DISTURBANCE TO WATERFOWL ON ESTUARIES

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Edited by Nick Davidson & Phil Rothwell

Wader Study Group Bulletin 68, Special Issue, August 1993

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Contents

principles for coping with potential recreational and waterfowl demands on estuaries in the future, and identify research needs.

We concentrate here on issues of disturbance to waterfowl feeding and roosting on estuaries whilst the birds are on their wintering grounds and during periods of spring and autumn migrations. The effects and implications of recreational disturbance on breeding waterfowl have rather different patterns of effect and implication (see e.g. Pienkowski 1993; Schultz & Stock 1993). They are not considered further here although the overall principle remains the same: people in too close proximity to birds have at least the potential for creating a disturbing effect.

STUDYING AND INTERPRETING DISTURBANCE

Coastal research is accustomed to dealing with two major sets of changing variables. First is the high dynamism of coastal systems, as seen through the physical, chemical and biological processes that shape estuaries and open coasts. Second is the ever-changing pattern of human uses of coastlines, characterised by many different activities often taking place simultaneously but independently. In studying the disturbance of human activities to birds there is also a third major set of variables: inter- and intra-specific differences in the responses shown by birds to even the same activity at different times and/or in different places (see e.g. Smit & Visser 1993).

This multiplicity of variables underlying the observed interactions between waterfowl and people makes it difficult to assess what is the cause and the implications of a particular instance of recreational disturbance. This is particularly the case for observational studies. Although these can identify correlational links between human disturbance and the responses of the birds it is often difficult to isolate key variables, and to assess whether human disturbance adds to or replaces natural disturbance levels from e.g. birds of prey. Furthermore, the magnitude of the disturbance to waterfowl may arise from synergistic effects of more than one activity. For example Townshend & O'Connor (1993) suggest that waterfowl numbers and usage at Lindisfarne in north-east England were affected by wildfowling activity, but chiefly when the presence of bait-diggers in just one part of the area prevented birds from using a zone established as a non-shot refuge (see also Bell & Fox (1991) and Owen (1993) for further discussion of wildfowling refuges).

Measuring and controlling for the many variables in dynamic coastal systems is a large task, and one that may not greatly help in building general models of waterfowl use of estuaries with which to compare the effects of a disturbance (see Cayford 1993 for further explanation). This is because most studies have so far relied on observational or semi-experimental ways of recording effects of disturbance and so cannot readily be used to deduce the extent of any impact of human disturbance on the birds. Conversely, it is just as difficult to use the available data to demonstrate that there is no impact on waterfowl of a particular disturbing activity. Cayford (1993) suggests that future research could concentrate on more experimental field manipulations as a way of controlling for confounding variables.

However, known general features of waterfowl ecology and population dynamics do help by providing a framework in which to judge disturbance effects. Cayford (1993) points out that optimal foraging theory is a useful basis from which to understand likely effects of disturbance on feeding. Many studies have shown that birds concentrate where feeding is best (often where there is best opportunity to maximise net energy gain). If birds are forced temporarily or permanently to leave these places (by disturbance) then there is an increased risk that their energy balance will suffer. However, the severity of this type of situation and ways in which birds respond again vary in a complex way. Responses depend on many factors such as whether there are alternative feeding areas available. Furthermore some parts of a population, e.g. juveniles, can be more affected than others.

Disturbance does not in itself always imply that it causes a serious problem to the birds, at least in the short-term. This is because waterfowl can compensate for disruptions to their natural behaviour patterns in a variety of ways. For example some species and individuals do not always feed for all the available time during the tidal cycle. These birds can extend their period of feeding to compensate for time lost during disturbance, in a parallel with the extended feeding times that occur during periods of high energy demand induced by cold weather (e.g. Davidson & Evans 1986). Some waders can accelerate food intake rates in response to reductions in time available for feeding (Swennen *et al.* 1989). Hence even apparently high rates of disturbance to feeding routines do not always lead to major reductions in food intake or overall usage of feeding areas - an example for Oystercatchers *Haematopus ostralegus* is described by Goss-Custard & Verboven (1993). But note that on the same estuary there is evidence that another waterfowl species (Wigeon *Anas penelope*) may be seriously affected by even occasional disturbance during key parts of the feeding cycle (Fox *et al.* 1993), emphasising the difficulty of extrapolating even from studies in the same location. Care also needs to be taken to ensure that conclusions about the intensity of disturbance are not drawn from only part of the time or area, since observations can be concentrated in those places and during those times when disturbance is greatest (Goss-Custard & Verboven 1993).

