SEASONAL GRAZING OF CANADA GOOSE (*Branta canadensis*) ON HIGH COUNTRY FARMLAND, CANTERBURY, NEW ZEALAND.

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Seasonal grazing by Canada goose (*Branta canadensis*) on high country farmland, Canterbury, New Zealand.

by Andrew Win

There is ongoing debate between landowners and recreational hunters about the significance of grazing by Canada goose (*Branta canadensis*) on New Zealand's high country farmland. The South Island Canada Goose Management Plan (1995), which includes in its aims the alleviation of such impacts, was developed in the absence of any quantitative measures of goose grazing intensity. This study aimed to quantify the impacts of Canada geese on one high country farm, through an exclosure study at Lake Grasmere, inland Canterbury. Fieldwork was conducted from July 1999 to June 2000, in conjunction with monthly observations of Canada geese on 69 ha of paddocks adjacent to Lake Grasmere.

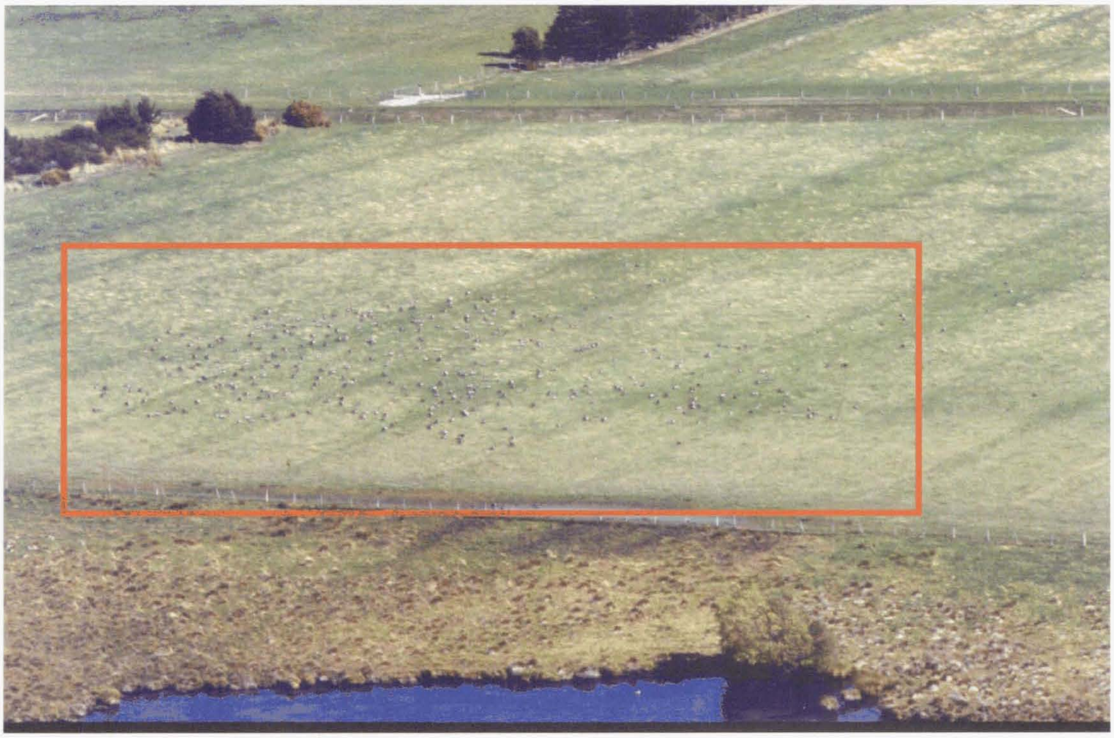
Canada goose numbers on the study site varied throughout the year, ranging from fewer than 10 geese in October and November 1999 to peak of over 400 in March 2000. These geese significantly reduced pasture production ($p<0.001$) on paddocks adjacent to the lake, with the differences in monthly dry-matter production between goose-grazed and ungrazed pastures ranging from less than

100 kg/ha in winter to 900 kg/ha in late summer and early autumn. The impact on pasture production was positively correlated with the number of geese each month ($p<0.05$). Observations of the behaviour of geese on the paddocks indicated that neither season nor time of day had any pronounced effect on their foraging intensity. Consequently, grazing pressure on pasture is determined primarily by the number of geese on the paddocks. Goose numbers and impacts were highest in late summer and early autumn. Goose damage at this time is of particular concern for high country farmers who are typically trying to maintain autumn-saved pasture to assist in over-wintering their stock. At present the North Canterbury Fish and Game Council culls this goose population annually. These results may in future assist managers to better assess the costs versus benefits of any proposed changes to goose management in the high country.

Keywords: *Branta canadensis*; Canada goose; density and distribution; disturbance; exclosure study; feeding behaviour; game birds; high country farming; pasture damage; pasture production; pests of agriculture.

Frontispiece

Canada geese on paddocks at Lake Grasmere.



Aerial photo of the Canada goose flock feeding on a paddock adjacent to Lake Grasmere.

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CHAPTER ONE

INTRODUCTION

This study aims to quantify the impact of Canada goose on high country farmland, to determine the effect of goose grazing on pasture biomass and relate this to seasonal changes in goose behaviour, abundance and distribution. This is important, because at present managers of Canada goose in New Zealand have no quantitative measurements of the impacts of geese on high country farmland. By quantifying when peak damage is occurring, goose managers may be able to better target control operations to mitigate periods of high goose damage to high country pasture. The results will also help inform the debate on issues such as farmers' compensation and the 'pest status' of the goose.

This thesis will give a general introduction of Canada goose the species, the impacts on farmland overseas and New Zealand, and the current management policies used in the United States, Britain and New Zealand. This will be followed by objectives, general methods of the study's and three separate chapters on Canada goose feeding behaviour, density and distribution and grazing impacts of Canada geese at Lake Grasmere. A summary chapter will then provide general conclusions.

1.1 The ecology of native Canada goose

Canada goose (*Branta canadensis*) is a member of the waterfowl family Anatidae, which it shares with six swan and goose genera (Soothill and Whitehead, 1996). There are 12 recognised Canada goose subspecies (Delcour, 1954), however, overlap in natural ranges has resulted in interbreeding between subspecies (del Hoya *et al.,* 1992). Their population status ranges from endangered and threatened subspecies such as the Aleutian Canada goose (*B. c. leucopareia*), to abundant subspecies such as the Atlantic Canada goose (*B. c. canadensis*) and the giant Canada goose (*B. c. maxima*) (del Hoya *et al.,* 1992).

The Canada goose is indigenous to North America and has a natural range that encompasses a major proportion of that continent (Palmer, 1976; Malecki and Trost, 1998). Canada goose is classed into two groups, migratory and residential. Migratory Canada geese have distinct summer and winter distributions. In spring geese migrate north to breed in Arctic latitudes in the Aleutian Islands, Alaska, and Canada from the Yukon to Newfoundland (Soothill and Whitehead, 1996), where they take advantage of the long day length, rapidly growing, highly nutritious plants, and low predation pressure (Hughes *et al.,* 1994). In particular, this migration allows the geese to take advantage of the spring flush in grasslands, which moves sequentially up latitudinal and altitudinal gradients (Owen and Black, 1990). In autumn, they return south to overwinter on the southern coasts of the United States and Mexico (del Hoya *et al.,* 1992). Canada goose migration occurs along four traditional routes in North America: the

Mississippi Flyway, Atlantic Flyway, Pacific Flyway and the Central or Prairie Flyway (Hill and Fredericks, 1997).

Some subspecies, such as the giant Canada goose, breed exclusively within the United States, in populations restricted to local areas (referred to as residential Canada geese from now on) (Ankney, 1996). In recent years, biologists have documented increases in populations of residential Canada goose (e.g. Ankney, 1996). Kelley *et al.* (1998) found that the residential Canada goose breeding population exceeded one million geese in both the Mississippi and Atlantic Flyways.

In North America, Canada goose nests colonially. Clutch sizes normally range between four and six eggs but may reach eight (Soothill and Whitehead, 1996). Incubation occurs for 28 days and goslings leave the nest within one to two days of hatching (Soothill and Whitehead, 1996). Geese have strong family bonds, with family groups staying together until the following year (del Hoya *et al.,* 1992). This has resulted in the development of complex behaviours in Canada goose (McWilliams and Raveling, 1998).

Canada goose is highly adaptable and its habitats are diverse (del Hoya *et al.,* 1992). Subspecies are found in a number of habitats ranging from tundra to semi desert (Soothill and Whitehead, 1996). Typically, suitable habitat includes a water source to provide roosting sites (del Hoya *et al.,* 1992).

Canada goose predominantly feeds on grasses, rushes, sedges (Soothill and Whitehead, 1996) and aquatic vegetation (Potts and Andrews, 1991). Geese feed mainly on habitats close to their roost sites so they are common on meadow grasslands, tundra and improved farmland, especially in winter (del Hoya *et al.*, 1992).

1.2 The ecology of introduced Canada goose populations

1.2.1 *Britain*

The Canada goose was introduced into Britain in 1665 as an ornamental bird in the waterfowl collection of King Charles II (Willughly, 1676 in Owen *et al.*, 1998). A number of introductions followed and the species began breeding in various locations, mainly in the grounds of stately homes (Owen *et al.*, 1998). Britain's Canada geese are large and pale, resembling the Atlantic Canada goose (*B. c. canadensis*). There is however, a great variation in size due to the inclusion of large individuals of the giant Canada goose (*B. c. maxima*) in some introductions. Canada goose populations have increased dramatically in Britain in recent decades (Ogilive, 1977). The first organised summer census of Canada goose in 1953 recorded 3 900 birds concentrated around their release points (Burton–Jones, 1956). A subsequent census in 1976 estimated that the population had reached 19 400 birds, a 5-fold increase over 25 years (Ogilive, 1977).

In Britain, Canada goose is sedentary, mainly on ornamental lakes and peat diggings (Owen *et al.,* 1998). Increasing numbers of lakes in Southern England, mainly through the development of gravel lakes beside river systems is the main cause of the growing number of Canada goose in Britain (Owen *et al.,* 1998).

Canada goose in Britain feed exclusively on agricultural lands (Owen *et al.,* 1998). Pasture and crop damage can be severe, especially when breeding and moult flocks trample and strip grain from standing crops (White-Robinson, 1984). Canada goose is of increasing concern to conservationists who believe that geese are responsible for degradation of valuable habitat, mainly through the destruction of bank-side vegetation and eutrophication of water bodies as a result of high quantities of faeces (Owen *et al.,* 1998). Geese are also a public nuisance, especially in public parks and estates, and aircraft strikes involving Canada goose have occurred at London's Heathrow airport (Owen *et al.,* 1998).

1.2.2 *New Zealand*

The first successful introduction of the Canada goose (*Branta canadensis*) into New Zealand occurred in 1905, when the Government introduced 50 individuals from the United States (Thomson, 1922; Imber, 1971). A number of introductions to both the North and South Island followed, but geese have only established in the wild in the South Island.

At the time of these introductions, only five subspecies of Canada geese were recognised and those brought to New Zealand were all recorded as the common

Canada goose (*B. c. canadensis*) (Thomson, 1922; Imber, 1971). Since then, seven more subspecies of Canada goose have been identified, of which three were within the 'common' Canada goose complex (Imber, 1971). Plumage characteristics, weights and measurements of Canada geese in New Zealand by Imber (1971) indicated that the New Zealand population is predominantly giant Canada goose (*B. c. maxima*), but interbreeding may have occurred with other subspecies introduced later into New Zealand, particularly the Atlantic Canada goose (*B. c. canadensis*).

The characteristics of the giant Canada goose have facilitated its establishment and success in the South Island. It is a relatively sedentary, rather than migratory, subspecies (White, 1986). The primary range of the subspecies in the United States is confined to tall tussock and mixed prairie areas, which are very similar to New Zealand's high country (Imber, 1971).

Canada goose is primarily found east of the South Island's Southern Alps, where the population was estimated to be between 28 000 and 35 000 birds in the early 1980s (Potts, 1984). Birds are widespread in the central inland areas of Marlborough, Canterbury and Otago (Potts, 1984). Some geese also occur on the West Coast and, by the late 1980s, about 8000 birds were present in the North Island as a result of introductions over the previous decade (Potts and Andrews, 1991). June trend counts conducted by the Fish and Game Council in 1999/2000 found approximately 29 000 Canada geese in the South Island (Ottmann, 2000).

In the eastern South Island, Canada goose occur in loosely separated populations associated with water habitats (White, 1986). The largest of these populations occurs at Lake Ellesmere, Canterbury, where 50–60% of the South Island's population overwinter (Holloway *et al.,* 1987). Geese tend to overwinter in coastal lagoons and disperse during spring to the foothills of the Southern Alps to breed (White, 1986). A banding project by the Department of Conservation in the 1980s found that birds banded at Lake Ellesmere migrated to the upper reaches of the Waimakariri and adjacent catchments (Holloway *et al.,* 1987). Migration is thus from sea level in the east to 900 m above sea level in the west (White, 1986; Potts and Andrews, 1991). This contrasts with the north-south migration of Canada geese in the United States (Owen, 1980; del Hoya *et al.,* 1992).

A marked increase in the development of crops and sown pastures in many South Island high country valleys in recent decades has increased the number of Canada goose populations overwintering on high country lakes and tarns (Potts and Andrews, 1991). This is similar to changes in Canada goose distribution seen in response to farming practices in the United States, where Orr *et al.* (1998) attributed the decline in goose numbers in traditional southeastern wintering states to the increased corn (*Zea mays*) planting in northern states. Similarly, the lesser snow goose (*Anser caerulescens*) now tends to spend longer at mid-latitude roosting sites due to increased availability of waste maize or corn (Davis *et al.,* 1989).

Canada goose in New Zealand has behavioural characteristics that differ from those seen in North American populations (Holloway *et al.,* 1987). Colonial breeding has been replaced by a more dispersed breeding pattern due to population control techniques used in the late 1970s and early 1980s (Holloway *et al.,* 1987). Control methods were nest and egg destruction and the cull of moulting adults and as a consequence geese now breed in more isolated areas of the Southern Alps (White, 1986). There is also evidence of an increase in clutch size among these more isolated breeding pairs, with six to eight eggs reported in some nests (Holloway *et al.,* 1987).

1.3 Impacts of Canada geese on agriculture

1.3.1 *Pasture*

Canada goose numbers in several countries have increased over recent decades (del Hoya *et al.,* 1992). Goose damage to crops and pasture has become an important management problem for wildlife biologists (Kahl and Samson, 1984). Early opinions were that the effects of goose feeding on farmland varied widely, ranging from beneficial to detrimental, depending mainly on the time of year the geese were feeding (Kear, 1970). Early studies by Kear (1965) in Britain and Kuyken (1969) in Belgium concluded that geese had no significant effect on agriculture however, more recently, several studies have shown that grazing by geese can reduce yields from agricultural grasslands (e.g., Patton and Frame, 1981; Bedard *et al.*, 1986; Bruinderink, 1989; Percival and Houston, 1992).

Canada goose damage on pasture varies from country to country, with the amount of damage affected by goose behaviour, season and habitat type (Owen and Black, 1989). In the United States, an increase in the number of residential Canada goose is causing considerable damage to pastures and crops (Ankney, 1996). This damage is accentuated with the arrival of migratory geese from the north (Kelley *et al.,* 1998). In the southern United States, large populations of Canada goose graze on pasture and grain fields and the damage caused during autumn and winter can be substantial (Hunt, 1984; Conover and Chasko, 1985; Conover, 1988). During the breeding season, migratory Canada geese cause damage to agriculture in northern states of United States, Canada and Alaska (Hughes *et al.,* 1994).

Other goose species have been found to cause agricultural damage. Scotland is an overwintering ground for barnacle (*B. leucopsis*) and greylag geese (*Anser anser*), which migrate from north European breeding grounds (Kear, 1970). In recent decades, the number of migrating geese overwintering in Scotland has increased (Patton and Frame, 1981). This has increased contact and conflict with agriculture (Kear, 1963; Patton and Frame, 1981). Geese feed primarily on lowland grassland and improved upland grasslands in west Scotland. Such grasslands are subjected to varying degrees of grazing intensity ranging from slight to severe. Patton and Frame (1981) found large yield losses in some areas but not in others in west Scotland grasslands. These differences were attributed to the intensity of goose grazing, although Patton and Frame (1981) were unable to measure the yield losses.

Agricultural damage by migrating geese occurs on Islay, an island 30 km off the west coast of Scotland. Goose damage has increased since the island has undergone extensive agricultural improvement (Percival and Houston, 1992). Geese feed primarily on improved grasslands, so the increase in numbers has brought them into conflict with the island's farmers. Farmers believe that goose damage is the cause of widespread yield loss from the island's pastures (Percival and Houston, 1992).

In the Netherlands, migrating geese have become a problem to farmers (Bruinderink, 1989). Total numbers of migratory geese visiting the Netherlands from winter to early spring have increased from 100 000 in the 1960s to 600 000 the late 1980s (Bruinderink, 1989). The rise of goose numbers has coincided with the intensification in dairy farming, increased application of nitrogen fertiliser, and improved drainage systems. This has lead to increased conflict between wild geese and farming (Bruinderink, 1989).

Canada geese also cause damage to agricultural activities in New Zealand (White, 1986). Geese feed primarily on private farmland and in recent years, improvement of high country farmland has resulted in increased conflict between geese and agriculture (Potts and Andrews, 1991). White (1986) suggested that Canada goose damage to pasture in the high country is seasonal, occurring mainly in autumn. Harris *et al.* (1987) believed that goose damage in the high country of the South Island intensifies the effect of winter weather conditions. In the high country, pasture saved in autumn reduces the impact of the long harsh winter because it is used to overwinter stock and feed pregnant ewes the following spring. The presence of geese decreases the amount of saved pasture reducing the number of stock that can be overwintered (Harris *et al.,* 1987). An economic assessment of Canada goose at Lake Grasmere Station was modelled by Harris *et al.* (1987), who concluded that a further 95 sheep could be run on the property in the absence of geese.

