Possible impacts of disturbance to waterbirds: individuals, carrying capacity and populations

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Disturbance to birds is defined as any human activity inducing unusual behaviour. Any deviations from undisturbed behaviour, but particularly escape responses from the disturbed site, are bound to result in extra energy expenditure. These extra costs have to be compensated for by an increase in food intake, achieved by either longer foraging bouts or by more efficient foraging. Birds disturbed while foraging suffer loss of foraging time which should also be compensated for. Because of this extra food consumption, the carrying capacity of sites for waterbirds, as expressed by the available food resources, is likely to be reduced in frequently disturbed areas. If the birds do not grow accustomed to human disturbance, repeated disturbances of areas will thus result in a lowering of their carrying capacity for waterbirds or in a decrease in body condition of the birds. Both these effects may lead to increased adult mortality, emigration and/or decreased reproductive success and, therefore, to negative effects on population sizes. Extrapolation of effects on individual birds suggests that site or population impacts are possible. Future efforts at assessing and evaluating recreational developments in important wetlands for birds, should attempt to take these large-scale effects of disturbance into account.

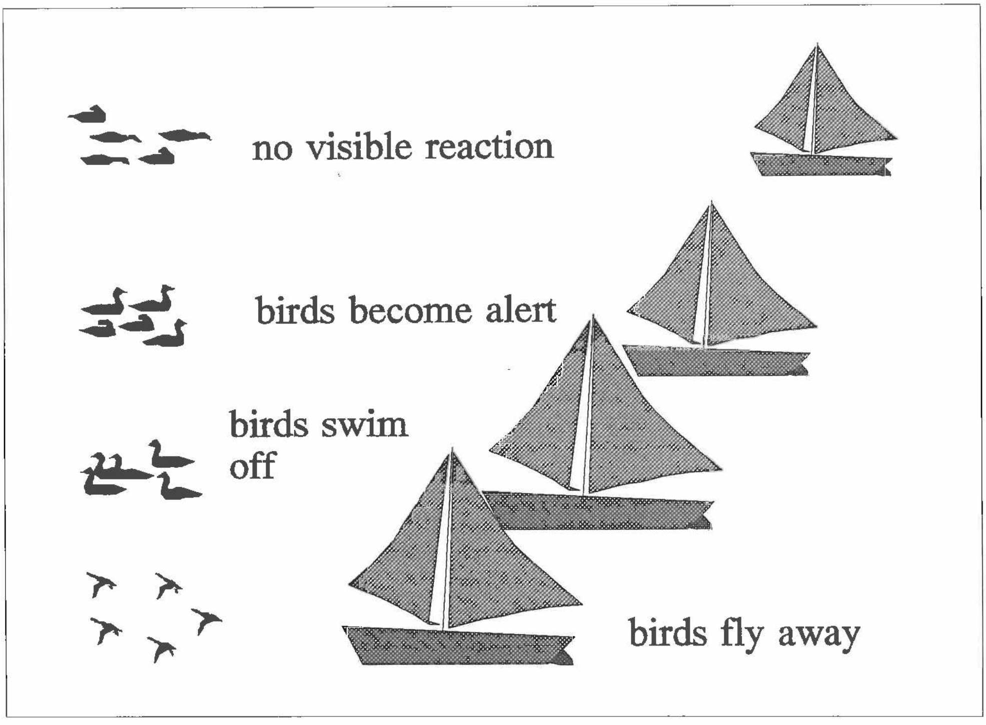
Keywords: Waterbirds, Disturbance, Carry Capacity

The normal behaviour of any bird may be disturbed by outside influences. Thus, any deviation from normal behaviour in response to unexpected occurrences in the vicinity of a bird can be defined as a disturbance. Waterbirds in their natural environment are primarily either engaged in foraging activities or in comfort behaviour, the latter including both resting and preening. In the breeding and pre-breeding seasons they also spend time in courtship display, nest building, incubation and in feeding young. Furthermore, many species, undergo a simultaneous feather moult in late summer, during which time they are flightless for about a month. In some areas, like in The Netherlands, an enormous increase in the recreational use of water bodies through aquatic and shore-based tourism has occurred since the 1960s and a further increase is to be expected in the future (eg Ter Haar *et al.* 1995). Waterbirds often respond to the presence of recreational activities in their environment by deviations from their predominant behaviour (eg Batten 1977, Tuite 1982, Putzer 1983, Tuite *et al.* 1983, Daalder & Brouwer 1984, Kuyk 1985, Dietrich & Koepff 1986, Vos *et al.* 1987, Grice 1990, Platteeuw & Henkens 1997). Such studies have demonstrated that disturbances occur and some have attempted to evaluate impacts. This paper aims to provide a framework, based on a literature review, within which the responses of individual waterbirds to disturbances may be converted to an assessment of their possible impacts at the level of local or regional populations and on the carrying capacity of the environment. The intention is to reveal what kind of knowledge of waterbird ecology and of the incidence of human disturbance, is necessary to assess and evaluate impacts quantitatively.

