British Trust for Ornithology

BTO Research Report No. 255

Effects of Reductions in Organic and Nutrient Loading on Bird Populations in Estuaries and Coastal Waters of England and Wales
Interim Report March 2001

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Report of work carried out by
The British Trust for Ornithology
in conjunction with HR Wallingford
under contract to
English Nature,
Countryside Council for Wales
and the Environment Agency

March 2001

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Registered Charity No. 216652

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1. This interim report presents a literature review of the effects of waste water discharges on coastal waterbird populations and the potential impacts upon them of the European Community's Urban Waste Water Treatment Directive (UWWTD) and Bathing Water Directive (BWD). It also summarises data collected to date concerning coastal water bird numbers, particularly within Special Protection Areas (SPAs), and water quality data within these areas.

2. The two directives aim to protect coastal and freshwater environments from the adverse effects of urban waste water (i.e. domestic waste water - sewage - and industrial waste water). Their main focus has been to end the discharge of raw sewage and industrial waste water effluents directly onto intertidal areas and into coastal waters, usually by providing 'secondary treatment' (which involves biological treatment of the waste water).

3. The impact of these directives on coastal waterbirds has raised some concern as in many areas outfalls may provide considerable food for bird species, either as directly edible matter or by artificially enhancing concentrations of invertebrate food

4. Sediments close to outfalls often become anaerobic due to a high Biochemical Oxygen Demand (BOD) and may in the most extreme cases become completely unsuitable for invertebrate life. The high nutrient loading may encourage algae to flourish, which will add to the organic matter originating from the discharge itself and further increase the BOD. Beyond this, sediments are occupied by an abundance of a small number of opportunistic species, notably the polychaete *Capitella capitata*, that are able to tolerate a depletion of Dissolved Oxygen (DO).

5. In the next zone, more moderate enrichment allows species characteristic of both polluted and unpolluted sediments to flourish and here the overall invertebrate biomass may be considerably enhanced. Beyond this zone the influence of organic enrichment diminishes and species diversity reduces.

6. A number of species may feed directly on waste matter released in the discharge. Gulls are particularly opportunistic and because they may act as carriers of *Salmonella* from the outfalls, have been the focus of a number of studies. Grain and other matter from food factories, breweries and distilleries may also provide considerable food for ducks. Invertebrate populations enhanced by the nutrient and organic enrichment provide food for wildfowl and waders.

7. A number of studies have reported changes in waterbird numbers following improved waste water treatment, though comparatively few have offered quantitative information that has linked such changes to alteration of the birds' food supply. In Scotland, the replacement of untreated discharges of waste water with primary treatment caused large declines in the populations of a number of duck species, notably Goldeneye and Scaup. Improved sewage treatment on the Clyde has similarly been followed by declines in the numbers of Shelduck, Pintail, Lapwing, Dunlin and Redshank. On previously grossly polluted estuaries, however, it has been suggested that waterbird numbers may have increased due to improvements.

8. Data concerning waterbird numbers have been collected from the Wetland Bird Survey (WeBS) Core Count and Low Tide Count Schemes. Core Count Data have been collected for all estuarine SPAs and for the Northumbria Coast SPA. Low Tide Count Data have been collected for 58 sites, of which 43 are protected as SPAs.

9. Water quality data have been obtained from Anglian Water and are promised from Severn Trent Water, Southern Water, South West Water, Welsh Water and Wessex Water.

2. INTRODUCTION: THE URBAN WASTE WATER TREATMENT DIRECTIVE (UWWTD), THE BATHING WATER DIRECTIVE (BWD) AND IMPROVEMENTS TO WASTE WATER TREATMENT

The Urban Waste Water Treatment Directive (UWWTD) (Directive 91/271/EEC and its Amending Directive 98/15/EEC) (Anon 1991a, 1998a) aims to protect the environment from the adverse effects of urban waste water (*i.e.* 'domestic waste water' - hereafter referred to as 'sewage' - and 'industrial waste water' from agri-foodstuff sectors) by requiring Member States to ensure that such water is collected and treated. Untreated water may adversely affect human health and the environment due to the following forms of 'pollution' (Anon 1999):

- discharges of nitrogen in its various forms: organic nitrogen, ammoniacal nitrogen, nitrites and nitrates from urban water and agricultural activities. Nitrates may pollute drinking water, cause eutrophication in certain waters, resulting in an ecological imbalance due to excessive algae growth, Ammoniacal nitrogen is particularly toxic to the aquatic fauna.
- discharges of phosphorus which, in spite of the reduction in the use of phosphates in detergents and washing powders, are responsible for cases of eutrophication, particularly in fresh waters or estuaries.
- a reduction in the amount of oxygen in water as a result of the decomposition of the organic matter contained in wastewater, endangering aquatic life through asphyxiation and disrupting the ecological balance of the water.
- discharges of pathogenic micro-organisms of faecal origin (bacteria, viruses, parasites) contained in urban waste water which could pose a health risk through contamination of drinking water supplies, waters used for bathing or other water sports and shellfish waters.
- discharges of hazardous, toxic and bioaccumulable substances (chemical compounds, heavy metals, hydrocarbons, etc.) from connected industries but also domestic activities (detergents, paints, solvents, etc.) posing a potential risk to aquatic life and human health.
- the adverse effects of waste water on the Special Protection Areas (SPAs) under the amended Council Directive 79/409/EECof 2 April 1979 on the conservation of wild birds and on the natural habitats and species referred to in Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.
- loss of value in terms of appearance and appeal to tourists of freshwater areas or coastal waters polluted by urban wastewater.

Sources of industrial waste water have been summarised by Pounder (1976a) and include food factory discharges, chemical effluents from the pharmaceutical and oil industries, mine water, pulp mill and cooling water discharges. Pollution problems may also come from sludge dumping.

The Bathing Water Directive (BWD) (Directive 76/160/EEC and its proposed revision COM(94)0036-94/00006SYN) (Anon 1976) aims to reduce the pollution of bathing water and to protect such water against further deterioration. (Bathing water is defined as all running or still fresh waters or parts thereof and seawater in which bathing is authorised or not prohibited and traditionally practised). The Directive requires Member States to identify bathing areas, to monitor them during the bathing season and to report the results of the monitoring to the Commission. The UWWTD and BWD together with the Nitrates Directive (Directive 91/676/EEC) (Anon 1991b), concerning the protection of waters against pollution caused by nitrates from agricultural sources, and the Drinking Water Directive (Directive 98/83/EC) (Anon 1998b) are to be combined within a new Water Framework Directive (Anon 2000).

