THREATS TO COASTAL WINTERING AND STAGING AREAS OF WADERS

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Coastal wetlands are exploited by man in many different ways. Some of these activities, *e.g.* land-claim, have irreversible effects on coastal ecosystems. Others have only short-term effects. In addition, the scale of activities vary considerably from place to place, so that effects also differ considerably. Coastal wetlands are used also by millions of waders and other waterbirds, which are ecologically dependent on them. This paper attempts to sum up all the possible threats to coastal wetlands and the birds using them. Categories of threat are arranged primarily according to their reversibility, and then their geographical scale and their frequency of occurrence. In many of the most important wintering areas along the East Atlantic, there are many identifiable threats. Less complete information from the Middle East and South-east Asia indicates that the level of threat to coastal wetlands in these areas may be even more severe. Our methods in this paper can only demonstrate the range of threats to coastal ecosystems. It is not yet possible to assess quantitatively the level of the total impact on any specific area. A more detailed understanding of the cumulative effect of the threats outlined in this paper is much needed on an internaional scale.

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INTRODUCTION

In terms of primary and secondary production coastal wetlands are highly productive. Their sheltered waters are important nursery areas for fish and shrimps, which are exploited by man. Additionally coastal wetlands may play an important role in the mineralisation of organic waste discharges, and mangrove areas can provide forestry products. Coastal wetlands are exploited by man in several other ways, such as for recreation and shipping. At the same time, millions of waders and other waterbirds (including for the purposes of this paper wildfowl, gulls and terns) depend on coastal wetlands for much of the year.

This paper is a brief review of the factors, both directly and indirectly linked with human activities, which actually or potentially pose a threat to coastal wetlands along the East Atlantic flyway. We define a threat as any factor that can have a negative influence on the conditions and populations levels of wild plants and animals, or on the natural vegetation and landscape of the area. Threats are listed according to the reversibility of their effects on the ecosystem, to their geographical scale, and to their frequency of occurrence. We have then tried to analyse to what extent the most numerically important wintering areas for coastal waders on the East Atlantic flyway are threatened by human activities. We focus on those sites with an average winter population of over 50 000 waders. However our findings apply also to sites holding smaller wintering populations, to migration staging areas along the flyway, and to a great extent to wintering and staging areas in other parts of the world (see also papers by Lane and Sagar, Parish, Hussain, and Hepburn in this volume).

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A SUMMARY OF THREATS

Table 1 summarizes the reversibility, geographical scale and frequency of occurrence of threats to the ecosystem, taking into account that irreversible threats, like any form of habitat destruction, should be considered the most serious, especially if they occur on a large scale. Table 1 is based largely on experiences in the international Wadden Sea area (Wolff and Binsbergen 1985). Each topic in this table is discussed briefly below.

THREATS WITH IRREVERSIBLE EFFECTS

1. Habitat loss due to land-claim, hydraulic sandfill and construction of barrages and salines

Habitat loss can be caused by the embankment of coastal areas for many purposes, including agriculture (*e.g.* the embankment of saltmarshes to create grazing pasture around the Wash in eastern England, and in many places around the Wadden Sea), industrial activities and harbour construction (*e.g.* at Teesmouth and the Orwell in eastern England, and the Dollarthafen), waste disposal, especially from pulverised fuel ash from power stations (*e.g.* on the Firth of Forth), recreational developments (*e.g.*) for marinas), and coastal defence works (*e.g.* Hoier, Nordstrander Bucht, Lauwersmeer, and the Delta region of The Netherlands). Similar effects are arise from hydraulic sand-fill (*e.g.* for the creation of artificial sand-beaches along the Niedersachen coast), the construction of salines for commercial salt production, and for coastal protection and tidal power barrages (*e.g.* Oosterschelde in Holland, Rance in Brittany, Bay of Fundy in Canada, and proposals for the Severn, the Mersey and many other British estuaries).

Table 1. Threats or potential threats to estuarine ecosystems along the East-Atlantic flyway, arranged initially according to their speed of recovery, and then by geographical scale, frequency of occurrence and effects on different elements of the ecosystem: non-biotic and landscape (N), micro-organisms (M), benthic organisms and fishes (Be), birds and mammals (B,M). (Table modified from Wolff and Binsbergen 1985.)