Potential sources of disturbance from recreational activity

Recreation in wetland areas occurs in a wide variety of forms. Within the IJsselmeer area in The Netherlands, sailing is the most abundant form of recreation, with vessels of varying types and sizes (eg Heidemij 1993, Ter Haar *et al.* 1995). Nonetheless, important numbers of motor yachts, speedboats (with or without water-skiing), windsurfers and jetskis also make use of particularly the most inshore parts. Furthermore, anglers and swimmers roam the shorelines and thereby potentially cause disturbance to birds staying close inshore. The influence of any of these forms of wetland recreation on the waterbirds using the same area varies according to the precise form of recreational activity, the duration of the activity and the behaviour of the people involved in it. Thus, fast and/or unpredictably moving vessels such as speedboats, windsurfers and jetskis are likely to disturb larger surface areas than motor yachts or sailing vessels that tend to move slower and along more or less fixed routes. Moreover, the first category of recreation tends to remain at more or less the same site, usually operating from a recreational beach, while the latter is more inclined to be *en route* from one place to another. Therefore, the category of 'fast moving' recreational activities will generally disturb a site for a relatively long period of the day but leave other sites virtually undisturbed, while the category of 'slow moving' vessels will generally disturb a larger area but for a much shorter period of time. Moreover, since the slow moving vessels

Figure 1. Schematic representation of the four types of waterbird response to approaching sources of human disturbance distinguishable in the field.



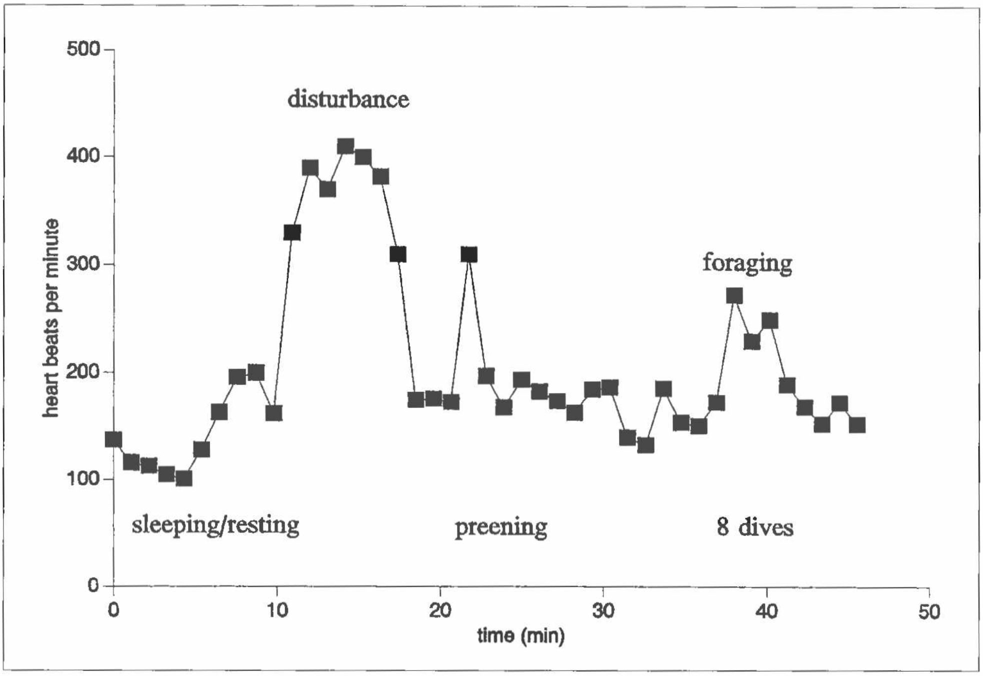


Figure 2. Fluctuations in the rate of heart beats in a captive male Tufted Duck during a sequence of sleeping/resting, some ten minutes of human disturbance and half an hour of preening and foraging afterwards. During the disturbance no visual change in behaviour could be discerned with respect to the period before. (courtesy of J.J. De Leeuw).

predominantly use the offshore areas of the lakes, which during daytime are only used by scattered flocks or individuals of piscivorous birds (eg grebes, cormorants, terns), they will only marginally disturb concentrations of resting waterbirds that generally occur in more sheltered inshore waters.

