A STUDY OF THE IMPACT OF HUMAN DISTURBANCE ON WIGEON *ANAS PENELOPE* AND BRENT GEESE *BRANTA BERNICLA HROTA* ON AN IRISH SEA LOCH

Réamann. G. Mathers,[1,2] Sally Watson,[3] Richard Stone,[2] and William I. Montgomery[2]

[1,2]11 Fairhead Road, Lisnacalligh, Carey, Ballycastle, Co. Antrim, Northern Ireland.
[2]School of Biology and Biochemistry, Queen's University of Belfast, The Medical Biology Centre, 97 Lisburn Road, Belfast. Northern Ireland.
[3]Department of Biometrics, Agriculture and Food Science Centre, Newforge Lane, Belfast BT9 5PX, Northern Ireland.

Numbers of over-wintering Wigeon on Strangford Loch have declined from a maximum of 20,000 in the 1970s to less than 2,000 in the 1990s, whereas Pale-bellied Brent Geese, which occupy similar habitats, have not suffered a similar decline. Human activity has increased around the Loch in recent decades and this may have contributed to the decline of Wigeon which are considered to be less tolerant to disturbance than Brent. This study assessed the types of human activity on Strangford Loch and their likely differential effects on Brent and Wigeon. Results confirmed that Brent are more tolerant of human activity than Wigeon. Wigeon reacted at greater distances from human activity than Brent, were more likely to fly greater distances and less likely to return to their former activity at this site. Human disturbance affected birds significantly because they were usually disturbed while feeding which is limited temporally by tidal patterns. The most common form of human activity was people walking. Based upon observed levels of disturbance and their effects upon food intake rates, a simple energy balance model correctly predicted presence/absence of Wigeon, but not Brent in four study areas of suitable habitat quality. It is concluded that disturbance could have contributed to the decline of Wigeon in Strangford Loch, although it is probably not the only factor involved. Future management of refuges must therefore take into account food supply and human access.

Key Words: disturbance, Brent Geese, Wigeon, *Zostera*

Disturbance by human activity has been shown to have a marked effect on the spatial and temporal distribution of non-breeding wildfowl, effectively reducing the carrying capacity of many sites (Korschgen *et al.* 1985; Tamisier & Pradel 1992; Gill *et al.* 1997). Disturbance may modify the feeding and roosting habits of wildfowl and place additional energetic stress on birds through increased locomotion costs and lost feeding opportunities, potentially reducing fitness and survival, particularly if it occurs during periods when they are already stressed by other factors, such as poor weather or food shortage (Madsen 1995; Riddington *et al.* 1996; Gill *et al.* 1997). The response to human disturbance by wildfowl differs between species, between sites and with type of human activity, with some species able to habituate to some forms of disturbance while others are more sensitive, being less able to adapt than others (Tuite *et al.* 1984; Keller 1989; Ward 1990; Ward & Andrews 1993; Madsen 1998 a). Setting aside limited sanctuary areas kept free of human disturbance, may increase the carrying capacity of the whole site for wildfowl (Batten 1977; Ward 1990; Hirons & Thomas 1993; Madsen 1993; Madsen 1998 b).

Strangford Loch, north eastern Ireland is increasingly becoming a focus for recreational activities which are likely to affect site-use by over-wintering birds (Brown 1990). Two herbivorous wildfowl species that over-winter at Strangford Loch are Pale-bellied Brent Geese *Branta bernicla hrota* and Wigeon *Anas penelope*. Herbivorous waterfowl feeding in the intertidal zone are especially susceptible to disturbance because of (i) the relatively low nutritional quality of the food and (ii) the restricted access to their feeding resource depends on the tide. Both factors limit their ability to compensate for lost feeding time (Mathers & Montgomery 1996; 1997). Numbers of Wigeon, the main quarry species on the Loch, have declined from winter peaks of around 20,000 in the 1970s to less than 2,000 in the 1990s, and this decline has been most pronounced at the northern end of the Loch where the main food is intertidal *Zostera* spp. (Portig *et al.* 1994; Mathers *et al.* 1998). Numbers of Pale-bellied Brent which are not shot, reach peaks of 9,000 to 15,000 in autumn over 70% of what is considered a geographically discrete population which almost exclusively winters in Ireland (O'Briain & Healy 1991).

