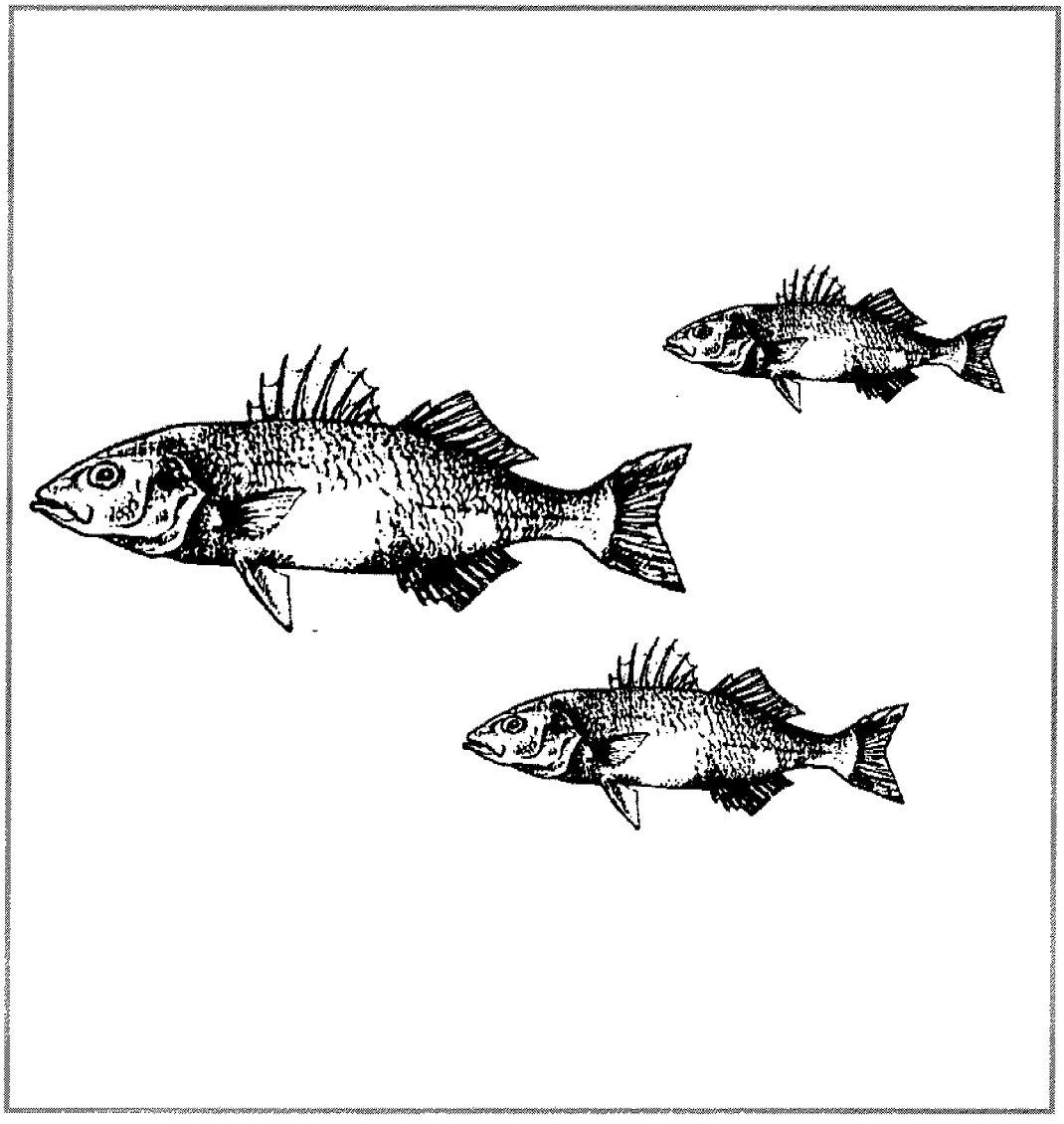
ENGLISH NATURE

Review of the status of estuarine fishes

No. 34 - English Nature Research Reports



MARINE BIOLOGICAL ASSOCIATION

working today
for nature tomorrow

English Nature Research Reports

No. 34

REVIEW OF THE STATUS OF ESTUARINE FISHES

by
Geoffrey W. Potts & Silja E. Swaby

The Marine Biological Association of the United Kingdom,
The Laboratory, Citadel Hill, Plymouth PL1 2PB

