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Impacts of disturbance on migratory waterfowl

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It is well known that disturbance from human activities can cause temporary changes in behaviour and locally affect temporal and spatial distribution of migratory and wintering waterfowl. But it is also known that, to some extent, birds can compensate for disturbance by altering their behaviour or habituating to human activities. Comparatively little is known about how these reactions to disturbance may impact on the large-scale dispersion of waterfowl and, ultimately, on their population dynamics. To be able to answer these questions, a better theoretical framework, based on optimal foraging theory incorporating predation risk, and field experiments are required. Furthermore, we need to study the waterfowl throughout their winter ranges to interpret the overall impacts of disturbance. This paper examines two cases where the impacts of disturbance have been assessed from field experiments. In one study, disturbance effects of shooting were tested by setting up experimental reserves in two Danish coastal wetlands. Over a 5-year period, these became two of the most important staging areas for coastal waterfowl, and the national totals of key species were significantly increased. A national management plan which will establish more than 50 new shooting-free refuges on Danish coastal areas within the next 5 years is likely to boost waterfowl numbers even more. Such retention of birds at more northerly sites on the flyway should result in a more efficient resource utilization and may positively affect the population dynamics where numbers are affected by winter resources. In a second study, the impacts of disturbance by farmers on spring fattening of Pink-footed Geese *Anser brachyrhynchus* were analysed. In undisturbed areas in northern Norway, abdominal profiles of the geese increased rapidly, whereas in disturbed sites they did not. Subsequently, geese that had used undisturbed sites reproduced better than geese from disturbed sites.

Over recent decades, increasing attention has developed on the effects of human activities on migratory and wintering waterfowl. The main causes of concern are the reductions in natural and semi-natural waterfowl habitats through human encroachment and the concurrent increased recreational use of the remaining areas. The most heated discussions have related to the disturbance effects of wildfowling, but increasing attention is being paid to the roles of leisure activities, aircraft and other traffic. Currently, environmental impact assessment deals with the habitat loss incurred by a development project and also with the possible disturbance effects in areas adjoining the construction work.

Field studies on disturbance have focussed mainly on local effects, i.e. the behavioural and distributional responses by birds to disturbance stimuli. As a result, it is well known that disturbance can cause temporary changes in behaviour and locally affect the temporal and spatial distribution of migratory and wintering waterfowl. It is also known that, to some extent, birds can compensate for disturbance by altering their behaviour or habituating to human activities (e.g. Davidson & Rothwell 1993a).

Comparatively little is known about the impacts of disturbance on the subsequent body condition, survival or productivity of the individual or population. Belanger and Bedárd (1990) estimated that man-induced disturbance could have a significant energetic consequence in autumn for Greater Snow Geese *Anser caerulescens atlantica* but could not demonstrate any impacts on body condition or population dynamics. As Cayford (1993) pointed out, many factors other than disturbance affect population dynamics and make it difficult to isolate key variables. Furthermore, in migratory waterfowl the impacts of disturbance can be difficult to detect because they may only become manifest thousands of kilometres away in the breeding areas (Davidson & Rothwell 1993b).

Disturbance is most likely to have an impact during those periods of the annual cycle when food resources are depleted and birds have difficulty in meeting their daily energy requirements. Such difficulties are most likely to arise when food intake needs to be high to enable the birds to build up nutrient reserves in advance of periods of high demand. In both waders and wildfowl, energy reserves are accumulated in late autumn and early winter; these reserves may be exhausted during winter but replenished during spring when

Table 1. *Estimated numbers of dabbling ducks passing through Denmark in autumn, calculated from bag statistics and recovery rates of individuals ringed and recovered in Denmark in the same autumn season, assuming that the proportion of the total population shot equals the direct recovery rate and that recovery rates are the same for all species (8–12%, which is the estimate for Teal) (from Madsen & Pihl 1993)*

	Annual bag	Recovery rate (%)	Estimated autumn passage
Wigeon *Anas penelope*	44,000	8–12	370,000–550,000
Teal *Anas crecca*	85,000	8–12	700,000–1,000,000
Mallard *Anas platyrhynchos*[a]	300,000	8–12	2,500,000–3,800,000
Pintail *Anas acuta*	7000	8–12	60,000–90,000
Shoveler *Anas clypeata*	4200	8–12	35,000–53,000