The main focus of these directives in coastal areas has been to end the discharge of raw sewage and industrial wastewater effluents directly onto intertidal areas and into coastal waters. Treatment may take three forms (Anon 1999). 'Primary treatment' entails treatment of urban wastewater by a physical and/or chemical process involving settlement of suspended solids, or other processes in which the BOD5 (five-day biochemical oxygen demand) of the incoming wastewater is reduced by at least 20% before discharge and the total suspended solids of the incoming wastewater are reduced by at least 50%. ‘Secondary treatment’ generally involves biological treatment with a secondary settlement or equivalent process. ‘Tertiary treatment’ entails treatment (additional to secondary treatment) of the nitrogen (nitrification-denitrification) and/or phosphorus and/or of any other pollutant affecting the quality or a specific use of the water. The Directives usually require secondary treatment, but may be more stringent (secondary plus tertiary treatment) for discharges in areas identified as sensitive by the Member States and in the relevant catchment areas. The treatment may be less stringent (primary treatment) under certain conditions and agreed to by the Commission or the Council for discharges in coastal waters or estuaries identified by the Member States as being less sensitive. No such sites have been designated in England or Wales, however.

The impact of these directives on coastal waterbirds has raised some concern as in many areas outfalls may provide considerable supplies of food for bird species, either as directly edible matter or by artificially enhancing concentrations of invertebrate food (Pearce 1998, Rehfisch 1998a, 1998b, Spray 1998). Pearce (1998) reported how sewage improvements may result in a decline in organic matter and thus the invertebrate life dependent upon it. Each of these articles has highlighted cases where declines in bird numbers have followed improvement programmes. The Ramsar Convention Bureau made reference to this dichotomy in its 1994 mission report for the Dee Estuary and recommended that a monitoring project should be set up at Heswall where a primary treatment plant was due to be upgraded to provide full treatment, including ultra-violet sterilization. This new treatment plant was completed during 1998. The area was particularly important for Redshank *Tringa totanus* that fed in sewage-enriched areas. However, it was the view of the bureau’s Monitoring Procedure team that the potential value for birds of locally sewage-enriched areas should not prevent the upgrading of treatment in the interests of the wider environment (Ramsar Convention Bureau 1994).

3. ORGANIC AND NUTRIENT ENRICHMENT DUE TO SEWAGE AND INDUSTRIAL WASTE WATER DISPOSAL

The impact of sewage and industrial waste water discharges on the quality of the receiving waters depends on a number of factors. The nature of the wastewater and the level of treatment received before discharge will have an effect on the magnitude of the organic and nutrient load. In the case of sewage, primary and secondary treatment have a significant effect on the organic load discharged but less impact on the total nutrient load. The particulate organic content of a discharge can have a significant effect on the impact, as particulate material will tend to settle close to the outfall if the currents are low enough. Dissolved material will tend to be more widely dispersed. As well as reducing dispersal, settlement of particulate matter can result in blanketing of the natural sediments in the vicinity of the outfall.

The hydrodynamics of the receiving waters can also have a major effect on the impact of discharges. In areas with high tidal ranges and/or large currents the natural dispersion will tend to minimise the impact whilst areas with low tidal range and currents will tend to be more sensitive.

The impact of discharges is also affected by the relative magnitude of other sources in the neighbourhood such as diffuse loadings into rivers. In the case of the north Northumbrian coast the diffuse nutrient load carried by the River Tweed has a significant impact on the nutrient budget of the adjacent coastal waters, which can mask the impact of small point source discharges. In this case there may also be a significant effect from sources in Scotland.
Diffuse nutrient sources, arising from agriculture, can also have an impact on the organic load. Nutrients fuel growth of phytoplankton and macrophytes and when the plants die there is an additional organic load.

The degree of organic loading in sediments is expressed by the Biochemical Oxygen Demand (BOD), a variable that indicates the amount of oxygen required by aerobic bacteria to help in the decomposition of the organic matter. Close to outfalls, BOD is high and Dissolved Oxygen (DO) is only available in the very upper sediments (Pearson & Rosenberg 1978). The boundary between these aerobic sediments and the anaerobic sediments below is referred to as the Redox Potential Discontinuity (RPD). Anaerobic bacteria below the RPD produce Hydrogen Sulphide, metal sulphides associated with this process causing the sediments to turn black.

4. WASTE WATER OUTFALLS AND INVERTEBRATE POPULATIONS

4.1 Effects of Waste Water Outfalls on Invertebrate Populations

The consequences of the increased organic and nutrient loading to coastal sediments due to sewage and industrial wastewater have been classically described by Pearson and Rosenberg (1978). In their model, sediments close to sources of nutrient and organic enrichment become anaerobic due to the high BOD and may in the most extreme cases become completely unsuitable for invertebrate life due to a depletion of DO and the high concentrations of Hydrogen Sulphide produced by anaerobic bacteria. The high nutrient loading may encourage algae to flourish (Perkins & Abbott 1972, Tubbs 1977, Smith 1996, Soltan *et al.* 2001) and this will add to the organic matter originating from the discharge itself and further increase the BOD. Mats of algae, such as *Enteromorpha* and *Ulva lactuca*, may support moderate numbers of the Laver Spire Shell*Hydrobia ulvae*, amphipods such as *Gammarus locusta*, Common Shore Crabs *Carcinus maenas* and if the RPD is not too near the surface, ragworms *Nereis diversicolor* (Tubbs 1977).

In the next zone, the RPD begins to get deeper and the sediments are occupied by an abundance of a small number of opportunistic species, notably the polychaete complex *Capitella capitata*, that are able to tolerate the depletion of DO (Pearson & Rosenberg 1978, Pearson *et al.* 1983). These polychaetes were characteristic of formerly highly polluted estuaries, such as the Tees (Gray 1976, 1979), and have been used as an indicator in a number of pollution related benthic studies (*e.g.* Gray *et al.* 1992, Grassle & Grassle 1976, Marine Pollution Monitoring Management Group 1998). *Capitella* are commonly found in sediments close to outfalls (Player 1970, Swartz *et al.* 1986).

Capitella and other pollution-tolerant species may help to aerate and detoxify organically enriched sediments through their mass action (Aller 1982) and thus make sediments suitable for some other species. Lugworms *Arenicola marina*, for example, may colonise such areas (Pounder 1976a), though McLusky (1968) found that sewage polluted sediments could not support the amphipod *Corophium volutator*. Studies of an area of sewage discharge on the Fraser River in British Columbia have found that sediments beyond the most severe pollution may also be colonised by the polychaetes *Manayunkia aestuarina* and *Eteone longa*, the Baltic Tellin *Macoma balthica*, the amphipods *Corophium salmonis* and *C. insidiosum* and copepods (Levings & Coustalin 1975, McGreer 1979, Harrison *et al.* 1999).

As the DO level in sediments increases and the RPD becomes even deeper, a transitory zone exists containing species characteristic of both polluted and unpolluted sediments. Species diversity and overall biomass may peak in this zone (Otte & Levings 1975, Pearson & Rosenberg 1978). Invertebrate community composition and activity in these sediments may also be affected by reduced salinity levels and by the moisture given to the mudflats when the tide is out (Yates *et al*. 1993). Beyond this zone the influence of organic enrichment diminishes and species diversity reduces.

