Escape distances from human pedestrians by staging waterbirds in a Danish wetland

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Abstract

To aid planning of public access routes and the zoning of recreational activity in a Danish restored wetland, variation in the reactions of staging waterbirds to human activity were explored, using escape distances (measured as the distance at which the birds flush) as an index of sensitivity to pedestrians. Manipulative experiments showed species-specific responses in escape distances, including effects of body mass, flock size, flock composition, visibility of the stimulus to the birds and season. Mean escape distances increased with the mean body mass recorded for each species, although Wigeon *Anas penelope* flushed at greater distances than expected for their size. Birds in mixed flocks of Mallard *Anas platyrhynchos* and Teal *Anas crecca* reacted at longer distances than those in single species flocks for either species. Grey Heron *Ardea cinerea* escape distances increased through the autumn. Information about escape distances can be useful for advising on reserve design and for planning access within reserves, but there was evidence that waterbird escape distances are site-specific which limits their wider applicability.

Key words: human disturbance, Grey Heron, Mallard, Teal, Wigeon.

The behavioural response of birds to human disturbance can be considered as a trade-off between food intake and the perceived predation risk posed by human presence. Escape distances, defined as the distance at which birds flush when a person or another disturbing stimulus approaches, have been used to measure the sensitivity shown by birds to human activity, and such measures have been incorporated into refuge design when planning disturbance-free areas for target species (Fox & Madsen 1997; Madsen *et al.* 1999; Rodgers & Schwikert 2002). However, escape distances and other behavioural responses to human disturbance can vary with a number of factors such as species (Smit & Visser 1993; Blumstein *et al.* 2003; 2005; Laursen *et al.* 2005; Møller 2008), flock size (Madsen 1985; Spilling *et al.* 1999; Laursen *et al.* 2005), weather (Laursen *et al.* 2005), the previous number of disturbances within the day

(Rees *et al.* 2005), geographical region (Blumstein *et al.* 2003) and the type and predictability of the disturbance stimuli (Smit & Visser 1993; Madsen 1998; Ward *et al.* 1999; Lafferty 2001). A number of studies demonstrate that several landscape and temporal factors affect escape distances in avian species, including wildfowl (Madsen 1985, 1998; Rees *et al.* 2005). Laursen *et al.* (2005) therefore have urged that the planning of public paths and recreational activity in wetlands should be based on escape distances measured on site. Yet further information on factors affecting waterbird escape distances is required to ensure that human access to wetlands is managed effectively and that public enjoyment of these sites can be achieved whilst keeping disturbance to the birds to a minimum (Guillemain *et al.* 2007).

Large parts of an extensive restored wetland located along the River Skjern in the western part of Denmark were opened to the public immediately after restoration. An evaluation of the regulations relating to public access and hunting was planned, in order to provide guidelines for developing access policy at the site. A study of waterbird escape distances and the covariates affecting their reaction to humans therefore was undertaken to determine conditions under which humans could access the area without significantly reducing its value to staging waterbirds. It was anticipated that escape distances would vary in relation to a range of factors such as vegetation cover, species body size, flock size, species composition of the flocks and the time of year. The study therefore aimed to test six specific hypotheses.

1. Escape distances vary with vegetation height. It was predicted that escape distances would be longer in taller vegetation because it was anticipated that an individual's chance of detecting an approaching pedestrian would decline with increasing vegetation height.

2. Interspecific differences in escape distances vary with interspecific differences in body size. Since other studies have found that body size may influence how rapidly birds can take off on being alerted, it was predicted that waterbird species with low body mass would have the shortest escape distances (*cf.* Blumstein 2006).

3. Escape distances depend on flock size. It was predicted that escape distance would increase with flock size, because more eyes would be expected to detect potential predators at an earlier stage.

4. Mixed flocks respond to the escape distance of the most sensitive species. It was expected that the least sensitive species would be directly affected by alert and escape behaviour of the most sensitive species.

5. Escape distances are sensitive to hunting activity in nearby areas. It was predicted that escape distances would increase after days with hunting. This was expected because shooting previously has been demonstrated to affect the escape distances of waterbirds (*e.g.* Owens 1977; Gerdes & Reepmayer 1983; Madsen 1985, 1988).