[a] The total bag is estimated at 625,000 Mallard, of which half is estimated to be hand-reared and released birds.

a rapid accumulation of nutritive stores takes place prior to migration and breeding (geese: Ebbinge 1989; Owen *et al.* 1992; dabbling ducks: Owen & Cook 1977, Fox *et al.* 1992; waders: Pienkowski *et al.* 1984). For some wader species, there is evidence that the carrying capacity of the estuarine wintering grounds has already been reached (Goss-Custard & Moser 1988, Moser 1988). For wildfowl, no conclusive evidence exists, but what is available tends to support the hypothesis that carrying capacity of the winter habitats limits populations (Bell & Owen 1990). Thus, impacts of disturbance are expected to be especially severe during the late winter when food has been depleted and energy demands are high. During spring staging, when days are longer and production of animal and plant prey has started, impacts are expected to be less severe. Susceptibility will increase, however, in situations with strong intraspecific competition for space-limited resources, as has been suggested to be the case in Dark-bellied Brent Geese *Branta bernicla bernicla* on their spring-staging areas in the Dutch Wadden Sea (Teunissen *et al.* 1985, Ebbinge 1992).

So far, most studies of disturbance have been observational, with the associated problems of controlling for confounding effects and determining causal relationships. One way of increasing the chances of isolating any impacts of disturbance is through large-scale field experiments (Gutzwiller 1991). In this paper, I review progress of two such experimental studies on migratory waterfowl. One involves a manipulative experiment to test whether or not human activities, in particular wildfowling, caused disturbance. The other involves a 'natural' experiment where the impact of human disturbance on body condition and subsequent breeding success of spring-staging Pink-footed Geese *Anser brachyrhynchus* could be assessed. Both studies are still in progress.

LARGE-SCALE DISPERSION OF AUTUMN-STAGING WILDFOWL

Positioned between the Baltic and the North Sea, Denmark occupies a central position for waterfowl using the East Atlantic flyway. Large areas of shallow-water fjords and lagoons provide the potential for large concentrations of migratory wildfowl. National surveys show that, in total, these wetlands may hold 200,000–300,000 dabbling ducks at one time in autumn (Joensen 1974). Based on a simple calculation of turn-over rates, however, Madsen & Pihl (1993) estimated that several million dabbling ducks pass through the country within one autumn (Table 1). Even though the analysis is crude and subject to bias, the magnitude of the difference between the numbers counted and the estimated numbers passing through indicates that there is a rapid turnover in numbers of dabbling ducks.

Through the 1970s and 1980s, there was considerable discussion between ornithologists and hunters about the possible disturbance effects of wildfowling on the numbers and distribution of waterfowl in Denmark. Prompted by this, a large-scale experiment was initiated in 1985 in two coastal wetlands declared as Ramsar sites under the Convention on Wetlands of International Importance. The aims were (1) to test whether or not human recreational use, particularly wildfowling, was limiting waterfowl numbers in Danish wetlands during autumn and (2) to develop empirically based refuge models that would allow sustainable use of the areas. The detailed results are given in Madsen *et al.* (1992a,b) and summarized in Madsen (1993a,b). The project was planned to terminate in 1991, but due to unexpected results, it will be continued until 1996. The project can be divided into three phases: 1985–1988, baseline observations; 1989–1991, experiments; 1991–1996, long-term monitoring of the effects of permanent refuges.

In both areas, the main habitat is shallow water with submerged Eel Grass *Zostera marina*, Yellow Cress *Ruppia* and Pondweed *Potamogeton*, with adjoining salt marsh and reed swamp. Swans, geese and dabbling ducks are the dominant waterfowl. During autumn, the areas are used mainly for wildfowling and fisheries and more extensively for leisure activities, e.g. walking, sailing and wind surfing. Wildfowling takes place on salt marshes from punts or from motorized boats.

