lowland areas in the Southland Region, the impacts that these species can have on native biodiversity, and options for managing expanding wild ungulate populations. It was completed by Landcare Research, Lincoln, for Environment Southland during October 2011 to June 2012, and funded by the Ministry of Business, Innovation and Employment (formerly Ministry of Science and Innovation) Envirolink fund (Project ESRC242).

Methods

• The findings in this report are based on an extensive literature review, as well as a telephone survey administered to 58 rural residents of Southland Region. Interviews and informal discussions were also held with key stakeholders, e.g. Department of Conservation, Environment Southland, and the New Zealand Deerstalkers' Association.

Main findings

- Wild ungulates, particularly red deer, fallow deer, and pigs, are widespread in lowland Southland, and observational/anecdotal indications are that they are expanding their ranges and increasing in numbers.
- The mechanisms responsible for new populations and range extension are not well understood, but are expected to include natural range extension, farm escapes, and illegal liberations.
- The Southland Plains contain remnant native vegetation of high conservation value. Expanding wild ungulate populations may threaten native ecosystems in lowland areas, and it may be necessary to adopt a precautionary approach whereby they are eradicated, controlled or excluded from selected locations.
- About half of respondents to a survey on attitudes to new populations of wild ungulates in Southland indicated they were concerned about the effects of these animals on native vegetation and fauna. Many were also concerned about the impacts or potential impacts on agriculture (particularly TB transmission, pasture, and crops), forestry, and human safety (poaching and poor firearms safety; motor vehicles colliding with animals).
- Wild ungulates may need to be controlled or eradicated in some areas of high conservation value in lowland Southland. If the animals are of domestic origin, the best and cheapest option is for farmers to immediately muster or lure any escaped individuals back behind their fences. Reactive management, particularly ground-based hunting, is likely to be the best approach to manage illegal liberations.
- In high-conservation-value sites with existing wild ungulate populations and with high connectivity to adjacent source wild ungulate populations, eradication may not be possible because of continual reinvasion. Ungulate-proof fences may be a viable alternative to prevent wild ungulates from affecting native biodiversity in these locations.

Recommendations

- Environment Southland should clearly articulate its goals and objectives for managing expanding wild ungulate populations on the Southland Plains. Do wild ungulate populations need to be controlled or eradicated, and if so, what impacts will management aim to mitigate? How will future incursions of wild ungulates be prevented?
- If the conservation of threatened native lowland sites is considered a high priority, then lowland sites that were until recently wild ungulate free need to be identified. The location and size of such areas should be comprehensively mapped, and sites should be prioritised based on their native biodiversity value, the potential impact of wild ungulates on that value, and the likelihood of preventing wild ungulates expanding into valued sites (if it has not yet occurred) or eliminating or mitigating their impact if they are present.
- Currently there is limited information about the distribution of wild ungulates in lowland Southland. We recommend that more detailed formal surveys of high-priority conservation areas and their surrounds will likely be necessary before effective strategies can be designed to mitigate the impact of wild ungulates. Survey design and methodology may differ based on geography, size of sites, species present, and management objectives. In addition, a survey using more detailed questions and targeted at a greater proportion of Southland residents might provide further information about the status of wild ungulates in the region.
- Environment Southland should decide on a strategic approach for such areas, choosing between either (1) precautionary eradication of all new populations as they emerge, to eliminate the risk of future unwanted effects on the structure and composition of the few remaining areas dominated by native biota; or (2) implementing low-level 'risk-identification' monitoring and implementing ungulate control in priority areas only when that monitoring identifies a risk of population increase to moderate or high levels.
- Because many new populations of wild ungulates are believed to have originated from farm escapes or illegal liberations, Environment Southland should consider undertaking a public awareness and community education programme. This programme should focus on the expansion of wild ungulates into areas of Southland from which they were previously absent, and the potential harmful effects that their expansion could have on remnant natural areas, agricultural production, and public safety. If Environment Southland decides that its management goal is eradication (or maintaining zero density) of wild ungulate populations on the Southland Plains, we recommend that DOC's management of wild/feral deer in Taranaki and Northland could be used as a model for Southland.
- In some areas, wild ungulates may have established populations that have distributions that fall under the administration of more than one organisation (national, regional or local). We recommend greater communication between organisations tasked with managing expanding populations of wild ungulates in Southland, including defining goals related to the management of wild ungulates in and adjacent to conservation reserves, sharing knowledge, and designing and implementing management strategies.

1 Introduction

Wild and feral ungulates (hoofed mammals) can modify native plant and animal communities and ecosystems in New Zealand; however, they are also valued as a resource by some groups and individuals. The following report summarises the state of knowledge about the current ecological status of wild ungulates (wild deer, feral pigs, and feral goats) and their impacts in lowland areas of the Southland Region. It also discusses options for managing expanding wild ungulate populations. It was completed by Landcare Research, Lincoln, for Environment Southland during October 2011 to June 2012, and funded by the Ministry of Business, Innovation and Employment (formerly Ministry of Science and Innovation) Envirolink fund (Project ESRC242).

2 Background

At least 12 ungulate species have established wild or feral populations in New Zealand since their introductions in the mid- to late-1700s to early-1900s (King 2005). Wild ungulates were initially considered a valuable resource and often given protection as trophy animals. However, many of these species became widespread and overabundant, with subsequent detrimental effects to native plant communities and ecosystems (e.g. Forsyth et al. 2010, and references therein). The population dynamics of most wild ungulate species in New Zealand have been well documented, as have the management techniques employed to reduce ungulate densities (e.g. Holloway 1950; Riney 1964; Caughley 1970). Briefly, state-funded control (initially ground-based culling and latterly aerial culling and aerial poisoning) and commercial hunting were the primary methods used to reduce wild ungulate densities.

Recently, there have been concerns that the densities of some wild ungulate species may again be increasing and their geographical range expanding, although evidence for this in some areas is primarily anecdotal. Several factors could be contributing to these increases, including in Southland: current restrictions on the use of wild game have resulted in subsequent reductions in commercial hunting; aerial poisoning methods designed primarily for possums (*Trichosurus vulpecula*) have been refined, and if used, kill fewer wild ungulates; poisoning is increasingly being viewed by many individuals and organisations as an unacceptable method of controlling ungulates; widespread deer (and goat) farming has resulted in inevitable escapes; and incidents of illegal liberations have increased (Fraser et al. 2000).

Expanding populations of wild ungulates could threaten native biodiversity in areas previously not affected by these species and efforts to control or eradicate the risk of bovine TB, as well as impact on human activities. Legislation set out in the Wildlife Act 1953, the Wild Animal Control Act 1977, the Conservation Act 1987 and the Biosecurity Act 1993 requires national and regional authorities in New Zealand to manage wild ungulates. Accordingly, understanding the current status of wild ungulates, as well as their known and potential impacts on native biodiversity and human welfare and safety, is important for councils when updating regional pest management strategies. In this report we summarise the state of knowledge about wild ungulates in lowland Southland and highlight key gaps that require further investigation.

The wild ungulate species of focus in this report have historically had well-established populations in some parts of the Southland Region, particularly in the hills and mountains in the west and in the Catlins to the east (Fraser et al. 2000; Garden et al. 2002). However, they are generally considered to have been absent (at least in recent times) from most or all lowland and coastal areas on the Southland Plains – possibly with the exception of scattered feral goat populations (Fraser et al. 2000). It follows that the remnant patches of native vegetation in lowland Southland have not been recently exposed to the potential impacts of wild ungulate browsing (although domestic livestock – cattle and sheep – may have impacted some of these areas). Thus, the focus of this review on the current status of wild ungulates in Southland is on their expansion (be it by natural spread, farm escapes or illegal liberations) into lowland Southland (we also use the term 'Southland Plains').

Unless explicitly stated otherwise, throughout this report we use the terms 'wild' to refer to wild or feral deer populations and 'red deer' to refer to red deer/wapiti-type animals. We use the term 'feral' to refer to pigs, cattle, goats, and sheep, except when we refer to wild or feral ungulates more generally; in this instance we use 'wild ungulates'.

3 Objectives

- Summarise the current status (distribution and density) of wild ungulate (wild deer, feral pig, and feral goat) populations in lowland Southland.
- Document the actual and potential impacts of new and existing populations of wild ungulates on native biodiversity and ecosystem health, particularly in significant remnants of lowland native habitat.
- Document other impacts of wild ungulates, such as those related to human safety, agricultural production, and disease.
- Review and recommend methods for detecting and monitoring wild ungulate populations in identified risk-areas.
- Develop a strategy to more effectively manage wild ungulate populations, and their impacts, in and adjacent to lowland areas of Southland including site- and species-specific recommendations, and integrative approaches to deer management across adjoining regions.

4 Methods

The findings in this report are based on an extensive literature review (including both published material and the unpublished material of which we are aware), as well as a telephone survey that was designed by Landcare Research and administered by Sigma Group to 58 rural residents of Southland Region (see survey results in Appendix 1). Interviews and informal discussions were also held with key stakeholders – the Department of Conservation (DOC), Environment Southland, and the New Zealand Deerstalkers' Association (NZDA). The survey was conducted to contribute to the above objectives, as well as to gauge public attitudes towards wild ungulates, their impacts, and methods of controlling them. The results of the survey have been used, where applicable, throughout the main body of this report, including in a map showing the current distribution of wild ungulates in Southland Region.

5 Current status of wild ungulate populations

Nine species of ungulates have established wild or feral populations in Southland (King 2005). These include pigs (*Sus scrofa*), cattle (*Bos taurus*), chamois (*Rupicapra rupicapra*), goats (*Capra hircus*), sheep (*Ovis aries*), red deer (*Cervus elaphus*), wapiti (*Cervus elaphus nelsoni*), fallow deer (*Dama dama*), and white-tailed deer (*Odocoileus virginianus*). Of these, cattle and sheep have localised herds containing comparatively few individuals (Parkes 2005a, b), white-tailed deer are confined to Stewart Island, and wapiti are confined to an area of approximately 2000 km² in northern Fiordland (Fraser et al. 2000; Nugent 2005b, c). Chamois are most often associated with mountain regions (Forsyth 2005) and consequently they are not considered in this review because it focuses on lowland areas in Southland. Instead we focus on the current status – distribution and density – of red deer (including red deer/wapiti-type animals that have established feral populations), fallow deer, pigs, and goats, because of their documented and potential impacts on the biodiversity of lowland areas and agriculture (Environment Southland 2007).

Note that although we do not include white-tailed deer in this review, isolated observations and anecdotal reports indicate that this species may have been liberated in various locations around Tuatapere and in other suitable habitat around Te Waewae Bay, Southland. It is not known if any of these suspected liberations have resulted in established populations.

The distribution of wild ungulates in Southland was revised by Fraser et al. (2000) between 1993 and 1996. This review was based on observational data obtained from surveys of DOC staff, local authorities, and informal sources. We use similar observational data on wild ungulates obtained from a survey of 58 rural landowners in Southland, as well as discussions with DOC staff and NZDA, to identify new populations of wild ungulates and, where possible, elucidate associated distributional patterns (Figure 1).

In general, 83% of respondents to our survey, as well as DOC staff and hunters that were interviewed, were of the opinion that wild ungulates (particularly red deer, fallow deer, and feral pigs) were extending their range through natural spread, illegal liberations and/or escapes from deer farms into lowland areas of Southland (see Appendix 1; Colin Bishop, DOC, pers. comm.; Lindsay Youngman, NZDA, pers. comm.).

5.1 Wild deer

5.1.1 Red deer

Red deer are the most widespread large wild mammal species in New Zealand (Nugent & Fraser 2005). Their estimated established range in Southland was 18 682 km² in the mid-1990s (Fraser et al. 2000). They are established in all major tracts of native forest within the Southland Region (e.g. Catlins, Hokonui Hills, Longwood Range, Takitimu Mountains), but these populations are largely isolated from each other by large tracts of unforested land (except in the Fiordland area). None of the populations within these large forest tracts are subject to direct state-funded control, but commercial and recreational hunting and incidental kill of deer during aerial 1080 poisoning operations keep these populations at varying levels below carrying capacity.

No new populations of red deer were reported from Southland based on surveys conducted between 1993 and 1996 although 82 new populations of red deer were confirmed in New Zealand, and of these 32% originated from farm escapes, 17% from illegal liberations, and 41% from unknown sources (Fraser et al. (2000). Wilson (2011) similarly reports that most new populations of red deer in the Auckland Region orginated from deer farm escapees or illegal liberations.

Since 1996, some new populations of red deer might have established in lowland areas of Southland where they were not known to occur historically, e.g. Bluff Hill, Omaui, Sandy Point, Waituna/Awarua wetlands (Figure 1; Appendix 1; Colin Bishop, DOC, pers. comm.). However, only five survey respondents indicated that they were aware of new populations of red deer in Southland (an additional three respondents indicated 'wild deer', but did not specify species). Thus, although observational and anecdotal reports suggest the current distribution of red deer in Southland may be greater than previously recorded, a more rigorous survey is required to obtain information about specific distributions in relation to remnants of native lowland habitat with high conservation value, as well as identifying the potential source(s) of new populations. This information is necessary in order to develop effective management strategies and determine which patches of remnant native lowland habitat are at greatest risk from red deer impacts.

5.1.2 Fallow deer

Fallow deer are the second most widespread deer species in the wild in New Zealand (Nugent & Asher 2005). They are present in all regions and now occupy c. 5000 km². A survey of Southland indicated that they occupied 308 km² in 1996 (Fraser et al. 2000). One new population was identified in Southland in 1996; however, in New Zealand more generally, they represented 16.3% of all new wild ungulate populations at that time. Farm escapes and illegal liberations were responsible for 33% and 24% of these new populations, respectively. The source of a further 24% of new fallow deer populations identified in New Zealand between 1993 and 1996 was unknown.