6. Escape distances of quarry species vary depending on season and the timing of the season. It was predicted that escape distances of quarry species would increase

during autumn and be higher in autumn than in spring.

Methods

Study area

Skjern Enge comprises 2,200 ha of restored wetlands in the Skjern River delta in western Jutland, Denmark. Escape distance measurements were carried out in the western part of Skjern Enge (55°55'N, 8°25'E; west of "Lønborg road", see Fig. 1 in Bregnballe *et al.* 2009, this volume) over open water (mainly < 50 cm in depth) and wet meadows with 40–90 m high vegetation including emerging herbs up to *c.* 170 cm in height. Wildfowl hunting was permitted on state-owned land in Øster Hestholm and in the eastern part of Skjern Enge (see Fig. 1 in Bregnballe et al. 2009, this volume) during 1 September–31 December but not in the area where the study was conducted. Shooting was allowed in Øster Hestholm every third week on Thursday and Friday evenings (280–678 shots per evening, $\bar{x}$ = 454, n = 8) and on Saturday mornings (81–350 shots per morning, $\bar{x}$ = 177, n = 4). Footpaths from which escape distances were measured were 2.5–4 km from the nearest state-owned areas with hunting. Hunting could occur throughout the open season on privately owned fields *c.* 0.3–1.2 km from the footpaths where escape distances were being measured, but shooting intensity usually was far lower here than on state-owned land.

Escape distances

The distance at which waterbirds reacted to the presence of a single walking person (hereafter "pedestrian") was measured as the distance between the birds and the pedestrian when the individual birds or flock first flushed. These measures of escape distances were recorded by the pedestrian when walking at normal speed along one of the public paths inside the study area. The person making the behavioural observations therefore also provided the source of disturbance. Successive locations on the footpath were used as observation points.

Focal individuals and flocks were chosen and observed from the time that an individual or flock close to the path was first seen by the pedestrian. Leica Geovid 8 × 42 laser rangefinder binoculars were used to measure the distance between the bird(s) and the pedestrian by pointing the laser beam at the individual, or at vegetation at the point where the individual(s) flushed, then reading the distance in the binoculars. Escape distances for flocks were measured to the nearest individual of the responding flock. All public paths adjoined waterfowl habitats, so the pedestrian usually approached the birds tangentially. Time, flock size (number of individuals of each species) and species composition were recorded together with a subjective assessment of whether or not the approaching pedestrian was obstructed from the birds' view by vegetation. The manufacturer of the laser rangefinder binoculars states that distances are measured to an accuracy of ± 1 m within a 0–350 m range (99.5% of escape distances were within this range) and at ± 2 m over 350–700 m (www.leica-camera.com). However, we presumed that many of the measures in the field were made with lower precision, especially because many measures where made to the vegetation from where the individuals had flushed and not to the birds themselves because they frequently flushed before the distance had been measured.

Escape distances were recorded between 07:00–13:00 h over 54 days in autumn 2003 (19 August–18 November 2003) and between 13:00–16:00 h over seven days in spring 2004 (1–24 April). All measurements in autumn were made by one person walking on public paths in 10 different sub-areas (88% from three sub-areas), and all measurements in spring were made by two other persons walking on public paths in two sub-areas. All three persons approached the birds at a similar rate and used the same recording methods.

Data analyses

Linear regression analysis was used to evaluate the relationship between species body mass and escape distance, based on body masses recorded in Cramp & Simmons (1977, 1983) and escape distances measured for single birds of 17 species. Data for single birds were used to avoid potential confounding effects of inter-specific differences in flock sizes which might influence the results. Lack of adequate sample sizes for a range of flock sizes precluded using GLM modelling to test the combined effects of both flock size and body mass on escape flight distances.

The effect of vegetation height (unobstructed view versus obstructed view) on escape distance for the different species was tested with one-way ANOVAs, using multiple *t*-tests with Bonferroni's correction. Differences in escape distances for birds with a clear view of the pedestrian compared with those whose view was obstructed by vegetation were additionally tested in an ANCOVA with species body mass included as a covariate, again only including data for single birds to avoid potential confounding effects of flock size.