Final Report to English Nature (Contract No: F72-12-54)

(Being an assessment of the fishes of twenty-two estuaries and coastal ecosystems carried out between December, 1992 and February, 1993)

© Marine Biological Association/English Nature (1993)
ISSN 0967-876X

DISTRIBUTION LIST

English Nature HQ
Keith Duff
Andrew Deadman
Rick Keymer
Malcolm Vincent
Alistair Burn
Dan Laffoley
Geoff Radley
Meaghan Grabrovaz

English Nature Regions

Ian Smith	Peterborough
Ian Paterson	Peterborough
Jeremy Dagley	Colchester
Chris Shaw	Newcastle
Mark July	Newcastle
Helen Stace	York
Teresa Fernandez	University of Hull
Roger Meade	Blackwell
Jim Andrews	Blackwell
Chris Lumb	Blackwell
Michelle Young	Blackrod
Alan Jemmett	Wirral Borough Council
Andy Clements	Newbury
Colin Tubbs	Lyndhurst
Richard Collingridge	Wye
Roger Morris	Wye
Kathy Kennedy	London
Andrew King	Taunton
Jim White	Wareham
Pat Sargeant	Trelissick
Rob Wolton	Okehampton
Library	12 copies

JNCC
Keith Hiscock
Pat Doody/Nick Davidson
Roger Mitchell

CCW
Mandy Richards
Rod Jones

SNH
John Baxter
Steve Atkins

External

Mark Everard	National Rivers Authority (5 copies)
Gill Witter	Worldwide Fund for Nature
Geoffrey Potts/Silja Swaby	Marine Biological Association (4 copies)
Marine Biological Association	Library (2 copies)

CONTRACT DETAILS

Background

The present proposals from the NRA for a water quality classification scheme fall into two parts:

1. A statutory scheme, based upon different use classifications for each stretch or body of water, having appropriate standards for each identified water use. In addition to ensuring that water quality will meet the use requirements for the area of water, these statutory standards must also ensure that any EC directive requirements are met. For estuaries and coastal waters, the use class will cover fisheries ecosystems, industrial or agricultural abstraction, water contact sports, harvesting of fish or shellfish, and special ecosystems.

2. A non-statutory scheme of General Quality Assessment, based upon biological and chemical criteria, to enable comparison between water bodies having different uses.

Whilst progress towards setting water quality standards for rivers is well advanced, this is not the case for estuaries and coastal waters. A large proportion (approximately 75%) of estuaries are partly or wholly notified as SSSIs, and English Nature sees as its priority the need to identify those estuaries which should be classified as special ecosystems in order to receive an appropriate level of water quality protection. Among those communities which are dependent upon estuaties and which are likely to require high water quality standards, migratory and resident fish communities are considered important. It is necessary therefore to obtain information on the location of important estuaries for fish communities and the likely impact of water quality on such communities, in order to propose suitable candidates for special ecosystem status.

The present contract examines the status of fishes from 22 British estuaries, 7 of which are included in the proposed Marine Consultation Areas, 16 the subject of a recent BEC Marine Consultancy Ltd review of estuary water quality data for EN, and an additional 6 to complete coverage of those estuaries which are the subject of a management plan under the EN Estuaries Initiative (Duncan *et al.*, 1992).

CONTENTS

1. SUMMARY

A review has been carried out on the status of estuarine fishes in England at 22 named estuaries and coastal areas. The information came from literature searches of published and unpublished material, from research and fisheries laboratories, fish biologists and other sources. Tables have been prepared to show the species diversity and distribution of estuarine fishes within English estuaries. The individual named estuaries and coastal areas are reviewed separately in an appendix.

