An experimental study of numerical and behavioural responses of spring staging dabbling ducks to human pedestrian disturbance

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Abstract

Controlled disturbance experiments were used to study distributional and behavioural responses of spring staging dabbling ducks to pedestrians in two parts of a restored wetland (Skjern River delta, Denmark), to inform management of human access to the site. Effects of a single pedestrian on the distribution and behaviour of dabbling ducks were recorded within uniform habitat along a public path. Dabbling ducks left areas <150 m from the source of disturbance, some were displaced 150–250 m, but most birds landed >250 m away and did not return within 1 h of the disturbance. Teal *Anas crecca* foraging activity was significantly reduced for at least 1 h following disturbance. Wigeon *A. penelope* flushed when up to 250 m from the pedestrian but gradually returned to within 150–250 m of the path, with post-disturbance numbers reaching 93% of pre-disturbance numbers 1 h after the disturbance. Wigeon foraged exclusively on land, but escaped into shallow waters when the pedestrian passed. They returned to land in the same area and had resumed foraging in all zones within 15 min after disturbance. Teal abandoned a smaller study site (2.3 ha) entirely following disturbance, dispersing elsewhere in the delta, without returning for at least 1 h.

Key words: human disturbance, Shoveler, Teal, wetland, Wigeon.

Many remaining wetlands of importance for waterbirds are now increasingly under pressure for recreational access. Conflicts between nature conservation interests and recreational use of wetlands supporting large numbers of staging waterbirds are therefore frequent (Davidson & Rothwell 1993) but may be avoided by providing appropriate areas or routes for people and also observation facilities (Guillemain *et al.* 2007).

Avian responses to human disturbance range from departure from the area to remaining and merely modifying their behaviour patterns (Platteeuw & Henkens 1997; Coleman *et al.* 2003; Rees *et al.* 2005). For instance, increased vigilance may cost feeding time and reduce foraging efficiency (Coleman *et al.* 2003). Moreover, birds may suffer physiological stress before behavioural responses are apparent (Platteeuw & Henkens 1997; Beale & Monaghan 2004a). The response amplitude may be influenced by a range of factors including the type of disturbance stimuli (Fox & Madsen 1997; Rees *et al.* 2005), distance to the source of disturbance (Beale & Monaghan 2004a, Blumstein *et al.* 2005, Laursen *et al.* 2005; Rees *et al.* 2005), species (Miller *et al.* 2001; Blumstein *et al.* 2003, 2005; Fernández-Juricic *et al.* 2005), habitat quality (Gill *et al.* 2001), individual energy state (Gill *et al.* 2001), flock size and flock composition (Madsen 1985; Burger & Gochfeld 1991; Taylor & Knight 2003; Laursen *et al.* 2005; Rees *et al.* 2005), intensity of disturbance (Burger & Gochfeld 1991; Quan *et al.* 2002, Coleman *et al.* 2003; Beale & Monaghan 2004a), and habituation (Rees *et al.* 2005; Møller 2008; Madsen & Boertmann 2008). It appears that the variation and interaction in these factors can lead to extensive site-specific variation in wildlife response to human activities (Møller 2008).

Some studies show adverse effects of disturbance associated with human recreation on staging and wintering waterbirds (Burger 1981; Bélanger & Bédard 1990; Durell *et al.* 2005), including effective (temporary) habitat loss (because birds avoid high levels of human activity; Madsen 1998b; Béchet *et al.* 2004), loss of feeding time (Madsen 1998a) and increased energy expenditure (when birds fly in response to human activities; Madsen 1998a; Béchet *et al.* 2004). Thus, one of the greatest challenges facing natural resource managers is to ensure the coexistence of wildlife and recreation (Knight & Temple 1995).

Public access to wetlands (such as public footpaths) is often close to important feeding and roosting areas for birds. Where waterbirds react to humans by ceasing feeding or taking flight, this is likely to have energy consequences for individuals, potentially reducing the overall carrying capacity of an area because food resources in disturbed parts are used to below their potential (Gill *et al.* 1996). When planning public access to wetlands, it is therefore necessary to know over what distance peripheral human access affects the behaviour and distribution of waterbirds and the local carrying capacity of the site (Platteeuw & Henkens 1997).