The distances to which invertebrate communities are affected by wastewater outfalls depend upon the volume and nature of the discharge, the depth of water into which it flows (Otway *et al.* 1996) and coastal and other currents (Sherwin 2000). Smith (1996), for example, found that the impact of poorly treated domestic sewage effluent was restricted to within 300 m of the discharge point for most species of invertebrates found living in a kelp bed in Australia. Anderlin and Wear (1992) similarly found that benthic communities were affected within a 500 m radius of an outfall in New Zealand. Taylor *et al.* (1998) reported a typical response in the benthic infaunal community in a study of untreated sewage discharging from two deep water outfalls in British Columbia. Within 100 m of the outfalls, overall abundance was increased and species diversity reduced, whilst toxins from the sewage were still apparent in sediments 400 m away. On rocky shores, rapid removal of the effluent by waves may reduce the impacts of discharges on invertebrates (Underwood & Chapman 1997). Eaton (2000a), though, in a study at Blyth in Northumberland, suggested that 40% of organic particulates in the water column there may have originated from local untreated sewage effluent and that this may have been an important food source for filter-feeding molluscs such as mussels *Mytilus edulis*, living on the rocky coast.

Whilst the effects of individual wastewater outfalls may be restricted to within a few hundred metres, the combined effects of several outfalls and nutrient enrichment from farmland may affect whole estuaries. In both the Rogerstown Estuary in Ireland (Fahy *et al.* 1975) and the Lillo-Rilland area of Holland's Delta Region (van Impe 1985), for example, increases in algae and invertebrates such as *Hydrobia ulvae*, *Corophium volutator* and *Nereis diversicolor* have been linked to increased organic inputs, from domestic sewage and from industrial and agricultural wastes. Eutrophication of the Ythan Estuary in Scotland (primarily due to nutrient inputs from farmland) has led to increased algal cover of mudflats and this has had deleterious effects on the distribution and abundance of benthic invertebrates, notably *Corophium volutator* (Raffaelli *et al.* 1999). The estuary is now designated as a Nutrient Vulnerable Zone under the 1991 Nitrates Directive (Directive 91/676/EEC; Anon 1991b).

4.2 Potential Impacts of the UWWTD and BWD on Invertebrate Populations

A number of studies have investigated how invertebrate (and algae) communities have changed following improved wastewater treatment. In the Fraser River Estuary in British Columbia, primary treated sewage was formerly discharged directly onto the mudflats of Sturgeon Bank. Diversion of this sewage in 1998 resulted in a gradual colonisation of previously grossly polluted and empty sediments by the sewage tolerant polychaete *Manayunkia aestuarina, Corophium* spp. and *Macoma balthica* (Rebele 1994). Harrison *et al.* (1999) though noted that the recolonisation of such mudflats may be affected by several interacting factors, including the organic carbon, metal and nutrient contents of the water and sediments as well as the sediment particle size. Recovery of the health of the estuarine environment in this study was monitored using two indicator species, *Corophium salmonis* and *Macoma balthica*.

In less overpolluted areas where wastewater discharges have enriched sediments, improvements to treatment may result in a decrease in invertebrate abundance. On the Clyde Estuary, for example, improvements to treatment have been linked to a decline in the abundance of *Corophium volutator* and *Nereis diversicolor* (Curtis & Smyth 1982, Thompson *et al.* 1986). In Boston Harbor, cessation of sewage sludge discharges in 1991 resulted in a general increase in invertebrate abundance and diversity over the following three years, with a particularly dramatic increase in the abundance and spread of the amphipod *Ampelisca* (Kropp *et al.* 2000). More recently there has been a gradual decline in the abundance and diversity of the infaunal community as it reverts to one more typical of less-polluted environments. As mentioned above invertebrates and algae on rocky shores may be less influenced by discharges of sewage than those inhabiting softer sediments and studies have shown that reductions or cessation of discharges may have only slight impacts on communities in these habitats (Underwood & Chapman 1997, Soltan *et al.* 2001).

5. WASTE WATER OUTFALLS AND BIRD POPULATIONS

5.1 Effects of Waste Water Outfalls on Bird Populations

The food available directly from sewage and industrial discharges and the changes in invertebrate densities resultant from organic inputs, as described above, may have a large influence on the populations of waterbirds that the local coastal areas are able to support. A number of species may feed directly on waste matter released in the discharge. Gulls are particularly opportunistic feeders and may feed on whatever food items are available in the discharge. Ferns and Mudge (2000) in their study on the south Wales and Dorset coasts found that Black-headed Gulls *Larus ridibundus* took a range of vegetable matter, including plant seeds and potato peelings, as well as bread, meat and a variety of indigestible items, including pieces of plastic and string. Their study also found that the abundance of both Black-headed Gulls and Herring Gulls *L. argentatus* was positively correlated to the volume of sewage discharged and that numbers were reduced by over half during periods of infrequent intermittent discharge. Sewage outfalls only supported a small proportion of the local population of each species (11% and 3% respectively), and each was also found in large numbers at refuse tips and on fields. The outfalls in the Dorset study area also supported fewer gulls than those in Wales, partly because they discharged into deeper waters and consequently less food was made available from them. Black-headed Gull was the most numerous species at outfalls in both study sites and Ferns and Mudge suggested that the average particle size of food items available at the sewers was perhaps too small to provide an adequate return for larger species. Outfalls were particularly favoured by juveniles of each of these two species. Other gull species recorded included Common Gull *L. canus* and Lesser Black-backed Gull *L. fuscus* and, very occasionally, Great Black-backed Gull *L. marinus*, Little Gull *L. minutus* and Mediterranean Gull *L. melanocephalus*. One other study has also quantified the degree to which outfalls are frequented by gulls. Fitzgerald and Coulson (1973), looking at gull populations along the Tyne and Wear estuaries, found that outfalls were particularly frequented by Black-headed and Herring Gulls, but to a lesser extent by Lesser Black-backed Gulls, Common Gulls and Kittiwakes *Rissa tridactyla*. A number of other studies have looked at the possible health risk that may result from gulls feeding at wastewater outfalls and refuse tips (MacDonald & Brown 1974, Fenlon 1981, 1983, Butterfield *et al.* 1983, Fricker 1984, Monaghan *et al.* 1985). In particular, there is a worry that gulls may act as carriers of *Salmonella* between these sources and the inland water reservoirs that they roost on at night. Gulls and other coastal waterbirds, which feed at wastewater outfalls, may also excrete large numbers of faecal coliforms and streptococci and thus affect the quality of bathing waters in a much larger area (Jones & Obiri-Danso 1999).