Comprehensive understanding of the significance of disturbance to estuarine waterfowl thus depends on understanding whether (and by how much) the birds have a buffering capacity remaining before facing reduced energy balance and so potentially reduced survival. This in turn relies in part on an understanding of such features as the carrying capacity of an area, the nutritional state and requirements of the birds and actual feeding rates in relation to potential maxima. Since this detailed information is often not available (and is very hard to establish), assessments must be based on more limited available information.

Another lesson to be learnt from using waterfowl ecology and population dynamics to underpin analyses of disturbance is the need to distinguish between effect and impact, and between whether it is individuals or populations that are affected. This is summarised in Figure 1. Many studies, for example most of those in this volume, report local (i.e. within an estuary or part of an estuary) effects on at least some individuals. Examples include cessation of feeding, changing feeding locations and moving roosting sites. In some cases there is evidence that total numbers of birds using an estuary decreased in response to human disturbance (Townshend & O'Connor 1993; Kirby *et al.* 1993). However, it is much harder to detect whether such changes have an impact on individual birds (e.g. by reducing their fitness to survive), or on a waterfowl population such that a biogeographical population declines. First this is because it is difficult to control for the many other factors that could affect fitness and population dynamics (see Cayford 1993). Second, waterfowl are highly migratory so that any effect of disturbance (e.g. leaving on migration in a poorer nutritional condition) could have its impact many thousands of kilometres away e.g. on migratory staging areas or arctic breeding grounds (see Evans *et al.* 1991; Davidson & Morrison 1992). Large-scale changes in the use of sites by certain species, apparently linked to changes in intensity of disturbance have been noted. Changes in the habits of species such as Wigeon and Brent Geese *Branta bernicla* in response to disturbance associated with shooting are well documented (Madsen 1993). Such changes in habit can be of a scale detectable across flyways.

Nevertheless, this volume includes many examples of studies showing at least local or short-term effects of disturbance, and there is evidence in at least some cases that such disturbance can and does lead to a substantial decrease in energy balance (e.g. Belanger & Bedard 1990). Furthermore, despite the very great variation in scale and pattern of observed disturbance responses there are some common features that emerge which can indicate the locations, times and circumstances of high vulnerability to disturbance. These are discussed below.

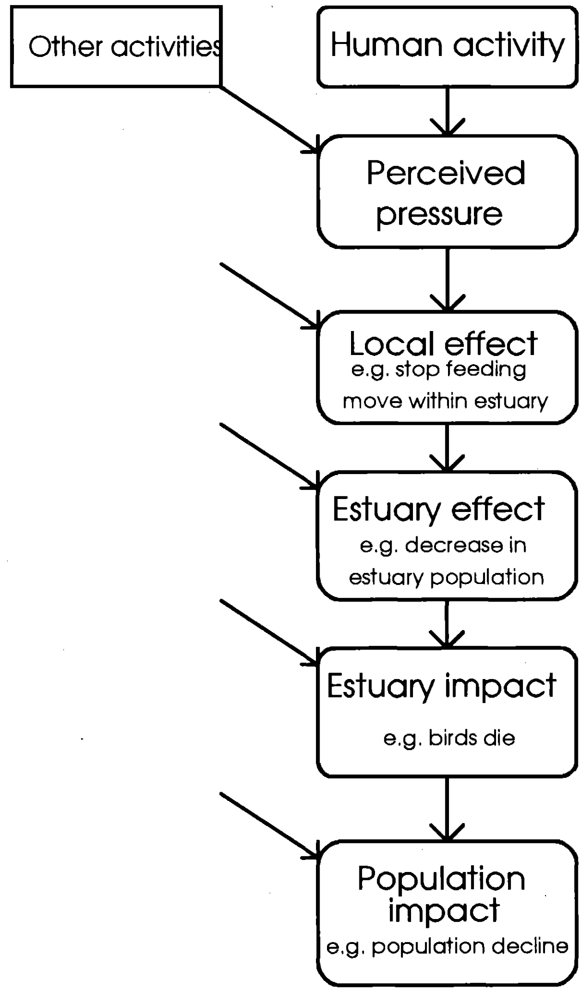


Figure 1. Stages in detecting effects and impacts of disturbance to waterfowl.

