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# The Impact of Noise and Artificial Light on Waterfowl Behaviour:

## A Review and Synthesis of Available Literature

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# The Impact of Noise and Artificial Light on Waterfowl Behaviour :

## A Review and Synthesis of Available Literature

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In respect of the Second Severn Crossing

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Contents

## Executive summary

1. The objectives of this report are to assess (i) the impact of noise associated with traffic and construction-related activities on waterfowl behaviour, and (ii) the impact of artificial light on waterfowl behaviour, including its effect on migration routes.

2. The report structure details theoretical considerations (population consequences of disturbance), sources of the literature, effects of noise and artificial light, other types of disturbance of relevance (recreation, shooting, bird scarers) for which there are bird data, conclusions and references.

3. Little of the searched literature dealt specifically with the first subject area ie. waterfowl, noise and road construction. To some extent the literature is biased towards detecting negative effects since studies are most often undertaken when a problem is perceived. Evidence of effects of noise disturbance has been found for geese, divers, and three species of waders. There are difficulties in making generalisations, not least because the ability of a species to compensate for, say, reduced feeding time caused by disturbance, is little known. Also, the relative importance of noise or construction *per se*, or the presence of people associated with the noise (ie. a busy road near to feeding grounds), is difficult to separate. The ability of a species to habituate to certain forms of disturbance is poorly understood, is likely to be species-specific but is probably more evident in colonial breeders or flock feeders than solitary individuals. The return of a species to its nest site following disturbance is evidence that some habituation takes place during breeding, and greater tolerance is generally shown with the progression of the breeding season. Habituation to noise disturbance is classically shown by the developed tolerance by birds to bird scarers used to protect agricultural crops, and to disperse birds from airports.

4. A number of studies have shown increased vigilance in flock members feeding near structures which impede their vision of the approach of potential predators. This tends to reduce their feeding time and is an important consideration.

5. The literature on the effects of artificial light was sparse. The presence of artificial light has the potential to affect birds in two ways, (i) by providing more feeding time by allowing nocturnal feeding, (ii) by causing direct mortality or disorientation. Attraction to street lights can cause local problems to seabirds on cloudy nights. Generally first year birds are implicated and the suggestion is that they learn to avoid attraction on subsequent occasions. Mass kills of migrants (mainly passerines) at light houses and gas flares at oil rigs are considered much more important. Waterfowl feature much less in reported mortalities at light houses and oil rigs, and are probably less attracted to artificial light conditions.

6. Relevant non-construction-related disturbance effects included water-based recreation such as power boating, coarse fishing, sailing and rowing, together with that related to shooting. Significant reductions in use of inland water bodies by waterfowl have been exhibited as a consequence of increased power boating, although coarse fishing, sailing and boating were also found to be important. Species differ in their tolerance of disturbance. Rarer, less opportunistic species such as goldeneye, shoveler and teal are least tolerant of such disturbance. Species-specific differences should be an important consideration in predicting responses to road-construction-related disturbance.

## 1. Introduction

This report addresses the likely impact on birds of disturbance caused during and after the construction of roads. More specifically it assesses i) the impact of noise associated with traffic and construction-related activities on waterfowl behaviour, and ii) the impact of artificial light on waterfowl behaviour including its effect on migration routes.

No attention is paid, in this report, to the degree of disturbance resulting from construction, nor to its measurement. The measurement of noise is not attempted because of the different prevailing conditions which would make even subjective assessment tenuous. The method adopted in the report is that of a literature review. In view of the sparsity of literature (see section 3) this report must be broad enough in its remit to allow generalisation from some specific studies remote from man-induced noise and light related disturbances, and for groups of birds other than waterfowl. Furthermore, the specific importance of the Severn estuary is not considered, since this is detailed adequately elsewhere (BTO 1989).

The report is structured in the following way : First, theoretical considerations are made since it is important to identify how birds are likely to respond to disturbances and which are the most important population consequences of disturbance. Second, sources of the literature are outlined. Third, sections on the effects of noise and the effects of artificial light are presented by providing discussive abstracts of available literature. Fourth, a brief section deals with other types of disturbance for which there are data for bird effects. A final short conclusion consolidates the previous sections. A full reference list is presented at the end of the report.