The importance of sewage and some industrial outfalls in maintaining duck populations has been well documented. Studies in Scotland have described how flocks of Scaup *Aythya marila* and Goldeneye *Bucephala clangula*, in particular, were in the past concentrated near sewage outfalls or outfalls discharging waste from food factories, breweries and distilleries (Thom 1969, Player 1970, 1971, Milne & Campbell 1973, Pounder 1974, 1976a, 1976b, Campbell & Milne 1977, Campbell 1977, 1978, 1984, Barrett & Barrett 1985, Campbell *et al.* 1986). The diet of duck in the vicinity of outfalls at Leith and Seafield in Edinburgh was described by Player (1970, 1971) and Campbell (1978). Their studies emphasized the importance of barley and maize grain and husk, directly discharged from distilleries, in the diet of Scaup and Goldeneye, and also of nematodes, nereid worms and gammarids, which would have been abundant in the nutrient, enriched sediments. Eiders *Somateria mollissima*, in contrast, fed primarily in mussels. Campbell (1978) reinforced the distinction made by previous studies in eastern Scotland (Thom 1969, Milne & Campbell 1973) between Scaup, Goldeneye and Pochard *Aythya ferina* that congregated in areas of artificially concentrated food and more marine seaducks – Eider, Common Scoter *Melanitta nigra*, Velvet Scoter *M. fusca* and Long-tailed Duck *Clangula hyemalis* – that usually gathered around more natural food concentrations.

The changes in invertebrate and algal biomass found in the vicinity of outfalls are also likely to affect the densities of a number of other surface-feeding ducks and waders. Close to outfalls, the extreme levels of nutrient and organic enrichment cause sediments to become deoxygenated and unsuitable for all but a few species of polychaetes, notably *Capitella capitata*. Over-enrichment in this zone may also lead to particularly dense mats of algae forming and their decay further depletes the sediments below of oxygen. This may provide a short-term food bonanza for some species, such as Oystercatcher *Haematopus ostralegus*, as due to the lack of oxygen, shellfish such as Common Cockles *Cerastoderma edule* and *Macoma balthica* may be forced up to the surface (Pounder 1976a). In the long-term, however, the sediments beneath the algal mats may become particularly impoverished of invertebrate food and this may lead to local declines in bird numbers (Tubbs 1977, summarizing the conclusions of Dunn 1972, Southgate 1972 and Portsmouth Polytechnic 1976). McLusky (1968), for example, found that sewage polluted anaerobic sediments on the Ythan Estuary in north-east Scotland did not support *Corophium volutator* and thus were particularly poor areas for feeding Redshank. Such areas may still hold lugworms *Arenicola marina*, however, and thus may support Curlew *Numenius arquata*, Black-tailed Godwit *Limosa limosa* and Bar-tailed Godwit *L. lapponica* (Pounder 1976a). Although they may lead to an impoverished infaunal community, mats of algae, may themselves support moderate numbers of amphipods such as *Gammarus locusta*, Common Shore Crabs *Carcinus maenas* and *Hydrobia ulvae* (Tubbs 1977), the latter being an important food source for Shelduck *Tadorna tadorna*, Pintail *Anas acuta* and Dunlin *Calidris alpina* (Olney 1965, Cramp 1977, Cramp & Simmons 1983). *Enteromorpha* is also itself grazed by Wigeon *Anas penelope* (Cramp 1977).

Beyond this polluted zone, oxygen levels rise and invertebrates may proliferate in the more moderately enriched organic levels (Pearson & Rosenberg 1978). This enrichment increases the overall abundance and diversity of invertebrates and may benefit a number of bird species (Pounder 1976a). In estuarine sediments, increases in the densities of *Nereis diversicolor* and *Corophium volutator*, for example, may benefit Curlew and Redshank respectively (Goss-Custard 1969, 1970, Goss-Custard *et al.* 1977). On rocky shores, nutrient inputs from sewage outfalls may promote the growth of mussel beds and benefit Turnstones *Arenaria interpres* and Purple Sandpipers *Calidris maritima* (Eaton 2000b).

Tubbs (1977) found that nine of 13 waterbird species had increased in Langstone Harbour during a 33 year period and attributed this partly to the increased local input of sewage effluent. (The main reason for change was a reduction in hunting pressure). Studies of the Rogerstown Estuary in Ireland (Fahy *et al.* 1975) and the Lillo-Rilland area of Holland's Delta Region (van Impe 1985) have also linked increases in organic inputs (from sewage and industrial and agricultural wastes) to increases in algae and invertebrates and thus to increased bird populations. Increased algal cover in the Ythan Estuary, a result of increased nutrient inputs from farmland, has reduced the abundance of *Corophium volutator* and this has in turn caused a recent decrease in bird numbers (Raffaelli *et al.* 1999).

Green *et al.* (1990) and Hill *et al.* (1993) investigated whether, in addition to physical, climatic and geographic variables, wader communities on British estuaries could be determined directly by water quality variables. Their studies found that the composition of wader communities was associated with salinity, ammoniacal nitrogen concentration in the water, percentage dissolved oxygen and the biochemical oxygen demand. In spite of these relationships, changes in the wader communities recorded over their 16 year study period were not related to any aspect of the nutrient status of estuaries.

Ravenscroft (1998) studied the association between wintering waterbirds and freshwater inputs on the mudflats of East Anglian estuaries. Inputs included natural flows from streams and ditches as well as discharges from storm-drains and pipes. On the Orwell, Stour and Blackwater, he found that Shelduck, Wigeon, Pintail, Dunlin, Curlew and Redshank all used such stream corridors in greater numbers than would have been expected if birds were distributed evenly across the estuaries. Densities of Shelduck, Grey Plover *Pluvialis squatarola*, Dunlin, Curlew and Redshank were also positively related to the rate of discharge of flows into the Orwell. These associations were attributed to the increased nutrient and freshwater flow into the mudflats.

5.2 Potential Impacts of the UWWTD and BWD on Bird Populations

A number of studies have reported changes in waterbird numbers following improved wastewater treatment, though comparatively few have offered quantitative information that has linked such changes to alteration of the birds' food supply. In some cases it is probable that improved wastewater treatment may benefit birds. Some British estuaries, such as the Thames and Mersey, were formerly so grossly polluted by sewage and other effluent that many mudflats had become anaerobic and had a relatively impoverished invertebrate fauna. Recent increases in bird numbers on these estuaries have been attributed to a re-establishment of a variety of invertebrates following improvements to sewage works (Harrison & Grant 1976, Head & Jones 1991, National Rivers Authority 1995). Other studies have focussed upon the problems that contaminants in sewage and other effluents may cause and how improved wastewater treatment may reduce the incidence of toxins in birds' tissues (Harrison *et al.* 1999, Wilson *et al.* 1999).

In areas where wastewater discharges provide large quantities of food directly into coastal ecosystems or where they have enriched the invertebrate biomass, however, improvements to disposal have the potential to seriously deplete bird populations. Studies in Scotland have demonstrated how dependent internationally important populations of duck formerly were on effluent discharges (Thom 1969, Player 1970, 1971, Milne & Campbell 1973, Pounder 1974, 1976a, 1976b, Campbell & Milne 1977, Campbell 1977, 1978, 1984, Barrett & Barrett 1985, Campbell *et al.* 1986). Pounder (1976a) expressed the concern felt by many about changes in sewage disposal and highlighted several areas where the introduction of primary treatment, settlement systems or the combination of separate short outfalls into single outfalls discharging into deeper water, could affect birds. The impact of changes at Leith and Seafield was reported by Campbell (1984). Here untreated sewage from Edinburgh was formerly discharged directly into the Firth of Forth via eight main outfalls (Anderson *et al.* 1981), but this system began to be replaced in February 1978 when a primary treatment plant came into operation. In the two winters following the plant's implementation, Campbell (1984) found that there had been considerable declines in the local numbers of both Scaup and Goldeneye and that the remaining birds preferentially used those outfalls least affected by the changes (see also Bryant 1987 for a summary). It was unclear, however, whether the fall in numbers was due to a redistribution of birds to other coastal sites or whether the changes had actually affected the species populations.

