Reindeer on South Georgia, Literature Review and Discussion of Management Options

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South Sandwich Islands
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South Georgia Nov:11th 1911

Edward.B.Binnie Esq,
Act Stipendiary Magistrate,
South Georgia.

Sir,

I have the honour to inform you that my brother, who is Manager of the Ocean Whaling Co:,and I have imported here to South Georgia 10 Reindeer (3 bulls and 7 cows) as these thrive very well in the cold region of the North, I feel sure they will thrive and become prolific in time,if they are left alone,which would most assuredly be an asset to South Georgia.

I would deem it a great obligement if an order could be issued for their protection.

Awaiting the favour of your reply
I have the honour
to remain,Sir,
yours respectfully,

C.A.LARSEN

Copy of the original letter from Captain C.A Larsen, informing the South Georgia Magistrate of his introduction of, and hopes for, reindeer on the island.
BAS Archives, ref LS7/3/7

Definitions of Terms (Convention on Biological Diversity, 2010)

Alien Species

A species occurring in an area outside of its historically known natural range as a result of intentional or accidental dispersal by human activities (also known as an exotic or introduced species) includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce.

Alien Invasive Species

An alien species which becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity.

Native (indigenous) species

A species, subspecies, or lower taxon, occurring within its natural range (past or present) and dispersal potential (i.e. within the range it occupies naturally or could occupy without direct or indirect introduction or care by humans).

Endemic Species

A species which is unique to a given area, and not found anywhere else globally

Executive Summary

South Georgia is a subantarctic island with a terrestrial flora and fauna that is relatively species poor, that has evolved in the absence of grazing animals, and as a consequence copes poorly with grazing pressure. The vegetation is dominated by the native and widespread coastal tussac grass, which is highly productive and provides a key habitat for other native species.

Reindeer are a northern hemisphere species that were introduced by Norwegian whalers for subsistence to two discreet areas of South Georgia on three occasions between 1909-1925. Combined, the areas occupied by reindeer equate to the largest snow free, and consequently most biologically productive, part of the island. Subsequent to their introduction, the reindeer herds were managed through regular hunts. Since the 1980 no hunting or management of the herd has occurred for which records exist (though anecdotal reports exist of resident British Forces hunting reindeer throughout the 1980's), and as a consequence the herds have expanded substantially, to the point where nearly all available grazing habitat has been utilised. The boundaries of these areas are limited by glaciers, which prevent the animals spread to the island as a whole.

Numerous different plant communities on South Georgia have been overgrazed by reindeer, the most significant being tussac and burnet communities, which has lead to areas becoming eroded. Once erosion occurs, the affected area is unlikely to recover. Extensive overgrazing of tussac grassland is clearly evident on the island, most notably on ridge tops and raised coastal areas, where large areas are completely denuded.

There are numerous introduced plant species on the island, of which some are more damaging than others. There is a particular association between reindeer and the introduced grass species *Poa annua*, which resists grazing far better than native species. As native plants become overgrazed by reindeer, the introduced grass replaces them, completely altering the habitat and landscape of grazed areas. Experiments in which reindeer were excluded from grazing certain

previously grazed areas have demonstrated that important native species, such as tussac and burnet, can recover after the removal of grazing pressure. This recovery of native species results in a decline in cover of the introduced grass *Poa annua*.

The Government of South Georgia (GSGSSI) is a signatory to various international treaties, which oblige the Government to safeguard native species and the environment through the management of introduced invasive species. As such, GSGSSI is required to investigate management options to minimise and prevent the impact of reindeer on the island.

Since 1955 there have been numerous recommendations made regarding the management of reindeer on South Georgia, although none have been acted upon. Climate change and the consequent recession of glaciers, combined with the detrimental impact of reindeer on native vegetation, through overgrazing, trampling, soil erosion, loss of native biodiversity and increased distribution of introduced plants, requires that the management of the herds as a whole be discussed and decided upon as a matter of urgency. The proposed island-wide rat eradication project also necessitates a re-evaluation of the management of the reindeer, as their exclusion from treatment areas is a prerequisite for the eradication of rats in those sites, due to primary and secondary poisoning considerations through reindeer consumption of rat bait, and the risk that reindeer consumption of bait would leave insufficient bait for the complete eradication of rats.

Management of large introduced herbivores on vulnerable islands has occurred on numerous occasions around the world. The management options debated during these comparable projects have been studied and relevant options presented in this document. They are:

- To take no action – retain all animals
- To contain the existing population and actively manage herds in order to maintain at current numbers.

- To eradicate one herd and monitor recovery of key habitats and communities
- Complete eradication of both herds
- To reduce numbers (cull) to a level at or below the ecological carrying capacity of the current range.

In order to control or eradicate the herds, shooting is considered the most humane and viable option. A combination of ground and aerial shooting would be used. Various alternative options were also considered, including non-lethal options, but each was considered inappropriate for use on South Georgia, and as such all were dismissed. Should shooting go ahead, consideration would have to be given as to whether to recover any commercially valuable products.

Eradication of large mammals is not without precedent. Reindeer have been eradicated from islands in the Arctic where their introduction has resulted in serious damage to native vegetation. Around the world, numerous mammals, such as goats, pigs, cattle, sheep, and horses, have been eradicated from islands as environmental best practice, with particular emphasis on removal of non-native mammals on other subantarctic islands.

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Darren Christie, South Georgia Environment Officer

Introduction

Invasive species are organisms (usually introduced by humans) that successfully establish themselves in, then overcome, otherwise intact native ecosystems (McNeely et al, 2001). Many native ecosystems have been altered and thousands of species have been irretrievably lost due to the presence of invasive species, especially on islands. Introduced species can adversely affect native species in a number of ways: through predation, competitive exclusion, as disease vectors, attacking them, or hybridising with them. They can also change the ecosystem by altering vital ecological processes (Wittenberg and Cock, 2001).

Globally, the presence of invasive introduced species is considered the single greatest threat to the biodiversity of island ecosystems (Wittenburg and Cock, 2001). The presence of invasive species on an island makes it more vulnerable to new invasions (e.g. high association between reindeer grazing and spread of introduced grass *Poa annua*). Consequently, South Georgia has recently been identified as the single most vulnerable island in the sub-Antarctic to alien invasion (Frenot et al, 2005).

Hernandez *et al.* (2002) suggest that invasive species are responsible for 39% of all species extinctions since 1600. Amongst well-researched taxa (such as mammals and birds), around 80% of extinctions in this period (post 1600) may have been of island species (Cheeseman et al, 2003). Island ecosystems tend to support high levels of endemism. Although they usually support fewer species per unit area than continental mainland areas (Whittaker 1998), islands are

home to disproportionately high numbers of endemic taxa (Cheeseman et al, 2003).

Decision-making in wildlife management often causes controversy, especially where this involves culling large mammals (Leader-Williams et al, 1989). As such, decisions must be defensible, transparent and preferably made on the basis of firm scientific evidence. Ultimately, an element of judgement is inevitable, at which point differences of opinion may become evident.

1 – History of reindeer on South Georgia

After the establishment of the commercial sealing and whaling industries on South Georgia, efforts were made to introduce numerous species in order to provide food or sport for the resident working population. The first attempt was an introduction of rabbits in the 1870's, followed by further introductions of sheep, geese, horses and cows. None of these introduced species had a high enough winter survivorship to establish viable long-term populations (Leader-Williams, 1978). The same appears to be true of pets such as cats (P. Biggs, personal communication, January 2009), and chickens (M. Richardson, personal communication, 28 October 2009).

Lindgren (1948) questions the motives for the introduction of the reindeer, noting that no effort was made to maintain the original domesticated character of the animals, and that the human overwintering population of the island subsisted on locally grazed cows, pigs and sheep, supplemented with whale meat, with no urgent need to develop reindeer breeding more rationally. However, it appears to be generally accepted that reindeer were originally transported to South Georgia in order to provide fresh meat for the whaling communities (Kightley and Lewis Smith, 1976).

There were three separate introductions, the first by Captain Larsen who introduced 8 does and 3 stags from Numedal in central Norway (Lewis-Smith, 1978) to Ocean Harbour (Barff) in 1909 (Bonner, 1958). By 1928 the herd had expanded to 500 animals, with an additional 200 estimated to have been killed in the period subsequent to their introduction. In 1911, two stags and three does were released at Leith on the Busen Peninsula, though Allen (1920) reports the 1911 introduction as consisting of 10 animals (3 stags and 7 females). The 1911 Leith animals increased in number to 20 animals, before all were killed in an avalanche that swept them into the sea (Olstad, 1930). There was a replacement introduction of 3 males and 4 females made to Husvik in 1925, and this herd survives to the present day (Bell and Dieterich, 2010). Lovatt (2007) found reference to a further four females, of unknown origin, being introduced to the

Husvik herd in 1928. Subsequent to their introduction, the Barff herd expanded rapidly, unlike the Busen herd, which was limited by hunting pressure (Kightley and Lewis-Smith 1976).

There has been speculation that the animals introduced to the Busen were of a different genetic stock to the Barff (derived from forest or domestic deer as opposed to mountain deer), due to the more sedentary behaviour displayed by those animals (Leader-Williams, 1978). However, further research has dismissed this, and it appears that both herds were sourced from Filefjeld Reinlag, Hemesdal, Norway (Lovatt, 2007).

There are currently two discrete land areas affected by reindeer, the Barff and Busen Peninsulas (see **Figure 1**). The Barff Peninsula covers 189km^2 (Barff 131km^2 + Royal Bay 58km^2) and the Busen Peninsula covers 124km^2 (Leader-Williams 1980a). Therefore the total land area affected by reindeer on the island is 313km^2, of which approximately 100km^2 is vegetated. This is one third of the entire vegetated area of South Georgia, (306km^2). These areas are coincidentally the most floristically rich and vegetated areas on the island, with unaffected areas elsewhere on the island only supporting a limited diversity of flora (Leader-Williams et al 1989). Of the 124km^2 covered by the Busen Peninsula, 88% was grazed up to 1994 when the last study was carried out (Moen and MacAlister, 1994).

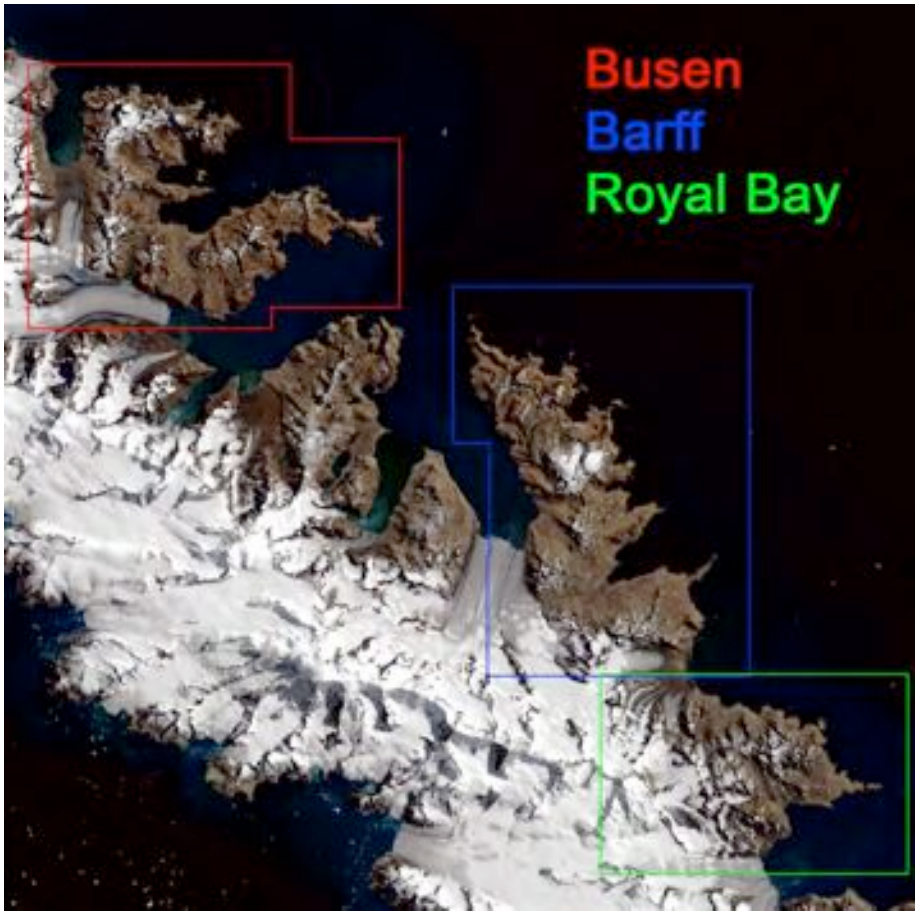

Figure 1 - Location of the two reindeer herds, Royal Bay area
(Adapted from the South Georgia GIS, 2009)

The Barff (which encompasses Royal Bay) and Busen populations have remained genetically isolated since their introduction (Leader-Williams and Payne, 1980), due to the presence of glaciers that terminate in the ocean, which act as an effective barrier to dispersal.

At some point between 1960 and 1965, a herd naturally established (as an extension of the Barff herd) at Royal Bay by crossing a glacier (Leader-Williams and Ricketts, 1982). Olstad (1930) states that the Barff herd had free reign between the Nordenskjold glacier in the North, and the Ross glacier in the South. However, Bonner (1958) states the Cook glacier as being the southern limit, with Payne (1972) adding that the glacier had retreated sufficiently between 1961 and 1965 to allow animals into the Royal Bay area. However it is unclear that the

retreat of the glacier alone allowed the spread of the animals, as the route described by Payne in 1973 along the shore side of the glacier was extremely treacherous, with overhanging ice cliffs and crevasses, and was considered to be unlikely to be crossable. Animals were observed crossing the body of the Cook glacier by an HMS Endurance helicopter in the early 1970's, suggesting grazing pressure rather than glacial retreat may have driven animals into the Royal Bay area (Lindsay, 1973). Burley (1966) confirmed reindeer crossing the glacier (footprints were found approx 1km inland), and deemed the route along the glacier snout as being virtually impossible to pass. Even by 1975 animals were not thought to regularly cross the Cook Glacier (Leader-Williams, 1975) and the Barff/Royal Bay herds were to all intents considered as separate herds. Allen (1920) notes that sealers reported reindeer ranging as far as the Ross Glacier but no further reports are recorded until Bonner (observation 1959), (Kightley and Lewis-Smith, 1976). Bonner (1959) reported that a sealing captain had seen reindeer at Doris Bay at the start of the season, and that the glacier no longer reached the sea. Given the movement of the population between the two sites, the Barff population will be considered as a single herd for the purposes of this document.

It should be noted that both the herds (the Busen and the Barff) are genetically unique, and that they are significantly differentiated from each other as well as from their source population (in Norway) so it is not appropriate to consider South Georgia reindeer as if it were made up of one homogenous population (Lovatt, 2007).

2 – Ecology of reindeer

2.1 - Population and population densities of reindeer on South Georgia

Reindeer are a northern hemisphere species that are well adapted to life in the Arctic. They have a long dense coat which consists of an outer layer of air-filled guard hairs, and a dense under-fur for extra insulation. They have large hooves that facilitate travel over snow and boggy ground, and long strong legs that allow travel over large distances and make them excellent swimmers. In the Arctic they undergo large migrations of up to 1000km, in order to maintain their lichen-based diet through winter. In the Arctic their chief predators are wolves, though lynx, wolverines, bears and golden eagles also prey on individuals though to a lesser extent. Man, especially native Inuits and Lapps, have herded and hunted reindeer, and their predators, for centuries and now exert a dominant influence on their ecology (Leader-Williams 1988). In contrast to their northern hemisphere relatives, the South Georgia herds are constrained in range by glaciers, have no predators, and are currently not managed in any way by man. The South Georgia animals are unusual when compared to their Northern hemisphere relatives in that they are non-migratory, occur at high densities, and as an adaptation to their new environment, do not depend on lichens for their winter forage (Leader-Williams et al, 1987).

Population densities of reindeer on South Georgia are much greater than those found in their natural northern range (Frenot et al, 2005). In Newfoundland reindeer are actively managed as they are of commercial value, and herd densities are deliberately maintained at 0.009 animals per km^2 (1 animal per $110km^{2)}$ in order to allow recovery of grazed plant species (Lindsay, 1973). In 1973, South Georgia reindeer densities were estimated to be between 14.3 animals per km^2 in Royal Bay and 0.9 animals per km^2 in the main Barff area (Lindsay, 1973, Payne 1972 and 1973). Leader-Williams and Payne (1980) estimated densities at 40 animals per km^2 for the Barff herd and 85 animals per km^2 in the Royal Bay area and Leader-Williams (1982) estimated a density for

the Busen of 58 animals per km^2. In contrast, Svalbard in the Arctic has a population density of approximately 5 animals per km^2 (Leader-Williams 1980a). In the northern hemisphere, 7 animals per km^2 is deemed the safe stocking rate for winter range, with rates of 18 animals per km^2 for St Matthew Island and 19 animals per km^2 for St Paul before their respective population crashes (Klein, 1968). The herds on South Georgia permanently occupy the same vegetated area, unlike northern herds, which migrate (Leader-Williams, 1980d).