## 2. Theoretical considerations

Broadly viewed, disturbance is 'any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment' (White & Pickett 1985). Disturbances are responsible for a change in the state of a system, and systems that are not in equilibrium may therefore be disturbed just as readily as those that are.

Disturbances can be a) natural, such as those caused by fires, avalanches which remove tracts of forest, or floods, or b) man-induced such as those caused by noise and artificial light. Populations of different species vary in the time they require to respond to a disturbance and to recover from it. Birds may be less sensitive than some other organisms (especially sessile ones) to small-scale disturbances (Wiens 1989). Most birds are highly mobile and can move to avoid localised disturbances. For example, during a bush fire in open *Eucalyptus* woodland, resident family groups of Splendid Blue Wrens (*Malurus splendens*) were seen flying from their territories into nearby unburned areas just ahead of the advancing flames. Some birds returned to their territories in the still smouldering bush within hours, and all of the groups had reoccupied former territories within several days. However, other studies have shown that densities of territorial individuals may remain unchanged or change only slowly in response to major changes in habitat structure produced by rangefire or physical removal of shrubs (Wiens 1989).

This report is concerned, however, with the possible effects of disturbance on passage and winter wildfowl and waders. There are a number of possible effects on birds - both direct and indirect. Direct effects relate only to direct mortality. For the purpose of this report both traffic (after construction) and attraction to light sources leading to mortality, are of this category. Indirect effects and the responses by birds to them are summarised in Table 1. Indirect effects do not cause mortality but result in affecting feeding time, interference with breeding and migration, and affect intra and interspecific competition for food or breeding space.

The most likely consequence of disturbance caused by noise and traffic from road construction relates to a reduction in feeding time and feeding area. In either case the habitat will become sub-optimal, and may result in the movement of birds away from the area under disturbance. For example, on estuaries in which feeding habitat is fully exploited by waders and wildfowl, any variable which results in a reduction in the availability of that habitat must be considered to increase bird density on adjacent areas or other feeding sites, as birds are displaced. This has been considered in some detail with respect to ecological impact assessments, using estuary wading birds as a model (Goss-Custard & Durrell 1990). However, the carrying capacity of the habitat is likely to differ between sites so that responses by birds might also differ. Further, habitat exploitation and carrying capacity has been more fully researched for waders than for wildfowl (BTO 1989). The duration and extent of severe weather is likely to exacerbate the importance of disturbance (Owen, Atkinson-Willes & Salmon 1986).

Table 1. Possible effects of disturbance and the potential responses given by birds to primarily noise-related (N) and artificial light-related (AL) disturbances during and after road construction.

| Effect | Potential response |
|---|---|
| Reduction of feeding time (N) | Harrassment, birds move elsewhere |
| Increase in feeding time (AL) | Birds aggregate at food source stimulated by greater light availability at night |
| Interference with breeding (N,AL) | Birds move elsewhere |
| Interference with migration (AL) | Birds disoriented, may lead to mortality |

| | |
|---|---|
| Reduced feeding area (N) | Risk of predation/mortality by proximity of humans or closeness to a structure causes birds to move elsewhere |

Goss-Custard & Durrell (1990) consider that for waders, it is important to understand the factors which determine winter numbers at levels of scale ranging from one estuary to the geographical range of an entire species or subspecies. Increasing or decreasing the opportunity for birds to exploit the food supply in one estuary, for example by road construction, might change bird numbers locally, but factors external to the focal estuary are likely to be of great significance to overall population responses. Movement away from the disturbed areas will not necessarily solve the population effects of the disturbance. Greater intra- and interspecific competition on newly settled sites could preclude any advantages in moving (Goss-Custard 1970, 1976, 1977, Goss-Custard, Jones & Newbery 1977). Further, acceptance that all estuaries present optimal habitats or habitat patches for waders and wildfowl equally is ecologically naive. Some species, for example grey plover, may be benefitting in some way from prevailing estuary conditions since their winter population is increasing in the U.K. (BTO Birds of Estuaries Enquiry), although factors operating on their breeding grounds may also be important. The exploitation of resources by birds at a site therefore has population responses exhibited by dispersal and dispersion. Disturbance may impact on these two processes.