Similar declines have been reported on the Moray Firth. The closure of a maltings, improvements to a distillery's effluent and the creation of a new deep water outfall for sewage have been linked to dramatic falls in the numbers of Goldeneye in the Invergordon-Dalmore and Burghead areas and the closure of an outfall at Carn Arc to the disappearance of Tufted Duck and a small flock of Goldeneye there (Barrett & Barrett 1985). Similarly, Thom (1969) linked a decline in Mallard *Anas platyrhynchos* and Teal *Anas crecca* numbers on the Tullibody Island – Kennet Pans stretch of the Firth of Forth to a cessation of distillery wash and Musgrove *et al* (2001) reported a decline in Mute Swan *Cygnus olor* numbers on the Stour Estuary following closure of a brewery. More recently Marsh (2000) noted a decline in the numbers of Goldeneye following the clean up of the Sandylands outfall in Lancashire.

Changes in wastewater disposal have also been linked to changes in the numbers of waders wintering on the Clyde Estuary. Prior to the 1970s, the estuary had been recovering from high pollution levels and over-enrichment of its mudflats and the initial reduction in pollution levels was speculatively linked to a concurrent increase in the numbers of waders (McKay *et al.* 1978, van Impe 1985). More recent study has shown that since 1970 numbers of Shelduck, Pintail, Lapwing *Vanellus vanellus*, Dunlin and Redshank have declined dramatically. Furness *et al.* (1986) suggested that this was due to a shortage of food, particularly of *Corophium volutator* and *Nereis diversicolor*, caused either by reduced nutrient enrichment of the mudflats or due to increased consumption of these invertebrates by fish. This theory was supported by the increase in numbers of Cormorants *Phalacrocorax carbo*, which feed mainly on flatfish. Flounders *Platichthys flesus*, in particular, are important predators of *Corophium volutator*, (Summers 1980) and apparently benefited on the Clyde from reduced waste water pollution and resultant increases in DO (McKay *et al.* 1978, Henderson & Hamilton 1986) (see also Section 6). Similar changes in organic pollution have also been linked to declines in Knot *Calidris canutus* and Dunlin at Kinneil on the Firth of Forth (Bryant 1987). At Heswall on the Dee Estuary, where the Ramsar Convention Bureau recommended that a monitoring project should be set up to monitor changes resultant from upgrading sewage treatment, Wetland Bird Survey (WeBS) counts have indicated a decline in the numbers of Redshank in the two winters since improvements were completed (Smith 2000). A similar sewage improvement programme has been implicated in the decline of Knot at Cleethorpes (Pearce 1998).

A more recent study investigated whether Purple Sandpipers and Turnstones had been affected by the cessation of the discharge of untreated sewage from short outfall pipes off the rocky coast of Hartlepool Headland in April 1998 (Eaton 2000b). A major improvement programme during the mid-1990s resulted in all sewage from the town being discharged further south having first received secondary treatment. Comparison of counts of birds between September 1999 and June 2000 and those undertaken between 1991 and 1994 showed no differences in bird numbers that could be attributed to the removal of sewage inputs. Furthermore, survival rates did not differ between the two periods and the diet of Purple Sandpipers appeared superficially similar to that recorded in an area at Blyth still enriched by sewage discharges. The study suggested that the lack of any adverse effect of the cessation of sewage discharge may have been due to the relatively short period since the change occurred. As suggested in section 4.2, however, it is possible that rocky shores are less enriched by sewage discharges than the soft sediments found in estuaries. Any reduction in discharges, therefore, may be less likely to affect the invertebrates and algal communities of rocky shores (Underwood & Chapman 1997, Soltan *et al.* 2001) and thus the birds that are associated with them.

6. WASTE WATER OUTFALLS AND FISH POPULATIONS

A number of studies have looked at the effects of wastewater discharges on fish, particularly in terms of their growth, immune responses and reproductive health (Costello & Gamble 1992, Secombes *et al.* 1992, Costello & Read 1993, Houlihan *et al.* 1994, Waring *et al.* 1996, Lye *et al.* 1997, 1998). Studies on the River Tyne have shown that increased discharges at the Howdon Sewage Treatment Works have resulted in increased fish populations, largely due to a rise in the numbers of small pelagic species such as Whiting *Merlangius merlangus*. Benthic fish species – Plaice *Pleuronectes platessa*, Flounder and Dab *Limanda limanda* did not benefit in the immediate vicinity of the outfall in these studies and were more numerous upstream of the treatment works (Gill & Frid 1995, Hall *et al.* 1997). Hall *et al.* (1997) suggested that this may have been due to a lack of food, such as *Corophium volutator*, in over-enriched areas close to the outfalls. Alternatively, the toxic effects of the effluent may have caused species that come into close contact with the estuary floor to avoid the outfalls (Elliott *et al.* 1988). Another study on the Tyne noted an overall increase in fish abundance and diversity since the earlier installation of primary treatment at Howdon and the return of migratory salmonids (Pomfret *et al.* 1988). The clean up of waste water discharges on the Thames has also resulted in the return of such species (Harrison & Grant 1976) and increases in DO on the Clyde have been linked to increased numbers of Flounder (McKay *et al.* 1978, Henderson & Hamilton 1986). In Australia, Smith *et al.* (1999) found that sewage discharges reduced the relative abundance of several common species in the fish community and also the total abundance of fish. In British Columbia, cessation of sewage discharges resulted in an increase in fish numbers, particularly in the area closest to the former outfall (Piercey *et al.* 1996).

7. DATA COLLECTION

7.1 Waterbird Count Data

Data concerning waterbird numbers have been collected from the Wetland Bird Survey (WeBS) Core Count and Low Tide Count Schemes. The Core Count Scheme collects information for most waterbird species on a monthly basis at all wetland habitats across the UK, including most estuarine and many freshwater sites, as well as a few non-estuarine coastal sites. Coastal sites are mostly counted at high tide. The data are primarily used to provide population estimates for species at the national and site level and thus to indicate long-term changes in numbers (Pollitt *et al.* 2000).

Collation of data for this project will concentrate upon the changes in bird numbers recorded within SPAs. A list of these sites is given in Table 1, together with the species for which they are notified. For estuarine sites, analysis of Core Count data would aim to determine whether long-term changes in water quality have affected bird numbers within the whole site. For the one non-estuarine Core Count site – the Northumbria Coast SPA – data analysis would be undertaken at a sector level.