Wigeon are considered more sensitive to human activities than Brent (Williams & Forbes 1980; Mayhew 1988). Fox *et al.*. (1994a) and Mathers *et al.* (1998) suggested that recreational disturbance may have been a factor in the decline in the north of Strangford Loch Wigeon population (Brown 1990). The aim of the present study was to test the hypothesis that Wigeon and Brent in Strangford Loch differ in their reactions to human activity. Furthermore, given different observed levels of disturbance in different parts of the Loch a simple energetic model was used to predict whether Wigeon could maintain their energy budgets in these areas and hence predict their presence or absence. The results are discussed in relation to the decline of Wigeon and the maintenance of numbers of Brent, and the future management of wildfowl refuges or 'Core Wildlife Areas' (CWAs) currently operating in at Strangford Loch.

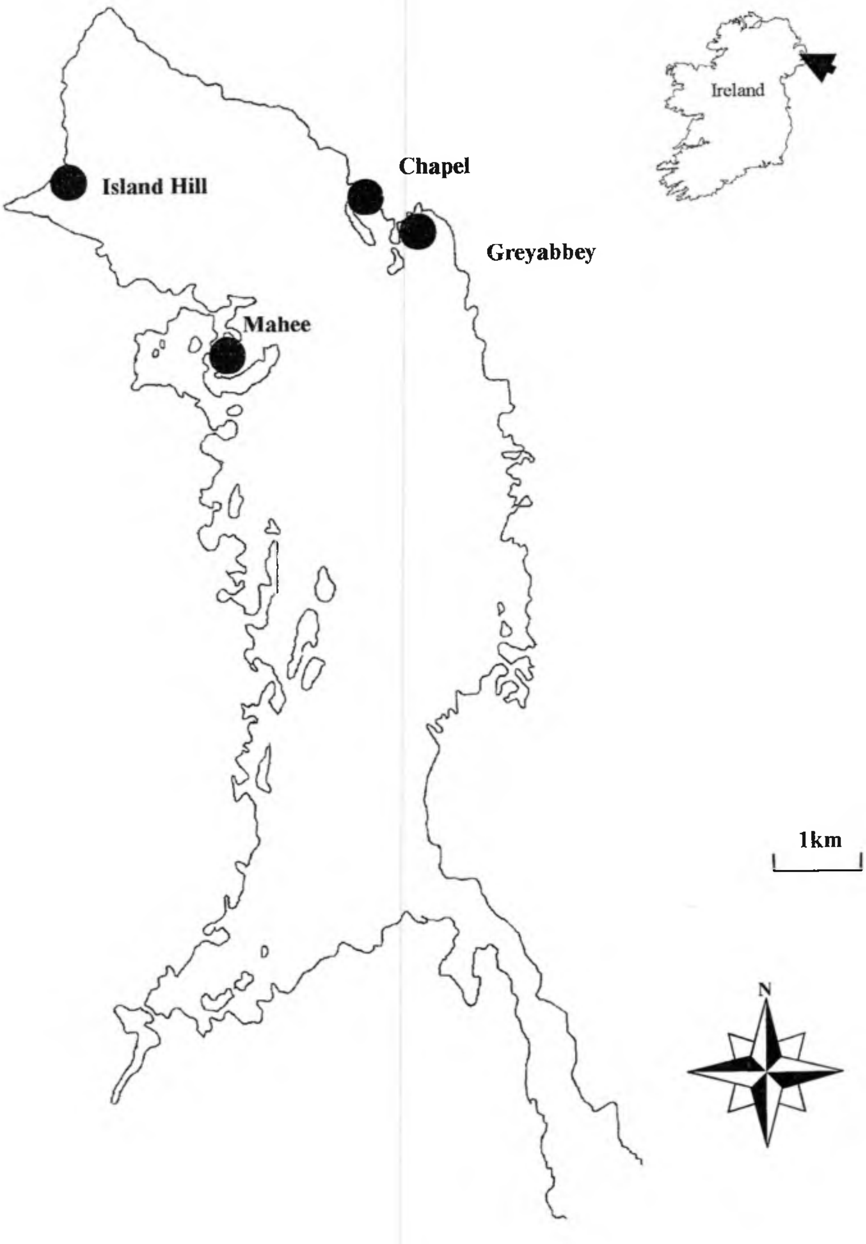

Figure 1. Location of Strangford Loch within Ireland and the location of four areas where observations of human activity were measured in relation to site use by Brent and Wigeon.