WHO IS MOST DISTURBED, BY WHOM, WHERE AND WHEN?

When during the annual cycle?

We have pointed out that human disturbance on estuaries adds to a baseline of disturbance from natural causes such as birds of prey or the rising of the tide forcing birds to abandon feeding grounds. The effects of such additional disturbance will be most serious at times when birds have difficulty finding sufficient food for their needs even under natural, undisturbed, conditions, i.e. when they are at or close to the threshold of meeting their energy balance. Such conditions can arise when either food is difficult to find and/or when demands for energy are high (Pienkowski et al. 1984). Problems of balancing the budget occur not just when birds find difficulty in meeting their daily existence needs. Wildfowl accumulate stores of fat and protein in advance of periods of high demand. At such times the daily food intake must greatly exceed that needed to supply short-term needs.

There are several circumstances and times of year when waterfowl are close to their energy balance threshold and so are vulnerable to additional disturbance. One is during periods of cold winter weather. At such times food becomes harder to find whilst energy demand for thermoregulation increases, so that food intake has to be increased. When severe weather lasts for a few days or more waterfowl regularly draw on fat and protein stores accumulated earlier in the winter. Even without additional problems caused by disturbance some waterfowl species regularly have increased mortality during cold weather (e.g. Davidson 1981, Davidson & Evans 1982). Such mortality can occur within about one week of the onset of cold weather. It usually seems to occur after birds have exhausted the fat stores that provide their major energy source during periods of insufficient food intake. Additional disturbance of waterfowl at such times, particularly if it involves flight, accelerates the rate of nutrient store use and so increases mortality risks. Recognition of this has led since the mid-1980s to the imposition in the UK and some other European countries of statutory bans on wildfowling during prolonged severe weather, a major objective being to reduce disturbance to non-quarry species.

In northern temperate regions most waterfowl accumulate energy reserves during the early part of the winter, with a peak in late December - late January (depending on species) broadly coinciding with the time when severe weather occurs most often. Waterfowl are therefore particularly vulnerable to severe spells outside this midwinter period, either in early winter whilst stores are still being laid down or in late winter/early spring when stores are declining. In early winter food intake must exceed daily needs for stores to be accumulated, so although disturbance may have no obvious impact at the time it may delay the timing of energy store gain, so increasing vulnerability to later periods of severe weather.

In spring and autumn many waterfowl are gaining large stores of fat and protein in preparation for their major migrations between Arctic breeding grounds and their wintering grounds in Europe and Africa. During these periods daily food requirements are high and some evidence indicates that birds are feeding at or near their maximum attainable intake (Ens *et al.* 1990). These problems of achieving high food intakes appear particularly acute in spring when birds are migrating on very tight schedules so as to reach breeding grounds at the right time. Hence in spring (especially from late April to late May) disturbance that reduces net energy gain could lead to birds migrating to their breeding grounds with reduced energy stores. In some years, arctic waders need to draw heavily on their stores soon after arriving on breeding grounds. If spring snow-melt is late and weather conditions are bad, reduced energy stores may affect breeding success and even adult survival (see Boyd 1992; Davidson & Morrison 1992). Several studies of disturbance during migratory staging have indeed shown population effects including reductions in numbers of birds using staging areas (e.g. Pfister *et al.* 1992) and substantial increases in daily energy expenditure that exceeded the compensatory capacity of the birds (Belanger & Bedard 1990).

For waders the period in autumn when they undergo a major moult may also be one when the direct and indirect effects of disturbance are high. Moult is a time when energy demands are high, because birds need to acquire nutrients for the growth of new feathers. However, as moult takes place at the end of summer when food is abundant and weather mild, waders generally seem to have little difficulty in meeting energy needs. Even so, waders seem to concentrate on large estuaries when moulting, and this is considered to be an adaptation to avoidance of disturbance (Prater 1981). Certainly flying when in active wing moult is less energetically efficient, and moulting birds may be less manoeuvrable and so more vulnerable to predators. Hence additional disturbance causing extra periods of flight during moult will increase vulnerability at this time of year which is often when largest numbers of people visit estuaries (see below). Some waterfowl become flightless during their autumn moult. Such birds seek seclusion and are particularly vulnerable to human disturbance that causes them to move from safe refuges to areas where depredation risk is greater.