The Low Tide Count Scheme provides data on the numbers of waterbirds present on subdivisions of the intertidal habitat within each estuary. Counts are undertaken by volunteers monthly from November to February within the period two hours either side of low tide (Pollitt *et al.* 2000). Sites for which counts have been undertaken are summarised in Table 2. As this table shows, most sites are not counted every year. For those sites with more than one year's counts, however, these data provide the best means for analysing the responses of waterbirds to changes in water quality as they are able to accurately show changes in species' feeding distributions.

Both these sets of data are being collated on an ArcView Geographical Information System (GIS) project. An example of the low tide feeding distribution of Dunlin in the Stour and Orwell Estuaries produced from the GIS is shown in Figure 1, together with the boundary of the SPA.

7.2 Water Quality Data

In parallel with the bird data collation, appropriate water quality data has been collated from two principle sources: the Water and Sewerage Companies (WSCs) and the Environment Agency (EA). The EA holds a national data-base of water quality measurements covering the whole of the coastline of England and Wales, including significant parts of the major estuaries. The EA also holds effluent discharge consents (which it issues to WSCs) for all licensed waste water discharges to all waters and substantial effluent sample data which it uses to monitor the compliance of effluent discharges with the consent conditions. The WSCs also hold copies of the consent conditions and asset databases detailing the location of their outfalls. These are the data that are in the process of being pulled together for this project.

In order to focus the collection of relevant data, we have used two approaches. Firstly, we recognise that the WSCs have, over the last 10 years been operating according to two Asset Management Plans (AMPs), known as AMP1 and AMP2. These defined the sewerage /sewage treatment improvements (amongst other things) which would be provided during the periods 1990-1994 and 1995 to 1999 respectively and thus can be used as a guide to changes in treatment levels and flows from coastal and estuarine outfalls. AMP1 dealt mainly with discharge to bathing waters, while AMP 2 picked up the remaining discharges to bathing waters and dealt with some early schemes required to meet the UWWTD. Although, the AMP1 and AMP2 programmes for each WSC were published, the publicly available versions did not provide sufficient detail for this project. However, the EA (and before it, the NRA) did keep a record of the proposed changes to treatment levels. We are currently awaiting a response from the EA regarding the availability of this information, which should cover the whole of England and Wales. These data will be most useful in the later phases of the project, when we will use it, together with the AMP3 (2000-2005) data (already obtained), to assist in predicting the future impact of the UWWTD on organic loading to estuaries and coastal waters.

In the mean-time, we have approached the WSCs to identify sites where they know major changes have been made to coastal/estuarine discharges and we have requested details of the consented flows and effluent quality and the required treatment level for these discharges, before and after the improvements. Table 3 summarises the sites identified so far at which major changes in organic load should have occurred within the last 10 years. We are currently awaiting data from the water companies detailing the outfall locations and consent conditions before and after improvement to treatment for all of the sites listed in table 3. These data will be located on the GIS, for cross reference with SPA and other protected areas and the bird data. To date, a full set of data has only been obtained from Anglian Water. Data has been promised from Severn Trent Water, Southern Water, South West Water, Welsh Water and Wessex Water. We have still to agree details of the data required from North West Water and have still to confirm most appropriate sites with Northumbrian Water and Yorkshire Water.

Details of the timetable and locations of future improvements are expected from EA.

Acknowledgements

Andy Musgrove provided bird data from the WeBS Low Tide Count scheme and Peter Cranswick and Colette Hall data from the WeBS Core Counts. WeBS is a partnership between the BTO, The Wildfowl and Wetlands Trust, the Royal Society for the Protection of Birds and the Joint Nature Conservation Committee (the latter on behalf of English Nature, Scottish Natural Heritage, the Countryside Council for Wales and the Environment and Heritage Service in Northern Ireland). Water quality data have been provided by Anglian Water and are promised from Severn Trent Water, Southern Water, South West Water, Welsh Water and Wessex Water. Andy Musgrove provided useful comments on the manuscript.

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Site Name	Species
Alde-Ore Estuary	AV, BW, DN, EW, RK, SU, SV, T., WN
Alt Estuary	BA, KN, SS
Benfleet and Southend Marshes	DN, GV, KN, OC, RP
Blackwater Estuary (Mid-Essex Coast Phase 4)	AV, BW, CA, CU, DB, DN, GG, GN, GV, LG, PT, RK, RM, RP, SU, SV, T., WN
Breydon Water	AV, BS, BW, CA, DN, EW, SV, WN
Burry Inlet	BW, CU, DN, GV, KN, OC, PT, RK, SU, SV, T., TT, WN
Chichester and Langstone Harbours	BA, BW, CA, CU, DB, DN, GV, KN, LG, OC, PT, RK, RM, RP, SS, SU, SV, T., TT, WN
Colne Estuary (Mid-Essex Coast Phase 2)	AV, BW, CA, DB, DN, GG, GV, RK, RP, SU
Crouch and Roach Estuaries (Mid-Essex Coast Phase 3)	BW, DB, SU
Deben Estuary	AV, DB
Dengie (Mid-Essex Coast Phase 1)	BA, BW, CA, DB, DN, GG, GV, KN, OC
Duddon Estuary	CU, DN, KN, OC, PT, RK, RM, SS, SU
Dyfi Estuary	WN
Exe Estuary	AV, BW, CA, DB, DN, GV, OC, RM, WN
Foulness (Mid-Essex Coast Phase 5)	AV, BA, BW, CU, DB, DN, GV, KN, LG, OC, RK, SU, WN
Hamford Water	AV, BW, DB, DN, GV, LG, RK, RP, SU, T., WN
Humber Flats, Marshes and Coast (Phase 1)	BA, CU, DB, DN, GN, GV, KN, MA, OC, PO, RK, RP, SS, SU, T., TT, WN
Lindisfarne	BA, DN, GV, KN, RK, RM, RP, SS, SU, WN, WS
Medway Estuary and Marshes	AV, BS, BW, CA, CU, DB, DN, GG, GV, KN, LG, MA, OC, PO, PT, RK, RP, SU, SV, T., TT, WN
Mersey Estuary	BW, CU, DN, GG, GV, PT, RK, SU, T., WN
Minsmere - Walberswick	EW, GA, SV
Morecambe Bay	BA, BW, CU, DN, GV, KN, OC, RK, SS, TT

Table 1. Coastal English and Welsh Special Protection Areas (SPAs) for which Wetland Bird Survey (WeBS) Core Count data have been collected and the waterbird species for which they are notified.