Canada goose damage to high country farmland has yet to be directly measured. Several studies have investigated goose damage (e.g., Kreger, 1977; White 1986), but these involved questionnaire surveys of high country farmers and thus did not directly measure the damage caused by geese. Results obtained in the surveys relied on the attitudes of farmers. Some farmers reported damage being 'very high', but such conclusions were generally not accepted as valid by the reports' authors (Kreger, 1977; White, 1986).

White (1986), in his study of 300 farm properties in the South Island high country, found that 15-20 farmers believed that 'unacceptable' levels of goose damage occurred periodically on their farms. However, he believed that farmers' estimates of goose damage were frequently 'inflated' due to several factors. First, stock did not use all forage that was available to them. Second, dry-matter losses due to autumn frosting of forage often coincided with geese damage. Third, inefficient goose digestion meant that less forage was eaten than farmers were inferring from the large numbers of highly visible goose droppings.

1.3.2 *Cereal and crops*

Canada goose damage to agriculture is not restricted to pasture. Crop depredation can also be a major problem (Kear, 1963). Kahl and Samson (1984) found that Canada geese caused a 30%-80% decrease in grain yield on winter wheat (*Triticum aestivum*) yield in Missouri.

Canada geese caused significant damage to crops in Britain (Owen *et al.*, 1998). Such damage is most pronounced in spring and summer, when breeding and moulting flocks attack adjacent crops (Owen *et al.*, 1998).

Grazing by greylag geese (*Anser anser*) on autumn-sown barley (*Horedeum vulgare*) in northeast Scotland significantly decreased the production of grain (Jalil and Patterson, 1989). These authors simulated goose grazing through hand clipping and found that the growth of autumn-sown barley was significantly reduced throughout the growing season. Simulated grazing slowed plant growth and delayed maturation with the damaged plants having decreased grain yield.

In New Zealand, goose damage to crops is generally considered to be minor because geese predominantly feed on pasture (White, 1986). However, in recent decades, Canada goose has become increasingly prominent on wheat stubble paddocks during autumn (White, 1986). Large populations of Canada goose feed on 'waste' grain after harvesting of paddocks surrounding Lake Ellesmere, Canterbury (Holloway *et al.*, 1987). At Lake Grasmere Station, Harris *et al.*

(1987) noted that Canada goose fed on turnip (*Brassica rapa*) crops during winter.

1.3.3 *Direct competition with livestock*

Canada geese can deprive the farmer of available pasture and thus compete with livestock (Kear, 1970). In England, in the early 1960s, complaints against wildfowl from farmers became more frequent with most concern in spring when geese were perceived to be competing directly with stock for 'spring flush' grasses (Owen, 1977). Patton and Frame (1981) in their study of Barnacle goose on improved pasture in Scotland, indicated that appreciable losses in available pasture resulted in farmers needing to obtain alternative stock feed and/or reduce the numbers of stock carried.

Harris *et al.* (1987) in their study of the economic impact of Canada goose believed that goose grazing reduced the amount of available pasture used to overwinter stock. The removal of pasture in autumn was enhanced by the lack of grass growth during winter (Harris *et al.,* 1987). Grass removed in autumn was not being replaced and therefore goose grazing impacts were seen as being particularly significant to farmers during autumn and spring.

1.3.4 *Fouling*

British farmers have complained that sheep and cattle avoid pastures contaminated by goose faeces (Owen, 1980; Summers and Grieves, 1982). Kear

(1963) found that stock avoid their own faeces and those of other mammals but found no evidence for the same reaction to goose droppings. Rochard and Kear (1965) experimentally tested the response of sheep to varying forms of goose fouling and found that goose droppings did repel sheep, either through taste or smell. However, the repellent factor in the droppings disappeared rapidly in normal weather conditions (Rochard and Kear, 1965).

In New Zealand, White (1986) believed that fouling of pasture has no major effect on sheep grazing because sheep will forage around fresh droppings (although they prefer non-fouled pasture, if given a choice). Conversely, in areas where soil and vegetation are short of nutrients, domestic animals are known to eat goose droppings (Rochard and Kear, 1965). On the Falkland Island, farmers observed sheep, cows and horses feeding on goose faeces (Summers and Grieves, 1982).

Brazely and Jefferies (1985) suggested that goose droppings are beneficial to pasture systems. They found that goose faeces supplied nitrogen for plant growth in a grazed salt marsh habitat during periods of nitrogen deficiency. However, the nitrogen in faeces is in the form of ammonia (NH_4^+), which is difficult for plants to absorb (Parsons *et al.*, 1983). Ammonia is also easily leached out of soil so much of the nitrogen potentially available to plants is lost (Hik *et al.*, 1991). Jalili and Patterson (1989) found goose droppings had no significant effect on the total yield of grain and straw in Scotland, as nutrients they supplied were negligible compared with fertiliser application.

1.3.5 *Nuisance*

The recent increase in Canada goose numbers has lead to nuisance problems in parts of the United States (Conover, 1988). Complaints from urban and suburban areas have occurred; geese forage on lawns in parks, golf courses, country clubs and backyards (Hawekins, 1970). High densities of faeces on grassed areas reduce the aesthetic value and recreational use of such areas. Conover and Chasko (1985) found that the primary reason for goose nuisance problems in suburban and urban areas was due to increased availability of food, through the maintenance of large areas of fertilised grasses.

In New Zealand, nuisance problems have occurred within the suburban and urban areas of Christchurch. Large populations of Canada goose are common on the Bromley sewage ponds and Travis Wetland Reserve (G. Ottmann, *pers. comm.* 1998). Culling these geese has resulted in public opposition and direct conflict with Goose Guardians, a pro goose and hunting group and anti-animal cruelty organisations such as Save Animals From Exploitation (G. Ottmann, *pers. comm.,* 1998).

1.3.5 *Disease*

Canada goose is a vector for various agriculturally important parasites and pathogens (Mason *et al.,* 1993); farmers complain about geese in their fields even when they are not causing damage to their crops (Mason and Clark, 1996). Goose fouling is believed to be a source of salmonella and, in New Zealand, reports of salmonella poisoning in sheep have come from farms, which have Canada goose feeding on their paddocks (G. Ottmann *pers. comm.,* 1998).

1.4 Management of Canada geese

1.4.1 *Natural range*

In the United States, 12 subspecies of Canada goose are found and these range in status from 'endangered' through to 'pest' (Malecki and Trost, 1998). Management of geese, therefore, ranges from Recovery Plans through to the development of hunting regulations and special goose seasons for problem subspecies (Kelley *et al.*, 1998). Migratory Canada geese are managed by four different flyway councils, the Pacific Flyway, Atlantic Flyway, Mississippi Flyway and the Central or Prairie Flyway (Trost *et al.,* 1990). Councils are also responsible for residential geese that use their flyways. States within these flyways have established protected wetlands, which provide resting stops for geese on their migratory routes (Malecki and Trost, 1998). The Fish and Wildlife service sets hunting regulations for Canada goose. Each state decides its own hunting season lengths and bag limits depending on the size of their resident goose population, with hunting season set to limit hunting impacts on endangered migratory Canada goose subspecies (Trost *et al.,* 1990). Hunting seasons are normally open around October and finish by the end of January.

As discussed previously, a major problem with Canada goose in the United States has been the increase in residential geese, resulting in greater damage to crops and pasture (Ankney, 1996), and the increase in numbers has also resulted in increased nuisance problems in suburban and urban areas (Conover and Chasko, 1985). Consequently, in 1999 the U.S. Fish and Wildlife service began to give greater attention to the problem of increasing goose numbers through the existing annual hunting framework (U.S. Fish and Wildlife Service, 2000). Outside the existing hunting season, the Wildlife Service created a special Canada goose permit that gives state wildlife agencies the opportunity to design programmes and take control of problem residential goose populations, without seeking permission for the Wildlife Service for each action (U.S. Fish and Wildlife Service, 2000).

Thirty-one states within all four flyways have been co-ordinated to carry out special goose seasons to target resident goose populations (Kelley *et al.,* 1998). Goose permits are restricted from March through to August to avoid the effects of goose control activities on migratory goose populations (Kelley *et al.,* 1998). A number of goose control techniques are used under the special goose season permits, with many of these controls intended to scare geese out of specific areas.

1.4.2 *Britain*

Canada goose in Britain is a recognised game species, with a set hunting season and bag limit (Owen *et al.,* 1998). The species is hunted during an open season that extends from October through to the end of January (Owen *et al.,* 1998). Outside the hunting season, Canada goose and its eggs may be destroyed under licences granted by the Ministry of Agriculture, Fisheries and Food (White-

Robinson, 1984). Such licences are granted for preserving public health or public air safety, preventing serious damage to crops, and conserving wild bird populations (Owen *et al.,* 1998).

A number of Canada goose control strategies have been initiated in Britain (Owen *et al.*, 1998). Recreational hunters are the main method used to reduce Canada goose populations. A variety of bird scarers are also used to discourage geese from specific areas. The development of wetland refuges managed to attract goose populations away from existing farmland has also been proposed (Owen, 1980)

1.4.3 *New Zealand*

Since its introduction into New Zealand, Canada goose has legally been a Crown resource (White, 1986). The increase in Canada goose numbers has led to changes in the laws that govern management of the species (Holloway *et al.,* 1987). Canada goose was a legally protected species until 1931, when legal protection was removed except for coastal areas outside the hunting season (Holloway *et al.,* 1987). This allowed farmers to 'disturb or destroy geese', as they felt necessary. In 1973, the species was declared a 'game bird' species under the First Schedule of the Wildlife Act, 1953 (White, 1986; Holloway *et al.,* 1987). Management committees were formed, consisting of representatives of the Wildlife Service, Acclimatisation Societies and farming interests (Holloway *et al.,* 1987). These committees determined hunter bag limits and the length of the hunting season.

Before 1987, the Department of Internal Affairs was responsible for the management of Canada goose (Holloway *et al.,* 1987). Between 1976 and 1987, the Wildlife Service, a Division of the Department conducted moult culling drives and egg-pricking operations to reduce Canada goose numbers in parts of the Southern Alps (Holloway *et al.,* 1987). In 1987, the Department of Conservation (DoC) assumed the functions of the Wildlife Service, with the passage of the Conservation Act 1987 (Holloway *et al.,* 1987). Since 1990, regional New Zealand Fish and Game Councils (previously Acclimatisation Societies) have undertaken the day-to-day management of Canada goose (Fish and Game, 1995).

In 1995, the South Island Canada Goose Management Plan (SICGMP) was established in response to increased pressure from farmers and hunters to manage goose populations more effectively (Fish and Game, 1995). The main goal of the Management Plan is to maximise opportunities for recreational hunters while mitigating the adverse effects of Canada goose on agriculture.

The strategy of the SICGMP was to contain Canada goose populations to a target level in selected management areas (Fish and Game, 1995). Five regional Fish and Game Councils are involved in the management plan and each has several management areas: Nelson/Marlborough (two), North Canterbury (five), Central South Island, (six), Otago (five) and Southland (two). Target population levels were established based on providing adequate numbers for hunters, while protecting farmers' interests. To maintain target levels, a three-tiered trigger system of control was established. Recreational hunters were perceived as the primary means of control, with organised recreational hunts and organised culls to be used subsequently if recreational hunting was not successful in reducing goose numbers to target levels (Fish and Game, 1995).

Since the inception of the SICGMP, many Canada goose populations have remained above the specified target levels. In North Canterbury, only two management areas have been reduced to target levels (Ottmann, 2000). The problem has been that the geese are highly mobile, so control measures in one management area have resulted in geese moving to other areas (Ottmann, 2000). Goose managers, therefore, have a problem reducing goose populations in all management areas.

A major underlying issue in current Canada goose management is how much damage geese are causing to pasture and crops. On lowland pasture, a study by J. Holloway (*unpublished data*) on paddocks adjacent to Lake Ellesmere found significant damage to pasture biomass throughout the growing season. To date, there has been no direct measurement of goose damage on high country farmland, although Canada goose damage is believed to be seasonal, with damage most prominent in autumn (White, 1986). Uncertainty about the extent of damage has fuelled the debate on issues such as the need for compensation for damage, and a change the status of geese from a game species to a pest species (G. Ottmann, *pers. comm.,* 1998).

1.5 Aim of thesis

The general aim of this study was to determine the spatial and temporal patterns of Canada goose damage on pasture in the New Zealand high country. To achieve this goal, three specific objectives will be investigated. These objectives are to:

- determine seasonal variations in Canada goose numbers, distribution and habitat preference on a high country farm;
- determine diurnal feeding behaviour patterns on that farm;
- quantify the impact on the farm's pastures through Canada goose grazing.

CHAPTER TWO

GENERAL METHODS

2.1 Study area

This study was conducted at Lake Grasmere station (171^0 45` E, 43$^0$ 3` S) situated near Arthurs pass, Canterbury.

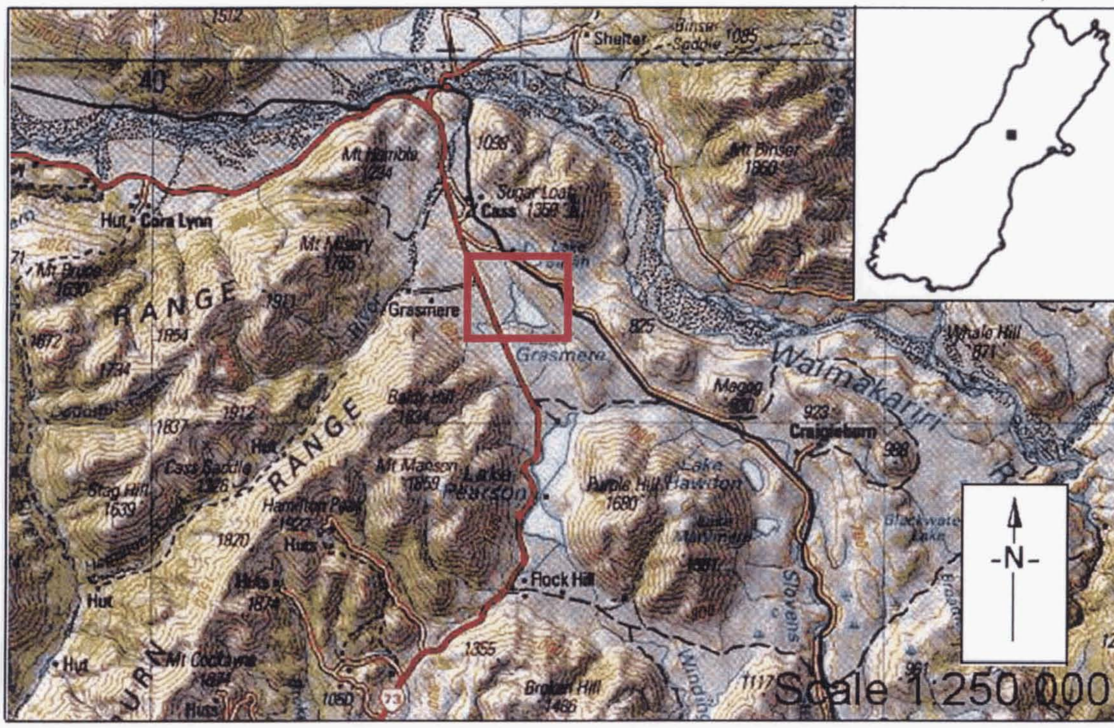


Figure 2.1 Location of study area, Lake Grasmere, Canterbury, South Island, New Zealand.

Lake Grasmere is an established wildlife refuge. The refuge is home to many native species especially, the Australasian crested grebe (*Podiceps cristatus*), an endangered wetland bird. The lake also provides a roosting site for other waterfowl species such as black swan (*Cygnus atratus*), paradise shelduck (*Tadorna variegata*) and Canada goose. In keeping with its refuge status, shooting and boating are prohibited.

Grasmere Station covers several thousand hectares of predominantly hilly native and exotic grassland, but encompasses a small area of flat cultivated land near Lake Grasmere in the Cass Basin. The small area of flat land, which encompasses the study site is managed by Lake Grasmere Lodge.

Lake Grasmere Station is an intensive high country farm, which runs sheep (*Ovis ovis)*, cattle (*Bos taurus*) and deer (*Cervus* spp.) throughout the year. Crops such as oats (*Avena sativa*) and barley (*Hordeum vulgare*) are also grown. Cultivated paddocks range in size from 4 to 36 ha. Paddocks are separated by hedgerows and macrocarpa (*Cupressus macrocarpa*) tree lines common along most paddock fence lines.

Throughout the study period most paddocks were under pasture composed of combinations of various perennial grasses and clovers (mainly ryegrass (*Lolium perenne*), cocksfoot (*Dactylis glomerata*) and red (*Trifolium pratense*) and white (*Trifolium repens*) clovers. Lucerne (*Medicago sativa*) was grown in paddock one (Fig. 4.3), while oats were grown in paddock five until March 1999, and was then cultivated for the remainder of the study period.

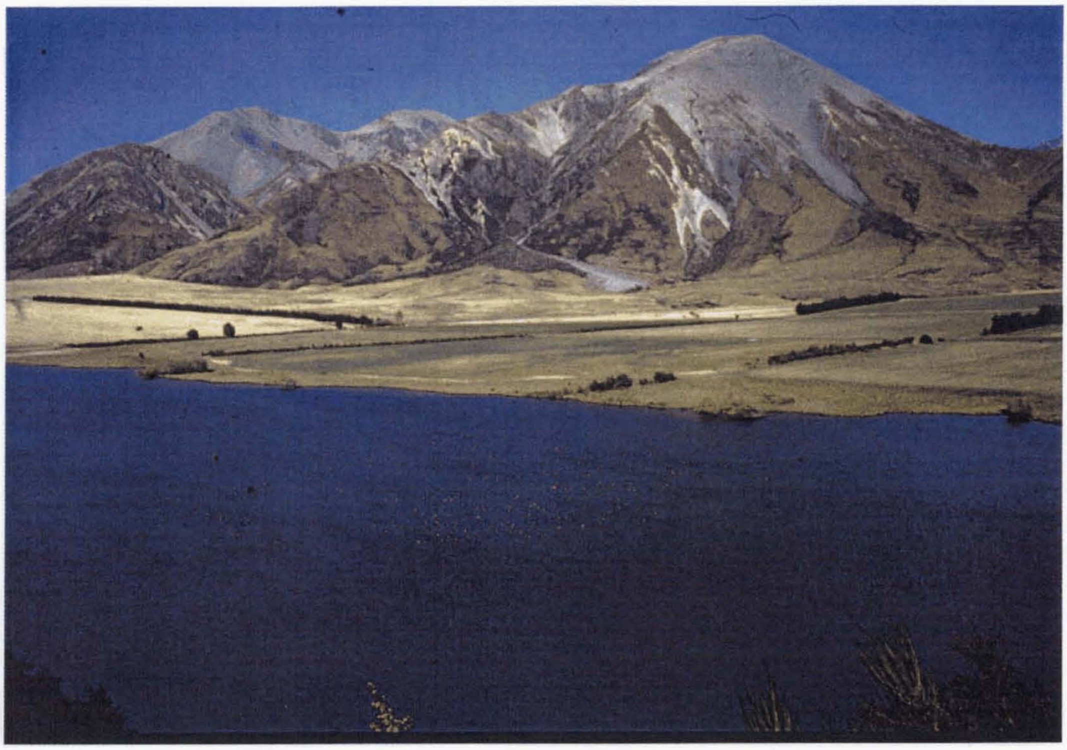


Plate 2.1 Lake Grasmere and adjacent paddocks including study area.