In terms of disturbance effects it is also necessary to differentiate between those attributed to construction and those attributed to the presence of humans during the construction process. Habituation to the disturbance, whether from noise, traffic, or artificial light, may be considerable. Birds are rather adaptable and may accommodate regular disturbance events, which suggests that habituation can take place over a relatively short period of time. This has been seen in least terns (Altman & Gano 1984). Hill & Player (in prep) found that avocets quickly returned to their nest-sites following disturbance caused by human intrusion at the nest-site as part of a gull productivity control programme.

## 3. Sources of literature

Ibis Abstracts and Ecological Abstracts were consulted from 1980 to the present time, resulting in an initial trawl of 35 papers bearing some relevance to the subject area. On individual inspection of these papers some proved irrelevant. A second trawl of those referenced in the initial material provided some additional papers. It is considered that the majority of available material was identified, with the earliest paper published in 1977, although some book references pre-date this. It was decided that material prior to this date would be unsatisfactory in the context of the subject of the study.

## 4. The impact of noise associated with traffic and construction-related activities

Few of the searched literature dealt specifically with the subject area ie. waterfowl, noise and road construction. However, other sources, including other bird groups, have been included for comparison particularly where human-induced disturbance has been studied.

With specific reference to roosts of estuary birds, disturbance is the one factor apart from tide height, which modifies greatly the distribution of roosts (Prater 1981). Few specific studies on the subject have been undertaken although Furness (1973) concluded that the quality of the roost site (habitat type and freedom from disturbance) modified the numbers and distribution of waders of Musselburgh on the Firth of Forth. He went further to suggest that the numbers of oystercatchers and redshanks, as observed at the sites, might be limited by disturbance which he observed caused birds to spend less time feeding in food-rich areas.

There are few data on disturbance caused by estuarine engineering operations. Prater (1981) states that waders, and to a greater extent wildfowl, will move away from the vicinity of active workings, although no specific studies are quoted. On the intertidal flats of Lavan Sands, Conwy Bay, no long-lasting adverse effects were noted when an oil pipe was laid from Anglesey to the mainland, although only a narrow route was used and the work was completed in a few weeks. A much greater impact was shown where the pipe crossed a saltmarsh (Rees 1978), although the species most affected were not quoted. Prater (1981) concludes that construction effects may be significant locally and engineering operations should avoid proximity to established roost sites.

Owens (1977) studied the responses of wintering brent geese to human disturbance. The study found that disturbed areas of the shore, proximity to traffic and places with poor visibility were avoided in early winter but were used later when other areas became depleted of food. The geese became habituated to the proximity of people and to some loud noises but not to low-flying aircraft which had the effect of making them fly. Disturbance in the worst areas prevented geese from feeding for up to 11.7% of the time and caused a seven-fold increase in the amount of time spent flying. Overall levels of disturbance were much lower than this and would have been unimportant so long as adequate food was available on which geese could feed during undisturbed periods, and at night (by compensatory feeding). However, a shortage of food probably prevented complete compensation for the effects of disturbance. It was suggested that disturbance could be greatly reduced by i) restricting public access to the sea wall in certain areas around high tide when the geese are pushed further up the shore, and ii) by controlling the numbers of low-flying aircraft. Further, the significant increase in dark-bellied brent over the past decade has been suggested to have been as a consequence of the creation of disturbance-free refuges throughout its wintering range.