Individual responses to disturbances

For a field observer, four different categories of responses to the approach of a potential source of disturbance can be distinguished:

No visible reaction: in the presence of a potential source of disturbance the bird continues doing what it was doing before.

Bird stops present activity and is alert: all attention is given to the source of disturbance.

Bird temporarily leaves the patch disturbed: bird is scared off, either flying or swimming/diving, and then either settles at another patch in the immediate vicinity or returns after disappearance of source of disturbance.

Bird leaves the site disturbed, not to return the same day.

These four categories may also represent four consecutive stages in the response of a bird or flock directly being approached by a source of disturbance (eg a sailing vessel; **Figure 1**).

Although experiments with Tufted Ducks *Aythya fuligula* in captivity, equipped with heart-beat telemetry recorders, have shown that disturbance may also influence physiology and therefore energy expenditure when no outward signs of behavioural changes can be discerned (**Figure 2**), most of this paper's considerations involve the clearly visible responses in the field. When a resting bird becomes alert, its metabolic rate increases by about a factor of 1.2 (Birt-Friesen *et al.* 1989),

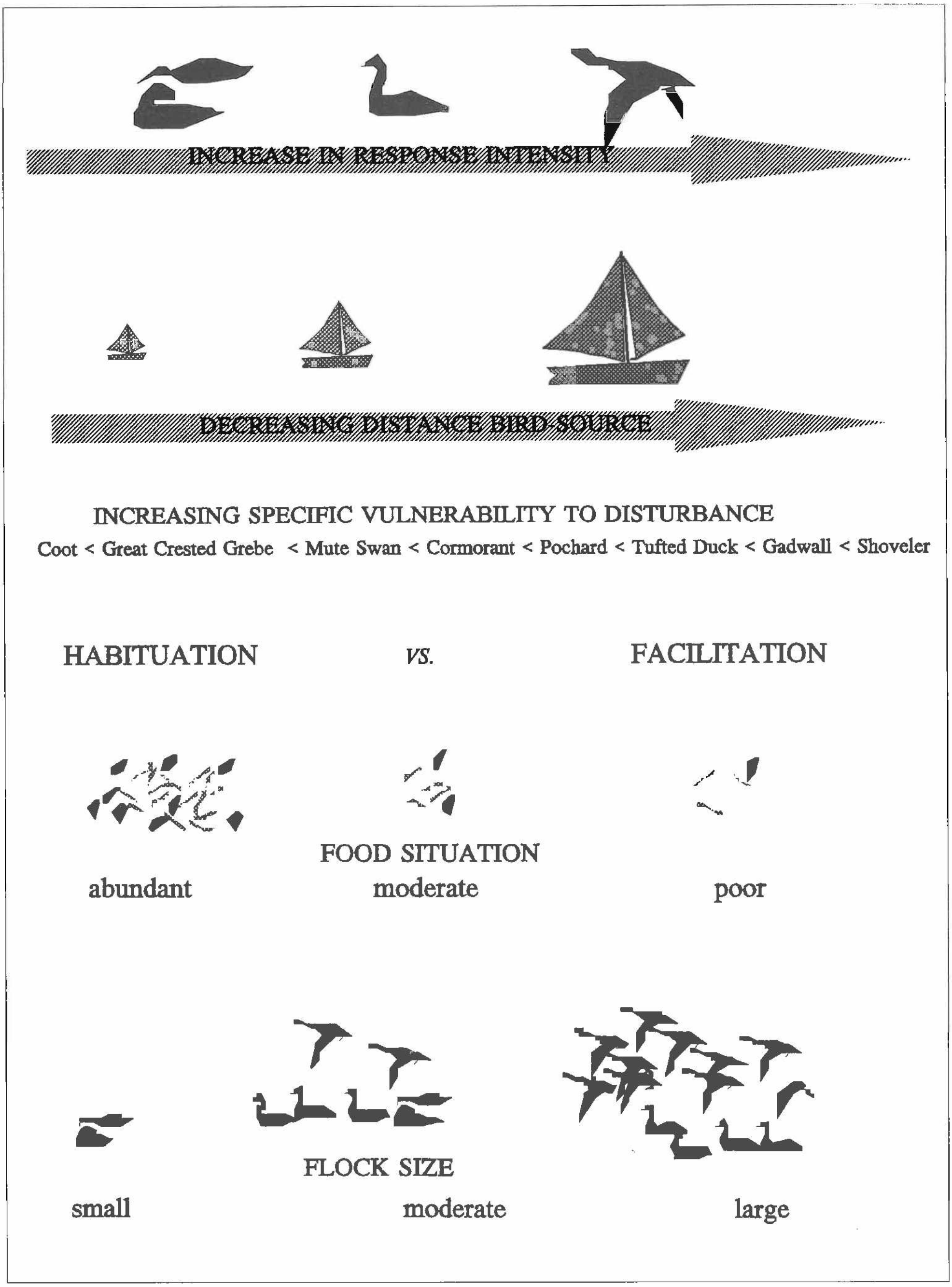


Figure 3. Schematic representation of the factors influencing the nature of an individual bird's possible response to human disturbance: distance to source; bird species; habituation vs. facilitation; food situation (or degree of satiation of the bird); flock size.

involving extra energy expenditure. A foraging bird being alarmed will probably not increase its energy expenditure significantly, but surely suffers a loss of feeding time, which should be compensated for later on. These negative consequences for maintaining a favourable energetic balance become even more acute when the bird is scared off through disturbance. Both flying and diving involve a two-times increase in metabolic rate with respect to surface swimming (Birt-Friesen *et al.* 1989), and the greater the time spent in avoiding the disturbing object, the greater the energy expenditure. When waterbirds are thus disturbed for about 6-7 hours a day (average duration of recreational activities at in the IJsselmeer region; Henkens 1996), daily energy expenditure on a crowded day may be about 20-50% greater than that on a quiet day.

Factors influencing individual responses

The nature of the individual response of a bird to disturbance largely determines the effects of the disturbed behaviour on its individual 'well-being'. It is, therefore, important to identify the factors that influence the nature of the individual response (**Figure 3**).