Survey respondents identified new fallow deer populations in the Balfour, Riversdale, and Winton areas (Figure 1; Appendix 1). Further, DOC staff and hunters also reported that fallow deer distribution in lowland Southland has increased, e.g. to Lilburn Valley and Happy Valley near Tuatapere, the north Takitimu Mountains, Mid Dome, Josephville, and Riverton area (Colin Bishop, DOC, pers. comm.; Lindsay Youngman, NZDA, pers. comm.). More fallow deer than red deer populations appear to have become established in lowland Southland since 1996 (Fraser et al. 2000; Appendix 1). Because fallow deer have low dispersal rates (Nugent & Asher 2005), it is suspected that at least some of the newly identified populations of this species have been illegally liberated or escaped from farm enclosures. We believe there is a widespread perception of fallow deer being a particularly popular species for illegal release because of their low commercial value but high recreational value.

5.2 Feral pigs

Feral pigs occupied about 93 000 km² or 34% of New Zealand in 2000 (McIlroy 2005). Their estimated range in Southland in 1996 was 5444 km² (Fraser et al. 2000), and included the Waitutu area, Hokonui Hills, the Catlins, Takitimu Mountains, Longwood Range, Taringatura Hills, Eyre Mountains westwards, Forest Hill, and Waiau Valley (Garden et al. 2002). One new population was identified in Southland in 1996, and at that time they represented 9.7% of all new wild ungulate populations in New Zealand. Illegal liberations were confirmed as the primary source of 88% of new feral pig populations, with the remaining 12% suspected to have originated from illegal liberations. Deliberate translocations often involve the transfer of feral piglets to new areas (McIlroy 2005). Fraser et al. (2000) state that the number of new populations recorded for feral pigs (n = 25) in 1996 was likely to be a substantial underestimate.

Feral pigs were identified as widespread in rural Southland by survey respondents, and in many cases were perceived to be occurring in areas from which they have been absent in recent times (Figure 1; Appendix 1). At least some wildlife managers and hunters also believe that feral pigs have become a more widespread problem in lowland Southland in recent years (e.g. Colin Bishop, DOC, pers. comm.; Lindsay Youngman, NZDA, pers. comm.). It should be noted, however, that feral pigs may have been widespread on the Southland Plains historically (late-1800s and early-1900s). Their range would have retracted from this area as the human population increased. Thus, if the views of the above landowners and wildlife managers are accurate then feral pigs appear to be recolonising some areas of the Southland Plains.

Many of the locations where pigs are now being seen (e.g. Invercargill and Edendale areas) are probably too far from source populations for the mechanism behind the establishment of the new population to be natural spread. Consequently, it is suspected that there have been a number of recent illegal liberations of feral pigs (as was also found by Fraser et al. 2000).

5.3 Feral goats

Feral goats occupied 39 500 km² (c. 14%) of New Zealand and 761 km² of Southland in 1996 (Fraser et al. 2000; Parkes 2005c). Garden et al. (2002) reported that goat populations occurred in a number of scattered localities in Southland in 2002, including the Clinton Valley, Omaui, Takitimu Mountains, and the Catlins. Two new populations were identified in Southland in 1996, and at that time they represented 24% of all new wild ungulate populations in New Zealand. Approximately 80% of new populations originated from animals that had escaped from farms.

A small number of survey respondents indicated that they had seen feral goats in areas of rural Southland where they were not aware of them 5 years ago, e.g. Gore, Riversdale, and Winton areas (Figure 1; Appendix 1). Densities of feral goats on DOC land in Southland are reportedly being reduced (Colin Bishop, DOC, pers. comm.).



Figure 1 New populations of wild ungulates (feral goats, feral pigs, and deer, including both red deer and fallow deer) identified by respondents to an Environment Southland survey, May 2012. The map depicts a widespread distribution of new ungulate populations across the Southland Plains.

6 Impacts of wild ungulates

6.1 Biodiversity and ecosystem health

There has been a long history of conflict over the management of introduced wild ungulates in New Zealand. On the one hand there are those that have focused on the conservation of native biota and who see wild ungulates as pests, whereas on the other hand there are a number of hunting organisations who view wild ungulates as a valuable resource. Similarly, there has been considerable debate on the similarity of impacts on native vegetation between introduced ungulates and extinct moa (e.g. Caughley 1988, 1989; Atkinson and Greenwood 1989; Batcheler 1989; Craine et al. 2006; Forsyth et al. 2010). It is currently accepted by most that although wild ungulates have occupied all habitats historically utilised by moa and have a partially overlapping diet, ungulates, particularly at high densities, can cause widespread compositional changes to grasslands and forest understorey (Forsyth et al. 2010). Nugent et al. (2011) add that where highly valued native species are extremely vulnerable to deer and other ungulates, there is little prospect of successful management for both conservation and hunting, but where the key native species of interest are less susceptible to ungulates, there is scope to both protect such species and to provide for moderate sustainable harvest. This latter possibility reflects marked differences in the relationships between deer (for example) density and their effects on individual plant species depending on whether they are highly preferred and/or vulnerable to deer browsing (affected at all deer densities) or are not highly preferred and/or are highly browse resistant (affected only at very high deer densities or not at all) (Nugent et al. 2001).

The purpose of this report is not to add to this debate, but rather to identify documented and potential impacts of newly liberated and well-established populations of wild ungulates on biodiversity and ecosystem health in the Southland Region. Firstly, we provide a general overview of wild ungulates in New Zealand, before concentrating on areas in Southland with significant remnants of lowland native vegetation and habitat.

6.1.1 General overview of wild ungulate impacts on native biodiversity

The impacts of wild ungulates on native biodiversity and ecosystem health in New Zealand have been widely documented (e.g. Allen et al. 1984; Choquenot & Parkes 1999; Wardle et al. 2001; relevant wild ungulate chapters in King 2005; Forsyth et al. 2010). We provide a brief overview of these impacts for red deer, fallow deer, feral pigs, and feral goats. It is important to note that most research focuses on changes induced within a few decades (or at most a century or so) of areas being colonised for the first time by wild ungulates, so reflect only the short- and/or medium-term effects.

Generally, the changes caused by red deer and fallow deer to the native New Zealand forest are similar (Nugent & Asher 2005; Nugent & Fraser 2005). The most obvious impact of moderate to high deer densities in the previously-deer-free forest present at the time of European colonisation is their selective and progressive removal of preferred food species from the browse tier, and the significant changes that this can have on the composition of native vegetation in many areas (e.g. Forsyth et al. 2010). Initially, the density and complexity of forest understorey can be reduced by the loss of palatable herbs, shrubs, understorey woody species, and seedlings. Subcanopy trees can also be killed by bark-

stripping (Holloway 1950). Where the removal of such species increases the availability of light and nutrients, these losses are usually accompanied by an increase in some unpalatable and browse-resistant species, with horopito (*Pseudowintera colorata*) arguably the best known example of such a species. Common favoured species include: broadleaf (*Griselinia littoralis*), lancewood (*Pseudopanax crassifolius*), marbleleaf (*Carpodetus serratus*), māhoe (*Melicytus ramiflorus*), kāmahi (*Weinmannia racemosa*), and large-leaved *Coprosma* species. Numerous studies have confirmed patterns of deer diet, feeding preferences, and browse damage (e.g. Rogers & Leathwick 1997; Nugent et al. 2001).

Although deer can affect regeneration in some forests, the long-term consequences are less clear than short-term feeding patterns and diet preferences of deer. There is a tendency to assume, based on plant-herbivore theory, that there will be an overall decline in plant biomass. However, some studies have shown an increase, over 20 years of deer browsing, in overall stem density and basal area in a North Island forest, despite reduced regeneration of some favoured species (Husheer 2007). The key implication is that deer are likely to drive long-term changes in plant community composition, but not necessarily cause major declines in forest cover. Nugent and Fraser (2005) provide a thorough review of the long-term consequences of deer browse to native forests.

Browsing by goats can similarly change the composition and biomass of vegetation in the understorey of native forests (Parkes 2005c). Effects can be especially pronounced in areas where goat numbers are high because they receive a high proportion of the biomass that they consume from leaves and branches that fall from the inaccessible canopy (Nugent et al. 2001). If regenerating seedlings and young saplings are more palatable to goats than windfalls, then palatable species may be removed from the forest structure. On a number of offshore New Zealand Islands and mainland locations, goats have modified the forest to include a dense grassland/sedge ground layer (see references in Parkes 2005c). The implications of this non-linear relationship are that goats must be reduced to very low densities in forests before any benefit to understorey plants can be expected (Nugent et al. 2001).

The consequences of pig rooting on native plants, community succession and on whatever the pigs are rooting to eat (plants or animals) is not well known for most places (Choquenot et al. 1996; Krull 2012). However, pigs have been shown to cause severe damage to biota in some areas of New Zealand (McIlroy 2005). Their rooting disturbs the ground and can remove litter invertebrates such as earthworms, and this process may affect long-term ecosystem processes including nutrient cycling, plant species composition, and the distribution, abundance and role of worms and other litter and subterranean invertebrates (Thomson & Challies 1988; Choquenot & Parkes 1999). Feral pigs are contributing to the decline in the numbers of native snails (*Powelliphanta* spp.) by destroying snail habitat and eating snails and their eggs (Meads et al. 1984). Pigs can directly threaten ground-nesting birds, e.g. seabirds in Auckland Island and the Lord Howe Island woodhen (*Tricholimnas sylvestris*) (Challies 1975; Miller & Mullette 1985). Conversely, they have been shown to pose little direct threat to kiwi (*Apteryx* spp.), although dogs used for hunting pigs can kill kiwi (McIlroy 2005).

6.1.2 Potential impacts of wild ungulates on native biodiversity in Southland

Southland Region contains some of the most important areas of lowland podocarp forest remaining in New Zealand (Lloyd et al. 2008). This forest formerly covered most of the Southland Plains, but it has been greatly reduced and fragmented to small isolated patches. The Southland Plains also contain raised bog peatlands and coastal habitats such as sand dune forests, estuaries, wetlands, gravel beach vegetation, and headland turf ecosystems (Lloyd et al. 2008). Like all New Zealand ecosystems, native vegetation in lowland Southland evolved without mammalian herbivores. Wild ungulates have historically been absent from most of the Southland Plains (e.g. Fraser et al. 2000), but may be extending their geographic range or establishing new populations in some areas of lowland Southland. Wild ungulates could impact native biodiversity and ecosystem health in remnants of lowland native habitat. The mechanisms by which this would occur have not been well studied in the Southland Plains, but are expected to be similar to other areas of New Zealand where studies have been conducted (see above).

Of particular relevance to lowland Southland are investigations of white-tailed deer diet in mixed conifer–broadleaved forest on Stewart Island (Nugent & Challies 1988), fallow deer in the beech, mixed, and exotic forest of the Blue Mountains, West Otago (Nugent 1990), and red deer diet in the Murchison Mountains, Fiordland (Lavers 1978; Lavers et al. 1983). Despite the differences between studies in the deer species involved and the difference in plant species available, the feeding patterns and preferences in forest ecosystems appeared broadly similar. Of particular note, in these studies and others, forest-dwelling deer relied heavily on the fallen leaves of species such as broadleaf. That feeding pattern has major implications in determining how easily deer impacts can be reduced by reducing their densities.

Provided that the native biodiversity remnants of concern are now adequately fenced to prevent ingress by domestic livestock, the vegetation within them is likely to contain a comparatively large biomass of the plant species that are highly preferred by deer and goats. This will provide them with some resilience to browsing impacts when initially colonised by wild ungulates, with consumed off-take being small relative to annual production. It is only when ungulate numbers increase to moderate or high levels that the general statements of ungulate impact above would begin to prevail. It is therefore crucial that any risk assessment process used to prioritise both monitoring and control/eradication efforts in the formerly wild-ungulate-free parts of lowland Southland take into account the likelihood of the ungulate populations reaching high levels, i.e. the manageability of the problem. As a general principle, manageability decreases as the size of area increases.

6.2 Other impacts of wild ungulates

The economic and social consequences of wild ungulate overabundance on human activities have been well documented in many countries (e.g. Côté et al. 2004; Keuling et al. 2009).

Deer can damage agriculture, horticulture, and forestry. However, the severity of the damage depends on multiple factors including deer abundance, forest or crop attractiveness to deer, alternative food plants, and hunting pressure or wariness of deer to human-occupied areas. Deer, particularly when they become abundant, can damage gardens and ornamentals. To a lesser extent, deer can also damage fences and other infrastructure associated with farms,

orchards or gardens. Such damage is rare in New Zealand because landowners have the ability to permit unrestricted hunting on a year-round basis, and where there is little or no cover (as on the pasture-dominated landscape of the Southland Plains), even light hunting pressure is sufficient to eliminate problem deer, or at least keep them confined to larger areas of cover. However, damage by deer may become a localised problem in areas where landowners do not allow any hunting or attempt to maintain high densities of deer on their properties.

Feral pigs can damage crops, pasture, and forestry, as well as fences associated with these areas. They are also known to kill lambs. In general, these events are believed to be rare and localised, except in back-country farms that are close to native forest or large areas of gorse and bracken (McIlroy 2005). However, survey respondents often highlighted pig damage and predation on lambs as a concern (Appendix 1). Most damage done by feral goats in New Zealand is associated with native vegetation. Although goats, particularly at high numbers, can cause damage to agriculture, horticulture, and forestry (Hughes 1993), they are often also viewed as a useful method of controlling woody weeds such as gorse and sweet briar on farms (Parkes 2005c).

Most survey respondents were not concerned about the impacts of wild ungulates on agriculture (Appendix 1). However, 18% and 11% of respondents did indicate that they were very concerned about the impact of wild ungulates on pasture or crops and forest plantations, respectively. This concern might be related to negative experiences with wild ungulates impacting agricultural values, and thus the number of concerned landowners might be expected to increase as wild ungulates continue to expand and increase in numbers.