An increase in reindeer numbers of 30% per year has been estimated (Bonner, 1955; Payne, 1982) during the irruptive stage of the Barff population expansion. Payne (1972) observed that, given the lack of parasites, disease and natural predators, some constraint would be required in order to prevent this annual increase from overwhelming the island's resources. In terms of natural mortality, numerous carcasses were found at the base of scree slopes and cliffs during fieldwork, suggesting animals were falling to their deaths whilst trying to graze tussac stools on steep slopes (Payne, 1972, Leader-Williams, 1974). It is likely that decreasing winter range carrying capacity (due to tussac degradation) is having a limiting affect on the population and keeping numbers under control, if not leading to a slow decline in population (Leader-Williams and Payne, 1980). Populations will also fluctuate in response to environmental conditions such as an extreme winter (Gunn *et al*, 2003). It is estimated that the Barff herd reached its maximum in the 1950s, at which point overgrazing led to a decline, which gradually stabilised into a steady population (Leader-Williams and Ricketts, 1982) (see **Figure 2**). The Busen herd reached its peak later on, in the 1970s (hunting had limited population growth until this point), and then declined dramatically (Leader-Williams and Ricketts, 1982).

Population counts have varied in accuracy over the years (Bell, 2001). However, population models estimate maximum populations to be 5000 animals on the Barff, and 1500 on the Busen (Lovatt, 2007). In reality, the Busen herd is currently thought to be 1000 (Bell, 2001, Lovatt, 2007) animals, and the most recent count on the Barff estimated a population of 2100 animals (Leader-

Williams, 1988). Bell and Deitrich (2010) estimate the total South Georgia population to be 2600 animals.

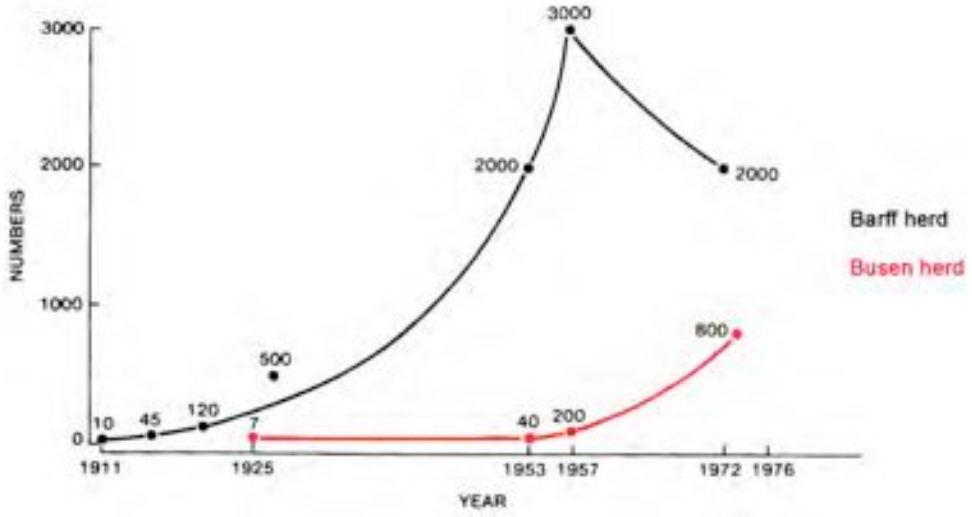

Figure 2 – Graph showing the population increase and decline of South Georgia reindeer since their introduction. (Adapted from Leader-Williams et al, 1989)

A high population density will force expansion into new areas if they are available. In the subantarctic Kerguelen archipelago, 10 reindeer were introduced in the 1950's. The population increased, and then decreased in response to lack of forage caused by overgrazing. In response to lack of forage, the remaining animals then swam in excess of 250m through open water to a neighbouring island, with the last of the animals leaving in 1980. The population on the new island is currently estimated to be 2000 animals (Chapuis et al, 1994). This demonstrates the potential risk of animals reaching new areas on South Georgia.

Population dynamics as displayed on South Georgia have been shown to follow a set 5-stage pattern in similar introductions around the world:

1 Introduction of an ungulate to a pristine environment that has abundant food resources and no predators.
2 The herd increases at a rapid rate.
3 The high density of animals causes overgrazing

4 Food resources become depleted

5 A sharp decline in the ungulate population occurs, normally due to starvation, following irreversible damage to the habitat. (Swanson and LaPlant, 1987).

The decline in the Barff population described by Leader-Williams (1988), and demonstrable recovery of vegetation in the absence of grazing as shown by exclusion experiments implies that South Georgia is currently half way through the fifth stage of this pattern, with irreversible damage (where topsoil has been lost) now starting to occur through erosion.

2.2 - Breeding and other relevant ecology

Within two years of introduction to South Georgia, the reindeer had altered their breeding season by 6 months in order to fit the austral seasons (Lewis-Smith 1978). The rut is estimated to peak between 20th and 30th March (Leader-Williams 1979b), continuing through the first 2 weeks of April (Leader-Williams and Rosser 1983), with the resulting calves being born in November (Leader-Williams 1979c) (see **Table 2**). Conroy (1988) observed that before the onset of the rut, between Jan-March, animals form herds according to sex – with groups of up to 20 stags and 40 females and calves seen. However, he also noted groups of animals half this size, with single female/calve pairs frequently seen.

Month	Event	Male Antlers	Pregnant Female Antlers
November	Calve	Growth (Velvet)	Cast
December		Growth (Velvet)	Growth (Velvet)
January	Formation of single-sex herds	Growth (Velvet)	Growth (Velvet)
February		Cleaning	Growth (Velvet)
March	Rut	Cleaning	Cleaning
April		Hard horn	Hard horn
May	Snow	Hard horn	Hard horn
June	Snow	Cast	Hard horn
July	Snow	Cast	Hard horn
August	Snow	Cast	Hard horn
September	Snow	Cast/Growth	Hard horn
October	Snow	Growth (Velvet)	Cast
November	Calve	Growth (Velvet)	Cast

Table 1 – Table highlighting key annual events in reindeer lifecycle (Derived from Leader-Williams, 1988)

During the rut the sex distribution within a group sample is 1:2.6 m/f (Leader-Williams, 1975). Males reach sexual maturity between 4-8 months of age (Leader-Williams and Ricketts, 1981) though access to females is limited by the competitive presence of older dominant males (Leader-Williams, 1979a). Females can first conceive at 16-17 months of age, with pregnancy rates of 90% for females of 18 months and older (Leader-Williams and Rosser 1983). The generation length for South Georgia animals is 4.2 years (Calculated as the mean lapse of time between a females date of birth and the mean date of birth of her offspring), meaning that to 2007 there had been 22 generations since the Barff introduction and 19 since the Busen (Lovatt, 2007). Males live to an average age of 7-8, and females are longer lived averaging 11-12 years (Leader-Williams and Payne 1980), with annual mortality between 30-40% (Leader-Williams 1980c). This is in comparison to Svalbard, where males live to between 12-13 years old and to females between 17-18 years old, with an annual mortality rate of 8.4%. Limited winter forage is the likely limiting factor in the population, with mandibular swellings (infected cavities in the jaw bone) resulting in loss of condition, and physical trauma caused by falls from cliffs (whilst trying to forage ungrazed areas) also significant causes of mortality (Leader-Williams 1980c). Parasitism does not seem to be significant amongst South Georgia reindeer, with the switch in seasons and lack of vector species eliminating all bar a few of the parasites that were inevitably introduced with the animals from Norway (Leader-Williams, 1980d).

2.3 - Condition of animals on South Georgia

Both herds on South Georgia experienced a severe genetic population bottleneck, as they both developed from a small (<20) number of animals. Despite this, both herds show a considerable resilience and maintenance of genetic diversity, though they do display evidence of decreased diversity and increased developmental instability (as shown by higher levels of fluctuating asymmetry whereby environmental stress or genetic anomalies result in random deviations from perfect symmetry when comparing the two sides of an animal) when compared to the founding herd (Lovatt, 2007).

The Barff herd increased in number far more rapidly than the Busen herd, which is likely due to its isolation having limited the hunting effort compared to the Busen herd (Kightley and Lewis-Smith, 1976). This is supported genetically; the Husvik herd shows a greater level of genetic relatedness than the Barff herd, demonstrating that the herd was smaller for longer (Lovatt, 2007).

Reindeer on South Georgia suffer from a higher than normal rate of dental abnormalities and mandibular swellings, due to their peculiar diet and dietary deficiencies. Up to a third of adult animals suffer from broken and missing teeth, with abscesses forming in the jaw. There is also a high rate of osteoporosis in the population (Leader-Williams 1980b). Teeth were also found to be calcified to an unusually high extent when compared to northern animals, resulting in extremely brittle teeth (Leader-Williams 1979b). Further study showed that incidence of mandibular swelling disease correlates with population density, and induces mortality through loss of body condition (Leader-Williams, 1982).

Native plants on islands may not necessarily be the dominant species in their community, and are naturally selected mainly for their ability to disperse; low rates of interspecific competition and an absence of native grazing herbivores mean plant species on islands can be extremely sensitive to grazing. The problem is exacerbated on South Georgia, as species-poor or simple communities have little capacity for ecological readjustment (Leader Williams et al, 1981).

Overgrazing results in poor quality forage, which leads to loss of body fat at which point animals have to utilise body proteins, which leads to loss of condition (Leader-Williams and Ricketts, 1982). At the time of the study by Leader-Williams and Ricketts (1982), the reindeer at Royal Bay had far richer forage than those on the Barff and Busen, as the herd had only recently established. The results of the study showed that the Royal Bay animals were larger, had better reserves of body fat, and were in better condition than the Barff and Busen animals, further supporting evidence of overgrazing in those areas. The results were so stark that is was concluded that loss of body condition due to overgrazing is a significant cause of mortality on the island, and forage availability is therefore the key limiting factor affecting final population size on the island (Leader-Williams and Ricketts, 1982).

There is a tendency for individual animals in island populations to be smaller than comparable animals on the mainland, as a response to environmental pressure (Lovatt, 2007). This is due to the fact that resource limitation and lack of predation pressure means small animals have a higher fitness, as they require less energy to survive and reproduce than larger animals. This effect is exacerbated by high population densities and intraspecific competition in areas that are species poor (in terms of forage). It was found that the skulls of South Georgia animals are statistically significantly smaller than animals in the original Norwegian herd from which they were sourced, a change that has occurred in only 20 generations, highlighting the competitive pressure the animals are under (Lovatt, 2007).

2.4 - Continuing range expansion of Busen herd

Until 1976, the Busen herd was restricted in range to the central part of the peninsula, with peripheral coasts and bays remaining ungrazed. This may have been due to the fact that hunting pressure kept the population to a level where grazing pressure had not forced the animals to the full extent of their potential range. The ungrazed areas on the Busen are only protected by steep mountain passes, unlike the glacier that protected the Royal Bay area on the Barff (McCann, 1987) prior to its retreat. However, with the effective cessation of hunting in the 1960's (Leader-Williams 1978), the population was allowed to expand unchecked. By 1986, grazing and population pressure had forced animals into these previously untouched areas (McCann, 1987). Since 1976, the range utilized by the herd has expanded 26%, to include the west side of Fortuna Bay (Bell, 2001) (see **Figure 3**) when lack of forage and over population forced animals into new areas. Of great concern is that occupation of the west side of Fortuna Bay appears to have occurred as a result of the retreat of the König glacier (Moen and MacAlister, 1994).

In 1976 Kightley and Lewis-Smith reported large areas of ungrazed burnet and tussac in the area of Leith Harbour, surmising that the herd had not reached its carrying capacity and was therefore only exploiting restricted areas for grazing. In 2006 large numbers of animals were seen grazing in this area, implying the herd had expanded greatly in the intervening years, or moved to new areas in search of ungrazed forage (*pers. obs*.).

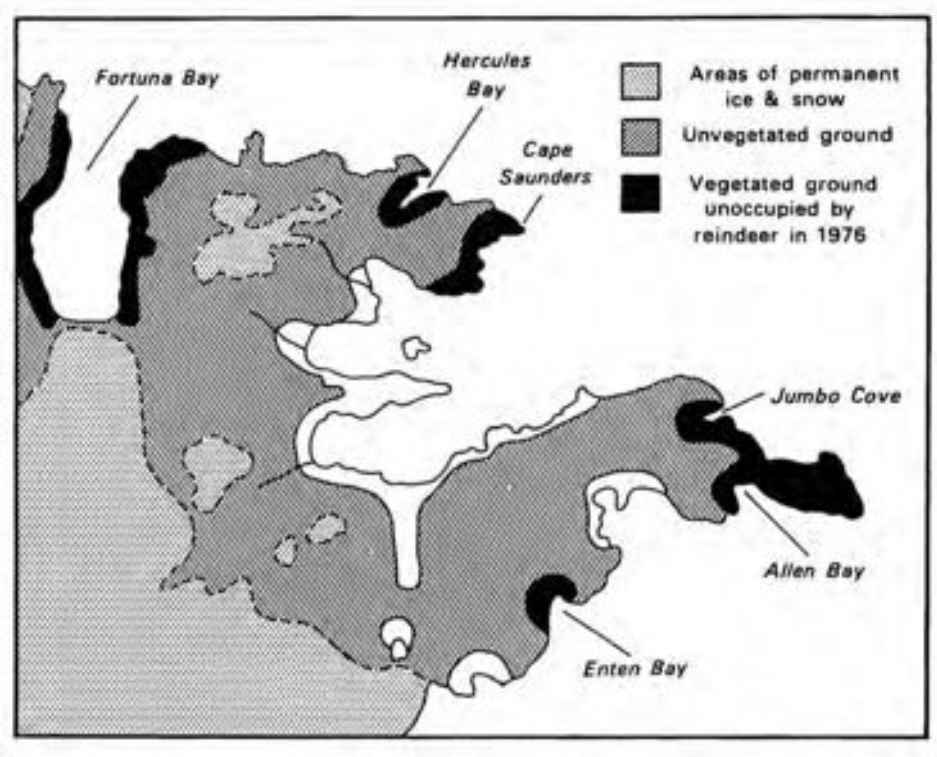

Figure 3 – Diagram showing the recent range expansion of the Busen herd. White un-hatched mainland areas are vegetated areas grazed by reindeer (Adapted from McCann, 1987)

3 - Effects of reindeer on vegetation

South Georgia does not have any native herbivorous animals, and as such the native vegetation is sensitive to any grazing pressure (Moen and MacAlister, 1994). The introduced reindeer have had a serious detrimental impact on vegetation across the range of the herds on the island. Exclosure experiments in affected areas have shown dramatic changes in vegetation composition, with complete recovery of native *Poa flabellata* and *Acaena magellanica* inside the exclosures, whilst the introduced *Poa annua* continues to spread in grazed areas. Trampling and grazing in combination have caused localised erosion, leading to a high proportion of bare earth in affected areas. (Vogel et al, 1984). The observations of erosion caused by reindeer in Bonner (1958), Payne (1972) and Lindsay (1973) are only anecdotal, with no supporting evidence. However, Leader-Williams (1975) is unequivocal as to the fact that reindeer were responsible for erosion caused by overgrazing, with independently verified observations.

To date, no species of vegetation is thought to have become extinct due to grazing pressure on South Georgia. Exclusion experiments have shown that key species can recover quickly with the removal of grazing pressure, though lichens may take decades to recover. Replacement swards of the introduced grass *Poa annua* now dominate extensive areas of coastal lowlands where native species have been locally eradicated by reindeer (Leader-Williams et al, 1987).

3.1 – Grazing effects and diet composition

By 1973, *Acaena magellanica* on the Busen Peninsula was almost completely eradicated by reindeer grazing (Kightley, 1974). Kightley described tussac in all grazed areas as having been "greatly devastated". Payne (1972) suggests that species and community composition on the Barff appeared to be changing due to impoverishment of the habitat by grazing. Kightley and Lewis-Smith (1976) state that of the vascular flora, the key species selectively grazed by reindeer are *Poa flabellata, Acaena magellanica* and the introduced *Poa annua*. Other vascular flora appears to be only casually grazed.