Evidently, in most cases, an increase in response-intensity occurs with a decreasing distance between the source of disturbance and the bird. Moreover, not all waterbird species show the same susceptibility to disturbance. Observations at Lake IJsselmeer suggest that Coot *Fulica atra* are the most confident species, remaining unperturbed at distances of <10 m, while Gadwall *Anas strepera*, Shoveler *A. clypeata*, Pochard *Aythya ferina* and Tufted Duck often fly off at distances of several hundreds of metres (Van Harskamp & Henkens 1994, Henkens 1996). Some of the wintering species in the IJsselmeer area seem to be even shyer (eg Scaup *Aythya marila* and particularly Goldeneye *Bucephala clangula*; Platteeuw & Beekman 1994), but these species generally do not have to cope with high densities of recreation.

In the case of frequently repeated disturbances, birds may grow accustomed to the presence of humans in their environment. This process is called 'habituation'. Habituation typically occurs when the source of disturbance appears in a rather predictable way, approaching slowly and steadily without any sudden movements and, of course, without imposing any real threat to the birds. Good examples of habituation are often found along frequently used navigation routes or close to yachting harbours. Birds like Coot, Mallard *Anas platyrhynchos* and Great Crested Grebe *Podiceps cristatus* in such places are often seen resting, preening, foraging or even breeding at distances of <50 m from vessels passing by. Breeding Great Crested Grebes on three small lakes with varying recreational pressure in Switzerland showed a decrease in disturbance distance with an increase in recreational pressure (Keller 1989) and a similar relationship was found for Great Northern Divers *Gavia immer* in Minnesota, USA (Titus & Vandruff 1981). These cases are clear examples of the occurrence of habituation. An increase in the incidence of human presence in the waterbird's environment does not, however, always induce habituation. If the appearance of the sources of disturbance is less predictable and/or the approach is faster and more sudden, birds may become even more inclined to fly off with an increasing frequency of disturbance. This process is called 'facilitation' and is particularly likely to occur at sites where disturbances frequently involve real threats, for example in hunting areas. Opening waterbird areas for hunting in Denmark, Germany and Switzerland invariably resulted in the abandoning of the area by most birds, while the reverse happened when hunting was stopped (Géroudet 1967, Brehm 1971, Meltofte 1982). Fast and unpredictably moving sources of disturbance like speedboats, windsurfers and jetskis are often experienced as more threatening than slowly and steadily moving vessels (Platteeuw & Henkens 1997). Future field experiments should be carried out to show whether these activities may also facilitate the escape response in birds, in a similar way as shown for hunting.