It is also possible that a disturbance-influenced redistribution in early autumn may influence bird distribution later in autumn and in winter. Knowing about such movements is important in interpreting effects of disturbance. Observed bird distributions later in the year may reflect the past history of human disturbance, especially if such redistribution involves moving to a different estuary, rather than disturbance observed at the time (see also Smit & Visser 1993).

Which species are most vulnerable?

The type and scale of response by different waterfowl to disturbance is very variable. Even the same species of bird can react in different ways at different times and on different estuaries - for example sometimes by habituating to repeated disturbance and at others becoming increasingly nervous. For example Redshanks *Tringa totanus* feeding in narrow tidal creeks with frequent passers-by on the shore may tolerate people within 20 m, yet Redshanks on some large estuaries fly off when a person is still over 100 m away. It is not clear which circumstances lead to habituation and which to disturbance. Amongst factors implicated in such variability are time of year, time of tide, weather conditions, flock size, feeding success, type of disturbing agent and past history of disturbance.

Some general patterns are, however, emerging from all this variability. Some bird species (e.g. Brent Goose, Redshank, Bar-tailed Godwit *Limosa lapponica* and

Curlew *Numenius arquata*) are more 'nervous' than others (e.g. Oystercatcher, Turnstone *Arenaria interpres* and Dunlin *Calidris alpina*). The presence of just one person on a tidal flat can create a surprisingly large *cordon sanitaire* in which birds stop feeding or fly off, in one study ranging from about 5 ha for gulls and 13 ha for Dunlins up to 50 ha for Curlews (Smit & Visser 1993). So a few people evenly scattered over the tidal flats can prevent birds feeding in a large area of many estuaries (see below). However, in extreme cases, for example Wigeon on parts of the Exe Estuary, it can even be just one disturbance incident at the wrong time that deters birds from feeding until the next tidal cycle (Fox *et al.* 1993).

What is most disturbing?

There are also general patterns about who and what causes most serious disturbance to estuarine waterfowl. Several studies have now found that the most widespread and long-lasting disturbance often comes from aircraft, and that the slower the aircraft the worse the disturbance - helicopters, microlights, and light aircraft (even when not low-flying) disturb more than jets (Smit & Visser 1993; Stock 1993). Fast (jet) planes also cause disturbance when flying low over feeding grounds and roosts (Koolhaas *et al.* 1993) although it is not clear whether the disturbance is induced more by the sudden loud noise or the planes' movement.

On the tidal flats, moving people and animals (especially dogs) generally create worse disturbance than people who stay in one place for some time. However, note that even these static types of use can cause major disturbance if they are intensive and/or widespread.

From water, close approach to roosting flocks on or near the shoreline causes serious disturbance. In addition since for many waders feeding is best on the tidal flats close to the water's edge, close approaches to muddy shores both by sailed craft (especially sail-boards) and high-speed powered craft create major disturbance also to feeding birds. Approaches from the water seem generally to disturb birds more than from land: e.g. in one study Curlews flew from a sail-board at 400 m away compared with about 100 m from a walker (Smit & Visser 1993).

Where?

A widespread view of human disturbance to waterfowl suggests that conflict is not a major issue because as birds are mobile they can readily fly elsewhere to avoid the disturbance. Ecological theory (see above) shows that the solution is not usually so simple. Furthermore, activities with disturbance potential do not occur in isolation from each other, nor in only one place. Surveys compiled in 1989 by the Nature Conservancy Council's Estuaries Review found, for example, that many recreational activities were taking place on half or more of the estuaries in Great Britain (Table 1). So birds moving to a different estuary as a disturbance-avoidance response are very likely to find many activities capable of causing disturbance occurring there too.

