Comparison of the behavioural ecology of Greenland White-fronted Geese A*nser albifrons flavirostris* and Canada Geese *Branta canadensis interior* in West Greenland- helping to explain recent population fluctuations in a species of conservation concern.

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1. Abstract

The global numbers of Greenland White-fronted Geese (GWfG), *Anser albifrons flavirostris,* are in decline. This is concurrent with increasing numbers of Canada Geese, *Branta canadensis interior,* occupying the same breeding areas as the GWfG in West Greenland throughout the summer months. Behaviour and habitat use of both species of goose on their breeding grounds during their flightless moult period was investigated in 2010. In general, Canada Geese showed greater alertness throughout the day, with more time spent with their heads held extremely high (a distinct alert position) and more time spent on the water (where, due to being flightless, they are safest in terms of reducing predator attacks). Whether or not these alert positions are linked to peaks in predator activity is unclear.

Both species exploited habitat nearer to the lake shore more than at increasing distances from the water's edge, but GWfG generally grazed further away from the lake edge than the Canada Geese.

It is apparent that GWfG suffer from being in smaller groups, due to lack of group alertness whilst feeding, but are unable to benefit from the increased numbers attained by living in a mixed-species flock with the Canada geese due to conflicts and aggression between the two which results in GWfG being suppressed on every occasion. The negative impacts of being in smaller, GWfG-only, groups may be a main factor in the reduction of the GWfG breeding success. The lower breeding success results in steadily smaller populations, which in turn accentuate these negative small group effects.

2. Introduction

The Greenland White-fronted Goose (GWfG), *Anser albifrons flavirostris,* is a rare sub-species of goose distinguished in 1947 from the European White-fronted Goose, *Anser albifrons albifrons,* by Christopher Dalgety and Peter Scott (Dalgety & Scott 1947; Fox *et al.* 1981). The GWfG is a grey goose, darker than other species of White-front, with adults having a large white patch on the front of the head around the beak, bold black bars across their underside and orange bills and legs. Their diet in winter typically consists of grass, clover, grain, winter wheat and potatoes (Fox & Stroud, 2002)

GWfG winter in Ireland and Western Scotland (October to March). During these winter periods, the geese live on peatlands and farmland, where they spend time attaining body condition in preparation for their long migration north for the summer months. The geese leave their wintering grounds in late March/ early April, depending on the weather. Staging areas in Iceland break up the 3000km journey, where the geese can recover their condition before reaching the breeding grounds in Greenland in early May (Glahder, 1999).

Once arrived in Greenland, there is a pre-nesting period of approximately 10 days when it is believed that the female maximises her nutrient intake in preparation for clutch initiation and sustaining herself through incubation which lasts 25-27 days (Fox, 2003) whilst the gander is predominantly alert for predators (Fox & Madsen 1981). The geese move to nesting sites, and throughout the incubation period the pair must be jointly alert to the high predation risk to their eggs from Ravens, *Corvus corax,* and Arctic Fox, *Alopex lagopus,* (Fowles 1981) the two main predators of nests and eggs. Once hatched in mid-late June, the young move with their parents to wetland feeding sites, towards the relative safety of the lakes. In this post-breeding stage, both the breeding and non breeding members of the population moult their flight feathers in order to replace their plumage for the up-coming migration south. This moult leads to a flightless period, which lasts 3-4 weeks (Belman 1981) reducing methods of predator escape and limiting feeding opportunities, with the sedge, *Carex rariflora,* becoming the dominant constituent of their diet (Madsen & Fox 1981). With this increased vulnerability to predators, alertness of the geese increases (more so in breeding pairs with young than in non-breeding individuals) and refuge is sought on the lakes. Once flight feathers have re-grown and body condition has been built up, the geese begin their return migration to Iceland in September, and then onwards to the UK for the winter in October.

Declines in the global numbers of GWfG from the 1950s to the 1970s, where the estimated population size fell to between 14,300 and 16,600, and dramatic changes in the demography of wintering geese populations in the UK and Scotland highlighted a cause for concern for the future of the Greenland White-fronts.). The Greenland White-fronted Goose Study (GWGS) was established in 1978 as an independent organisation, dedicating efforts towards the study and conservation of Greenland White-fronted Geese (http[1]). A law passed in the early 80's banning the hunting of GWfG on their wintering grounds saw numbers double between then and 1999 to over 35,600 (Fox *et al* 2006), but since this peak, a steady decline in numbers has occurred, with the current population now consisting of about 23,000 geese (Fox & Francis, 2010).

Studies are now looking at the effects of inter-specific competition pressures put upon the GWfG by Canada Geese, *Branta Canadensis interior,* in the summer period in Greenland and how this may be affecting their population numbers.

Canada Geese, which traditionally breed in sub-arctic Canada have now expanded their range to the GWfG breeding ranges in parts of Western Greenland (e.g. Bennike, 1990; Frimer & Nielsen, 1990; Boertmann, 1994; Fox *et al.,* 1996) (Appendix 6). Prior to 1980, Canada Geese were rarely seen summering in West Greenland, but since then a rapid increase in their numbers has been observed, concurrent to the declining numbers of GWfG. A post moult aerial survey was carried out in 2007 by Fox and Glahder (2007), with 1888 sightings of GWfG and 6071 sightings of Canada Geese. These numbers, applied to the current known population number of GWfG, suggests that the current number of Canada Geese post moult in West Greenland is more than 41,500 (Fox & Glahder, 2007). The decrease in GWfG population size has been shown to be due to a reduction in the numbers of geese breeding successfully (as opposed to changes in the mean brood size or adult survival rate (Trinder, *et al* 2005)), possibly a direct effect of the Canada Geese presence.

The race of Canada Geese which have moved into the GWfG breeding area (*Branta canadensis interior* – Fox *et al.* 1996) is a larger, heavier goose than the GWfG (Palmer, 1976). Observations of inter-specific encounters between the Canada Geese and GWfG showed Canada Geese being dominant to the GWfG each time (Jarrett, 1999), which supports an observation made by Schoener (1983) that smaller species are generally out-competed by larger species. This direct competition generally results in the GWfG securing lower quality food, and less suitable breeding space.

As well as the annual census for GWfG, ringing expeditions have been organised by the GWGS, where the birds were captured and marked with leg rings and neck collars in order to keep track of individuals and monitor their movements. Here, in conjunction with the GWGS, we continued census and behaviour studies in the Isunngua region of West Greenland on both the GWfG and Canada Geese in the summer of 2010, and repeated parts of the study carried out by Kristiansen & Jarrett in 1998-99 (Kristiansen & Jarrett, 2002). We observed behaviour and habitat use between the GWfG and Canada Geese and explored how this might link to the rapid decline of GWfG numbers.

3. Methods

The field work for this study was carried out between 7th July and 31st July 2010, in the Isunngua area of West Greenland, (67°05'N, 50°30'W) north of Kangerlussuaq (Jarrett, 1998). Much of the methodology here follows that of Kristiansen & Jarrett, 2002.

3.1 Census

The census data was collected within a ~30km² area and ground was covered on foot throughout the field study duration. The aim of the census was to record every goose which was seen within the area, and to record their species (Canada Goose or GWfG), along with as much additional data which could be obtained such as sex, age (Juvenile/adult), abdominal profile (below), lakes seen on, whether breeding or non breeding, whether collared or not, and the codes on any present collars.