Threat	Speed of recovery	Geographical scale	Frequency	Effects on ecosystems N	M	Be	B,M
Irreversible							
1 Land-claim, hydraulic sandfill, barrage schemes	000	***	++(++)	*	*	*	*
2 Sea wall construction	000	***	++(++)	*	*	*	*
3 Construction of causeways	000	**	+(+)	*	*	*	*
Long & medium term							
4 PCBs and Pesticides	00	***	++++			*	*
5 Oil spills	00	***	+	*	*	*	*
6 Heavy metals	00	***	+(+)			*	*
7 Mussel & oyster culture	00	**	++++	*	*	*	*
8 Organic discharge	00	**	++++		*	*	*
9 Extraction of natural gas, incl. transport	00	**	+(+++)	*	*	*	*
10 Chemical pollution (e.g. from harbour industries)	00	**	+(+)		*	*	*
11 Sand & shell extraction & dredging	00(0)	**	++(++)	*	*	*	*
12 Pipeline construction, accidents from broken pipelines	00	*(*)	+	*		*	*
Short term							
13 Fisheries (fish, shrimps)	0	***	++++			*	*
14 Disturbance (civil planes)	0	**(*)	+++				*
15 Boating, aquatic sports	0	**(*)	+++				*
16 Military activities	0	**(*)	+++	*			*
17 Hunting	0	**(*)	+++				*
18 Industrial noise	0	**	++++			(*)	*?
19 Thermal pollution	0	**	++++		*	*	(*)
20 Shipping activities	0	**	++++	*		*	*
21 Cockle dredging, mussel seed fishing	0	**	+++			*	*
22 Tidal flat walking	0	**	+++			(*)	*
23 Lugworm digging	0	*(*)	+++			*	*
24 Seismic research	0	*(*)	++	*		*	*
25 Scientific research	0	*	+++	*	*	*	*

Based on observations of feeding ecology and behaviour, Goss-Custard (1977, 1979) concluded that the number of birds an estuary can support is limited. Loss of feeding grounds will force some of the birds to feed in less preferred areas or to leave the estuary altogether. This implies that, at least in certain areas, habitat loss may directly affect the number of birds using the area. Effects of habitat loss to birds using these sites as a feeding area have been studied in only a few places.

Studying the effects of land-claim at Teesmouth, Evans (1981) found a decrease in the numbers of several species, but no clear change in some others. None changed in direct proportion to the area of mudflats lost. Large-scale hydraulic engineering projects have be carried out in the Dutch Delta area for the past 25 years. Three estuaries have been changed into fresh or brackish water lakes. The complete damming of the Haringvliet/Hollands Diep and Grevelingen estuaries in 1970 and 1971 (Figure 1) resulted in a loss of 13 500 ha of intertidal land. Unfortunately, only one simultaneous midwinter count covering the whole Delta area had been carried out before 1971. There were also 8 counts from the Grevelingen estuary prior to its closure (Wolff 1967, Wolff *et al.* 1975). Regular midwinter counts of the entire Delta area have been made since 1974,

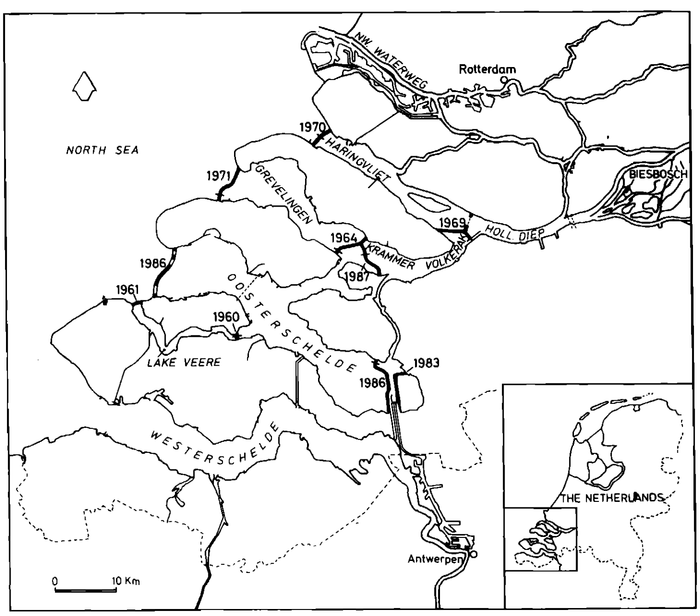

Figure 1. The Dutch Delta area, showing the years in which the separate estuaries have been dammed or barraged.

Table 2. Size (ha) and January average numbers in 1967, and from 1975 to 1980 for Oystercatcher, Curlew and Dunlin from 5 estuaries in the Dutch Delta area. Haringvliet became tideless in 1970, Grevelingen in 1971 and the Krammer-Volkerak in 1987. In the Oosterschelde, the mean tidal amplitude will decrease from 3.50 to 3.05 m. Data from Wolff (1967) and Meininger *et al.* (1984).