Fallow deer, red deer, and pigs infected with bovine TB have been confirmed in New Zealand (McIlroy 2005; Nugent & Asher 2005; Nugent & Fraser 2005). The prevalence of TB in wild New Zealand fallow deer populations is unknown, but high prevalences of TB infection in fallow deer have occasionally been reported for farms overseas (Nugent & Asher 2005). Fallow deer have been implicated as the cause of new TB outbreaks in cattle and farmed deer in New Zealand. There are occasional severe outbreaks of TB in farmed red deer in New Zealand, and red deer alone can maintain the disease when they are kept at high density. In the wild, however, deer-to-deer transmission of TB is rare and prevalence in deer declines when sympatric populations of infected possums are reduced to low densities (Nugent 2005a). Infected feral pigs are found in most areas where TB is established in other wild animals and livestock. Nationally, however, TB levels have declined by >95% over the last 18 years, and few cattle or deer herds are now infected (<60 nationwide). For the Southland Plains, intensive possum control is likely to have reduced possum numbers to well below the level at which TB could persist or re-establish, making it unlikely that wild ungulates could cause a TB problem in the near future.

Unlike North America, Japan, and Europe (Groot Bruinderink & Hazebroek 1996; Côté et al. 2004), collisions between vehicles and wild deer or other wild ungulates are comparatively uncommon in New Zealand. This reflects the strong contrast in hunting management between New Zealand and those countries; there, hunting is only permitted during short seasons, whereas in New Zealand hunting is permitted year round with no limits on age or sex. The consequence is that the most sought after species (deer and pigs) are usually reduced to low densities in accessible areas, reducing the potential for interaction with vehicles. Nonetheless, the results of a recent survey conducted in Southland indicated that approximately 20% of 58 rural landowners were aware of one or more collisions that had occurred between motor

vehicles and wild ungulates (Appendix 1; Figure 2). If wild ungulate numbers are increasing in Southland (as they are suspected to be), the number of collisions between motor vehicles and ungulates could also increase and possibly become at least a localised problem. Forty percent of survey respondents were concerned about the potential risk that wild ungulates could pose to motorists.



Figure 2 Fallow deer killed by a collision with a vehicle, Queenstown-Lakes District, Otago, April 2012 (photo: R. Bowman).

In general, survey respondents did not perceive wild ungulates to be a direct threat to human safety; although there was minor concern about the agressiveness of feral pigs and deer during the mating season (Appendix 1). However, illegal hunting (i.e. poaching) on private land or public land not designated for hunting was identified as a concern by >60% of survey respondents, and >40% were very concerned about poaching. Safety of humans and livestock was overwhelmingly the primary concern associated with poaching, particularly when spotlights are used to identify and shoot animals at night. The view was also expressed that many poachers/hunters do not adhere to rigorous safety standards when using firearms, and many firearm users are inadequately trained in firearms use (Appendix 1).

7 Methods for detecting and monitoring ungulate populations

There is a vast literature on methods for detecting and monitoring animal populations, including ungulates. To make this section less cumbersome, we provide a comprehensive review of these methods, particularly as they have been applied to ungulates, in Appendix 2. Here we have chosen to focus on monitoring theory and methods that are expected to be most applicable to wild ungulates and their management in Southland.

Monitoring programmes can be expensive. We emphasise the need to identify why wild ungulate management is necessary, the impacts that their management will mitigate, and that the management will mitigate any impacts they cause. This may include monitoring their potential impacts to native biodiversity in high-conservation-value areas or agricultural production and human safety.

7.1 Monitoring decision process

Predicting and quantifying the current and potential distributions and population trends of wild ungulates is a critical step in evaluating management options (e.g. Gormley et al. 2011). For example, control and eradication efforts should focus on the current distribution, containment should focus on the interface between the current and potential distributions, and incursion monitoring should focus on the potential distribution (e.g. Myers et al. 2000). In Figure 3 we provide a monitoring decision process for likely scenarios for managing wild ungulates in Southland. This monitoring decision process initially assumes that animals need to be detected in an area, and then if detected in an area, it outlines various management options, some of which may require population trends to be monitored.

The first line of defence against invading species is early detection (Gherardi & Angiolini 2008). This is because detecting an invasive species, particularly one that is suspected to be an aggressive coloniser, before it becomes established maximises the chances of eradication. Thus, methods are required to confirm the presence of one or more wild ungulate species in an area where they are suspected to be or to have some degree of certainty that they are absent from that area. If eradication of a species from an area has been attempted, it is also important to have some degree of certainty that no individuals remain in that area or to identify reinvasion before the invaders establish and become a problem again. Formal survey methods related to this component are called 'detection' or 'presence/absence' monitoring. Camera traps and faecal pellet transect and sign surveys are examples of methods that are often used in detection studies for ungulates (Table 1).

In addition to formal systematic presence/absence surveys, informal reporting by landowners or other interested observers often provides a first indication of a problem, particularly in the context of lowland Southland where the areas of interest are typically small remnants surrounded by developed lands. For example, Fraser et al. (2003) note that unreported escapes and illegal liberations of deer are generally first noticed by landowners, and in Northland, DOC has a toll-free number (0800 FIND DEER), which reports to the deer project coordinator. This system has already resulted in the successful recapture of several mass deer escapes, i.e. it encourages farmers to report early and not just rely on their own devices, and is visible evidence that management agencies are taking the problem seriously. **Table 1** There are numerous methods that have been used to monitor wild ungulate populations or the outcome of their control (see Appendix 2); in this table we summarise those methods that are likely to be most applicable to monitoring wild ungulate populations in Southland Region. Note that we have included 'DNA-based capture–recapture' as a recent advance in monitoring; however, because of the current high cost of this method we do not at present advocate its use for wild ungulate management in Southland.

Method	Species	Main advantages	Main disadvantages	
Information from the public	All	Cheap, and often provides the first indication of animal 'presence'	May provide limited or unreliable information about distribution and population size	
Faecal pellet surveys	Deer, goats	Useful index of abundance; established protocol for New Zealand; non-invasive	Can be difficult to differentiate between pellets if more than one species is present; prone to biases associated with defecation and decomposition rates; has been used to estimate density, but this is controversial	
Camera traps	All	Non-invasive; usually provide accurate determination of species; can provide robust index of abundance	Initial cost of cameras is high	
Catch-Per-Unit-Effort (Hunter index)	All	May be a useful index if rigorous data are available; cheap if data are obtained from routine control work	Difficult to meet assumptions, i.e. suited to large populations subject to intensive and well- recorded hunting effort	
DNA-based capture– recapture ¹	All	Can provide good estimates of density and abundance	Expensive; vulnerable to genotyping errors and individual heterogeneity in capture probability ²	
Forward-looking infrared (FLIR) cameras	All	May be useful to determine presence of new populations or to estimate minimum population size in open/semi- open habitat	Difficult to detect animals through forest canopy	
Seedling ratios	Deer, goats	Robust, affordable tool to monitor the short-term outcomes of ungulate control	May not be useful to assess effect of pig-rooting, and not useful to assess effects on native animals or in grassland	

¹ DOC is currently funding the development of techniques for reliable recovery of DNA from ungulate faeces, which is showing promising signs of success, and which could make this option a cheap way of assessing population size when the population is small (<20 individuals).

² Methods have been developed to account for genotyping errors and individual heterogeneity in capture probability (see Appendix 2 for details).

Where formal surveys are conducted, the probability of detecting a single wild animal (perhaps an escapee from a deer farm) or a few wild animals is very low, and data from detection surveys will consist mostly (or entirely) of no detections. It is difficult to interpret what the 'zeros' represent. Are they reflective of no animals in the area surveyed or a lack of ability to detect the individual/s in the area surveyed? Current presence/absence methods allow detection probabilities to be estimated, i.e. to estimate the probability that an individual is observed or detected at a site given that it was present at a sampling point. For example, Gormley et al. (2011) used a combination of detection methods to determine 'presence', and found that this approach improved the detection probability by about 25% compared with the best method (faecal pellet groups) used alone. However, this study represents a best-case scenario because it was conducted in an area where many deer were present. In the case of low density or patchy new wild ungulate populations a stratified design is recommended, i.e. more effort (e.g. faecal pellet transects) would be given to areas known or suspected to have most animals (Fraser et al. 2003). Attempts to eradicate a population from an area are faced with the same problem as described above, i.e. do no detections mean that the population has been eradicated or that the survivors were not detected in the survey? In reality, and as discussed above, 'presence' is often confirmed qualitatively from observations made by people working or living in the area (Fraser et al. 2003).

Three choices are available if no animals are detected in a survey: cease monitoring, monitor periodically or monitor continuously (Figure 3). Given the expense associated with surveys, continuous formal monitoring is likely not affordable; although a 'wild ungulate hotline' could be established as a low-cost alternative. Similarly, formal surveys may need to be restricted to high-conservation-value areas at greatest risk and neighbouring habitat that might facilitate the movement of wild ungulates into the area of conservation concern, i.e. movement corridors. If wild ungulates are detected in an area, there are five steps that managers might choose to take: no management action; monitor population trends with no other management action; attempt to eradicate the population with subsequent monitoring; control the population without monitoring; and control the population with monitoring (Figure 3).

In some cases it may be necessary to monitor population trends or estimate density or abundance of existing populations. This may be particularly relevant to situations where control aims to keep wild ungulate numbers low to minimise their negative impacts or when no control is deemed necessary unless a population increases to or beyond some predetermined threshold. There are myriad methods for monitoring ungulate populations, many of which we discuss in Appendix 2. Because of the logistical difficulty, expense, and often difficult-to-meet assumptions of density estimation methods (e.g. Krebs 1998), we suggest that indices of abundance are likely more appropriate and affordable methods for wild ungulate management in Southland. For large well-established populations, cameras and faecal pellet transects are often used to infer trends in ungulate population abundance, and seedling ratios have been used as a robust, affordable tool to monitor the short-term outcomes of ungulate control (Fraser et al. 2003; Sweetapple & Nugent 2004). New methods involving DNA obtained from hair or faecal pellets have been used successfully to estimate population size, but are currently expensive and thus not recommended for widespread use at present (but see comment in Table 1; also see Appendix 2 for a discussion on DNA-based capturerecapture).



Figure 3 Schematic of a monitoring decision process that assumes that wild ungulates first need to be detected, i.e. establish their presence or absence in a location. If animals are detected, next steps may involve the development of a strategy (or strategies) to manage them or mitigate their effects (see text). If they are not detected, managers must decide whether to continue to monitor a site or not. The flow chart leads the reader to recommended monitoring methodology via the grey arrows (monitoring methods are discussed in more detail in Appendix 2).

The appropriate monitoring method/s and survey design for wild ungulates in Southland will be dependent upon a number of factors. The design will likely be site- and/or scale-specific, wild ungulate species specific, and management-objective-specific. We highlight those monitoring methods that are most likely applicable to wild ungulate management in Southland (Table 1). However, we reiterate that monitoring programmes are often expensive and long-term, and thus clear management objectives should be identified prior to embarking on monitoring, or attempts to control or eradicate wild ungulates.

8 Strategies for managing the impacts of wild ungulates

The qualitative information used to assess wild ungulate distribution in lowland Southland in this report suggests that wild deer and feral pigs have far wider distributions than previously suspected. Indeed it was suggested that all suitable habitat (patches of forest and scrub) on the Southland Plains has at least low densities or errant individuals of one or more wild ungulate species (see Appendix 1; Colin Bishop, DOC, pers. comm.).

To use the terminology in the Environment Southland Regional Pest Management Strategy (2007), lowland Southland may no longer be in the Absent Phase of the Infestation Curve. Rather, survey data and anecdotal observations suggest that many areas may have ungulate populations in the Lag Phase (initial establishment), whereas some areas may have reached the Explosive Phase (populations and density are increasing rapidly). This has major implications for management.

This 'infestation curve' typology appears to be largely based on the 'eruptive oscillation' concept of population growth that often follows colonisation of a previously unoccupied area in which a large supply of food has accumulated. However, there is an implicit assumption that the population is not automatically limited by hunting, an assumption that depends on whether or not the species is (1) highly desired as a game animal (i.e. deer and pigs are more desirable than goats); (2) protected by the landowner (some landowners are known to want to establish viable populations for hunting on their land), and (3) the amount and nature of cover available.

Focusing on the latter, unforested areas surrounded by farmland provide poor cover for ungulates, so these are likely to be noticed quickly by landowners. The same is true of forest remnants of only a few hectares (i.e. much smaller than the usual home range of the ungulates, with is of the order of 100 ha for female fallow deer (Nugent & Asher 2005), 2–3 times larger for red deer (Nugent & Fraser 2005), and larger still for pigs (McIlroy 2005) . The New Zealand hunting culture is such that visible game animals are typically removed quickly (either legally or illegally). There is therefore little risk of new populations in such areas going unnoticed and reaching high density, unless protected by the landowner. This is especially so for unforested areas. Without government-funded intervention, the likely outcome in such small areas of up to several hundred hectares is that the population will either be driven to extinction by private hunting, or will persist at low density (especially if topped up by ongoing colonisation events). In that situation, impacts of deer and goats on plant communities are likely to vary widely, but if there is a large accumulation of preferred food plant biomass, and easy access to high-quality pasture nearby, it is likely that effects will be restricted to only the most highly preferred plant species.

For areas of more than 100 ha or so, especially those within a few kilometres of a large established source population, there is likely to be a greater risk of populations reaching densities at which their impacts could substantially affect the native biota. We suggest that these areas should be the main areas of concern in lowland Southland. The key information needs are therefore a knowledge of the size and distribution of previously (pre-2000) ungulate free remnants of predominantly indigenous biota, some characterisation of the nature of cover (from hunting and casual visual detection), and their location in relation to potential source populations. That would allow an assessment of risk of permanent establishment, the potential to reach high density in the absence of governmental

intervention, and the likely ease of eradication – a level of detailed assessment that is beyond the scope of this report.

For the larger at-risk areas, and as noted previously, early detection of invading species is key to attempts at eradication or control to 'zero density' (Gherardi & Angiolini 2008). Where rigorous formal longitudinal monitoring (i.e. not a one-off survey) of high-conservation-value areas is conducted, early detection is most likely to occur in the Lag Phase, which is also defined as the period when attempts at eradication are most likely to be successful. However, while eradication might be cost-effective and logistically feasible in the site in which the population was detected, the eradication programme should consider the target site in the context of the spatial mosaic surrounding it, i.e. eradication efforts are likely to be affected by spatial scale. This may be particularly relevant to wild ungulate management in lowland Southland if populations are as widespread as currently suspected. In other words, eradication efforts at a chosen site might be continually hampered by reinvasion from the source populations surrounding it.