Madsen (1985) studied the impact of disturbance on field utilisation of pink-footed geese in West Jutland, Denmark. Disturbance was broadly defined as both actual which puts geese into flight (eg. traffic, humans, aircraft), and potential such as landscape features and structures which may hide potential predators. The impact of roads and landscape features on field utilisation was examined. The flight distance of goose flocks increased with flock size and was longer in autumn than in spring. Roads with a traffic volume of more than 20 cars per day disturbed birds up to a distance of 500m in autumn, but less in spring. Lanes with 0-10 cars per day also reduced the use of adjacent fields by geese but less so than roads with the heavier traffic. Windbreaks and banks etc., which hinder an open view reduced the use of land up to 200-300 m from such structures. It was concluded that the width of an area of habitat must exceed 500m with no hindrances in order to be acceptable to flocks of pink-footed geese in autumn. In both spring and autumn larger flocks took off at a greater distance from a car than smaller flocks, presumably because larger flocks were capable of greater vigilance. Utilisation of habitat was measured as the mean number of goose days per hectare per visit. In terms of providing suitable habitat for pink-footed geese the size of the area should depend on size of the population, shyness, proximity to other goose feeding or roosting areas. For example, the study concluded that 1000 pink-footed geese would need a) extensive feeding grounds at a distance of 500m away from roads with traffic volumes greater than 20 cars/day; b) traffic on lanes should be regulated as even less than 1 car per day has a depressing effect on goose utilisation, although generalisation of this finding to other situations is probably likely to depend on lane size, quality of food in the fields, and season (cf. Forshaw 1983); c) the width of the area should exceed 1 km and windbreaks, plantations and other structural features should not be established in the area.

Forshaw (1983) found for Pink footed geese in Lancashire that vehicles caused 36% of disturbance incidents, aircraft 20%, humans 20% and shooting activities 6%. Vehicular disturbance was greater when vehicles stopped close to feeding geese. The geese usually played no attention to low-flying propeller driven aircraft but were significantly disturbed by military jets and helicopters. Humans were tolerated more closely if in a vehicle than on foot. The low disturbance caused by shooting was attributed to the low level of shooting in the area. Much greater effects are exhibited on the more heavily shot Ribble estuary. Birds disturbed from feeding in a field milled in the air over the site before settling again when the disturbance was passed. If the source of the disturbance continued the birds were observed to move elsewhere in the vicinity. Prolonged disturbance caused flocks to split and scatter to a number of sites.

Norriss & Wilson (1988) calculated indices of disturbance for wintering Greenland Whitefronted geese based on observed disturbance rates (no. of disturbance flights made per hour) and the quality of feeding on refuges in Ireland. Agricultural disturbance was the single most important factor, with overall rates of disturbance highest on intensively managed land. Disturbance from shooting contributed between 10-22% of all disturbance flights, whilst aircraft contributed 19-67% up to 31

January. The provision of feeding refuges produced stable or increasing populations. Disturbance free refuges have been considered important factors in the increase in this and other geese populations. No correlation was found between disturbance index and the proportion of juveniles within each flock although this cannot be taken to be causal. However, disturbance levels directly influenced the energetic costs of feeding and hence the suitability of a site, by increasing flying time and reducing time available for feeding.

Heimberger, Euler & Barr (1983) studied the impact of a construction activity (cottage development) on the reproductive success of common loons (a diver) in central Ontario. Generally the study found that hatching success declined as the number of cottages within 150m of the nests increased. Once the eggs had hatched however, chick survival was independent of cottage development. The authors compared the level of human activity near 8 nests within 150m of at least 3 cottages with that around 8 nests with no development. There was a highly significantly greater activity effect around the former. They suggested though that some loons around the developed areas may have become habituated to humans (presumably during one season, although details are not given). Four other studies (Lehtonen 1970, Vermeer 1973, Bundy 1979, Andersson *et al* 1980) found that the building of cottages at the waters edge had a significant negative effect on the breeding success of divers, and reduced the lakes' utilisation by them.

van der Zande, Keurs & van der Weijden (1980) investigated the impact of roads on the densities of four bird species (lapwing, black-tailed godwit, redshank and oystercatcher) in an open field habitat. Disturbance effects for lapwing, black-tailed godwit and redshank but not oystercatcher were found. The disturbance effect on the numbers of nests and individuals ranged from 500-600m proximity for a quiet rural road to 1600-1800m for a busy highway. This amounted to a 60% reduction in bird populations related to type of road. A plot of bird density (y-axis) on distance (x-axis) followed a positive logistic ('S' shaped) curve. The relationship between traffic volume (x-axis) and total population loss (y-axis) was positively logistic. Additional disturbance was found to be caused by farms, other buildings and plantations, suggesting that disturbance caused by a road is not easily eliminated by planting trees alongside, since the presence of trees caused significant avoidance by these wading birds, presumably by interfering with their capacity to detect the approach of predators.