	Intertidal Area(ha)	Year	Oystercatcher	Curlew	Dunlin
Haringvliet	3 000	1967	10	1 400	2 900
	0	1975-80	2	360	24
Grevelingen	5 500	1967	23 730	5 090	9 120
	0	1975-80	180	285	450
Krammer-Volkerak	5 000	1967	1 980	1 780	5 730
	5 000	1975-80	6 200	1 050	4 060
Oosterschelde	16 900	1967	46 000	6 700	23 000
	16 900	1975-80	86 000	6 060	45 000
Westerschelde	8 250	1967	9 300	2 200	24 000
	8 250	1975-80	10 500	2 100	37 000
Total area	38 650	1967	81 000	17 200	65 000
	30 150	1975-80	105 000	10 950	90 000

i.e. after the damming, so that the data collected do not allow detailed assessment of the effects of the damming on the size of the wader populations. The data are summarised in Table 2, and do not indicate any dramatic changes in bird numbers between 1967-71 and 1975-80. This may imply that this habitat loss may have been compensated for by birds moving to the remaining intertidal areas. Additional eveidence for this comes from monthly censuses of waders since 1964 on one feeding area in the western part of the Oostershelde. A sophisticated statistical approach using time-series analysis showed that the closure of the adjacent Grevelingen estuary resulted in an increase in the numbers of Oystercatchers *Haematopus ostralegus* feeding on that mudflat. The Oystercatcher was, and is, the most numerous wader in the Dutch Delta (Table 2).

Future developments in the Dutch Delta region may provide additional evidence on the extent to which habitat loss affects existing wader populations. A huge storm surge barrier was completed in 1986 at the mouth of the Oosterschelde, with a secondary dam in the eastern part of the area. Another secondary dam in the northern branch of the estuary has been recently closed, in spring 1987. The combined effect of these three hydraulic engineering projects will be a loss of about 40% of the intertidal habitat of this internationally important area for waders. Overall monthly counts are being made (Meininger 1984), and between 1984 and 1986 23 000 waders (almost 80% of the Oystercatchers) have been ringed, and 4000 of these were colour-ringed. First indications of the effects of closure come from a period of severe weather in Februry 1986. At this time the tidal amplitude was partially reduced by closure of the barrier. Oystercatchers in the central and northern parts of the Oosterschelde had difficulty in maintaining normal weight levels. The average weight of adults (535 g) was about 40 g less than under identical frost conditions in the previous winter (before barrier closure). In the western part of the Oosterschelde weight did not differ between the 2 winters. At the same time as the observed losses of weight, there was considerably increased mortality of Oystercatchers: 5 100 corpses were collected, mostly from the central and northern parts of the estuary. By comparison, during the 1985 cold spell, less than 1 500 Oystercatchers died (Lambeck *et al.* in prep.). The implication is that during the 1986/86 winter the carrying capacity of the feeding areas during severe weather may have been locally decreased, *i.e.* the estuary can support fewer birds since the construction of the tidal surge barrier.

Construction of salines must be considered also as a form of irreversible habitat destruction, since salines are mostly constructed on areas of intertidal mudflats or salt marshes. The consequences are often less severe than in many other forms of habitat destruction, since newly developed salines can still support some wader populations (Rufino *et al.* 1984). However, due to their particular feeding requirements, not all species using the original intertidal habitats are able to shift to feeding in salines.

Although we have described estuarine land-claim as an irreversible effect, there are some possibilities for the restoration of intertidal lands, although such work has yet to be attempted on a large scale, and its success is uncertain (see Davidson and Evans this volume).

2. Sea-wall construction

Sea-wall construction doea not necessarily lead directly to reclamation of intertidal habitat, and sea-walls may be constructed on the mainland itself. However, the experience in many areas, and especially in the international Wadden Sea is that to protect a new sea-wall, small, or sometimes large, reclamations seawards are needed.

An even more serious effect of the embankement of upper levels of intertidal land is that the natural compensation for any dipping of land levels or rise in sea level is inhibited. Land dipping is a local phenomenon *e.g.* along the coasts of the southern North Sea; rise in sea-level occurs worldwide. The CO_2 and trace