Individual responses may also vary according to the situation at the site. A foraging bird at a site with abundant food resources will be more inclined to remain than at a site where food availability is low (**Figure 3**). Similarly, an individual less saturated with food (eg a recently arrived migrant) may be harder to scare away from the feeding patch than a well-fed bird. Other aspects of site or patch quality, such as the amount of shelter from wind or waves, may be equally important for roosts or nesting sites. These sites are bound to be abandoned sooner through disturbance by a hungry bird about to leave for the foraging grounds anyway, than by a well-fed bird (eg Visser 1986).

Finally, flock composition of the birds is a source of great variability in the nature of the responses of the individual waterbirds to human disturbance (**Figure 3**). Generally, the distance at which a bird attempts to escape from a source of disturbance increases with flock size. Members of a flock tend to imitate each other and therefore each flock tends to be as shy as its shyest individual. Thus, we also see that mixed-species flocks tend to fly off at the disturbance distance of the most timid species (Henkens 1996).

Extrapolating individual responses to real-life situations

In spite of the variability in individual birds' responses to disturbance, it should be attempted to extrapolate the most frequently observed response at any particular site to the 'real-life' situation. Only in this way can the necessary steps be taken towards quantitative assessment of the impact of disturbance on birds and sites.

For an impact assessment on birds, it is important to estimate the numbers that are kept away by the presence of human disturbances, as well as the time during which the birds are kept away. Usually, the best possible estimate of the numbers disturbed is obtained by subtracting the numbers still present during disturbance from the numbers present before. However, this calculation may provide an underestimate when more birds are likely to visit the site at the period of maximum disturbance than at the period before, or when the site has suffered so much disturbance in the past that the shyest species have already abandoned it. Conversely, an overestimate is possible in cases when the birds tend to leave a particular site anyway at the time disturbances are most likely to occur. Moulting Great Crested Grebes at Lake Ijsselmeer mainly forage at dawn and dusk, thus seemingly avoiding peak recreational activity. This phenomenon, however, was shown to be related to the availability of their prey in the upper water layer at precisely these times (Piersma *et al.* 1988, Van Eerden *et al.* 1993). The duration of disturbance depends on both the number of disturbances and the individual duration of each.

For impact assessments on particular sites, the duration of the disturbance as well as the surface area disturbed should be known. In order to estimate the latter, so-called 'disturbance distances' (defined as the distance within which behavioural changes due to disturbance effects begin to occur) have to be known for the various species of waterbird present at the site. Many field studies have been dedicated to establish these 'disturbance' or 'flight' distances, either through direct observations (eg Batten 1977, Putzer 1983, Daalder & Brouwer 1984, Kuyk 1985, Dietrich & Koepff 1986, Vos *et al.* 1987, Henkens 1996) or through experimental disturbances directed by the researchers themselves (eg Biemans 1987, Platteeuw & Beekman 1994). The disturbance distance (d) can be considered as the radius of an imaginary circle drawn around a bird within which no disturbance is tolerated, but alternatively also serves as the radius of the imaginary circle around a non-moving vessel within which no birds (of a certain species) will be left (**Figure 4**). Usually, however, recreational vessels (or canoes or windsurfers) will be moving at a velocity of v m.s-1, thus sweeping clear a surface area of $2.v.d + \pi.d^2$ [m^2] each second (**Figure 4**). Any bird within the disturbance distance will be scared away from this belt of water for at least the time it takes for the vessel to cross the area. Disturbance