Escape distance has often been used to assess the sensitivity of waterbirds to different types of human activities and to contribute to refuge design, for instance for advising on the width of buffer zones (Fox & Madsen 1997; Rodgers & Smith 1997; Madsen *et al.* 1999; Rodgers & Schwikert 2002). However, the use of escape distance has been criticised (Hill *et al.* 1997; Blumstein 2003), because many factors affect escape distances. Furthermore, escape distances do not account for responses where birds do not disperse from the disturbed site, such as changes in behaviour patterns (Coleman *et al.* 2003) and may not reflect relative susceptibility to disturbance amongst individual birds (Gill *et al.* 2001; Beale & Monaghan 2004b; Gill 2007). Hill *et* *al.* (1997) and Coleman *et al.* (2003) recommended that controlled "before and after" experiments should be carried out to investigate the distributional and behavioural effects of disturbance effects on a local scale.

This paper presents the results of a study of the effects of human disturbance on dabbling duck behaviour and spatial distribution in an extensive restored wetland, for advising on the extent of buffer zones and location of access routes that would minimise human disturbance to birds at the site. Specifically, this study aims to determine the extent of behavioural (lost feeding) and distributional (displacement) consequences of disturbance, and whether these vary between species and the size of the habitat patch being used by the birds.

Study area and methods

The study was undertaken in a wetland restoration area in the lower River Skjern, west Jutland, Denmark (55°55'N, 8°25'E). Two experimental study sites were established (Fig. 1), both shallow seasonally flooded meadows (mainly 0–0.1 m deep) with higher areas with short grass. Both could be overlooked from fixed observation points and most dabbling ducks present could see pedestrians on the footpaths which run along each of the study sites. The larger study site A was a section of continuous habitat divided into three 350 m wide observation zones, extending 0–150 m, 151–250 m and 251–450 m into the wetland, almost parallel to the public path. The borders delineating the zones were not physically marked out but natural contours in the landscape and vegetation features were used to define the zones which enabled observers to be consistent in assigning birds to zones. Dabbling ducks fed in all three zones when undisturbed, so it was assumed that the entire area offered suitable habitat. Study site B was a flooded meadow somewhat isolated from other meadows, *c.* 150 × 150 m in size (Fig. 1).

Experiments were carried out from March–April in 2003 and 2004 giving a total of 25 observation days from both years at the large study site A and 16 days at the small site B. The path along study site A (but not study site B) was closed to public access during morning hours to prevent uncontrolled disturbance before each experimental trial. One person acted as the pedestrian whilst a second person, concealed from the birds' view, made counts and behavioural observations from a dike (Fig. 1). Before each experiment, birds were counted four times at 15 min intervals. Counts and records of individual activities were made using a telescope. Three categories of activity were used: foraging, roosting and 'other' activity, the latter consisting mainly of alert, preening or social activities. Counts and behavioural data were recorded at the same time by scanning the area from left to right, in same direction as the pedestrian would be walking. As one or more birds came into view, the activity of each individual was dictated onto a tape recorder. Activities were recorded during all counts, at *c.* 15 min intervals. At both study sites the pedestrian approached the study site immediately after the fourth count, walking at normal speed interspersed by short stops, simulating someone observing wildlife. In the eastern part of zone ≤150 m