2.2 Climate

The climate of the area is characterised by hot summers and cool winters (Andrews and Potts, 1991). The mean temperature for the Cass Basin for the last five year including 1999 ranged from 13^{0}C in 1996 to 15^{0}C in 1998. Temperature fluctuations ranged from below 0^{0}C temperature, recorded in winter, to mid 30^{0}C in summer (Craigieburn weather station temperature data, NIWA, 1995-1999). This is consistent with mountainous environments that show large variations in temperature with altitude (Greenland, 1977). The predominant wind for the area is northwest with northeast and southerly winds also common. Severe frosts occur frequently in the late autumn and winter.

The annual rainfall at Lake Grasmere is approximately 1300 mm (Greenland, 1977). The high rainfall at Cass is attributed to its location in relation to the steep annual rainfall gradient that occurs between high rainfall gradients on the West Coast to low values in the east. Snowfalls are uncommon and snow seldom persists for more than a few days (Greenland, 1977).

2.3 Duration of study

Feeding behaviour and goose density and distribution studies were conducted from March 1999 to April 2000. The exclosure study was delayed due unexpected problems and was therefore conducted from July 1999 to June 2000.

CHAPTER THREE

CANADA GOOSE FEEDING BEHAVIOUR

3.1 INTRODUCTION

In New Zealand, few studies have observed Canada goose (*Branta canadensis*) feeding behaviour, although such studies are common overseas. From these studies, it is known that the Canada goose adapts its feeding behaviour to changes in season, habitat and nutrient requirements (Raveling, 1979; Prins *et al.,* 1980; McWilliams and Raveling, 1998), that result from their breeding and migration cycles (Hanson, 1953; Summers and Grieves, 1982; Davis *et al.,* 1989). These changes in feeding behaviour are related to changes in the profitability of feeding on the available food supply (i.e., to changes in the amount of energy gained per unit time; Owen and Black, 1990). Individual components of grazing behaviour, such as length of feeding bout or the rate of pecking can be varied to maximise nutrient intake (Harwood, 1977).

Feeding behaviour of Canada goose is strongly influenced by its inefficient digestive system (Mattocks, 1971). Compared with most grazing vertebrates, geese have simple alimentary tracts (Harwood, 1977). Vegetation passes through the gut in two to four hours, with large plant fragments still visible in the faeces (Harwood, 1977). This rapid passage of food leaves little opportunity for any digestive process more complex than the simple absorption of cell solutes (Mattocks 1971).

Seasonal changes

Canada goose tends to select habitats that provide forage with high protein (McWilliams and Raveling, 1998) and energy content (Owen, 1971; Raveling, 1979; Prins *et al.,* 1980). Geese typically feed primarily on high protein vegetation (such as pasture) in spring and summer and shift to high-energy foods (such as grain) in autumn and winter (Owen, 1980). In autumn, cackling Canada goose, frequently fed on winter wheat (Raveling and Zezulak, 1991). Davis *et al.* (1989) found that feeding activity of snow goose in winter in North America predominantly occurred in habitats containing high energy forage such as corn (*Zea mays*), pasture and winter wheat (*Triticum aestivum*). Potts and Andrews (1991) noted that the geese at Lake Grasmere fed on turnips (*Brassica rapa*) during winter.

Feeding activity is a predominant behaviour in Canada goose in spring, as adults prepare to breed (McLandress and Raveling, 1981; McWilliams and Raveling, 1998). This high feeding rate improves their body condition, which is an important determinant of their reproductive success. Gauthier *et al.* (1988) found that the feeding activity increased from winter to spring, which is a reflection in the rise in energy requirements as snow geese progressed from wintering to spring fattening and finally to nesting.

McWilliams and Raveling (1998) found that cackling Canada goose in California spent 58-78% of its time feeding in spring. Nastase (1998) found that Canada goose in Pennsylvania spent 60% of its time feeding over the whole year. These feeding rates, however, are less than observed feeding rates in some other goose species. Barnacle goose (*Branta leucopsis*) in the Netherlands devoted 82.5% of its time to feeding (Ebbinge *et al.,* 1975), whereas white-fronted goose (*Anser albifrons*), in Britain, spent 90 % of the time foraging during spring (Owen, 1972).

After the incubatory period, breeding snow goose need protein so individuals increase feeding rate in early summer to maximise their protein intake (Harwood, 1977). Harwood (1977) estimated that an adult snow goose in Canada spent between 75-85% of its time feeding during the summer.

Feeding activity in geese is lowest in winter. Davis *et al.* (1989) found that snow geese in North America did not feed on extremely cold days but, instead, remained at the roost site, sleeping or loafing. McWilliams and Raveling (1998), in comparison, found that feeding did not decrease between autumn and winter but geese instead had periods of inactivity during severe cold to conserve energy. In the Falkland Islands, feeding activity increased in the Falkland upland (*Chloephaga picta*) and ruddy-headed (*Chloephaga ribidiceps*) goose in winter compared with summer (Summer and Grieves, 1982).

Diurnal changes

Feeding activity in geese typically follows a bimodal pattern, with early morning and late afternoon peaks of feeding activity and a midday resting period (Davis *et al.,* 1989). Cook *et al.* (1998) found that giant Canada goose (*B. c. maxima*) in south-eastern Michigan showed this distinct diurnal behaviour. These geese typically roosted overnight on open water and flew to outlying agricultural areas to feed and loaf during the day (Davis *et al.,* 1998). Greylag goose (*Anser anser*), pink-footed goose (*Anser brtachynchus*) and snow goose all show this bimodal pattern of feeding (Newton and Campbell, 1973).

In New Zealand, Potts and Andrews (1991) found that Canada goose have a distinct bimodal feeding pattern, with geese, on average, spending 70 % of their time feeding on paddocks at Lake Grasmere. Disturbance by farm work, grass height in paddocks, and the preference for open areas, all influenced the amount of feeding that occurred on pasture at Lake Grasmere (Potts and Andrews, 1991).

Other than Potts and Andrews (1991), there have been no other published studies on the seasonal or diurnal changes of goose behaviour in New Zealand. The fieldwork reported in this chapter aims to determine the seasonal and diurnal changes in Canada goose behaviour at Lake Grasmere. This is done with the over-all aim of relating goose behaviour to damage caused to farmland in the South Island high country.

3.2 METHODS AND MATERIALS

Two observational studies of grazing flock behaviour were conducted at Lake Grasmere from 31 March 1999 to 1 April 2000. Seasonal and diurnal changes in individual goose were determine by a 'focal' individual goose study (Altmann, 1974), while an 'interval' study (Altmann, 1974) was conducted to determine seasonal and diurnal changes in flock behaviour. Observations for both studies were made in the first and third weeks of every month to establish changes in bird behaviour within months and between seasons. Observations were conducted from a single observation point situated on Long Hill (171° 43' E, 43° 1' S), which had a clear view of the entire study site.

Individual goose study

In the first study, focal animal observations (Altmann, 1974) were conducted at 0900 h (morning), 1200 h (mid day) and 1500 h (afternoon). During each observation period, 10 geese were randomly selected from the goose flock using a 20x spotting scope. To select individuals, the observer randomly directed the spotting scope at the grazing flock and after looking away for a short period of time then choose two individuals in the centre of the field of view.

Each observation period involved observing the two focal geese for five minutes, scoring their behaviours every 10 seconds. This was repeated five times to achieve a sample size of 10 geese per sampling period. Observations were conducted only if geese were present on the paddocks within the study site at observation times. Observations were not carried out if the grazing flock comprised fewer than 10 geese or was outside the study area.

The six categories of goose behaviour used for this study are described in Table 3.1.

Table 3.1 Six goose behaviour categories used for the individual and grazing flock studies (modified from Summer and Grieves, 1982).

Behaviour	Description
Grazing	Head and neck below the plane of the goose's back; pecking at food source with its bill.
Preening/Loafing[1]	Preening-bill grasping and moving feathers; shaking and fluffing feathers. Loafing-head buried in feathers; position also associated with sitting on ground
Vigilance	Goose in upright position, observing its surroundings.
Searching	Goose walking with head down below the plane of its back searching for food.
Interaction	Displays (usually aggressive) that occur between individuals (including vocal calls).

[1] Preening and loafing both represent comfort behaviours and were grouped together for analysis.

Data analysis

For each goose, the observations of each behaviour category were converted into a percentage of the total goose activity for each five-minute observation period. The percentages of each behaviour for the 10 birds were then averaged to provide a single data point for each observation period. Kruskal Wallis one-way ANOVA was used to assess seasonal and diurnal behaviour differences in these percentages.

Grazing flock study

In the second study, interval sampling (Altmann, 1974) was conducted from 0800 h to 1700 h on the same days as the first study. At 30 min intervals, 20 geese were randomly selected (see individual goose study) within the grazing flock and their behaviours scored. The same six goose behaviours selected for the individual focal study (Table 3.1) were used for this sampling method. Flock behaviour was recorded only if the geese were present on the paddocks within the study area. Observations were not conducted if the grazing flock was fewer than 20 geese or was outside of the study area.

Data analysis

The raw counts of goose behaviour were converted to percentages of the total number of the 20 geese observed. The percentage behaviour for each of the 20 birds was then averaged to provide a single data point for each observation period. Preening and loafing were again grouped together as comfort behaviours. Kruskal Wallis one-way ANOVA was again used to assess seasonal and diurnal differences in those percentages.

3.3 RESULTS

Seasonal goose behaviour

Individual goose study

Grazing was the dominant activity of individual geese on paddocks at Lake Grasmere. Grazing was least frequent in summer, occupying 66 % of their time and increased in autumn, occupying 74 % of their time. However, these differences between seasons were not statistically significant (Kruskal Wallis one-way ANOVA, $F_{3,156}$ = 1.43, p=0.24) (Fig 3.1). Vigilance behaviour ranged from 9% in summer to 22% in spring but again, the difference between seasons was not significant (Kruskal Wallis one-way ANOVA, $F_{3,156}$=1.33, p=0.26). Time spent preening/loafing ranged from 8% in spring to 25% in summer but was not significantly different between seasons (Kruskal Wallis one-way ANOVA, $F_{3,156}$=0.15, p=0.94). Searching and interaction behaviours were the least common behaviour categories, averaging only 4% of total goose activity.

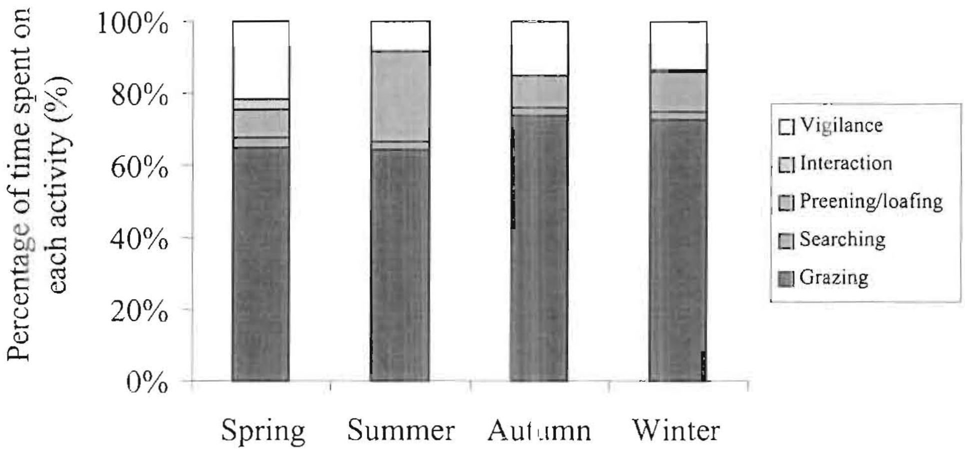


Figure 3.1 Seasonal changes in the behaviour of individual geese at Lake Grasmere (10 birds per observation, 3 observations per day, number of observations days per season=spring 3, summer 5, autumn 8, and winter 4).

Flock study

Grazing was the dominant behaviour observed in the flock; on average, 61 % of geese were grazing at any given observation time (Fig 3.2). Grazing intensity ranged from 49% in spring to 67% in autumn but these seasonal differences were not statistically significantly (Kruskal Wallis one-way ANOVA, $F_{3,16}$=0.41, p=0.75). Vigilance behaviour ranged from 12% in winter/spring to 25% in summer. Time spent in vigilance behaviour did not differ significantly between seasons (Kruskal Wallis one-way ANOVA, $F_{3,16}$=0.84,p=0.50). Preening/loafing ranged from 12% in autumn to 21% in summer but again this was not significantly different between seasons (Kruskal Wallis one-way ANOVA, $F_{3,16}$=1.71, p=0.20). Only 2.3% of geese were searching and interacting with other individuals at any given observation time.

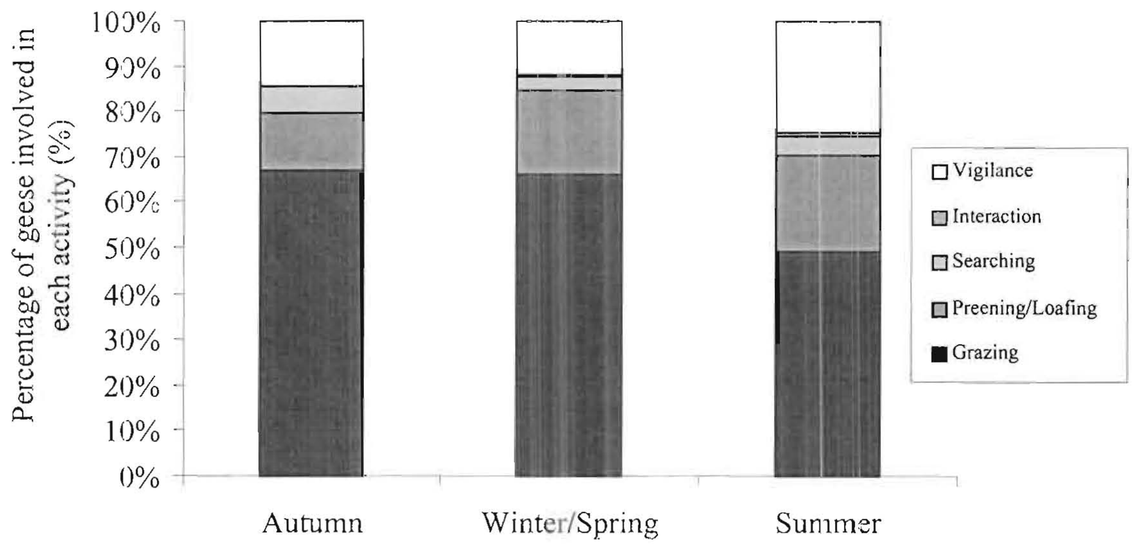


Figure 3.2 Seasonal changes in the behaviour of Canada geese at Lake Grasmere. (n=20 geese per observation time. number of observations per season; autumn 3, winter/spring 6, summer 4. Winter and spring were pooled together as both seasons' results were similar).

Diurnal goose behaviour

Individual goose study

The proportion of time geese spent grazing did not vary significantly during daylight hours (Kruskal Wallis one-way ANOVA, $F_{18,141}=1.05$, $p=0.41$) (Fig. 3.3). However, vigilance behaviour, which represented 12.6 % of total goose activity, differed significantly between time intervals (Kruskal Wallis one-way ANOVA, $F_{18,141}=1.68$, $p=0.001$). Moreover, vigilance and grazing were significantly negatively correlated (Linear regression, $F_{1,18}=7.28$, $p=0.01$) (Fig. 3.4). Preening/loafing behaviour represented 13.6 % of their activity (ranging from 8% in the morning to 17% at midday; (Fig. 3.5), but did not significantly differ between time intervals (Kruskal Wallis one-way ANOVA, $F_{18,141}=0.54$, $p=0.93$). Searching and interaction behaviours were the least common behaviours, representing only 3% of total goose activity. Neither behavioural category differed significantly between time intervals (Kruskal Wallis one-way ANOVA, $F_{18,141}$=0.90, p=0.58 and Kruskal Wallis one-way ANOVA, $F_{18,141}$=0.67, p=0.83, respectively)

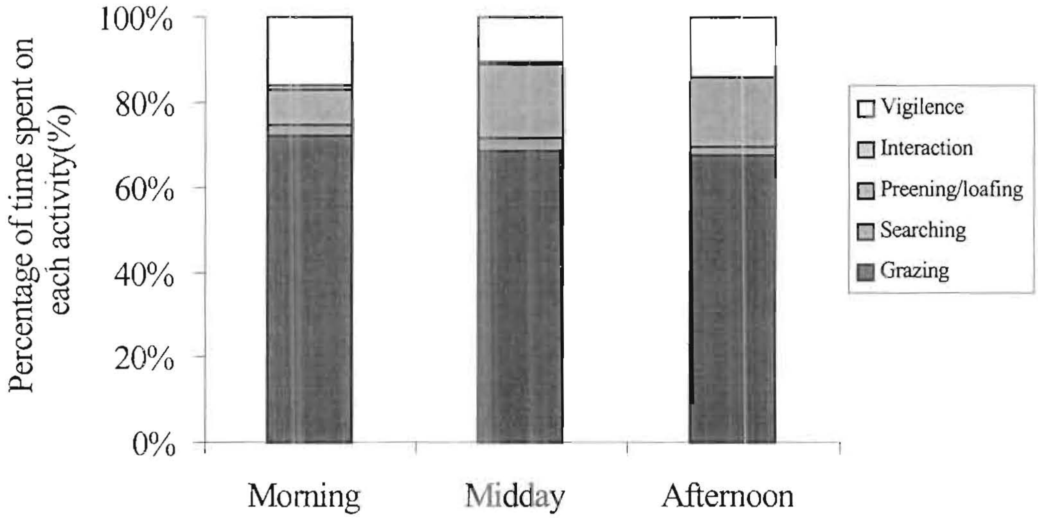


Figure 3.3 The change in behaviour of individual Canada geese (n=20) during a five-minute observation period at three time intervals during the day (morning=09:00 hrs, midday=12:00 hrs, afternoon=15:00 hrs).