One-way ANOVAs using Duncan's multiple range tests were used to test for differences in escape distances between seasons. Stepwise regression determined whether day number during autumn (with day 1 = 19 August), flock size, time after sunrise, time before sunset, number of raptors present per walk (range = 0–3, $\bar{x}$ = 0.7) and the number of shots heard per minute walk (range = 0–0.5, $\bar{x}$ = 0.04) contributed significantly to the variation in escape distances for each species observed in autumn. There was no evidence for significant effects of time after sunrise, time before sunset, number of raptors present per walk and number of shots heard per minute walk; these parameters therefore were not included in further analyses. The regression analyses were carried out for eight single-species and mixed-species flocks for which there were > 10 observations (17 groups; see Table 1); of the mixed-species flocks, there were sufficient data only for Mallard *Anas platyrhynchos* with Teal *Anas crecca*. Human visibility (*i.e.* whether the birds had an open view of the pedestrian) and season (spring or autumn) were included as independent variables. For mixed-species Mallard and Teal flocks the proportion of Mallard in the flock was entered as an independent variable. Only flock size was tested for the spring data as

Table 1. Escape distances and flock sizes for nine waterbird species giving mean, standard error and sample size. Only groups with at least five observations are included; *n* = the number of observations used to compile mean escape distances and associated flock sizes.

	Escape distance (m)		Flock size		
	Mean	**s.e**	**Mean**	**s.e**	***n***
Birds with unobstructed view					
Single species flocks, autumn 2003					
Greylag Goose	230	14.47	66.3	18.98	7
Wigeon	205	8.73	127.3	59.91	26
Great Cormorant	193	15.96	3.7	1.28	10
Grey Heron	177	9.13	1.9	0.58	31
Mallard	166	5.50	16.0	2.14	79
Lapwing	162	22.38	43.4	21.24	5
Teal	156	11.09	30.2	6.18	25
Coot	68	10.78	89.7	46.92	6
Mixed species flocks, autumn 2003					
Wigeon/Mallard	195	10.78	68.0	24.83	5
Mallard/Teal	181	10.55	54.1	9.74	20
Single species flocks, spring 2004					
Grey Heron	255	23.94	1.6	0.40	5
Wigeon	190	8.57	5.4	1.40	32
Teal	166	5.00	6.0	0.63	88
Mallard	157	8.52	2.6	0.28	38
Coot	58	6.46	1.1	0.13	8
Birds with obstructed view					
Single species flocks, autumn 2003					
Greylag Goose	171	12.92	26.5	12.44	24
Grey Heron	148	5.83	1.5	0.15	96
Mallard	108	3.40	17.8	2.19	188
Lapwing	89	10.20	3.3	2.17	11
Teal	84	6.21	14.7	2.97	54
Greenshank	78	6.99	1.3	0.14	32
Coot	67	12.60	73.4	25.82	8
Mixed species flocks, autumn 2003					
Mallard/Teal	149	7.47	61.2	9.00	33
Single species flocks, spring 2004					
Wigeon	117	6.51	8.0	4.71	9
Teal	114	6.37	8.1	2.69	34
Mallard	60	5.55	2.1	0.17	48
Coot	49	11.30	1.4	0.24	5

the other variables were not noted in this season. Variables significant at $P \leq 0.05$ were retained in the stepwise regression models.

The effect of the intermittent hunting (shooting over three days at three-week intervals) occurring on state-owned land 2.5–4 km from the observation areas on the sensitivity of quarry species and species that could be regulated by shooting (Greylag Goose *Anser anser*, Wigeon *Anas penelope*, Teal, Mallard, Great Cormorant *Phalacrocorax carbo* and Grey Heron *Ardea cinerea*) was also investigated. Escape distances for these species were grouped into two time categories: 1) observations made before the first hunt (19 August–11 September) together with observations made 0–10 days before each of the following hunts three weeks later, and 2) observations made 1–7 days after a hunt. Differences in escape distances recorded for the different time periods were tested using an ANCOVA with species body mass included as a covariate. Due to insufficient sample sizes, hunting effects were not tested at a species level. All analyses were carried out using SAS 9.1.3 software.