On many British estuaries many different types of recreational activity take place, so the potential for synergistic effects and impacts is considerable. For example Table 2 shows that out of the 155 British estuaries half or more of 18 categories of aquatic-based recreation occurred on 52 estuaries (34% of British estuaries) and that only six estuaries, mostly in northern Scotland, had no aquatic recreation recorded. Diverse aquatic recreational use is particularly common in

Table 1. The frequence of occurrence of some widespread recreational activities on the British estuarine resource. Data on the 155 British estuaries gives known occurrence in 1989 and comes from JNCC's Estuaries Review database being developed from the work of the NCC Estuaries Review (Davidson *et al.* 1991).

Activity	British estuaries No.	%
Power-boating	75	48
Sailing	125	81
Sail-boarding	88	57
Water-skiing	66	43
Canoeing	76	49
Bathing/general beach use	106	68
Angling	132	85
Walking/dog walking	116	75
Bird-watching	140	90
Motor-cycling	44	28
Horse-riding	69	45
Golf-courses	47	30
Light aircraft flying	43	28

Table 2. Examples of the diversity of different aquatic-based recreational activities on British estuaries. Data on the 155 British estuaries gives known occurrence in 1989 and comes from JNCC's Estuaries Review database being developed from the work of the NCC Estuaries Review (Davidson *et al.* 1991).

Country	Total no. of estuaries*	No. with ≥ 50% activity types	% with ≥ 50% of activity types
England	81	35	43
Scotland	50	6	12
Wales	28	14	50
Great Britain	155	52	34

* total for each country includes those estuaries shared between two countries, e.g. Severn, Dee, Solway.

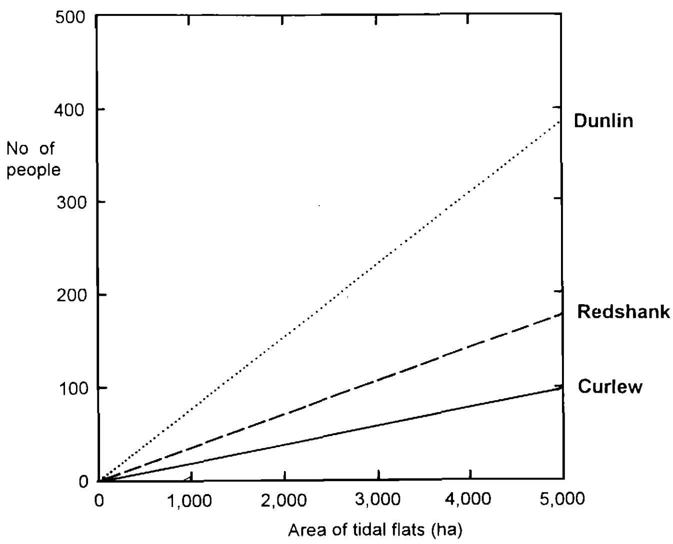


Figure 2. The numbers of mobile people who, if evenly spaced, would disturb three different wader species (Redshank, Curlew and Dunlin) from different areas of tidal flats, derived from data in Smit & Visser (1993).