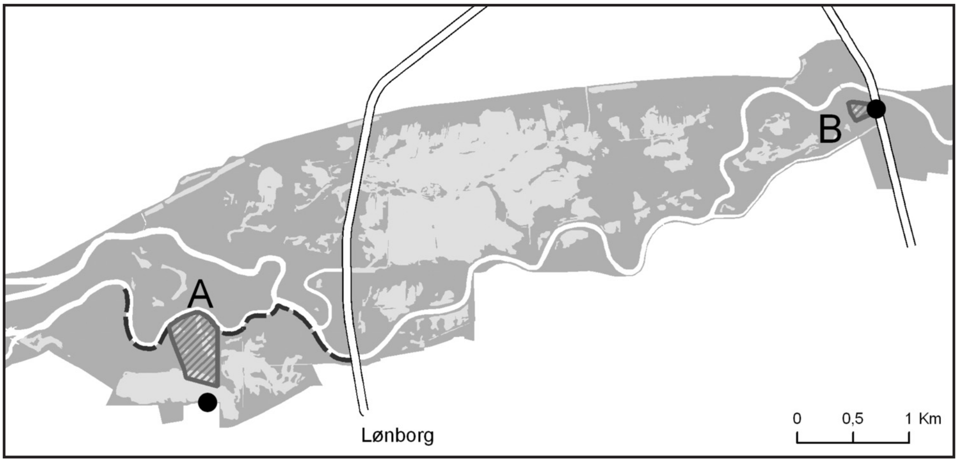

Figure 1. Western part of the River Skjern project area showing the location of study sites A and B (hatched). The thick broken line denotes the footpath along which the pedestrian at study site A walked (from east to west). The filled dots indicate the location of static observation points from which counts and behavioural observations were made. The river is in white and permanently inundated areas are shaded light grey. The two roads that cross the area are also shown.

from the pedestrian, high vegetation precluded accurate counts of birds prior to disturbance. The number of birds in this area was estimated by comparing counts of flushed birds made by both observers after transcription of data from their tape recorders and taking the mean value. The activities of the birds present in that part of the ≤150 m zone were not recorded.

As soon as the pedestrian was more than *c.* 100 m beyond the study area, she was rendered invisible to the birds because of tall vegetation, so at this point the birds were again counted and their activities recorded. It took *c.* 20 min from the first birds in the study area detecting the approaching pedestrian (*i.e.* some birds became alert) until the pedestrian was >100 m from the study area and the first post-disturbance count was conducted. Since it took *c.* 10 min to count the birds and record their activity, we refer to the first post-disturbance count as 15 min after disturbance, although the exact time between the birds being disturbed and the first post-disturbance count varied among individuals depending on where they were located in relation to the pedestrian. Another three counts were made at 15 min intervals after the first post-disturbance count. At both study sites only one controlled disturbance event was carried out per day. The public had free access to the path along study site A throughout the day on days when no experiments were undertaken. Due to uncontrolled human disturbance (including angling and mountain biking) within the study site (which occurred during 16 counts), mass scares (when most birds flew away without evident cause: 3 counts), sudden changes in weather (4 counts) and technical problems (3 counts), a total of 26 out of 200 counts were excluded from the dataset. Data from 2003 and 2004 were pooled for analysis.

Effects of the experimental disturbance of dabbling ducks on their numbers and distribution among zones (study site A) were analysed for species with ≥ 10 individuals present prior to disturbance on at least five days over both years. For analysis of the effects of the pedestrian on numbers within each zone, the criterion was that ≥ 5 individuals had been present prior to disturbance on at least five days. Changes before and after disturbance in the total numbers present and in the numbers present in each zone were tested using paired t-tests to compare the last pre-disturbance count with numbers recorded during each of the four post-disturbance counts. Numbers of birds were log-transformed to ensure that these data approximated to a normal distribution. Additionally, Kolmogorov-Smirnoff tests were used to compare the distribution of ducks across the three zones prior to disturbance, in relation to their distribution for each of the four counts made after the disturbance. Undisturbed bird distribution was taken as the average bird distribution over the four counts conducted before the disturbance event.

Bird activity was expressed as the proportion of birds feeding in each zone. To ensure that analyses were based on sufficient numbers of individuals, we only included records of the proportion foraging (within the zone) if it was based on ≥ 25 individuals (an arbitrarily chosen limit) before disturbance and at each record subsequent to disturbance. This restricted the analysis to Teal *Anas crecca*, Shoveler *A. clypeata* and Wigeon *A. penelope*. Normal (undisturbed) activity was taken as the average of the four recordings made before the birds were disturbed. All activity data were arcsine square root transformed before analysis, to meet assumptions that the data are samples from a normal distribution. ANOVA was used to test for differences in activity between the undisturbed situation and each of the four recordings of activity after the disturbance. Only data from study site A were included in the analyses of effects of the pedestrian on activity because the dabbling ducks present at study site B always left the site and did not return within the first hour after disturbance.