Results

Escape distance

A total of 735 escape distances were measured for 26 species in 2003, and 269 escape distances for five species in 2004. Most of the data were recorded for nine species: four autumn quarry species (Greylag Goose, Wigeon, Teal and Mallard), two regulated by shooting under license (Great Cormorant and Grey Heron), one quarry species rarely hunted in the study area (Coot *Fulica atra*), and two wader species not hunted in Denmark (Greenshank *Tringa nebularia* and Lapwing *Vanellus vanellus*). Mean escape distances for these nine waterbird species with at least five observations per group are shown in Table 1.

Relationship with body mass

There was a significant positive linear relationship in autumn between species body mass (quarry and non-quarry species included) and escape distance for single birds with and without an unobstructed view of the pedestrian (unobstructed view, $F_{1,50} = 12.93$, $r^2 = 0.206$, $P = 0.0007$, $y = 0.0482x + 98.78$; obstructed view, $F_{1,152} = 39.20$, $r^2 = 0.209$, $P < 0.0001$, $y = 0.0466x + 66.62$; Fig. 1). Among birds that had an unobstructed view of the pedestrian, mean escape distance increased with mean adult body mass across the six quarry species when including data recorded for all flock sizes, although this was not significant as the mean escape distance for Wigeon was higher than expected in relation to the other species ($F_{1,4} = 5.54$, $r^2 = 0.581$, n.s., Fig. 2). When excluding Wigeon, the association between species body mass and escape distances was statistically significant ($F_{1,3} = 78.26$, $r^2 = 0.963$, $P = 0.003$).

Vegetation height

The height of vegetation influenced whether or not single birds or flocks had a partly obstructed view of the pedestrian and escape distance appeared to be related to vegetation height for a number of species.

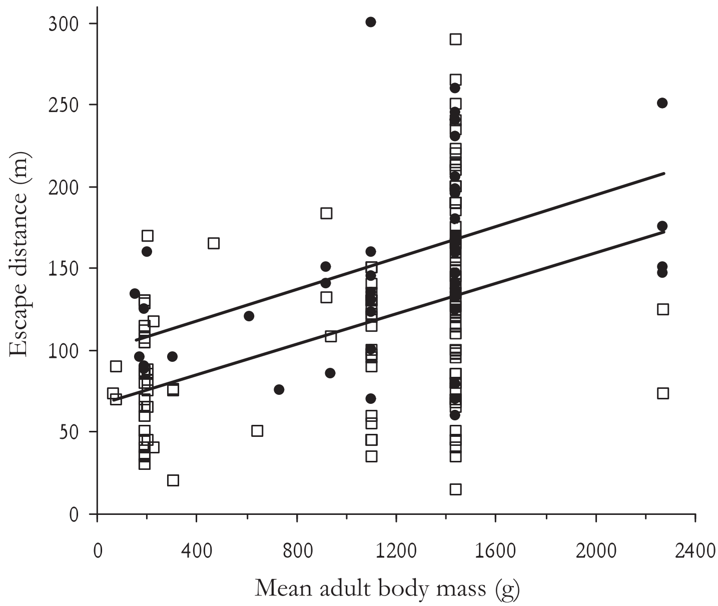

Figure 1. Escape distances for 17 species of single birds (flock size = 1) in autumn in relation to the mean adult body mass (g) recorded for each species (from Cramp & Simmons 1977, 1983). The upper line is the regression for birds with a clear view to the pedestrian (●, *n* = 52) and the lower line is the regression for birds with their view obstructed by vegetation (□, *n* = 150).

An example is given for Mallard in Fig. 3. Great Cormorant, Grey Heron, Greylag Goose, Wigeon, Teal, Mallard and mixed flocks of Mallard and Teal (but not Coot) all showed significantly longer escape distances when birds had unobstructed views of the pedestrian than when their view was obstructed by vegetation (one-way ANOVA, multiple t-tests with Bonferroni's correction, $1.97 < t < 2.57$, $P < 0.05$). Among the 17 species included in the test of the relationship with body mass (Fig. 1), single birds with an unobstructed view to the pedestrian showed longer escape distances than single birds whose view was obstructed by vegetation (ANCOVA with body mass as covariate, $F = 40.77$, d.f. = 1, $P < 0.0001$; Fig. 1).