Fig.1. A collared Canada Goose, next to a GWfG, caught on the 2008 expedition to Isunngua. Photo by R. Stroud.

The abdominal profile of the geese is used as a measure of their condition, and is compared against a scale of 0-4. (Appendix 7)

Each lake which in the study area was approached with great care. The geese are very aware of human presence and would be disturbed and flushed onto different lakes if they became aware of an observer (Greenland White-fronted Goose Study, 2009), so a concealed viewpoint often up to 2 km away would be used to carry out counts from. Natural cover such as boulders and ridges atop hills were used to conceal the observers in the landscape.

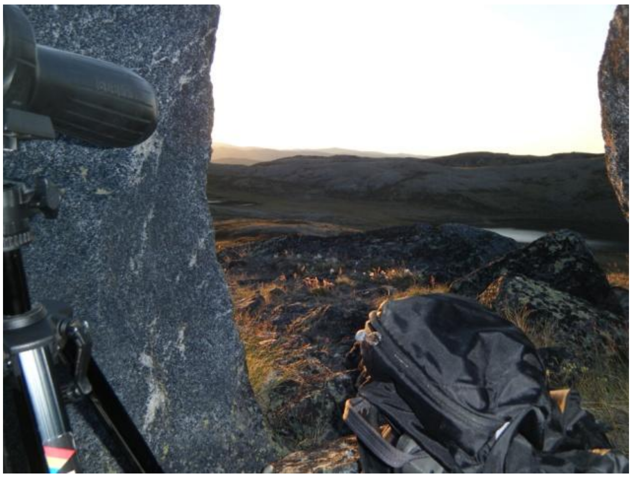


Fig. 2.1. Concealed viewpoint of Lake M/N amongst boulders

Fig. 2.2. Topography of the landscape.

Binoculars of 10x – 40x magnification and telescopes of 25x – 45x magnification were used to view the geese and gather the required data.

3.2 Lake Forms

During the census process, forms to record the physical attributes of each lake were filled out (Appendix 8). On each expedition these forms have been completed for the lakes visited, creating a large catalogue of information. It was our aim to fill in the gaps and retrieve data from lakes which had not yet been recorded.

3.3 Behaviour Study

A preliminary behaviour study was carried out in the UK at Barnwell Country Park on a group Canada Geese. The four team members tested the data collection techniques here and made some adjustments to the behaviour ethogram before heading out to Greenland. (Appendix 1-2)

The official behaviour studies in Greenland began on 10/07/2010. Lakes to use were identified on the first few census days. Lakes were chosen with present geese and suitably concealed observation points from which to view the geese from. Lakes R, M/N (grouped together as one lake), V, S, U and Y (Appendix 4) were the observation lakes, all of which were allopatric for Canada Geese, apart from lake S which as allopatric for GWfG. Ideally a sympatric site would have been observed, but one was not found, and another GWfG allopatric site would also have been used, but again, no more were found. This is in contrast to previous year's studies, where multiple GWfG allopatric and at least one sympatric site have always been located.

The most concealed viewing site for each lake was identified to reduce the chance of observer presence being noticed by the geese. Telescopes (25x – 45x magnification) and binoculars (10x – 40x magnification) were used when required, and at 5 minute intervals, the instantaneous behaviour of each goose was recorded using the prepared ethogram. The behaviours were split into activities (such as walking, swimming, standing) and posture (such as head up, up end, head on back), and where possible, breeders (male or female), non breeders and juveniles were recorded separately. A scan sampling technique was used, so the numbers of geese carrying out each activity and each posture was recorded (Appendix 1-2). The distance of juveniles to their parents was noted (in goose lengths) as was the distance of groups from the shore.

Throughout the duration of time spent in the field, all Raven and Arctic Fox calls and sightings were recorded. The time and area which they were seen/heard were noted for each incident.

3.4 Habitat Use Transects

Transects of 18 m length placed every 3 m were laid out around lakes T, S and R, and variables recorded at 3 m intervals along each:

The number of droppings were counted in a 4 m^2 area around the 3 m mark along the transect. This area was measured by placing a peg in the ground with a 113 cm string attached which was walked around taut. This 113 cm radius gives a circle with an area of 4 m^2. The numbers of new and old droppings (old droppings identified as 'dry' = pre 2011) within this area were recorded, along with number of roost piles and how many droppings were within each roost pile.

Vegetation height was measured using card which was balanced on top of the vegetation with which a ruler could be slotted through to the ground and the card-ruler intercept was recorded (cm). Whilst looking at the vegetation, a note was made as to whether it had been grazed or not. The only other herbivores in the area which graze are

Caribou, *Rangifer tarandus groenlandicus,* and Musk Ox, *Ovibos moschatus wardi*, neither of which feed near lakes, so wouldn't have an impact on these findings.

The gradient of the ground was estimated at each point.

An index related to the suitability of the area for grazing geese was estimated on a scale of 0-5 (0=unsuitable, 5=very suitable), taking into account the present vegetation/ground type on which the point fell, e.g. *Carex rariflora* coverage=5, *Betula nana* and rock=0.

Transects 100 m long were also laid out at four points (N, E, S and W aspects) around each of these lakes and the same information was gathered at 5 m intervals along these transects.

4 Results

4.1 Lake Use

Goose presence in 2011 was noted for each lake which has been recorded since 1988, along with which species occupied each lake. The percentage change in the composition of geese on the recorded lakes over the years (1988-2010) is plotted on Fig. 3.