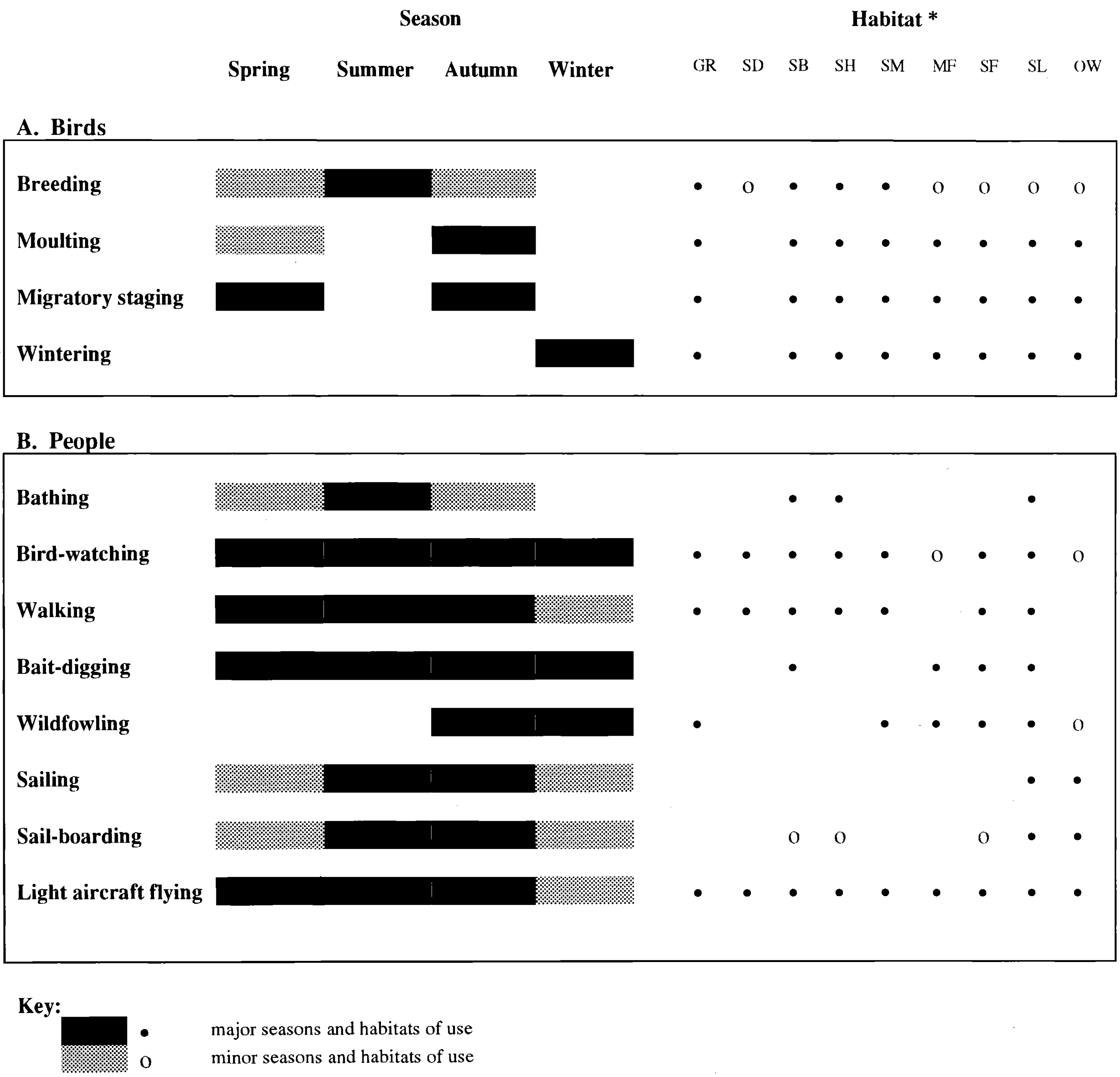
Wales and parts of England, with few Scottish estuaries being used for more than eight aquatic activities. A similar pattern of multiple-purpose use of estuaries occurs for land-based recreation. Furthermore there tends to be a greater diversity of recreational activity on estuaries that form part of the Ramsar/SPA network of internationally important sites: internationally-important estuaries average 6.7 activities/estuary; other estuaries average 5.1 activities/estuary. So in Britain there is at least potential recreational disturbance to waterfowl in many places, and from many different activities in any one place, with estuaries in Wales and southern and eastern England having most potential pressure.

The size of the area available to birds may also affect levels of disturbance: on small estuaries there may be few alternative locations available for birds moving away from a disturbance, and it takes only a few activities in different places to make much of such an area untenable to birds of some species. A hypothetical example is shown in Figure 2, which shows the cumulative size of a minimum *cordon sanitaire* created for different wader species disturbed by increasing numbers of mobile people. This implies that for some shy species such as the Curlew as few as 20 evenly distributed people could prevent birds from feeding on over 1,000 ha of estuary, an area of tidal flats equivalent to estuaries such as Hamford Water or Southampton Water. Of course it is highly unlikely such a 'worst-case' situation would ever occur, not least since many parts of the tidal flats of estuaries are too soft for people to move on them (e.g.Goss-Custard & Verboven 1993). Nevertheless, such figures do give an indication of the considerable potential for disturbance from intensification of human activity even where it involves quite small numbers of people. Land-claim which narrows the width of intertidal shore available to birds for feeding will tend to exacerbate such disturbance problems since some shy species generally avoid feeding on narrow shores (e.g. Bryant 1979).