Flock size and mixed flocks

Escape distances increased with flock size in Mallard, Teal and in mixed Mallard–Teal flocks, with Mallard having longer escape distances than Teal when correcting for flock size effects (Mallard, $F_{1,186} = 25.95$, $r^2 = 0.12$, $P < 0.0001$; Teal, $F_{1,52} = 4.88$, $r^2 = 0.086$, $P = 0.032$; Mallard versus Teal, ANCOVA with flock size as covariate, $F_{1,238} = 10.88$, $P = 0.001$; Fig. 4). Against expectations, mixed Mallard–Teal flocks had significantly longer escape distances than single species flocks of both Mallard and

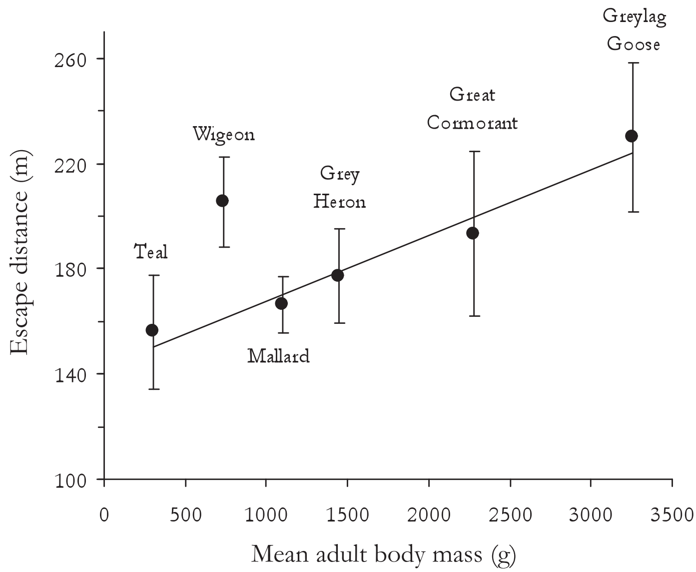

Figure 2. Relationship between the mean (±95% C.I.) escape distances in autumn for six quarry species where the birds had an unobstructed view of the pedestrian (all flock sizes included) and the mean adult body mass (g) recorded for each species (from Cramp & Simmons 1977, 1983). The line represents the fitted linear regression excluding Wigeon (see text for details of fitted models).

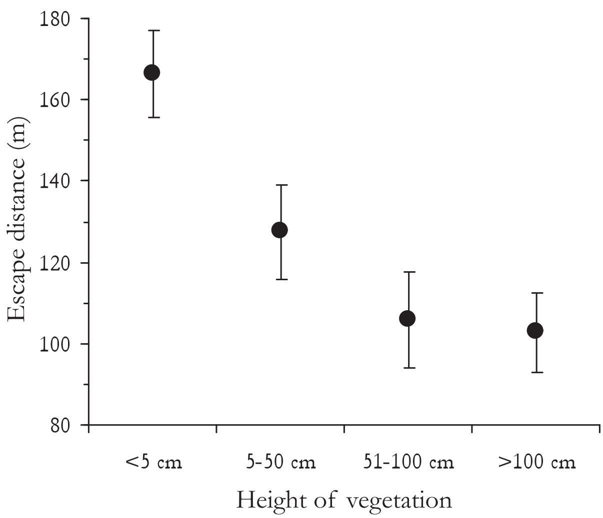

Figure 3. Relationship between the mean (±95% C.I.) escape distances of Mallard in autumn for four categories of vegetation height (28 < *n* < 96). The category of vegetation height "< 5 cm" includes bare soil and open water.

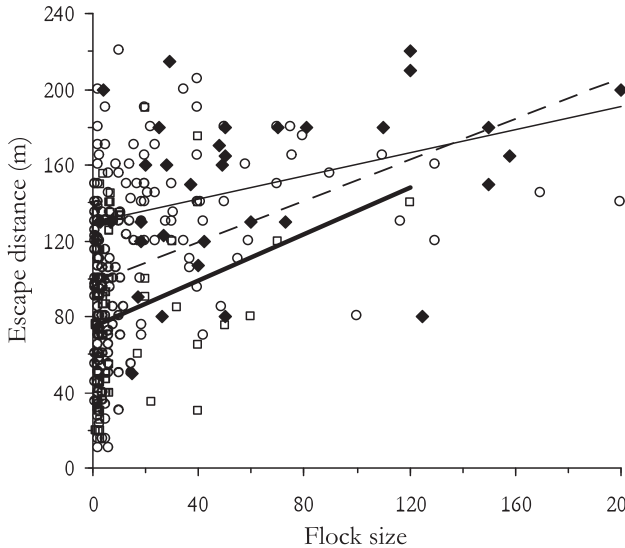

Figure 4. Escape distances in relation to flock size for Mallard (○, dotted line, *n* = 188), Teal (□, thick line, *n* = 54) and mixed Mallard–Teal flocks (♦, thin line, *n* = 33) with lines denoting the fitted linear regressions.