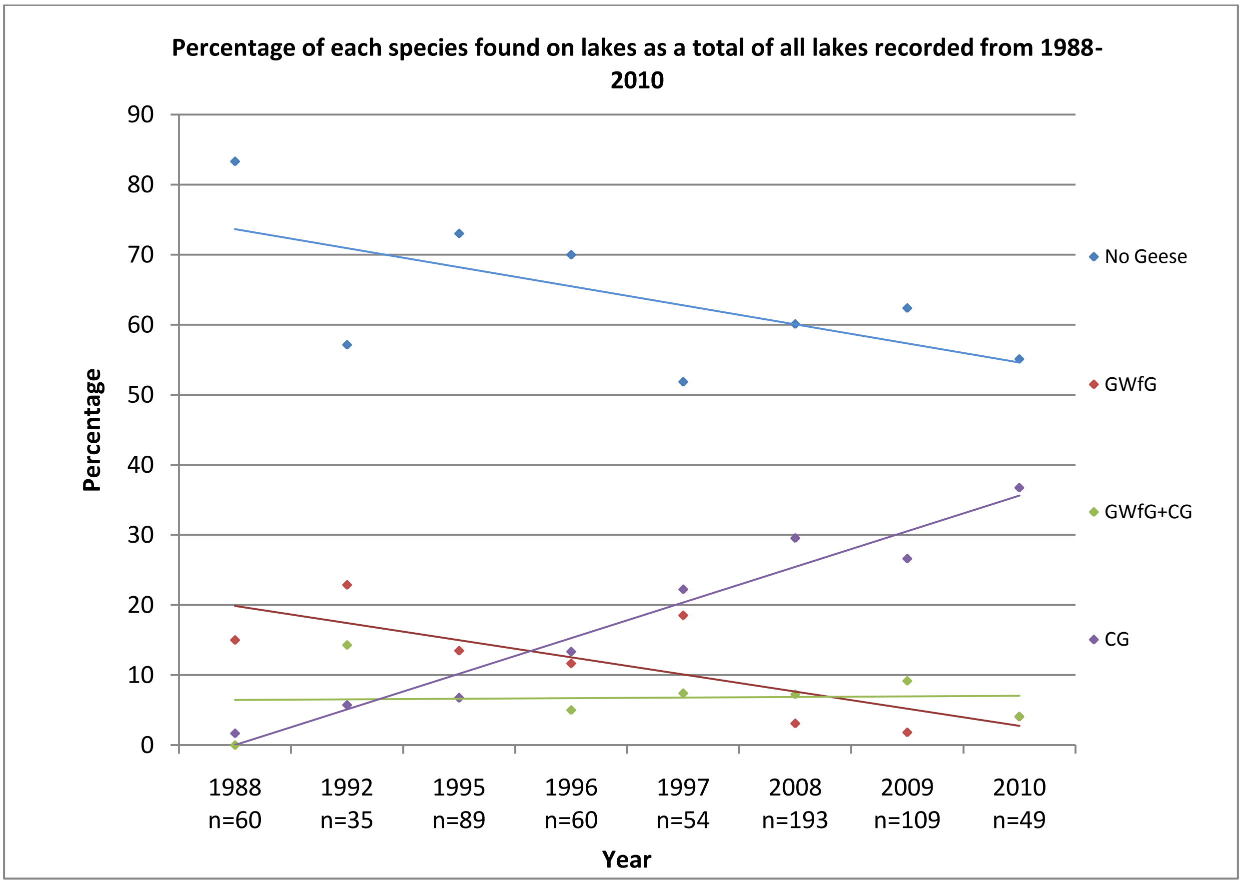


Fig. 3. The proportions of lakes holding GWfG, Canada Geese, both species, and with no geese present on the lakes each year as a percentage of the total lakes visited in that year.

Until recent years, relatively few zero counts were recorded which could have an effect on the trend for goose absent lakes here, and data from 1989 and 1998 has been omitted as it is not comprehensive enough to give accurate comparisons.

The lakes used for the behaviour study were lakes: R, M, N, V, S, U and Y. The composition of geese on these lakes over the period 1988-2011 is noted below.

Lake R: In 1992 only GWfG were present on this lake, observations in 1996 and 1997 also show the allopatric presence of GWfG. The next two observations, in 1998 and 2008 show sympatric use of the lake, with both GWfG and Canada Geese occupying the area. By 2009 and 2010 the lake was used allopatrically by Canada Geese.

Lake M: In 1988, GWfG were in allopatric occupancy. In 1995, 1996 and 1998 both GWfG and Canada Geese were using the lake, and by 2009 and 2010 the observations show that only Canada Geese occupied.

Lake N: This lake was observed since 1988, but the first time geese were seen using it was in 1997, these were Canada Geese in allopatry, a trend which continued throughout 2008, 2009 and 2010.

Lake V: In 2008 and 2009 GWfG and Canada Geese were present in sympatry, in 2010 only Canada Geese were present.

Lake S: All recorded observations (from 2008-2010) show allopatric use of the lake by GWfG.

Lake U: In 2008 and 2009, both GWfG and Canada Geese used the lake, in 2010 only Canada Geese were present.

Lake Y: In 1997, only GWfG present, in 2008, 2009, 2010 only Canada Geese present.

4.2 Behaviour Study

4.2.1 Time Budgets

For the duration of the behaviour study, the amount of time (in 5 minute intervals) that the geese spent displaying each of the behaviours was recorded. The mean time spent by GWfG breeders and Canada Goose breeders (Fig. 4) on each behaviour is plotted below.

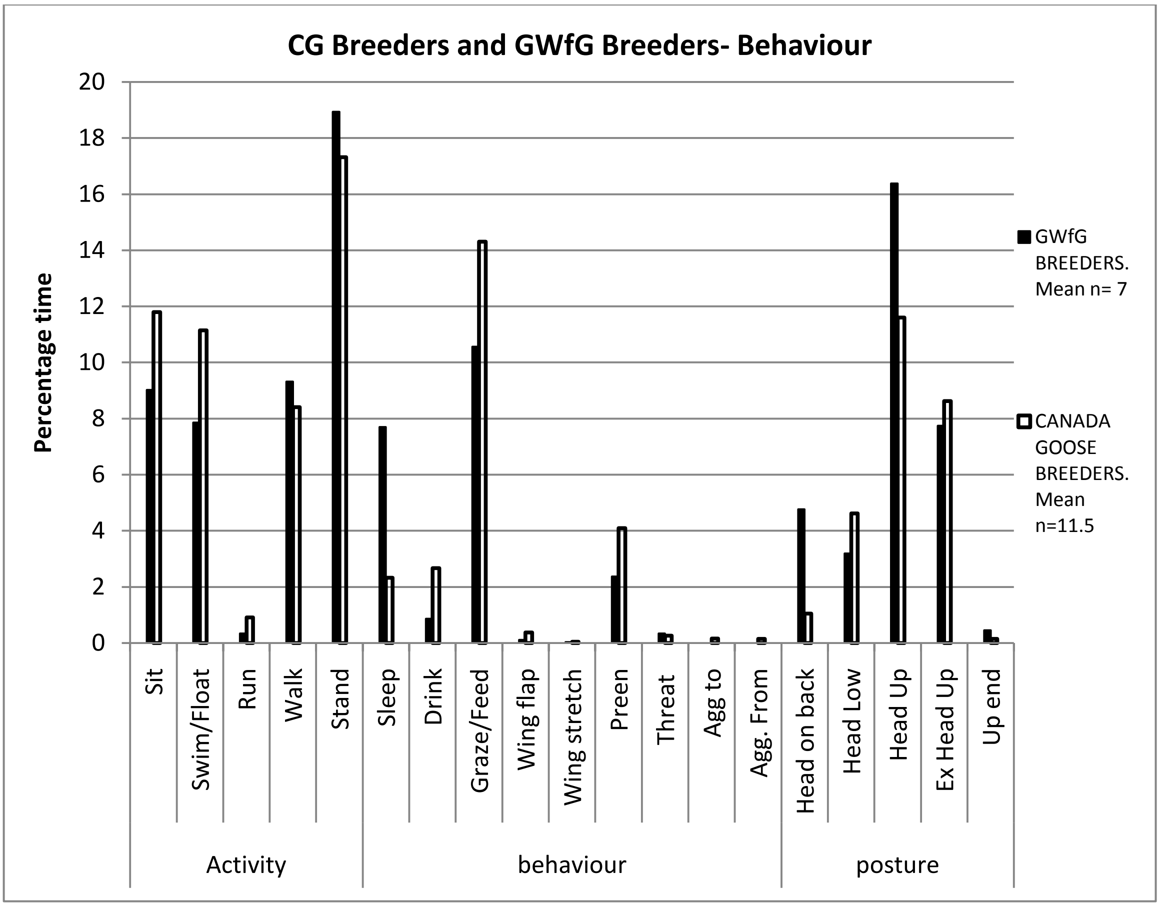


Fig. 4. Mean time as a percentage of the total observation period spent by the GWfG breeders and Canada Goose breeders displaying each of the behaviours throughout 24 hour periods.