Like the presence of birds on estuaries many recreational activities show marked seasonality and many are restricted to a few of the suite of habitats on coasts and estuaries. This means there are complex patterns of both geographical and temporal overlap between birds and people. This is illustrated in Figure 3. Different waterfowl are present on estuaries throughout the year, but their habitat usage differs seasonally. Most species breed chiefly on the upper parts of sandy beaches, shingle ridges and saltmarshes, as well as on coastal grazing marshes and other grasslands, and relatively small numbers use tidal flats for feeding. In contrast, when arctic and boreal breeding populations return in autumn and early winter they utilise all habitats (except for generally little use of mature sand-dunes) for feeding and for roosting, this usage continuing until late spring (Davidson & Stroud in press). However, many recreational activities occur chiefly in late summer and early autumn, leading to little overlap with periods of main bird usage of some habitats. Activities that occur throughout the year, or largely in winter, can carry a high risk of causing disturbance. However, it is probably the late summer/early autumn period (and sometimes also in spring) when most recreational activities take place, intensity of use is greatest, and waterfowl are most vulnerable. This period coincides with the latter part of the breeding period for local breeders and particularly with the arrival and moulting of the more northerly breeding populations.

Interestingly it seems that sand-dunes (in winter) and saltmarshes, particularly those with well developed creek systems restricting access, may be the habitats where waterfowl are least vulnerable to anthropogenic disturbance. Even so there are places where bird use even of saltmarshes does appear to be restricted by recreational use, for example of parts of the Wadden Sea by spring-staging Brent Geese (Stock 1993). However, it is firm, sandy flats, sand beaches and shingle ridges that often seem to be amongst the most widely and intensively used by both people and birds, and where conflicts may be most common (see e.g. Pfister *et al.* 1992).

Inevitably Figure 3 is a generalisation and masks what can be major differences between different estuaries in the pattern of uses and the overlaps of birds and people. Such variation can often arise through differences of ease of access to the shoreline. Nevertheless Figure 3 does give some pointers to where conflict of use is most likely to arise. It also shows that some activities, notably low-flying by light aircraft and micro-lights, affect the whole estuarine resource rather than just some habitats. This, coupled with the relatively wide-scale and long-lasting effects on



* Habitat types are: GR grasslands; SD sand dunes; SB sand beaches; SH shingle; SM saltmarsh; MF mudflats; SF sandflats; SL shoreline; OW open water.

Figure 3. Seasonal occurrence of birds and selected recreational activities, and their usage of estuarine habitats.

waterfowl induced by low-flying aircraft, place this activity amongst the most capable of creating widespread and serious disturbance to waterfowl. It may also be amongst the most difficult to control locally.

MANAGING FOR WATERFOWL AND POTENTIALLY DISTURBING ACTIVITIES

Although there are many instances in which waterfowl and people appear to co-exist on estuaries with or without zonation with little or no damaging effects, there are widespread examples where effects and impacts of varying severity have been described, despite the complexity of unravelling such multifactorial phenomena. Clearly people's recreational and other uses of estuaries can and do lead to disturbance to waterfowl with often uncertain consequences, so the guiding principle of managing for human activities in areas that support important waterfowl populations needs to be one of avoidance or limitation of overlap through temporal and locational zoning. Unlike some other estuarine activities there is often considerable potential for flexibility in the pursuit of recreational uses of estuaries.

The potential effects and impacts of disturbance have been widely recognised in wildlife conservation legislation and agreements, as has the need to develop conservation measures for birds whilst taking into account human uses. For example Article 4.4 of the EC Directive on the Conservation of Wild Birds requires Member States to 'take appropriate steps to avoid ... any disturbances affecting the birds, in so far as these would be significant having regard to the objectives of this Article'. These objectives are the taking of special conservation measures concerning the habitat of Annex I species (including migratory waterfowl) in order to ensure their survival and reproduction in their area of distribution. In its judgement on the recent Leybucht Bay (Germany) case the European Court found that the significance of the disturbance related to the level at a single site rather than at the population level e.g. involving a population decline.