Few estuaries have detailed surveys of their fish populations and most will need to be subjected to separate and detailed fish assessment. Of those examined some showed low species diversity apparently as a consequence of pollution in the estuary. The most significant factor influencing the distribution of estuarine fishes was low oxygen levels resulting from high BOD following the discharge of untreated sewage. In areas where sewage treatment had been carried out, water quality was improved and there were signs of a recovery in the fish populations. Industrial effluent can result in serious pollution. Estuarine fisheries are mostly in decline as a result of reduced fish stocks and some measures have been introduced to protect fish nursery grounds in many estuaries.

The value of using fish diversity as an index of the "health" of an estuary is discussed and clearly established.

2. INTRODUCTION

Prichard's (1967) definition of an estuary is most widely accepted and states that an estuary is a "semi-enclosed body of coastal water opening to the sea and which is measurably diluted by fresh water run off". This definition was adopted by NERC in their Estuarine Review (1975) and more recently in the review of Nature Conservation in estuaries of Great Britain (Davidson *et al.*, 1991).

British estuaries represent a unique wildlife resource that needs to be recognised and protected. More than almost any other habitat, estuaries are subjected to human pressure, through land reclamation, interference and manipulation, through over-exploitation and as open sewers into which domestic and industrial wastes are discharged. At the same time estuaries provide shelter for ships, have ports, and form part of our maritime trading heritage. More recently as industry is forced by legislation to clean up its discharges, and as maritime trade decreases, a new pressure emerges as estuaries are increasingly used for leisure activities. These activities include the building of holiday homes on once wild and unspoiled country-side, the development of marinas, water sports, angling, ferry services, and the whole infrastructure of tourism. Each has an effect on the estuarine environment and by disturbance, by pollution, by modification will have an effect on the fauna of estuaries (Davidson *et al.*, 1991; Kennish, 1990).

Fish represent the largest and most mobile element in the aquatic ecosystems of estuaries (Kennish, 1990). Estuarine fishes show tolerance of high turbidity, temperature extremes, and a wide range of salinities and dissolved oxygen levels and the distribution of species in an estuary is determined by these limits. The number of species able to survive in estuarine conditions is also reflected in the species numbers found at different levels of the estuary, such that species numbers are high in the marine conditions found at the mouth of estuary, and progressively decreases at higher levels in brackish and freshwater conditions. Their mobility allows them to make full use of this dynamic environment; as predators hunting the large concentrations of prey organisms, as prey seeking shelter, or during spawning. Estuaries are typically characterised by relatively few species highly adapted to the estuarine environment. Based largely on their biology a number of schemes have been put forward to define estuarine fishes and these are reviewed by Kennish (1990). Examples are discussed by Day (1951), McHugh (1967), Perkins (1974), Moyle and Cech (1982), and Dando (1984). All are rather similar and combine a number of characteristics based on distribution and reproductive patterns and their relative dependence on the estuary.

The scheme of McHugh (1967) may be taken as typical and uses breeding, migratory and ecological criteria. They are as follows:

1. Freshwater fishes that occasionally visit brackish water.

2. Fully estuarine species living almost their entire lives in estuaries.

3. Anadromous and catadromous species migrating in and out of estuaries to spawn.

4. Marine species visiting estuaries to feed.

5. Marine species using estuaries as seasonal nursery grounds.

6. Vagrants who are found in estuaries at irregular intervals.

Fishes form a vital component in the fauna of estuaries, and in terms of biomass are by far the most significant vertebrate group. In many estuaries the commercial exploitation of fishes has reached levels where urgent need for stock management needs to be introduced. In addition, the wider use of estuaries as sites of urban and industrial development have so affected water quality that fish populations are significantly reduced. Thus, the fish species diversity of an estuarine ecosystem is a measure of its health, and in heavily polluted rivers conditions may deteriorate to a level where fish diversity is low or even absent. Indeed it is quoted that the loss of species in estuaries is comparable to the much published degradation the of rain-forests and may be comparable in terms of the global environmental impact. However, as the problem of estuarine pollution is tackled, so fish populations return and become indicators of environmental recovery as fish reflect not only the health of the invertebrate population upon which they depend as food, but also the water quality with its levels of pollutants, oxygen levels and other elements.