Methods

Survey of human activity and effects on Brent and Wigeon

A standard form was designed to record opportunistically human activity around Strangford Loch, Northern Ireland and its impact on the behaviour of Brent and Wigeon. Data were recorded using standardised categories on tidal state, source of human activity, distance from birds, bird species and number, behaviour of the birds before disturbance, their reaction to human activity, and the time elapsing before the birds resumed their original behaviour. This form was distributed during 1991/92-1993/94 to monthly bird counters, wardens, bird watchers and wildfowlers and was used whenever and wherever any human activity was observed in the proximity of Brent or Wigeon. Low numbers of returns in the first and second years in comparison to the third, made it difficult to make comparisons between years so all data were pooled for analysis. Data were analysed using GLIM after the methods of Montgomery *et al.* (1997) carried out on numbers of reaction categories broken down by species, wildfowl activity before disturbance, height on foreshore, reaction, source of disturbance, distance to disturbance, size of flock, if birds resumed previous activity and time for birds to resume. Results are presented as accumulated analysis of deviance where deviance ratios approximate to χ^2 and degrees of freedom are those lost in removing each factor in successive models (only significant factors are presented) (Genstat 5 Committee 1993).

Disturbance levels at different sites in Strangford Loch

A further survey involved an assessment of the frequency and duration of human activity on four sites in northern Strangford Loch (**Figure 1**) Chapel, Mahee, Greyabbey and Island Hill). All sites contained *Zostera* spp., which is the traditional intertidal food of Brent and Wigeon in the Loch (Portig *et al.* 1994; Mathers & Montgomery 1996).

Model of sites suitability

Based on results of this study and other literature a simple energetic model was developed to assess the site suitability of these specific areas around the Loch. This was used to predict the likelihood of each of the four sites holding Wigeon and Brent Geese tested against actual observations. Given that the daily existence energy (DEE) of a bird is related to its mass based on the equation DEE = 647 x mass$^{.74}$ in kJ per day^{-1} (Boudewijn 1984), then using a mean weight of 0.7kgs for Wigeon (Drent 1978) and 1.4kgs for Brent (Cramp & Simmons, 1986) they require 496kJ and 829kJ per day respectively to fulfil their DEE. If we take the net energy (the energy the birds actually extract from the food) of Wigeon and Brent feeding on *Zostera* spp. on the Danish Wadden Sea as a template for energy intake, then these species consume 592kJs and 986kJs per day repectively (Madsen, 1988). Based on observed feeding times of Brent and Wigeon on Strangford Loch, the net energy intake is 1.23kjs and 1.17kJs per minute based on 480 and 840 minutes of observed feeding time per day respectively (Mathers & Montgomery, 1996). Thus, Wigeon must have at least 403 minutes to feed everyday in order to meet their DEE while Brent require 708 minutes.

Table 1. The percentage of Brent Geese (n=196) and Wigeon (n=101) engaged in a range of activities in the vacinity of human activity taken from all records 1991/92 to 1993/94.

Height up Foreshore	Brent Geese	Wigeon
High	10.2	12.9
Mid	43.6	43.6
Low	46.2	43.6
Activity of wildfowl		
Feeding	91.4	82.2
Non feeding	8.5	17.8
Size of Flock		
<100	42.6	63.4
100+	57.4	36.6

Most human disturbance only occurs during daylight hours and both Brent and Wigeon continue to feed at night (R. Mathers pers. obs.). As there are two tidal cycles within every 24 hour period only one tidal cycle of 240 and 420 feeding minutes for Brent and Wigeon respectively is likely to be affected by human disturbance. Why temporal feeding opportunities for both species are different is related to the topography of the foreshore, geographical position of the *Zostera* beds in mid to upper foreshore, coupled with differences in the feeding behaviour and physical dimensions of the two species (Mathers & Montgomery, 1996).

Based on the frequency and duration of disturbance a *crude site suitability threshold* (CSST) was calculated such that CSST =1 which is the threshold t which a bird is> its maintainence energy requirements:

CSST = Total daily feeding time - (Total daily feeding time/2) / Interval between disturbances x (duration of disturbance incident + time taken to resume)+1/2 total daily feeding time / Daily existence energy.

Results

Survey of human activity and effects on Brent and Wigeon

A total of 196 discrete disturbance events involving Brent and 101 incidents involving Wigeon, were available for analysis from the three years. Walkers were the most common source of human activity accounting for 63% and 68.5% of all human activities which affected Brent and Wigeon respectively. The remaining sources of disturbance comprised highly mobile activities, including horse-riders and wind-surfers. Most records (75.4%) of human activity causing a reaction were within 250m of Brent, while 65% of cases were