Flemming et al (1988) studied the effects of human disturbance on reproduction and behaviour of Piping plovers in Nova Scotia. Disturbance through the presence and abundance of people, pedestrian tracks and vehicle tracks on beaches was related to a decline in the plover. Beaches with heavier traffic produced fewer chicks surviving to 17 days largely because of reduced feeding time.

The following papers deal with studies of disturbance which do not involve waterfowl. Their relevance to waterfowl could be questioned although they provide useful comparative material providing, therefore, a fuller overview of disturbance :

Havlin (1987) found that densities of passerine birds using roads and their verges declined as the road aged, due largely to increased succession and a change in roadside vegetation.

Knight (1984) investigated the response of nesting ravens to people in areas of different human densities. Nests in rangeland (scrub) were significantly further from a highway and dwellings and could be approached more closely than farmland nesting ones where human densities were greater. Farmland breeders were more timid.

Michael (1978) studied the effects of highway construction on game animals in the US. Only two birds were studied - ruffed grouse and wild turkey. The latter was most affected by construction and traffic, tending to avoid such areas.

## 5. The impact of artificial light on waterfowl behaviour including its effect on migration routes

The presence of artificial lights has the potential to affect birds in two ways, i) by providing more feeding time by allowing nocturnal feeding, ii) by causing direct mortality or disorientation. A combination of atmospheric 'bad-weather' conditions does lead to kills among nocturnal migrant birds at artificial light sources. The problem is particularly acute if the light source is from a tall structure such as a light house which can attract birds from a large radius. Kills are also known to be correlated with the lunar cycle, which is in keeping with the effect that the phase of the moon has on the congregation of birds around lighthouses.

The lighthouse on Bardsey Island has been reported most commonly as a major source of attraction of seabirds and migrants (Elkins 1983). Migrant passerines are most commonly attracted to structures such as lighted towers, oil rigs and their associated gas flares, particularly in the North Sea. This most often occurs to nocturnal migrants in dense fog or cloud accompanied by precipitation. The refraction and reflection of light by water droplets increases the sphere of illumination and confuses the migrants (Elkins 1983). Mitigating measures, involving the flood-lighting of the revolving light of lighthouses, and gas flares on oil rigs, has been proposed. At Bardsey, an area of gorse bush is artificially lit under weather conditions when bird 'fall-outs' are expected, in order to reduce the number of birds which fatally strike the lit tower.

In an ongoing study (A.D. Fox, Wildfowl & Wetlands Trust, *pers comm*) wigeon, feeding on intertidal *zostera* were not affected by light from street lamps. In some cases feeding took place at night under the partially illuminated conditions.

In a recent unpublished study of estuaries in north-east England, sanderling were observed feeding visually (rather than tactilely) at night under the artificial illumination provided by street lamps (R. Langston BTO *pers comm*).

Birds, mainly dunlin, on the Plym in Cornwall in the early 1980's, have been observed roosting next to a large roundabout lit by artificial light (Devon and Cornwall Wader Ringing Group).

Redshank and Oystercatcher have been observed feeding on the Forth estuary within 50m of street lighting (N. Clark BTO pers comm). A current study on the Mersey by BTO has demonstrated extensive night feeding by many species of waders and wildfowl, but the study area is not close to artificial lighting and so no conclusions can be made of the effect of this illumination on the birds' feeding behaviour.