AV = Avocet *Recurvirostra avosetta*, BA = Bar-tailed Godwit *Limosa lapponica*, BS = Bewick's Swan *Cygnus columbianus*, BW = Black-tailed Godwit *Limosa limosa*, CA = Cormorant *Phalacrocorax carbo*, CO = Coot *Fulica atra*, CU = Curlew *Numenius arquata*, DB = Dark-bellied Brent Goose *Branta bernicla bernicla*, DN = Dunlin *Calidris alpina*, EW = European White-fronted Goose *Anser albifrons*, GA = Gadwall *Anas strepera*, GD = Goosander *Mergus merganser*, GG = Great Crested Grebe *Podiceps cristatus*, GN = Goldeneye *Bucephala clangula*, GV = Grey Plover *Pluvialis squatarola*, KN = Knot *Calidris canutus*, LG = Little Grebe *Tachybaptus ruficollis*, MA= Mallard *Anas platyrhynchos*, MS = Mute Swan *Cygnus olor*, OC = Oystercatcher *Haematopus ostralegus*, PO = Pochard *Aythya ferina*, PT = Pintail *Anas acuta*, RK = Redshank *Tringa totanus*, RM = Red-breasted Merganser *Mergus serrator*, RP = Ringed Plover *Charadrius hiaticula*, SS = Sanderling *Calidris alba*, SU = Shelduck *Tadorna tadorna*, T. = Teal *Anas crecca*, TT = Turnstone *Arenaria interpres*, WN = Wigeon *Anas penelope*, WS = Whooper Swan *Cygnus cygnus*.

Site Name	Species
Northumbria Coast (Northumberland Shore & Durham Coast)	PS, TT
North Norfolk Coast	AV, BA, CA, DB, DN, EW, GA, GV, KN, LG, OC, PT, RK, RP, SS, SU, SV, T., WN
Orfordness-Havergate (part of Alde-Ore Estuary)	AV, RK
Pagham Harbour	DB, PT
Poole Harbour	AV, BW, CA, CU, DB, DN, GN, PO, RK, RM, SU, SV
Portsmouth Harbour	DB
Ribble and Alt Estuaries (Phase 2)	BA, BS, BW, CA, CU, DN, GV, KN, OC, PT, RK, SS, SU, T., WN, WS
Ribble Estuary	BA, BS, BW, DN, KN, OC, SS, SU, WN
Severn Estuary	BS, CU, DN, EW, GA, GV, MA, PO, PT, RK, SU, SV, T., TU, WN
Solent and Southampton Water	BW, CA, CU, DB, DN, GA, GG, GV, LG, PT, RK, RM, RP, SU, SV, T., WN
Stour and Orwell Estuaries	BW, CA, CU, DB, DN, GG, GN, GV, KN, MS, OC, PT, RK, RP, SU, TT, WN
Tamar Estuaries Complex	AV
Teesmouth and Cleveland Coast	KN, RK, SU, SV
Thames Estuary and Marshes	AV, BW, DN, EW, GA, GV, KN, LG, PT, RK, SU, SV
Thanet Coast and Sandwich Bay	TT
The Dee Estuary	BA, BW, CA, CU, DN, GV, KN, OC, PT, RK, SU, T., TT, WN
The Swale	AV, BA, BW, CA, CU, DB, DN, EW, GA, GV, KN, LG, OC, PT, RK, RP, SU, SV, T., WN
The Wash	AV, BA, BS, BW, CA, CU, DB, DN, EW, GA, GN, GV, KN, LG, MA, OC, PT, RK, RP, SS, SU, TT, WN, WS
Traeth Lafan/Lavan Sands, Conway Bay	CU, OC
Upper Solway Flats and Marshes	BA, BW, CA, CU, DN, GG, GN, GV, KN, MA, OC, PT, RK, RP, SS, SU, SV, T., TT, WS

Table 1. Continued.

AV = Avocet *Recurvirostra avosetta*, BA = Bar-tailed Godwit *Limosa lapponica*, BS = Bewick's Swan *Cygnus columbianus*, BW = Black-tailed Godwit *Limosa limosa*, CA = Cormorant *Phalacrocorax carbo*, CO = Coot *Fulica atra*, CU = Curlew *Numenius arquata*, DB = Dark-bellied Brent Goose *Branta bernicla bernicla*, DN = Dunlin *Calidris alpina*, EW = European White-fronted Goose *Anser albifrons*, GA = Gadwall *Anas strepera*, GD = Goosander *Mergus merganser*, GG = Great Crested Grebe *Podiceps cristatus*, GN = Goldeneye *Bucephala clangula*, GV = Grey Plover *Pluvialis squatarola*, KN = Knot *Calidris canutus*, LG = Little Grebe *Tachybaptus ruficollis*, MA= Mallard *Anas platyrhynchos*, MS = Mute Swan *Cygnus olor*, OC = Oystercatcher *Haematopus ostralegus*, PO = Pochard *Aythya ferina*, PT = Pintail *Anas acuta*, RK = Redshank *Tringa totanus*, RM = Red-breasted Merganser *Mergus serrator*, RP = Ringed Plover *Charadrius hiaticula*, SS = Sanderling *Calidris alba*, SU = Shelduck *Tadorna tadorna*, T. = Teal *Anas crecca*, TT = Turnstone *Arenaria interpres*, WN = Wigeon *Anas penelope*, WS = Whooper Swan *Cygnus cygnus*.

Site Name	SPA Status	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00
Adur Estuary								X	
Alt Estuary	SPA					X	X	X	
Blackwater Estuary (Mid-Essex Coast Phase 4)	SPA			X					
Breydon Water	SPA							X	X
Burry Inlet	SPA			X		X			
Camel Estuary		X							
Carmarthen Bay								X	X
(Chichester and Langstone Harbours) - Chichester Harbour	SPA	X	X			X	X	X	
(Chichester and Langstone Harbours) - Langstone Harbour	SPA		X			X		X	
Cleddau Estuary							X		
Clwyd Estuary		X							
Colne Estuary (Mid-Essex Coast Phase 2)	SPA			X					
Conwy Estuary						X			
Crouch and Roach Estuaries (Mid Essex Coast Phase 3)	SPA				X				
Deben Estuary	SPA							X	
Dengie (Mid-Essex Coast Phase 1)	SPA	X							
Duddon Estuary	SPA	X	X	X					
Exe Estuary	SPA		X						
Fal Estuary					X				
Fowey Estuary					X				
Hamford Water	SPA	X					X		
Hayle Estuary								X	
Humber Flats, Marshes and Coast (Phase 1)	SPA							X	
Inland Sea					X				
Kingsbridge Estuary			X						
Lindsfarne	SPA	X							
Medway Estuary and Marshes	SPA					X	X		
Mersey Estuary	SPA					X	X	X	X

Table 2. Estuary sites for which WeBS Low Tide Count data have been collected, their SPA status and the years for which data were available.