Results

At study site A most waterfowl in the zone close to the path (≤ 150 m) responded to the approaching pedestrian by taking flight. All Teal and Shoveler present in this zone left whilst the pedestrian was walking along the path and did not return to ≤150 m of the path during the 60 min following disturbance (Teal: $\bar{x} = 75$ before disturbance, $\bar{x} = 0$ at counts 1–4 after disturbance, $17.01 < t < 18.86$, $18 < n$ (events) < 23, $P < 0.0001$; Shoveler: $\bar{x} = 17$ before disturbance, $\bar{x} = 0$ at counts 1–4 after disturbance, $10.90 < t < 12.13$, $15 < n < 17$, $P < 0.0001$). Shoveler often landed in marshes on the other side of the river (usually >400 m from the path). Shoveler was the only species where the total numbers at the study site were significantly lower during all four counts following disturbance (Shoveler $\bar{x}$ = 26 before disturbance, $\bar{x}$ = 12–16 at counts 1–4 after disturbance, $2.25 < t < 4.29$, $15 < n < 20$, $0.0004 < P < 0.04$). Almost all displaced Teal landed >250 m from the pedestrian, remaining there for at least 1 h. Teal in zones 151–250 m and 251–450 m from the path did not fly, but there was a significant reduction in the birds recorded feeding in these two zones during the first hour after disturbance (Fig. 2). It is unknown to what extent the decline in the proportion foraging in zone 251–450 m was due to the influx of the birds displaced from zone ≤150 m, but there was no influx to zone 151–250 m so the decline in foraging activity in this zone was entirely an effect of individuals changing activity. For Shoveler comparisons of activities could be made for individuals present in the zone furthest from the path, and the individuals present here showed no significant change in the proportion feeding.

Unlike Teal and Shoveler, some Wigeon remained within 150 m of the path as the pedestrian approached (Wigeon: $\bar{x}$ = 75 before disturbance, $\bar{x}$ = 4–55 at counts 1–4 after disturbance, $2.03 < t < 3.68$, $5 < n < 9$, $0.081 < P < 0.015$). Some of the Wigeon that flushed from within 250 m and flew to zone 251–450 m gradually returned to zone 151–250 m (numbers reached 93% of pre-disturbance numbers 1 h after disturbance), but few returned to within 150 m of the path (Fig. 3). Wigeon in study area A foraged exclusively on land, but escaped into shallow waters when the pedestrian passed by. Foraging on land was quickly resumed after the pedestrian was out of view, and by 15 min after disturbance the proportion of

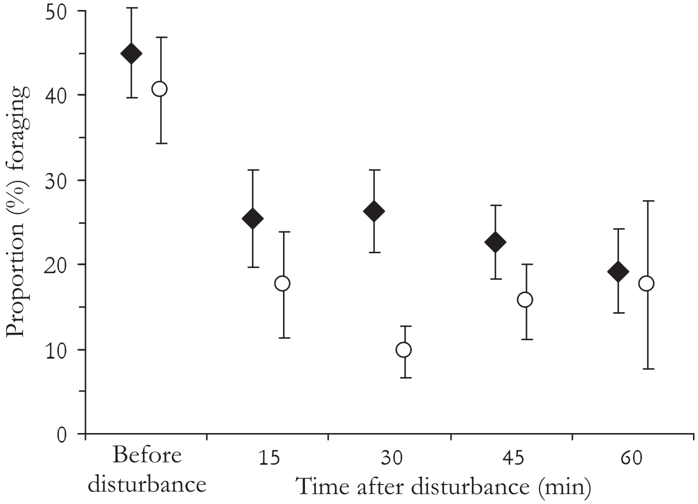

Figure 2. Mean (± s.e.) proportion of Teal engaged in foraging activity in zone 151–250 m (○) and zone 251–450 m (♦) before controlled disturbance events and at the four counts made after disturbance at study site A. The difference in foraging activity across time periods was statistically significant (One-way ANOVA: zone 151–250 m, $F_{4,77} = 4.84$, $P = 0.0016$; zone 251–450 m, $F_{4,107} = 4.59$, $P = 0.0018$).