Studies at Royal Bay showed that after only ten years of the arrival of reindeer, lichens were virtually eliminated and closed swards of the grass *Deschampsia antarctica* were severely overgrazed. Within forty-five years on the Barff Peninsula, reindeer had completely eliminated closed swards of *Acaena magellanica* (Leader-Williams 1980a). Further studies established that the rushes *Juncus scheuchzerioides* and *Rostkovia magellanica* are also selectively grazed in the summer months (Leader-Williams 1980b), in addition to *Poa flabellata, Acaena magellanica* and the introduced *Poa annua*.

Of all the flora, it is the macrolichens that are the most affected by grazing (Kightley and Lewis-Smith 1976). In *Festuca* grassland and mixed tussac/bryophyte banks, grazing limits podetia (a stalk-like body of lichens) height to 1cm. In corresponding ungrazed habitats podetia form dense stands 5-10cm tall and can form up to 75% of the vegetation cover in some exposed grasslands. In grazed areas macrolichens are either scarce or totally absent. Due to their slow rates of growth and regeneration, lichens are extremely vulnerable to trampling and grazing, and are unable to recover in areas where grazing persists. In the Arctic similar effects on lichens have been recorded, with controlled grazing of lichen stands having been introduced in an effort to maintain adequate feeding grounds (Lindsay, 1973). Lindsay stated that the total elimination of lichens from the Barff Peninsula was inevitable, and in the long term any hope for recovery of lichens was unlikely unless numbers of

reindeer were reduced immediately. The need for a cull to manage the population was raised by Leader-Williams in 1975.

In the 1970's the density of reindeer was found to be seriously inhibiting vegetative regeneration of any form (Kightley and Lewis-Smith 1976). The effect of intensive grazing and trampling on the native vegetation has been described as devastating. In contrast to native species, the alien grass *Poa annua* tolerates severe grazing and trampling and has increased dramatically. It now dominates extensive areas formerly occupied by native plants (Lewis-Smith 1982) (see **Figure 4)**.

Stomach samples taken in 1928 from reindeer on the Barff Peninsula consisted primarily of tussac grass, *Poa flabellata,* with a small amount of *Festuca erecta* and greater burnet, *Acaena magellanica* (Olstad, 1930). Bonner (1958) mentions that in the 30 years since work carried out by Olstad (1928), greater burnet (*Acaena magellanica*) had been almost entirely grazed off the peninsula by reindeer. This is an observation supported by Lindsay (1973). A comparison of rumen contents between South Georgia and Norwegian reindeer found that in South Georgia reindeer 90% of all plant particles in the rumen consisted of grasses, compared to only 65% in Norwegian reindeer (Mathiesen *et al*, 2000). Bonner (1958) noted that reindeer appeared to feed mainly on tussac grass (as does Payne, 1972), and the South Georgia herds are globally the only stock of feral reindeer whose staple diet is not primarily lichens. Whilst tussac is undoubtedly the main dietary component, both Payne (1973) and Lindsay (1973) observed the almost total eradication of "reindeer lichens" on the Barff, indicating that reindeer may still preferentially graze lichens whilst they remain available. The loss of lichens in grazed habitats is evidenced by the total lack of any lichens found in rumen contents of South Georgia reindeer in 1999 (Mathiesen *et al*, 1999).

Figure 4 – Photograph showing field of *Poa annua* (and a closeup view of a *Poa annua* plant) to the exclusion of native species (Osborne et al, 2009)

It has been noted that reindeer are wasteful feeders, pulling at leaves and dropping large quantities of tussac, completely killing stands (Bonner, 1958; Payne, 1972 and 1973; Leader-Williams, 1974). Additional damage to vegetation occurs in summer when animals rub the velvet off their antlers on tussac stools (Kightley and Lewis-Smith 1976) (see **Figure 5**).

Figure 5 – Photograph showing a reindeer antler rubbing on a tussac stool, with eroded mossbank clearly visible. Husvik, Busen peninsula (Author, 2007)

In 1958 grazing was deemed not to be a serious issue, as the amount of tussac was vastly more extensive than the number of deer (Bonner, 1958). However, the effect of the subsequent population increase prior to the visit of Payne in the 1970's is apparent in his description of areas of tussac on the Barff as having been completely eliminated. He also observed notable overgrazing at Tonsberg Point on the Busen Peninsula (Payne, 1972, 1973). Kightley and Lewis-Smith (1976) note severe degradation of tussac stools caused by intensive grazing pressure, with formerly dense stands of tussac reduced to scattered live plants interspersed amongst dead plants and eroding stools, in marked contrast to Bonner's (1958) observations less than 20 years previously. Therefore it appears that tussac grassland is only seriously affected by high densities of reindeer (Leader-Williams et al, 1981). However, the relationship between the area of ungrazed vegetation in general and the population density of reindeer is such that a relatively low number of animals can graze a significant proportion of the vegetation available (see **Figure 6**) (Moen and MacAlister, 1994). Tussac plays many important roles in the ecosystem; stabilising soil and providing a

habitat for key invertebrate species and birds. As a result, overgrazing of tussac has far reaching negative consequences on the ecosystem as a whole (Leader-Williams 1985).

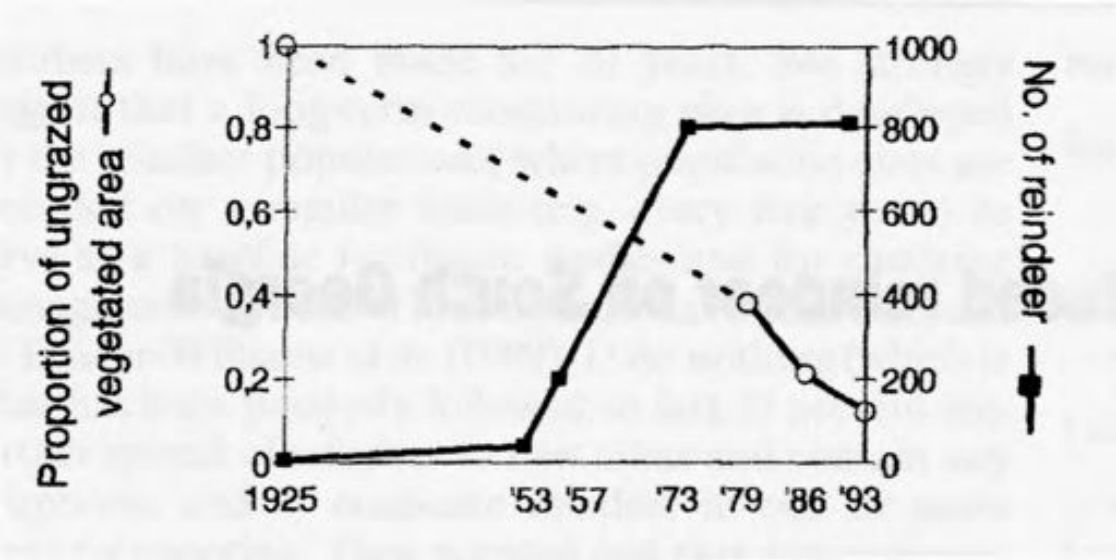

Figure 6 – Graph showing the relationship between the number of reindeer present in the Busen herd, and the proportion of ungrazed vegetation remaining over time (From Moen and MacAlister, 1994)

The most selectively grazed plant through the summer is greater burnet (*Acaena magellanica)* which, in the absence of grazing, grows in closed swards with a dense canopy at a height of approximately 30cm. These communities have an understory of *Tortula robusta* and it is also an important associate in various other community types such as *Festuca* grassland. However, in grazed areas the plant is almost completely eradicated. Where still present in grazed areas, the plant occurs sporadically as a creeping rhizome with small leaves, and shoots that rarely exceed 5cm (Kightley and Lewis-Smith 1976). Comparison of live above-ground biomass of *Acaena magellanica* show weights of 1850g/m^2 in long established ungrazed swards, and weights of 65g/m^2 in grazed areas (Leader-Williams et al, 1987). Reindeer grazing reduces biomass accumulation in leaves and in rhizomes, having a profound effect on the *Acaena* population as a whole (Moen and Walton, 1996).

Three grasses appear to be selectively grazed in the summer months, including the natives *Festuca contracta* and *Deschampsia antarctica* (Leader-Williams 1980b). The grass *Poa annua* is an introduced and successfully naturalised alien plant that forms the second most important summer dietary constituent of reindeer. Due to its tolerance of trampling and grazing, the largest swards of the species occur in areas grazed by reindeer. It readily invades degenerate communities where native species have been removed, and can attain a cover of up to 90% in those grazed areas. In areas where *Poa flabellata* and *Acaena magellanica* have been eradicated by grazing the grass establishes rapidly, and it can also be spread within deer excrement, which also serves to enrich the soil and subsequently aids the colonisation of the species (Kightley and Lewis-Smith 1976). However, the grass only poorly tolerates competitive pressure by native species if they are allowed to recover in the absence of grazing (Vogel et al, 1982).

Summer pasture on South Georgia was found to be of high quality for reindeer, due to its high mineral and carbohydrate quantity, and high rate of digestion (Mathiesen and Aagnes Utsi, 2000). During periods of unrestricted forage ability in the summer, reindeer were found to be discriminating feeders, selecting forage species at a time when they offer maximum nutritional value. The species most grazed in the summer (*A. magellanica, P. annua* and *D. antarctica*) are the most nutrient rich species available. In summer the diet is diverse, with a mixture of nutrient rich flora (as above) and energy rich tussac. In winter, diet is energy rich but nutrient poor, due to the lack of availability of any species other than tussac. Tussac, whilst high in carbohydrates is low in mineral nutrients and crude protein, hence the preference for other species in summer (Pratt and Lewis-Smith, 1982).

The limiting effect of snow cover on South Georgia means some of the summer forage species are unavailable for up to six months (Leader-Williams et al, 1981). Indeed, the success of reindeer on South Georgia can be attributed solely to the existence of the winter-green tussac grass (*Poa flabellata)* (Lewis-Smith, 1982). Overgrazing on other sub-Antarctic islands with introduced reindeer reliant on

lichens as forage has resulted in catastrophic population collapses (Leader-Williams, 1980a).

One of the key limiting factors for ungulates living in polar-regions is their winter food supply, as demonstrated by the spectacular population crash of reindeer on St Matthew Island in the Arctic. The population was almost entirely dependent on lichens for winter forage, and given the low biomass and slow growth rates of lichens, they are quickly depleted under continuous grazing pressure. Lichens are also very slow to recover. As a result, the reindeer effectively eradicated their only source of forage, and the population crashed as a result. In the course of a single winter, the population reduced from 6000 animals to 42, of which only one survivor was male (Klein, 1968).

The abundance and regenerative ability of tussac on South Georgia has resulted in a higher sustained population than was possible on Arctic islands (Leader-Williams et al, 1987). In general, forage quantity acts to govern population size (having the greatest effect in winter), while the quality of the forage determines the size of the individual (having the greatest effect in summer) (Klein, 1968).

The proportion of tussac grass as a dietary component varies seasonally; it is a less significant constituent of summer diet (15-30% (Leader-Williams and Payne, 1980)) than of winter (>95%) (see **Table 2**). It is an important winter resource for deer, as during early and mid winter tussac foliage protrudes above the snow, during which time the plants are heavily grazed (Kightley and Lewis-Smith 1976). Reindeer cannot dig deeper than 60cm to forage in snow, and in winter tussac is the only species still accessible (Leader-Williams 1980a). As a result tussac forms 95-100% of winter diet (Leader-Williams and Payne, 1980). In late winter, when snow cover is heaviest, tussac is the only food source widely available, and the animals scrape away the snow to graze on the foliage, and actively target basal portions of tillers and developing shoots in the lower parts of the plants. This prevents much of the following season's growth from taking place, and exposes roots to frost and desiccation that can kill new tillers. Erosion then occurs through further trampling and wind and frost action until the stony

substratum is exposed (Kightley and Lewis-Smith 1976). In localised areas such as ridge tops and coastal flats, reindeer have completely eradicated tussac grass, which in many instances was replaced by the alien grass *Poa annua* (Leader-Williams et al 1981) (see **Figure 7**).

Month	Proportion of diet
January	15-30%
February	15-30%
March	15-30%
April	15-30%
May	60-80%
June	95-100%
July	95-100%
August	95-100%
September	95-100%
October	60-80%
November	60-80%
December	15-30%

Table 2 - The proportion of tussac grass in reindeer diet throughout the year. (Derived from Leader-Williams and Payne, 1980)

Many features of grazing pressure are the same between the different reindeer populations around the world, though impact varies according to plant community. The negative influence of grazing and trampling is obvious in tussac grass, *Acaena* swards and moss banks, but the complete absence of certain species (such as lichens) due to selective grazing is not so immediately obvious (Kightley and Lewis Smith, 1976). These more subtle impacts include:

- Absence or scarcity of terricolous fruticose and foliose lichens in *Festuca* grasslands
- Absence or scarcity of *Acaena spp* from various communities

- Reduction in cover afforded by macrolichens (Kightley and Lewis Smith, 1976).

Four types of overgrazing are deemed to occur on South Georgia, classified through extensive surveying and observation (Leader-Williams, 1988):

1 **Tussac overgraze**: areas of former tussac grassland that have been reduced to bare tussocks or mossbanks

2 **Dwarf-shrub overgraze**: areas of former dwarf-shrub sward that have been converted to dead litter, or grown over by mossbanks after the loss of *Acaena magellanica*.

3 **Invasion of introduced species**: mesic meadows or tussock grasslands in which the dominant species had been reduced or eradicated, and replaced by *Poa annua*.

4 **Erosion sites**: areas where vegetation cover has been reduced, but where in addition, topsoil has slipped extensively.

As of 1988, severe overgrazing of the first three categories was evident over much of the Barff and Busen areas. Overgrazing of category four was only evident in the Barff area, where reindeer have been established the longest (Leader-Williams, 1988).

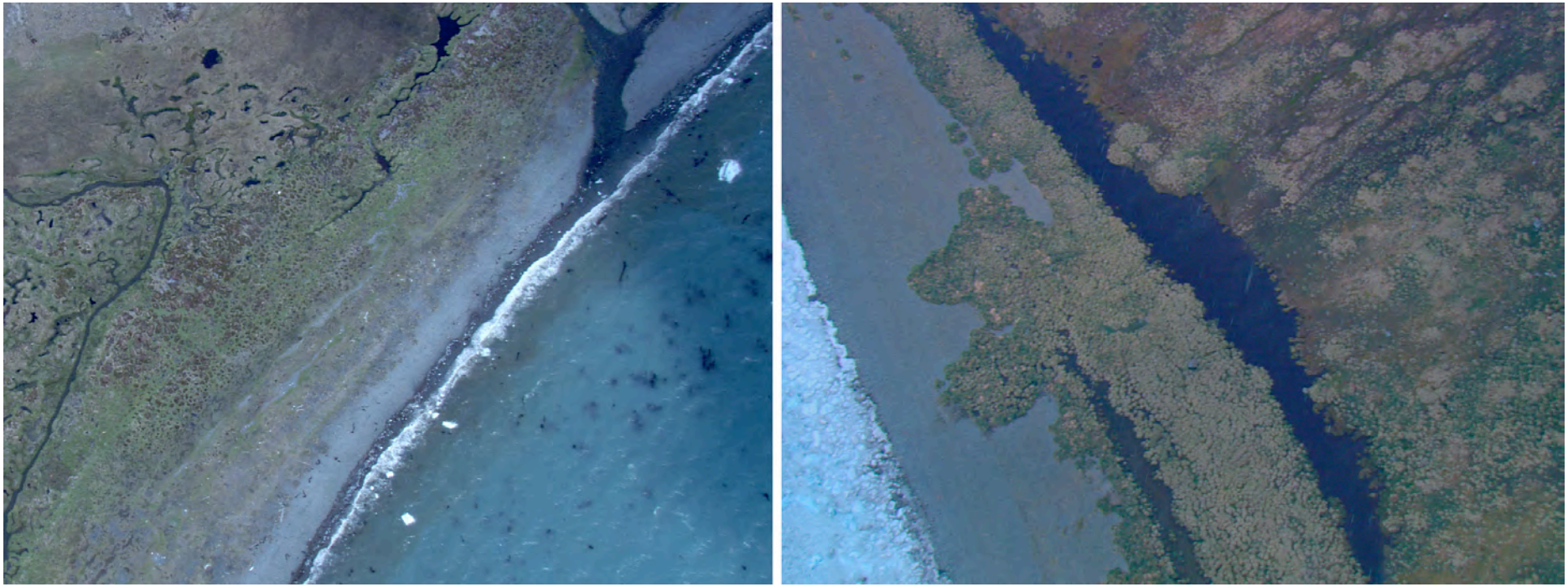

Figure 7 – Aerial photograph of coastal areas on the Barff Peninsula, showing (left) the complete absence of tussac grass, eroded areas and eroded tussac pedestals compared to (right) minimally grazed tussac showing healthy pedestals (GSGSSI, 2008).