Scott (1980) compared the behaviour of Bewick's swans at a refuge site with that from surrounding fenland. At the refuge, birds were fed ad lib on grains, and feeding density peaked at feeding times, being much greater than that for birds on fenlands. The birds were highly aggregated at the refuge as a consequence of both food supply and lack of disturbance due to the banning of shooting. At a similar refuge at Slimbridge (Gloucestershire) birds were attracted by food to feed under flood lit conditions at night or early evening. The attraction to food under artificial light caused a major winter aggregation of the species within the Western palearctic.

Imber (1975) studied the behaviour of petrels (*Procellaridae & Hydrobatidae*) in relation to mood and artificial light. They were found to feed more intensively on moonless nights under which their prey were nearer the surface of the sea. Fledglings were particularly liable to be attracted to artificial lights situated near the breeding colony. It is suggested that nocturnal-feeding petrels are instinctively attracted to light sources because they exploit bio-luminescent prey.

Reed *et al* (1985) studies attraction to artificial lighting in procellariform birds during autumn. Species studied were Newells shearwater *Puffinus auricularis newelli*, dark-rumped petrel *Pterodroma phaeopygia sandwichensis* and band-rumped storm petrel *Oceanodroma* castra. Lights from the largest coastal resorts were shielded to prevent upward radiation on alternate nights during two fledging seasons. Shielding was shown to decrease attraction by about 40%. Most attraction occurred 1-4 hours after sunset and a full moon dramatically decreased attraction to artificial light. This attraction is well known and is documented in 21 species of procellariforms. Light attraction is not restricted to petrels or even seabirds. Birds have been known to be attracted to fires, lighthouses, gas flares on oil rigs, and ceilometer lights at airports (now modified by shifting their spectra into ultraviolet and turning them on only briefly).

Telfer *et al* (1987) reports further on the attraction of Hawaiian seabirds to light. Nightly 'fallout' (attraction and disorientation) of seabirds was significantly reduced during full moon, but increased as the new moon approached. Heaviest fallout occurred in urban coastal areas particularly at river mouths. Fallout constituted 97% fledglings which are susceptible after leaving their nesting grounds for the first time. Less than 1% of these birds were subsequently recaptured at artificial light sources on subsequent nights. The paper presents a solution to reduce 'photo-pollution' by shielding street lights and other man-made light sources (as described above). Results of experiments are reported in Reed *et al* (1985).

Verheijen (1980, 1981) consider and document bird kills at lighthouses and other tall structures in the US. The distribution of bird kills at tall lighted structures between 1935-1973 were considered as if they were a sample of a circular distribution of nights in a lunar month. The distribution proved to be non-uniform with a highly significantly greater number of kills clustered around new moon nights. The artificial light source destroys the natural angular light distribution as an orientational requirement to such a degree that birds can no longer cope with it. Moonlight, whether or not weakened and scattered by clouds, can restore the natural spatial properties of the light field around an artificial light source to such an extent that birds can withdraw from this source and prevent being trapped by it.

Mead (1983) discusses how the attraction of birds to lighthouses (and gas flares by inference) has been used to log migration. Particularly notorious victims of attraction are snipe, water rail, sedge and grasshopper warblers. Passerines, however, which fly at low altitudes are generally more susceptible than the stronger flying waders, ducks and geese which fly at higher altitudes.

No specific references to the effects of light on waterfowl migration were found although one might expect increased attraction to road lights which may enhance feeding time (as found by Scott 1980).

6. Other non-construction-related disturbance effects of relevance

Effects of recreation

A significantly greater amount of work has been done on the effects of other non-construction related disturbances on waterfowl. One major category is the effect of recreation and different types thereof. A useful summary of the effects of water-based recreation on waterfowl is given in Owen, Atkinson-Willes & Salmon (1986).

Tuite, Hanson & Owen (1984) investigated ecological factors affecting winter wildfowl distribution on inland waters in England and Wales with particular reference to the importance of disturbance by water-based recreation. Multiple regression was used to separate out the effects of physical attributes of water bodies and use by wintering wildfowl under varying levels of recreational pressure. The impact of disturbance varied considerably between different species. The most susceptible species to disturbance from recreation were teal, shoveler, and goldeneye. The most tolerant were mute swan, tufted duck, pochard and mallard. Greatest impact was caused by power boating, with coarse fishing, sailing and rowing also important. In some cases recreational boating (power) could be considered to limit carrying capacity of a water body.