Baseline studies indicated that in both study areas wildfowling was the only critically disturbing activity during autumn. Therefore, experiments addressed solely disturbance from this source. It was predicted that if shooting was

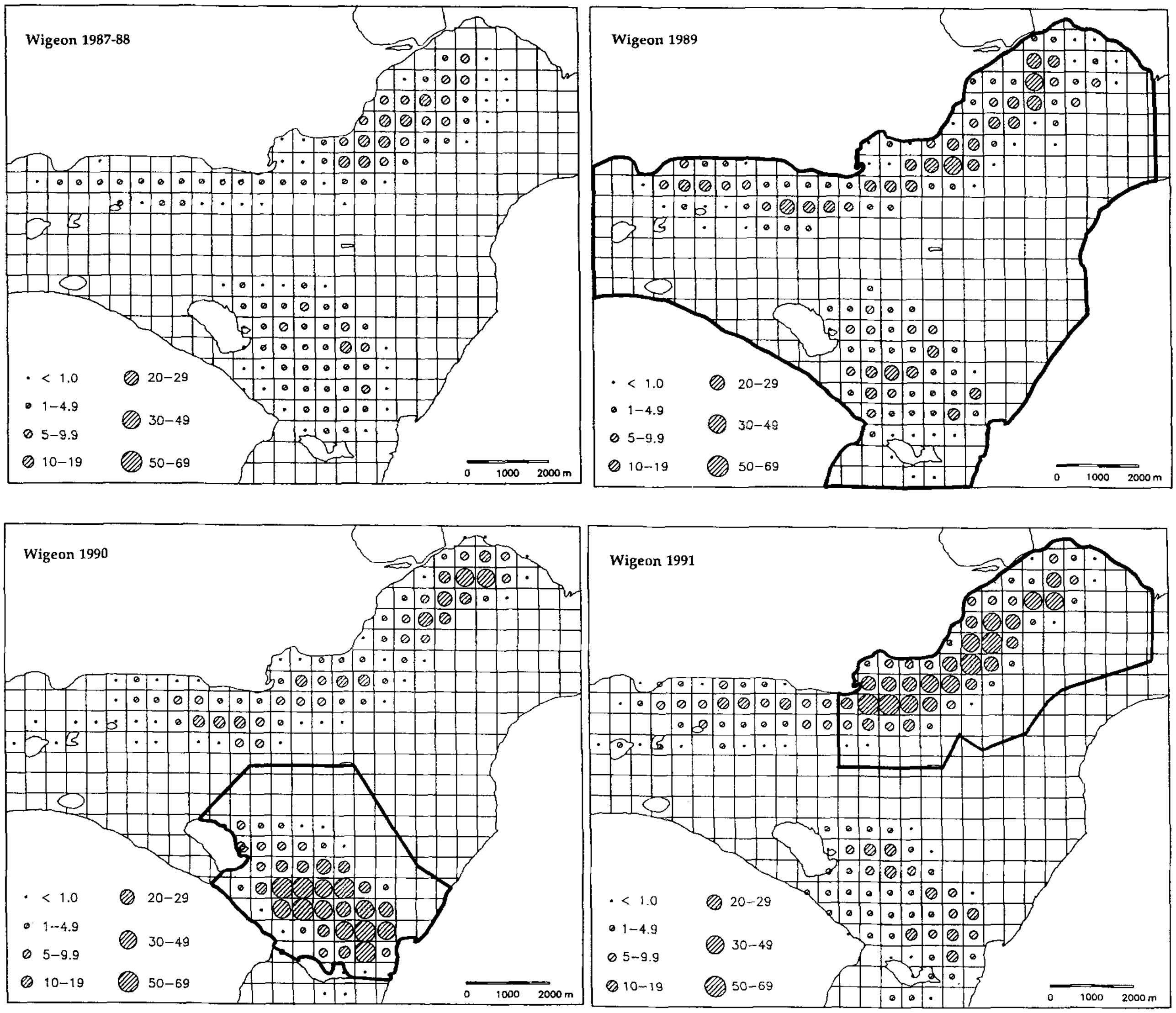

Figure 1. Distribution of Wigeon in Nibe Bredning, a large shallow-water fjord in northwest Denmark, 1987–1991. Numbers are expressed as Wigeon-days spent during autumn in 500-m × 500-m squares of shallow water. In 1987–1988, no refuges existed; in 1989 there was a ban on shooting from mobile punts in the whole area; in 1990, there was a complete shooting ban in the southern part of the area; in 1991, there was a complete shooting ban in the northern part. Refuge boundaries are shown by broad lines.