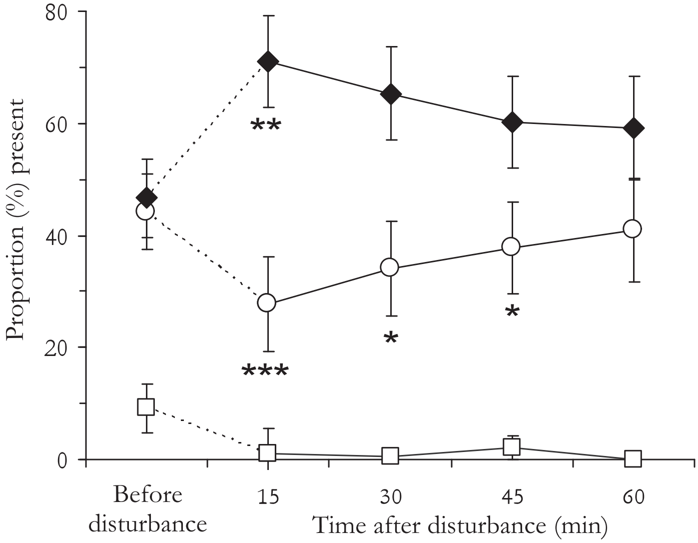

Figure 3. Mean (± s.e.) proportion of Wigeon counted at zones 0–150 m (□), 151–250 m (○) and 251–450 m (♦) before controlled disturbance events and at the four counts made after disturbance at study site A. Significant differences compared with the proportion present before disturbance are marked: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$. The mean numbers of Wigeon present at the entire study site A prior to disturbance was 239 (± C.I. 41.3), $n = 23$ observation days.

birds foraging was as high as before the disturbance.

At the small study site B, Teal was the only dabbling duck present. All 8–60 Teal present at study site B prior to disturbance on the 16 observation days abandoned the site when the pedestrian on the footpath approached the area with Teal. The Teal left for alternative areas elsewhere in the river delta and no Teal returned to this site within the first hour after disturbance.

Discussion

Effects of wetland size and distance from disturbance stimulus

Teal responded differently to the same experimental disturbance stimuli at the two study sites. In the larger wetland (study site A), Teal took flight but landed within the study site, whereas they left the smaller study site B entirely. Study site A was large with habitat suitable for Teal more than 250 m from the public path, whereas suitable habitat extended only to *c.* 100 m away from the pedestrian at site B. Hence if Teal were to remain within study site B they would have to tolerate a person coming to within < 100 m, which is less than the average escape distance of 166 m observed for Teal with unobstructed view in the Skjern river delta in spring (Bregnballe *et al.* 2009). Teal within site B therefore were forced to find alternative sites in other parts of the river delta, abandoning the study site entirely. They also flew further than birds re-landing within study site A and thus presumably incurred greater energy costs.

The displacement response at study site A decreased with distance to the source of disturbance. All Shoveler and Teal and most Wigeon within the 0–150 m zone took flight in response to the appearance of the pedestrian, but only a small proportion of birds departed from 151–250 m, and none from 251–450 m.

Prior to disturbance, Wigeon foraged in large flocks on land, but escaped to shallow water areas as the pedestrian passed, which is an established anti-predator response for this species (Mayhew & Houston 1987). This response has implications for managing refuge areas with large numbers of Wigeon, which would benefit from a juxtaposition of short grass foraging areas and shallow water that would provide an escape refuge.

Temporal consequences of disturbance

None of the dabbling ducks which abandoned the zone closest to the pedestrian returned to this zone within the first hour after the disturbance event. This supports the results of other studies which show that wildlife commonly avoids disturbed sites for some time after the cause of disturbance has departed, and that human activity can completely empty a site of birds if persistent (Stalmaster & Newman 1978; Burger 1981; Laursen & Rasmussen 2002). Hence, frequent and persistent disturbance may exclude birds from otherwise suitable habitat and this may equate with habitat loss, albeit temporarily (Fox & Madsen 1997; Miller *et al.* 1998; Durell *et al.* 2005; Finney *et al.* 2005; Gill 2007).

At study site A, most birds landed nearby in habitat similar to the original habitat and stayed there for at least one hour, which suggests that the alternative habitat offered an adequate refuge. On the other hand, in contrast to Wigeon, Teal did not fully resume their foraging activity in the refuge within the first hour, which raises the question of whether the available refuge habitat was suitable or sufficient.