The present review examines the status of fish in twenty-two estuaries and coastal areas (Figure 1). The quality of data for each estuary is highly variable and, with few exceptions, it is recommended that second stage surveys are carried out to establish the ichthyofauna for each site. Fish species diversity is a good index of water quality and the community structure of estuarine fishes is increasingly seen as a measure of environmental conditions (Potter *et al.*, 1986; Pomfret *et al.*, 1988; and Henderson, 1988; Swaby & Potts, 1990). The present study reviews the current literature on estuarine fishes and makes recommendations on how they may be used in the conservation and management of the estuarine resource.

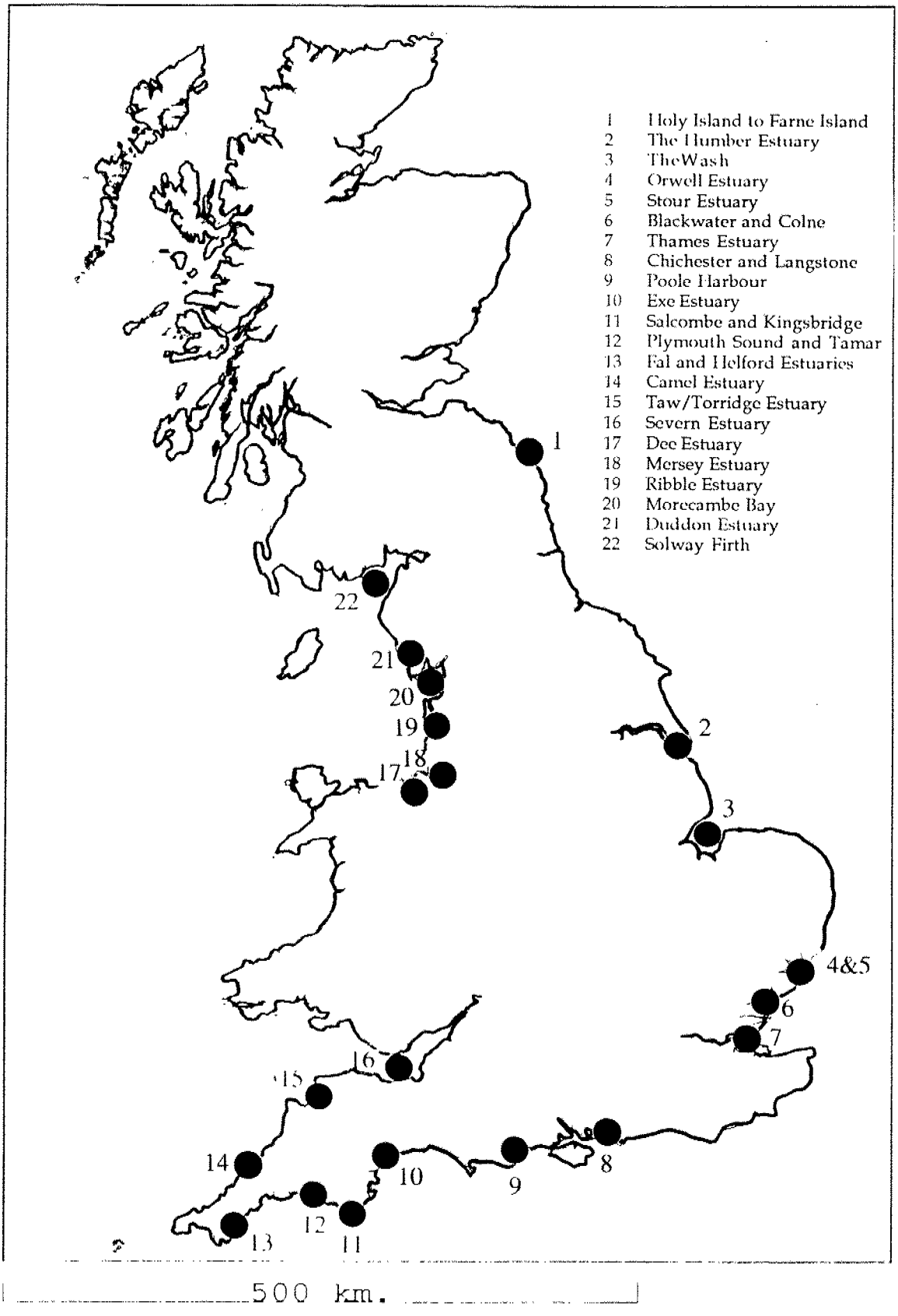


Figure 1. Map showing the distribution of twenty-two estuaries and coastal areas considered in this report.

3. ESTUARINE FISHES

3.1 Introduction

In reviewing the status of English estuarine fishes it has been necessary to examine a wide range of literature, some of which dates back to the mid 19th century. Where possible, reviews have been used and particular mention should be made of the important publication "Nature Conservation and Estuaries in Great Britain", produced by the Nature Conservancy Council (Davidson *et al.*, 1991), and which provides the most comprehensive overview of the subject so far. In the present report information on each of the 22 estuaries or coastal areas have been summarised separately in Appendix II. General statements on the geomorphology and physical characteristics are described as well as the total area and extent of the tidal influence from the estuarine mouth.

The major activities that take place on the estuary are discussed and where relevant, past activities that have a bearing on the quality of wildlife in each estuary. Fishing, shipping and dock facilities, mining and transportation, agriculture and urbanisation, all have an impact on the quality of the estuarine environment. Many first became prominent in the early part of the 19th century during the industrial revolution and have undergone cycles of change ever since. These are considered in general terms at the beginning of each section, but are dealt with in greater detail in the sections that follow ((3.4) on Fish and Fisheries, (3.5) Impacts, and (3.6) Water quality).