causing disturbance and suppression of waterfowl numbers below the carrying capacity set by the food resources, the creation of refuges would lead to (1) a redistribution of birds that would be most pronounced in quarry species, with increased densities within the refuges, and (2) the overall increase in bird numbers would be most pronounced amongst quarry species. To test this, refuge areas were set up in both study areas during a 3-year period. Waterfowl numbers and distributions were compared with the baseline counts. In one area, the experimental reserves comprised only shallow water, while in the other, salt marsh was included.

In both areas, the experiments showed that wildfowling caused disturbance; not only did the birds redistribute themselves as expected (see Fig. 1), but numbers increased, most dramatically in dabbling ducks and quarry geese (4–20-fold increases) but also in protected swans, geese and waders (2–5-fold increases) (Madsen *et al.* 1992a,b and unpubl. data). Furthermore, in most quarry species, the staging periods were prolonged by up to several months compared with the baseline periods.

In most species, numbers progressively built up during the three experimental years, suggesting a lag in response. When permanent refuges were set up in 1992, following the experiments, it became possible to monitor longer-term changes. In one area the growth in numbers may now be levelling off (as exemplified by Wigeon *Anas penelope* in Fig.

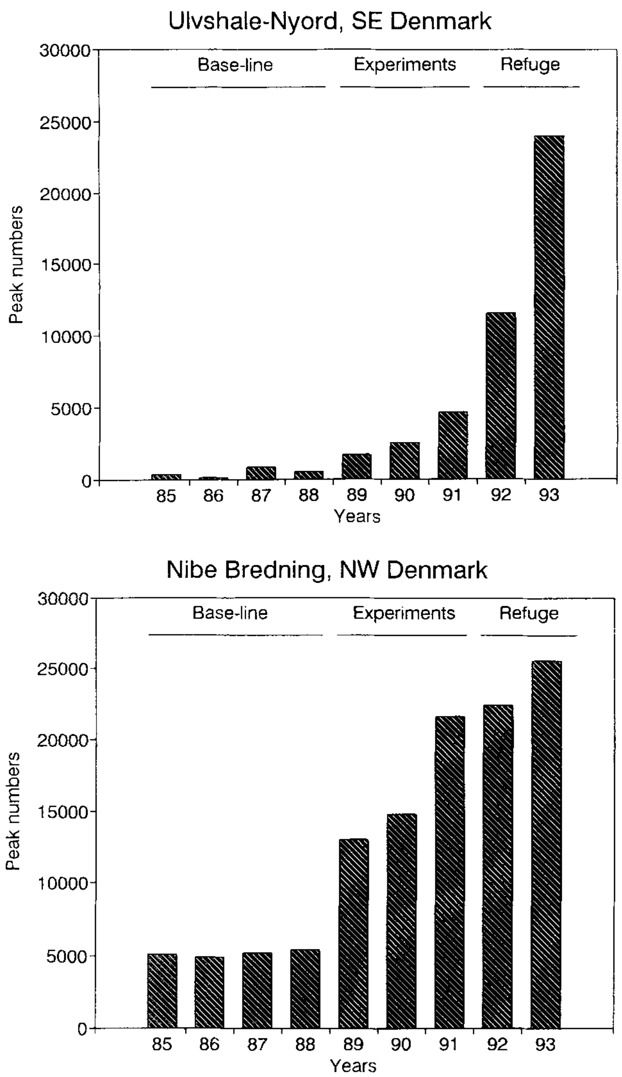

Figure 2. Development of autumn-staging Wigeon numbers in two Danish wetlands, 1985–1993. During 1989–1991, experiments with different refuge systems were carried out, and from 1992 onwards, there have been permanent reserves in both areas.