Although it is difficult to determine appropriate management strategies because of the dearth of information about the current distribution, densities, and impacts of wild ungulates, we suggest a precautionary approach to the management of these animals in recently occupied high-conservation-value sites in lowland areas. That is, because evidence shows that wild ungulates can negatively impact native vegetation (see 6.1.1 above), they should be managed as pests and where possible they should be prevented from expanding into areas from which they were previously absent, or if already present, they should if possible be eradicated. If populations are found to have 'escaped' the Lag Phase and entered the Explosive or Consolidation Phases this might not be feasible; in this instance we discuss other possible management strategies.

Many techniques are available to deal with new ungulate populations. If the animals are of domestic origin, the best and cheapest option is for farmers to immediately muster or lure any escaped individuals back behind their fences (Fraser et al. 2003). Alternatively, ground hunting with or without dogs, as well as some limited opportunity for aerial shooting, are likely to be the most feasible methods for removing better-established populations of wild ungulates from patches of suitable habitat in lowland Southland (Fraser et al. 2003). In some areas, particularly small patches of native forest where ungulates are present, it might be possible to use a 'wall-of-death' approach whereby professional hunters are employed to systematically work their way through the patch and ideally shoot all individuals in the population. Many ungulate populations have been successfully eradicated from New Zealand using this approach (Fraser et al. 2003). However, as is illustrated by ongoing (c. 15 years) attempts to eradicate the Russell sika deer (Cervus nippon) population, this can be difficult (J. Parkes, unpubl. Landcare Research report). Further, even if eradication from the targeted patch was successful, it would prove fruitless if source populations allowed for easy reinvasion. Wild ungulate populations within the source populations may in some instances also be controlled to low densities; however, extending control or eradication to include source populations then becomes an even greater logistical and financial challenge.

If wild ungulates have spread throughout most of the Southland Plains, as is suspected to be the case, it is unlikely that eradication and maintenance of near zero-densities will be possible from all areas. Rather eradication is most likely to be successful in the most isolated patches of habitat, i.e. forested patches located in predominantly pastureland and far from source populations. In high-conservation-value sites that are prone to reinvasion, the most feasible and practical management option may be surrounding the site with a high deer- (or other species) proof fence. Due to the destructive capability of feral pigs, consideration will need to be given to the structure of fences (or if they are feasible at all) in areas where pigs are present. Lethal control of pigs may be required. Control options for feral pigs have been thoroughly described in unpublished reports (e.g. Parkes unpubl. 2011, 2012; Saunders & Yockney unpubl. 2012); for convenience, we provide a summary of these methods in Appendix 3.

Because of the close proximity of many lowland sites to small urban communities or rural residences, poisoning of wild ungulates will likely not be an option. Eighty-three percent of survey respondents stated that they would prefer to see wild ungulate populations controlled by professional or recreational hunters (Appendix 1), suggesting that poisoning of ungulates will be controversial. Further, risks to domestic dogs if 1080 poison is used are significant from both primary and secondary poisoning. A plan to avoid this risk (no baiting on private land where dogs are present, removal of dogs while poison is available, provision of muzzles, etc.) would be required. Finally, there are no toxins currently registered for use on feral pigs in New Zealand, so poisoning is not a legal option for controlling this species at present. However, note that encapsulated sodium nitrite (a new toxin for feral pigs) is anticipated to become available for commercial release soon, and it may become a valuable tool for controlling the impacts of feral pigs and possibly deter their illegal release.

It is difficult to provide a single best strategy, or indeed a suite of appropriate strategies, for managing wild ungulates in lowland Southland. Currently, there are too many 'unknowns' that require further assessment before effective management strategies can be developed. The distributions of the various species need to be more clearly understood. High-conservation-value areas affected by invading wild ungulates need to be identified and prioritised. Key factors such as ecological and environmental importance of each area, relative probability of successful control or eradication, probability of reinvasion, etc., will need to be assessed. Strategies will likely need to be considered and designed on a site-by-site basis.

9 Conclusions

- Available information suggests that wild ungulates, particularly red deer, fallow deer, and pigs, are currently widespread in lowland Southland, and may be expanding their ranges and increasing in numbers. The mechanisms responsible for new populations and range extension are not well understood, but are expected to include natural range extension, farm escapes, and illegal liberations.
- The Southland Plains contain remnant native vegetation of high conservation value. Expanding wild ungulate populations may threaten native ecosystems in lowland areas, and it may be necessary to adopt a precautionary approach whereby they are eradicated, controlled or excluded from selected locations.
- About half of respondents to a survey on attitudes to new populations of wild ungulates in Southland indicated they were concerned about the effects of these animals on native vegetation and fauna. Many were also concerned about the impacts or potential impacts to agriculture (particularly TB transmission, pasture, and crops), forestry, and human safety (collisions between motor vehicles and animals).
- The survey also identified a broader issue associated with expanding wild ungulate populations and their spatial distribution in relation to increasing human populations in

Southland, as well as New Zealand more generally, and that is safety. Poor knowledge and skills associated with the use of firearms, as well as not clearly identifying targets, were issues of high concern to respondents. These problems are not confined to poachers but also to many legal hunters. These issues are recognised by some organisations in New Zealand and good-hunter training and safety courses are provided, e.g. the Hunter National Training Scheme (HUNTS). Although unlikely to deter all poachers or eliminate all risk associated with this activity, mandatory hunter education courses in firearms safety and use, target identification, game animal species, ecology and ethics may help to further educate hunters and promote safety in New Zealand and reduce firearms-related incidents.

• A lack of information precludes detailed, site- and species-specific management strategies for wild ungulates from being developed for Southland. However, ground-based hunting and limited aerial shooting are likely to be the most feasible lethal control options in most locations. Protecting selected sites of high conservation value with high fences may also be a useful tool in some areas.

10 Recommendations

- Environment Southland should clearly articulate its goals and objectives for managing expanding wild ungulate populations on the Southland Plains. Do wild ungulate populations need to be controlled or eradicated, and if so, what impacts will management aim to mitigate? How will future incursions of wild ungulates be prevented?
- If the conservation of threatened native lowland sites is considered a high priority, then lowland sites that were until recently wild ungulate free need to be identified. The location and size of such areas should be comprehensively mapped, and sites should be prioritised based on their native biodiversity value, the potential impact of wild ungulates on that value, as well as the likelihood of preventing wild ungulate expansion into valued sites (if it has not yet occurred) or eliminating or mitigating their impact if they are present.
- Currently there is limited information about the distribution of wild ungulates in lowland Southland. We recommend that more detailed formal surveys of high-priority conservation areas and their surrounds will likely be necessary before effective strategies can be designed to mitigate the impact of wild ungulates. Survey design and methodology may differ based on geography, size of sites, species present, and management objectives. In addition, a survey using more detailed questions and targeted at a greater proportion of Southland residents might provide further information about the status of wild ungulates in the region.
- Environment Southland should decide on a strategic approach for such areas, choosing between either (1) precautionary eradication of all new populations as they emerge in order to eliminate the risk of future unwanted effects on the structure and composition of the few remaining areas dominated by native biota; or (2) implementing low-level 'risk-identification' monitoring and implementing ungulate control in priority areas only when that monitoring identifies a risk of population increase to moderate or high levels.

- Because many new populations of wild ungulates are believed to have originated from farm escapes or illegal liberations, Environment Southland should consider undertaking a public awareness and community education programme. This programme should focus on the expansion of wild ungulates into areas of Southland from which they were previously absent, and the potential harmful effects that their expansion could have on remnant natural areas, agricultural production, and public safety. If Environment Southland decides that its management goal is eradication (or maintaining zero density) of wild ungulate populations on the Southland Plains, we recommend that DOC's management of wild/feral deer in Taranaki and Northland could be used as a model for Southland.
- In some areas, wild ungulates may have established populations that have distributions that fall under the administration of more than one organisation (national, regional or local). We recommend greater communication between organisations tasked with managing expanding populations of wild ungulates in Southland, including defining goals related to the management of wild ungulates in and adjacent to conservation reserves, sharing knowledge, and designing and implementing management strategies.

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Appendix 1 – Attitudes towards new populations of wild ungulates and their impacts and management in Southland Region

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Introduction

From the database provided, Sigma Group managed to contact 60 people, 58 of whom decided to participate in the survey. As this survey is a qualitative survey, the comments are more important than the percentage responses provided (as the margins of error will be very large – given the small sample size in relation to the size of the population in the area). However, the percentages will provide a valuable in-sight into the views and opinions of the respondents which may have to confirmed with a larger survey at sometime in the future (if required).

The comments listed in this report are preceded by a number. This number refers to the particular respondents. Thus '2' prior to the comment is respondent number two, hence this particular respondent's responses can be followed throughout the report to identify trends. Similarly the demographic section also identifies the respondent via their number. Thus, respondent '2' is a male dairy farmer between the ages of 35 years and 50 years.

Attitudes towards new populations of wild animals and their impacts and management in Southland Region

1. Deer, goat, and pig presence

Environment Southland (ES) is seeking information on the distribution of wild deer, pigs and goats, generally described as wild animals, in lowland areas of Southland with high conservation values.

- a.) Are you aware that these wild animals may be extending their range through natural spread, illegal liberations or escapes from farms into lowland areas in Southland?
- Yes: 83% No: 17% Don't know: 0%
 - b.) Are you aware of any wild animals on your property? On neighbouring properties? If so, what species and when?
- Yes: 42% No: 58% Don't know: 0%

Species and when

- 1 Red deer, now and again in the morning.
- 8 Wild pigs and red deer. They are over there all the time.
- 13 Wild pigs, wild red deer, and wild goats. Goats all the time, deer in the early morning.
- Never see the pigs, only the damage they do.
- 15 Wild red deer always there.
- 17 Wild red deer all the time, wild pigs rarely.
- 21 Wild pigs and red deer, sometimes on a daily basis.
- 24 Wild deer. Come out at night.
- 27 Wild red deer at least once a year.
- 28 Wild red deer and wild pigs.
- 31 Red deer and wild pigs, they come and go.
- 32 Wild pigs and red deer.
- 35 Wild pigs and deer.
- 36 Red deer. Lowland Southland areas and river beds.
- 39 Wild pigs rooting up the ground.
- 42 Wild deer and wild pigs. They are always there.
- 44 Fallow deer, they come and go. Wild pigs from time to time but get rid of them easily.
- 45 Deer, possums, and goats. Deer about 20 times a year. Possums always at night. Goats about 30 times a year.
- 47 Red deer.
- 49 Had a few wild deer but nothing lately.
- 51 Wild deer every now and again.
- 52 Fallow deer, red deer, and wild pigs. Most are living on our property.
- 53 Wild goats.
- 54 Wild pigs and red deer.
 - c.) Are you aware of any wild animals elsewhere in rural Southland where you were not aware of them 5 years ago? If so, what species, when and where?
 - Yes: 14% No: 86% Don't know: 0%

Species – when and where (for 'Yes' respondents)

- 7 February, hills, red deer.
- 9 Round Hill, red deer.
- 10 Wild pigs, red and fallow deer, and goats.
- 11 Wild red deer and wild pigs.
- 13 Pigs in Lumsden.
- 22 Wild pigs, Tuatapere and Lumsden areas.
- 23 Wild pigs, Island Bush.
- 28 Red deer, more numerous and widespread but don't cause us any trouble.
- 33 Wild pigs, wild deer, and goats. Wild pigs kill the lambs.
- 38 Wild deer seen in the last 5 years.
- 40 Wild pigs in the Hokonui Hills.
- 49 Wild deer over the last 5 years but none before that.
- 57 Wild pigs in Te Anau.

2. Towards an understanding of impacts

Recreational hunting of wild animals is an important economic, social and cultural activity for many people in Southland. The following set of questions is not directed towards existing wild animal populations or hunting opportunities. Instead it is aimed at gaining an understanding of the potential impacts of new populations of wild animals on the environment and farming in the more developed and populated areas in Southland.

Environmental Impacts

- a.) Are you aware of any impacts that wild animals are having on the environment? (This may include: damage to native vegetation because of browsing or rubbing, pig rooting, trampling in swamps, grazing in swamps, grasslands, etc.) If so, what impacts, which species are responsible, and where have the impacts occurred?
- Yes: 53% No: 47% Don't know: 0%

Species and where impacts (for 'Yes' respondents)

3 – Wild pigs rooting road. Wild goats eating plants. Red deer digging holes in the ground.

5 – Pigs rooting the ground. Deer damaging native vegetation.

8 – Pig rooting.

10 – Pigs rooting up the ground. Deer damaging young trees.

11 – Pigs and deer are doing most of the above. Pigs root, graze and knock bush around a bit.

- 12 Pigs rooting the ground. Red deer and goats kill trees by digging and bashing them.
- 13 Pigs rooting. Deer eating crops. And goats eat whatever they want.
- 14 Red deer eat small plants in the forest.
- 15 Red deer do damage to fences and eat crops.
- 16 Wild pigs rooting the ground. Wild deer eat the native bush.
- 19 Wild pigs root the ground in several areas, mainly around the hills.
- 20 Wild pigs transmission of TB.
- 21 Pigs rooting up the ground. Deer knocking all the bark off trees on our farm.
- 22 Wild pigs rooting up the ground.

24 – Wild pigs, wild deer, wild goats, and wild possums. Pigs root up ground, destroy water and soil value. Deer do the same. Goats eat everything. Possums then finish off the rest of vegetation.

- 25 Pigs rooting in the ground and killing lambs.
- 29 Wild pigs make a mess wherever they go rooting up the ground.
- 31 Wild pigs rooting the ground. Wild deer eat the crops.
- 32 Pigs root ground. Deer open up native bush by eating the under growth and ruin it.
- 34 Wild geese and wild pig rooting.
- 35 Wild pigs but no actual impact on grazing.

40 – Deer and pigs cause a lot of damage. Pigs root the ground and carry TB. So worry about contact with my herd of cows.

41 – Wild pigs.

42 – Wild pig problems rooting up the ground. Wild deer eating the young plants in the bush.