3.2 - Trampling

Areas of marshy ground are liable to be trampled into peaty mud that is devoid of vegetation, where the deer's sharp hooves have cut down through the soft turf (Bonner, 1955). Observers note well defined tracks, which even in dense vegetation are barren with little opportunity for regeneration, that lead to ponds whose surrounding terrestrial and semi-aquatic vegetation are badly broken up (Kightley and Lewis-Smith 1976). Trampling of moss-banks was deemed to be extremely detrimental to the environment of the island by Lindsay (1973). Of particular concern were wet areas frequently traversed by reindeer, which became so churned up that they became areas of only bare peaty mud – a description that notes only minimal numbers of fur seals in the area (Lindsay, 1973). A report of a visit to the Barff in 1979 describes networks of extensive reindeer tracks across large areas of the Peninsula (Headland 1979).

Trampling removes leaves from tussac stands, with subsequent weathering resulting in the death of the plant (Kightley and Lewis-Smith 1976). Bryophytes do not appear to be selectively grazed, and the majority of damage appears to be from trampling (Kightley and Lewis-Smith 1976) as reindeer can sink to a depth of 20cm in wet bryophyte banks. These holes can remain indefinitely due to slow growth rates, and the long-term effect of trampling leads to erosion of the banks (Kightley and Lewis-Smith 1976).

3.3 - Results of an exclusion experiment

In the 1970's, Kightley and Lewis-Smith (1976) established a long-term exclusion experiment to monitor and survey the vegetation changes caused by reindeer grazing. A mixture of large 10mx10m exclosures and smaller 2.5mx2.5m cages were erected across key habitats, in stands of the island's principal plant communities in order to monitor changes in the composition, abundance and productivity of plant species in permanent quadrats inside and outside the fences (Lewis-Smith 1982). Within 16 weeks of construction *Acaena magellanica* was observed to have grown to heights of 15-20cm, where no comparable growth was observed in control sites. Surviving tussac stands in exclosures grew long entire leaves (see **Figure 8**), whereas stands in control sites had frayed and short leaves due to grazing and antler rubbing (Kightley and Lewis-Smith, 1976).

Figure 8 – Photograph showing the recovery of tussac grassland in the absence of grazing pressure, either side of a wire fence. Sorling Valley exclosure, Barff Peninsula (Author, 2007)

Over seven years of observations, the greatest changes were observed in communities dominated by *P. flabellata, P. annua* and *A. magellanica*, with little change observed in bog communities dominated by rushes (*Rostkovia magellanica* and *Juncus scheuchzerioides*) and bryophytes. Considerable regeneration by *P. flabellata* (see **Figure 9**) and *A. magellanica* (see **Figure 10**) occurred where vegetation was protected, and the introduced *P. annua* decreased as other native species overgrew it (see **Figure 11**), indicating an intolerance of competition, although it remained dominant where grazing kept it closely cropped. There was little sign of lichen recovery (Lewis-Smith, 1982), though on islands in the Kerguelen archipelago it took over ten years for lichens to recover in the absence of reindeer (Chapuis et al, 1994).

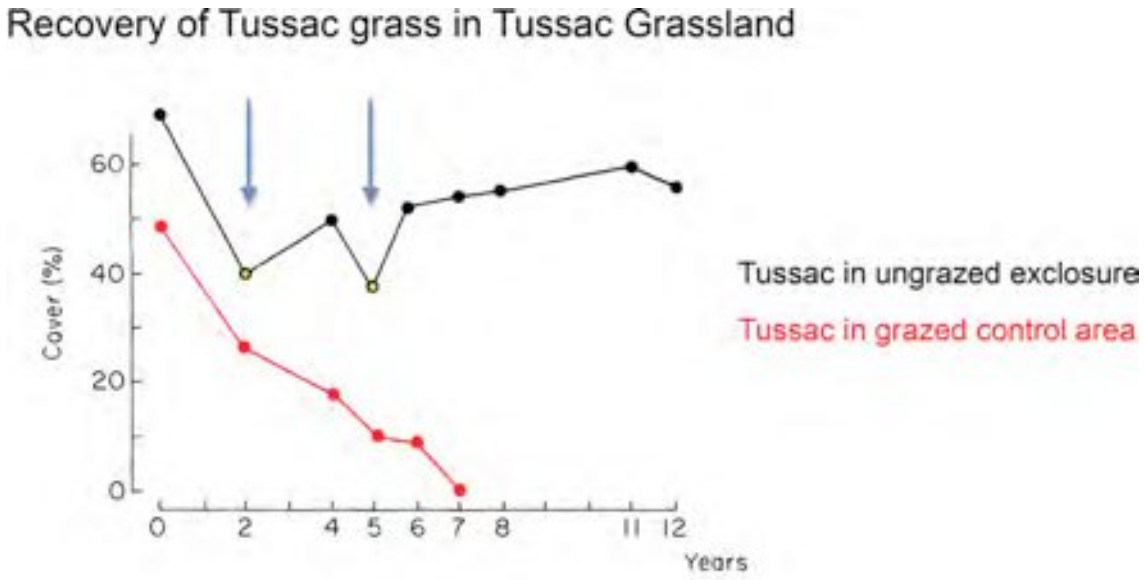

Figure 9 – Graph showing average percentage cover of tussac grass over time in exclosures and control areas. The arrows highlight points where deer broke through the exclosures and grazed, as is apparent by the drop in vegetation cover during these years (Adapted from Leader-Williams *et al,* 1987)

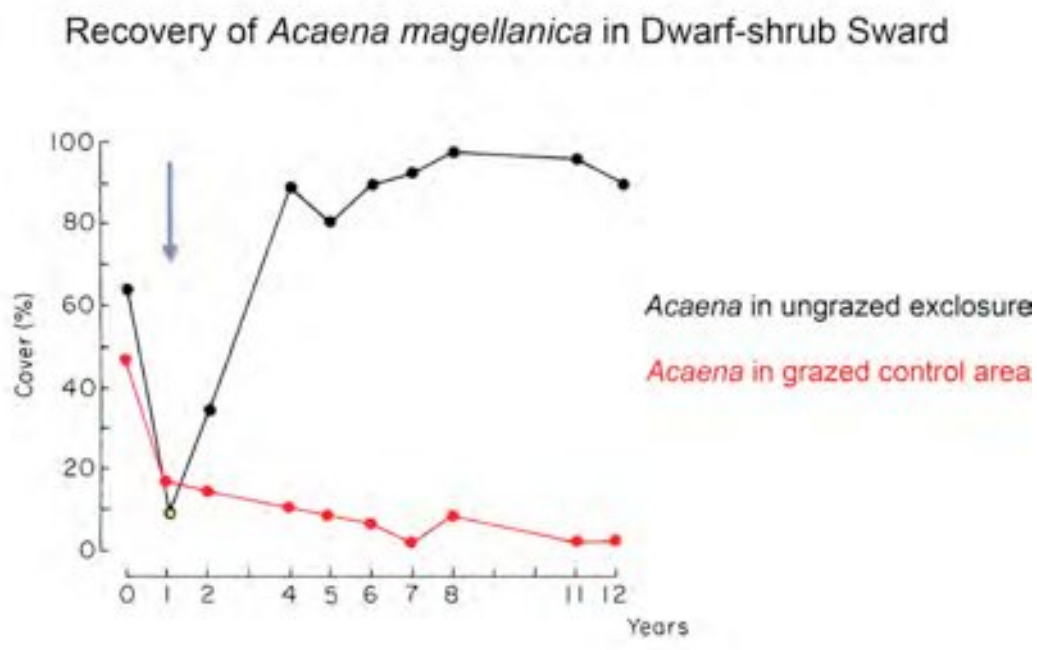

Figure 10 - Graph showing average percentage cover of *Acaena magellanica* over time in exclosures and control areas. The arrow highlights the point where deer broke through the exclosures and grazed, as is apparent by the drop in vegetation cover during these years (Adapted from Leader-Williams *et al,* 1987)

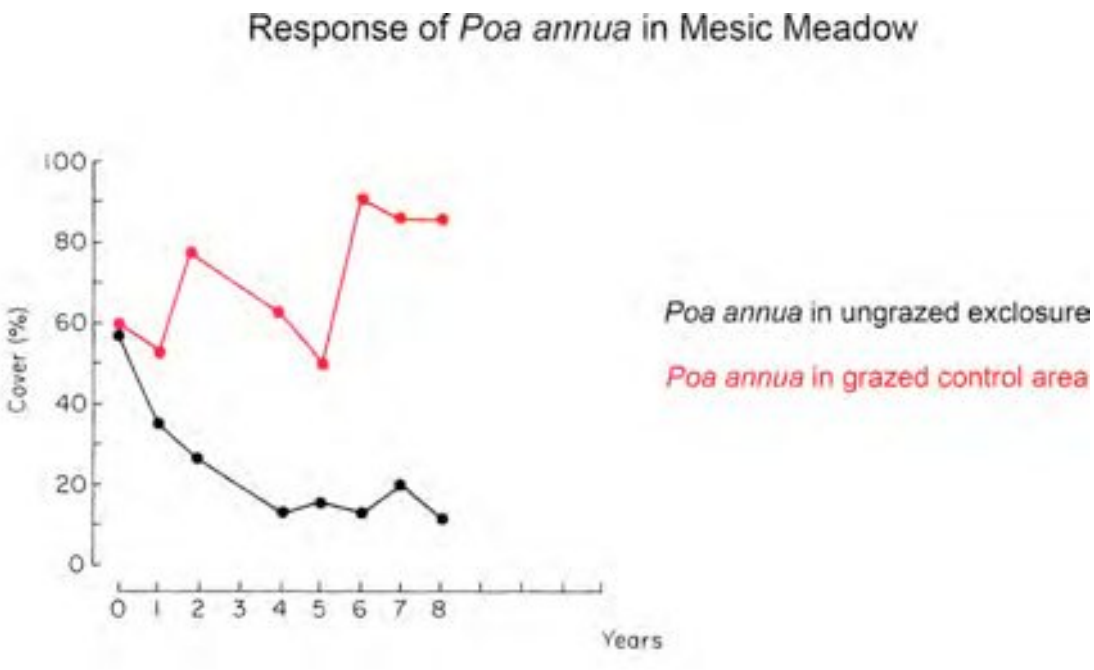

Figure 11 - Graph showing average percentage cover of *Poa annua* over time in exclosures and control areas (Adapted from Leader-Williams *et al*, 1987)

Provided damage to the vegetation had not resulted in soil erosion and root destruction, regeneration appeared to occur quite rapidly and the plant communities recovered to their original state (Lewis-Smith, 1982). In areas where grazing had progressed too far (resulting in erosion with loss of topsoil) recovery of tussac grass was not possible, even in exclosures (Vogel et al, 1984). In areas with a long history of grazing, grazing eventually caused the tussac to die and the pedestals to become overgrown with mosses – wind exposure of these degraded slopes then causes erosion (Moen and MacAlister, 1994). Given this revegitative point of no return, it is important that any management action first occurs where the reindeer have been present in high numbers for the longest. If overgrazing continues unchecked, lack of management in reindeer areas may preclude recovery of climax vegetation in the long term (Leader-Williams et al, 1987). The exclusion experiment demonstrated that several of the important components of the vegetation impacted by reindeer rapidly regain their former abundance when grazing pressure is removed, with the exception of macrolichens which may take several decades to recover (Leader-Williams et al, 1987). As lichens only recover their former abundance several decades after damage due to grazing or trampling, they provide a good example as to the

delicate balance between reindeer and the habitat they inhabit (Leader-Williams, 1988).

The exclusion experiment demonstrated that the species that showed the greatest recovery on cessation of grazing were tussac grass and *Acaena magellanica*, both species conversely showed the greatest decline in control plots. In contrast, the introduced *Poa annua* showed the greatest decrease in exclusion plots and the greatest increase in control plots. After 12 years of protection from grazing, exclosure plots showed no sign of recovery of macrolichens, though comparison with northern hemisphere sites shows recovery can take decades (Leader-Williams et al 1987). A further study of remaining exclosures in 2002 did not analyse data statistically, but showed that trends in vegetation recovery had continued in the 20 years between studies, with many exclosures being "overwhelmingly dominated by *Acaena magellanica*" in stark contrast to control sites (Poncet and Scott, 2002).

In 2008 GSGSSI commissioned a botanist to revisit any remaining exclosures, and to carry out transects to compare grazed and ungrazed communities. The results are summarised below:

In 1973 the Sorling Valley exclosure was recorded as dry meadow, dominated by *Rostkovia magellanica,* and in the first 12 years of the experiment there was no *Poa flabellata* present (Leader- Williams, Smith, and Rothery, 1987). In contrast, this exclosure site is now vegetated with a regenerating tussac-mossbank community with significantly higher lichen cover than outside. This clearly shows the significant detrimental effect that reindeer have had on total tussac cover in reindeer populated areas of South Georgia (Upson, 2009).

Both the exclosure and control site at Husvik were co-dominated by *Festuca contracta* and *Acaena magellanica* when the experiment was started in 1973 (Leader-Williams, Smith, and Rothery, 1987). Now, 35 years on, there is almost total ground cover by *Acaena magellanica* within the exclosure and less than 5 % outside (see **Figure 12**) (Osborne et al, 2009; Upson, 2009). This clearly shows

the preference of reindeer for *Acaena magellanica* and the dramatic effect grazing can have on vegetation composition. Outside the fenced area the vegetation has been completely modified to *Rostkovia*-dominated bog (Osborne et al, 2009). Overall, results from the study show that removal of reindeer would be necessary to allow the recovery of more natural plant communities on South Georgia (Upson, 2009).

Figure 12 - Image showing the stark contrast at the remaining Husvik exclosure, with near 100% cover of the native *Acaena magellanica* within compared to no *Acaena magellanica* outside (Osborne *et al*, 2009)

As a general rule on southern islands, marine tussac communities are the most vulnerable to grazing by introduced herbivores, with other communities only beginning to suffer when grazing pressure is high. If grazing reaches such an extent that erosion and soil loss occurs, biological productivity of these areas is permanently reduced. However, on South Georgia the impact of the reindeer has not precisely followed this rule, with fellfield, dry-meadow, dwarf-shrub heath

and mesic meadow communities being affected prior to tussac communities. Tussac was only affected when reindeer reached peak densities (Leader Williams et al, 1981).

There are three reasons for the differences described above:

1 Reindeer prefer lichens as forage, to the extent that these have now been virtually eliminated from grazed areas on the island.

2 Reindeer have overgrazed species high in nitrogen and phosphorous content, which are available in summer (*D. antarctica* and *A. magellanica*), from a flora that is predominantly formed of species low in those elements.

3 Finally, other sub-Antarctic islands only have deep snow cover at higher altitudes. Tussac communities are available to some extent all year round, whereas inland plant communities are covered by snow, to the exclusion of reindeer for 5-6 months of the year (Leader Williams et al, 1981).

In addition, heavy snow cover on the island causes a significant reduction in seasonal carrying capacity, which in winter determines the upper population limit. As a result, the reindeer population densities on South Georgia are unlikely to be as high as they would have been in the absence of snow cover, with grazing pressure on tussac grassland kept at a lower level than would normally be expected (Leader Williams et al, 1981).

The limiting effect of winter forage availability is further evidenced by Leader-Williams and Ricketts (1982), who compared body size, fat levels and condition between the herds. Body fat reserves, condition and body size throughout development are each dependent on the quality and quantity of forage availability (see section 2.3, Condition of animals on South Georgia).

4 – Other impacts of reindeer

4.1 - Impact of reindeer on invertebrates

The impact of herbivores on invertebrates on sub-Antarctic islands is likely to be significant (Chapuis et al, 1994). The entire turnover of primary production on the island takes place in and on the soil through a chain of decomposers, or is accumulated as peat. The key species in this chain is the native herbivorous perimylopid beetle *Hydromedion sparsatum*, which in control sites in ungrazed areas of the island forms 33.6% of all epigeic invertebrate fauna. In reindeer areas they form only 7-9% of the fauna. Their habitat is the fresh litter and upper layers of soil, where they feed on young plant seedlings. Reindeer grazing reduces the volume of vegetation and therefore litter, and trampling compacts the surface soil leading to further reduction in these key animals (Vogel et al 1984) which carry out a vital ecological process.

It would seem that by far the most profound factor impacting the species composition and abundance of indigenous invertebrate communities is the presence of reindeer, with the significant effect that this has on the indigenous vegetation and habitats of South Georgia (Key and Key, 2009). Their impact on invertebrates includes the significant change in vegetation architecture as *Poa flabellata* tussac grassland is reduced to short, non-indigenous annual meadow grass 'lawns', moss carpets, bare soil, peat or stones, coupled with considerable reduction in plant litter and overwintering sites on such short grass. Erosion to bare substrate of several vegetation types leads to reduction in area that can be occupied by indigenous invertebrates (Key and Key, 2009).