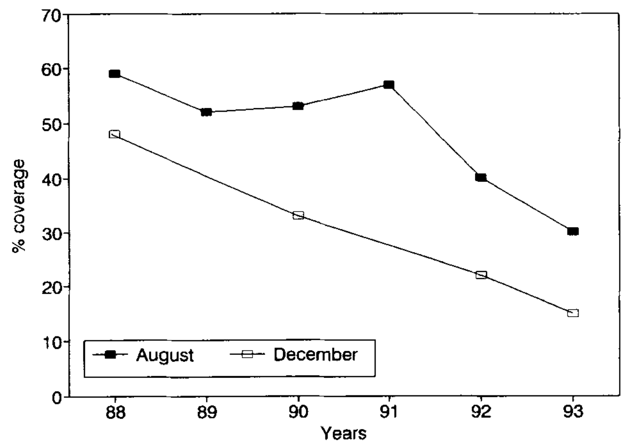

Figure 3. Cover of Eelgrass in Nibe Bredning, August and December 1988–1993, at water depths of 0.5–2.0 m. The cover was estimated at 46–90 transect points; each point covered an area of *c.* 200 m^2, and points were 100 m apart on four transect lines. Two December samples (1989, 1991) were not carried out due to severe weather. In the early summers of 1992 and 1993, there was a marked die-off of Eelgrass, probably due to shading by algae.

2), whereas in the other area there is still an exponential growth in numbers. It is still too early to judge whether or not the food resources can support more birds; however, in both areas heavy grazing by waterfowl on the submerged vegetation has been observed, and in one area *Zostera* is now almost fully depleted in the refuge area by early winter (Fig. 3).

The increases in numbers of some of the protected species can be explained by the increase in the population size over the same period; e.g. swans have increased in the Baltic due to a series of mild winters. But in most quarry species, the local increases were much greater than would be expected on the basis of the overall population increase. Food supplies in the two areas either were stable throughout the study period or decreased (Fig. 3) and cannot explain these local increases in numbers.

While the numbers of birds grew in the two study areas, no concurrent reductions in waterfowl numbers were observed in neighbouring staging areas (Madsen *et al.* 1992a,b). This suggests that, rather than being a result of 'draining' birds from adjacent areas, the increases in the refuges were due to the cumulative effect of an increasing number of birds staying for a longer period than previously. In other words, the birds were 'captured' by the refuges and hence were 'lost' from areas farther down the flyway.

By the creation of the two reserves, two of the most important sites for coastal waterfowl in Denmark were established. Consequently, the national autumn staging numbers of both Wigeon and Shoveler *Anas clypeata* have nearly doubled.

As a result of an historic agreement made in 1992 between non-governmental environmental organizations and the hunters association, under government regulations approximately 50 new waterfowl refuges will be established in Danish Special Protection Areas over the next 5 years. If the areas and habitats are properly selected, according to the experience from the experimental reserves, this large-scale 'injection' of disturbance-free areas could lead to dramatic increases in the autumn-staging numbers, particularly of dabbling ducks and some goose species (Madsen & Pihl 1993). The scale of this extension to the Danish refuge network is so large that it could affect the autumn dispersion of substantial parts of several flyway populations. The experience from the experimental reserves, along with earlier work in the Danish Wadden Sea (Madsen 1988), shows that, due to disturbance, waterfowl leave staging areas when resources