Teal (ANOVA, $F_{2,274}$ = 20.28, $P < 0.0001$, Duncan's multiple range test shows significant differences between all three means at $P = 0.05$). Stepwise regression showed that the proportion of Mallards in flocks did not contribute significantly to the variation in escape distances for mixed species flocks (linear regression: with unobstructed view $F_{1,15}$ = 1.29, r^2 = 0.079, n.s.; with obstructed view $F_{1,29}$ < 0.01, r^2 = 0.00, n.s.).

Effect of hunting

Within the groups "before hunts" and "after hunts", species body mass was the only variable associated with escape distance. This was true both for birds with and for birds without an unobstructed view of the pedestrian. Although not statistically significant, ANCOVAs with species body mass as a covariate indicated that escape distances may be higher after the hunts, both for birds with an unobstructed view of the pedestrian (ANCOVA, $F_{1,231}$ = 3.12, P = 0.079, n.s.) as well as for birds with their view obstructed by vegetation (ANCOVA, $F_{1,421}$ = 3.06, P = 0.0813, n.s.). Data for dabbling ducks are given in Table 2.

Autumn versus spring and within season variation

The comparison of escape distances between spring and autumn for the two quarry species Mallard and Teal was limited to single birds and flocks of < 10 individuals because flock size had a significant effect on escape distance (at least in autumn) and for both species there were no or few records in spring of escape distances for flocks of ≥ 10 individuals. Among birds with their view

Table 2. Mean escape distances (m) for dabbling ducks (with s.e. and sample size in parentheses) before and after hunting days on state-owned land. Escape distances were measured at 2.5–4 km distance from the hunting area. A hunting session was an evening hunt on Thursday and Friday followed by a morning hunt on Saturday. There was then a break of 2.5 weeks to the next hunting session. Data from birds with and without an obstructed view of the pedestrian were pooled.

Hunting session	Before hunting	After hunting
1	122 (± 5.71; *n* = 109)	126 (± 9.00; *n* = 42)
2	119 (± 9.77; *n* = 48)	130 (± 8.01; *n* = 41)
3	139 (± 7.18; *n* = 64)	142 (± 7.23; *n* = 48)
4	134 (± 10.88; *n* = 30)	152 (±7.73; *n* = 59)

partly obstructed by vegetation, Mallard showed longer escape distances in autumn than in spring (ANOVA, $F_{1,162} = 18.5$, $P < 0.0001$; $\bar{x} = 92$ m, $n = 115$ and $\bar{x} = 60$ m, $n = 48$, respectively) whereas for Teal escape distances were longer in spring than in autumn (ANOVA, $F_{1,64} = 12.5$, $P < 0.0008$; $\bar{x} = 106$ m, $n = 30$ and $\bar{x} = 3$ m, $n = 36$). It was not possible to test for such differences amongst other species because of small sample size or differences in flock sizes between seasons.

An exploration of changes in escape distances of eight species through the autumn showed a significant change only for Grey Heron, whose escape distances increased during the autumn season (Fig. 5).

Discussion

Larger species showed longer escape distances than smaller ones (confirming the findings of Burger & Gochfeld 1991; Rodgers & Schwikert 2002; Laursen *et al.* 2005), presumably because of the greater time required for heavier birds to take flight and escape from potential predators. Increasing wing load (mass/wing area) reduces take-off speed (Witter & Cuthill 1993) even within species (Burns & Ydenberg 2002), although other factors influence flight capability (*e.g.* flight muscle development, Guillemette & Ouellet 2005). Wigeon showed greater escape distances than predicted from body mass, perhaps because few escape distances were measured for the larger Wigeon flocks, in comparison with other dabbling duck species (see Table 1). Bregnballe *et al.* (2001) and Laursen *et al.* (2005) both report longer escape distances for Wigeon with an unobstructed view during autumn in Denmark than the present study ($\bar{x} = 299$ m, 95% C.I. ± 180 m and $\bar{x} = 269 \pm 34$ m, respectively), but they also