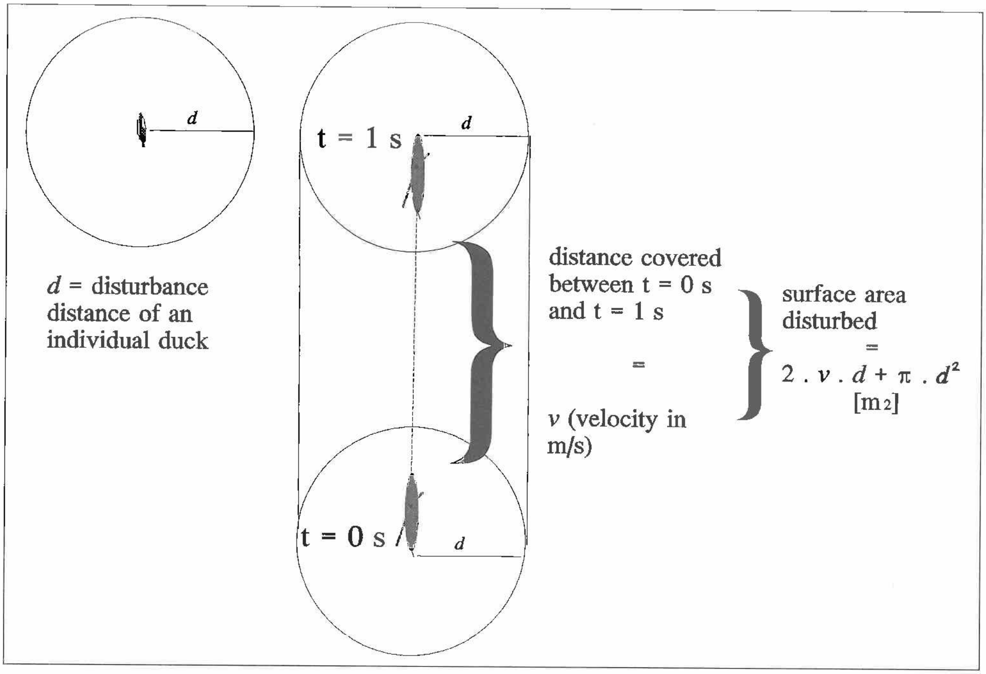


Figure 4. Relationship between distance at which a bird responds to disturbance (d), vessel speed and the surface area disturbed by a vessel per unit of time.

time is further enhanced by the time interval between disappearance of the source of disturbance and the return of the birds to their original site and behaviour, the so-called 'recuperation time'. This time lag will have to be estimated in the field.

Evidently, dose-effect relationships are complicated and species-dependent and should be mainly concerned with the translation of incidence and 'nature' of recreational activity at a given site to surface area 'swept clear' per day. The possible consequences of (temporary) unavailability of certain roosts or foraging grounds for waterbirds and the carrying capacity of their environment are discussed in the next section.

Consequences of temporarily abandoning a site

When waterbirds are scared away from a site, and therefore have to take refuge at an alternative one, their energy expenditure increases for a number of reasons. The stress involved, as expressed by an acceleration of the heart beat frequency, as well as the extra swimming, flying and/or diving activity caused by the disturbance all contribute to this increase. Diving ducks on a 3750 ha lake were flushed off by recreational vessels about five times per day at a density of, on average, one boat per km^2, involving about an hour extra flying time per day (Korschgen *et al.* 1985). Extra pressure may result from loss of foraging time or from increased travelling time between roost and feeding site (when forced to take refuge on roosts at larger distances from the feeding sites). Thus, disturbances of foraging Snow Geese *Anser caerulescens atlantis* in Canada by hunters and low-flying aircraft resulted in an increase of energy expenditure per hour of 4-5% because of extra flying activity, and of 3-20% because of loss of foraging time (Bélanger & Bédard 1990). Similar losses have been demonstrated for Snow Geese by Davis & Wiseley (1974) and for Brent Geese *Branta bernicla bernicla* by Owens (1977) and