Cryer et al (1987) reported on the disturbance of overwintering wildfowl by anglers at two reservoir sites in South Wales. The distribution of wigeon, pochard, and mallard was strongly influenced by the presence of anglers ie. birds concentrated in the central sector of the reservoir. The feeding rate of wigeon is also reported to be reduced by human disturbance whereas coot are most tolerant (Cramp & Simmons 1977).

Korschgen et al (1985) investigated the disturbance of diving ducks by boaters on a migrational staging area, and found that human disturbance can be detrimental to the production of breeding waterfowl. Continued disturbance during migration and wintering periods can have a dramatic effect on a bird's energy balance. The study concluded that birds had to fly an additional 1 hour per day because of disturbances. In some situations under heavy disturbance in which ducks cannot feed profitably during the day, they have been reported feeding at night to make up the energy deficit. Diving ducks in the Upper Mississippi River altered their typical patterns of diurnal activity because of intensive hunting pressure.

Effects of shooting and control measures

A review of shooting-related disturbance is presented in Owen, Atkinson-Willes & Salmon (1986), but a project undertaken by the Wildfowl and Wetlands Trust with the British Association for Shooting and Conservation has yet to be published in the scientific literature. The project aimed to investigate shooting disturbance close to refuges and nature reserves. There is much evidence now that local disturbance on shooting days causes greater use of refuges by wildfowl, suggesting that some local movements occur as a result of the shooting activity. In a survey of the effects of recreation activity on wildfowl, shooting did not appear to have significant negative effects on bird abundance.

Draulans and van Vessem (1985) deliberately disturbed grey herons either severely or lightly in order to investigate prevention of damage to fish farms. Increased frequency of severe disturbance reduced heron abundance at farms whereas slight disturbance had no effect. At fish farms under artificial lights herons fed preferentially at night or at twilight periods. Herons responded more to slight disturbances when more birds were present (see also Owens 1977), probably because of increased vigilance in larger groups. Consequently large wader roosts would probably be more susceptible to disturbance than small numbers of birds. Indeed, Lazarus (1978) showed that vigilance in white-fronted geese, measured by the number of birds vigilant in a flock, was significantly positively correlated with flock size. Table 1 referred to a possible reduction in feeding area caused by proximity of the area to a construction feature, which increased the risk of being caught unawares by a predator. Metcalfe (1984) observed this effect in turnstone and purple sandpipers by investigating the effect of reduced visibility caused by objects adjacent to the prey, on vigilance. A reduction in visibility caused an increase in the level of vigilance in both species, indicating an increase in vulnerability. The increase was due to individuals being less able to see both approaching predators and neighbouring feeding waders with which they compete.

Effects of bird scarers, aircraft and human disturbance

Altman & Gano (1984) found that disturbance by harrier jets did not deter least terns from building nests on the take-off pad. Birds remained on the pad when it was being used. This tolerance of noise has been documented in other species, particularly terns (as given in the paper) although no reference is made to waterfowl.

Murton (1971) reviewed the effect of airport scaring devices on birds which cause airstrikes, as well as for agricultural crop protection. Various disturbance methods have been used including various noise machines, shellcracker cartridges and pyrotechnics such as Very lights, to bioacoustics involving the playback of recorded distress calls through a loudspeaker system. Murton concludes that on the whole scaring devices have the disadvantage that birds get used to them, supporting the statement on habituation in section 2, so that their efficiency rapidly declines. Murton further refers to similar habituation being developed when the disturbing factor is traffic noise and aircraft engines. Reference is made to an experiment in which ten automatic bird scarers producing loud explosions by the combustion of acetylene in a pressure chamber, were sited on either side of an airfield runway. These proved effective for one week, after which birds even started perching on them. O'Connor & Shrub (1986) suggest that scaring devices which rely on simulating shooting usually work best if they are mixed with real shooting, and that many birds become accustomed to ignoring harmless bangs which are regularly timed in one spot.