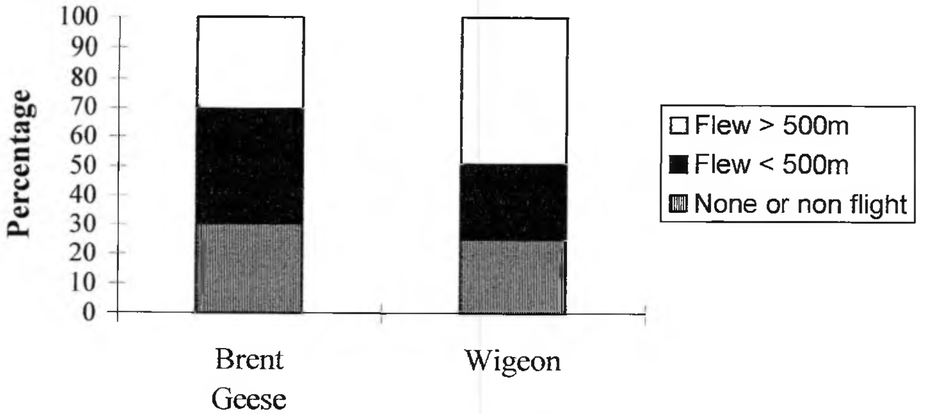

Figure 2. The percentage of Brent Geese (n=196) and Wigeon (n=101) in each reaction type in all records from 1991/1992 and 1993/94.

Table 2. The percentage of reaction distances in relation to two categories of flock size and three categories of human activity for Brent Geese (n=196) and Wigeon (n=101), 1991/92 to 1993/94.

Brent	Flock Size	Distance	People	Mobile
	0-100	0-100	17.86	2.55
		100-250	12.25	4.59
		>250	3.57	2.04
	100+	0-100	9.18	3.06
		100-250	16.33	9.18
		>250	9.69	9.69
Wigeon	**Flock Size**	**Distance**	**People**	**Mobile**
	0-100	0-100	16.83	1.98
		100-250	18.81	4.95
		>250	12.87	7.92
	100+	0-100	7.92	0
		100-250	12.87	1.98
		>250	3.96	9.90

within 250m of Wigeon. Most human activity was recorded when birds were feeding on the low to mid foreshore (**Table 1**).

There was a difference in the reaction of Brent and Wigeon to human activity, with Brent significantly less likely to fly >500m compared to Wigeon (**Figure 2; Table 2**). Brent were significantly more likely to resume their previous activity (86.3%) when compared to Wigeon (62.9%) (**Table 3**). Overall birds which reacted most strongly were less likely to resume feeding or their previous activity and, of those that did resume, birds which reacted most strongly took longer to do so (**Table 3**). The species difference was marked with 68.8% of Brent most likely to resume feeding or their previous behaviour within five minutes compared to 42.8% of Wigeon (**Figure 3; Table 3**). Reaction of wildfowl to different sources of activity varied significantly with distance (**Table 2 and 3**). Walkers had a greater than expected effect at distances <250m, while highly mobile activities had a greater than expected effect at >250m. Brent were less likely to react at distances >250m when compared to Wigeon (**Table 2 and 3**).

Flock size had a significant effect on reaction with larger flocks more likely to react at longer distances from human activity than smaller flocks (**Table 2 and 3**). There was a significant difference in the tolerance of wildfowl to different types of human activity, with birds more likely to react at distances >250m to highly mobile activity (horse-riders etc.) and between 100m and 250m when disturbance was by walkers (**Table 2 and 3**).

Disturbance levels at different sites

Frequency and duration of human activity varied between the four sites surveyed (**Figure 4**). The mean interval between human activity varied from seven minutes 44 seconds to 68 minutes, while the mean duration of the activity event varied between five minutes 23 seconds to 13 minutes eight seconds (**Figure 4**).

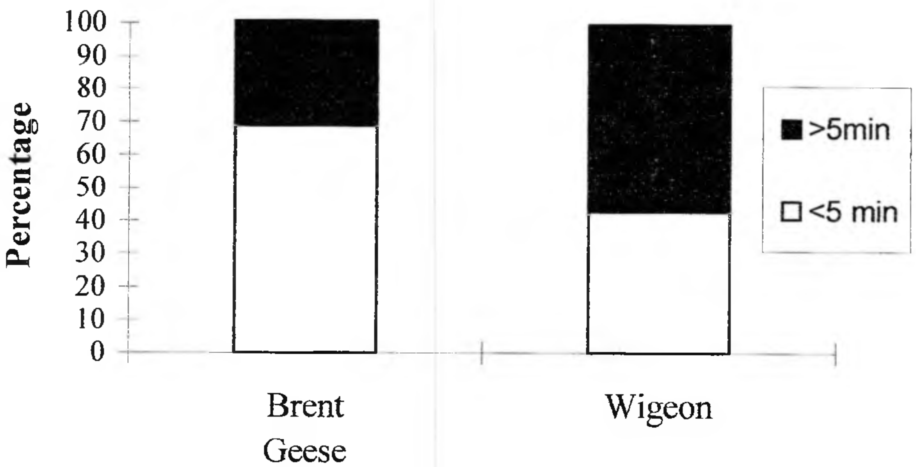

Figure 3. Time taken by Brent Geese (n=148) and Wigeon (n=52) disturbed by human activity, to resume feeding or their previous activity, in all records from 1991/92 to 1993/94.