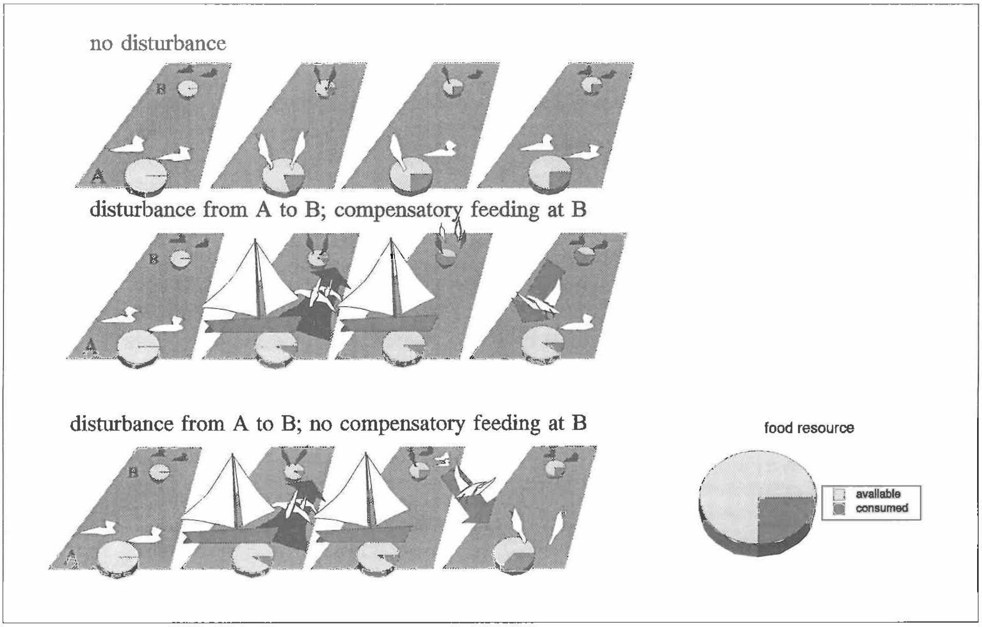


Figure 5. Consequences of repeated disturbances of waterbirds from a potential feeding site (A) to an alternative site (B) on the availability of food resources. Two examples are illustrated: with compensatory feeding at alternative site (B) (food resources at (B) are heavily over-exploited partly due to enhanced intra-specific competition, food resources at A underexploited) and without compensatory feeding at B (food resources at B are exploited at a 'normal' level, food resources at A are over-exploited).

Riddington *et al.* (1996). Birds that have to change their feeding sites because of disturbance will have to forage elsewhere. There they may meet higher densities of conspecifics, entailing a higher incidence of agonistic interactions and a corresponding extra loss of energy and foraging time. This phenomenon has been observed for waders foraging at low tide in the Dutch Wadden Sea (Zwarts 1972, Zegers 1973).

The extra energy expenditure caused by repeated disturbances will have to be compensated for by either an increase in foraging time or an increase in food intake per unit of foraging time. When this compensatory feeding proves to be impossible a deterioration in physical condition is inevitable. Pink-footed Geese *Anser brachyrhynchus* compensate for each minute of extra flying time by extra foraging of 1.5-2 minutes (Schilperoord & Schilperoord-Huisman 1984). If the disturbance took place early in the morning, this compensation could easily be achieved within the same day, but disturbances in the afternoon were compensated for by foraging at night or by an early start the next morning. The Snow Geese in the study by Bélanger & Bédard (1990) realised the foraging compensation by increased feeding activity at night (4-32% more). Also, for fish-eating Cormorants *Phalacrocorax carbo*, it was estimated by Grémillet & Schmid (1993) that a disturbance of 30 mins would result in requirement for an extra 23 g of fish.

In the long run, the consequences of frequent disturbances to the waterbirds at a particular site will also be noticeable at the level of the carrying capacity of the wetland site. In the case of disturbance from a potential feeding site (A) to an alternative quiet site (B), the birds involved will either feed at (A) when all is quiet again, or at (B) where they are likely to meet competition from conspecifics (**Figure 5**). In both cases the daily food consumption tends to be higher than in the undisturbed situation, because of the need for compensation. Thus, the availability of food resources will diminish (**Figure 5**), which eventually leads to a decrease in carrying capacity. Alternatively, the disturbed birds may not be able to compensate for their extra energy losses and suffer a direct decrease in body condition. This might make them more vulnerable to diseases, parasites etc., may increase mortality and may decrease their reproductive output. These risks are particularly high at critical stages of the year (eg breeding, moulting or wintering), when density- dependent environmental factors are operating. Disturbance to roosts has much the same potential impact, although loss of foraging time will generally be a less important factor. The extra energy requirements caused by stress and extra activity are likely to be similar and in many cases the alternative roosts will be less favourably situated with respect to the feeding sites. The importance of a favourable distance between a breeding colony and the main feeding grounds for body conditions as well as for reproductive success has been demonstrated quite convincingly for Cormorants (Platteeuw & Van Eerden 1995, Platteeuw *et al.* 1995). When the birds have to fly further for their fish, their energy expenditure increases, but they are unable to catch more. Thus, adult body mass will diminish and less food will be brought back for the chicks. So it can be appreciated how the occurrence of repeated disturbances at a site, if it does not cause habituation among the birds, may lead to a population downfall, either through a decrease in carrying capacity or through a deterioration of the body condition (**Figure 6**).