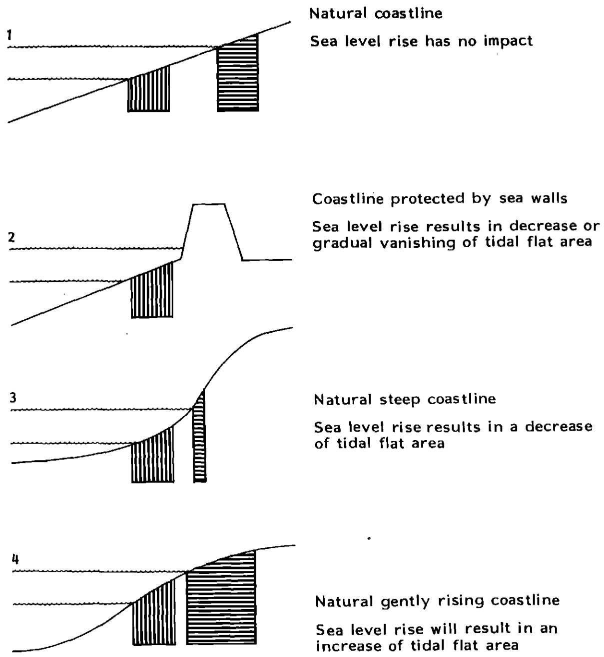

Figure 2. The effects of sea-level rise on the tidal flat area of four types of coastline. The original area of tidal flats is shown vertically hatched. The area of tidal flats after sea-level rise, or land dipping, is shown horizontally hatched.

gas enrichment of the atmosphere resulting from various human activities, in addition to a natural rise in sea-level, means that a global sea and ocean level rise of 50-150 cm is predicted between 1985 and 2050 (Barth and Titus 1984, Robin 1986). This is mainly a consequence of a global rise in temperature of 2-4°C, which leads to an expansion of ocean water, and a further melting of arctic, and possibly also antarctic, glaciers.

The effects of this sea-level rise will differ from place to place. However many existing areas of interidal land will be inundated. Where there are no artificial sea-defences, there is the potential for landward encroachment of intertidal lands where the hinterland is low-lying, although not necessarily elsewhere (Figure 2). However such a shift of intertidal land will be impossible where sea-walls have been constructed, and much of the intertidal habitat in such areas will disappear.

3. Construction of causeways

Causeway construction breaks up the unity of a coastal ecosystem, and has far-reaching effects on the hydrology, transport of nutrients and sedimentation in the area concerned. As a side-effect several kinds of disturbance are given a chance to penetrate into formerly undisturbed areas. Salt marshes may develop on both sides of solid causeways, at the cost of intertidal feeding areas.

THREATS WITH LONG AND MEDIUM TERM RECOVERY RATES

4. Polychlorinated biphenols (PCBs) and pesticides

PCBs constitute a serious long lasting threat to estuarine ecosystems, especially in industrialized countries. Their effects may be enhanced as a result of accumulation in the ecosystem (Langston 1978), although de Voogt *et al.* (1985) found no evidence of accumulation in waders. Though not yet found to affect bird populations in estuaries, PCBs should be considered a serious threat. This applies especially to fish-eating species. It takes a very long time before body levels drop, especially in carnivores. This is due to the very low excretion rates, as well as to continuous intake from PCBs in the environment. PCBs appear to affect the hormone balance of female adult seals, which results in a decreased fertility. This is the most likely reason for the dramatic decline of the Harbour Seal *Phoca vitulina* population in the Dutch part of the Wadden Sea (Reijnders 1986). In past years several countries in north-west Europe have banned their use for uses which will result in their spread into the ecosystem.

Discharge of waste water containing pesticides near Rotterdam caused a dramatic decrease of several seabird species in the Dutch coastal waters in the early sixties (Koeman 1971). For instance, the Sandwich Tern *Sterna sandvicensis* population of the island of Griend decreased from 18 000-25 000 pairs in 1954-1957 to only a few hundreds in 1965. After the pesticide discharge had been stopped there has been a gradual increase to 4 000-6 000 pairs in recent years (de Vries and Vossebelt 1986). Awareness of the negative consequences of persistent pesticides on marine ecosystems have resulted in a gradual decrease of their use in many European countries. Though still present in all kinds of organisms, their effects to the ecosystem have decreased considerably. However, because of their relatively low costs, several persistent pesticides are still produced on a large scale, mainly for export to developing countries where they may still have large effects in ecosystems.

5. Oil spills

The risk of an oil spill is always present on the intensively used shipping-routes along the West-European coasts. Offshore oil exploitation platforms in the North Sea continuously pollute the marine ecosystem, and accidents pose an extra threat. A large oil spill can affect the whole coastal or estuarine ecosystem (Bergman 1982, Dauvin 1982). In such a case, effects may be noticeable for some tens of years, since during low tide the oil penetrates into the sediment thereby affecting benthic communities (Kuiper *et al.* 1984) and hence the animals exploiting these for food. In general seabirds are relatively severely affected as a result of oil spills. Only a few drops of oil may indirectly cause the death of these birds because the oil can cause loss of the insulation of the feathers. Waders run a risk also more directly, by eating toxic oil particles. The grounding of an oil tanker at Scharhorn Riff in the German Wadden Sea in January 1955, spilling 8 000 tons of oil, was estimated to have caused the death of 500 000 birds of 19 different species (Goethe 1968)

6. Heavy metals

High levels of heavy metals may occur locally, thereby seriously polluting the ecosystem. A recent example is the death of over 3 000 birds, half of these waders, in the Mersey estuary in north-west England from 1979-1981, as a result of alkyl-lead poisoning after eating prey contaminated with effluent from a petrochemical works (Bull *et al.* 1983). Some heavy metals have been found to accumulate rapidly in shorebirds (Goede 1985). Organotin compounds used as antifouling agents on boats are of increasing concern as estuarine pollutants.