4.2.2 Predator Response

The behaviour of each group of geese was recorded when potential predators were seen or heard. Figures 5.1 - 5.3 below show breeders and non-breeders of each species, and the behaviours observed for each group as a mean of the percentage of the total geese observed when there was a predator presence.

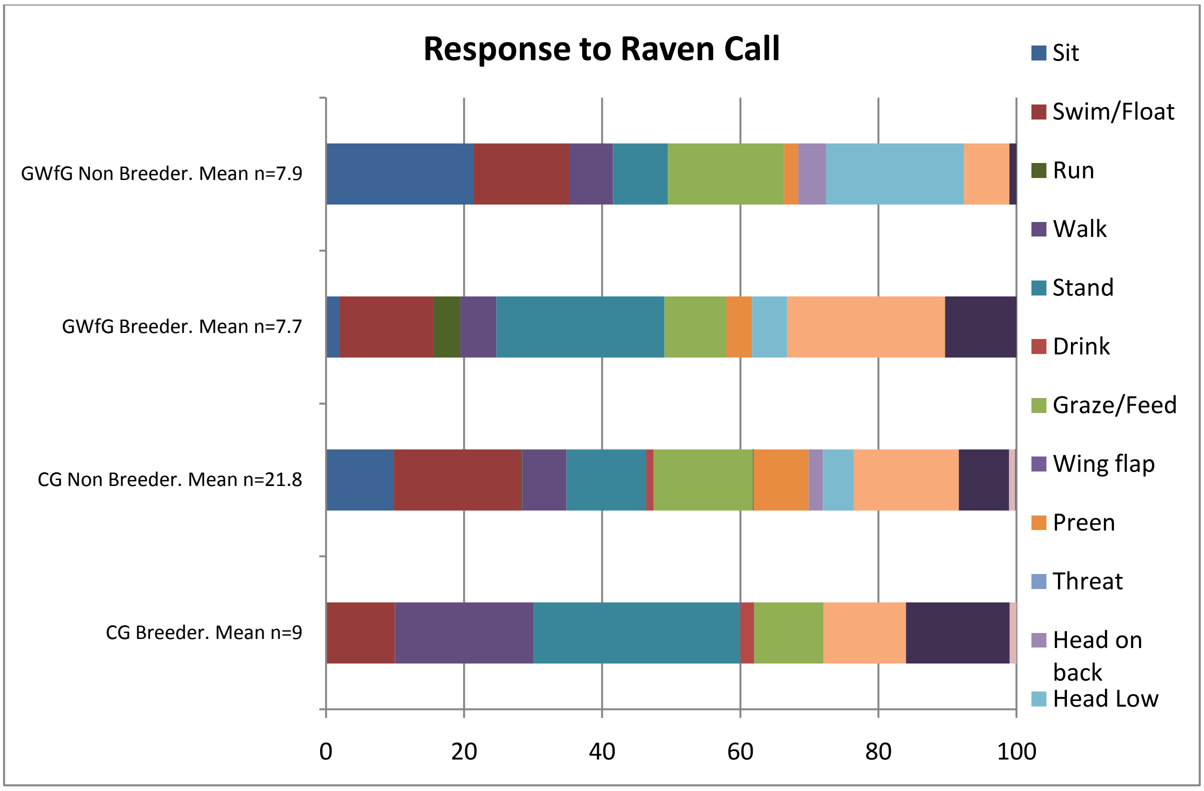


Fig. 5.1. The percentage of geese (CG breeders, CG non breeders, GWfG breeders and GWfG non breeders) displaying each behaviour as a total of each time a Raven was heard calling.

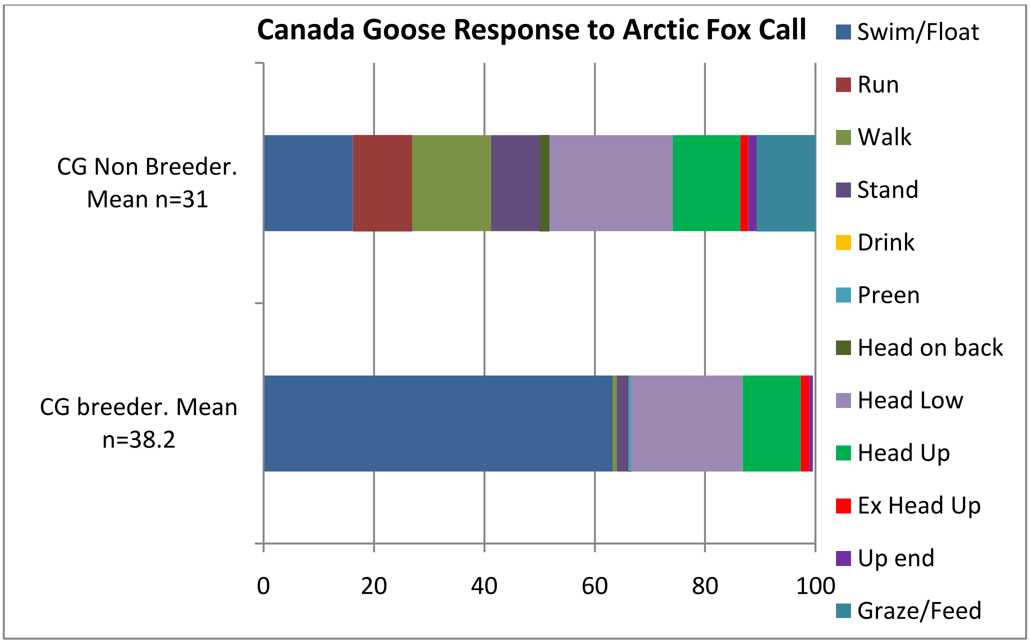


Fig. 5.2. The percentage of CG breeders and CG non breeders displaying each behaviour when Arctic Fox calls were heard.

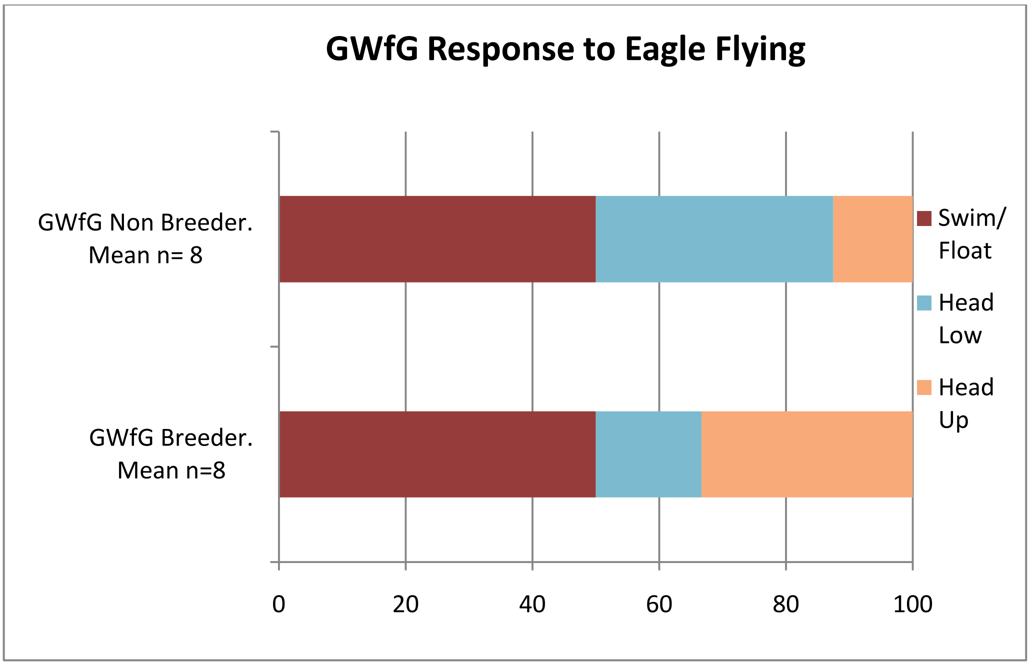


Fig. 5.3. The percentage of GWfG breeders and GWfG non breeders displaying each behaviour when eagles were seen flying overhead.