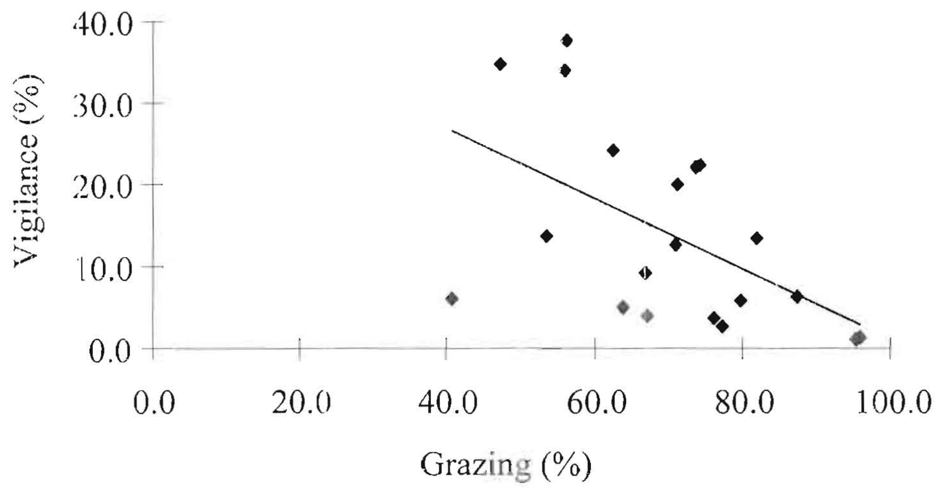


Figure 3.4 The relationship between grazing and vigilance behaviour of Canada goose individual (n=20). ($y = -0.4301x+44.075$, $R^2 = 0.2899$)

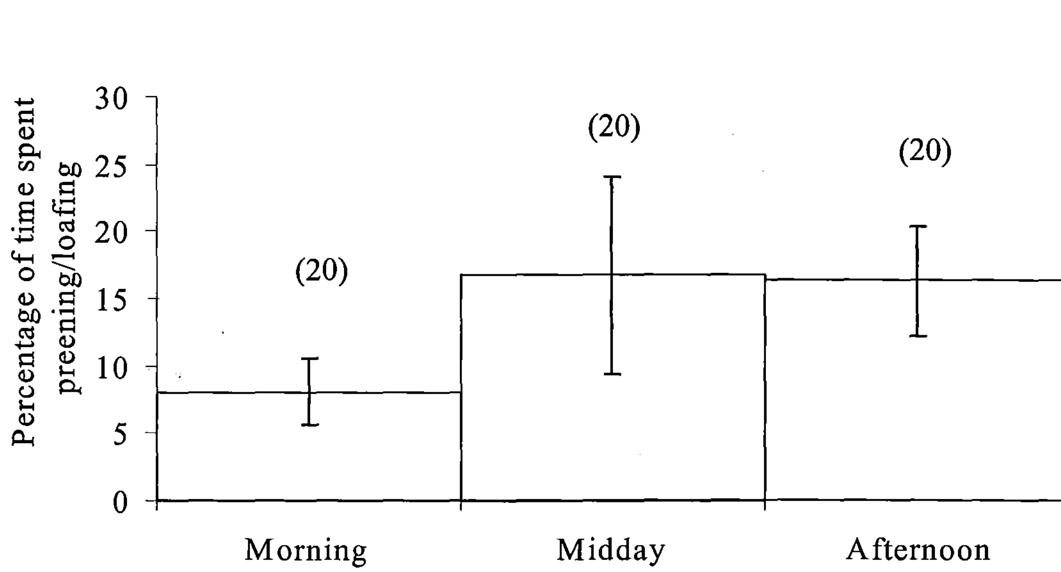


Figure 3.5 Diurnal change in preening/loafing behaviour (mean±se) by Canada geese at Lake Grasmere (all seasons pooled). Number of geese represented in parenthesis above each error bar.

Grazing flock study

Grazing behaviour was the dominant behaviour observed during the day (on average 69.6% of geese at any given observation time) (Fig 3.6). Grazing activity tended to peak at midday and in the early evening, although the proportion of the flock that was grazing did not differ statistically between time intervals (Kruskal Wallis one-way ANOVA, $F_{2,17}$=0.22, p=0.80). On average, 20.2% of geese were vigilant, with vigilance peaking when the frequency of grazing was low. The level of vigilance, however, did not differ significantly between time intervals (Kruskal Wallis one-way ANOVA, $F_{2,17}$=0.32, p=0.73), Preening/loafing accounted for 9.9 % of goose activity. Preening/loafing levels were not significantly different between time intervals (Kruskal Wallis one-way ANOVA, $F_{2,17}$=1.15, p=0.34). Searching and interaction were the least common behaviours (4.2 % of observed goose behaviour).

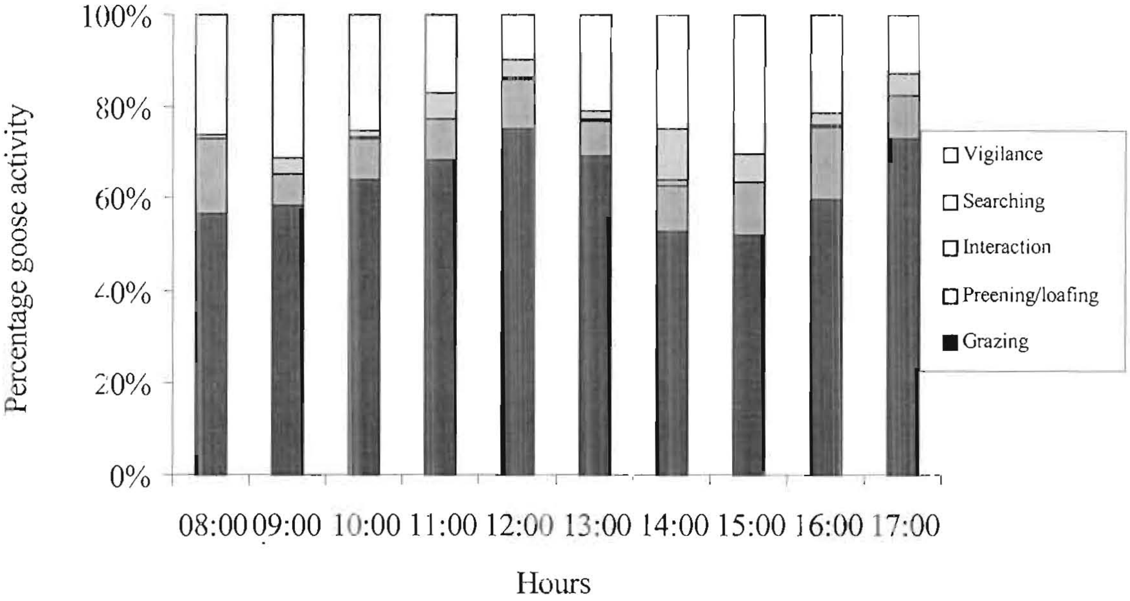


Figure 3.6 Diurnal change in average goose behaviour in a Canada goose flock between 08:00 h and 17:00 h at Lake Grasmere.

3.4 DISCUSSION

Seasonal goose behaviour

Geese on the paddocks adjacent to Lake Grasmere spend most of their time grazing regardless of the season or time of day. The high amount of grazing observed in both the individual study and the grazing flock study (69.5 % and 61% respectively) is consistent with the earlier study by Potts and Andrews (1991) who estimated that on average geese at Lake Grasmere spent 70 % of the time grazing. It is also consistent with studies of Canada goose behaviour overseas. McWilliams and Raveling (1998) found that cackling Canada goose in California spent 56-78 % of its time feeding during spring and Nastase (1998) estimated that feeding represented 60% of a Canada goose's annual time budget. The current estimate is, however, less than observed in some other goose species.

For example, barnacle goose devoted 82.5% of its time to feeding in the Netherlands (Ebbinge *et al.,* 1975), and white-fronted goose in Britain spent 90 % of its time feeding (Owen, 1972).

McWilliams and Raveling (1998) believed that time budgets and feeding activity varied between habitats. They suggested that such differences are dependent on the diurnal activity budget, which, in turn, affects the habitat in which geese are present (Davis *et al.,* 1989). During this study, Canada geese fed on only the 69 ha of farmland adjacent to Lake Grasmere. This is consistent with Potts and Andrews (1991) who stated that the paddocks adjacent to the lake were the only terrestrial feeding habitat available to geese at Lake Grasmere. Since geese used paddocks as a feeding habitat, it is therefore to be expected that grazing is the dominant behaviour when geese are on paddocks.

Gauthier *et al.* (1988) found that as geese fulfilled their nutrient requirements, feeding rate decreased. No such trend was evident in this study, perhaps because at Lake Grasmere farm activity often disturbed geese and thereby reduced the amount of time they could be on the paddocks. It seems likely that these geese are compensating for disturbance by maximising their feeding opportunity whenever they are able to be on paddocks. Once their requirements are fulfilled they simply move off the paddocks, back on to the Lake (see Chapter 4)

There was a trend for feeding activity to increase from summer to autumn (Fig 3.1). This can be attributed to increased energy requirements during autumn when the geese are increasing their energy reserves in preparation for winter (cf. Summer and Grieves, 1982; Davis *et al.,* 1989).

Reduced feeding in summer can be attributed in part to the low energy requirements of (Canada) geese at that time. During summer, warm temperatures and high quality food resources reduce the need to feed, and allows time for increased comfort behaviours such as preening and loafing (this will be discussed later, page 42).

Vigilance is a common behaviour in goose species due to the presence of discrete family units that are at risk from predators (especially in North America) (Raveling, 1979). At Lake Grasmere, vigilance represented 17% and 14% of the total goose activity in the two studies respectively. There was a trend for individual geese to be most vigilant in spring (Fig. 3.1). This is consistent with the work of Davis *et al.* (1989) who found that alert behaviours occurred most frequently early in migration (before the geese bred). Increased vigilance was associated with an increase in interactions between individuals, most of which involved aggressive behaviour (A. Win, *pers. obs.,* 1999).

In the grazing flock experiment, overall levels of vigilance were highest in summer. Nastase (1998) found that mated males, especially with family groups were most agonistic and alert during the post-incubatory period. At Lake Grasmere, an increase in aggressive behaviours, mainly between family groups, occurred in summer. However, aggressive behaviour accounted for <1% of total goose activity and so would have had negligible effect on goose impacts on pasture. Davis *et al.* (1989) found that the activity patterns of adult and juvenile snow geese on terrestrial feeding sites differed for all behaviours. They found that adult males spent more time vigilant than juvenile geese did. This is similar to the results reported by Nastase (1998) who found that mated adult geese spent more time vigilant and alert than unmated geese.

In this experiment, there was no identification of age class or sex. Earlier studies by Fredericks and Klass (1982) found that juvenile geese in family groups typically spent more time feeding than adults, while Owen and Black (1990) believed that juvenile geese fed longer without interruptions. These findings are different from McWilliams and Raveling (1998) who found that there were age differences in foraging behaviour. Nastase (1998) also found no difference in feeding behaviour between sex or age classes. He, instead, found that mated male adult geese spent less time performing comfort behaviours such as preening and loafing. The effect age and sex classes have on these behaviour results, however, can not be ruled out.

Preening and loafing tended to increase in summer. Preening and loafing behaviours normally occur at Lake Grasmere (A. Win *pers. obs.,* 1999), however, in summer, geese spent more time performing preening and loafing when on paddocks, presumably because the increase in temperature and daylight hours and the reduction in maintenance energy requirements, reduced the need to feed continuously. Similarly, Gauthier *et al.* (1988) has suggested that, as the length of time spent on feeding habitats increased comfort behaviours such as preening and loafing increased due to the decrease in feeding rate.

Diurnal goose behaviour

The relatively constant amount of grazing throughout the day seen in the geese that are using the paddocks contradicts the general bimodal pattern of goose behaviour observed in most other studies (e.g., Kahl and Samson, 1984; Davis *et al.,* 1989). Instead, the general bimodal pattern of feeding behaviour was reflected in the changes in the number of geese on the paddocks around Lake Grasmere (see Chapter 4).

Potts and Andrews (1991) believed that Canada goose fed more consistently and extensively on farmland at night at Lake Grasmere. While night feeding was not measured in this study, it is acknowledged that geese may feed more extensively at night and this may affect the amount of feeding that occurs on paddocks during the day.

It seems likely that diurnal feeding behaviour of Canada goose at Lake Grasmere is being strongly influenced by disturbance. Disturbances, predominantly from farm activity, resulted in the feeding flock returning to the lake. After each disturbance geese would return to the feeding site within one to two hours. These disturbances occurred at various times of day, reducing the amount of time geese could feed on paddocks. The high and relatively constant feeding activity seen when they are on paddocks may be a consequence of this disturbance.

Vigilance was most frequent in the morning and it may be that high amounts of disturbance in the morning account for this increase. During the study it was observed that farm activity occurred predominantly between 08:00 h and 12:00 h (mainly involved moving stock and feeding out), so it may be that this established pattern of regular disturbance could make the geese wary at certain times of the day.

In overseas studies, as the day progresses geese begin to fulfil their nutritional requirements and more time available for comfort behaviours (e.g., Gauthier *et al.*, 1988). However, preening and loafing did not show this diurnal trend in this study. Most individuals were still grazing during later parts of the day. This was because geese that had met their nutritional needs tended to leave paddocks and perform comfort behaviours elsewhere. This again suggests that disturbance is an important factor influencing paddock use at Lake Grasmere.

3.5 CONCLUSIONS

Grazing was the dominant behaviour performed by Canada goose when on paddocks at Lake Grasmere. The high amount of grazing is attributed to habitat availability, with paddocks at Lake Grasmere being the only suitable terrestrial feeding habitats available to the geese (Potts and Andrews, 1991). Geese tended to graze more intensively in autumn (when they need to put on body condition for winter) and in the morning, but these effects were minor and not statistically significant. Consequently, grazing pressure on the pasture is primarily determined by how many geese are on the paddocks rather than by seasonal or diurnal changes in their feeding intensity while on the paddocks. The fact that paddocks are used for feeding suggests that disturbance has an important role in influencing their habitat use at Lake Grasmere.

CHAPTER FOUR

CANADA GOOSE DENSITY AND DISTRIBUTION

4.1 INTRODUCTION

Canada goose (*Branta canadensis*) is a highly adaptable species found in diverse habitats, ranging from tundra to semi desert (del Hoya *et al.,* 1992; Soothill and Whitehead, 1996). Canada goose has been successful since its introduction to New Zealand because of this adaptability (White, 1986).

In New Zealand, most Canada goose inhabit privately owned farmland (White, 1986; Potts and Andrews, 1991). The Canada goose is an intelligent bird and the difficulty of shooting them, combined with intensified development of South Island high country in the 1970s, has meant that goose numbers have increased markedly in recent years (Imber, 1971). This increase has resulted in the geese becoming a 'pest' on high country farms (White, 1986).

Since 1982, annual trend counts have been conducted by the now defunct Wildlife Service and, recently by, regional Fish and Game Councils, to determine annual changes in Canada goose populations within the South Island (White, 1986). Migration patterns were studied from 1982 to 1987 by banding 1000 Canada geese annually at Lake Ellesmere (N.C.A.S, 1982; 1983; 1984; 1985; 1986; 1987). However, there have been no studies of goose migration patterns in New Zealand since 1987.

To date, there is little published information on seasonal variation in goose population densities and distribution in New Zealand. Potts and Andrews (1991) while looking at the feeding behaviour of Canada goose at Lake Grasmere recorded the seasonal changes in goose numbers from 1984-1986. They found that the population fluctuated seasonally, with numbers peaking in March, when c.500 geese were recorded. Goose numbers decreased during winter as geese migrated to coastal areas to overwinter. The goose population at Lake Grasmere was lowest in spring, coinciding with breeding in high country river valleys).

Very little is known about seasonal movements of Canada goose in New Zealand. Much of the early data obtained by banding projects in the 1980s is outdated because of changes in goose migratory behaviour as a result of increased agricultural development in the high country (Holloway *et al.,* 1987). Trend counts provide little information on seasonal movements because they are an indication of the distribution and local abundance on only a single day within a year. This study, therefore, aimed to evaluate the seasonal fluctuations of the Canada goose population at Lake Grasmere, as part of an overall study to determine the impact of geese on high country farmland.

4.2 METHODS AND MATERIALS

Goose density and distribution were recorded from March 1999 to April 2000 from an observation point situated on Long Hill, a hill beside Lake Grasmere (Fig 2.1) that had a clear view of the entire study area.

Observations were made for one day in the first and third weeks of every month. On each observation day, counts were conducted at 30 min intervals from 08.00 h to 17.00 h using a 20 X spotting scope. At each count, goose numbers on each paddock and the type of habitat class they were using were recorded. Flock position was plotted on a map of the study area.

The three habitat classes used for the study were 'pasture', mainly ryegrass (*Lolium perenne*), cocksfoot (*Dactylis glomerata*), red clover (*Trifolium pratense*) and white clover (*Trifolium repens*), the 'lake' and the 'lake margin' (defined as dry land within 10 m of the lake edge). If geese were not on paddocks at the observation time, a zero count was recorded. Hourly observations were not conducted if initial inspection indicated that no geese were present in the study area.