Other international agreements include the recognition of the need to manage disturbing activities. The forthcoming African/Eurasian and Asian/Australasian Waterfowl Agreements have a series of action plans which include the need for range states to take measures to reduce the levels of disturbance to migratory waterfowl caused by human activities including hunting, fishing and other outdoor recreation. The action plans identify appropriate measures such as the establishment of disturbance-free zones in protected areas where no human access is permitted, and the establishment of core sanctuary areas within major waterfowl hunting areas (IWRB 1993). International conservation plans for individual waterfowl species currently under development also recognise the importance of managing for recreational and other disturbance (e.g. Stroud in press). They also identify the need for information on the pattern and distribution of potentially disturbing activities and populations on a waterfowl flyway scale, using compatible methodologies (Davidson et al. 1991; in press).

Organisations involved in developing strategies for coastal and estuarine conservation within Great Britain also recognise recreational and other disturbance to waterfowl as a key issue that needs addressing in the preparation of integrated coastal zone management (e.g. Rothwell & Housden 1990; English Nature 1992). English Nature's initiative for the promotion of estuary management plans based on sustainable estuarine use includes objectives aimed at identifying and resolving multi-use conflicts so as to avoid damage to estuarine wildlife (Grabrovaz 1993).

There has already been considerable work on the integration of recreation with other estuarine uses, and with the needs of waterfowl and other estuarine wildlife. There are numerous examples of the development of refuge areas and use of zonation (both temporal and locational), especially in relation to wildfowling (e.g. Hirons & Thomas 1993; Madsen 1993; Owen 1993; Townshend & O'Connor 1993) as well as attempts to manage more general leisure and recreational usage (e.g. Kirby *et al.* 1993). In addition, types of conflict between individual sports and nature conservation have been assessed by Sidaway (1988) and good practice examples of coastal recreation management, including those aimed specifically at reducing disturbance to waterfowl, are being widely publicised (e.g. Sports Council 1992).

FUTURE DIRECTIONS

Continuing to develop ways of integrating the many different recreational uses on an estuary, both with each other and with migratory waterfowl populations so as to avoid continuing or increasing pressure on this internationally important part of our wildlife heritage is one of the keys to achieving successful integrated coastal zone management. The importance of achieving such integration is increasingly recognised as an essential plank in establishing sustainable use of estuaries for the future. Such integration can be achieved in a variety of ways: through education and the provision of information, and through voluntary and statutory agreements and zonations.

Implementing the best approach to minimising disturbance to waterfowl in each location depends on a good understanding of the behaviour and needs of both birds and people. Otherwise there are risks of exacerbating rather than reducing a problem, for example by establishing zones in incorrect places in relation to bird usage. However, for the reasons we have described above such information is not always available nor easy to acquire. A recent workshop (Doody 1993) has identified key topics requiring further research on coastal recreation in the UK. These include:

- reviewing of current literature and research on the relationship between ecological and recreational issues;
- establishing standardised methods for assessing recreational impact;
- experimental work on habitat and species features to establish when changes occur in relation to the level and timing of activity and in relation to zoning;
- reviewing people's attitudes to recreational disturbance of ecological features; and
- assessing the vulnerability of habitats, species and sites in relation to recreational uses.

These recommendations for research on broader recreational issues than just disturbance to waterfowl link closely with Cayford's (1993) view that much of the future research should be experimental. Much of the research on the topics listed by Doody (1993) would contribute valuably to our understanding of how disturbance affects waterfowl. This current volume helps to increase the availability and variety of the existing information base. In doing so it clearly reveals the need for further research in order to understand the ways in which a wide variety of factors influence the extent, effect and impact of disturbance to estuarine waterfowl.

Additionally, we believe that much more effort is required to achieve an understanding of fluctuations in population sizes of species site by site, region by region and flyway by flyway. The opportunities to examine impacts of permanent habitat loss caused by development or coastal squeeze should be exploited. They could tell us much about the behaviour of individuals and populations in response to major perturbations. We would also encourage the increase in the use of major experimentation on populations. The massive impacts on distribution and population size caused by removing or imposing reserve status or on the commencement or cessation of a disturbing activity such as shooting, mud walking or military use deserves greater attention. Such work has to be on a truly international scale. Only by examining the full geographical range of a species and the factors influencing its distribution and survival will we be able to begin to answer some of the questions surrounding sustainability and maintenance of biodiversity.

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* 'Effects' and 'impact' are used in the biological sense: i.e. effect=observed response; impact=implies reduction in survival at individual or population level.