4.2.3 Alertness Index

An alertness index was calculated for the Canada geese on lake M/N and for the GWfG on lake S. (Only lake M/N was used for the Canada geese to help keep the difference between the total numbers of geese observed for each species small) The index was calculated for every hour for a 24 hour period on each of the lakes. The result gives a single arbitrary value for each species on the hour, this arbitrary value provides a sound representation of group alertness (higher value = higher alertness). The alertness index was calculated as follows:

The amount of geese from each lake in position 'head on back'(HB), 'up end'(UE), 'head low'(HL), 'head up'(HU) and 'extreme head up'(EHU) on the hour was divided by the sum of these numbers. Each position was given a value, HB and UE=1, HL=2, HU=3 and EHU=4, with higher numbers corresponding to higher levels of alertness. This head position/sum scan value was then multiplied by the corresponding value for each position. The sum of the resulting values for each time is the alertness index for that time.

Due to times when the geese were out of sight, some of the alertness index=0. These time slots were deleted, as it would imply extremely low alertness in the interpretation of the results, instead of out of sight.

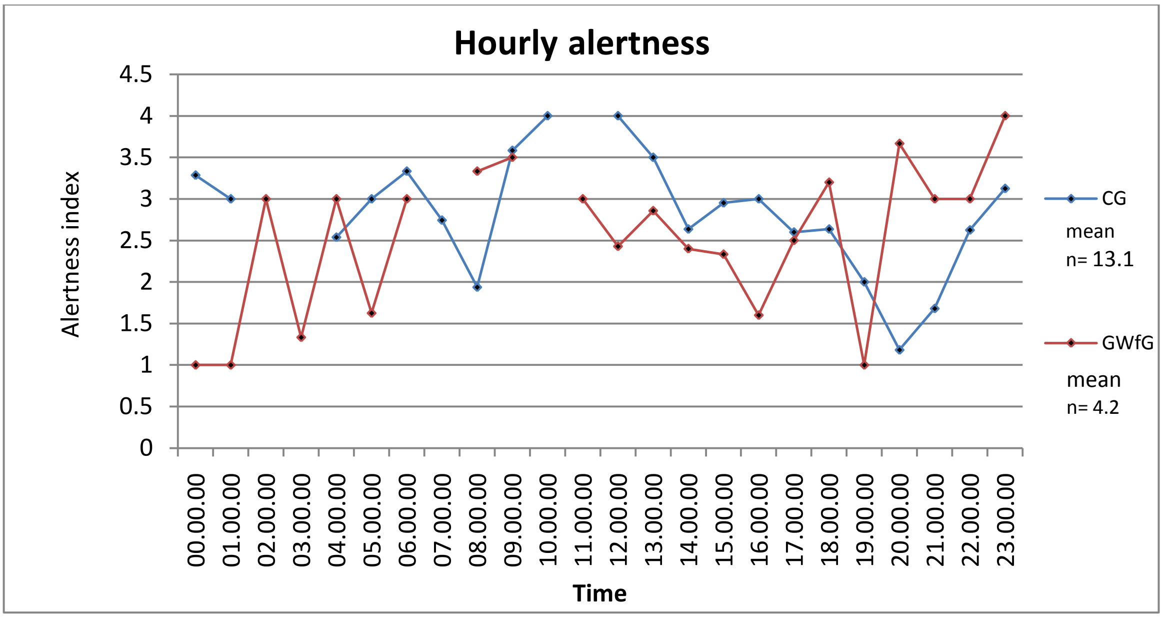


Fig. 6. Hourly alertness of all Canada geese and GWfG throughout one 24 hour period, on lakes M/N and S respectively, using the calculated alertness index. Gaps are present where values of 0 were omitted. The group sizes here varied around the mean; from 48 down to 1 for the Canada geese, and between 8 and 1 for the GWfG.

Using the data sets from both lakes, a test was run, using minitab software, to ensure that there was equal variance between the two. Once this was confirmed, the data was split at noon to produce separate am and pm data. A split here relates to a change of predator intensity (see fig. 7. Below) A two sample t-test was run between the am Canada geese and GWfG, and the pm Canada geese and GWfG. A two sample t-test was then carried out on Canada goose am and pm, and GWfG am and pm (Table 1). The resulting P-values from these tests show whether there is a significant difference between the data sets. P=<0.05 indicates a significant difference, and P=>0.05 indicates that there is no significant difference between the data sets.

Table 1.The resulting p-values from the t-tests. Green indicates significance, red indicates no significance.

	CG am	GWfG am	GWfG pm
CG am		P=0.032	
CG pm	P=0.015		P=0.473
GWfG pm		P=0.444	

A p-value =<0.05 shows that there is a significant difference between CG and GWfG in the am data, and P-value =>0.05 shows there is no significant difference between CG and GWfG for the pm data.

A significant difference is shown between Canada geese in the am data sets and pm data sets, whereas there was no significant difference between am and pm for overall GWfG alertness.

Each time a Raven *Corvus corax* or Arctic Fox *Alopex lagopus* was heard calling or seen, a note was made of the time and the area. Fig. 7 shows the distribution of the audible and visual presence of these predators throughout the day.