Finally, the value of the estuary in conservation terms is mentioned largely from data presented by Davies *et al.*, 1990. Britain is fortunate in having such a variety of estuaries in all shapes and sizes and which is estimated to form over one quarter of the estuarine resource in western Europe. Their complexity provides a variety of habitats each with its own distinctive fauna and flora. However, it is not just for the resident wildlife that estuaries are considered important in conservation terms, but also for many species that use them as staging posts in wider migrations. The importance of Britain's estuaries as feeding and overwintering grounds for waders and waterfowl has resulted in many being designated SSSIs or having a reserve status. For just the same reason many species of fish use estuaries while on migration to feed, breed and as sites to shelter. It is interesting that like the birds, they too depend on the productivity of the invertebrate faunas to provide essential food resources. Thus, areas designated of special conservation value to waders are also likely to be significant to fish populations, and for the same reason will need innovative management to reconcile the environmental pressures that are a part of estuarine life.

3.2 Estuarine habitats

As has been stressed, estuaries come in many shapes and sizes and are typified by a wide range of habitats, most of which are influenced by different degrees of mixing between salt and freshwater. The variable salinity imposes osmotic stress on organisms in the estuarine ecosytem resulting in species highly adapted to tolerate the estuarine environment. Often species diversity is low. The range of habitats include, subtidal, intertidal, mudflats, sandflats, saltmarshes, shingle, rocky shores, lagoons, sand dunes, grazing marshes and coastal grasslands (Davidson *et al.*, 1991). All, but the last three, contain fishes which represent in biomass and species numbers the most important vertebrate group.

The habitat diversity is determined by many factors, but perhaps the most important being the extent of the maritime influence at the mouth of the estuary. Thus, sites like the Holy Island to Farne Island coast, the mouth of the Salcombe and Kingsbridge Estuaries, Plymouth Sound, the lower reaches of the Severn Estuary, Morecambe Bay and the Solway Firth will all contain a full range of marine habitats at their mouths and a diverse and rich marine fauna associated with them. Hiscock (1990) identifies the complexity of sublittoral benthic habtiats and it should be recognised that these provide good shelter and breeding substrates for many fishes.