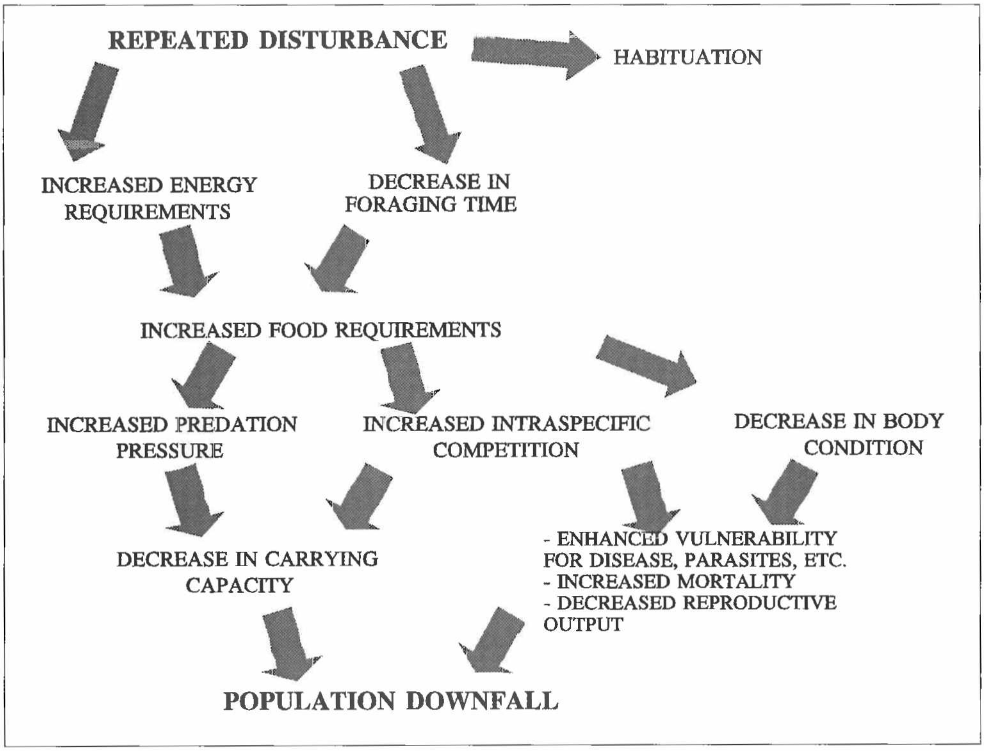


Figure 6. Schematic overview of the routes along which repeated disturbances may either lead to habituation of individual birds or to a population downfall.

Conclusion

It is clear that assessments of the impact of human disturbances on waterbirds are not at all straightforward and, besides numerical information on the birds and recreational pressures, require some very specific knowledge of waterbird ecology, of the behaviour of people and of the vulnerability of birds to disturbance, both in time and in space. Both for the assessment of impacts in existing situations and for an evaluation of different possible future developments in recreational pressure, information should be collected on the following items:

Temporal and spatial use of the area by the birds

Food choice and food availability in time and space

Availability of suitable roosting sites

Flying distances between roosts and foraging sites

Frequency of occurrence of sources of disturbance

Timing of occurrence of sources of disturbance

Density of sources of disturbance

Spatial distribution of sources of disturbance

Vulnerability of birds to disturbance (at which distances and/or recreational densities do birds of different species leave and what is the time lag between the end of human presence and return of the birds - recuperation time, to be added to duration of presence of disturbance)

Variations in response due to different sources of disturbance predictability and/or velocity of sources of disturbance (habituation *vs.* facilitation)

Of course, it will often be almost impossible to take all of these aspects into account when making plans for sustainable wetland development. Nonetheless, attempts should be made to incorporate as much of this information as possible in the planning process, preferably by means of spatial and temporal GIS-based models. Such models will not only help with assessment, but with solutions also for the coexistence of recreation and waterbirds in the same wetlands and, very importantly, will identify any shortcomings in the necessary information.

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