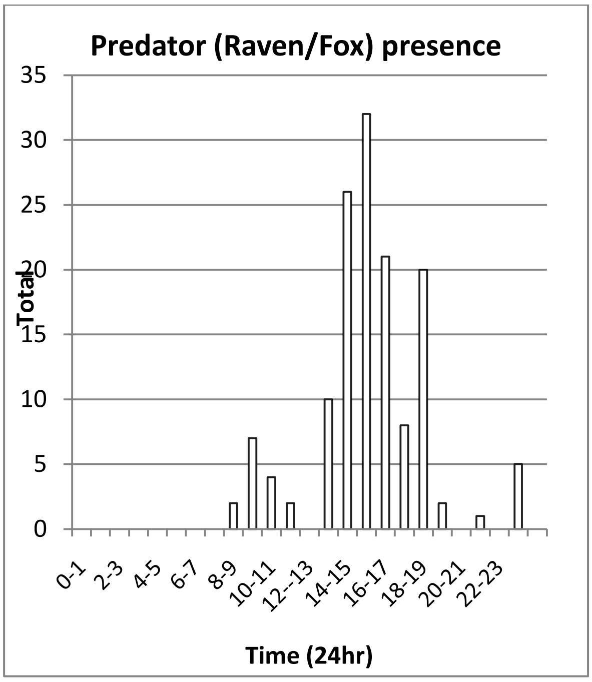


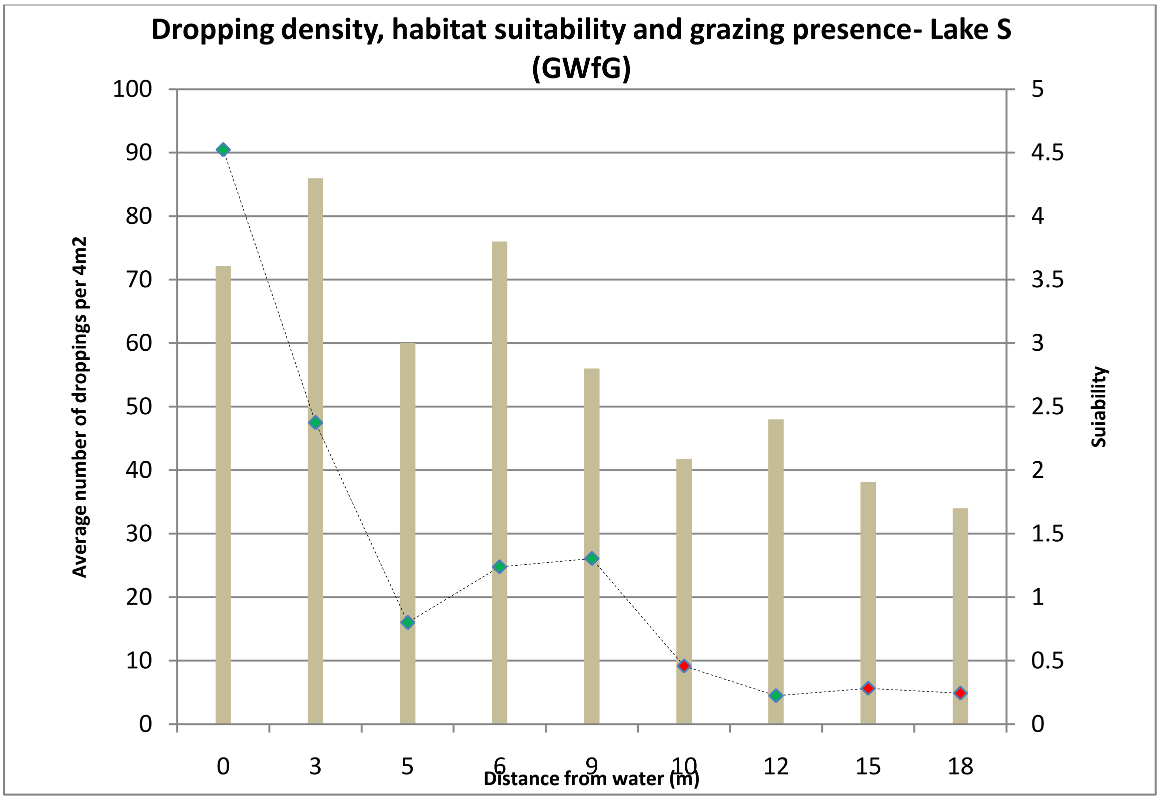
Fig. 7. Diurnal pattern of Arctic Fox and Raven calls and sightings within the study area. All observations were recorded.

4.3 Habitat Use

The habitat use transects for Lake T (inhabited by Canada Geese) and Lake S (inhabited by GWfG) have been analysed here to serve as comparison for habitat exploitation between the two species. The distribution of droppings in relation to their distance from the lake edge, and the presence of grazing, are being used as an indicators as to how much the geese utilise areas in relation to their distance from the lake.

Fig. 8 shows the average dropping densities at distance intervals from the water edge on each of the lakes, whether grazing was present at each distance and the average habitat suitability scores. A roost pile has been given the same weighting here as a single dropping, as it is the exploitation of the habitat areas that we are looking at and a roosting bird is an individual exploitation event. A score of 1 is given to grazed areas and 0 given to un-grazed areas. A median of all the same distance points from each transect is then applied to indicate whether each distance was generally grazed or not on the lake as a whole.

A significant difference is shown between the distribution of droppings on each lake ($P=<0.001$) when a chi-square test is applied.



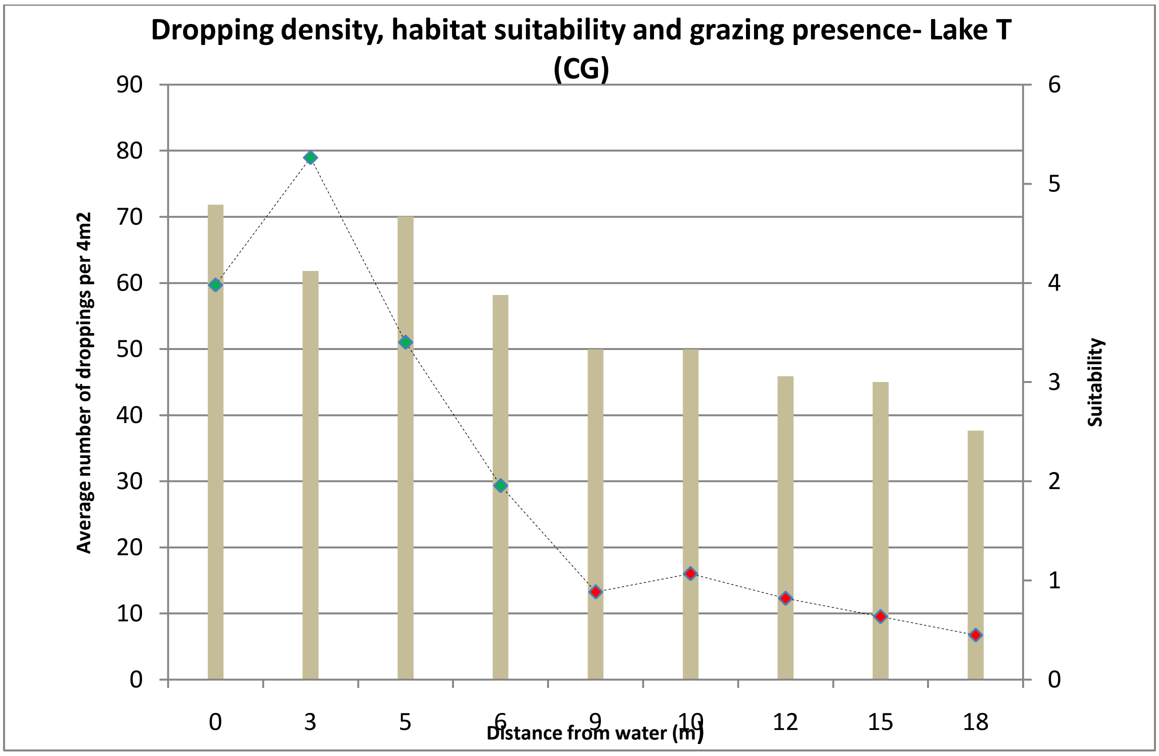


Fig. 8. Number of droppings (when roost piles=1) at each distance along the transects as an average of the total transects per lake. Green points indicate grazed areas, and red points indicate non grazed areas. The bars show the average suitability of the habitat (in terms of vegetation) at each distance from lake edge on a scale of 0 (not suitable) – 5 (very suitable). Lake S is allopatric for GWfG (23 transects measured) and Lake T is allopatric for Canada geese (33 transects measured).