Data analysis

Habitat use

Mean goose numbers were determined for each habitat class, for each observation day, by averaging the number of geese seen in each habitat during each count that day. The means for the two observation days each month were then averaged to obtain the mean number of geese present in each habitat that month.

Changes in diurnal paddock use

Seasonal pasture use was calculated by averaging the total numbers of geese in paddocks at each count throughout an observation day. Observation days were then grouped into winter/spring, summer and autumn and the average paddock use calculated for each season. Winter and spring were pooled together due to small sample sizes and because data showed similar trends. Diurnal patterns in habitat use for each season were determined by averaging the number of geese on paddocks at each time interval from 08.00 h to 17.00 h, within each season.

Goose densities and distribution

Mean seasonal goose numbers on each individual paddock were determined by averaging the monthly means for each paddock within each season. Goose densities were calculated by dividing mean goose number in each paddock by the paddock's area. The results were mapped after grouping goose densities into five categories (< 1 goose/ha, 1-4 geese/ha, 5-9 geese/ha, 10-14 geese/ha)

4.3 RESULTS

Seasonal changes in habitat use

The total number of geese at Lake Grasmere ranged from <10 in late winter and early spring to >400 during mid summer and late autumn (Fig. 4.1). Goose numbers peaked at 430 in May 1999 and were lowest in October and November 1999 (which coincided with breeding outside the study area). This seasonal variation in goose numbers was highly significant (One way ANOVA, $F_{2,10} = 15.92$, $p < 0.001$).

Geese used the lake as a roost site throughout the year, and this was their predominant habitat from June 1999 through to January 2000. Pasture was the main habitat used in late summer and early autumn of 1999 and 2000. Geese used the lake margin only in April, August and September 1999 (Fig.4.1).

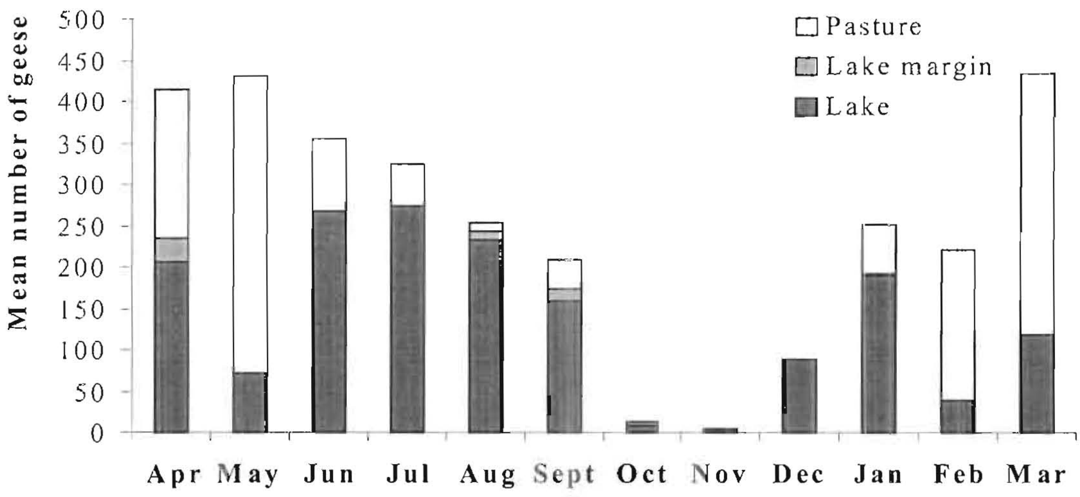


Figure 4.1 Mean number of Canada goose in the three main habitat types at Lake Grasmere from April 1999 to March 2000 (n=2 observation days per month)

Seasonal changes in paddock use

When the monthly data were pooled into three main seasons, analysis confirmed that seasonal changes in mean number at Lake Grasmere were highly significant (One way ANOVA $F_{2,10} = 15.92$, $p < 0.001$). Mean goose numbers on paddocks were highest in autumn (254±53 geese) and also high in summer (216±39 geese). Paddock use was significantly lower in winter/spring with an average of only 41±11 geese found on the paddocks.

Diurnal changes in paddock use

Seasonal differences in diurnal paddock use were also evident. The number of geese on paddocks in summer showed a bimodal pattern, with more than 300 geese on paddocks at 08:00 h and from 14:00 h to 17:00 h (Fig. 4.2). Diurnal densities in winter/spring showed the opposite trend, with goose numbers highest on paddocks during the middle of the day (Fig. 4.2). Except in the early morning, goose densities in autumn were constantly high throughout the day

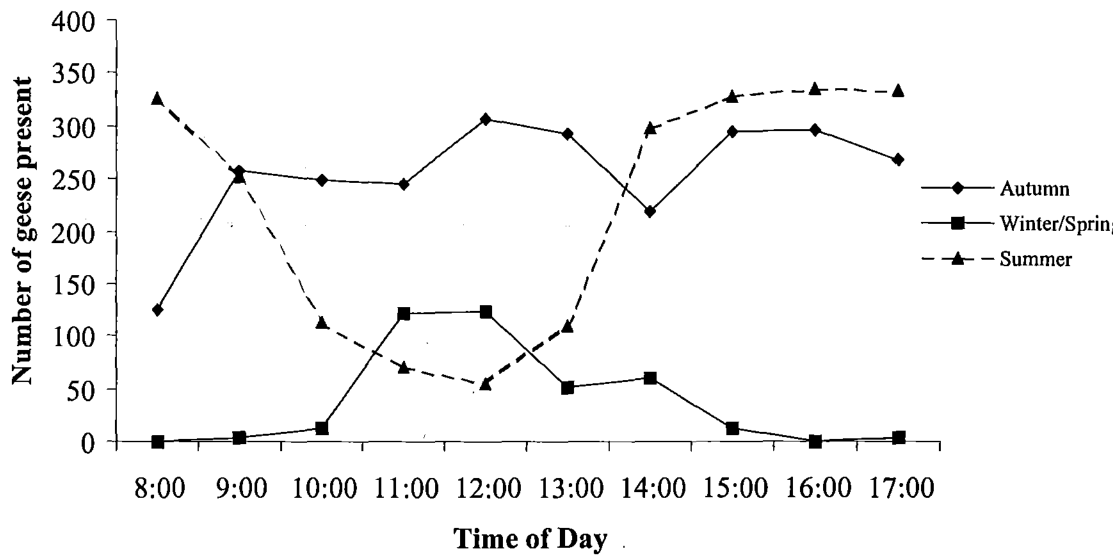


Figure 4.2 Diurnal changes during different seasons in the number of Canada geese on pasture adjacent to Lake Grasmere.

Seasonal changes in goose distribution

Autumn

Geese were most widespread on the study area in autumn, when they grazed eight paddocks within the study area (Fig. 4.3a). Goose densities ranged from < 1 goose/ha (in paddocks 1, 2 3 and 8) to >10 goose per hectare in paddocks 5 and 7. Paddock 7 had the highest density during autumn (12.2 geese/ha). Goose density on the lake margin during autumn was 1.6 geese/ha.

Winter

Geese were less abundant and widespread on the paddocks in winter (Fig 3b). They were restricted to paddocks 6 and 7 where densities were 1.4 and 4.5 geese/ha, respectively. Goose density on the lake margin during winter was 2.4 geese/ha.

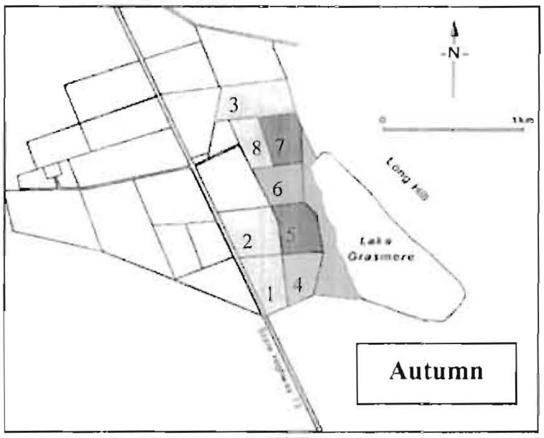
Spring

Geese were restricted to paddocks 6 and 7, with densities of <1 goose/ha and 1.4 geese/ha, respectively. Goose density on the lake margin during spring was 1.7 geese/ha. These low spring densities were due to emigration of geese to breeding areas outside the study area (Potts and Andrews, 1991).

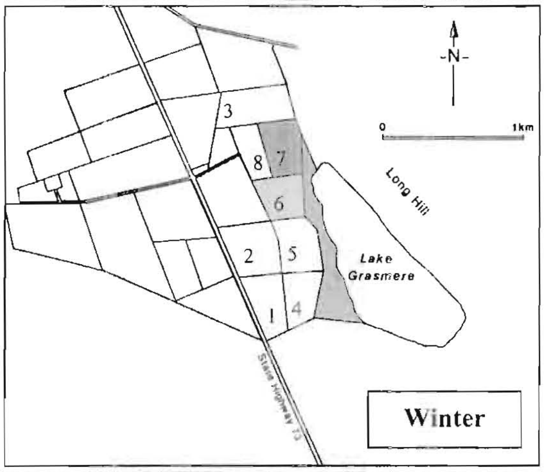
Summer

Geese were more widely distributed in summer than in winter and spring, with geese evenly spread over paddocks 4, 5, 6 and 7. Goose density was highest on paddock 5 (5.8 geese/ha). Paddocks 4, 6 and 7 had lower densities (1.2, 1.3 and 4.8 geese/ha, respectively). During summer <1 goose/ha was present on the lake margin, which was the lowest density recorded at the lake margin during the study.

a)



b)



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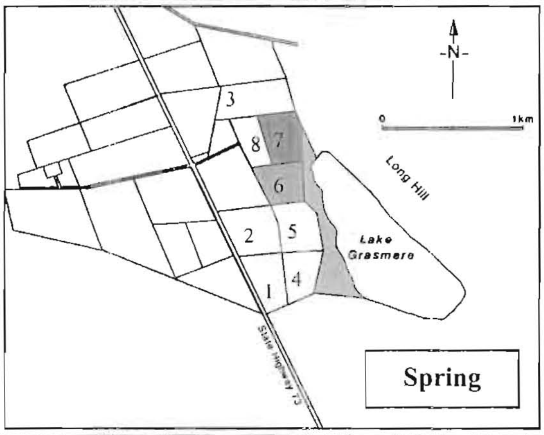

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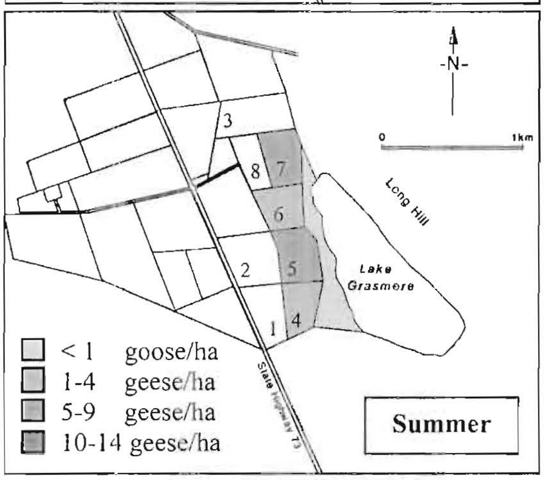

Figure 4.3 Seasonal densities and distributions of Canada goose at Lake Grasmere from autumn 1999 to summer 2000.

4.4 DISCUSSION

Goose density at Lake Grasmere

Canada geese were present at Lake Grasmere for 10 months of the year. The population fluctuated from over 430 geese in May 1999 to fewer than 10 geese in October 1999 (Fig. 4.1). This seasonal cycle is consistent with the earlier study by Potts and Andrews (1991), although goose numbers were lower than the reported peak of c. 500 geese in March 1985.

The population at Lake Grasmere decreased from May 1999 until October 1999 (Fig. 4.1). The annual migration from breeding areas in the high country to coastal areas to over winter, as described by Imber, (1971) and Potts (1984) is believed to be the reason for this decline. However, it is important to note that over 150 geese overwintered at Lake Grasmere.

The population at Lake Grasmere, is relatively sedentary. This tendency has been attributed to behavioural characteristics of the subspecies *B. c. maxima* (Imber 1971). However, Potts and Andrews (1991) believed that agricultural development explains the increase in the number of Canada goose overwintering at Lake Grasmere. Pasture improvement, through the introduction of exotic grasses and the use of fertilisers provides a high quality food resource that enables geese to overwinter in the harsh high country environment (Potts and Andrews, 1991). The large number of geese now overwintering at Lake

Grasmere suggests that agricultural development is altering Canada goose distribution in New Zealand.

Canada goose numbers at Lake Grasmere were lowest in early spring. The low numbers are attributed to the departure of geese for breeding and brood rearing sites outside the study area. This is consistent with Potts and Andrews' (1991) who found that the Canada goose population at Lake Grasmere declined to fewer than 50 over early spring in 1984 and 1985.

Geese returned from breeding in early December, with over 250 geese found at Lake Grasmere in early January (Fig. 4.1). This increase occurred significantly earlier than described by Potts and Andrews (1991). This sharp increase in population size at Lake Grasmere is attributed to the return of family groups from breeding sites. Raveling (1979) found that, in North America, geese that bred on the same breeding grounds during the summer also tended to roost together during winter. In New Zealand, geese breed in isolated high country river valleys (Potts and Andrews, 1991). White (1986) believed that adults always return to the wintering grounds that they used the previous year. The significant increase in Canada geese returning to Lake Grasmere can be related to the increased number of adult geese returning from breeding areas.

The seasonal fluctuation evident in the goose population at Lake Grasmere highlights a problem with the present goose monitoring systems. The standard June 'trend count' records only population abundance and distribution on a single day each year (Holloway *et al.,* 1987) and so is unable to indicate seasonal changes in densities and distribution of Canada goose populations. For example, in June 1999, the goose population at Lake Grasmere was 350 geese (Fig. 4.2), but this count does not alert managers to the high concentration in geese present at the lake in late summer and early autumn. In the United States, Malecki and Trost (1998) argued that estimated population parameters from winter counts do not provide the reliability or precision required to attain management goals. They stated that mid-winter surveys may provide reliable estimates of the total number of geese for trend counts, but they are not easily related to changes in individual goose populations. Nor are they likely to be a good indicator of goose impacts on pasture.

The main problem with goose surveys in the United States is the amount of intermixing between populations (Malecki and Trost, 1998). Similarly, in New Zealand, Canada goose populations are loosely separated and intermixing frequently occurs throughout the year because of the birds' high mobility (White, 1986). The standard June 'trend counts' do not account well for the intermixing between goose populations and the effect of this mixing on goose abundance in particular areas.

The lack of an efficient monitoring system limits the ability of managers to effectively manage goose populations to restrict the damage they cause to high country farmland. The trend counts are intended to help determine the need for future culling operations (Fish and Game NZ, 1995). At Lake Grasmere, the annual cull is usually conducted in May. The number of individuals removed is determined from the results of the previous year's June trend count for the whole of the Waimakariri/Hurunui management area (Fish and Game NZ, 1995).

A major objective of the current Canada Goose Management Plan (Fish and Game NZ, 1995) is to mitigate the impact of Canada goose on farmland. In terms of goose damage, the June trend count is problematic, because it does not identify the period of greatest goose density. Determining when goose densities are at their greatest might assist managers to more effectively manage populations so as to reduce the amount of damage that occurs to farmland.

Goose distribution at Lake Grasmere

The diurnal feeding pattern of geese at Lake Grasmere varied with the seasons (Fig. 4.2). These patterns reflect changes in feeding behaviour in response to changes in habitat quality (Raveling 1979, Prins *et al.,* 1980, McWilliams and Raveling, 1998) and nutrient demands (McWilliams and Raveling, 1998).

Pasture quality is a major determinant of habitat selection by Canada goose (Owen and Black 1990). Geese select habitats that provide optimum energy returns (McWilliams and Raveling, 1998). Summers and Critchley (1990) found that the age of pasture swards is important in field selection by Brent goose (*Branta bernicla*), with the amount of live grass present in the pasture sward influencing field selection. The percentage of dead and decaying material in pasture swards increases with age, reducing pasture quality (Vickery, 1983). Pasture quality clearly influences paddock use at Lake Grasmere. In winter, frosts reduce pasture quality by increasing the amount of dead and decaying dry matter. During this time, geese hardly fed on paddocks and spent long periods roosting on the lake. In contrast, geese fed on all paddocks surrounding Lake Grasmere in late spring-early summer, when pasture quality and grass growth (associated with 'spring flush') is highest.

Trade-offs occur in the benefits gained when selecting feeding sites. In a study of field selection by pink-footed goose (*Anser brachyrhynchus*), Gill (1996) found a direct relationship between the benefits of feeding at a foraging site, and the effort needed to travel to it. The winter distribution at Lake Grasmere reflects this relationship, with geese spending long periods roosting on the lake. Low temperatures in winter influence the trade-off relationship. Geese in paddocks 6 and 7 in winter were reluctant to fly but instead walked to both paddocks (A Win, *pers. obs.,* 9/7/1999). This is consistent with the results reported by Raveling *et al.* (1972) who found that Canada goose was reluctant to fly in winter. Davis *et al.* (1989) found that lesser snow goose (*Anser caerulescens*) did not feed on extremely cold days, but instead remained at the roost site sleeping or loafing.

The paddocks immediately adjacent to Lake Grasmere are the most preferred by Canada goose, with goose densities at times exceeding 10 geese/ha. This is similar to Potts and Andrews (1991) who found that geese spent up to 18% of their time on paddocks adjacent to the lake. Gill (1996), in a study of the pink-footed goose, suggested that the distribution of geese increases when preferred pastures become depleted. At Lake Grasmere, high goose density during late summer appears to have reduced the quantity and quality of pasture swards on preferred paddocks adjacent to the Lake, forcing a shift change to less preferred paddocks in autumn.

Higher numbers of Canada goose were observed feeding on paddocks in this study than in the earlier study by Potts and Andrews (1991). They recorded fewer than 100 geese on paddocks throughout the year, with the lake being the dominant habitat for geese for the majority of the year.