By facilitating the spread of species such as the introduced *Poa annua*, which are unsuitable for the native perimylopid beetle *Hydromedion sparsutum*, reindeer are indirectly affecting the body size of the insects, reducing their fitness (Chown & Block, 1997).

4.2 - Impact on ACAP and other bird species

The Agreement on the Conservation of Albatross and Petrels (ACAP) was extended to South Georgia in 2004. The ACAP Agreement, together with its Action Plan, describes a number of conservation measures that contracting Parties need to implement in order to improve the conservation status of these threatened seabirds. Seven of the 26 currently listed ACAP species breed on South Georgia and South Sandwich Islands (SGSSI). For all of these species, SGSSI hosts significant proportions of the global breeding population, including the largest populations for four of the seven species (Wolfaardt, 2009).

Because of the importance of tussac grass in stabilizing soil, and as a habitat for invertebrates and burrowing bird species, the consequences of overgrazing by reindeer are far-reaching (Leader-Williams, 1985). The main impact of reindeer on ACAP species is through their trampling and heavy grazing, which negatively impacts the terrestrial biodiversity and ecological integrity of affected areas and thus undermines the quality of nesting habitat for burrowing petrel species (Wolfaardt, 2009). Specifically, reindeer have been acknowledged as being a threat to white-chinned petrels, *Procellaria aequinoctialis* (Birdlife, 2009). The species is listed as Vulnerable in the IUCN redlist, and the population is declining at 1.8% per annum globally (Wolfaardt, 2009). A survey of white-chinned petrels on South Georgia found the highest densities on a peninsula not inhabited by reindeer or by rats (Martin et al, 2009).

The opening up of previously dense tussac grassland by reindeer grazing has provided greater access to skuas, assumed to result in increased predation of storm petrels, Antarctic prions and blue petrels (McIntosh & Walton, 2000).

4.3 - Associated introduced plant species

As indicated by Leader Williams *et al.* (1987), reindeer have a significant and detrimental impact on the native vegetation. The impact of reindeer grazing on the introduced plant species on South Georgia appears to vary according to the species. Reindeer appear to control the population of dandelions (*Taraxacum officinale)* but act as a vector for the spread of *Poa annua*, maintaining this species in dense, closely grazed swards (Osborne et al, 2009).

The dandelion readily colonises suitable habitat, competing with the native vegetation. As the seed is wind dispersed it is easily spread over large distances and therefore has a high invasive potential. Should the reindeer be removed from South Georgia, there is likely to be a rapid increase in *Taraxacum officinale* at previously grazed sites where the reindeer were selectively grazing it out. *Taraxacum officinale* is widespread on South Georgia, and therefore control or eradication of this species would currently be unrealistic and the cost prohibitive (Osborne et al, 2009).

Poa annua tends to colonise bare and degraded areas rather than directly invading native vegetation. However, in some areas it has been found to be invading patches of damp moss. As it is tolerant to grazing, it is maintained in dense lawns where reindeer are present, and may prevent the native vegetation from re-colonising. It is also highly tolerant of trampling, so populations are maintained in areas heavily impacted by people and wildlife, along pathways and in fur seal breeding areas. It flowers and sets seed continually throughout the summer months. The seed is highly viable and may be dispersed by both wind and wildlife. Reindeer are likely to be a significant vector for the spread of *Poa annua*, distributing seeds across their range in their dung (see **Figure 13**). Since *Poa annua* already has such a wide distribution and high seed viability it is inevitable that this grass will eventually spread to all suitable habitat across South Georgia. Control or eradication of this species would currently be unrealistic and the cost prohibitive (Osborne et al, 2009).

Figure 13 – Photograph showing *Poa annua* growing out of reindeer dung in an area of *Rostkovia magellanica* bog at Stromness. *Poa annua* does not naturally invade bog vegetation, making it particularly conspicuous in this instance (Osborne *et al*, 2009)

5 - Retreat of glaciers on South Georgia

Reindeer on South Georgia are restricted in range due to the presence of glaciers, the majority of which act as barriers to further expansion (Leader-Williams, 1988). The coastal glaciers on South Georgia have shown a trend of accelerating retreat over the past fifty years, with the most rapid increase occurring in the past decade. This has occurred simultaneously with the recent period of climate warming that began in the 1930s. Analysis of the rates of advance or retreat of over 100 coastal glaciers on South Georgia from the 1950s to the present show that 97% of these glaciers have retreated over the period.

The average amounts of retreat show that the majority (64%) of glaciers retreated by between 0 and 500 m since the first observations were made. Two glaciers stand out as having retreated the most: the Neumayer Glacier has retreated by 4.4 km since 1957 (see **Figure 14**), and the ice front fed by the Ross and Hindle Glaciers has retreated by 2.14 km since 1960.

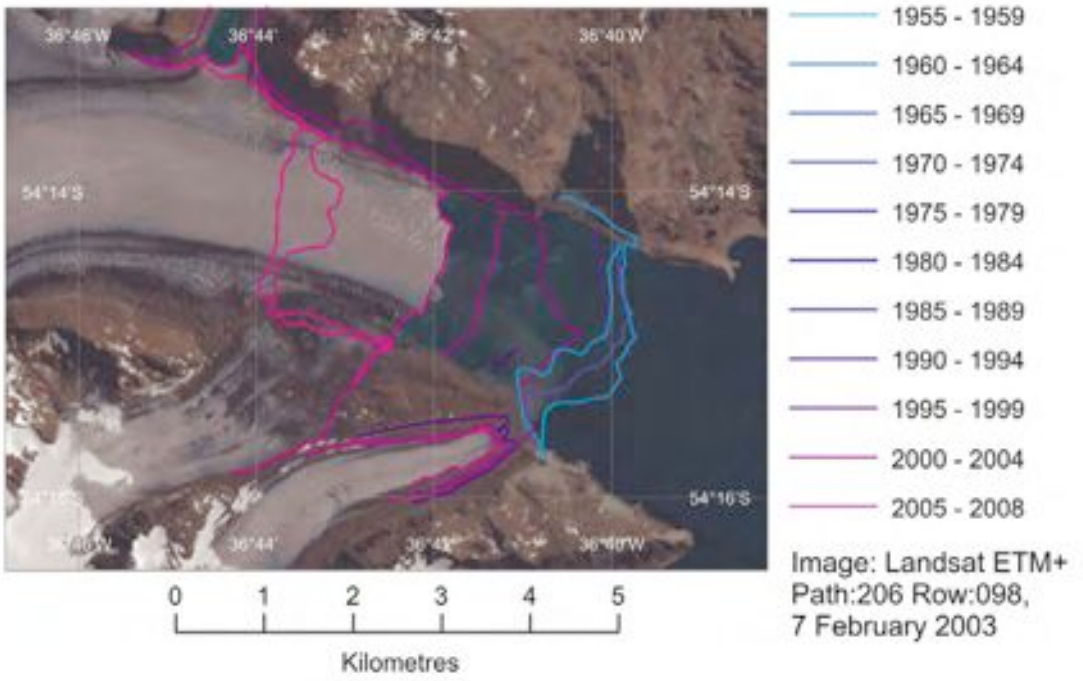

Figure 14 – Diagram showing the retreat of the Neumayer Glacier since 1955 (Cook *et al,* 2010)

The rate of retreat for all 103 glaciers has increased from an average 8 ma^{-1} (meters per annum) in the late 1950s, to 35 ma^{-1} at present revealing an accelerating rate of retreat since the 1990's. Glaciers in the northeast of the island are currently showing an average retreat of 60 ma^{-1}. Of these, some individual glaciers have shown particularly great changes, for example the rate of decrease of the Neumayer Glacier has increased from 3 ma^{-1} retreat in the late 1950's to 384 ma^{-1} retreat at present (see **Figure 15** below).

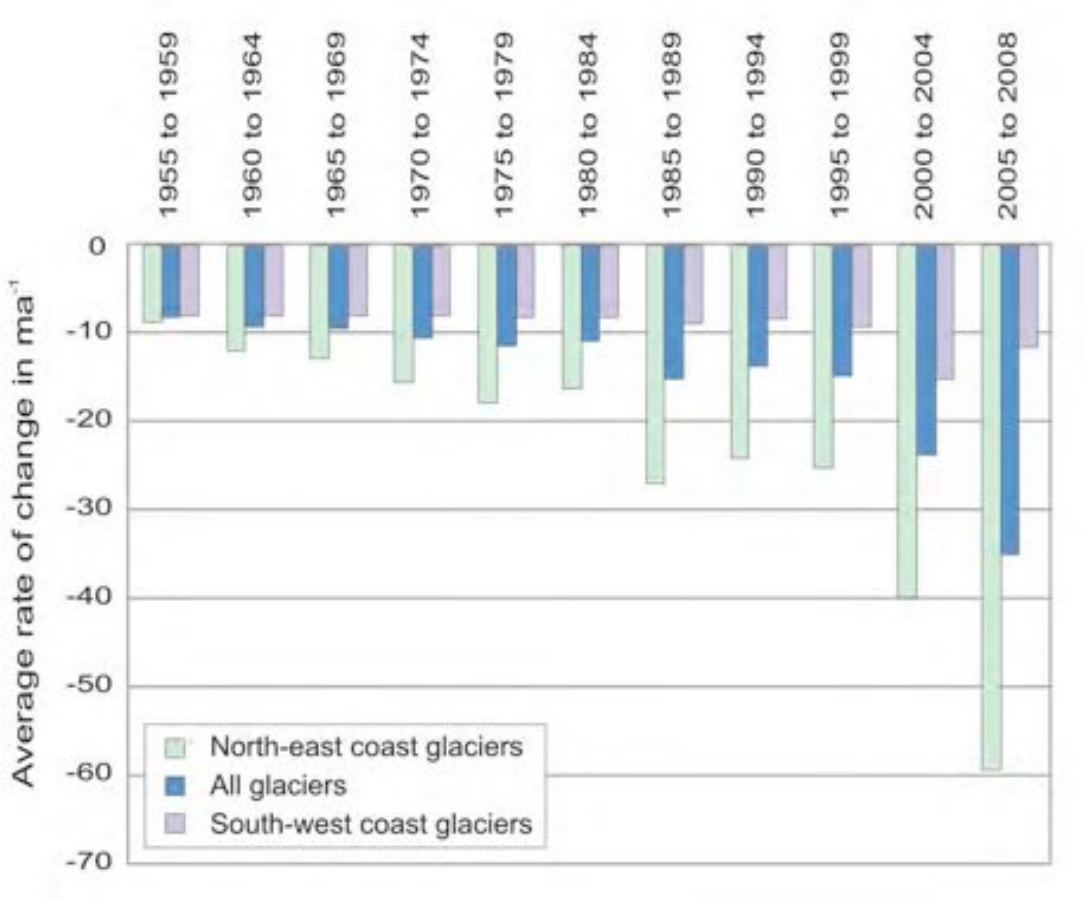

Figure 15 – Graph showing the increasing rate of retreat of glaciers on South Georgia since 1955 (adapted from Cook *et al,* 2010)

There is a corresponding trend of increasing average annual temperature over time on the island, (see **Figure 16)**, which drives the melting of the glaciers. The accelerating rate of decline of the glaciers means that their role as barriers containing the reindeer herds is unlikely to continue. Consideration of what

management action should be taken, and when to take it, should therefore take this into account.

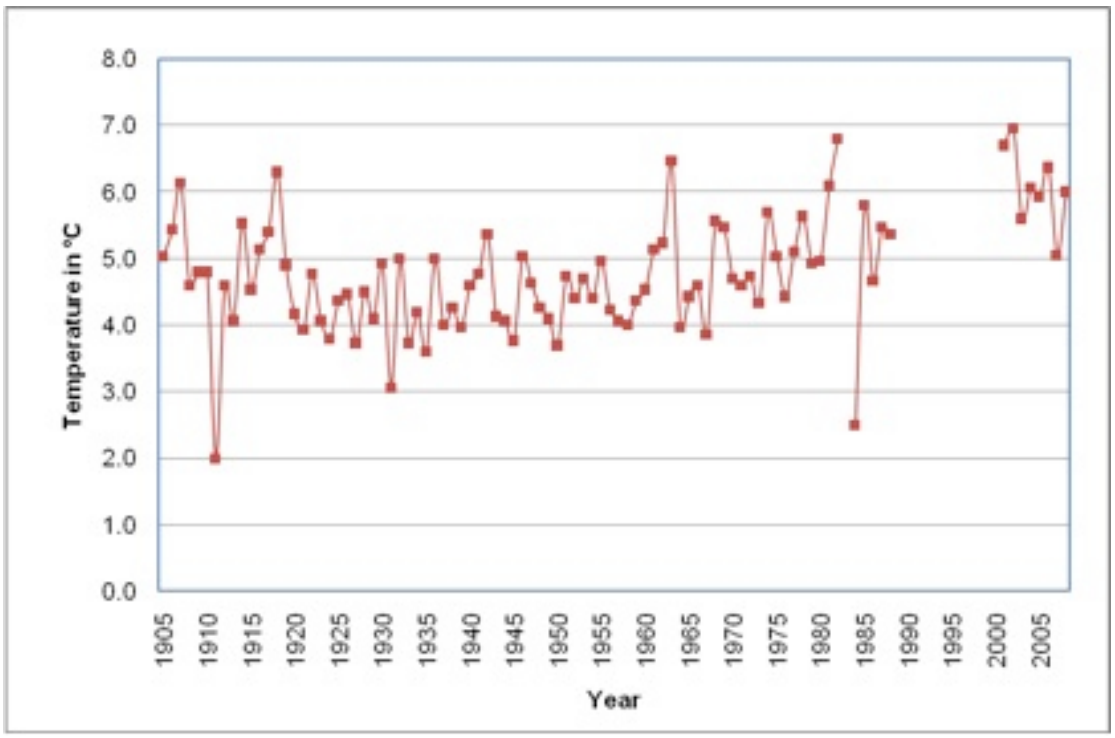

Figure 16 – Graph showing the average summer temperatures recorded at Grytviken, South Georgia between 1905 – 2005 (Cook *et al*, 2010)

6 - International Conventions and national obligations

The Environment Charter for South Georgia (UKOTCF, 2010) is an agreement between GSGSSI and the UK Government. The Charter sets out separate Guiding Principles and Commitments for both parties.

Guiding Principle 7 states that GSGSSI must strive "to safeguard and restore native species, habitats and landscape features, and control or eradicate invasive species."

Commitments 2 and 6 state that GSGSSI will:

> 2- Ensure the protection and restoration of key habitats, species and landscape features through legislation and appropriate management structures and mechanisms, including a protected area policy, and attempt the control and eradication of invasive species.
>
> 6 – Implement effectively obligations under the Multilateral Environmental Agreements already extended to SGSSI and work towards the extension of other relevant agreements.

South Georgia is covered by several international treaties that require positive management action from GSGSSI to deal with the problem of introduced species (McIntosh & Walton, 2000).

The Convention on Biological Diversity (CBD) (Rio Convention 1992) has not been extended to South Georgia by the UK Government, unlike most of the other UK Overseas Territories. It is the intention of GSGSSI to have the CBD extended to the territory. Article 8h states that Governments are obliged to "prevent the introduction of, and control or eradicate those alien species which threaten ecosystems, habitats or species".

The Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention 1979) was extended to SGSSI on 23 July 1985. It requires signatories to "take concerted conservation and management action to preserve the welfare of listed species".

The Convention on Wetlands of International Importance (especially waterfowl habitat) (Ramsar Convention 1971) was extended to SGSSI on the 5th January 1976, though to date no sites have been designated. The Convention calls for the "establishment of strict protection measures to ensure that the ecological character of sites is not placed at risk" (read 4.3.3).

The Agreement on the Conservation of Albatross and Petrels (ACAP) was extended to South Georgia in 2004 (see section 4.2, Impact on ACAP and other Bird Species). It requires signatories to:

1. Conserve and, where feasible and appropriate, restore those habitats that are of importance to albatrosses and petrels (Art III, 1a).

2. Prevent introductions, eliminate or control non-native species detrimental to albatrosses and petrels (Art III, 1b).

When obligations under these various conventions are considered, it is clear that GSGSSI is bound to consider management options to minimise or remove the impacts of reindeer on the island.

7 - Impacts on proposed island-wide rat eradication

Of great significance is the link between reindeer management and the proposed island-wide rat eradication project managed by the South Georgia Heritage Trust. This is a project fully supported by GSGSSI, and one that has received significant sums of charitable donations, and is gaining increasing international publicity.