Species specific differences in responses

Teal and Shoveler in the larger wetland were displaced from within 150 m of a pedestrian for more than an hour after a disturbance event, and Teal settling within 151–450 m showed significantly reduced feeding activity. Although Wigeon showed less dramatic responses, they too suffered displacement from original feeding distributions and reduction in feeding times. Other studies have shown that costs associated with displacement to less favoured areas as a result of disturbance include reduced habitat quality (Béchet *et al.* 2004), greater interference competition (Dolman 1995) and higher predation risk (Blumstein 2003). In addition, Wigeon took refuge on water in areas unsuitable for foraging, but they quickly returned to the meadow and had resumed feeding within 15 min of flight. On the other hand, if habitat is not limiting, birds may be more or less willing to abandon habitat in response to a disruptive stimulus depending on whether or not they can compensate the loss of intake rate in some way. For instance, an abundance of suitable habitat elsewhere may mean that the cost of departing is small, or alternatively birds may be able to compensate for temporary energy loss by increasing their food intake rate, or extend the period spent feeding to compensate for the reduction in foraging time during the disturbance (Bélanger & Bédard 1990; Platteeuw & Henkens 1997; Gill 2007). The species-specific responses shown may reflect a differential ability of the species observed to compensate for lost feeding time. For instance, Wigeon feed on relatively poor quality swards of plants with low nutrient value, which forces birds to spend most of the day foraging to meet energy demands (Mayhew 1988; Madsen & Fox 1995). Compared to Wigeon, Teal forage more on energy-rich seeds or invertebrates (Madsen *et al.* 1998), so need to spend less time feeding to meet daily energy requirements. Teal (and to some extent also Wigeon) also forage at night (Clausen & Joensen 2002) so the disruption of feeding following disturbance during the day therefore may not be critical for this species.

Management implications

Wetland restoration schemes increasingly need to meet the demands of public access to the countryside whilst maintaining local biodiversity. In the case of the restored wetland in the Skjern river delta in Denmark, it is clear that Teal and Shoveler will abandon areas within 150 m of a pedestrian and that Teal will reduce feeding activity in areas to which they were displaced for more than an hour. Teal completely abandoned small wetland units less than 150 m in extent. These data suggest that at this site, a buffer zone of > 150 m is required to protect against effective habitat loss caused by human access, and that the buffer should be extended further to permit undisturbed feeding. Given that Wigeon habitat exploitation was reduced at distances of up to 250 m from the source of disturbance and that a decline in Teal feeding activity was also recorded over this distance, we recommend that 250 m buffer zones along areas aimed to be disturbance-free should be adopted, even wider if reductions in feeding activity are to be avoided. In this study, disturbance effects were observed for a single pedestrian, but larger parties of people could affect birds to a greater degree and at larger distances (Burger & Gochfeld 1991; Beale & Monaghan 2004).

The results confirm that protection of waterbird habitat from peripheral sources of disturbance is most effectively attained by concentrating conservation efforts into large, regular shaped areas. Such refuges encompass relatively large disturbance-free core-areas compared to small or irregularly shaped refuges which are more susceptible to extended edge effects (Fox & Madsen 1997). Such refuge design can also help support more vulnerable species with longer escape distances, such as geese (Madsen 1985), and will suffice to protect waterbirds in other seasons including the open season and the moulting period, when birds are especially vulnerable to human disturbance (Madsen *et al.* 1999). The spatial extent of paths should be restricted to smaller areas rather than a complex network in order to set aside refuge areas to reduce the effects of disturbance (Klein 1993, Fernández-Juricic *et al.* 2005, Finney *et al.* 2005). We also highlight the importance of combining opportunities for the public to experience wildlife from refuge boundaries with the need to avoid establishing public paths that adjoin or lead into waterbird habitat, which would increase the frequency with which the birds are exposed to pedestrians. This can be achieved by constructing screened paths that lead to observation hides or towers, to ensure that pedestrians are invisible to waterbirds using adjacent wetlands.

Acknowledgements

We thank the National Forest and Nature Agency for making the experiment possible through dispensations from access restrictions.

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