During the course of this study, geese at Lake Grasmere were observed to use the lake mainly for comfort behaviours such as preening and loafing. This differs from Potts and Andrews (1991) who recorded large numbers of geese feeding on aquatic vegetation in the lake (Fig. 4.4). They believed that feeding on the lake was due to relative ease of access and availability of aquatic vegetation located in areas located in least disturbed areas. Differences between results from this study and that of Potts and Andrews (1991) may be attributed to improvements of pasture quality. The increased use of fertilisers and exotic grasses provides higher quality food resources, may have altered habitat use by Canada goose; paddocks are now the preferred feeding habitats at Lake Grasmere. This feeding pattern is similar to that described by Cook *et al.* (1998) who found that giant Canada goose in Michigan, U.S.A., fed on agricultural areas, which provided high nutrient crops such as corn and maize, but roosted overnight on lakes and wetlands.

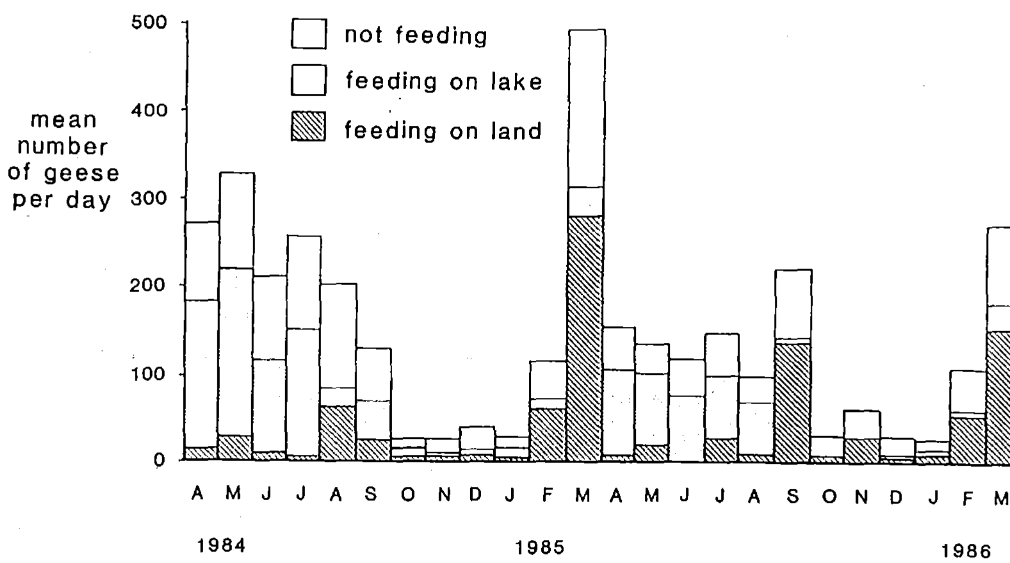

Figure 4.4 Seasonal patterns of population change from 1984 to 1986 at Lake Grasmere (from Potts and Andrews, 1991).

Energy demands of geese

Seasonal shifts in habitat use have been well documented in the Canada goose (Reed *et al.,* 1977; Raveling, 1979; Raveling and Zezulak, 1991). These changes are a response to differences in energy demand and nutrient requirements. Raveling and Zezulak (1991) found that cackling Canada goose (*B. c. minima*) fed frequently on winter wheat during autumn, while Davis *et al.* (1989) found that Canada goose spent more time on corn stubble, pasture and winter wheat during winter. Previous studies at Lake Grasmere found that turnip (*Brassica rapa*) crops were used more frequently than pasture during winter (Harris *et al.,* 1987). In New Zealand, Canada goose fed predominantly on pasture (White, 1986), therefore the change in pasture paddock use at Lake Grasmere is likely to be a reflection of changes in their energy and nutrient requirements.

Overseas, goose feeding increases in spring due to the need to accumulate fat reserves for spring migration (McLandress and Raveling, 1981; Gauthier *et al.* 1984; Gauthier, 1993). McLandress and Raveling (1998) found that cackling Canada goose spent 78% of its time feeding in spring; Nastase (1998) found that Canada goose spent 60 % of its time feeding. In contrast, Canada goose at Lake Grasmere spent on average 70 % of its time feeding at Lake Grasmere year-round, with no significant difference between seasons. However, the amount of time geese spent on paddocks did differ (Fig. 4.2). Increased paddock use in autumn may reflect the need to increase fat reserves for winter, which may be especially important for individuals overwintering in the high country.

Disturbance

Potts and Andrews (1991) found that the diurnal feeding patterns of Canada goose at Lake Grasmere were clearly influenced by a strong behavioural tendency to use open areas free of disturbance. Farm activity and traffic on the neighbouring State Highway tended to be highest during daylight hours, and clearly influenced when and where the birds fed (A.Win *pers. obs.*, 1999). It was evident that disturbance, especially farm work, directly impacted on the distribution of geese at Lake Grasmere.

Farm work on paddocks adjacent to the lake often disturbed geese and caused them to move away from the paddock in which they had been feeding. Newton and Campbell (1973) and Keller (1991) also found a positive correlation between frequency of goose feeding and human disturbance. However, from personal observations, geese returned to feed on paddocks within an hour of being disturbed. This is similar to findings by Summer and Critchley (1990) who found that if human disturbances were brief (less than 20 minutes), Brent goose would return immediately to its feeding site.

Canada goose showed varying degrees of tolerance to disturbance, with geese most tolerant of farm work during summer and autumn. During this time, geese were also observed feeding closer to other disturbance factors (such as the State Highway). Gill (1996) found that pink-footed goose tolerated disturbances more when the geese were far from their roosting sites, especially when food resources were depleted. Goose distributions were largest in autumn at Lake Grasmere, with geese feeding on less-preferred paddocks some distance from the lake. Increased tolerance to disturbance was evident during this period.

Potts and Andrews (1991) suggested that paddock openness influenced goose distribution at Lake Grasmere. However, this study suggests that selection of feeding sites by Canada goose at Lake Grasmere is primarily influenced by proximity to the lake, with paddock use decreasing with increasing distance. Similarly, Gill (1996) found that preferred paddocks were those directly adjacent to roosting sites. Therefore, paddock openness only partly determines paddock selection at Lake Grasmere.

4.5 CONCLUSIONS

Canada goose showed distinct seasonal fluctuations in population number and distribution at Lake Grasmere. The population was highest in late summer-autumn, which lead to high densities and broad distributions on paddocks. Canada goose impact on farmland is probably greatest in this season. The seasonal fluctuation in goose populations at Lake Grasmere suggests that the present monitoring system is unable to detect in a reliable way, changes in individual Canada goose populations. Monitoring seasonal changes in goose densities is needed to help managers more effectively manage goose populations.

Distribution and density of Canada goose on paddocks varied throughout the year, as a consequence of changes in goose feeding behaviour. Since paddocks directly adjacent to Lake Grasmere are the only terrestrial feeding habitat, these changes in goose feeding behaviour influenced both the seasonal and diurnal paddock use at Lake Grasmere. Canada goose selects habitats that provide high-energy returns. Pasture quality varies in the high country and is highest in late summer and early autumn. Consequently, autumn distribution were large and densities on paddocks highest at this time. Conversely, low pasture quality in winter due to grass die back and low grass production was reflected in the geese spending a large proportion of their time on the lake.

During late summer-autumn, geese are in the process of acquiring fat reserves for winter. Therefore, they increase the frequency and length of feeding bouts and select habitat that provide high-energy returns. The increase in paddock use and the high densities in late summer are a reflection of the increase in energy demands.

Goose distribution at Lake Grasmere is also influenced by disturbance. Disturbance events mainly farm work influences where and to what extent Canada goose feeds on paddocks. Canada goose at Lake Grasmere selects paddocks with low disturbance, which tends to be associated with distance to the Lake at certain times of the day.

To summarise, goose distributions and densities on paddocks at Lake Grasmere are a reflection of geese feeding behaviour, which responds to changes in habitat quality and energy demand. In autumn, high pasture quality and increased energy demand as geese prepare for winter and high goose numbers at Lake Grasmere combine to produce a high density of geese foraging over a large area of paddocks adjacent to the lake. This seems likely to result in significant grazing pressure on paddocks at Lake Grasmere. The consequences of this grazing pressure on pasture production are addressed in the next chapter.

CHAPTER FIVE

GOOSE GRAZING EFFECT ON PASTURE PRODUCTION

5.1 INTRODUCTION

The grazing impact on pasture by goose species has been widely discussed in New Zealand and overseas. Early opinion was that the effects of goose feeding on farmland could vary quite widely, from beneficial to detrimental, depending mainly on the time of year that they are present on farmland (Kear, 1970). Studies by Kear (1965) and Kuyken (1969) concluded that geese have no effect on agriculture in Britain. In recent decades, newer studies have looked to establish the impacts of geese on agriculture. Several have subsequently confirmed that grazing by geese can reduce yields from agricultural grasslands (e.g., Patton and Frame, 1981; Bedard *et al.*, 1986; Bruinderink, 1989; Percival and Houston, 1992).

The improvement of New Zealand's grassland through the use of introduced grasses (especially ryegrass, *Lolium perenne*), and the use of nitrogen fertilisers has led to increased goose impacts on this country's agriculture (Potts and Andrews, 1991). Similarly, in Britain geese that traditionally fed on low quality native grassland are now found to feed more on improved pastures (Summers, 1990). Dark-bellied brent goose (*Branta bernicla*), which traditionally fed on grasses and sedges on tidal mudflats (Campbell, 1946), now feed inland on winter wheat (Summers, 1990). This has raised concerns amongst Britain's farmers over the increase in goose damage to their crops (Summers, 1990).

Canada goose damage in New Zealand is clearly seasonal (White, 1986) however; the improvement of farmland in the high country has resulted in many Canada goose populations becoming sedentary (Imber, 1971). Goose populations are therefore present on high country farmland for long periods of time. Consequently, the amount of goose damage that occurs over different seasons has become important.

This chapter attempts to quantify the effect of goose grazing on pasture biomass at Lake Grasmere. This is important because, at present, managers of Canada goose in New Zealand have no quantitative estimates of goose impacts on high country farmland. In particular, this chapter aims to determine the seasonal variation in goose damage in the high country. By quantifying when peak damage is occurring, goose managers may be able to better target control operations to alleviate periods of high goose damage to high country pasture.

5.2 METHODS AND MATERIALS

Exclosure plots were established on paddocks at Lake Grasmere over a 12-month period to determine the difference between non-grazed and goose-grazed pasture. Exclosures (0.5 m x 2 m x 1m) were constructed of hexagonal wire netting with a large (19 mm) hole size to mitigate the impact of 'cage effects' on pasture growth. All exclosure and control plots were established with the 1 m side facing northwest to help reduce the variability in between plot measurements. Control plots were established within 20 m of the exclosure plots to reduce habitat variations, each marked by a single white peg placed two metres away on a 45^0 angle from the top right hand corner of the control plot.

Preliminary observations of geese feeding next to exclosure cages and control pegs were carried out during the summer of 1998/99. These observations suggested that Canada goose feeding behaviour was not affected by cages or pegs. In a preliminary trial of three exclosure plots in March 1999, when there was minimal grazing of the plots, the drymatter production in the grazed and ungrazed plots did not differ (Kruskal Wallis one way ANOVA, $F_{1, 24}$= 1.85, p=0.19), which suggests the exclosures themselves had negligible effect on pasture production.

Plate 5.1 Exclosure and control plots in paddock.

Exclosure plots were established monthly from July 1999 to June 2000, except for the months of September and October 1999 due to lambing on the study site. (During these two months, fewer than 10 geese were present over that period and it was assumed that they would have had negligible affect on pasture production). Each month, two replicate sets of 10 exclosures and 10 control plots were established on mixed-pasture paddocks that were free from sheep grazing. Only 10 exclosures were sampled in November 1999 and April 2000; only one paddock was available in November and in April, cattle gained entry to a paddock and trampled and grazed most of the exclosure plots there.

The pasture swards in the exclosure paddock contained a mixture of ryegrass (*Lolium perenne*), cocksfoot (*Dactylis glomerata*), timothy (*Phleum pratense*), white clover (*Trifolium repens*) and red clover (*Trifolium pratense).* In both pasture field sites, exclosure plots and controls were established randomly, except that all plot locations were > 20 metres from field edges, as geese tend to feed in the centre of the fields whereas mammalian herbivores such as hares (*Lepus europaeus occidentalis*) and rabbits (*Oryctolagus cuniculus*) concentrate their feeding on the edges (Conover, 1988).

Site factors for each exclosure and control plot were recorded at the start of each month to clarify the paddock condition before establishment. The number cf goose, sheep, rabbit faeces (per plot) and average grass height (mm) were recorded to determine the amount of grazing that occurred on the paddocks. The distances from the lake (m) and fence line (m) were also recorded to determine whether these factors influenced the amount of goose damage. All sites were then kept free from sheep grazing for the subsequent month.

At the end of each month, three 0.1 m^2 sub samples of above ground vegetation were clipped from exclosure and control plots. Vegetation sampling quadrats were randomly located within each plot, however, samples were not taken <100 mm from the exclosure's fence to avoid any edge effect of the exclosure on pasture growth. Rooted vegetative material was clipped to ground level using clipping shears to obtain a precise measurement of pasture growth.

Clippings were placed in clear polythene bags with labels showing exclosure plot number, site number, and date. Upon the return to the laboratory, samples were dried in a force draught oven for 24 h at 60 ^{0} C and then weighed to obtain dry matter (in grams).

Data analysis

Each month, the three subsamples from each plot were averaged to obtain one single monthly biomass estimate for each plot. Data from each exclosure and control plot were entered into Microsoft Excel 5.0, with data analysis carried out in Statistics 5.0.

To determine whether control plots and exclosures were significantly different from one another, site factors (i.e., grass height (mm) and the counts of goose, sheep and hare/rabbit faeces per plot) were compared using two-sample t tests. Dry weight comparisons between exclosure and control plots were made using a one-way ANOVA. Monthly differences in pasture dry matter production between control and exclosure plots were then regressed against monthly goose population means to determine the relationship with Canada goose numbers.

The amount of dry matter removed by an individual goose (kg/goose/day) was calculated by dividing the monthly difference (in kg/ha) between ungrazed and grazed plots by the average number of geese on paddocks during that month. This average was calculated by dividing the mean number of geese in all habitats for each month (i.e., the totals shown in Fig. 4.1) by the average area of paddock used by geese over the whole year. This calculation assumes that all geese in the study area fed on the paddocks at some point during the day. Field observations carried out at various times suggested that this assumption is valid.

5.3 RESULTS

Monthly dry matter differences

Monthly pasture dry matter production on goose-grazed pasture at Lake Grasmere was significantly reduced in all months surveyed (one-way ANOVA, $t_{1,318}$=18.08, P < 0.001) (Fig. 5.1). Differences between grazed and ungrazed plots were greatest in autumn, peaking at 900 kg/ha/month in March 2000 (Fig. 5.2). Differences were smallest in winter and early spring, with less than 100 kg/ha removed in July and August 1999 (Fig. 5.2). Initial grass height and goose, sheep and rabbit faeces densities were not significantly different between ungrazed and grazed plots (Initial grass height (two-sample t test, $t_{1,159}$=-0.18, p=0.83), Goose faeces (two-sample t test, $t_{1,159}$=1.64, p=0.10), sheep faeces (two-sample t test, $t_{1,159}$=-0.06, p=0.90), and hare/rabbit faeces (two-sample t test, $t_{1,159}$=0.55, p=0.59)) (Table 5.1). Therefore, the observed difference in pasture production between grazed and ungrazed pasture is attributed to grazing by Canada goose.

Table 5.1 Initial comparisons of site factors between exclosure and control plots on the day each exclosure was constructed.

Site factor	Exclosure			Control		
	Mean	N	se	mean	N	se
Initial grass height (mm)	49.6	160	4.0	48.6	160	4.1
Goose faeces (no. per plot)	7.3	160	0.8	9.1	160	0.8
Sheep faeces (no. per plot)	4.9	160	0.7	4.9	160	1.1
Hare/Rabbit faeces (no.per plot)	0.1	160	0.7	0.2	160	0.1

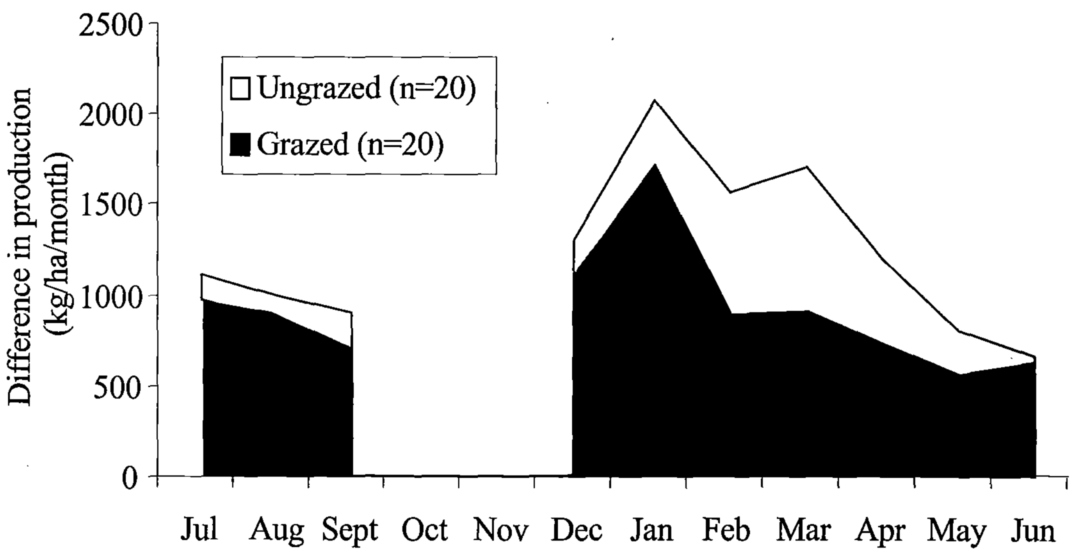

Figure 5.1 Monthly drymatter production on goose-grazed and ungrazed pasture plots from July 1999 to June 2000. Pasture production was not measured in October or November, as Canada geese were absent from the study are in those months.