Removal of the introduced reindeer from areas identified for rat baiting is necessary in order to achieve island wide rat eradication for three key reasons:

1 Reindeer have been observed to eat blank cereal bait which is identical to that used in rat eradication projects (though without the poison content) (*pers obs*, 2007). In order to ensure that a sufficient quantity of bait remained to eradicate the rats after reindeer consumption in the treatment areas, a significantly larger volume of bait would have to be used in those areas, greatly increasing both costs and the amount of poison in the ecosystem. Furthermore, some reindeer mortality could result, and killing of ungulates by poisoning with anticoagulant toxins is not considered humane. Furthermore, sub-lethal poisoning could also occur, causing great distress and suffering to animals affected.

2 Reindeer carcasses resulting from death through the consumption of poison bait would contain high concentrations of poison, which would then be available to scavenging birds such as giant petrels, gulls, skuas and the native South Georgia pintail. This could result in significant secondary poisoning of the avian fauna of the island, which would be unacceptable.

3 If the reindeer were not removed, thus preventing the effective eradication of rodents in the two affected areas, the value of the proposed island-wide rat eradication would be compromised. If the two areas were not cleared of rats, they would act as a reservoir for further invasion of

neighbouring cleared areas, given that the glaciers currently acting as barriers to the movement of introduced species are retreating at an increasing rate. The combined areas are a substantial proportion of the vegetated area of South Georgia, which would see enormous benefits from the removal of rats.

Technically, it could be possible to corral the reindeer into a fenced area (probably a headland) and carry out the rat eradication on the remainder of the peninsula. After a suitable period of time to allow the bait to degrade, the animals could be released and the untreated area then treated with poison. However, this would be enormously complicated and expensive, and would have welfare implications for the reindeer during confinement. It would also seriously reduce the chances of success of the rat eradication, as the untreated area could act as a reservoir for reinvasion of the rest of the peninsula requiring a buffer zone to be created and retreated around the containment area.

If the eradication of rodents were achieved whilst preserving the populations of reindeer, the environmental benefits of rat removal would be greatly reduced. The grazing out of tussac areas has largely removed suitable habitat for pipits and burrowing petrels to return to. The tussac will only recover in the absence of grazing pressure.

Also of consideration are the cost-sharing and logistical benefits of utilising helicopters and pilots already mobilised for the rat eradication project to carry out any management of reindeer, should aerial eradication be considered an appropriate form of management. This would provide a far more cost-effective means for GSGSSI to achieve its stated aims for the management of the reindeer herds.

8 - Management Options

Before undertaking any management action, it is necessary:

- to specify the objective - i.e. restoration of an endangered species or environment.
- to determine the tolerable level of impact of an alien species, if any.
- to evaluate short and long-term, direct and indirect repercussions of the control on the biota (ecological and genetic effects), and on the system as a whole.
- to consider the possible genetic value of the isolated introduced population (Chapuis et al, 1994).

Introduced species eradication and control is standard practice for various Governments around the world, as part of environmental good governance and has been implemented on numerous islands (Clout and Veitch, 2002).

Leader-Williams *et al* (1989) discussed the merits of maintaining the South Georgia reindeer herds as a scientific resource. However, the removal of the herds in itself presents a scientific opportunity, to study the response of vegetation to the removal of grazing pressure, which compensates for the long-term loss of the perceived resource. Lovatt (2007) discusses the importance of linking genetic distortions as a result of bottleneck events with measures of fitness – something not achievable with the small sample sizes utilized in her study. She states that robust data that demonstrates the linkage would have very useful implications in the management and conservation of endangered species by using genetic distortions as an early warning system for reduced fitness. The eradication of reindeer and subsequent access to carcasses would allow data to be collected from a large sample size, which could be analysed for evidence of the described linkages. Data could also be collected to expand on the body of existing literature regarding South Georgia reindeer, and to update life tables with contemporary rates of reproductive success and survivorship (Lovatt,

2007). Collection of this data could be considered in order to maximise the scientific return from the herds before their scientific potential is lost.

Reindeer have been eradicated from Hagemeister Island in Alaska in the 1990's, due to substantial damage caused by grazing that removed 95% of the lichen population (Ebbert and Byrd, 2002). Recommendations have been made for the eradication of reindeer on Adak Island in Alaska, but land ownership conflicts mean removal is unlikely (Department of the Interior and Wildlife Service (DIWS), 1994).

Recommendations have been made for the removal of donkeys from uninhabited islands around the Cayman Islands, Turks and Caicos Islands, from mainland Ascension Island and from Anegeda Island in the Lesser Antilles (Invasive Species Specialist Group, (ISSG), 2009). Axis deer have been eradicated from Point Reyes in the USA (National Parks Service (NPS), 2006), and feral horses from national parks in Australia. Cattle have been fenced and shot on St Paul Island (France), and goats have been eradicated from approximately 120 islands globally (ISSG, 2009). Feral pigs have been eradicated from numerous islands around the world, including large-scale projects such as Santiago Island in the Galapagos Archipelago (ISSG, 2009).

The South Georgia Management Plan (McIntosh and Walton, 2000) states that under the Governments objectives for environmental management, reindeer are the first priority for removal in order to allow recovery of native plant communities. The proposal suggested the translocation of animals from South Georgia and the subsequent establishment of a viable herd in the Falkland Islands, followed by a phased eradication. This translocation would also serve to preserve the genetic value of the populations.

8.1 – Translocation to the Falkland Islands

The translocation of reindeer from South Georgia to the Falkland Islands in 2001 was carried out to preserve the genetic resources of at least one SG herd, and to diversify the agricultural sector of the Falkland Islands (Bell and Dieterich, 2010). A second herd was also established privately on Beaver Island in the Falkland Islands (Sally Poncet, personal communication, May 2009).

In 2001, over a period of 13 days, a team of 11 people managed to herd and corral a total of 67 reindeer calves at Husvik. Animals were held captive for a period of between 8 – 20 days before transport, during which time 11% of the animals died through poor adaptation to dietary change (an average mortality of 10% is normal for captured reindeer in the northern hemisphere). All 59 animals shipped to the Falklands survived the sea voyage (Bell and Dieterich, 2010). The only previous attempt at translocating South Georgia reindeer was made in 1971, where 8 animals were captured and transported to Isla Navarino in Chile at the behest of the Chilean Government. All except 1 animal died during the rough sea voyage on HMS Endurance (Headland, 1984).

8.2 - Identification of management options

Leader-Williams et al (1989) discussed management options for the reindeer, and suggested that there is no scientific justification for the removal of reindeer for 3 key reasons;

1 reindeer only occupy limited areas of the island, leaving large areas unaffected

2 reindeer are not known to have caused any extinctions to date

3 they keep rat populations down in grazed areas by reducing the tussac habitat available to rats

However, these arguments no longer hold sway in the face of current circumstances, for the following reasons:

1. Whilst it is true that reindeer currently occupy only a limited area, that area is considered the richest vegetative area of the island (Greene, 1964). Whilst grazing may have undermined the value of the areas affected, the recovery of vegetation that is possible in the absence of grazing demonstrates that this status is recoverable. With glacial retreat and grazing pressure, it is likely that at some point in the future the reindeer will reach new areas unless removed or contained.

2. Whilst reindeer have not caused known extinctions in a global sense, they have caused significant reductions of key native species and major reductions on floral and invertebrate biodiversity. In the long term, in areas where grazing has progressed too far (resulting in erosion) recovery of tussac grassland and other species is not possible, even in the absence of grazing pressure (Vogel et al, 1984).

3. Whilst rat population numbers appear to be dependent on tussac grass (Pye and Bonner 1980), the planned SGHT rat eradication programme eliminates any beneficial side effects of overgrazing in relation to rats.

In 1986, a review of management of the sub-Aantarctic islands called for a management plan for reindeer to prevent excessive damage to the environment, and recommended that consideration be given to removing the animals completely (Smith and Lewis-Smith, 1987).

A survey report of alien plant species by Kew Gardens in 2009 recommended that because of their impact on the native vegetation, the reindeer be removed as soon as possible. The subsequent effects of reindeer removal on introduced plant species should then be monitored in addition to monitoring the recovery of the native vegetation (Osborne et al, 2009).

Potential management options (not all mutually exclusive) that have been identified are as follows:

A No Action (DIWS, 1994) (8.3)

B Containment - prevent spread to new areas and contain any new irruptions (Leader Williams, 1989) (8.4)

C Eradication of one herd (NPS, 2006) (8.5)

D Eradication of both herds (NPS, 2006) (8.6)

E Reduction in numbers (cull) to a level at or below the ecological carrying capacity of the current range (NPS, 2006) (8.7)

8.3 - Management option A – Retain all animals

Under this option, no direct management action would be taken.

Advantages:

- GSGSSI would not have to carry out a logistically difficult and expensive operation that will inevitably be unpopular with some members of the public, though would still need to move/corral the animals in order to facilitate the rat eradication project.
- The reindeer would remain to be used as a scientific study resource in the future. However, in the past 20 years GSGSSI has only received one request to carry out reindeer research, which formed the basis of Lovatt (2007).

Disadvantages:

- Rat eradication would only be possible on the Barff and Busen peninsulas if the animals were temporarily corralled or moved to a new area.
- With global warming and the continuing retreat of glaciers, reindeer will almost certainly establish in new areas leading to further habitat degradation and unchecked population expansion, with concomitant additional danger to native species and habitat. Future expansion to new areas would likely require management action.
- GSGSSI would fail to meet its international obligations.
- Habitat degradation will continue, likely to a point where localised erosion will occur on coasts and coastal ridges with no opportunity for recovery in the presence of continued grazing pressure.
- The fitness of the individual animals and herds will decline as forage quality and availability is reduced, resulting in either an animal welfare issue and/or a population crash.
- Would likely generate criticism from national and global environmental groups to maintaining reindeer in the face of scientific evidence as to their damage to South Georgia.

8.4 - Management option B - Containment - prevent spread to new areas and contain any new irruptions

The main bodies of the herds would be left untouched. Regular surveys of glaciers/boundaries would need to be undertaken to ensure populations are contained. Any animals found outside of these areas would be culled. Regular census of populations would need to be undertaken, and a cull considered should populations be found to be increasing.

Advantages:

- Cost to GSGSSI of containment cheaper in the short term than all other options except taking no action, however cost of corralling or moving animals to facilitate rat eradication in those areas would be substantial.
- Maintaining reindeer populations would avoid any potential for negative public reaction to a full eradication, though there would likely be criticism from environmental/conservation organisations and individuals.
- The reindeer would remain to be used as a scientific study resource in the future. However, in the past 20 years GSGSSI has only received one request to carry out reindeer research, which formed the basis of Lovatt (2007).

Disadvantages:

- Long term cost involved in maintaining population.
- Rat eradication would only be possible on the Barff and Busen peninsulas if the animals were temporarily corralled or moved to a new area.
- With global warming and the continuing retreat of glaciers, reindeer would almost certainly establish in new areas leading to further habitat degradation and unchecked population expansion, with concomitant additional danger to native species and habitat. Future expansion to new areas would likely require management action.

- GSGSSI would fail to meet its international obligations.
- Habitat degradation will continue, likely to a point where localised erosion would occur on coasts and coastal ridges with no opportunity for recovery in the presence of continued grazing pressure.
- The fitness of the individuals and herds would decline as forage quality and availability is reduced, resulting in either an animal welfare issue and/or a population crash.
- Would likely generate criticism from national and global environmental groups to maintaining reindeer in the face of scientific evidence as to their damage to South Georgia.

8.5 - Management option C - Eradication of one herd only

Were this management option to be acted upon it is likely that the Busen herd would be removed, and the Barff herd retained, as stated in "South Georgia, Plan for Progress – Managing the Environment 2006-2010" (Pasteur and Walton, 2006). The document states the intention to eradicate the Busen herd before the end of 2010, in order to allow the recovery of the flora and to ensure no further reindeer were injured in the debris of the old whaling stations. Recovery of the flora would be monitored to establish the desirability of removing the Barff herd in the future (Pasteur and Walton, 2006). It is felt that as the Busen herd is still expanding into previously ungrazed sites, prompt action would be more beneficial than on the Barff where the whole area is grazed. However, it could be argued that serious erosion is already occurring on the Barff, and prompt removal could potentially be more beneficial in the short term than on the Busen. The Barff population has also been shown to be both more genetically diverse than the Busen, and based on measures of fluctuating asymmetry, is also thought to be more developmentally stable (Lovatt, 2007).

Advantages

- Removes grazing pressure on the targeted area and allows recovery of the chosen peninsula to a more natural state, before any further long-term damage is done.
- Would allow the proposed rat eradication to proceed in that area.
- Would maintain the heritage and scientific value of the animals in the maintained herd.
- Would potentially reduce potential negative public reaction to a full cull.
- No long term management costs for the targeted peninsula.

Disadvantages:

- Rat eradication would only be possible on the non-targeted peninsula if the animals were temporarily corralled or moved to a new area.
- With global warming and the continuing retreat of glaciers, reindeer would almost certainly establish in new areas leading to further habitat degradation and unchecked population expansion, with concomitant additional danger to native species and habitat. Future expansion to new areas would likely require management action.
- GSGSSI would fail to meet its international obligations.
- Habitat degradation would continue, likely to a point where localised erosion occurs on coasts and coastal ridges with no opportunity for recovery in the presence of continued grazing pressure.
- The fitness of the individuals and herds would decline as forage quality and availability became reduced, resulting in either an animal welfare issue and/or a population crash.
- Would likely generate criticism from national and global environmental groups to maintaining reindeer in the face of scientific evidence as to their damage to South Georgia.
- It could be argued that if the justification exists to eradicate one herd, it exists for both – or conversely that if there is insufficient justification to eradicate both herds then neither should be eradicated

8.6 - Management option D – Complete eradication of both herds

Advantages

- Removes grazing pressure and allows recovery of the island to a more natural state.
- Would allow GSGSSI to meet its international obligations.
- Would allow the proposed rat eradication to proceed.
- No long-term management costs.
- No risk of spread of reindeer to new and previously undamaged areas due to glacial retreat.
- Constitutes a positive management action in line with environmental best practise for sub-antarctic islands.

Disadvantages:

- High short term cost in order to achieve full eradication.
- Potential for negative public and media reaction to removal of reindeer.

8.7 - Management option E – Reduction in numbers (cull) to a level at or below the ecological carrying capacity of the current range

If this were the favoured option, it would be necessary to establish the ***Ne*** (effective population size) value for the herd, in order to maintain genetic diversity. The animals would likely disperse widely, making annual culls to control numbers difficult. Therefore, it may be preferable, though not technically essential, to fence the animals into a given area. This area would need to be accessible to tourists, as there would seem little value in maintaining the animals if they were never seen. There would be significant issues with the terminating ends of fences, given the ability of reindeer to swim, and interaction with the fence by native wildlife.

Control measures are not necessarily successful in conserving biodiversity because ecological systems are rarely restored in their entirety or integrity, as the pressure is not entirely relieved. The reversibility of degradation depends on the resilience of the communities involved (Chapuis et al, 1994).

Advantages

- Reduction in grazing pressure would allow some recovery of the island to a more natural state.
- Would potentially allow the proposed rat eradication to proceed, as small herds could more easily be corralled and moved to avoid local baiting operations.
- Would retain heritage and some scientific value of the animals.
- Would potentially reduce any negative public and media reaction to a full cull.

Disadvantages:

- Would complicate rat eradication effort, as animals would need to be moved from baited/not-baited areas during operations, increasing the risk of failure of the rat eradication and risking poisoning of reindeer.
- Possible significant costs involved in establishment of fences if this were to occur.
- Possible costs in annual fence maintenance that would likely suffer snow damage and seal damage.
- Fences may cause injury and/or death to native wildlife and reindeer.
- High short-term cost in order to achieve reduced population.
- Costs involved in researching what population level the island could sustain with minimal damage, and to what level the population can be reduced to and remain genetically diverse and viable.
- Long term costs involved in maintaining population at low level.
- Potential for negative public and media reaction to partial cull of reindeer.
- Potential criticism from national and global environmental groups to maintaining reindeer in the face of scientific evidence as to their damage to South Georgia.
- With retreat of glaciers, it is likely that small groups may spread to new and previously untouched areas. Small groups of animals over a large area would be difficult to locate, making their continued management costly and logistically difficult, especially if no helicopters were present on the island in the long term to facilitate hunting.