C. Thomas (*pers comm*) at Manchester Airport has been studying bird strikes during the 1980's. Lapwing and black-headed gull are the major source of bird strikes at airports and they are dispersed with the use of bird scaring cartridges fired from a Very pistol, and cassette tapes of birds in distress. Distress tapes have a longer lasting effect although the birds become habituated to the sound if it is used repeatedly without reinforcement from the presence of a human. Similarly birds become habituated to automatic bird scaring equipment at airports.

Poole (1981) studied the effects of human disturbance on osprey reproduction and showed that increased human activity had no affect on the production of young, although the nests most vulnerable to human activity were those in remote sites subjected to sporadic invasions of people.

Bunnell et al (1981) conversely found that the decline of white pelicans in British Columbia appeared related to disturbance by humans (low-flying aircraft), through reduced survivorship of young and overall productivity. Proximity to an unadopted rough road reduced the numbers of human visitors and hence access to breeding sites.

Westmoreland & Batt (1985) experimentally manipulated human disturbance to nests of mourning doves and found that disturbed nests suffered significantly higher daily mortality rates than those undisturbed.

## 7. Conclusions

There were few studies reported in the literature that specifically dealt with the two subject areas - effects of noise and artificial light. Noise disturbance was reported to affect feeding activity and distribution of geese, wildfowl and waders. However, compounding variables such as the presence of humans at the noise source make interpretation difficult. If human activity remains concealed it is quite possible that some species of estuary birds could habituate to the noise. Furthermore, as food supplies diminish during the winter it is apparent that tolerance of disturbance in some species decreases. However, such tolerances are species specific. Generally, rare, less opportunistic species are less tolerant of disturbance than commoner ones. Disturbed birds that move elsewhere to feed or roost may do so into less favourable or sub-optimal conditions. As such the degree of compensation afforded by moving may be slight, and at present is poorly understood.

With respect to constructions, the actual structures can play a significant role in reducing the attractiveness of a feeding area to waders and wildfowl. Wildfowl appear less tolerant of these than do waders. If their view of the approach of potential predators is impeded it appears that such feeding and roosting grounds may become sub-optimal, perhaps causing birds to move elsewhere. In general 'good' feeding and roosting sites of large wader and wildfowl flocks need to be large open expanses.

Most studies have concentrated on the effects of disturbance to feeding birds. Some of the material quoted in this report suggested a disturbance effect of roads and building construction on breeding birds, eg loons and waders. In all references found such disturbance had a negative effect on reproductive output, and in some cases bird density.

The ability of birds to habituate to noise disturbance is important and requires consideration however. Of the two cases quoted in this report ie. least terns on harrier jet pads and avocets disturbed by human nest-observers, habituation and acceptance of the disturbance was rapid. It is well known for breeding birds generally that tolerance of disturbance during breeding increases with the progression of the breeding period. Incubating birds are much less likely to desert their clutch than birds which are laying (Crick, BTO pers comm). Further, colonial breeding species may be more likely to tolerate higher levels of disturbance than solitary breeding individuals purely because they live in groups and are therefore afforded some protection by the usual vigilance which prevails when compared to solitary breeders. The classic example of noise habituation is exemplified by tolerance of bird scarers, whether used to protect agricultural crops or to disperse birds from airports. Habituation is common to noise that is repeated at a regular frequency and which is not supported by reinforcement by the presence of a human.

Attraction of migrants to lighthouses during cloudy nights or as a new moon approaches is reasonably well known. Such instances are reduced under full moon conditions. First-year juveniles of some seabirds, notably petrels, were attracted to street lighting in a number of studies. This problem has been reduced significantly by shielding artificial street lights along coastal fronts. Consequently such shielding should be incorporated into constructions of new roads which are close to bird breeding areas, although the benefits to waders and wildfowl are likely to be less evident than was the case with first-year petrels. It is anticipated that some nocturnal feeding may be permitted under road-light illumination of adjacent wader and wildfowl feeding grounds, as has been documented in a number of cases.

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