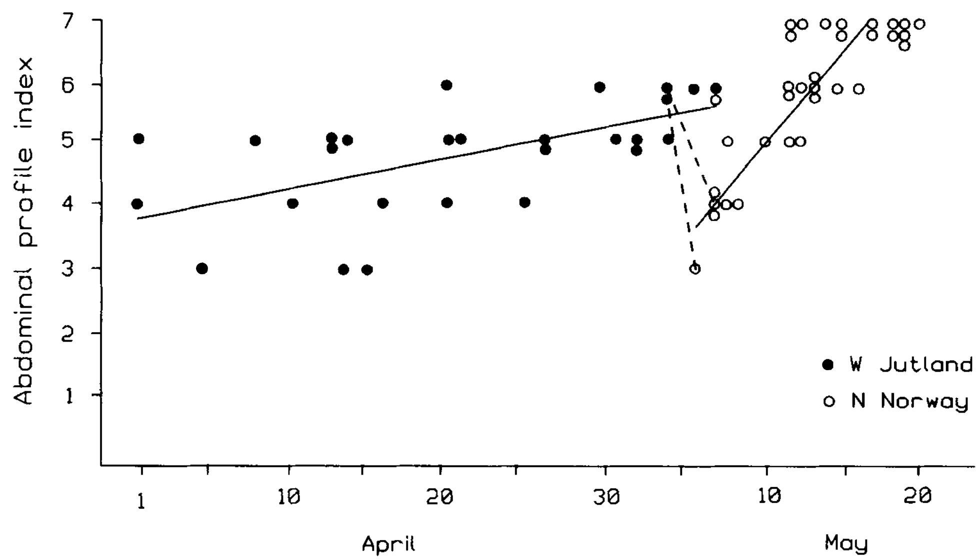

Figure 4. Development of abdominal profiles in neck-banded female Pink-footed Geese during spring 1992 in west Jutland, Denmark, and Vesterålen, north Norway. Data from 20 females, seen on several dates and in both areas, are shown. Lines were fitted by eye. Two females, shown by stippled lines, were observed with a lapse of 1 and 2 days in Denmark and north Norway, respectively.

are still plentiful. Consequently, creating these reserves should result in improved resource utilization along the migration routes and, if population sizes really are limited by winter resources, lead to improved winter survival.

The effects of the new refuges on numbers and distributions of coastal waterfowl will be monitored by the National Environmental Research Institute. Studies will be initiated to analyse the effects on population turn-over and dispersion, on impacts on body condition and, it is hoped, on survival rates in selected populations. Thus, we hope to establish whether the refuges will just redistribute birds along the flyways or will lead to increased population sizes.

BODY CONDITION AND BREEDING SUCCESS OF PINK-FOOTED GEESE

As a prelude to nesting, arctic-breeding geese lay down body reserves of fat and protein on their spring-staging areas. During three seasons, we studied the timing and dynamics of the accumulation of reserves by the Svalbard population of the Pink-footed Goose (Plate 1). The development of abdominal profiles of individually neck-banded geese was followed during their spring staging in western Denmark and later in Vesterålen, northern Norway. We used a seven-point scale of the abdominal profile index (API), modified from Owen (1981). Geese were caught and marked in three springs (1990–1992) in western Denmark. For both females and males, there was a significant linear relationship between weights at capture and the abdominal profiles scored immediately afterwards in the field (J. Madsen, unpubl. data). Geese were observed intensively throughout spring, yielding an average of 20 resightings per individual per season.

In western Denmark, geese gradually build up their condition from March until their departure to the staging areas in northern Norway in early May (Fig. 4). They lose condition during the flight, but during their 1–3-week stay in northern Norway, they build up their reserves even faster, reaching a peak prior to departure for the Svalbard breeding grounds between 15 and 20 May. In Denmark, the geese feed on pastures and newly sown cereal fields, whereas in northern Norway, they feed on fertilized grasslands used for sheep grazing and hay making.

The API for both sexes increased rapidly after arrival in northern Norway in 1991 and 1992. In contrast, the API changed only slightly in 1993 (Fig. 5). As weather conditions were comparable in all 3 years and grass growth rates mea-

Plate 1. Pink-footed Goose in alert posture.