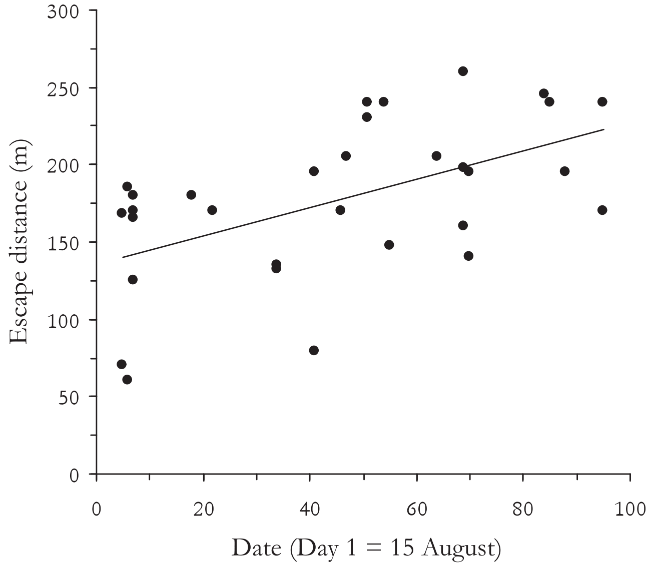

Figure 5. Escape distances in relation to date during autumn for Grey Heron with an unobstructed view of the pedestrian. Day 1 = 15 August. Linear regression: $F_{1,29} = 11.91$, $r^2 = 0.291$, $P = 0.0017$.

found that Wigeon had longer escape distances than other species in their respective study areas.

Vegetation height appeared to affect the birds' ability to detect pedestrians: Significantly shorter escape distances were found for six out of eight species (singly and in flocks) when their view of the approaching pedestrian was partly obstructed by vegetation.

Escape distances increased with flock size for Mallard, Teal and mixed Mallard–Teal flocks, as found for other species (Owens 1977; Madsen 1985; Spilling *et al.* 1999; Laursen *et al.* 2005; Rees *et al.* 2005). Predator detection probability presumably increases with increasing flock size (Beauchamp 2003), despite individual decreases in vigilance with increasing flock size (Elgar 1989). Madsen (1985) and Spilling *et al.* (1999) found no further increase in escape distance beyond a threshold flock size in Pink-footed Goose *Anser brachyrhynchus*, White-fronted Goose *A. albifrons* and Bean Goose *A. fabalis*, but no such threshold was reached amongst Dunlin *Calidris alpina* in flocks of up to 9,000 individuals (Laursen *et al.* 2005).

Only Grey Heron (generally a non-quarry species, shot under licence) showed an increase in escape distance as the hunting season progressed. This species is regulated by shooting near the fish farms east of Skjern Enge, so some birds may have experienced being shot at. Alternatively, higher ratios of juvenile Grey Herons in early autumn may allow closer approach due to their inexperience at this time and may explain the gradual increase in escape distances, as demonstrated for Magpies *Pica*

pica (Dhindsa & Boag 1989). Mallards with their view partly obstructed by vegetation showed longer escape distances in autumn than in spring. This difference could be an effect of exposure of Mallard to hunting in autumn but not in spring, or because escape distances were measured before midday in autumn but mainly in the afternoon in spring. Another, more plausible explanation is that some of the Mallards for which escape distance was measured were breeding in the area, and these individuals may have contributed to the spring data.

Against expectations, mixed flocks of Mallard and Teal reacted at longer escape distances than did single-species flocks for either species. There is no obvious explanation for this since the proportion of Mallard in the mixed flocks did not affect escape distances, except that individuals in mixed flocks may be less sensitive to the relatively unfamiliar alarm signals from other species.