7. Mussel and Oyster cultures

Mussel and Oyster cultures not only take plaktonic food which thereby becomes unavailable to other organisms but especially Mussels accumulate fine sediments from the water which are deposited on the mussel beds as pseudofaeces. The relatively muddy areas which develop in this way are avoided by, for instance, shrimps and several flatfish species, but are preferred by other fish species, crabs and shellfish-eating birds (Dankers 1986). However, the total impact of Mussel and Oyster cultures is still largely unknown.

8. Organic discharge

Organic discharge and fertilisers, brought into estuaries through run-off into river systems and from coastal waters, have led to increasing plankton growth in coastal waters of the North Sea (Cadee 1986) and elsewhere. This may have had enriching effects locally on the whole food chain in estuarine and marine ecosystems, *i.e.* in some areas on the Swale estuary (Millner 1980). However, high concentrations of organic material may lead to an increasing oxygen demand and even anaerobic situations, which eventually cause a dying-off of organisms in those areas (Essink 1984). High amounts of organic discharge from cardboard industries and potato flour factories in the northern part of The Netherlands have led to local but serious problems in the Dollard, creating a zone of very low oxygen saturation and severely affected macrobenthic fauna of approximately 7 km^2 around the outfall each autumn (van Es *et al.* 1980). In Langstone Harbour in southern England, eutrophication led to the growth of extensive mats of green algae, which resulted in a reduced diversity and biomass of the infauna, and led to an increase in epibenthic animals. Several wader species and Shelduck *Tadorna tadorna* avoided areas of algal mats for feeding, even in winter when the mats had disappeared (Nicholl *et al.* 1981). Rapid recovery generally occurs as soon as the pollution sources disappear (McKay *et al.* 1978).

9. Extraction of natural gas

Apart from the visual aspects, the effects of natural gas extraction are normally limited. However in the event of an accident large amounts of methane and/or nitrogen gas may flow into the water, potentially resulting in large oxygen-poor areas. Local mortality of benthic animals and fish may result. In general, construction of pipelines is necessary to transport the gas (for effects of pipeline construction see under 12.). As a result of natural gas exploitation on the Dutch Wadden Sea island of Ameland, the island and its surroundings are expected to sink by about 26 cm during the next 20 years (Dankers, pers. comm.). Although this sinking will be compensated partly by sedimentation it is unclear to what extent this will occur. The loss of intertidal mudflats and saltmarshes cannot be excluded. Under some conditions gas production platforms flare off gas. Such flares can attract and kill birds, especially nocturnal migrants (Bourne 1979).

10. Chemical pollution

Estuaries in industrialized areas face accidental or permanent dumping of a large variety of waste products, eventually leading to serious and long lasting detrimental effects to the ecosystem (Kohler and Holzer 1980, McLusky 1982). As a side-effect of the use of power plants along estuaries some chemical pollution may occur, due to cleaning of fouling organisms. The reversibility of the effects of chemical pollution are highly dependent on the nature of the product and the rates at which it is discharged and dispersed. A special type of pollution in this category is the dumping of polluted harbour sludge, which often holds high concentrations of toxic substances, like heavy metals, pesticides and oil-products. This activity produces relatively small areas of new intertidal wader habitats, albeit heavily polluted.

11. Sand and shell extraction and dredging

Obviously sand and shell extraction kills benthic organisms living in areas where these activities take place. It also creates holes in the sea bottom or in the tidal channels. In large channels these holes may disappear rather quickly. However, in areas with weak currents extraction holes can remain for many years (van der Veer *et al.* 1985), causing habitat loss for feeding waders. Another serious side-effect of these activities can be a continuously increased turbidity of sea water in large areas. This has potentially large-scale, but still unknown consequences, to the ecosystem.

12. Pipeline construction and accidents due to broken pipelines

Pipeline construction through mudflats sometimes remains visible for several years. Due to changes in sediment composition changes to benthic communities may be long-lasting. Accidents with broken pipelines are comparable with those already mentioned under Oil spills and Chemical pollution.

THREATS WITH RELATIVELY RAPID RECOVERY

13. Fisheries on fish and shrimps

Fisheries generally have limited effects on the ecosystems, though overfishing may occur regionally. Locally, fishing activities can disturb birds or seals.