Many fish live in the water column or like the mullet feed on surface vegetable matter or graze algal films from benthic mudflats. The higher up the estuary the more restricted the habitats and in many, mud and sand flats dominate great areas of the mid-estuary as found in the Wash, Blackwater, lower Thames, Exe, Helford, Dee, Ribble and Duddon Estuaries. These mudflats are the productive centre of many estuarine ecosystems with characteristic faunas. The overall producitvity of an estuary depends on many factors, but perhaps, most importantly upon the freshwater catchment and the drainage patterns into the estuarine basin. While many nutrients are flushed into the sea, much settles out to form the fine muds and organic particulate sediments that are so much a feature of estuaries. In these mudflats, burrowing organisms abound and molluscs, amphipods and worms feed on the rich organic debris. In turn, these invertebrate faunas are preyed upon by waders and wildfowl when the mudflats are exposed at low water, and by fishes when the tide returns.

Central to most estuaries is a tidal channel, often enlarged by dredging to form a navigational channel. This can be important to the passage of fish up the estuary and may be used by thousands of salmonids on their breeding migrations. Obstacles such as weirs, can prevent the free passage of fish and often artificial fish passes are constructed. The movement of fish may also be influenced by the strength of tidal flow which may be considerable, as in the Severn Estuary with a tidal range of about 15 m. at spring tide. By contrast, the freshwater draining into the upper end of the estuary will influence the suitability of the ecosystem as a habitat for fishes. Seasonal precipitation in the catchment area is critical and strong winter rains, or snow melt waters in northern latitudes can flush out the maritime influence.

3.3 Fish lists

The fish lists prepared have come from many different sources. While initially the review was to concentrate on changes in fish status in the last 50 years, in reality, the information was too scattered and it became necessary, in some instances to use records from the 19th century in order to produce comprehensive species lists. As a result, it has not been possible to identify changes of condition in the estuary and corresponding changes in the fish fauna. Nevertheless, it was considered important to bring together the most comprehensive species lists that can represent the optimum species carrying capacity of the estuary. Some lists are small and reflect the fact that few surveys have been carried out in the region (Holy Island to Farne Island coast and the Duddon Estuary) while others may reflect changes in the use of the estuary that have been detrimental to fish populations (Mersey, Stour, and Colne Estuaries). Where evidence is available these issues are considered in the reports of the individual estuaries (Appendix II).

The lists were mainly compiled after extensive literature searches using the library of the Marine Biological Association with its special publication "The bibliography of the estuaries and coastal waters of the British Isles", its South West Waters database, and the Aquatic Sciences and Fisheries Abstracts (ASFA) CD-rom retrieval system. The Marine Biological Association's British Marine Fishes Database was essential in bringing together lists of estuarine fishes, different aspects of their breeding biology, habitat preferences and feeding activities. While published species lists were uncommon, individual species records were mentioned as a secondary part of other surveys. ERICA, the database of the Cornish Biological Records Unit was particularly valuable with respect to Cornwall. Much of the information came from a variety of unpublished records and internal reports that were provided by the Sea Fisheries Committees; City, Borough, and District Council environmental officers; Federations of Sea Anglers and regional fishery officers of the National Rivers Authority. Other records came from the private field logs of fish biologists and individuals.

Attempts to provide firm dates for species lists proved impossible in most cases, as previous published lists were often compilations from a variety of sources collected over many years. Other individual records were, at times, undated. The lack of consistent and comparable data makes it difficult or impossible to determine decreases or increases in a population, unless taken from one reference source. Summary tables of the distribution of fishes found in English estuaries are given in Appendix I. The status of each species in each estuary, whether resident, migratory with other information on their biology is given in Table 2. The juveniles of some species are only found in specific estuaries and these are treated under each estuarine account (Appendix II).

The individual species list for each named estuary or coastal area, and the sources they were derived from, are given in Appendix II. It should be stated that the inclusion of a fish in the list for an individual estuary should not be taken as an indication of the current situation.