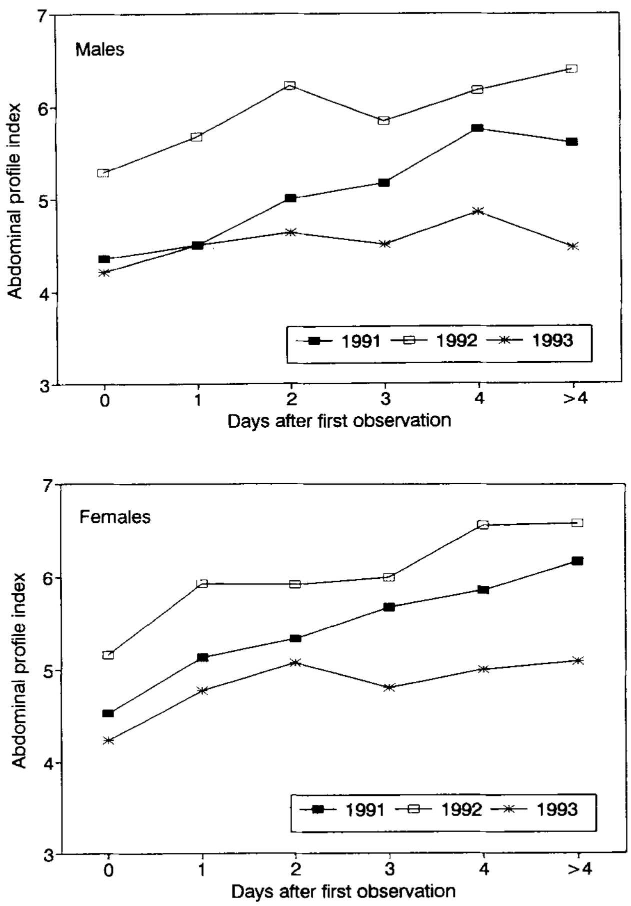

Figure 5. Development of abdominal profiles in individually neck-banded female and male Pink-footed Geese in Vesterålen, north Norway, 1991–1993. Calculated abdominal profiles are means for individuals when first observed (day 0) and thereafter resighted during the following days. The minimum sample size is 25 individuals for each year and sex.

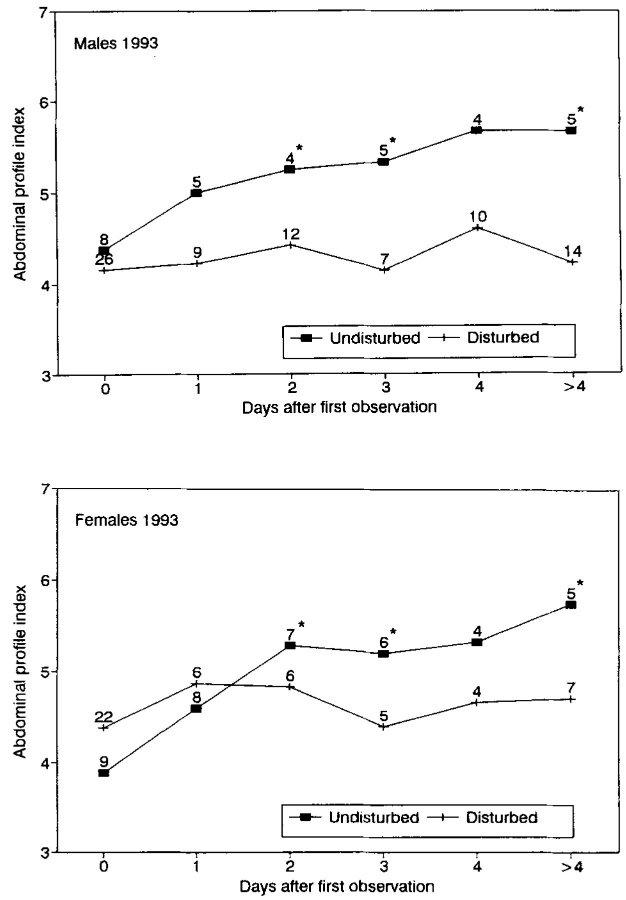

Figure 6. Development of abdominal profiles in individually neck-banded female and male Pink-footed Geese which were disturbed frequently by farmers or were undisturbed, respectively, while feeding in fields at Vesterålen, north Norway, 1993. Calculated abdominal profiles are means for individuals when first observed (day 0) and thereafter resighted during the following days. Numbers above points are sample sizes, and asterisks indicate that there is a significant difference between abdominal profiles of birds in undisturbed and disturbed sites ($P < 0.05$, Mann-Whitney U-test).

sured in 1992 and 1993 were similar, food supply cannot explain the differences between 1991, 1992 and 1993.