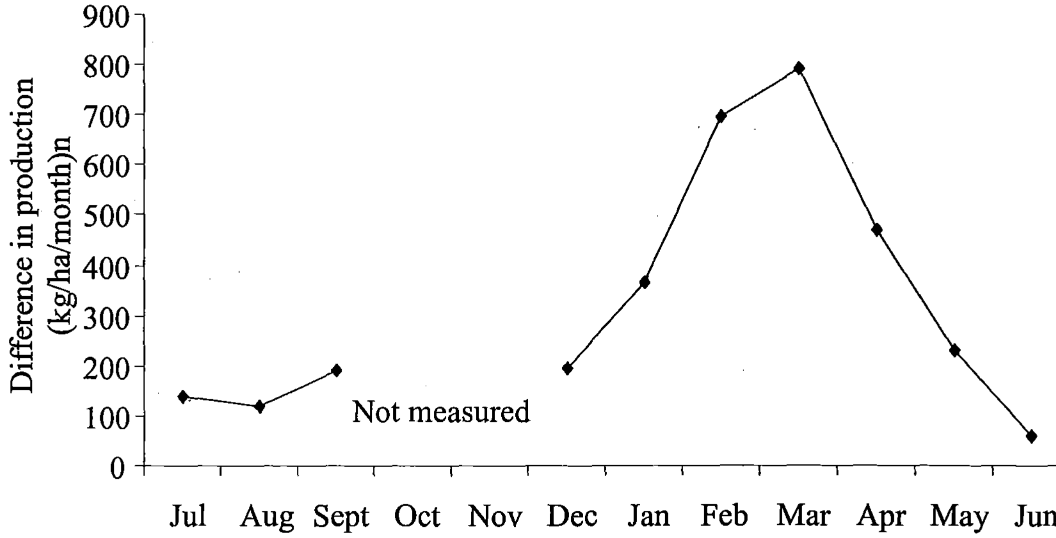

Figure 5.2 Monthly differences in dry matter production between goose-grazed and ungrazed pasture plots (n=20 exclosure and control plots except November and April which had sample sizes of 10 exclosure and control plots). No measurements were made for the two months when no geese were absent from the study site.

Monthly dry matter production difference between grazed and ungrazed plots was positively correlated with mean monthly goose numbers (Linear regression, $F_{1,10}$ =5.15, P=0.046). However, goose numbers only explained 34% of the variation in drymatter differences (Fig. 5.3).

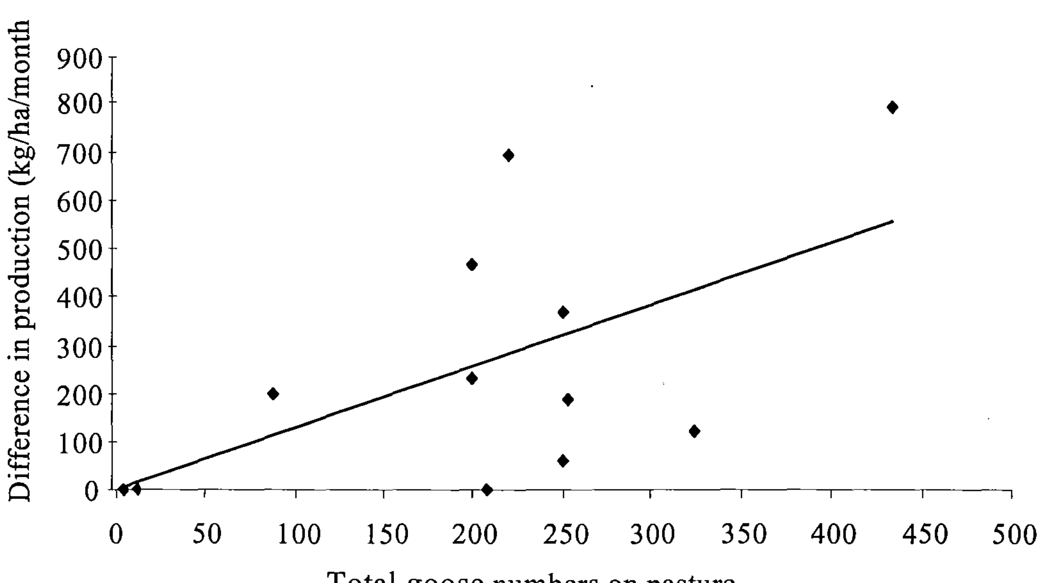

Figure 5.3 Relationship between total goose numbers on pasture and the difference in drymatter between goose-grazed and ungrazed pasture plots. (y=1.289x-2.382, R^2= 0.34)

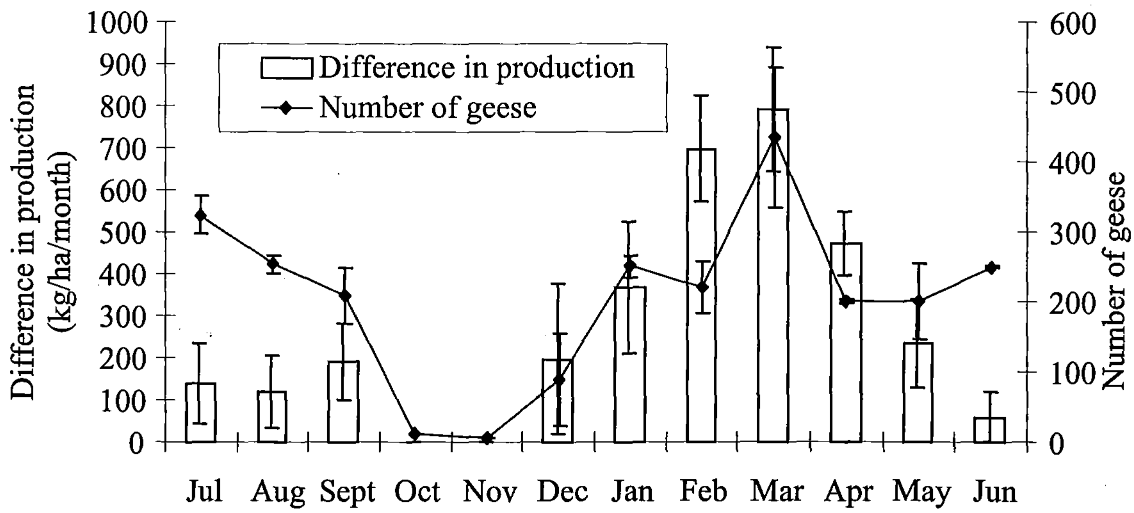

Figure 5.4 Monthly difference (mean±s.e.) in dry matter production on goose-grazed and ungrazed plots in relation to the total goose number in all habitats (mean±s.e.). (Difference in production, n=20, except December and April were n= 10; Number of observations, n=2)

Individual goose consumption

Individual goose consumption averaged 1.29 kg/goose/day and ranged from 0.25 kg/goose/day in June to 3.5 kg/goose/day in February (Fig. 5.5).

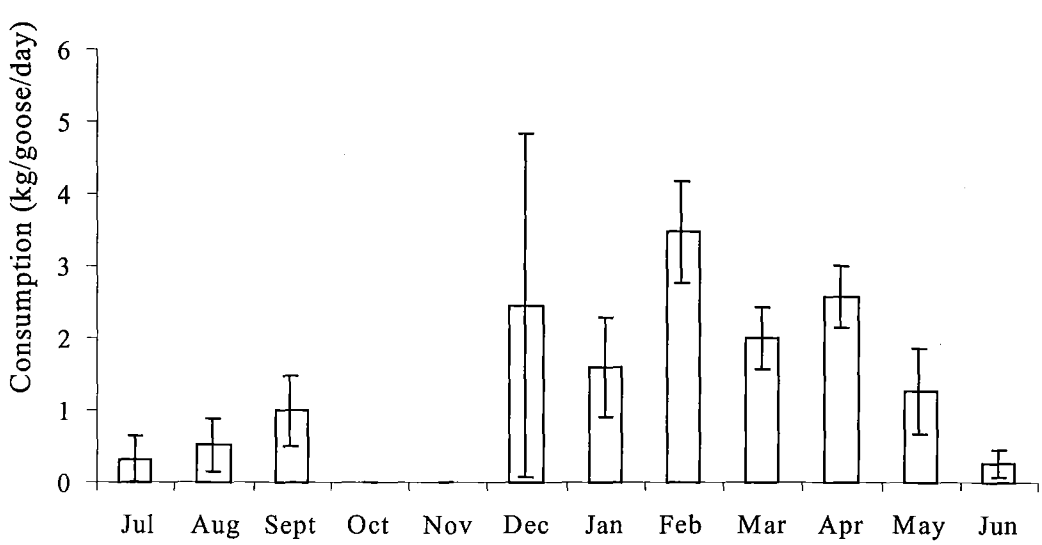

Figure 5.5 Estimated average daily drymatter consumption (±se) by individual Canada goose at Lake Grasmere. The details of these calculations are shown in Appendix 1.

5.4 DISCUSSION

Canada goose at Lake Grasmere significantly reduced pasture production on paddocks adjacent to the lake in all months surveyed (One-way ANOVA, $F_{1,318}$ =18.08, P<0.001). This difference was positively correlated with goose numbers (Linear regression, $F_{1,10}$=5.15, P=0.046). Canada goose impact varied seasonally, ranging from less than 100 kg/ha in winter to 900 kg/ha in autumn. This difference in the amount of goose consumption is due to major changes in goose density (Chapter 4) minor changes in feeding behaviour (Chapter 3).

In this study, Canada goose fed exclusively on the 69 ha of farmland adjacent to Lake Grasmere. This is consistent with the observations of Potts and Andrews (1991) who found that paddocks adjacent to the Lake Grasmere were the only terrestrial feeding habitat used by Canada goose.

Canada goose densities at Lake Grasmere varied throughout the year, with goose numbers peaking at 430 in May 2000 (Fig 4.1). Goose numbers were consistently high during autumn, with numbers constantly exceeding 400. Average annual densities in each paddock ranged from <1 goose in paddock 1 to 12.2 geese/ha in paddock 7 (Chapter 4).

Grazing varied little during the year with feeding ranging from 66% to 74% of total goose activity (Chapter 3). The high damage in autumn is therefore primarily due to high goose density and increased feeding intensity on paddocks.

Potts and Andrews (1991) believed that Canada goose fed more consistently and extensively at night. Though night feeding was not measured in this study, the quantification of damage to pasture by geese takes into account all feeding on paddocks, both at night and during the day.

Percival and Houston (1992), in a study of grazing by barnacle goose (*Branta leucopsis*), found a large reduction in grass standing crop in the early spring with a distinct positive correlation between yield loss and goose grazing intensity. However, goose-grazing intensity explained only 28% of the variance in yield loss. At Lake Grasmere, goose numbers explained 34% of the variation seen. Therefore other factors such as weather conditions, habitat quality and seasonal variation in habitat use are influencing the amount of Canada goose consumption at Lake Grasmere.

The effect of weather on goose consumption

Percival and Houston (1992) believed that a major factor affecting goose consumption was the weather; they cited severe cold in winter or heavy autumn or spring rains, as examples (Percival and Houston, 1992). Weather conditions influence the ability of plants to compensate for grazing impacts (Parsons *et al.*, 1983). Kear and Rogers (1963) discussed the depressive effect on grass yield by goose grazing at the start of the growing season in spring. In a cutting trial they found that there was little depression in grass productivity in spring. High nutrient reserves, water and warmer temperatures during spring allowed plants to respond to grazing, resulting in increased ability of plants to compensate for grazing (Kear and Rogers, 1963; Hik *et al* 1991). Parsons *et al.* (1983) found that low grazing intensity can increase pasture production during spring. In contrast, Kuyken

(1969) found that grass yield during winter declined by similar amounts on grazed and ungrazed areas.

In New Zealand, pasture growth is limited by temperature in winter and soil moisture in summer (McKenzie *et al.,* 1999). In the high country, cold temperatures associated with winter result in low winter pasture production and in most cases winter conditions result in dormant pasture growth for 3 to 4 months a year (Matthews *et al.,* 1999). Pasture production in the high country is therefore characterised by late spring/early summer peaks with a smaller autumn flush (McKenzie *et al.*, 1999)

Cold weather conditions tended to reduce the amount of feeding by Canada goose at Lake Grasmere. During winter it was observed that the geese were reluctant to feed on paddocks adjacent to Lake Grasmere and, instead, spent a large proportion of their time roosting on the lake (presumably to conserve energy). Similarly, Davis *et al.* (1989) found that snow goose (*Anser caerulescens*) in the Missouri River valley did not feed on extremely cold days, but remained at the roost site sleeping or loafing.

Cold conditions also influenced habitat selection by Canada goose at Lake Grasmere, with the lake being its main habitat over winter. Gill (1996) found that pink-footed goose (*Anser brachyrhynchus*) field selection was influenced by a trade- off between the cost of travelling to the feeding site, against the benefits of feeding. Cold temperatures in winter increase the costs of travelling to feeding sites because more energy is expended. As a result, it could be that, Canada goose spends long periods roosting on the lake during winter. However, Potts and Andrews (1991) believed that the increase in the use of the lake at Lake Grasmere in winter was due to grass die back as a result of frosting; this reduces pasture quality and so in winter the geese prefer to feed on aquatic vegetation.

The effect of grass quality on pasture consumption

The selection of feeding sites by Canada goose is influenced by pasture quality (Summers, 1990) so, at Lake Grasmere, it seems likely the quality of pasture influences the amount of damage caused by Canada goose. Goose species prefer high protein and carbohydrate food resources and energy reserves (Owen, 1971, Raveling, 1979, Prins *et al.* 1980, McWilliams and Raveling, 1998).

Pasture quality increases with pasture growth (Hik *et al.,* 1991). Early stages of pasture growth have high nitrogen content due to photosynthetic energy being used to produce tillers (Hik *et al.,* 1991). However, when pastures reach senescence, pasture quality decreases with more photosynthetic energy used for seed production (Hik *et al.,* 1991). In America, Canada goose times migration to capitalise on spring flushes in grasslands, effectively utilising vegetation in a highly nutritious and digestible state (Owen and Black, 1990). Due to the high country environment at Lake Grasmere, the period of significant grass growth is from November through to April (McKenzie *et al.,* 1999). High goose numbers (Chapter 4) and peak foraging effect (Chapter 3) coincide with this period, with geese presumably taking advantage of the high quality food resource.

The amount of consumption that occurs to pasture swards is influenced by the plants' responses to herbivory (Maschinski and Whitman, 1989). Plant morphology and phenology, the amount of pasture removed and the length of the period between grazing events all influence the amount of grazing losses (Hik *et al.*

1991). The capacity for regrowth of vegetation following defoliation depends on plant mechanisms, the relative availability of resources such as water, nutrients and light, as well as the growth form of the plant itself (Hik *et al.* 1991).

Pasture consumption by geese at Lake Grasmere increased in autumn. This increase may be due to the inability of grass to compensate against grazing later in the growing season (Bedard and Lapointe, 1991). Colder temperatures in autumn limit the ability of pasture swards to respond to grazing. Constant grazing is known to restrict plant production, while low temperatures and nutrients reduce the ability of pasture swards to respond to grazing (Bedard and LaPointe, 1991). Therefore, high grazing pressure especially in early stages of spring growth may reduce the nutrients available, which then restricts the amount of pasture growth over the subsequent growing season. Therefore, Canada goose grazing at Lake Grasmere is not only removing the standing crop of pasture available to stock but may also be reducing the amount of pasture produced over the growing season.

Implications of goose consumption for farming practices

Kear (1970) suggested that the impacts of goose feeding on New Zealand high country farmland vary widely, from beneficial to detrimental, depending mainly on the time of year they feed. Goose grazing has a direct impact on farming practices because geese are in direct competition with stock for available food resources (Patton and Frame, 1981). This impact is most acute when available food resources are depleted during late winter and early spring. Therefore, the important issue involved in goose grazing on farmland is the effect on food availability and how much grass a goose actually consumes in competition with stock.

Harris *et al.* (1987) in their study of the economic impact of Canada goose believed that goose grazing severely reduced the amount of available pasture used to over-winter stock. The removal of pasture in autumn is made more acute by the lack of grass growth during the winter (Harris *et al.*, 1987). Grass removed in autumn is not replaced and therefore goose grazing impacts are particularly significant to farmers at that time of year.

Autumn-saved pasture is important in the South Island high country areas as it reduces the effects of harsh winters on stocking rates (Harris *et al.*, 1987). This pasture is used to feed overwintering stock and more importantly to provide a high nutrient food source for pregnant ewes in the following spring (Harris *et al.*, 1987). Harris *et al.* (1987) believed that Canada goose grazing in effect 'lengthens the winter' in the high country. The effect of Canada goose grazing is therefore influenced by both the intensity and timing of pasture removal.

Patton and Frame (1981) in their study of Barnacle goose on improved pasture in Scotland indicated that appreciable losses in available pasture resulted in farmers needing to obtain alternative stock feed or reduce the numbers of stock carried. Through a farm modelling analysis Harris *et al.* (1987) estimated that at Lake Grasmere a further 95 sheep could be grazed in the absence of geese. Furthermore, the impact of Canada goose can be more severe when pasture is removed during the period when farmers need it the most.

When comparing the Harris *et al.* estimates of goose consumption with this study similar amounts of damage (kg/dry-matter/ha) were found, except for a notable difference in late summer to autumn (Fig. 5.6). The reasons for these large differences is that Harris *et al.* (1987) used data obtained from Potts and Andrews

(1991), who recorded feeding behaviour and the number of geese feeding on the lake and paddocks between 1984-1986. The numbers of geese on paddocks recorded by Potts and Andrews (1991) were significantly lower than numbers recorded in this study. Estimates of goose damage were based on mean goose numbers on paddocks, and so the low numbers of geese recorded on paddocks by Potts and Andrews (1991) resulted in the low estimate in goose damage by Harris *et al.* (1987).