Table 3. Data analysed by regarding the counts in various tables of interest as poisson response variables and modelling then using a log-linear model (Genstat 5 Committee 1993). This involved fitting a saturated model involving explanatory factors and one or more response factors and seeking to discard, in a hierarchical manner starting with the highest order interactions, terms involving the response factor(s) and any interactions with the explanatory factors. (Only significant factors are presented.) The mean residual deviances that are markedly different from unity indicate over dispersion in that the model is not sufficient resulting in the data being variable for poisson distribution, e.g. that 'species x reaction x source of human activity' was significant indicates that a complex process was in effect and a simpler model could not be fitted.

Effect	d.f.	Deviance ratio and significance	Mean residual deviance	d.f. deviance	Table factors
Activity of wildfowl before human activity x height up the foreshore	2	11.97**	3.07	4	Species (2) x animal activity (2) x location position up shore (3).
Species x reaction	2	6.04**	1.91	4	Species (2) x reaction type (3)
Reaction x resumed previous activity	2	36.78***	9.59	4	Species (2) x reaction type (3) x resumed (2)
Species x resumed previous activity	1	11.43***	4.34	3	Species (2) x reaction type (3) x resumed (3)
Distance x source of human activity	2	22.26***	3.48	10	Species (2) x size of flock x distance from source of activity (2)
Species x reaction x source of human activity	4	11.37*	11.37	4	Species (2) x reaction (3) x source (3)
Reaction x time to resume previous activity	2	22.5***	6.36	4	Species (2) x reaction (3) x time to resume (4)
Species x time to resume previous activity	1	7.87**	3.60	3	Species (2) x reaction (3) x time to resume (4)
Species x activity before	1	4.87*	1.73	3	Species (2) x activity of birds before (2) x position up the shore (3)
Species x distance from human activity	2	7.08*	1.91	10	Species (2) x size of flock (2) x distance from activity (3) x source (2)
Flock size x distance from human activity	2	12.05**	2.45	10	Species (2) x size of flock (2) x distance from activity (3) x source (2)