Table 3 - Comparison of Management Options

Management Option	Long-term effects on habitat	Long-term management requirements	Benefits	Disadvantages	Effect on rat eradication	National & International obligations and commitments
No action	Reindeer likely to spread to new areas as glaciers retreat, causing increasing damage to habitats	None	Reindeer remain for tourist/ heritage value and as a scientific resource	Large parts of the islands habitat damaged by reindeer; reduction in native vegetation; reduction in burrowing birds;	Reindeer would need to be gathered and held for the duration of the baiting period.	Failure to meet: SG Environmental Charter Commitments; CMS, ACAP and CBD.
Containment	Damage to habitats would be limited to existing areas	Regular checks of glacial retreat; frequent culling		Costs of long-term monitoring		
Reduction in numbers to carrying capacity	May allow partial recovery of habitats	Regular culls to keep population levels in check		Costs of long-term monitoring		
Eradication of one herd	Habitat on one peninsula would be able to recover	Monitor habitat recovery; monitor remaining herd and containment	One large area would recover; likely increase in native vegetation and burrowing birds	One peninsula would continue to be damaged; potential for spread of single here, so containment also required	Reindeer in remaining herd would need to be gathered	
Eradication of both herds	Habitat on both peninsulas able to recover	Monitor habitat recovery	All areas would recover; likely increase in native vegetation and burrowing birds	Loss of tourist / heritage / scientific value of reindeer	No additional action required	Would address commitments in SG Environmental Charter, to CMS, ACAP and CBD.

9 Methods of achieving management options

Any form of active control technique has the potential to cause suffering to target animals. To minimize this suffering, the most humane method available should be employed. This will be the technique that causes the least amount of pain and suffering to the target animal, with the least harm or risk to non-target animals, people and the environment, and should be the most appropriate for use in the given situation. The humaneness of a technique is highly dependant on whether or not it is correctly employed; it is therefore important to consider whether sufficient resources are available to fully implement that technique, and to ensure that practitioners are suitably experienced and skilled (Sharp and Saunders, 2005).

Choice of control programme should be measured against the following criteria (English, 2001b):

1. Is it a technique that is likely to be an effective means of reducing reindeer numbers?
2. Is the method cost-effective?
3. Is the method humane?
4. Is the method available and applicable now, in terms of effective technology?

Both lethal and non-lethal methods of achieving the above management options have been considered and are discussed below. However, lethal removal of animals is the most efficient and cost effective management tool for the control and eradication of large mammals (Williams et al, 2006), and is the most applicable for the circumstances on South Georgia. Should a decision be taken to remove the reideer, the chosen method of removal would be shooting. No other options were considered to be viable using the criteria above. A decision would also have to be taken as to whether to recover commercially valuable products from the carcasses.

9.1 - Shooting as a management option

Shooting is considered more humane than capture and removal, as animals are not subject to the stresses of mustering, corralling, and long-distance transportation which will inevitably result in a percentage of stress-related mortality (Sharp and Saunders, 2005). Shooting can be carried out from the ground or aerially, using a helicopter as a shooting platform. It is likely that a combination of both methods would be used on South Georgia.

If carried out responsibly, shooting is relatively target specific, and does not usually impact on other species. However, there is always a risk of injuring or killing non-target animals if shots are taken when reindeer are in the vicinity of non-target species. Therefore, shooting in the vicinity of non-target species (such as beaches and coastlines where seals and penguins are present) would be discouraged under best practise procedures.

Any shooting on the island would be carried out in the most humane way possible. This would be achieved through strict adherance to best practice guidelines developed elsewhere. Weapons used on South Georgia would meet the UK guidelines for minimum rifle calibre and specification as established in The Deer Act 1991.

Public attitudes to aerial and ground shooting are markedly different, as was found following feral horse control in Australia. In October 2000, a cull of feral horses was carried out in Guy Fawkes River National Park (GFRNP), New South Wales, Australia, which received national media attention. In response to community concerns as to the humaneness of the process, the New South Wales (NSW) Minister for the Environment banned the aerial culling of horses in national parks in NSW and set up an independent inquiry into the cull, and the future management of free-ranging horse populations in GFRNP and parks elsewhere in NSW (New South Wales National Parks and Wildlife Service (NSW NP&WS), 2006). It was found that a significant part of negative public reaction followed unbalanced media reports (English, 2001b).

As part of the enquiry, the use of ground shooting was discussed in a public workshop, and there was found to be very little opposition to the ground shooting of some horses, even amongst those who were implacably opposed to helicopter shooting (English, 2001a).

The enquiry concluded that the use of aerial shooting in Guy Fawkes River National Park was an appropriate technique under the circumstances, and that it was carried out in a humane way, using approved protocols (NSW NP&WS, 2008).

9.2 - Historical shooting of deer on South Georgia and response to disturbance

Historically it is not clear how many reindeer were shot from the Busen herd. On the Barff peninsula between 1940-1955 it is estimated that 100 animals per year were shot (Leader-Williams, 1978). Subsequent to the closing of the whaling stations in 1965, this number declined to approximately 20 animals per year until 1972. Bonner noted in 1958 that should regular hunting cease at any stage, it would become necessary for a certain number of deer to be killed occasionally in order to prevent the stock outgrowing the grazing resources of the area.

It has been observed that as long as the deer do not catch sight of a man, they are surprisingly unafraid of shooting, and will continue to graze around the carcasses of fallen animals (Payne, 1972). The Busen animals are also relatively simple to herd on foot, though difficult terrain, namely steep scree slopes, prevents herding of animals out of Cape Saunders, Leith Harbour and Fortuna Bay, and would only be possible by use of helicopter (Bell and Dieterich, 2010). The Barff animals are much more sensitive to disturbance, and are therefore more difficult to herd and manage (Dieterich and Bell, 2000).

Leader Williams (1974) discusses the difficulty of approaching animals in February, only being able to get as close as 60 yards through careful stalking, and suggests that operating during and after the rut would allow a closer approach.

Shooting on South Georgia would not be feasible in winter, due to adverse weather conditions. Shooting programs should not be undertaken when females are fawning, which occurs on South Georgia in November. The optimum time for any shooting operations therefore would be March/April, when animals have aggregated for the rut and when a closer approach is possible. This would however conflict with the end of the tourist season. Any operations would therefore require careful planning to deconflict the two.

9.3 - Ground Shooting

Ground shooting for non-commercial purposes is of limited applicability in managing the impacts of feral animals when compared with aerial platform (helicopter) shooting. Best estimates give ground shooting only one-fifth the capacity of aerial shooting in areas where both can be undertaken (Saafeld and Zeng, 2008). However, ground shooting is less likely to induce a flight response in animals than a low-level helicopter overflight, which makes it more appropriate for use near non-target wildlife aggregations and other sensitive areas. Ground shooting as a control technique, if properly carried out, it is one of the most humane methods of managing feral deer (DEWHA, 2004).

Shooting from the ground is considered by RSPCA Australia, and by the Commonwealth Department of Primary Industries and Energy in Australia, to be the most effective, and often the only method for humanely destroying feral animals, especially when the marksman and target are both stationary (SSCAW, 1991). Shooting from the ground is implemented when foot access is good, the control area is small and the temperament of the animal allows a close approach. It is impractical where large-scale control is required, access is difficult and rapid pursuit by vehicle is impossible, under which circumstances control by shooting from helicopters is necessary (SSCAW, 1991). Ground shooting is not suited to rough country, as wounded animals cannot be effectively pursued and dispatched and would therefore suffer unnecessarily (Sharp and Saunders, 2005).

The Australian Government's Department for the Environment sets out key welfare and safety considerations of ground shooting deer (DEWHA, 2004), as does the UK Deer Initiative (The Deer Initiative is a broad partnership of statutory, voluntary and private interests dedicated to "ensuring the delivery of a sustainable, well-managed wild deer population in England and Wales") which has produced a series of Best Practice guides (The Deer Initiative, 2009). Key considerations drawn from these sources are as follows:

Herd flight response is a limiting factor for humane and instantaneous killing of deer. Silenced rifles may reduce animal disturbance and facilitate accurate shooting (DEWHA, 2004), though animals are likely to quickly learn to respond to gunfire. Silencers would be purchased for this reason for any ground operations on South Georgia, the use of which would reduce muzzle velocity of the round, but with careful selection of weapon type and calibre the velocity would still meet the minimum requirements as set out in the BASC code of practise (2009). Shooting of individuals should stop when the flight response of the herd limits further accurate shooting (DEWHA, 2004).

Ground shooting advantages:

- The most humane form of lethal control, as long as equipment is appropriate and marksmen are accurate and responsible.
- With appropriate equipment, such as silencers, ground shooting is less likely to elicit a flight response than aerial shooting.
- Increased accuracy over aerial shooting means most animals killed with a single shot, resulting in a more humane death.
- Suitable for use in sensitive areas.
- Location of every carcass can be accurately recorded for recovery.

Ground shooting disadvantages:

- Labour intensive and time consuming.
- Terrain will limit applicability where access is compromised or impossible.
- Returns are low per unit effort

9.4 - Aerial Shooting

The Australian Government has developed a set of Standard Operating Procedures and Codes of Practice for aerial shooting of animals, which aim to provide guidelines for the humane control of pest species. They were written in consultation with various animal welfare groups, including the RSPCA (Sharp and Saunders 2005). Aerial operations on South Georgia would be carried out in accordance with these guidelines.

Aerial shooting is best used to target animals in remote, inaccessible or rugged terrain. In areas of heavy-cover, effectiveness is limited since reindeer may be concealed and difficult to locate from the air, though this is unlikely to occur on South Georgia where cover is limited. The optimal period for aerial shooting is when animals form natural aggregations, such as before and during the rut (March/April).

Aerial shooting can be a humane method of destroying animals when it is carried out by experienced and skilled shooters and pilots as long as; the animal can be clearly seen and is within range; the correct firearm, ammunition and shot placement is used; and wounded animals are promptly located and killed. Aerial shooting occurs with the pilot positioning the helicopter some 40-50 meters behind the target animal (English, 2000). Shooting from a moving platform can significantly detract from the shooter's accuracy therefore helicopter shooting operations do not always result in a clean kill for all animals. Follow-up and "overkill" procedures are therefore essential to ensure that all wounded animals are killed quickly (Sharp and Saunders, 2005).

Reindeer are easily frightened by gunshots, helicopter rotor noise, wind etc. and may injure themselves by running into obstacles or each other, or injure other animals whilst stampeding. Shooting should be avoided in areas where this may occur, or should only be carried out on the ground.

Aerial shooting from helicopters is recognised as the optimal control action to

achieve large population density reductions over broadscale areas, particularly in short time frames, and the only available control action that can be used in very remote or inaccessible areas (Saafeld and Zeng, 2008). Teams involved in shooting from a helicopter should consist of a qualified and experienced shooter, a qualified and experienced pilot and a spotter who locates the animals and records the location and number of animals shot (Sharp and Saunders 2005).

There is a cost/density relationship for aerial control of animals, due to the increased flight time required to find animals as their density decreases. Costs associated with this management method are hard to estimate, as logistics and operational requirements for comparable operations vary greatly. As a rough estimate for aerial shooting, indicative costs for control of feral camels in Australia were $20–$30 per animal at high density (densities greater than 0.3 animals/km2); $40–$100 per animal for densities in the range 0.3–0.1 animals/km2; and a cost per animal greater than $100 for densities less than 0.1 animals/km2 (Saafeld and Zeng, 2008). Costs on South Georgia are likely to be higher by virtue of its remote location.

While the cost per head for aerial shooting is greater than that for other methods of control, and increases substantially as density decreases, the efficacy of this method of control for broadscale management of feral animals justifies its position as the preferred method of control (of feral animals in Australia) (Saafeld and Zeng, 2008). On South Georgia, aerial control may be the most cost effective option, due to the speed of control compared to ground shooting, and logistical difficulties of supporting ground teams.

Aerial shooting advantages:

- Returns are high per unit effort where animal density is high.
- Large areas can be covered quickly.
- Vegetation on South Georgia is not high or dense enough to provide cover for reindeer, so helicopter shooting is applicable to all but the most sensitive of areas.
- Use of helicopters facilitates the recovery of carcasses if required.

Aerial shooting disadvantages:

- Not suitable for application in environmentally sensitive areas where noise disturbance is of concern, and where flight response of reindeer could pose a risk to other species.
- Not suitable for application in areas where flight response of reindeer will result in injury or death, for instance in the vicinity of steep slopes, water and cliffs.
- Returns are low per unit effort where animal density is low – expense per animal increases as density decreases
- Due to having to shoot a moving animal from a moving platform, accuracy is compromised, requiring an "overkill" policy to be employed, which has consequences on whether meat is recoverable or fit for human consumption.

10 - Alternative methods of control or eradication

Options discussed below have been considered in management plans for deer in New Zealand and two sites in the USA (Brown, D. 2005, NPS., 2006 and DIWS, 1994). After consideration they are all felt to inappropriate management options for South Georgia, by virtue of not fulfilling the criteria established by English (2001b).

10.1 - Translocation of animals to locations outside of South Georgia, with eradication of non-translocatable population

To an extent this has already been done with the establishment of two herds in the Falkland Islands (Bell and Dieterich, 2010). Whilst a small number of animals can be transported, it is neither feasible nor desirable to translocate the entire South Georgia population. The previous translocations targeted calves, due to their small size and ability to consume both milk and solid forage, making logistics much simpler (Bell and Dieterich, 2010). Yearlings could also be translocated as their small size allows for easy handling, and they are more resilient than other age classes (DIWS, 1994). It is considered that the transport of adult animals would cause considerable animal welfare issues, and is therefore discounted. Young animals could be offered up to supplement the existing Falklands populations, but this should not be at the cost of GSGSSI. Adult reindeer would still have to be culled. Because of these serious limitations, capture and relocation of deer has been largely abandoned as a management tool by wildlife professionals in the United States (Williams et al, 2006).

Advantages:

- Removes grazing pressure on the targeted area and allows recovery of the chosen peninsula to a more natural state, before any further long-term damage is done.
- Allows proposed rat eradication to proceed in that area
- Will maintain the heritage and scientific value of the animals in the maintained herd.
- May reduce potential negative public reaction to a full cull.
- No long-term management costs.
- GSGSSI would meet its international obligations.

Disadvantages

- Extremely high cost – up to 10x more expensive per animal to translocate rather than kill (DIWS, 1994).
- Logistically complicated and labour intensive (Williams et al, 2006).
- Not all animals could be moved, still a need to cull all adults.
- Humane issues, given stress of capture, handling and transport. Mortality could be as high as 20% (DIWS, 1994).

10.2 - Use of chemical sterilants or physical sterilisation

Fertility control is seen as a preferred method of ungulate control as it offers a humane and target-specific alternative to lethal methods. However, hormones to control fertility are difficult to administer to large numbers of free-roaming animals, and there is no long-acting or permanent drug presently available; therefore annual treatment would be required. Consequently, its application is not currently feasible for situations where animal numbers are high and their territory large, such as on South Georgia. Currently its main application is for limiting small, isolated populations where eradication is not the aim (Sharp and Saunders, 2005).

Because reindeer are polygynous and a small proportion of stags accomplish a large proportion of breeding effort, male contraception is inefficient and impractical. Surgical sterilization, because of the time and cost required to accomplish safely, is impractical for large numbers of wild ungulates (NPS, 2006)

One development of potential interest is the use of "biobullets" – cellulose pellets that can be charged with a drug and fired from a modified gun from a range up to 40m. The pellet will then dissolve in the muscle of the target animal releasing the drug (Warren and White, 1993). However, given the number of animals on the island, and the difficulties of navigating the terrain in order to access all the animals, use of biobullets to treat every female animal repetitively over time is impractical. Females could also be administered with subcutaneous implants, but this would require handling of all females (English, 2001a) on the island, and is therefore impractical

Short-term contraceptives have been shown to work in axis deer, but require annual boosters (NPS, 2006). Given the number of animals involved on South Georgia (and assuming such drugs work on reindeer), the costs and logistics of administering such drugs annually would be high and ongoing, due to the need to re-administer annually. No permanent sterilants or contraceptives are

licensed for deer (NPS, 2006), but if such products became available the costs and logistics of their administration would again be high.

Oral contraceptives are a threat to non-target species if birds scavenge carcasses of treated animals, making their application particularly unsuitable for use on South Georgia. Ordinarily the drugs are administered by lacing food with the drugs, which in itself is a threat to non-target species through scavenging (Williams et al, 2006).

Immuno-contraception (the use of molecular biology technology to immunise animals against their own sperm or eggs) has been trialed in horses in the USA, but a major limitation is the need to inject the immunising compounds into the animals, making this method impratical for use on South Georgia (English, 2001a).

Other than through the use of biobullets, all of these methods require that the reindeer be captured and handled as a part of the process (English, 2001a) – making none of them a practicable option on South Georgia at this time.

It is doubtful that contraceptive techniques will ever be cost effective or recommended for widespread use in free ranging populations of deer – whilst the agents themselves may be economical, the logistical, personnel and operating expenses of delivery to a significant proportion of a population will be prohibitive (Warren and White, 1993).