14. Disturbance by civil planes

Civil planes or helicopters, especially low-flying ones, can cause great disturbance to birds (Burger 1981, 1983) and seals. Their effect is not usually long-lasting, although some birds may be chased away from their original feeding areas or roosts. In areas with frequent aerial activities some habituation appears to occur, but it is not known whether this applies equally to all species.

15. Boating and aquatic sports

Boating activities cause considerable local disturbance (Koepff and Dietrich 1986), especially in areas with many marinas (Prater 1981). The rapidly increasing sport of wind-surfing can cause additional kinds of disturbance, especially in areas of shallow water. As a consequence of disturbance birds may be forced to use alternative (less-preferred) roosts or feeding sites, and so may incur extra energy expenditure. An additional problem are flat-bottomed ships which can spend low tide periods on the exposed tidal flats. Activities of people around these ships may cause additional disturbance to feeding shorebirds.

16. Military activities

Some estuarine areas are intensively used for military activities. These include target practice with tank-artillery, jets and warships, and training flights with helicopters and jets. Apart from producing noise, the activities from planes and boats may also cause disturbance. Studies on the effects of military activities in the Wadden Sea have shown that several wader species may leave areas previously used as high tide roosts. Effects of military activities were enhanced by the recreational use of the study area at the same time. As a result of both disturbance from recreation and military activities Curlews *Numenius arquata* and Bar-tailed Godwits *Limosa lapponica* on the island of Terschelling were forced to spend an extra 15 mins flying per day (Smit and Visser 1984, Visser 1986). Studies on the effects of noise produced by military activities in particular, have been reviewed by Platteeuw (1986). Preliminary studies by Smit (1986) have shown that in an area with intensive target practice, the food intake of Oystercatchers and Curlews did not differ betwen days with and without shooting. However, a slight decrease in the densities of some species was noted on days of heavy shooting, indicating that some birds left the heavily disturbed area.

17. Hunting

Effects of hunting greatly depend on scale of the activities and the size of the area where the activities are carried out. As an immediate effect of hunting, waders are killed. Apart from this, there is a local effect of extremely high densities of lead pellets deposited in the ecosystem. These have a potential risk of being eaten by waterfowl and eventually causing death of the bird through lead poisoning (Clausen and Wolstrup 1979, Mudge 1983). Finally, hunting is very disturbing to birds and mammals. In several areas, like most coastal wetlands in Denmark (Meltofte 1982) and France, and locally in the Mediterranean especially in small wetlands in Italy, Greece and Turkey, hunting pressure is extremely high. This may force birds to concentrate in only unfavourable or inaccessible parts (Joensen and Madsen 1985), or on nature reserves and refuge areas. Severe disturbance from hunting, especially in small sites, may force birds to leave the area altogether.

18. Industrial noise

Industrial noise can be great in some estuaries. Whether or not birds are disturbed is yet to be properly investigated, but seems unlikely. Effects on benthic animals and fishes may occur as well, but have not been studied.

19. Thermal pollution

Power plants are usually sited where there is access to large quantities of cooling water *i.e.* along estuaries or other large water bodies. Relatively warm waste-water can have local effects on the ecosystem. Loi and Wilson (1979) found an increased abundance of some macrobenthic species.

20. Shipping

Shipping activities may have the same disturbing effect as fisheries. In general, effects occur on a small scale and most probably do not constitute a real threat. However, accidents may cause pollution with oil or chemicals (see under 5. and 10.).

21. Cockle dredging and mussel seed fishing

Effects of mechanical cockle dredging have been quantified in the Dutch Wadden Sea (de Vlas 1982). In "bad" cockle years fisheries may take some tens of percents of the total cockle population (de Vlas 1982). However, no effects could be demonstrated on birds depending on the larger bivalves for food. Effects on other benthic animals are still noticeable one year after dredging, but gradually diminish as a result of resettlement. Effects of mussel seed-fishing are not yet known but form part of a general long-term study on the effects of mussel culture by the Research Institute for Nature Management in The Netherlands. Between 1952 and 1978 a total of 16 000 Oystercatchers were shot in Morecambe bay because they were considered a serious pest of cockle fisheries. A further 11 000 were killed in the Burry Inlet in South Wales for the same reason (Prater 1981).