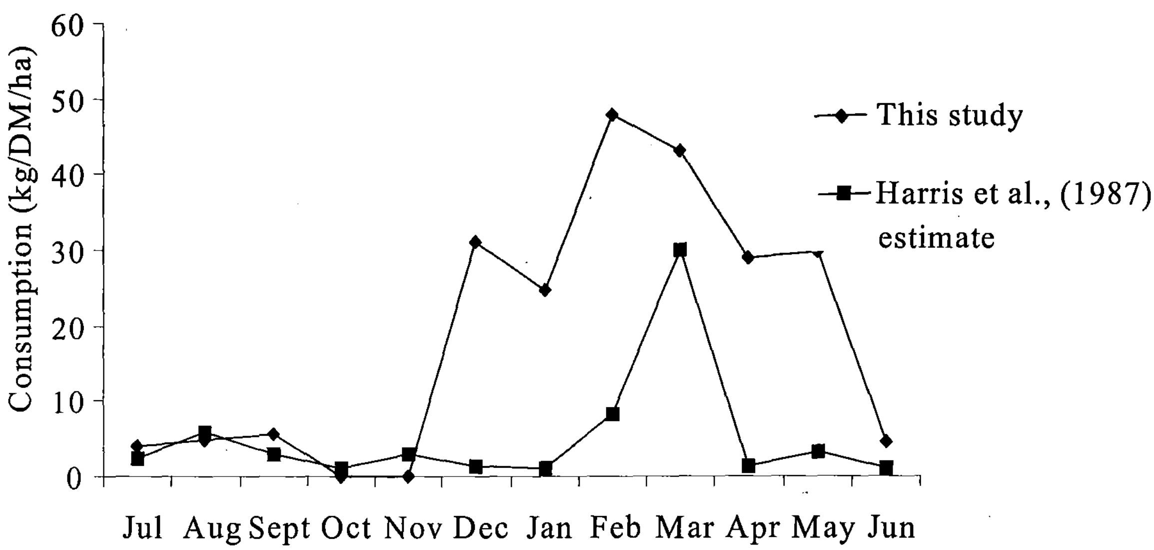

Figure 5.6 Comparisons between the estimate of goose consumption (Harris *et al.*, 1987) and the direct measurement of goose consumption through exclosure plots (this study).

The method of determining goose consumption by Harris *et al.*, however, needs to be addressed. Harris *et al.* determined goose consumption and the amount of goose damage to farmland by multiplying mean number of geese feeding on paddocks by the days of the month. This provided an estimate of goose feeding days, which was then multiplied by White's (1986) estimate of individual goose consumption (0.35 kg/DM/goose/day). A major problem with Harris *et al.*(1987) estimates is the large confidence intervals involved with the mean goose numbers feeding on paddocks. Confidence intervals were regularly greater than the mean.

The use of White's (1986) estimate of individual goose consumption also needs to be questioned. White estimated that Canada goose consumed 6-8 % of its body live-weight based on overseas studies of intake and egestion and energy balance of various geese of different weights. These studies involved a number of different conditions, which are hard to compare with New Zealand conditions. First, each study involved different species, which may not have similar intakes to Canada goose in New Zealand. Associated with this, each study involved species feeding on different food sources. Therefore, the comparison of these studies to the intake of Canada goose in New Zealand based on percentage live body weight may not be reliable in determining the amount of pasture Canada goose consumes per day. This problem is further accentuated because New Zealand environmental conditions are different from continents such as North America and Europe. The winters are milder in New Zealand compared with those of Europe and North America; thus the demand on nutrient intake to maintain energy reserves is reduced.

In New Zealand, Canada goose is predominantly a grazer, feeding mainly on pasture (White, 1986). In contrast, Canada goose in North America supplements its diet in winter by feeding on high energy food resources such as corn and maize (Orr *et al.* 1998). The energy demands of the annual cycle of geese also differ between New Zealand, North America and Eurpoe. Geese are mainly sedentary in New Zealand and do not migrated massive distances unlike geese in North America. However, Canada goose is now overwintering in the high country, therefore energy requirements of these geese are likely to be higher than the figure estimated by White (1986), due to increased energy demands to maintain body temperature.

Management of goose populations could aim to mitigate periods of goose damage by targeting control operations to reduce the goose population before the damage occurs. Goose numbers at Lake Grasmere increased early as they returned from breeding in early December. Numbers peaked at 400 geese in autumn when the amount of pasture removed was greater than 900 kg/ha (Fig. 5.1). Targeting control operations to reduce the Canada goose population in February or March would reduce impacts on farmland but also increase the benefit to managers by effectively managing goose populations.

Changing farming practice could help to minimise the impacts of Canada goose on high country farmland (Owen, 1980). Studies on the impacts of winter grazing by sheep on perennial rye grass (*Lolium perenne*) show that the negative effects on early spring herbage production can be counteracted by use of nitrogen fertilisers (Bruinderink, 1989). Potts and Andrews (1991) mentioned that decreasing the size of paddocks and increasing the number of hedgerows around paddocks is an option farmers can take to reduce the amount of goose damage because smaller paddocks with more hedgerows deter geese from feeding due to the lack of openness. However, smaller paddocks are uneconomical to farmers and often incompatible with modern agriculture (Potts and Andrews, 1991). In any case this study suggests that paddock openness is less influential in field selection and that disturbance, pasture quality and accessibility to paddocks influence where Canada goose feeds (Chapter 4). Damage is, however reduced where geese do not like to feed (such as near roads and buildings; Potts and Andrews, 1991), so the most valuable crops could be grown in these areas.

Consumption by individual geese

Determining the amount of dry matter removed by an individual goose is important in Canada goose management decisions. The direct measurement of goose consumption presented here was based on a localised population, which intensively grazes paddocks surrounding Lake Grasmere. Since the estimate is based on exclosures within these paddocks, the estimated amount of pasture removed by individual geese may be larger than the average pasture consumption by geese in New Zealand. Exclosures were placed in paddocks that had high goose densities and hence high grazing pressure. Therefore these figures need to be used with caution when determining goose damage in highly mobile population such as Canada goose at Lake Ellesmere, which move vast distances to feed.

Implications of using an exclosure study

Conover (1988) stated that the effect of goose grazing on leaf biomass is difficult to assess without using exclosures because an estimate of plant growth in the absence of grazing is required. Exclosures were used in this study because they gave an indication of the expected pasture growth in the absence of geese, which helped to quantify consumption. However, the effects of exclosures on grass growth do need to be considered. Exclosure plots can affect grass growth by reducing light intensity and wind velocity, which affects relative humidity and photosynthesis (Frame, 1981). Differences in the microclimate inside and outside of exclosure plots influences the amount of grass growth.

Frame (1981) found that the effect of exclosures on pasture growth ranged from a 10-15 % increase to an actual decrease in herbage accumulation compared with control areas. The exclusion of animals can stimulate the rate of pasture growth inside an exclosure because defoliation by herbivores and the depressive effect of trampling are removed (Brown and Evans, 1973). However, exclosure can restricted pasture production due to the fact that grass growth is not stimulated by the grazing which increases the production of tillers (Hodgson and Illius, 1996). Pasture production also decreases as pasture swards mature because competition for light increases (Hik *et al.,* 1991). Therefore, the ability of exclosure to determine the impact of the grazing herbivore targeted is restricted. Therefore, it is important to minimise the effect of the exclosure on pasture growth to get a true indication of the impact of grazing on pasture production.

In this study, care was taken to reduce the impact of exclosures on pasture production. Exclosure plots were constructed with wire mesh that had a large hole size (19 mm) to reduce the impacts on light intensity and wind. Exclosure plot trials were undertaken for one month in each area and plots were removed and established in a new area the following month. This approach was based on recommendations by Marsh (1978) who found that short-term exclosure by cages had no significant effect on final yields in each season.

Another problem with the use of exclosure plots is that they may exclude several herbivores, which can make it difficult to identify the impact one specific herbivore (Frame, 1981). At Lake Grasmere a number of other herbivores are present in the area. Paradise shelduck are frequently with Canada goose on paddocks, however, monthly counts showed that their numbers rarely exceeded 50 individuals. It was therefore assumed that paradise ducks may impact pasture production at Lake Grasmere but their damage would be minimal compared with that caused by the large number of Canada goose.

Hares and to a lesser extent rabbits, are present at Lake Grasmere. However, faecal counts of exclosure and control plots suggested that their grazing was minimal (Table 5.1). To mitigate any hare and rabbit impact, exclosure plots and controls were established > 20 metres from field edges, within which most of these small mammalian herbivores concentrate their feeding (Conover, 1988).

5.5 CONCLUSIONS

A consequence of Canada goose at Lake Grasmere is significantly decreased pasture production. The amount of damage to pasture by geese that occurs is influenced by weather conditions and pasture quality.

Goose damage was positively correlated with goose numbers. Since Canada geese spent the majority of their time feeding on paddocks, changes in goose density and distribution influence how much goose damage occurs on farmland. Density, goose behaviour, habitat quality, energy demands and disturbance all affect the distribution of geese and the amount of time they spend on paddocks.

Grazing pressure increases in autumn as the geese utilise the good quality, fast growing pasture to increase body condition for winter (White, 1986). In addition, high goose densities at Lake Grasmere at that time of year increase the impact of grazing by geese.

Cold conditions in the high country reduce the ability of pasture to respond to grazing by Canada goose, especially in autumn (Hik *et al.,* 1991). Canada goose removed up to 900 kg/ha of dry matter per month in autumn. This removal by

Canada goose significantly reduces saved pasture for overwintering stock. The implications of this is that farmers will need to either reduce stocking rates or bring in outside food sources such as silage or hay (Patton and Frame, 1981; Harris *et al.*, 1987).

CHAPTER SIX

GENERAL CONCLUSIONS

6.1 Thesis conclusions

Since its introduction into New Zealand the amount damage Canada goose causes to high country farmland has been widely debated. Before this study, the loss of pasture that it is responsible for had not been directly measured. This study has quantified the amount of goose damage that occurs on one high country farm and has related damage levels to seasonal and diurnal changes in goose feeding behaviour and numbers.

Grazing was the dominant behaviour performed by Canada goose when on paddocks at Lake Grasmere. Although geese tended to graze slightly more intensively in autumn (when they need to put on body condition for winter) and in the morning (when they are presumably hungriest), these effects are minor and not statistically significant. Consequently, grazing pressure on pasture is primarily determined by how many geese are on the paddocks, rather than by any seasonal or diurnal changes in their feeding behaviour while on paddocks.

Canada goose numbers on the study site varied throughout the year, ranging from fewer than 10 in October-November 1999 to peak of over 400 in March 2000. The numbers of geese actually seen feeding on paddocks, which followed a similar seasonal pattern, were generally higher than those reported by Potts and Andrews (1991) from their 1984-1986 observations at Lake Grasmere.

The exclosure trials demonstrated that Canada goose significantly decreased pasture production in months surveyed, on paddocks adjacent to Lake Grasmere. Goose damage ranged from less than 100 kg dry matter/ha/month in late winter to early spring to 900 kg dry matter/ha/month in the late summer and early autumn.

Goose grazing impacts were most evident in late summer and autumn because geese utilise the good quality pasture and fast pasture growth rates to increase their body condition before winter (White, 1986). In addition, high goose densities at Lake Grasmere at this time of year increased the impact of grazing by geese. Grazing was pressure positively correlated with the extent of dry-matter losses over the various seasons.

Pasture growth in the high country is restricted from November to April, with a dormant period common from late autumn to early spring. In autumn, the ability of pasture to compensate for grazing is reduced due to decreases in temperature, available water and nutrients. Goose grazing in autumn therefore removes pasture that cannot be replaced over winter, thus increasing the impact of Canada goose.

The increased number of geese seen in this survey compared with Potts and Andrews (1991) suggests that pasture development in the high country over recent years may have increased the amount of goose damage on high country farmland. The use of improved exotic grassland and fertilisers has provided high quality habitats which geese utilise.

In this study, over 150 geese overwintered at Lake Grasmere, an increase of about 100 since the counts conducted by Potts and Andrews in 1984-86. It seems likely that further improvement of agriculture land in the high country will increase the presence of geese on paddocks, which may further escalate goose damage problems. In the future, goose managers may need to be more active in reducing the impacts of Canada geese in the high country.

6.2 Implications for farmers

Goose grazing has a direct impact on farming practices because geese are in direct competition with stock for available food resources (Harris *et al.,* 1987). This impact is most evident when available food resources are depleted during late winter and early spring (Harris *et al.,* 1987). Therefore, the important issue for management of goose grazing on farmland is their effect on forage availability and how much pasture biomass a goose actually consumes in competition with stock.

In the South Island high country, autumn saved pasture is the predominant technique used to reduce the effects of harsh winters on stocking rates (White, 1986). This pasture is used to feed over-wintering stock and, more importantly, to provide a high-nutrient food source for pregnant ewes in the following spring (Harris *et al.,* 1987). Canada goose significantly reduces the amount of available pasture to over winter stock at Lake Grasmere, so the implication is that the farmer is forced to either reduce the stocking rate or bring in additional feed to support wintering stock.

6.3 Management Implications

The consumption of pasture by Canada goose is a major point of contention for goose management in New Zealand, with increasing debate between farmers and hunters as to whether the problem is a significant one, or not. Surprisingly, the South Island Canada Goose Management Plan (Fish and Game NZ, 1995) was developed without any reference to measurements of the amount of production loss Canada goose causes to farmland. Without a measure of pasture loss to geese, managers have no way to determine whether Canada goose really is a problem to farmers, whether the damage is seasonal, and whether the current management plan is a cost-effective way to control goose numbers.

This study provides managers with a direct measurement of the amount of pasture damage geese caused on one high country farm. It indicates that goose damage there was most severe in late summer and autumn, which is a critical period for farmers who are trying to maintain autumn-saved pasture to over winter stock.

If the primary aim of the goose culling is to reduce goose damage, it is recommend that goose managers cull in late summer (late February to early March) when goose numbers at Lake Grasmere are increasing. A significant reduction in goose numbers at this time should reduce the numbers of geese feeding on paddocks during the season when their impact is most severe.

Fish and Game Councils presently use a single annual trend count to determine annual changes in goose numbers and distributions. This current method is useful for the intended purpose, but it is not suitable determining changes in goose numbers and distribution between seasons. This study showed that goose numbers on the study area varied markedly throughout the year, with numbers peaking at over 400 in autumn. Goose managers need to be monitoring these seasonal changes throughout the high country. By establishing seasonal patterns, goose managers will be better able to predict high goose numbers in management areas, thereby allowing more time to plan for subsequent culls.

Currently, much of Fish and Game's management seems based on human perceptions rather than on scientific research. This is evident in the development of the South Island Canada Goose Management Plan (Fish and Game NZ, 1995), which has no specific objective regarding goose-grazing impacts. Instead it focuses on reducing goose numbers, without requiring managers to investigate whether these reductions are indeed reducing goose damage on farmland.

Management of geese in New Zealand by Fish and Game is problematic because it is an organisation funded totally by revenue gained from the sale of hunting licences. However, it has a statutory requirement to control geese to prevent unacceptable levels of 'damage' to farmland. Therefore, Fish and Game must walk a fine line between trying to fulfil the statutory requirements of goose control, while also maintaining a sufficient hunting resource. Ottmann (2000) found that in the early stages of the South Island Goose Management Plan (Fish and Game NZ, 1995) some hunters believed that Fish and Game were advocating the farmers' interests rather than hunters'. Conflict arises because of an extreme difference in opinion between stakeholder groups (hunter and farmers) and because management action seemed to occur as a result of pressure from farmers rather than any measurement of the severity of the goose problem.

Goose management appears to be initiated when farmers believe that geese are impacting their farm. However, farmers cannot properly estimate the impacts of geese on their farms without information about the amount of pasture that they remove. The information in this study is a first step in measuring the extent to which Canada geese may be causing damage to farmland, which should assist in future management of Canada goose in New Zealand. In particular, measurement of the impact of geese on pasture production should allow managers to begin comparing the costs of their control work with the likely savings to farmers resulting from reduced goose damage.

6.4 Future research

In other parts of the world the impact of goose damage has been widely discussed. However, in New Zealand this study of pasture damage by Canada goose is the first of its kind. More work is needed to determine the impact of Canada goose in other areas, especially in lowland areas such as Lake Ellesmere. Further information on goose migration and the seasonal impacts of geese in other parts of the South Island is needed.

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Finally, I would like to thank my parents who instilled in me the presence of mind to set goals and work hard to achieve them. They may not know quite what I have been doing for the last two and a half years (Mum still tells people 'I think he is STILL doing something to do with geese'), but I still thank them for their love and support throughout this time.

Winna

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	Grazed plots				Exclosure plots							
Month	Grazed1 (mean n=10)	se	Grazed2 (mean n=10)	se	Exclosure 1 (mean n=10)	se	Exclosure 2 (mean n=10)	se	Grazed	se	Exclosure	se
Jul	925	98	1015	76	1075	110	1145	92	970	62.0	1110	71.7
Aug	1051	86	692	65	1002	115	979	55	871.5	53.9	990.5	63.7
Sept	992	125	422	68	1265	114	529	0	707	71.1	897	57.0
Oct	0	0	0	0	0	0	0	0	0	0.0	0	0.0
Nov	0	0	0	0	0	0	0	0	0	0.0	0	0.0
Dec	2215	185	0	0	2412	305	0	0	1107.5	92.5	1206	152.5
Jan	1352	106	2067	185	1956	127	2199	195	1709.5	106.6	2077.5	116.4
Feb	1326	99	403	81	2030	34	1094	220	864.5	64.0	1562	111.3
Mar	1389	100	431	73	2222	156	1180	215	910	61.9	1701	132.8
Apr	1445	112	0	0	1916	106	0	0	722.5	56.0	958	53.0
May	557	93	576	49	874	150	723	99	566.5	52.6	798.5	89.9
Jun	580	116	620	93	737	109	580	105	600	74.3	658.5	75.7

Difference in production (monthly)	se	Difference in production (daily)	se
140	94.79	3.16	3.16
119	83.47	3.97	2.78
190	91.17	6.33	3.04
0	0.00	0.00	0.00
0	0.00	0.00	0.00
197	178.36	6.57	5.95
368	157.81	12.27	5.26
697.5	128.37	23.25	4.28
791	146.53	26.37	4.88
471	77.10	15.70	2.57
232	104.10	7.73	3.47
58.5	58.50	1.95	1.95

Appendix 1: Spreadsheet calculations of daily dry matter consumption (kg/ha) on paddocks adjacent to Lake Grasmere.