45 – Goats and deer eating our crops and possums have an impact on our native vegetation.

- 47 Red deer, but don't do significant damage.
- 52 Pigs root up the grass. Deer wallow in the bogs but no great deal of damage.
- 54 Pigs rooting the ground. Wild deer stripping the trees.
- 56 Pigs rooting the ground and deer eating young native trees.
- 57 Wild pigs rooting the ground.

b.) Are you concerned about wild animals affecting any of the following:

- a. Native vegetation.
- Yes: 49% No: 51% Don't know: 0%
 - b. Habitat for native fauna.
- Yes: 53% No: 47% Don't know: 0%
 - c.) Do you think wild animals are having or could have long-term effects on the biodiversity values contained in native habitats on private land in Southland?
- Yes: 56% No: 44% Don't know: 0%
 - d.) Do you have any other concerns about wild animals and their impacts on the environment?

Responses from 'Yes' respondents

8 – Illegal releases of pigs. More control of pigs, not in native bush areas but on the pine tree areas.

12 – Wild geese eat the grass ahead of the sheep. Possums carry TB and must be kept to a limited amount.

- 13 The disease that the wild animals bring with them.
- 14 Possums can cause the spreading of TB.
- 16 Pigs and possums carry TB, which is always a concern.
- 21 Possums are a big concern as they strip the bark on the native trees.
- 22 Wild pigs carrying TB.
- 27 If they are not controlled they would have a bad impact on the environment.

29 – Concern about ferrets and stoats. They kill and eat our native birds. Possums because they spread TB and eat our vegetation and mature trees.

- 30 Have concerns of the bovine TB carried by the possums.
- 33 Possums kill the bird life which is not good as they take the eggs.
- 35 Animals could breed disease like TB.
- 36 Yes, but it is the same and no greater than domestic animals.
- 38 TB and local diseases.
- 42 The main problem is to control the population so the deer don't eat our crops.
- 45 Have an effect on cropping by eating it.
- 46 Only with regard to TB issues.

47 – Pigs root up the land but not to any great extent, because the numbers aren't high enough.

48 – The possums are encroaching in native areas and feed on bird and plants and spread TB.

- 49 The cattle farmers. TB is spreading from the wild deer and wild pigs.
- 52 Main concerns are the spread of TB.
- 56 Damage to native and nature in general.
- 57 None as they don't expand too much.

Responses from 'No' respondents

2 – Consider the use of 1080 by DOC as more of a problem.

54 – Possums are eating bird's eggs.

Economic Impacts

a.) Are you aware of any economic impacts associated with wild animals on your property? On neighbouring properties? (Including, but not limited to, damage to fences, pasture or crop loss, interference with livestock, water troughs, etc.) If so, what impacts and what species?

My property:

• Yes: 27% No: 73% Don't know: 0%

Neighbour's property:

• Yes: 22% No: 78% Don't know: 0%

Species and what impact (for 'Yes' respondents)

- 7 Wild pigs rooting the ground.
- 9 Mallard ducks.
- 10 Deer eat the crops. Wild pigs eating lambs.
- 11 Mainly eating grass and some eat the crops.
- 13 Deer and goats eat crops. Concerned that the pigs are eating young lambs.
- 17 Deer eating my crops.
- 21 Deer damage to the crops and grasses and certain amount of pig rooting on the paddocks.
- 22 Wild pigs kill the lambs and cause pasture damage, and deer grazing on winter crops.
- 31 Deer eat the crops and damage fences.

32 – The wild pigs rooting the ground. Deer taking swedes. Pigs, deer, possums, and stoats are responsible for spread of TB.

42 – Wild deer knock down fences, and spread disease that can be transferred from deer to cattle.

- 45 Crop losses by deer and goats eating it.
- 49 Damage to fences quite often Deer break top fences.
- 52 Lose the odd lamb.

- b.) Do wild animals represent an economic opportunity (positive) or are they an economic liability (negative) in lowland Southland? Why?
- Opportunity: 44% Liability: 46% Don't know: 10%

'Why?' Opportunity comments:

1 – They can be harvested.

4 – It is good for hunters. Shooting them helps to get rid of them.

9 – The whole deer industry has been based on feral deer, also the recreational hunter can sell the meat.

- 11 Because they could be commercially sold for meat.
- 14 Opportunities for the hunters to use the meat or to sell at restaurants. Or for own use.
- 18 Good for hunting and selling meat to restaurants.
- 19 Opportunity for recreational hunters.
- 23 Game meat able to be sold in NZ.
- 24 The skins, meat and horns are of value when sold.

25 – Recreational hunters and professional hunters can sell the meat in international and domestic markets.

26 – Good for hunting and export of meat. But there is a possibility of the numbers becoming too great.

- 28 The hunting and selling of meat.
- 29 Offer opportunities for game shot and meat if you want it.
- 33 Good for hunters and sport.

34 – Hunting tourists from overseas are good for the area probably wouldn't come otherwise.

- 36 For recreational hunters and commercial hunting and as an export for NZ.
- 37 Meat can be exported and good for NZ.
- 41 Because a lot of people like to go hunting.
- 44 Because of recreational value for local hunters.
- 47 The hunting benefits for tourism and meat value.
- 50 The meat can be sold for human consumption and can be exported.
- 53 Because they provide sport and meat.
- 54 A lot of people like hunting them.
- 55 For recreational hunters, which is a great sport.
- 56 Recreational hunters can make money by selling wild meat / skins.
- 57 Because they eat out stock making our operation more expensive.

'Why?' Liability comments:

1 – Because if you have any wild animals like pigs they can damage the property.

- 5 The damage they do and the risk of carrying diseases.
- 7 It costs money to keep them under control and replacing the damage they do.
- 8 They don't provide economic benefit at all.
- 10 Because they cost us money every year by eating our food.
- 12 They are of no value to the farmer if not a hunter but do a lot of damage to farms.
- 13 They do a lot of damage, and if uncontrolled chase and attack livestock. Hunters without permission on property chasing wild animals also a problem.
- 15 Red deer are dangerous and damage fences to get in.

- 16 The damage they do to land on farm and eating crops.
- 20 The cause of a lot of damage and the risk of carrying disease.
- 21 Because we lose out on the grass they graze.
- 29 Because if they are not controlled they will eventually make an environmental impact.
- 22 Unless the numbers are kept down the farmers have a problem with recreational
- hunters who are quite dangerous. They kill the male and leave the female with her babies.

27 – From a hunter's point of view they could be really economic but from a

conservationist's point of view a liability.

- 31 Not many options of commercially harvesting them.
- 32 Because of the economic cost they cause.
- 35 If they cause problems then they are a liability.
- 39 Because of damaging fences and water troughs, etc.
- 42 Because they are destructive.
- 45 They are affecting the income of farming enterprises.
- 46 Once again the issue of spread of TB.
- 49 Because of the damage they can do to farms.

52 – As soon as people want money they start farming them and will never get rid of them that way.

58 – They carry diseases and can pass them on to other animals.

Agricultural impacts

- c.) Are you aware of any wild animal impacts to any of the following, and how concerned are you? (not concerned/somewhat concerned/very concerned):
 - i. Pasture or crops.
- Not concerned: 56% Somewhat concerned: 26% Very concerned: 18%
 - ii. Forest plantations.
- Not concerned: 61% Somewhat concerned: 28% Very concerned: 11%
 - iii. Market gardens or orchards.
- Not concerned: 79% Somewhat concerned: 16% Very concerned: 5%
 - iv. Nurseries or residential lawns and gardens.
- Not concerned: 85% Somewhat concerned: 12% Very concerned: 3%
 - d.) Are you aware that wild deer, pigs and goats might facilitate the transmission of bovine tuberculosis?
- Yes: 96% No: 4% Don't know: 0%
 - e.) Are you concerned about any of the potential impacts of wild animal activity for agriculture? If so, which impacts are of greatest concern? If not, could you comment on the reason?
- Yes: 75% No: 25% Don't know: 0%

Comments from 'Yes' respondents

- 2 Once again the economic cost of a TB outbreak would be high.
- 5 Very concerned of a TB outbreak.
- 7 You would never know when there could be an outbreak of TB.
- 9 General concern of TB outbreak.
- 10 It is a concern especially with wild pigs spreading the TB disease.
- 11 Always concerned there could be an outbreak of TB.
- 12 Always a worry about the breakout of TB.
- 13 Deer give my cattle TB on my farm.
- 14 Would be very concerned if they transmit the TB disease.
- 15 Always the concern in case of outbreak of TB.
- 16 Always afraid of an outbreak of TB.
- 18 There are that many rules in place and if you keep to the rules you should be ok.
- 19 Always concerned about an outbreak of TB.
- 20 An outbreak of TB.
- 21 Always concerned about TB outbreak.
- 22 The bovine TB is always a concern amongst cattle because it would affect the overseas markets. Also deer farmers are concerned about TB.
- 23 Concerned they spread TB.
- 24 Cause outbreak of TB.
- 25 Concerned about outbreak of TB and pigs carrying other diseases as well.
- 26 Concerned about an outbreak of TB.
- 27 An outbreak of TB would set back all the work the AHB and MAF have done in almost eradicating this disease.

28 – If pigs increased, but I feel there is enough private control to keep the numbers down. Always concerned about a TB outbreak.

- 29 Because of a TB outbreak and too many wild animals in certain places.
- 30 Always concerned of an outbreak of TB in the animals.
- 32 Concerned about the TB outbreak even though it seems under control.
- 33 Concerned about TB outbreak among Cattle.
- 35 They pollute the water ways.
- 37 Concerned about a TB outbreak.
- 38 Concerned about a TB outbreak.
- 39 Concerned but I don't think it is a problem in lowland Southland at this stage.
- 40 Always concerned if the cows got TB.
- 42 The threat of TB to cattle.
- 43 Have concerns about bovine TB spreading among wild animals and infecting our cattle on our dairy farm.
- 44 Wild pigs are a problem if they get out of control.
- 45 They affect the export earnings of the agriculture throughout the country.
- 46 The spread of TB.
- 47 The TB, but I feel it is well addressed by the Animal Health Board.
- 48 The spread of TB.
- 49 The TB in wild animals which they can spread to farm animals.
- 52 Always concerned about outbreak of TB.
- 54 Always concerned about outbreak of TB.
- 55 It can spread to domestic animals and cattle.

- 56 Bit concerned if animals are not controlled possums are the worst carriers of TB.
- 57 We don't want TB as we have cattle on the farm.
- 58 Always concerned with the outbreak of TB, especially from possums.

Comments from 'No' respondents

- 1 Because Animal Health Board do all they can to control it.
- 4 If you have a problem the farmers sort it out themselves.
- 8 It is a very, very low risk.
- 31 Our area is a TB-free area.

Health and safety Impacts

- f.) Are you aware of any collisions between motor vehicles and large wild animals?
- Yes: 21% No: 79% Don't know: 0%
 - g.) Are you concerned about the potential risk that large wild animals could pose to motorists? (Not concerned/somewhat concerned/very concerned).
- Not concerned: 60% Somewhat concerned: 38% Very concerned: 2%
 - h.) Are you aware of any harmful or dangerous encounters between people and/or domestic animals and large wild animals at recreation areas (conservation areas, parks, public walkways, etc.)?
- Yes: 5% No: 95% Don't know: 0%
 - i.) Are you concerned about encountering wild animals, and if so has it changed your behaviour? For example, would you be reluctant to use recreation areas if a particular species was present? (Not concerned/somewhat concerned/very concerned).
- Not concerned: 68% Somewhat concerned: 28% Very concerned: 4%

Comments from 'Not concerned' respondents

- 1 They are not a threat.
- 2 They are frightened of humans.
- 5 Never had an issue with them, they just run away.
- 6 I am not afraid of them.
- 8 Common sense, if you don't want to be involved, just avoid them.
- 10 Not afraid of them.
- 11 I am more concerned about illegal poachers than wild animals.
- 12 Don't think they have too much to fear.
- 13 I don't think they would damage me.
- 15 They are more frightened of me than I am of them.

- 17 Not afraid of the wild animals, they are afraid of people.
- 18 More frightened of us than we are of them.
- 19 I am used to them, so not afraid.
- 20 They are afraid of us.
- 21 Wouldn't worry me, they are frightened of us.
- 23 Because they do not attack people.
- 24 They are more afraid of us than we are of them.

25 – Because I am not frightened of them and it would be very rare to have an encounter like that.

- 28 Very rarely see any in those areas; if you do they disappear very quickly.
- 30 Don't go to the above places.
- 33 Have no concern, they are scared of us.
- 35 Don't know of any areas where wild animals are.
- 36 Happy to go there. I have myself trained wild pigs and deer.
- 41 Wild animals are more afraid of me than I am of them.
- 43 I think it would be very rare to see large wild animals in any of those places.
- 48 Not concerned because animals are more scared of me than I am of them.
- 51 Don't think any wild animals are around in those areas.
- 53 Am not frightened of them, they will run first.
- 54 No real wild animals to be afraid of.
- 55 Not enough around to cause major problems.
- 56 Usually when a wild animal sees a human they run the other way.
- 57 Only really wild animals attack you and we do not have many of them in our country.

Comments from 'Somewhat concerned' respondents

- 4 I think I would be very lucky to find one there.
- 7 Hope they are more frightened of me than me of them.
- 9 Don't go to places where they could be.
- 22 In the mating season.
- 31 They are more afraid of us than we are of them.

38 – You wouldn't want to go to a recreational area if a big wild pig was there as it could attack.

42 – We wouldn't go there if there were any wild pigs in the area or when the deer were mating.

- 46 Wild animals wouldn't be looking for someone to attack.
- 50 Never seen wild animals there anyway. More scared of us than we of them.

Comments from 'Very concerned' respondents

- 14 Because wild pigs can be very aggressive.
- 27 Wouldn't like to get close to an animal.
- 49 If wild pigs were in the area.
 - j.) Are you concerned that increasing wild animal populations in more developed and populated areas may encourage illegal hunting with associated risks to

human safety, property and livestock? (Not concerned/somewhat concerned/very concerned). If yes, could you please elaborate?