Advantages:

- Non-lethal, therefore likely to avoid any negative public reaction.
- Long-term allows GSGSSI to meet its international obligations.
- In the long term is a positive management action in line with environmental best practise for sub-antarctic islands.
- In the long term removes grazing pressure and allows recovery of the island to a more natural state.

Disadvantages:

- Long-term management option.
- Likely to be the most expensive of all management options.
- Long term investment both financially and logistically to annually administer contraception.
- Risk to non-target scavenging bird species.
- Impossible to guarantee every animal treated, so population may continue to expand in the short term.
- Rat eradication would not be possible in non-targeted peninsula, which would serve as a reservoir of rats which could invade cleared areas, and the overall value of the rat eradication project would be reduced.
- With global warming and the continuing retreat of glaciers, reindeer will almost certainly establish in new areas leading to further habitat degradation and unchecked population expansion, with concomitant additional danger to native species and habitat. Future expansion to new areas would likely require management action.

10.3 - Poisoning

The use of the poison 1080 with carrot baits or as a gel has been used in New Zealand to control deer. However, 1080 is extremely toxic to non-target animals, and reindeer carcasses would need to be recovered in order to prevent mortality of scavenging birds by secondary poisoning. The carcasses would need to be buried or burned to remove the risk. Use of 1080 by aerial or ground baiting is expensive (Brown, 2005) (though not necessarily more expensive than an aerial shooting operation), and likely to cause serious public concern. Therefore, the use of poison has been rejected as a management option.

Advantages:

- Allows GSGSSI to meet its international obligations.
- Allows rat eradication to proceed in target areas.
- Removes grazing pressure and allows recovery of the island to a more natural state.

Disadvantages:

- Severe risk of primary and secondary non-target poisoning.
- Non-humane way of killing.
- Likely to generate strong negative public reaction.

10.4 - Use of recreational hunting as a control method

Recreational hunting is felt to be of very limited value in controlling deer, as recreational hunters remove too few animals, focus on easily accessible areas and tend to target adult male deer as trophies. It has never been seen as an adequate control tool in Australia or New Zealand, with most successful control programmes being carried out by professional shooters working in intensive campaigns. At best recreational hunting may reduce deer populations in a localised area (Booth, 2008).

Advantages:

- Low cost (or potential profit) to GSGSSI.

Disadvantages:

- Unlikely to achieve either effective population control or eradication.
- GSGSSI could be seen to be exploiting and financially profiting from the reindeer, and this may generate negative public opinion.

10.5 – Introduction of disease and/or parasites

Reindeer on South Georgia are largely free of parasites and transmittable disease (Leader-Williams, 1988). Introduction of parasites and disease may reduce and limit the population, but would be unlikely to eradicate it. It is likely to be seen as inhumane, and introduction of exotic species such as diseases, vectors and parasites is against GSGSSI policy and prohibited under proposed legislation. Whilst unlikely that reindeer diseases and parasites would transfer to native species, the possibility cannot be discounted without further research. The herd would still need to be culled, in the long term, resulting in long-term costs.

Advantages:

- Possible reduction in reindeer population may relieve some of the negative effects of grazing.

Disadvantages:

- Unlikely to achieve either effective population control or eradication.
- Research as to non-target risks expensive.
- Potential negative public reaction.

10.6 – Chemical Immobilisation

The use of immobilising drugs delivered by dart rifle to capture and remove feral animals is seen as a humane way of capturing animals for onward transport, either for translocation or butchering. However, there are significant technical difficulties involved in darting animals in difficult terrain, where it would be difficult to approach reindeer as close as the 40m that is required for accurate and effective use of dart rifles. This could potentially be overcome through the use of attractants, but there is still a potential problem in the way that an animal may behave after darting. Some animals may subside quickly and with no issues, but others will certainly move away and may stumble or fall in rocky ground. There is almost no way of controlling the situation once an animal is darted and until it falls down, which could result in serious injury or death. In addition to these animal welfare concerns, there is the additional issue of what to do with the reindeer once it is unconscious, which may depend on where the animal falls. The only way to move the animal would be to lift it out by helicopter (English, 2001a), which would not be feasible for the large numbers of reindeer on South Georgia.

The use of chemical immobilisation would be an expensive, labour-intensive method of capturing the reindeer. There would always be a need for the direct involvement of experienced veterinarians, given the nature of the dangerous drugs that are used, and given the range of potential animal welfare and human safety problems that can arise. The method may well be considered for the capture of individual animals, but does not appear to be a suitable option for the removal of large numbers of animals (English, 2001a).

Advantages:

- Humane, less stressful than mustering, corralling and trapping.
- Minimises risk of injury during transport as opposed to moving a conscious animal.

Disadvantages:

- Risk of significant injury or death prior to drugs taking full effect.
- Limited range of rifles, limiting use in difficult terrain.
- Drugs restricted to use by vets.

Table 4 – Comparison of management methods

Control Method	Efficiency	Humaneness	Other considerations	Environmental Cost/Impact	Cost
Aerial Shooting	Effective for large and small numbers, best returns where density is high Cover large areas quickly Helicopters can also be used for carcass recovery if required	Likely to induce panic and flight response, which could result in injury or death to reindeer or native animals Not all animals killed cleanly, though follow up is fast with a helicopter	Effective in open terrain and areas inaccessible on foot "overkill" policy to be employed, which has consequences on whether meat is recoverable or fit for human consumption	Noise disturbance Potential for panicking animals to stampede through penguin and seal colonies	Expensive, costs increase as density of animals decreases
Ground Culling	Effective for small numbers Highly effective if contained in a corral	Most humane form of lethal control Chance of not being able to follow up injured reindeer in the field	Effective in flat open terrain Increased accuracy means most animals killed with single shot, more meat recoverable	Minimal impact	Expensive and labour intensive for large numbers
Translocation	Effective for small, sensitive areas Impractical for large areas Labour intensive to herd animals	Stress of capture, handling and transport could result in mortality of up to 20%	Not possible to remove all animals, still a need to cull remainder Where would the animals be translocated to?	Potential impact on movement of other fauna due to fencing	Extremely expensive, up to 10x more expensive than shooting
Fertility Control	Currently labour intensive Requires recapture Long-term management option	Possible injury in capture/handling	As yet no suitable drug for long term sterilisation Impossible to guarantee treatment of every animal	Risk to scavenging birds of consuming carcasses Animals may spread to new areas with glacial retreat	In the long term likely to be the most expensive management option

Poisoning	Effective	Not humane Risk of sub-lethal exposure resulting in pain, incapacitation, permanent damage	Not felt to be an acceptable form of control	Severe risk of primary and secondary non-target poisoning	Moderate
Recreational Hunting	Not effective	If carried out by experienced hunters, then humane	Difficult to manage and supervise Won't achieve meaningful reduction in numbers	Disturbance to non target species if not managed responsibly	None – would generate income
Introduction of Diseases or Parasites	Unlikely to have significant effect on population	Not humane	Not an acceptable form of control	Biosecurity considerations to introducing new non native organisms	Research of suitable organisms and non-target risks expensive
Immobilisation	Difficult to administer Impractical for large numbers	Can result in injuries if reindeer stumble over rough ground Less stressful than mustering	Requires clear/open area for darting Rifles limited in range	Impact of vehicle when retrieving animal Noise disturbance if helicopters used	Very expensive for large numbers Good for targetting individuals
Mustering	Effective Requires skilled pilots Require a good knowledge of the reindeer herd & terrain	High risk of injury to animals Stress considerations from mustering	Flat open terrain valleys Hard to deal with escapees	Trampling of areas Non target fauna at risk from stampeding animals	Very expensive, especially as animals would need to be processed in some way, either translocation or killing

11 - Recovery of commercial products

Commercial products include meat, antlers and velvet. Leader-Williams (1976) wrote that summer culling when all deer are in velvet could be a lucrative business (for example it is a trade commodity in China), as it is in New Zealand.

Commercial recovery of large feral animals is not always possible, for various reasons. Firstly, the numbers of feral animals may make the operation uneconomic. Rough and inaccessible terrain makes mustering from the ground and air difficult. When harvesting is uneconomic, lethal methods of control are applied. Lethal methods include "shooting to waste" from the ground and from helicopters, whereby carcasses are not recovered (Senate Select Committee on Animal Welfare (SSCAW), 1991).

In order to recover commercial products, animals would need to be killed as humanely and cleanly as possible. Reindeer would be field dressed then transported to a central area for storage and further transport, with or without butchering. Efforts would be made to salvage meat where possible, though carcasses would be abandoned if:

- Salvage endangers the recovery crew.
- Salvage causes unnecessary disturbance to wildlife or other deer.
- The meat is unfit for human consumption.
- The animals are inaccessible after death (DIWS, 1994).
- It ceases to be cost effective (if cost of recovery is greater than the value of the product), though there may be other reasons, than economic ones, to do so.

If this option is taken it is intended that tenders are called for the processing of the meat, rather than GSGSSI take on the logistical burden and costs associated with extracting commercial products, marketing them and/or finding a market.

Animals could be killed in the wild and their carcasses recovered on foot, by quad bike or helicopter, or the animals corralled in the vicinity of a processing station and killed. Both methods carry high costs.

Advantages:

- Some costs may be recouped, though a cost-benefit analysis would need to be carried out. The costs of helicopter/vehicle/man time, ground support, butchery, meat inspection, frozen storage and transport will be substantial.
- May be more acceptable to the public if animal carcasses are utilised in some way, rather than being left to decompose.

Disadvantages:

- Public may see GSGSSI to be profiting from the cull unless PR managed carefully.
- Nutrients and biomass are removed from the ecosystem rather than recycled into the soil or made available to native scavengers and decomposers (DIWS, 1994).
- Logistically difficult and potentially expensive.
- Extraction of carcasses by helicopter or vehicle will have an environmental impact in terms of ground disturbance and emissions.

If it were decided to recover commercial products other than by recovering carcasses, then there there are numerous issues involved with mustering of animals should it be decided to corral them in a set location:

Mustering will inevitably cause stress and anxiety to reindeer, and has the potential to cause serious injury. Mustering is only applicable where animal densities are high, and is normally carried out by vehicles, or by helicopter (Sharp and Saunders, 2005).

The success or otherwise of mustering and containing wild animals will depend very much on the skill and experience of the personnel who are involved. Critical elements will be the location, layout and materials used to construct enclosures (English, 2001a).

Trapping and handling wild animals in enclosures is very stressful, and presents the very real possibility of serious injury or death if they are not well handled. There are substantial animal welfare issues to be confronted in any such activity if the reindeer are to be trapped, handled and transported in a way that is acceptable. The process of mustering, trapping and handling of feral animals is not without risks to the people involved, even if they are very experienced (English, 2001a).

Mustering should be carried out when conditions are cool or mild. The tail end of the herd should set the pace rather than being forced to keep up with the leaders. Helicopters are unnecessary where the terrain can be covered adequately on foot. A helicopter can be used to bring reindeer out of rough terrain onto flatter, more open country where people wait to herd them (English, 2001b).

Minimising Stress

Stress is a cumulative response of an animal to its surroundings and may result in severe physiological effects. Reindeer may be susceptible to the following conditions resulting from prolonged or excessive stress during capture (English, 2001b):

- Capture myopathy – excessive or prolonged exertion increases the risk of stress-related muscle necrosis. This condition is common in wild and feral animals subjected to capture, and is associated with severe pain. It can result in collapse and sudden death during or following pursuit of animals for long distances during capture, or after stressful transport.

- Acute lameness due to foot injury or damage to tendons, ligaments or bones.

- Fight injuries due to mixing unfamiliar groups or individuals.

- Bruising and injury caused by rough capture techniques and poorly designed handling facilities.

Suffering of reindeer must be minimised during capture by pushing the animals no faster than is necessary during muster, using quiet and patient handling in the corral, providing food and water, and by separating age and size classes. The whole process must be designed to ensure that there is minimal excitement or panic among the animals, and that they are not chased to exhaustion. They should not be pressured or forced into corners where they panic or try to escape. The intention must be to keep the animals as calm as possible throughout the operation. Reindeer may be injured by fighting or by running into fences or other fixed objects if they are impatiently handled. Enforcing a new social structure on reindeer and confining them in corrals with strange reindeer greatly increases their stress levels and can result in a higher incidence of injuries. Normal social groups should be maintained whenever possible. Injuries can be dependent on social behaviour and the degree of aggressive interaction between reindeer (English, 2001b).

11.1 - No recovery of commercial products

Advantages:

- Logistically a smaller and less complicated operation.
- Operationally cheaper and faster due to reduced manpower requirements and fewer helicopter/vehicle hours.
- Less environmental impact in terms of emissions and disturbance than a full recovery operation.

Disadvantages:

- Will likely be seen by many as wasteful, even though carried out as part of a conservation management action not a commercial venture.
- Will potentially temporarily boost the populations of rats and scavenging species such as skuas due to a plentiful supply of carrion, though inflated population would be unlikely to survive through the following winter and in the absence of continuing availibility of carcasses.

12 - Legal status of reindeer on South Georgia

GSGSSI is currently undertaking a legislative review to introduce a new suite of modern laws. There are two pieces of extant legislation relevant to the management of reindeer, the Falkland Islands Dependencies Conservation Ordinance, 1975, and Firearms Ordinance 1948. Similar laws have been replaced by new legislation in the Falkland Islands, but not in South Georgia (Pickup, 2009).

Currently, the legislation in force on South Georgia pertinent to the management of reindeer is the Falkland Islands Dependencies Conservation Ordinance, 1975. Subsequent to 1975, or to SGSSI becoming a Dependant (and subsequently Overseas) Territory of the UK (in 1985) no further legislation addressing wildlife has been enacted.

The Falkland Islands Dependencies Conservation Ordinance, 1975

This Ordinance prevents any major (or total) cull of Reindeer on South Georgia, for the following reasons:-

(a) Section 2 defines "native mammal" as “any species belonging to the Class Mammalia indigenous to the Dependencies [i.e. SGSSI] or occurring there through natural agencies of dispersal, as well as reindeer *Rangifer tarandus*. "

Therefore, Reindeer are, for the purposes of the legislation classified as a "native mammal" and are therefore given total protection in Section 3 of the Ordinance, which indicates that: "No person shall wilfully, except as permitted under this Ordinance” –

(a) Kill, wound. capture, molest or export any native mammal [or native bird]

Permits issued by the Commissioner (under Section 5), authorising activities mentioned in Section 3(a) are then constrained by the conditions imposed by Section 6 (1) which states that "Permits.....shall be limited so as to ensure as far as possible that" –

> (a) the variety of species and the balance of the natural ecological systems are maintained; and
> (b) no more native mammals or birds are killed or taken in any one year than can normally be replaced by natural reproduction in the following breeding season"

Section 6 (2) then goes on to say that " A permit "shall only be issued for the following purposes" –

> (a) to provide indispensable food for local use in limited quantities, and in conformity with the purposes and principles of this Ordinance;
> (b) to provide specimens for scientific study or scientific information;
> (c) to provide specimens for museums, zoological gardens, or for other educational or cultural institutions or uses;
> (d) to provide for regulating the management and use of living resources.

In consequence the existing legislation does not provide the means to undertake a major cull/eradication of reindeer on South Georgia. This is not the case in proposed new legislation as described below.

Wildlife and Protected Areas Ordinance (Proposed)

As part of GSGSSI's legislative review, it is intended that a Wildlife and Protected Areas Ordinance will replace the Falkland Islands Dependencies Conservation Ordinance, 1975. The proposed legislation would provide protection to all "protected wild mammals" on SG. The identity of such mammals is set out in Schedule 1, viz:

1. Marine mammals of the Orders *Cetacea* (whales, dolphins and porpoises) or *Pinnipedia* (seals);
2. Reindeer (*Rangifer tarandus*]

Section 22 would allow for the issuance of permits, but it would also set out the conditions in respect of (and including) "protected wild mammals" under which permits could be issued. Such conditions would be quite specific and precautionary. Specifically 22(2) states that a permit shall not be granted:

> (a) to kill, capture, or handle a wild bird, protected wild mammal or native invertebrate

However, draft Section 22(8) states that:

"Nothing in subsections (2) (6) and (7) [the constraining conditions on the issue of permits] shall have effect in relation to reindeer (*Rangifer tarandus*) so as –

> (a) to limit the purposes for which a permit under subsection (1) in respect of them may be granted; or
> (b) to require any limitation of a kind mentioned in subsection (7) to be imposed in a permit granted under subsection (1) in respect of reindeer.

The proposed new legislation would therefore provide the means to carry out a partial or total cull under permit, as appropriate, from the Commissioner.

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