22. Walking on tidal flats and saltmarshes

Tifal flat walking is a popular sport in the Wadden Sea. Thousands of people in organised trips participate throughout the year. As a direct effect benthic animals may get damaged due to trampling, eventually causing their death. However, experiments on a cockle population have shown that only very high densities of walking people resulted in a decrease in cockles (Wolff *et al.* 1982). More important is that birds, and occasionally seals, are disturbed, sometimes in large numbers. Some bird species already appear to fly up at several hundreds of metres away (Wolff *et al.* 1982). Sources of diturbance in Delaware Bay (New Jersey, USA) in descending order of abundance were fishermen, dogs, clam-diggers, off-the-road vehicles, children and joggers (Burger 1986). The effects of these disturbances to birds will depend largely on the frequency of these activities. Disturbance of high tide roosts by dogs, horse-riders and walkers in the Dee estuary, in north-west England probably caused a very strong decrease of their use by birds. Bar-tailed Godwits *Limosa lapponica* declined by 99%, Dunlin *Calidris alpina* by 81% and Knot *Calidris canutus* by 79% between 1976 and 1986. The birds involved have, at least partly, switched to use roosting sites in the Alt estuary, for which an extra 40 km round trip per tidal cycle is necessary (Mitchell and Moser in prep.). This involves a considerable amount of extra energy expenditure. The ultimate effect of this extra energy demand is unknown.

23. Lugworm digging

As with many other topics, the effects of digging for lugworms *Arenicola* or ragworms *Nereis* depends largely on its frequency and intensity. Bait digging, to provide bait for fisheries, is mostly done by hand. In the process of extracting of lugworms, all other benthic species living in that area may be affected and suffer an increased mortality. The effects of digging activities and extraction of worms gradually disappear, due to resettlement. Some species may regain their original population level after a few months. For others it may take much longer (van den Heiligenberg

1987). The presence of people on the tidal flats disturbs on birds. In intensively used areas such as parts of the Dutch delta area, and Lindisfarne in north-east England, some species of birds can be forced away continuously from their preferred feeding areas.

24. Seismic research

Seismic research may cause disturbance to benthic animals, fishes and shorebirds in nearby areas. In shallow waters and on tidal flats, explosives are used. These are positioned at a depth of a few meters in the sediment. In deeper water, an air-gun technique, using compressed air is utilised. In both techniques a small amount of energy is released. No research has been carried out to study the effects, but the indications are that effects on the ecosystem are limited.

25. Scientific research

Scientific research may affect all types of organisms living in the study areas since it can include water and mud sampling, fishing, and catching of birds. However, these activities are generally very localised and are not carried out very frequently. Therefore effects are local and of little impact.

Actual and potential threats to wetlands in the East Atlantic that hold populations of over 50 000 waders are summarised in Table 3.

DISCUSSION

Irreversible habitat degradation must be considered the most serious threat to wetlands. However, reversible threats also can cause serious deterioration of wetlands, making parts or even whole estuaries unsuitable for birds. Several activities at the same time may have cumulative effects. This implies that even where separate activities may not appear to pose a major threat, a combination of some of these can have far reaching consequences. This applies especially to different sources of pollution or disturbance. When such a combination of threats occurs on a regular basis or on a large scale they may even lead to a total disappearance of birds from a particular area.

Especially in the southern parts of Europe, there is a tendency to reclaim the higher parts of the salt marshes for various kinds of human use *e,g,* agriculture and waste disposal. These activities tend to progressively spread out over an area, and are usually accompanied by road construction, building activities and increased disturbance. The proportion of the total surface of the salt marshes threatened in this way in western France is estimated to be 35%, and in Portugal 80% (Dijkema 1985). As a consequence of such activities the opportunities for wader to roost undisturbed are reduced. Furthermore, human activities tend to spread out over especially the higher parts of the remaining tidal flats. This applies both to heavily disturbed sites in the Mediterranean, and in some other areas such as the Dee estuary in western Britain (see under 22). On the Dee, some of the waders continue to use the low tide mudflats for feeding, despite being forced to move outside the estuary to roost.

Table 3 indicates that at present the number (but not necessarily the effects) of serious irreversible threats to the most numerically important African wintering area, the Banc d'Arguin is less than in other major coastal wetlands of the East Atlantic. However, in 9 out of the 16 wetlands some kind of irreversible habitat destruction is going on at the moment, or is proposed (Table 3). Activities with long term recovery rates are under way or are being planned in almost all wetlands listed in Table 3. The total number of threats shown in the table is not of course the ideal measure for the total impact of human activities to the areas concerned. For instance the effects of a large scale and continuous pollution in a certain area may be much more severe than those of the 5 small and occasional

Table 3. Coastal wetlands along the East Atlantic flyway which hold an average wintering population of >50 000 waders, and a summary of known actual and potential threats. The numbers of threats refer to those in Table 1. Wader numbers are based on data from IWRB files; information on threats is based on Prater (1981), Wolff and Binsbergen (1985) and Bredin (pers. comm.).