• Not concerned: 37% Somewhat concerned: 21% Very concerned: 42%

Comments from 'Not concerned' respondents

- 5 Give hunters access and they are very good.
- 8 It is just not an issue.
- 10 Recreational hunters keep the numbers down.
- 23 Not a big population in built up areas.
- 33 Not concerned, it won't come to this in our area.
- 28 They don't get a chance to increase as they are kept under control by farmers.
- 34 Because it has always happened.

Comments from 'Somewhat concerned' respondents

6 – I have a nephew who is involved in it. Which is always a risk.

7 – Recreational hunters are not being careful enough and sometimes don't get permission from the farmers and could be dangerous for people or stock.

- 12 Because there is always the problem of hunters trespassing on your property.
- 16 Because of inexperienced people using guns and posing a risk of causing an accident.
- 19 Safety is an issue because if recreational hunters don't have permission that is an issue.
- 30 It is always a possibility.
- 37 Hunters can end up shooting their mates when very busy.
- 45 The illegal hunting places a risk to people in the area not knowing they are there.
- 51 Non-professional people with guns can cause a lot of trouble.
- 54 Concerned for peoples' safety if object is not identified.
- 58 Sometimes the wrong person owns a gun and they do not always identify their target.

Comments from 'Very concerned' respondents

9 – Because recreational hunters can cause accidents if they don't identify an object.

11 – Because they are illegal poachers and don't get any permission and extremely dangerous.

13 – Already covered that question, don't like hunters on my property without permission as its dangerous.

14 – The recreational hunting is becoming an issue. My concern is the numbers of people being shot because they are not identifying their target.

18 – The idiots who don't know how to use guns safely could cause an accident.

20 – It is called bush fever, people get all hyped up when they see a wild animal if out hunting and to not observe the safety rules or the gun licence rules.

21 – Especially where firearms are involved.

22 – Concerned about hunting.

24 – As a lot of the hunting is done at night it is easy to make a mistake and they don't follow hunting protocol.

- 25 Very concerned about that.
- 26 Just from purely a safety point of view.
- 27 Illegal hunting without permission.

31 – The recreational hunters should get permission from the farmers before going ahead with hunting.

- 35 Illegal hunting could cause accidents such as shooting a human or livestock.
- 36 People have been shot by people using spotlights.
- 39 Because untrained people use guns badly.
- 40 Unprofessional hunters are always a danger to people and livestock

43 – Hunting animals on private properties is always a concern especially when it is done without the property owner's permission.

- 44 Farmers at Waikaia area are sick of poachers.
- 47 Illegal hunting because spotlighting at night can be dangerous to humans.
- 49 Because it can cause a danger to humans if using high powered bullets.

52 – The more people we have driving around with spotlights the more people are going to get shot.

- 55 People with firearms some not very responsible.
- 57 Too much carelessness amongst recreational hunters not identifying their target.

3. Attitudes towards wild animals

If it is found that wild animals have spread into areas of lowland Southland where they are impacting on conservation and/or farming and that some form of management, including eradication, may be required, what are your views on the possible options for managing these new populations?

- a.) Would you support ES managing wild animals in order to protect lowland sites with high conservation values?
- Yes: 53% No: 44% Don't know: 3%
 - b.) Would you support ES managing wild animals in order to protect economic values, such as farming and forestry, etc, in lowland areas of Southland?
- Yes: 53% No: 44% Don't know: 3%
 - c.) Do you agree with preventing the spread of wild animals into lowland sites from which they are currently absent in order to protect native biodiversity?
- Yes: 71% No: 21% Don't know: 7%
 - d.) Would you support ES assisting landowners to manage wild animals on their land by providing control materials or pig traps, at a reduced cost? At no cost?
- At a reduced cost: 44% No cost: 56%

- e.) How do you feel about wild animal control or eradication methods at a small number of selected high conservation value sites? What methods would you support: professional hunters, recreational hunters, poisoning?
- Professional hunters: 52% Recreational hunters: 31% Poisoning: 15%
 - f.) Do you have any native or natural areas on your property that you believe would be classified as a 'High Value Area'? If yes, would you like to see it (them) protected from the potential impacts of wild animals?
- Yes: 38% No: 62% Don't know: 0%
 - g.) Would you support ES using targeted rates money to assist with the control of wild animals?
- Yes: 41% No: 56% Don't know: 3%

Comments from 'Yes' respondents

14 – Depending on level of cost added to the rates.

Comments from 'No' respondents

4 – Would support getting rid of possums and magpies.

Comments from 'Don't know' respondents

- 13 Would like to see their budget before I answer the above questions.
- 50 Feel everybody should pay as everybody gets the benefit of biodiversity.
 - h.) Would you prefer to see wild animal populations reduced or eradicated, or strategies such as deer fences used to exclude wild animals from high conservation value sites? Why?
 - Yes: 70% No%: 27% Don't know: 3%

Comments from 'Yes' respondents

- 1 Got no money and should not be spending it on such things.
- 2 I think you can't eradicate deer, pigs or goats from an area.
- 5 They should be kept under control.
- 6 Would prefer the fencing because it would keep wild animals out.
- 7 If they can be reduced then they can be kept under control by recreational hunters.
- 9 To keep them under control.
- 10 Would like to see them eradicated.
- 12 We are not hunters and would like to see the end of them.

14 – I think reducing them would help to keep them under control and still allow recreational hunters to enjoy their sport.

- 16 It would help keep the numbers down if you had a fence.
- 17 It really depends on the area.
- 19 Not worth putting fences up and wouldn't like the eradication of certain areas.
- 20 Fencing would be too expensive so recreational hunting is the answer.
- 21 Like the deer fences to keep wild animals out.
- 22 Feel reducing the population is the answer.
- 26 In a lot of cases eradication is not feasible.
- 27 They create a problem at the moment so if numbers are lower, then it would all be much better.
- 28 Prefer it to stay as it is now.
- 29 I don't want to see too much bureaucracy coming into animal control.
- 30 But leave enough for game shooters to still enjoy their sport.

33 – Would keep wild animals out and give the hunters opportunities to carry out their sport.

- 34 Because fences would help to keep them out of valued areas.
- 35 High fences would help keep wild animals out of high conservation areas.
- 36 Because I don't want to see game animals exterminated.
- 38 It is the only way to be effective.
- 39 Because high fences are a good idea.
- 40 Would like to see the high fences put up where possible to stop the animals.
- 42 It would be great on our farm to have high fences.
- 43 Feel high fences would control a lot of the unwanted animals.
- 46 Eradication by professional hunters operating a deer culling business is better.
- 49 Would eliminate them from the area, especially wild deer.
- 50 Because they would last a long time and keep wild animals out.
- 52 Reducing would help, but eradication would be nearly impossible.
- 55 If reduced, there would still be plenty for recreational hunters and their sport.
- 56 It is better to reduce as we still need some for hunters' sports and overseas tourists.
- 57 Don't want eradication, as they are good for recreational hunting.
- 58 Need to keep their number under control, hence population needs to be reduced.

Comments from 'No' respondents

- 4 Waste of time and money.
- 8 The question is far too wide.
- 11 Think farmers should do it yourself.
- 18 Because it would be a cost to the taxpayers. The farmers can deal with them.
- 15 Depends on the price
- 25 I am happy with the situation of hunting the animals staying the same.

23 – Because population of wild animals is so low and have very little impact on the environment.

- 24 No, because fencing is very expensive. Eradication should be the goal.
- 45 Wouldn't wash on high county farms.
- 47 Too hard for high country farms and too costly.

Comments from 'Don't know' respondents

32 – I don't think fences are a legitimate function of ES.

37 – Feel recreational hunters should be able to go and do it and get the meat for themselves.

- 41 Because there is not enough recreational hunters to control the wild animals.
- 44 Deer fences would help to keep a lot of the wild animals out of the property.
- 51 None of these methods.
- 52 We have very few wild animals and they don't worry us at all.
- 54 I do not support any. Don't like controls for govt departments.
 - i.) Would you support the establishment of 'Wild Deer (or other wild animal) Free' zones in areas of high-conservation value in Southland?
 - Yes: 48.1% No: 51.9% Don't know: 0%
 - j.) Which town do you live in or closest to?
- 1. Tokanui
- 2. Winton-Wreys Bush Highway
- 3. Mossburn
- 4. Winton
- 5. Edendale
- 6. Invercargill
- 7. Manapouri
- 8. Invercargill
- 9. Lumsden
- 10. Winton
- 11. Tuatapere
- 12. Lumsden
- 13. Riversdale
- 14. Lumsden
- 15. Winton
- 16. Te Anau
- 17. Riverton
- 18. Winton
- 19. Garston
- 20. Tuatapere
- 21. Tuatapere
- 22. Otautau
- 23. Lumsden
- 24. Tuatapere
- 25. Te Anau
- 26. Mataura
- 27. Otautau

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- 28. Te Anau
- 29. Invercargill
- 30. Manaporui
- 31. Tuatapere
- 32. Otautau
- 33. Winton
- 34. Ohai
- 35. Mossburn
- 36. Mossburn
- 37. Invercargill
- 38. Riversdale
- 39. Edendale
- 40. Balfour
- 41. Otautau
- 42. Riversdale
- 43. Mataura
- 44. Riversdale
- 45. Winton
- 46. Invercargill
- 47. Gore
- 48. Wyndham
- 49. Winton
- 50. Winton
- 51. Gore
- 52. Balfour
- 53. Gore
- 54. Tuatapere
- 55. Gore
- 56. Otautau
- 57. Lumsden
- 58. Tuatapere

k.) What type of property do you manage?

- 2. Dairy /grazing
- 3. Didn't answer
- 4. Cattle
- 5. Dairy
- 6. Sheep
- 7. Sheep
- 8. Sheep and beef
- 9. Sheep farm
- 10. Sheep and beef
- 11. Sheep and beef
- 12. Sheep and beef
- 13. Sheep, deer, and cattle

- 14. Sheep farm
- 15. Sheep and deer
- 16. Sheep and beef
- 17. Sheep
- 18. Dairy farm
- 19. Deer farmer
- 20. Dairy beef
- 21. Sheep and beef
- 22. Dairy farm
- 23. Sheep
- 24. Sheep, crop, and silage
- 25. Sheep and beef
- 26. Sheep and beef
- 27. Sheep and beef
- 28. Sheep
- 29. Sheep and beef
- 30. Sheep and beef
- 31. Sheep and beef
- 32. Dairy farm
- 33. Sheep and beef
- 34. Deer
- 35. Sheep and beef
- 36. Sheep farm
- 37. Private property but work on local farm
- 38. Sheep and beef
- 39. Sheep, beef, and dairy grazing
- 40. Dairy farming
- 41. Cropping
- 42. Sheep and beef
- 43. Dairy farm
- 44. Sheep and beef
- 45. Hillcountry and dairy
- 46. Sheep and deer farm
- 47. Sheep and beef
- 48. Dairy farming
- 49. Sheep and beef
- 50. Dairy farm
- 51. Cropping
- 52. Beef and sheep
- 53. Sheep and beef
- 54. Deer farm
- 55. Sheep and deer
- 56. Sheep and beef
- 57. Sheep and beef
- 58. Sheep

Which age group do you belong to and what is your sex?

1	51 to 65	Male
2	36 to 50	Male
3	Didn't answer	Didn't answer
4	36 to 50	Male
5	51 to 65	Male
6	51 to 65	Male
7	36 to 50	Male
8	51 to 65	Male
9	51 to 65	Male
10	51 to 65	Male
11	51 to 65	Male
12	36 to 50	Female
13	36 to 50	Male
14	36 to 50	Female
15	36 to 50	Male
16	51 to 65	Male
17	18 to 35	Male
18	36 to 50	Male
19	36 to 50	Male
20	51 to 65	Female
21	36 to 50	Male
22	51 to 65	Male
23	51 to 65	Male
24	51 to 65	Female
25	51 to 65	Male
26	51 to 65	Male
27	51 to 65	Male
28	51 to 65	Male
29	51 to 65	Male
30	51 to 65	Male
31	51 to 65	Male
32	51 to 65	Male
33	36 to 50	Male
34	36 to 50	Male
35	51 to 65	Female
36	51 to 65	Male
37	36 to 50	Male
38	51 to 65	Male
39	51 to 65	Male
40	51 to 65	Male
41	18 to 35	Male
42	18 to 35	Female

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43	36 to 50	Female
44	36 to 50	Male
45	36 to 50	Male
46	51 to 65	Female
47	51 to 65	Male
48	51 to 65	Male
49	36 to 50	Male
50	36 to 50	Male
51	36 to 50	Male
52	51 to 65	Male
53	51 to 65	Male
54	51 to 65	Male
55	36 to 50	Male
56	36 to 50	Male
57	36 to 50	Male
58	51 to 65	Male

4. Wash-up Question: Post-survey

- Do you have any other questions, comments or concerns regarding the spread of wild animals, their impacts, and the best way to manage them?
- 8 I feel the questions asked in the survey are not specific enough to get a valid answer.
- 19 Possum control should be continuous, especially if targeting rate money.
- 21 I think there needs to be education on the most effective ways to control deer and pigs.
- 22 The wild pigs are being spread by recreational hunters, so numbers should be maintained by them.
- 24 I am inspired by the last wish of Sir Paul Callaghan that NZ would get rid of all noxious animals.
- 25 I would like to have had more information about what the situation is before answering the questions.
- 29 I think farmers should be left to control wild animals on their own property.
- 36 I consider feral cats to be a major pest for two reasons, they spread bovine TB and destroy large numbers of native birds.
- 42 We get frustrated with recreational hunters because they disturb the peace and kill the male deer only leaving the females to breed. It's the same with the pigs.
- 44 The work being done at the present time seems perfectly adequate.
- 47 Professional hunting is keeping the numbers down.
- 50 I am more concerned about how much this survey is costing.

Appendix 2 – Review of monitoring methods for ungulates

1. Introduction

Predicting and quantifying the current and potential distributions of wild ungulates, and monitoring their population trends can be an important component in evaluating where control, containment, or eradiction efforts might need to be focused in identified risk areas. In this appendix, we provide a comprehensive review of methods that have been used to detect presence–absence of ungulates and to monitor their populations. Our focus is on those methods that are most applicable to the New Zealand system and relevant wild ungulate species, and on recently developed methods and how they compare to current monitoring methods used in New Zealand.