No significant increase in escape distance was found following hunting activity on the nearby state-owned hunting area, although there was a tendency for an increase despite the large distances between the hunting area and the study sites (2.5–4 km). The large variation in escape distances made it difficult to obtain sufficient samples for comparison of escape distances over the short period of time. On a larger temporal scale Gerdes & Reepmayer (1983) and Madsen (1985) have shown that escape distances of geese were markedly longer during the open season in autumn compared with spring, indicating that the birds are more sensitive to human presence during the hunting season. Burger & Gochfeld (1991) showed that migratory birds wintering or staging in India, where no hunting takes place, also exhibit longer escape distances than local residents. They attributed this to the migratory species arriving from the north where hunting and disturbance of birds was more common. Even though birds habituated to the new conditions and reduced their escape distances during the winter season, the results suggest that hunting may affect escape distances even in areas where it is not practised (Burger & Gochfeld 1991).

Implications for management

Escape distances for Mallard, Wigeon and Teal with an unobstructed view of the pedestrian were shorter than those reported from the Danish Wadden Sea, where flocks were approached directly across open mudflats (Laursen *et al.* 2005; Laursen in Madsen *et al.* 1999). In Skjern Enge, birds were approached tangentially, which may explain some of the differences between the two studies. Nesting gulls (*Larus* sp.) discriminated between people walking directly towards the nest and those walking tangentially (Burger & Gochfeld 1981), although escape distances were longer in four out of five South American grassland species when approached tangentially (Fernandez-Juricic *et al.* 2005). The angle of approach and the general visibility of pedestrians therefore need to be included in management recommendations for wetland sites.

For linear reserves such as Skjern Enge, the best ratio of undisturbed core area to total refuge area is achieved by protection in the widest parts of the reserve (Fox & Madsen 1997). Footpaths through the centre of waterfowl habitat will greatly reduce the area exploited by staging waterfowl. Since escape distances are highly variable, Laursen *et al.* (2005) suggested taking the variation into account when creating buffer zones. If the data converge to a normal distribution (in a statistical sense) this can be achieved by adding two standard deviations to the mean escape distance (corresponding to protecting 98% of all flocks, Laursen *et al.* 2005), although this may be affected by sample size. In the present study the Greylag Goose showed the longest escape distance of 230 m (s.d. ± 40 m), equating to a buffer width of 310 m. Alternatively, Fernandez-Juricic *et al.* (2001) suggested using the distances at which birds are alerted when planning buffer zones, which in that study of park-dwelling species was on average 1.5 times longer than the escape distances of the same species (Fernandez-Juridic *et al.* 2001). Although some studies have been performed (*e.g.* Rees *et al.* 2005), it appears that few such alert distances are available at present for European waterfowl.

Escape distances in this study were stimulated by a single person walking at a normal pace. Results may vary for different and less predictable disturbance stimuli, for instance cyclists, joggers, larger parties of people, anglers, wildfowlers, dog walkers or people moving off footpaths may cause greater disturbance (Smit & Visser 1993; Lafferty 2001; Beale & Monaghan 2004b; Rees *et al.* 2005), which would require wider buffer zones.

It has been stated that information about escape distances have limited usefulness because escape distances are highly variable and affected by numerous factors (Hill *et al.* 1997; Gill *et al.* 2001). Furthermore, the distance at which an animal chooses to flee is likely to depend on its options such as access to alternative undisturbed habitat (Gill *et al.* 2001; Frid & Dill 2002; Stillman & Goss-Custard 2002; Beale & Monaghan 2004a). Despite the hypothesis that flee responses are mediated by availability of alternative habitat (Gill *et al.* 2001), and the experimental support for it (Stillman & Goss-Custard 2002; Beale & Monaghan 2004a), escape distances can still be useful tools in reserve design and planning of access paths within reserves. Birds with longer escape distances are more likely to fly greater distances and less likely to return to their former activity at the site in question (Mathers *et al.* 2000; Bregnballe *et al.* 2001). Hence valuable waterfowl habitat closer to a disturbance source than one escape distance will not be exploited fully. In particular, we recommend using locally derived escape distances to inform the width of buffer zones along public paths on wetlands by: 1) using the escape distances of the largest species present (which shows the longest escape distances) to provide the most cost-effective guide for reducing effects on all other species, 2) adjusting the width of the buffer zone in accordance with local factors such as mean flock size and vegetation height, so that pedestrian access can be achieved with minimal disturbance to resting and feeding waterbirds, and 3) taking account of seasonal changes in susceptibility.

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