The overall trend is for the use of habitat to decline with increasing distance from lake edge on both of the studied lakes, but with Canada geese on Lake T exploiting the habitat at 3 m more than at 0 m. This is surprising, considering that not only is it 'safer' for the geese closer to the water, but also that on the habitat suitability scale, the suitability average is slightly lower at 3 m than it is for both 0 m and 5 m (0 m=4.79, 3 m=4.12, 5 m=4.67).

5. Discussion

5.1 Lake Use

A notable increase in the percentage of Canada Geese on lakes observed in the Isunngua area has occurred between 1988 and 2010 alongside an opposite trend in GWfG numbers (Fig. 3.). The significant change in species composition is widely believed to be a result of recent colonisation of Canada Geese and subsequent inter-specific competition (Fox *et al.* 2006). Under some circumstances, there is evidence to suggest that GWfG may benefit from feeding in mixed species flocks when their feeding behaviour was studied in association with Greylag Geese, *Anser anser,* in Iceland (Kristiansen *et al.*1998). During that study, when Greylags were present, the GWfG spent significantly less time alert, due to the Greylag's increased vigilance, which allowed GWfG to increase the time they spent feeding. No inter-specific aggression was recorded during feeding. This information suggests that the GWfG are positively density dependant, when feeding rates are positively related to group density (Mills, 2007). However, when observed in sympatric situations with Canada Geese in West Greenland, all inter-specific interactions resulted in the GWfG being suppressed by the dominant Canada Geese, and lower quality food was consumed by the GWfG when in sympatry (Kristiansen & Jarrett 2002). This incompatibility of the two species may encourage the GWfG to separate off into smaller discrete feeding flocks, and occupy lakes allopatrically. When feeding allopatrically, allee effects (negative results of density dependence) can become apparent for the GWfG resulting in reduced feeding efficiency, due to reduced density. Cessation or reduction of GWfG feeding can occur due to heightened alertness (Jarrett, 1999), and additional reduction of feeding success can arise due to the potential of lower quality food being available. However, Successful pre-breeding feeding is essential to maximise reproductive output of breeding geese (Fox & Ridgill, 1985). The reduction in breeding success, which is main factor in the decline of GWfG numbers (Trinder *et al.* 2005; Fox *et al.* 2006) due to these negative interactions with the Canada Geese, could be having a consequential effect on the following years breeding success. Examples in another race of White-fronted Geese have shown beneficial effects in terms of nest defence and pre-breeding feeding alertness, contributed from the young of the previous year's brood (Fox, 2003). If this were the case for the GWfG, one year with low reproductive output could have a compounding negative effect on subsequent year's reproductive successes due to this lack of juvenile assisted vigilance and feeding density dependence.

Due to the number of suitable lakes seen during the census which were unoccupied by geese, it can be assumed that the carrying capacity of the area is not a limiting factor in the successful breeding of a sustainable population of GWfG.

5.2 Behaviour Study

Various factors will influence the behaviour of individual geese. Whether the focal bird is male/female, breeder/non breeder will affect the observed behaviour. Increased vigilance and decreased feeding is usually displayed by breeding males over that of breeding females (Batt *et al.*1992), and non breeding waterfowl have been shown to feed more, but be alert less, than breeding birds (Lessells, 1985). Presence of chicks, and their age, will also have an influence. Young chicks will demand an increase in vigilance from parents, whereas older chicks can contribute to group alertness (Fox, 2003) as a result of increased group size, lowering individual vigilance. The time of day, related to light, temperature and predator activity, can affect the behaviour adopted, although parenting duties can overshadow diurnal behavioural rhythms, as shown by Giroux *et al.* (1986).

5.2.1 Time budgets

Fig. 4. indicates that Canada Goose breeders spent more time on the water than the GWfG breeders. The lake is the safest place for the flightless geese when threatened by predators during this moulting period (Fox, 2003). The Canada Geese also spent far less time sleeping than the GWfG, and spent more time in the 'Extreme head up' position, this aside, they still managed to spend more time grazing, drinking and preening than the GWfG.

The increased alertness of the Canada Geese in both body position and time spent on lakes could be an indication that they are more sensitive to predator presence. This heightened vigilance and sensitivity can allow on-shore feeding to occur when there is less risk to themselves and to their goslings. This combination could result in lower predation and therefore higher survival rate than that shown for the GWfG who do not appear as vigilant.

More time spent grazing by the Canada Geese could have a close link to this security they create for themselves, allowing maximum food input in a safe environment. Not only do the geese need to maximise their intake of nutrients prior to breeding and incubation (Fox, 2003), but they must maintain high nutrient intake throughout the moult period. Increased feeding time means that the Canada Geese are likely to more easily gain adequate nutrition to re-grow their flight feathers during a time when nutritional stress is common, and attain better body condition for the return part of their migratory journey (Fox *et al.* 1998). If the GWfG are not capable of spending as much time feeding as the Canada Geese, their new flight feathers and accumulated fat reserves may not be sufficient for their migration at the end of the summer, a potential cause for a reduction in numbers arriving at the wintering grounds. In contrast, Kristiansen & Jarrett (2002) found that allopatric GWfG spent more time grazing than allopatric Canada Geese, and also found that sympatric GWfG spent significantly more time grazing than sympatric Canada Geese, a condition which we were unable to test as a result of not finding a sympatric lake.

5.2.2 Predator response

The inability to fly during the post breeding moulting period limits the methods of predator escape for geese (Belman, 1981). Pronounced differences in the percentages of geese from each group which were sitting when Ravens called are shown in Fig. 5.1. Sitting, here, is being interpreted as a fairly relaxed behaviour. The breeders were sitting less than the non-breeders when Ravens called, with the Canada Geese of each group sitting least. The same pattern between the 4 groups is shown for the amount of time spent with 'extreme head up', a posture indicating very high alertness (given the highest arbitrary value of 4 for the alertness index). It is to be expected that the non-breeders would show lower alertness when Ravens were heard calling, as Ravens predate on eggs and newly hatched young, not adult birds (Fox, 2003) so the presence of a Raven poses little or no threat to them. Although behaviour is likely to change at different stages in the breeding cycle, the lower alertness/reaction to Raven presence shown by the GWfG breeders could be a reflection of poorer nest defence during their incubation period and again be a link to their lower reproductive success.

The Canada Goose response to Arctic Fox calls (Fig. 5.2.) show that the breeders spend a much greater amount of time swimming than the non-breeders. Arctic Foxes are possibly the most important predator to geese (Fowels, 1981), they attack nests for their eggs and goslings but are unlikely to attack an adult goose due to the risk of physical attack on the Fox itself (Fox, 2003). The observations are therefore in keeping with the expected results, that breeders are either more aware of Fox presence, or respond more cautiously when an encounter may occur. However, the non-breeders do show a degree of alertness when Fox calls are apparent, in that the 'run' category is fairly well represented, a category which is absent amongst the breeders during Fox calls. Running by the non breeders could be an alertness response to the predator and it would be expected that they are running towards the safety of the lake. The fact that the breeders aren't running is probably because the majority are already in their safest position on the lake. Whether the breeders responded faster than the non-breeders and made their way to the lake before their behaviour was recorded by the observers (either due to being closer to the shore to begin with, or that they detected the presence of a Fox before the non-breeders did) or that they have taken precautionary measures to be already present on the lakes during the peaks in predator activity, is uncertain.