We categorise methods into two sub-headings, indices of abundance and density estimation. The use of indices of abundance in wildlife management has been criticised (e.g. Garshelis et al. 1990; Anderson 2001, 2003; White 2001). For example, White (2001) cautions not to start a project that attempts to monitor an animal population unless it can be done right. He states that monitoring using only an index will likely result in the validity of the index being questioned, and hence the entire monitoring effort will be wasted. However, methods that attempt to estimate actual number or density of animals are often difficult and expensive, and they may require difficult-to-meet assumptions that, when violated, result in estimates of questionable quality (Krebs 1998; Engeman 2003, 2005). Krebs (1998) states that estimates of relative abundance obtained from index methods may be adequate for many ecological and management problems, and they should always be used when adequate because they are much easier and cheaper to determine than absolute density. Thus, we suggest that careful consideration must be given to management questions and objectives when determining which approach is most appropriate to use for wild ungulates in Southland and elsewhere in New Zealand.

2. Indices of abundance

Indices are not estimates of actual population numbers, rather they are applied to make relative comparisons between populations or to monitor trends within a population (Caughley 1977; Krebs 1998). Engeman (2005) states that population indices obtain maximal utility when they possess certain desirable qualities, including being practical to apply, being sensitive to changes or differences in the target species' population, having an inherent variance formula and allowing for precision in index values, and relying on as few assumptions as possible.

Although attempts to estimate actual abundance or density from an index are frequently seen in the literature, this form of estimation is considered inappropriate by many researchers because it yields only an indication of correspondence among methods, with the benchmark still only an estimate of unknown quality (Caughley & Sinclair 1994; Engeman 2005). In order to estimate actual abundance or density from an index would require additional study where known densities (not density estimates) were related to index values with a statistical model that accounts for factors such as detection rates (Engeman 2005). We review a few studies (primarily on ungulates) that provide approaches to estimating actual abundance or density from an index. However, we wish to make it clear that this approach is not universally accepted because estimates obtained from indices are most often related to other density estimates (as opposed to known densities). Consequently, the result will be an estimate of unknown quality (Caughley & Sinclair 1994; Engeman 2005). Although this approach may be adequate in many circumstances, we reiterate that careful consideration must be given to management questions and objectives when determining study methods and desired level of accuracy of estimates.

2.1 Faecal pellets

Faecal pellet counts have been widely used to index deer abundance and population change, particularly in habitats in which animals are difficult to count directly (e.g. forests with a closed canopy) using approaches such as aerial surveys (e.g. Bennett et al. 1940; Fuller 1991; Marques et al. 2001; Patterson et al. 2002; Hebblewhite et al. 2005). They have been widely used to estimate the relative abundance of deer in New Zealand forests (e.g. Riney 1957; Bell 1973; Batcheler 1975; Baddeley 1985; Forsyth 2005; Forsyth et al. 2007). Although pellet counts have most frequently been used to monitor deer populations, they have also been used to assess a wide range of other taxa, e.g. rabbits and hares (Forys & Humphrey 1997; Hodges & Mills 2008), kangaroos (Vernes 1999), antelope (Bleisch et al. 2009), and elephants (Walsh et al. 2001). A Faecal Pellet Index (FPI) protocol was developed for the Department of Conservation by Landcare Research to standardise methods of estimating changes in the relative abundance of feral deer in New Zealand (Forsyth 2005; also see Forsyth et al. 2007). The FPI remains the most common method of estimating long-term changes in the relative abundance of feral deer in New Zealand.

Pellet indices work on the assumption that the relationship between pellet counts and actual abundance (or density) is positive and linear (Fuller 1991; Forsyth et al. 2007). The validity of this assumption has been questioned. Fuller (1991) found that high variation in defecation rates and observer bias affected the relationship between pellet counts and estimated deer density. He concluded that the use of pellet groups to index deer numbers or population change is limited. In contrast, Forsyth et al. (2007) modelled the relationship between faecal pellet indices and actual deer density from 20 enclosures in New Zealand, and found that the slopes of the linear relationships between indices and density were positive. Forsyth et al. (2007) suggest that the small sample size and uncertainty in deer density estimates, which were derived from aerial surveys, may have affected Fuller's (1991) results.

Faecal pellet counts are often used to estimate abundance or density of ungulate populations (e.g. Bailey & Putman 1981; Marques et al. 2001; Smart et al. 2004; Acevedo et al. 2010; Koda et al. 2011). This can be done variously; however, 'plot clearance' and 'standing crop' are two of the most widely applied methods (Marques et al. 2001; Campbell et al. 2004). Plot clearance is based on the number of pellet groups deposited within an area from which pellets were initially cleared, whereas all pellets or pellet groups are counted using the standing crop method. Both methods require knowledge of defecation and pellet decomposition rates. Marques et al. (2001) state that the plot clearance method can provide more accurate estimates of actual abundance or density than the standing crop method. However, unless there are enough resources to survey a large number of plots in areas where animal densities are low, the clearance method often results in estimates with poor precision because a large number of plots contain zero pellets (Buckland 1992; Campbell et al. 2004; Smart et al. 2004).

Many researchers caution against using pellet counts to estimate abundance or density and instead advocate their use as an index (e.g. Fuller 1991; Smart et al. 2004; Forsyth et al.

2007). This is because there are a number of potential biases that can result from the various parameters used to estimate abundance or density. Variation in defecation rates and observer bias, which may increase or decrease the detectability of pellets, can influence the relationship between pellet counts and abundance or density (Rogers 1987; Fuller 1991; Forsyth et al. 2007). Detection rates/probabilities using pellet groups can vary substantively (e.g. >0.9, Lehmkuhl et al. 1994; <0.2–1.0, Jenkins & Manly 2008; 0.74, Gormley et al. 2011), and detection is likely heavily influenced by ground cover (Forsyth et al. 2007). Gormley et al. (2011) recommend using additional field survey methods to reduce the overall probability of false negatives at sampled locations. The rate at which pellets decompose also varies greatly among seasons and regions due to differences in vegetation, temperature, precipitation, and the community of organisms that promote pellet decomposition (Van Etten & Bennett 1965; Lehmkuhl et al. 1994; Marques et al. 2001; Brinkman et al. 2011), and accordingly this parameter is an especially controversial point when used to estimate deer abundance (Koda et al. 2011). The faecal accumulation rate technique has been suggested as a useful approach to avoiding the issue of unknown or variable decomposition rate (Koda et al. 2011); however, it is still prone to biases such as defecation rates, observer bias, and detection rates.

Despite issues relating to the use of pellet groups as an index or to estimate abundance, they remain a widely used, cost-effective method for monitoring ungulates in forests with closed canopy. Forsyth et al. (2007) encourage managers wishing to use this method as an index of abundance to first evaluate the relationship between the index and deer density in their geographic area of interest.

2.2 Camera traps

Infrared or white-light flash cameras are widely used in vertebrate ecology to remotely collect data on animal presence, activity, and behaviour, and to produce indices of population abundance or estimate population size (e.g. Brooks 1996; Karanth & Nichols 1998; Cutler & Swan 1999; Moruzzi et al. 2002; Kays et al. 2011). Estimating abundance using camera-traps requires the identification of individuals that have previously been captured and marked or that are naturally recognisably marked (Karanth & Nichols 1998; but see Rowcliffe et al. 2008). Where these requirements cannot be met, as is often the case, camera-traps can be used to produce indices of abundance (e.g. Carbone et al. 2001; Silveira et al. 2003; Engeman 2005; Bengsen et al. 2011). In this case, camera surveys are designed to capture observations (photographs) of animals from cameras distributed within the study area operating over consecutive days. Indices of abundance can be calculated as a simple count of the number of observations of a species recorded, standardised over a certain number of days. However, designs that allow variance estimates to be calculated are preferable because they allow for the assessment of index precision and the application of standard statistical procedures such as hypothesis testing (Engeman 2005; Bengsen et al. 2015).

Although significant correlations between camera trapping rates and independent estimates of density have been demonstrated (e.g. Carbone et al. 2001; O'Brien et al. 2003), the use of camera trapping rate as an index of abundance is controversial primarily because it does not estimate the probability of detection (e.g. MacKenzie et al. 2002). Rowcliffe et al. (2008) state that in an extreme interpretation, this would mean that correlations between trapping rate and density would only be reliable if they were recalibrated for every location and time period to which they were applied, thus negating the need for the index. Further some studies

suggest that cameras are inferior to other sampling methods. For example, Long et al. (2007) found that the probability of detecting various carnivore species in north-eastern USA was substantively lower for cameras (black bear, *Ursus americanus*, 0.33; fisher, *Martes pennanti*, 0.28; bobcat, *Lynx rufus*, 0.13) compared with scat detection dogs (black bear, 0.87; fisher, 0.84; bobcat, 0.27).

Despite such criticisms, many studies advocate the use of camera traps for determining the presence of species, estimating occupancy rates, and monitoring populations for a wide range of taxa (e.g. Cutler & Swann 1999; Silveira et al. 2003), including ungulates (e.g. feral pigs, Bengsen et al. 2011; sambar deer, *Cervus unicolor*, Gormley et al. 2011; alpine musk-deer, *Moschus chrysogaster*, black musk-deer, *M. fuscus*, and Himalayan brown goral, *Nemorhaedus goral*, Sathyakumar et al. 2011). Basic advantages of camera traps include that they are comparatively non-invasive, require low labour, usually provide accurate determination of species, can be used in forest with dense canopy cover and other habitats that may be difficult to sample using alternative methods, and can provide robust data for many questions (Silveira et al. 2003). We suggest that cameras may be a viable alternative, or complementary field survey method to pellet transect surveys in New Zealand. They may be particularly useful for wild/feral pigs (e.g. Plhal et al. 2011), because pigs tend to leave few droppings compared to deer, thus potentially making data obtained from pellet surveys merely anecdotal for pigs (Engeman et al. 2001; but see Acevedo et al. (2007) who state that faecal dropping transects may be useful in areas with high densities of pigs).

2.3 Dirt-tracking plots

Dirt tracking plots (as with cameras above) may be a useful alternative or complementary method to pellet transect surveys, particularly for feral pigs. They can simultaneously monitor changes in the relative abundance of multiple species (Engeman et al. 2002); although this may create problems with accurate identification of spoor. Engeman et al. (2001) found no evidence that feral pigs either avoided or were attracted to tracking plots, but state that spoor detection and identification can be affected by weather (wind and rain), vehicle use, type of substrate, and poor plot preparation. They do, however, conclude that tracking plots are an effective method of assessing changes in the relative abundance of feral pigs and some other mammalian species (also see Longoria & Weckerly 2007). Estimates of detection probabilities for collared peccary (*Pecari tajacu*) at tracking plots in south Texas ranged from 0.43 to 0.77 for 3-week time intervals (Longoria & Weckerly 2007), whereas the detection probability for Roosevelt elk, Cervus elaphus roosevelti, at tracking plots in north-western California was estimated to be 0.95 (Weckerly & Ricca 2000). The difference in detection probabilities between the two species is believed to have occurred because elk are much larger than peccary and consequently leave deeper and more obvious spoor (Longoria & Weckerly 2007). Dectection probabilities can vary between sampling sites, at least at a landscape scale (Longoria & Weckerly 2007). Although many authors advocate the use of tracking plots, few report the monetary and labour costs associated with this method or how they compare to alternative monitoring methods.

2.4 Catch-per-unit-effort of hunter index

The CPUE or hunter index method is often described as an unreliable method for indexing ungulate populations (Fryxell et al. 1988; Lancia et al. 1996; Engeman et al. 2001; Hatter 2001; Acevedo et al. 2007). For example, Hatter (2001) conducted an assessment of the

relationship between CPUE and abundance for black-tailed deer, Odocoileus hemionus columbianus, and moose, Alces alces. He found that CPUE underestimated the population rate of decline and may overestimate rate of increase. Hatter (2001) concluded that wildlife managers should not use CPUE to estimate rate of population change unless the relationship between CPUE and actual abundance is known. CPUE methods often have difficult to meet assumptions, namely the population must be closed and all individuals are equally susceptible to hunting (Lancia et al. 1996). CPUE is also prone to biases such as a lack of cooperation of some hunters, which can result in unreliable or no information on hunter success being reported (Acevedo et al. 2007), less experienced hunters with lower success rates are often less likely to participate in surveys, and hunter effort is likely concentrated in areas of high ungulate density and/or within habitats where animals are more vulnerable, as density declines (Hatter 2001). It has, however, been argued that CPUE methods have been applied meaningfully in New Zealand, primarily because of the availability of long-term rigorous datasets. For example, Fraser and Nugent (2003) used annual kill data collected over a 40year period to determine trends in red deer density in the Murchison Mountains, New Zealand. Similarly, Brennan et al. (1993) found that kill-rates of feral goats recorded by the Department of Conservation (DOC) in Marlborough, New Zealand, provided linear indices of goat population size. Thus, if hunting effort is measured reliably, the CPUE method may provide a robust and cheap (i.e. if the data arealready available) method of estimating ungulate densities. We recommend that data on hunter effort should be confined to those provided by professional hunters employed by DOC (or a similar organisation).

2.5 Bait take

Bait take, i.e. the amount or proportion of bait removed, has been used to estimate changes in the relative abundance of deer, feral pigs, and bears (Choquenot et al. 1993, 1996; Engeman 2005). For example, Choquenot et al. (1993) assessed feral pig abundance using bait take before and after conventional trapping in New South Wales, Australia. These authors report that indices of abundance that require bait consumption will only indicate the presence of those animals that find and accept bait, and thus will overestimate population reduction achieved by control techniques. Engeman et al. (2001) add that bait-take observations will likely introduce bias into the assessment by conditioning the animals being observed. We do not recommend this method for monitoring ungulates in New Zealand.