*$P<0.05$; **$P<0.01$; ***$P<0.001$

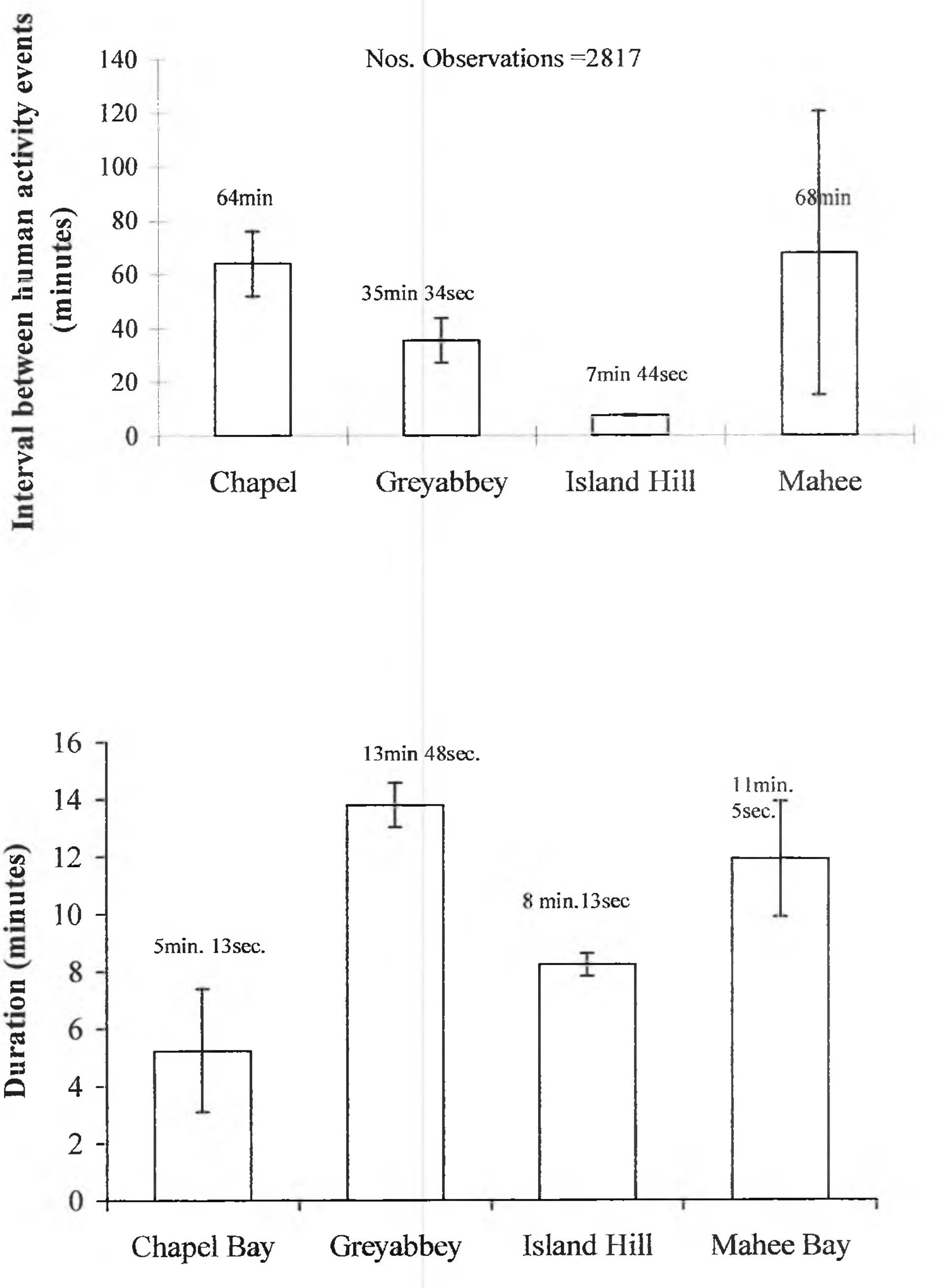

Figure 4. Human activity duration and frequency from four sites (n=in Strangford Loch during winter 1995/96 - 1996/97. (Number of observation hours Chapel 280.5, Greyabbey 425, Island Hill 318 and Mahee 390).

Model of site suitability

Based on results of this study and other literature, a simple energetic model was developed to assess the site suitability of these specific areas around the Loch. This was used to predict the likelihood of each of the four sites holding Wigeon and Brent Geese tested against actual observations. Given that the daily existence energy (DEE) of a bird is related to its mass based on the equation DEE=647 ' $mass^{.74}$ in kJ per day^{-1} (Boudewijn 1984), then using an approximate weight of 0.7 kgs for Wigeon and 1.4kgs for Brent Geese (Cramp & Simmons 1986) the require 496kJ and 829kJ per day respectively to fulfil their DEE.

Discussion

Feeding by wildfowl on intertidal areas is limited temporally by inundation (Fox *et al.* 1993; Madsen 1988; Mathers & Montgomery 1996). Thus, disturbance resulting in the cessation of feeding is likely to have direct impact on their energy budgets by causing a reduction in their food intake and, in some instances forcing birds to move to less disturbed areas in order to meet their daily energy requirements (Stock 1993; Madsen 1995). This is likely to be exacerbated when food resources are depleted and birds already have difficulty in meeting their daily energy requirements (Madsen 1995). As the energetic content of intertidal *Zostera* spp. on Strangford Loch is poor when compared to other *Zostera* spp. areas 13kJ/g compared to areas in Essex and Kent southern England at 20kJ/g and Lindsfarne in northern England 18.6kJ/g, it is especially important that wildfowl using this resource maximise their feeding time and efficiency (Charman 1979; Madsen 1988; Percival & Evans 1996; Mathers & Montgomery 1997). Brent can more easily achieve an energetic balance as they have a feeding window of 840 minutes per day compared to 480 minutes for Wigeon (Mathers & Montgomery 1996). Also, Brent geese extract the whole *Zostera* plant, including the underground portion (rhizomes) which are high in easily digestible water soluble carbohydrate and low in fibre (Mathers & Montgomery 1997; Mathers *et al.* 1999). This is likely to reduce further the temporal pressure on these geese to meet their daily energy requirement. Significantly, Wigeon only exploit the above ground and less digestible portions of the plant further adding to the temporal constraints in meeting their energy requirements (Mathers & Montgomery 1996; 1997). At Strangford Loch, most human activity occurs in the vicinity of Brent and Wigeon while birds were feeding either on the mud or at the edge of the tide. Human access is facilitated by the firm sandy substrate which comprises most of the foreshore (Portig *et al.* 1994). As Wigeon are limited both in their feeding time and food quality, it is likely that disturbance will have a greater impact on them compared to Brent (Mathers & Montgomery 1996; 1997). Indeed, despite human activity Brent continue to use all *Zostera* beds in Strangford Loch, and are the single greatest cause in its seasonal depletion (Portig *et al.* 1994; Mathers *et al.* 1998). In contrast, the areas of *Zostera* spp. exploited by Wigeon are restricted and tend to be associated with areas of reduced human disturbance (Mathers *et al.* 1998).