Site Name	SPA Status	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00
(Minsmere – Walberswick) - Blyth Estuary	SPA						X		
Morecambe Bay	SPA								X
North Norfolk Coast	SPA						X		
Pagham Harbour	SPA				X	X	X	X	X
Pegwell Bay				X					
Poole Harbour	SPA		X						
Portsmouth Harbour	SPA	X					X	X	
Ribble Estuary	SPA						X		
Severn Estuary	SPA							X	X
(Solent and Southampton Water) - Beaulieu Estuary	SPA					X		X	
(Solent and Southampton Water) - Bembridge Estuary	SPA					X		X	
(Solent and Southampton Water) - Greater Solent	SPA					X		X	
(Solent and Southampton Water) - Medina Estuary	SPA				X	X		X	
(Solent and Southampton Water) - Newtown Harbour	SPA					X		X	X
(Solent and Southampton Water) - NW Solent	SPA	X				X	X	X	
(Solent and Southampton Water) - Southampton Water	SPA			X	X	X	X	X	X
(Solent and Southampton Water) - Western Yar	SPA					X		X	
(Solent and Southampton Water) - Wootton Creek	SPA					X		X	
(Stour and Orwell Estuaries) - Orwell Estuary	SPA			X	X	X	X	X	X
(Stour and Orwell Estuaries) - Stour Estuary	SPA					X			X
Tamar Estuaries Complex	SPA						X		
Taw and Torridge Complex				X					
Teesmouth and Cleveland Coast	SPA					X			
Thames Estuary and Marshes	SPA		X					X	X
The Dee Estuary	SPA					X	X	X	
The Swale	SPA	X							
Traeth Lafan / Lavan Sands, Conway Bay	SPA				X				
Tyne Estuary								X	
Upper Solway Flats and Marshes	SPA							X	X
Wear Estuary					X				

Table 2. Continued.

Company	Location	Outfalls	Comment on Changes
Anglian Water	Humber Estuary	Grimsby (Pyewipe)	Crude to Secondary 1999
	Lincolnshire Coast	Cleethorpes (Newton Marsh)	Crude to Secondary 1995
	Stour/Orwell Estuary	Ipswich (Cliff Quay)	Crude to Secondary 1995
	Stour/Orwell Estuary	Felixstowe	Crude to Primary 1995
	Stour/Orwell Estuary	Harwich and Dovercourt	Crude discharge abandoned at Dovercourt. Primary discharge begun on Stour Estuary
North West Water	Mersey		
	Ribble Estuary		
	Morecambe Bay		
Northumbrian Water	Farne Islands		
	Tyne Estuary		
	Tees Estuary		
Severn Trent Water	Severn Estuary	Gloucester	Crude to Primary 1991 to Secondary 1995
South West Water	Exe Estuary	Exmouth	Primary to Secondary 1995
	Teign Estuary	Various	New LSO 1994
	Kingsbridge Estuary	Salcombe/Kingsbridge	Crude to Secondary 1994
	Plymouth Sound, Plym and Tamar Estuary Complex	Plymouth	Crude to Secondary 1997
	Fowey Estuary		Crude to Secondary 1993/4
	Fal Estuary	Falmouth	Crude to Secondary and UV 2000
	Camel Estuary	Wadebridge	Crude to Seconday 1990
	Camel Estuary	Padstow	Crude to Secondary and UV 1995
	Taw and Torridge Estuaries	Barnstable	Crude to Secondary 1995
	Taw and Torridge Estuaries	Bideford	Crude to Secondary 1995

Table 3. Sites of major changes in sewage treatment within the last 10 years (limited to coastal/estuarine areas close to/in SPAs) [to be completed]

Company	Location	Outfalls	Comment on Changes
Southern Water	Solent	Pennington	Crude to Primary 1996
	Isle of White	Sandown	Gradual transfer of flows by 2000
	Thames Estuary	Medway Valley (various)	Primary to Secondary
	South Coast	Dover/Folkestone	Primary to Secondary 1999
	South Coast	Eastbourne	Primary to Secondary 1996
	South Coast	Shoreham	Primary to Secondary 1996
	South Coast	Worthing	Eastern outfall abandoned 1996
	South Coast	Newhaven and Lewis	Transferred Primary discharge from river to coastal waters 1999
Thames Water	None		
Welsh Water	Severn Estuary	Various	Waiting for details
	Dee Estuary	Various	Waiting for details
Wessex Water	Severn Estuary		
	Poole Harbour		
Yorkshire Water	Humber Estuary		

Table 3. Continued.

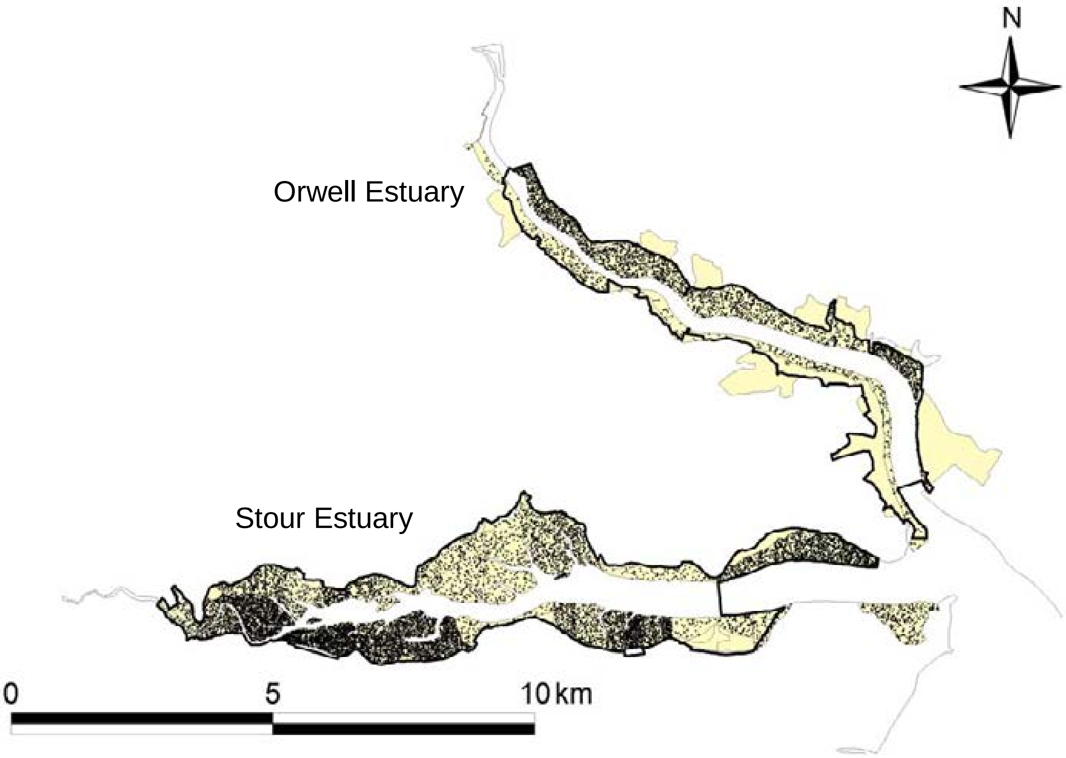

Figure 1. The low tide distribution of Dunlin on the Stour and Orwell Estuaries in East Anglia, showing the 'Stour and Orwell Estuaries' SPA boundary in bold.

One dot equals ten birds.