2.6 Vehicle and aerial surveys

Although more commonly used to estimate density using distance sampling methodology (Burnham et al. 1980; Buckland et al. 1993; see Abundance and Density Estimation Methods, Distance Sampling – Line Transects and Point Counts below), vehicle and aerial surveys can be used to estimate distribution and changes in relative abundance of ungulates (e.g. Lushchekina et al. 1999; Latham et al. 2011). Methods, e.g. transects surveyed, vehicle and aircraft speed, height above-ground-level for aerial surveys, type of aircraft, weather conditions, and time of year, should be kept consistent for all surveys. For example, Latham et al. (2011) were interested in assessing white-tailed deer and moose numbers in a woodland caribou, *Rangifer tarandus caribou*, range in north-eastern Alberta, Canada, following large-scale industrial expansion into the region. These authors replicated the study design of James et al. (2004), who had assessed the relative abundance of deer and moose in this caribou range before large-scale increases in industrial activity, and were able to show that white-tailed deer numbers had increased 17.5-fold.

Vehicle and aerial surveys are generally used to estimate density/relative abundance of species that live in more open habitats, e.g. pronghorn antelope, *Antilocapra americana*, in the prairies in the USA (Whittaker et al. 2003) and Mongolian saiga, *Saiga tatarica mongolica*, and wild Bactrian camels, *Camelus bactrianus*, in the Gobi Desert, Mongolia (Lushchekina et al. 1999; Reading et al. 1999). Because most habitats with ungulates in New Zealand are densely forested, particularly lowland forests in Southland, we do not recommend traditional vehicle or aerial surveys to estimate the abundance of wild ungulates. However, in open or semi-open habitat, a fixed-wing or rotary-wing aircraft operating with a forward-looking infrared (FLIR) camera (e.g. Barber et al. 1991; Belant & Seamans 2000) may prove to be a useful tool to confirm the presence of wild ungulates or to estimate percent reduction following control. We recommend assessing the probability of detection, perhaps using a known number of goats tethered in various habitats, prior to using this method.

2.7 Seedling ratios

Seedling ratio indices (SRI) have been used successfully as a robust, affordable tool to monitor the short-term outcomes of ungulate control (Sweetapple & Burns 2002; Sweetapple & Nugent 2004). Of key importance for this method, indices for high-preference plant species have been shown to be negatively correlated with ungulate abundance, with a wide response range over small changes in animal abundance (Sweetapple & Nugent 2004). Following eradication or control of ungulates, SRIs for high-preference plants respond by increasing. Thus, the method can be used to compare the impact of ungulate browsing on forest understoreys before and after control, and in essence provides an index of animal abundance because of the strong relationship between the two variables. SRIs have been used to assess the impact of browsing from a number of introduced ungulates in New Zealand and Hawai'i (Sweetapple & Burns 2002; Sweetapple & Nugent 2004), and thus the method would be useful to assess the efficacy of ungulate control on lowland forest in Southland. The extent of pig-rooting has been used as an index of pig abundance (Hone 1988), and thus could be used in concert with SRIs where feral pigs are of concern.

3. Abundance and density estimation methods

The most direct way to estimate the abundance of a population is to count all individuals in a known area, i.e. a census (Burnham et al. 1980). This approach provides a sample area of known size, and therefore an estimate of population density can be obtained by dividing the number of individuals counted by the area censused. Methods based on that approach usually are called quadrat, plot, or strip sample methods (Burnham et al. 1980). However, these methods can be very time consuming, and often impractical or impossible for highly mobile species such as wild ungulates. Consequently, we do not discuss these methods further. Instead, we focus on four sampling procedures – distance methods, distribution–abundance models, capture–mark–recapture, and DNA-based capture–recapture – that are commonly used to estimate abundance and density of wildlife populations.

We reiterate that density-estimation procedures are often difficult and expensive to implement for many species of animals, and they may require difficult-to-meet analytical assumptions that, when violated, result in estimates of questionable quality (Krebs 1998; Engeman 2003, 2005). Thus, although they are considered preferable to indices of abundance by some authors (e.g. Anderson 2001, 2003; White 2001), careful consideration must be given as to whether the additional expense of density estimation is warranted and if analytical

assumptions can be met (Engeman 2005). See Krebs (1998) for an examination of potential problems with mark–recapture methods and Burnham et al. (1980) for a similar discussion on line-transect methods.

3.1 Distance sampling – line transects and point counts

Distance sampling methods allow for an estimation of the detection probability of animals, as well as an estimate of density (e.g. Burnham et al. 1980; Buckland et al. 1993, 2001). The basic idea is the same for line transects and point counts; that is, surveys are performed on randomly selected lines or points and observers record the distance from the line or point to all animals detected within some truncation distance. The sample units are therefore a set of strips (line transects) or circles (point counts) of known size. They have the following assumptions: animals on the line or point are detected with certainty, animals are detected in their initial location (instantaneous sampling), and distances are measured without error (Buckland et al. 2001). Point counts are most often used to estimate the abundance of birds (e.g. Verner & Ritter 1985; Buckland 2006), whereas line transects are considered more appropriate for species such as wild ungulates (e.g. Burnham et al. 1980; Karanth et al. 2004; Wegge & Storaas 2009).

Line transects can be flown using fixed-wing or rotary-wing aircraft, or traversed on the ground by walking, driving in a vehicle, or ridden on horseback (Burnham et al. 1980; Wegge & Storaas 2009). Distance can be calculated by measuring the sighting distance and angle, from which the perpendicular distance can then be computed, or the perpendicular distance from the observer to an observed animal or group of animals can be measured directly. Methods to estimate distance from a line transect to an animal include using a tape measure, rangefinder, or visual estimation; alternatively, internal reference points can be placed on an aircraft window or an external sighting frame can be used to bin detected animals into a given number of distance intervals (e.g. Estes & Gilbert 1978; Burnham et al. 1980).

Because ungulates are highly mobile species, it may be difficult to use ground-based distance-sampling methods to estimate feral ungulate numbers and monitor their population trends in Southland. However, this approach may be appropriate for feral goat populations in comparatively open habitat. Similarly, because deer and pigs in New Zealand are most often found in forest with dense canopy cover, the use of aircraft as a monitoring technique will likely be ineffective. Marques et al. (2001) outline a method of estimating deer abundance from ground-based line transect surveys of faecal pellets. Although this method is deemed inappropriate by some researchers (see discussion in Faecal Pellet Indices), it may be adequate in some circumstances. This method provides a slight variation on historical methods used in New Zealand in that it counts pellet groups along a narrow (1- or 2-m-wide) transect (i.e. line sampling to some truncated distance), as opposed to counting pellets or pellet groups in circular plots. A single, sytematic sweep from one end of a narrow transect to the other is purported to be more efficient (i.e. higher detection of pellet groups and faster) than systematically searching plots (Marques et al. 2001).

3.2 Distribution-abundance relationships

Distribution–abundance (occupancy–abundance) relationships are a fundamental pattern in ecology (Andrewartha & Birch 1954) and apply both intra- and inter-specifically (i.e. within and among species) (Gaston et al. 2000). Usually occupancy increases with abundance and

consequently researchers have applied this positive relationship to estimate the abundance of organisms via occupancy surveys (Gaston et al. 2000; Borregaard & Rahbek 2010). Occupancy surveys (i.e. presence–absence data) are the most common form of information collected because they are less expensive and require less effort to collect than abundance (Gaston et al. 2000). Positive correlations between occupancy and local abundance have been found for a wide variety of taxonomic groups, including plants, butterflies, birds, and mammals (e.g. Lacy & Bock 1986; Pollard et al. 1995; Blackburn et al. 1997; Boecken & Shachak 1998). There are a number of occupancy models that can be used to extrapolate abundance of a species (e.g. Hui et al. 2009); however, it should be noted that estimates of abundance (or density) between different occupancy models can vary substantively because of assumptions associated with the distribution of a species and habitat heterogeneity (Hui et al. 2009; Borregaard & Rahbek 2010).

It has been suggested that distribution-abundance relationships can be used as a guide to estimate densities for decision-making in pest management (e.g. Sileshi et al. 2006). Obtaining these relationships for ungulates using direct methods such as observations of animals from the air or ground will be difficult or impossible in New Zealand's forest; indirect methods such as pellet surveys would need to be used to assess occupancy instead. Use of animal sign, e.g. ungulate pellets, in distribution-abundance models is problematic however, because sign of one individual can be detected in more than one survey unit during a sampling period. In such cases, data on occupancy across a range of animal densities would be required in order to develop predictive models of abundance; these data can be prohibitively expensive and logistically difficult to obtain in the New Zealand context.

3.3 Capture-mark-recapture

The literature on capture–mark–recapture is extensive, as are the models that can be used to estimate abundance (density) and survival. Krebs (1998) provides a good overview of this literature and methods. Similarly, the methods that can be used to obtain capture–mark–recapture data are extensive. Consequently, we do not provide an exhaustive review of these topics in this report, rather we focus on methods that may be applicable to ungulates in a New Zealand context. We do, however, provide a more detailed overview of recent advances in DNA-based capture–recapture (see below). Although capture–mark–recapture methods are believed to be less biased than indices of abundance (Anderson 2001; White 2005), they are often difficult and expensive and may require difficult-to-meet assumptions (Krebs 1998; Engeman 2003, 2005). Although we recommend that indices of abundance are adequate for most management objectives in New Zealand, capture–mark–recapture may be useful in some instances.

Because most individuals within deer, goat, and pig populations in Southland (and elsewhere in New Zealand) will not have naturally recognisable features, a sample of animals would require capturing and 'marking'. A variety of methods, such as using numbered tags, can be used to 'mark' individuals in a population. To estimate abundance, another sample of individuals needs to be captured, some of which will have been marked during the first capture programme and are now known as recaptures. Although population size can be estimated from as few as two captures, more than two visits are required to estimate survival (Lebreton et al. 1992). Models that test hypotheses about the survival process and estimate survival rates are considered critical to understanding animal poulation dynamics (Lebreton et al. 1992). Krebs (1998) provides a good overview of the models (and their assumptions) that can be used to estimate population size.

Although traditional capture–mark–recapture methods have been used to estimate ungulate abundance (e.g. roe deer, *Capreolus capreolus*, example in Lebreton et al. 1992), distance methods and more recently DNA-based capture–recapture tend to be more common approaches for estimating ungulate abundance.

3.4 DNA-based capture-recapture

DNA-based capture–recapture (CR) has become a common method of estimating animal abundance in demographically and geographically enclosed populations at one point in time (Lukacs & Burnham 2005a). Samples containing DNA (e.g. faecal pellets and hair) are collected, often non-invasively, and DNA is extracted and amplified at several microsatellite loci. These methods have been applied to estimate abundance in a wide variety of taxa, including ungulates (e.g. argali, *Ovis ammon*, Harris et al. 2010; mountain goat, *Oreamnos americanus*, Poole et al. 2011; Sitka black-tailed deer, *Odocoileus hemionus sitkensis*, Brinkman et al. 2011). Lukacs and Burnham (2005a) state this method is most useful for relatively small populations, up to a few thousand individuals. Beyond this size, a very large number of samples would have to be collected and analysed making the study cost prohibitive. Poole et al. (2011) found that costs associated with estimating mountain goat abundance using DNA-based CR were about six times greater than aerial survey methods, but produced a more statistically rigorous estimate with a quantifiable level of confidence around the estimate.

DNA-based CR has a number of issues which are not problematic in conventional CR; in particular genetic CR methods are especially vulnerable to genotyping errors and individual heterogeneity in capture probability (Creel et al. 2003; McKelvey & Schwartz 2004; Lukacs & Burnham 2005a). These problems can lead to bias in estimators of population parameters (Creel et al. 2003). A vast theory exists on models that can be used to estimate animal abundance from non-invasive genetic data, and if and how models handle genotyping errors and individual heterogeneity in capture probability (see references in Lukacs & Burnham 2005a; also see McKelvey & Schwartz 2005; Wright et al. 2009; Ebert et al. 2010). For example, extensions to closed population CR models have been developed to include a parameter estimating genotyping error rate (Lukacs & Burnham 2005b) and an estimator that helps to account for individual heterogeneity in capture probability (Lukacs 2005). A method based on data augmentation has been developed that allows data from samples that include uncertain genotypes to be modelled (Wright et al. 2009). Program CAPTURE includes models that can accommodate heterogeneity (e.g. Poole et al. 2011). Individual heterogeneity might also be reduced in the field by adapting the sampling design to the characteristics of the population (Ebert et al. 2010). The software MARK, CAPTURE, and CAPWIRE are most often used to estimate population size from DNA-based CR data (Otis et al. 1978; White & Burnham 1999; Miller et al. 2005; White 2008).

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Method	Main advantages	Main disadvantages	Legal in New Zealand	Best phase of eradication ¹
Hunting with trained dogs	Can remove all pigs	Skilled hunters and dogs essential	Yes	All and mop-up
Trapping	Humane and easy to use	Some pigs are untrappable	Yes	Knockdown
Poisoning	Can remove wary pigs	Non-target and humaneness	No ²	All and mop-up
Lethal snares	Efficient	Inhumane	No	All
Spotlight shooting	Selective	None	Yes	Mop-up trap shy or poison averse individuals
Foot snares	Can catch wary pigs	Daily checks required	Maybe	Mop-up
Fertility control	Humane	No proven record	No	Not for eradication
Aerial shooting	Efficient	Habitat and cover dependent	Yes	All

Appendix 3 – Control methods used around the world to control feral pig populations

Adapted from Parkes (2012, unpubl. report)

¹ Managers should consider eradication programmes for species like feral pigs in three phases. Phase 1: 'Initial Knockdown' aims to reduce the initial population to low levels quickly. This minimises the 'two steps forward, one step back' costs when a slow reduction of the population allows survivors to breed and replace (all or some) of their losses. Phase 2: 'Mop-up' targets the few wary survivors that remain after Phase 1. This often involves a change in tactics to obtain results most rapidly. Phase 3: 'Validation' aims to determine whether any individuals remain, i.e. has eradication been achieved.

² Currently there are no toxins registered for use on feral pigs in New Zealand. However, sodium nitrite baits have recently been developed for poisoning feral pigs and may soon be registered for use on pigs.