The present study suggests that Wigeon had a longer 'tolerance distance' (TD) than Brent reacting to more human activity distances >250m. Thus disturbance is likely to reduce the foraging area of foreshore available to Wigeon by that distance. This is supported by several studies which show bird distribution and food exploitation rates correlate with distance from disturbance loci e.g. (Madsen 1985; Gill *et al.* 1997). The lower tolerance to human activity by Wigeon compared to Brent may be due to their status as a quarry species while the latter are protected. Other studies indicate that hunting causes an increased sensitivity to people in quarry species across all human activities (Gerhard 1994; Madsen & Fox, 1995; Fox & Madsen 1997; Madsen 1998a). To add to the differential effect of disturbance on these species Wigeon were also more likely to react with a longer 'escape flight distance' (EFD) flying frequently >500m from disturbance than Brent thus increasing energy costs due to evasion flight. Further, as Wigeon were much less likely to resume their previous activity than Brent, those that did took much longer. Flock size had a significant effect on the reactions with larger flocks reacting at greater distances. This concurs with Batten (1977) who studied the disturbance of ducks on inland waterways, and Madsen (1985) who found that larger flocks of Pink-footed Geese reacted more readily to human activity than smaller flocks. It is hypothesised that larger flocks increase the chance of a potential source of danger being detected. As just one bird elicits a response in the whole flock during disturbance, there is also a greater chance of a large flock containing particularly reactive individuals than smaller flocks. Therefore, good quality sites attracting many birds can paradoxically become more vulnerable to disturbance such that thus the sites potential may never be reached unless disturbance is reduced. The work carried out here concurs with that of Mayhew & Houston (1989) who also illustrated that for Wigeon large flocks were indeed more reactive than smaller ones.

The reduced 'tolerance distance', by Brent and Wigeon to highly mobile human activities suggests that these are particularly potent at eliciting a response (Owens 1977; Campbell 1994; Riddington *et al.* 1996; Madsen 1998a). Highly mobile activities may have a greater impact on Wigeon compared to Brent as they respond (a) at a greater distance, (b) move further away (c) and stay away for a longer period than Brent.

Winter is a difficult period for herbivorous wildfowl which may already have considerable difficulty meeting their daily energy demands (Mayhew 1988). At Strangford Loch Wigeon are disadvantaged relative to Brent due to the poor energetic quality of *Zostera* shoot and their limited feeding period (Mathers & Montgomery 1996;1997; Mathers *et al.* 1999). In most areas human activity is regular, predictable and directional (occurs along set routes). In these areas Brent habituate with birds feeding on the high shore less than 50m from a main road (R. Mathers, pers. obs.). This type of behaviour has been noted with a range of wildfowl elsewhere (Burger 1981; Madsen 1998a; b). Wigeon were never recorded in close proximity to any source of regular disturbance stimulus, indicating that distance from human activity is likely to be a stronger factor in 'site suitability' for this species. Whether Wigeon numbers would increase if the disturbance burden is removed is unclear, but based on information from elsewhere (Madsen 1993; 1995), it seems likely that an increase would occur. Indeed Madsen (1998a) showed that that removal of disturbance can elicit from a 4-50 fold