Area	Country	Approx. winter popn.[a]	Threats 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Banc d'Arguin	Mauritania	2100					+								+												+
Wadden Sea	Netherlands	370		+		+	+		+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+		+
Wadden Sea	West Germany (Niedersachen)	270	+	+		+	+		+	+	+	+	+	+	+	+	+	+	+			+	+	+	+		+
Gulf of Gabes	Tunisia	240					+					+		+	+								+				
Delta	Netherlands	228	+	+		+	+	+	+	+		+	+		+	+	+				+	+	+	+	+		+
Morecambe Bay	Great Britain	159	+	+		+	+					+		+	+	+	+			+		+	+				
Wash	Great Britain	128	+	+			+								+	+	+	+					+				
Archachon	France	101		+		+	+		+						+	+	+		+				+	+			
Wadden Sea	West Germany (Schlewig-Holstein)	100	+	+	+	+	+		+		+		+		+	+	+	+	+			+	+	+			+
Dee	Great Britain	96	+	+		+	+	+		+		+		+	+	+	+			+		+					
Solway	Great Britain	73		+		+	+								+	+	+			+							
Humber	Great Britain	69	+	+		+	+			+		+	+		+	+	+			+		+					
Ribble	Great Britain	68	+	+		+	+	+		+		+		+	+	+	+			+		+					
Baie du Mont St. Michel	France	55		+	+	+	+		+	+					+	+	+		+				+	+	+		+
Tejo	Portugal	54				+	+	+	+	+		+	+		+	+	+		+			+	+				
Severn	Great Britain	53	+	+		+	+	+		+		+	+		+	+	+			+	+	+					

[a] population x1000

human activities. However, the total amount registered per site does give an indication of the total range of major human activities in many areas. It appears that the Wadden Sea, in spite of several nature protection measures, faces many threats in both the Dutch and German parts of the area.

It must be emphasized that small sites, not listed in Table 3, are also important as part of the coastal wetland network. Although not continuously harbouring large numbers of birds they often play an important role as a staging area during autumn and spring migrations. Because of rapid turnover of individuals the number of birds using these sites can be many more than the total number present at any one time (Kersten and Smit 1984). Their value to migrating wader populations is still insufficiently well studied but may be even more important that currently realised.

Large wetlands elsewhere in the world are being reclaimed also at a very high rate. Dramatic examples can be found in the Arabian Gulf and in South-east Asia (see Parish this volume). A provisional estimate of the size of tidal flats remaining in the Arabian Gulf is approx. 2500 km^2, which are probably being used by 1-2 million wintering waders (Zwarts pers. comm.). According to all checklists from this area waders are much more numerous in spring than in winter, suggesting that several million waders use these areas in spring. During the last 10 years, about 50% of the Saudia Arabian tidal flats, which originally amounted to approx. 200 km^2, have been reclaimed, mainly for building purposes (Zwarts pers. comm.). These habitat losses may have serious consequences for birds using this still very poorly studied migration route (see Summers *et al.* this volume). Much the same applies to many rapidly degrading wetlands in South-east Asia. About 70% of the mangroves and mudflats have disappeared in the Philipines during the last 30 years, and another 20% are threatened in the next decade. In Thailand many wetlands on the west coast have been turned into fish and shrimp ponds or oil palm plantations, as a result of which 50% of the wetlands and mudflats already have degraded and another 30% is threatened (Parish 1985, this volume). Stoutjesdijk (1982) estimates that at least 150 000 km^2 of coastal wetlands worldwide have been already reclaimed in the past. Segeren (1983) estimates that 9 million km^2 of wetlands may still be under threat of reclamation, of which coastal wetlands probably amount to over 1 million km^2. A further serious problem, especially in South-east Asia, is the hunting of waders and wildfowl fo food (see Parish this volume). Parish estimates that perhaps some tens of percent of the total flyway population is killed annually by hunting.

It is clear that there are still very many threats facing coastal wetlands worldwide. Efforts to promote a better awareness of these areas and marine ecosystems, must continue to develop. A more profound understanding of the role wetlands, not only in terms of nature conservation but also in terms of the economic benefit for people, can lead to a more sound management from which also waders and other waterbirds may profit (see also Dugan, this volume). This applies both to the relatively well studied wetlands in NW Europe, and to the highly threatened wetlands in, for instance, the Arabian Gulf and SE Asia. Research and conservation measures are urgently needed to preserve these most important areas.

The listing we have made here reveals the large range of threats facing coastal wetlands. However a listing such as this cannot give a clear impression of the magnitude of the threat to each site. It is extremely difficult, given the current level of understanding of the effects of the various threats, to make such an assessment. Nevertheless, such an assessment would seem a vital next stage in developing an effective conservation strategy for coastal wetlands worldwide. This need is particularly pressing since the threats to many coastal wetlands appear to be increasing.

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