Both GWfG breeders and non breeders responded to an eagle sighting by moving onto the water, with the majority of breeders adopting the more alert 'head up' position whilst the majority of non-breeders remained 'head low'. This reduced alertness of non-breeders has been observed in past studies (Fox & Ridgill, 1985).

An Arctic Fox attack was witnessed on a group of Canada Geese during a census day. The adult geese formed an outward facing circle with the goslings in the middle, and moved systematically towards the lake, with the adults warning off the Fox that was making repetitive lunges at the group. Only as they reached the lake edge and the goose formation broke momentarily was the Fox able to penetrate the circle and successfully take a gosling. This strategic form of predator defence shows great dependence on high numbers of adults being present. Similar group defence by GWfG against an Arctic Fox was observed in 1979 by Fowels (1981), where the geese moved aggressively towards an attacking Fox to warn it off. It was concluded that this behaviour was an extreme defensive reaction and was only conducted as a last resort when safety of water was too far away to retreat. This is in agreement with the observed Canada Goose defence here.

5.2.3 Alertness

Fig. 6. shows that the range of alertness shown by GWfG is larger than that of the Canada Geese, who show a more diurnal pattern than hourly fluctuations. Canada Goose alertness peaks during the middle of the day, whereas the GWfG show most of their higher alertness in the late evening.

Fig. 7. indicates that the activity of Raven and Arctic Fox peaks in the afternoon to early evening, between 13.00 and 19.00. Stroud (1982) observed a strong positive correlation between high predator activity and GWfG alertness in 1979, when predator activity peaked at midday. In 1984, Fox & Stroud (1988) observed the same relationship; however, the peak of Arctic Fox activity had shifted to dawn and dusk, and subsequently, so had the alertness of the GWfG. Here, we would expect to observe increased vigilance from the geese during this afternoon/evening period as a response to the increased predator activity. In contrast to Fox & Stroud (1988), both species of goose appear to be on the whole reducing their alertness during this time period according to the calculated alertness index, with the Canada Geese generally maintaining a higher alertness than the GWfG throughout the period. This lower alertness of the GWfG could be a factor resulting in their lower breeding success and

survival rate, contributing to their overall decline in numbers.

The peak of Arctic Fox and Raven activity seems to have shifted again now from that shown in 1984, but it is apparent that the goose alertness hasn't followed suit. This could be due to a fairly recent shift in the diurnal rhythms of the predators and a lag is occurring before the goose rhythms will synchronise. Another possibility is that here, the Fox activity is grouped with Raven activity, which hasn't been done in the past studies (e.g. Fox & Stroud 1988), so a difference between the two could throw the true peaks for each off a little. A third point to note is that the predator activity data is probably affected by observer bias. As the recording of predators was not a focal activity and was done on the side of the census/behaviour studies, less recording effort would have occurred through the night during less sociable hours due to the observers being more 'active' during the daytime. Due to this, these results may be used lightly as a guide, and should not be relied on with too much weight, perhaps a study should to be carried out during the next breeding season which focuses on this, so that equal effort is put into recording predators and goose alertness.

The large differences in group size could also be a factor affecting the levels of vigilance able to be conducted within the group, as shown by Madsen (1981).

Before midday, a significant difference is shown between the alertness of Canada Geese and GWfG. This is the time of day when predator activity is at its lowest, so the more consistent high alertness of Canada Geese could be linked with an overall heightened alertness of Canada Geese, whereas the GWfG may only become alert when predators actually present themselves.

However, a more significant difference is shown in Canada Geese between am and pm, with pm vigilance (when predator activity peaks) being lower than am vigilance. This phenomenon is harder to explain. Again, the potential for observer bias in the predator activity data could be a key factor here, as could observer presence, having an effect during behaviour observations. Perhaps sun position or other conditions drew the attention of the geese towards the observer hides more so in the morning than the afternoon/evening, accounting for this increased alertness.

5.3 Habitat Use

There is a declining trend in the dropping density on both the GWfG occupied lake, S, and the Canada Goose occupied lake, T, as distance from the shore increases. High dropping density at a point suggests that the area is highly exploited by the geese, either for grazing or roosting. These results, showing that both species prefer to spend time at closer distances to the lake edge, support the findings of Kristiansen and Jarrett (2002) who found a significant declining habitat use from the shore, using dropping density as an indicator.

On the GWfG lake, the highest dropping density was at a distance of 0 m (on the lake shore). This correlates with a decline in habitat suitability as the distance from the shore increases, except that the highest suitability score on Lake S was given at 3 m. On the Canada Goose lake, the highest dropping density is at 3 m although, again, higher habitat suitability scores are given at either side of this point. This slight discrepancy between peak dropping density distance and peak habitat suitability on both lakes could be explained due to feeding occurring at further distances (in the more suitable habitat) and movement of geese closer to the shore where they are safer in between feeding bouts.

Generally the Canada Geese didn't graze further than 6 m from the lake edge, whereas the GWfG are shown to regularly graze up to 12 m from the shore. This conforms to the results found by Kristiansen & Jarrett (2002), who also observed GWfG exploiting habitats further from the shore on allopatric sites than Canada Geese on allopatric sites. Kristiansen & Jarrett observed that this trend was reversed on sites sympatric for both geese. On the sympatric sites the Canada Geese exploited habitat further from the shore, and the GWfG were forced to consume mosses of lower nutrient quality (apparent through faecal analysis) which were abundant nearer the lake edge. This inconsistency between the allopatric and sympatric site data could be a result of interference competition (Kotrschal *et al.* 1993) from one species to another due to a limiting food resource. One species (GWfG) can be encouraged to utilise an area which the other (Canada Goose) is reluctant to use, to avoid competition (Madsen & Mortensen, 1987).

6. Conclusions

Much of the data shown suggests that the GWfG are dependent on high densities. The reasons for this may be to (1) maximise the available feeding time, due to reduced individual vigilance, (2) maximise potential feeding habitat, due to an increased group vigilance (3) increase awareness of predators by having overall higher group alertness, or (4) reduce successful predator attacks by displaying group defence (directly observed here in Canada Geese, but this behaviour has potential to be generic amongst other goose species). In association with other species of goose (excluding Canada Geese), the GWfG appear to benefit from the higher numbers attained from existing sympatrically, mainly due to increased group vigilance, but in the majority of observed situations with Canada Geese, the GWfG do not benefit from the increased numbers, and are instead pushed towards low quality feeding, and possibly less suitable breeding sites (although no conclusive evidence has been shown to support this theory).

The smaller group numbers caused by GWfG living in allopatric conditions, appear to have resulted in reduced individual alertness as a pay-off for continuation of sufficient feeding. This can increase the risk of predator attack, and potentially lower breeding success. Declines in the numbers of GWfG will accentuate the mentioned allee effects, which could cause a continuous decline in breeding success per annum.

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