There was little conflict with farmers during the first 2 years of the study. By spring 1993, however, the farmers had lost patience, following years of negotiation for a compensation scheme for grass production lost to the geese. In consequence, most farmers in Vesterålen organized a campaign against the geese, scaring them off the fields as often as possible. In two areas, however, the farmers did not scare the geese. This created a 'semi-experimental' situation in which the development of API in disturbed and undisturbed site-faithful geese could be compared. Approximately two-thirds of the birds observed on two or more occasions remained within either the disturbed or undisturbed sites. In the disturbed sites, the API of females and males did not change during the staging period, whereas in the undisturbed sites, the API increased (Fig. 6). Growth rates and nutrient content of grass in the two areas were not measured, but field condition or management did not appear to differ. Furthermore, there appears to have been no difference in the quality of birds utilizing the disturbed and undisturbed sites. Thus, there was no significant difference in API on arrival (Fig. 6) or in past breeding success, recorded on the wintering grounds during the previous three seasons (J. Madsen, unpubl.). The most likely explanation for the difference in development of APIs in 1993 was the disturbance caused by farmers.

The breeding success of the marked geese was assessed in the subsequent autumn and winter of 1993–1994. Of 13 pairs with one or both birds carrying neck collars and which had used the undisturbed sites in northern Norway in the previous spring, six bred successfully (46%). In contrast, of

42 pairs using the disturbed sites, only seven bred successfully (17%). The difference is significant ($\chi^2_1 = 5.02$ with Yates' correction, $P < 0.05$). So, despite the small sample sizes, the data indicate that disturbance can affect body condition and subsequent reproductive output. At the same time, the results also highlight the importance of body reserves for reproductive success.

The Norwegian farmers have announced that they will continue their scaring campaign in spring 1994. We shall attempt to follow this to see how the disturbance affects the energy budgets of individual geese and their ability both to accumulate body reserves and to produce offspring.

FUTURE RESEARCH NEEDS

Before a more quantified judgement can be made about the impacts of disturbance, there is a need for a more basic understanding of waterfowl population regulation on the one hand and their dispersion and local and large-scale movements on the other. Optimal foraging theory provides a useful theoretical framework for analysing factors affecting patch selection and exploitation (Cayford 1993). By viewing disturbance as a predation risk, it should be possible to interpret with greater precision the factors that trigger a bird to stay or leave a foraging patch.

The experimental reserve study suggests that some of the present distribution of waterfowl may result from human-induced disturbance, pushing birds out of some areas and concentrating them in others. It is already known that shooting can have a widespread impact on dispersion of waterfowl. This is perhaps best exemplified by geese. For example, in autumn, Pink-footed Geese from Svalbard virtually bypass Denmark as a result of disturbance and fly to the Dutch and Belgian wintering grounds (Madsen & Jepsen 1992). Similarly, in Belgium and in the Lower Rhine in Germany, major wintering concentrations of White-fronted Geese *Anser albifrons* have developed as a result of bans on shooting (Meire & Kuijken 1991, Mooij 1991). These examples show that we need to analyse disturbance effects in the context of the larger flyway, a need which does not make interpretation any easier.

Models have been developed to predict the consequences of habitat loss on shorebird populations (Sutherland & Goss-Custard 1991, Goss-Custard *et al.* 1995). In situations where human-induced disturbance results in birds abandoning a site, disturbance can be regarded as equivalent to habitat loss, although its effects are reversible. The difference between construction-induced habitat loss and disturbance is that, to a certain extent, birds can buffer or compensate for the disturbance by catching up on lost feeding opportunities later. Alternatively, they might habituate to the disturbance stimuli. Madsen (1993b) showed that there may be threshold levels of activity below which the use of a site by waterfowl is largely unaffected by human use. Beyond this point, however, bird use will drop. Furthermore, some activities will have lower thresholds than others. From both a modelling and a nature management point of view, the identification of such cut-off points is essential and provides a challenge for future research on disturbance.

The ultimate goal of research on disturbance is to ensure that management optimizes the twin goals of wildlife preservation and recreational opportunities (Cole & Knight 1991). Likewise, 'wise use' and 'sustainable use' are concepts which are used increasingly by nature managers and politicians in relation to wetland and population management. These concepts need to be defined operationally on a sound ecological basis. While disturbance is surely an important component of what will inevitably be a complex equation, researchers and managers need to discuss the definitions of the term so that a more unified research approach can be formulated to look into the problem and, in turn, help define acceptable levels of recreational activity.

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