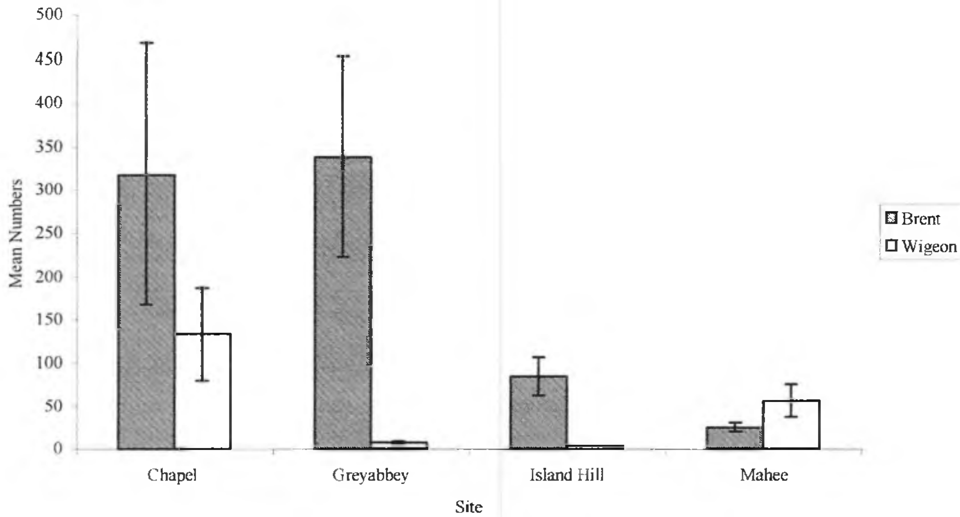

Figure 5. Mean numbers of Brent and Wigeon per 100m² at each of four study areas during two weekly counts during October to April 1994/95 and 1995/96.

increase in dabbling ducks. This is supported by the basic site suitability threshold calculated for Wigeon on Strangford Loch, with the site comparisons in terms of feeding time required to meet DEE indicate that disturbance may be a significant reason why Wigeon are absent from large areas of the Loch. Of the four sites tested only the two areas (Chapel Bay and Mahee Bay) that were above the calculated time required to meet the DEE actually regularly hold Wigeon (Mathers & Montgomery 1996; Mathers *et al.* 1998; R. Mather, pers. obs.) and the site of highest disturbance almost never holds Wigeon (R. Mathers pers. obs.) (**Figure 5**).

While Brent are also negatively affected by human activity, they are less adversely affected. This is probably due to the interspecific differences which allow Brent a greater ability to compensate for negative impacts. These include the feeding methods Brent employ which means they can extract a nutritionally superior diet from *Zostera* in terms of quality and quantity (ie they feed on shoots and rhizomes instead of just shoot as is the case for Wigeon) (Mathers & Montgomery 1997; Mathers *et al.* 1999); they can feed for longer periods within each tidal cycle (Mathers & Montgomery 1996); and their likely dominance in any biological interaction (Mathers & Montgomery 1996; Mathers *et al.* 1998) and because they are a non quarry species they have a greater tendency to habituate to regular disturbance. This is likely to explain why the Suitability Index (DEE) does not relate to the distribution of Brent at each of the four sites (**Figure 5**) (Mathers & Montgomery 1996; Mathers *et al.* 1999). However, as Strangford Loch is an important site, holding up to 70% of the geographically discrete Irish wintering population of Brent (O'Briain & Healy 1991), an increase in human activity should be curtailed before the threshold level for this species is also reached.

There are several refuges or 'core wildlife areas' (CWAs) on intertidal foreshore of Strangford Loch which could be significantly improved to support Wigeon. At present hunting disturbance has ceased in these areas, but all other forms of human disturbance persist. Madsen (1998b) has illustrated that refuge creation is an effective management tool in improving the conservation value and biodiversity of wetlands. However, on Strangford at present CWAs act more in name than in practise, with most areas still undergoing regular disturbance from a range of human activities (R. Stone pers. obs.). A reduction of all forms of human disturbance to wildfowl in CWAs is the primary and most obvious need. The creation of buffer zones around CWAs which exceed the TD of Wigeon would also be highly beneficial, thus a minimum 250m buffer is required. CWAs must also be large enough to encompass an escape flight distance (EFD) of wildfowl, thus ensuring that even if disturbed, birds will not normally have to leave the site. As most EFDs are >500m for Wigeon CWAs should be at least 1km in size. The main intertidal food of Brent and Wigeon on Strangford Loch is *Zostera* spp. which grows on the mid to upper foreshore (Portig *et al.* 1994). For this reason buffer zones should, in some cases, include adjacent areas of land to ensure that food in the upper shore remains within the TD of wildfowl. Highly mobile activities must be removed from areas important for wildfowl. This could be achieved by zoning these activities and restricting them to lesser used habitats.

What constitutes a disturbance event varies greatly between species, but if conservation objectives are to be achieved in the management of large multi-species systems, it is best to plan management of human disturbance to account for the needs of the most sensitive species in order to satisfy the requirements of the rest. Of the two main herbivorous wildfowl that use Strangford Loch, Wigeon are much more sensitive to disturbance than Brent and future management strategies must reflect this vulnerability if the numbers of this species are to revert towards the numbers previously recorded and the value of Strangford Loch as the key staging area for the Irish Brent Goose population is to be maintained and enhanced.

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