3.4 Fish and fisheries

Many estuarine fishes are commercially important and in the larger estuaries significant fisheries exist or used to. Where details are published a summary of the fishery is given under the named estuary, but no attempt has been made to analyse the fishery landing statistics that would provide information on the state of a particular stock. Overall trends within the fisheries are given, but they are, at times, rather dated and there is a need for a separate review of the current state of estuarine fisheries in England. The Sea Fisheries Committees were useful in bringing information together.

The role of estuaries and shallow bays as breeding and nursery ground for many fishes suggest that regulation needs to be introduced to ensure that young fish stocks are not caught or damaged. A move towards this has been introduced with respect to bass although numbers are still being killed as a consequence of other fishing operations and on power station inlet screens.

While commercially important fishes have been the subject of a significant literature, the non-commercial species have been largely neglected. Their importance as potential indicator species justifies their inclusion in estuarine surveys which have, to date, largely concentrated on benthic invertebrates.

3.5 Impacts

More than almost any other aquatic environment estuaries have been the subject of human manipulation, interference and exploitation. The result is that English estuaries exhibit a graded series of impacts which affect the wildlife resource of the estuary. The impacts can be broadly classified as irreversible (land reclamation, urbanisation, industrialisation etc.) and reversible (pollution, fisheries etc.). Davidson *et al.*, (1991) reviews the impact of human activities on estuaries and lists 117 activites in a total of 155 sites. Of these approximately 80 activites will directly affect estuarine fishes.

The following list summarises the main human impacts on estuaries, most of which have an effect on estuarine fishes.

Coast protection and sea defences
Barrage schemes
Power generation
Industrial port and related development
Extraction and processing of natural gas and oil
Military activities
Waste discharges
Sediment extraction
Transport and communication
Urbanisation
Tourism and recreation
Wildfowling and hunting
Bait collecting
Commercial fisheries
Cultivation of living resources
Management killing of birds and mammals
Wildlife habitat management
Education and scientific research

Estuarine fishes are dependent on the estuarine ecosystem in feeding and spawning activities and when on migration runs, and are often vulnerable to disturbance and exploitation. Irreversible impacts include land reclamation which, has over recent centuries, accounted for an overall loss to the estuarine resource, and may result in the loss of a whole estuary (Davidson *et al.*, 1991).

Other gross disturbances to estuaries result from the construction of dams, weirs and barrages which impede the passage of catadromous and anadromous fishes. While research has been conducted into fish passes, no totally satisfactory solution has been found. Barrages pose a particular problems and more research is needed on the changes such structures have on the tidal regime, sedimentation patterns as well as obstacles to migratory fishes. The efforts of land claim, major construction works, power stations, physical barriers, dumping and dredging on the sensitive nursery areas of estuarine fishes can have a serious effect on adult fish populations. Industrialised and urban effluents have an important impact on fish populations. Localised toxic spills can kill thousands of fish by poisoning and by asphyxiation and in the long term chronic pollution will gradually degrade the estuary killing off most aquatic wildlife.

Of particular significance is the increasing use of estuaries as centres of recreation and leisure and focal points of urban development. What is common to all estuaries examined has been the increase in "people pressure" with the accumulating problem of sewage discharges. Untreated sewage leads to eutrophication and bacterial oxygen demand (BOD) can result in estuarine waters becoming anoxic. This either kills the resident fish population or effectively blocks the passage of fishes up or down the estuary.

The problem was clearly identified in the 19th Century following the discovery of the "water closet" when raw sewage was directed into rivers and estuaries (Wheeler, 1979). Nowadays, with proper treatment there is no longer a need to tolerate the levels of pollution that were once common. The Thames is a success story where a series of moves to control effluent discharges has resulted in a significant recovery of the estuary which now contains an estimated 112 species of fish whereas, as recently as 30 years ago, only eels were present. By contrast the industrial North West still shows signs of chronic pollution and much impoverished estuarine fish populations. Other impacts are reviewed in the individual named estuaries (Appendix II).

3.6 Water quality

The measurement of water quality is difficult and depends very much upon the primary objectives of any survey. It may be measured as physical, chemical or biological parameters or as combinations of these. The shortcomings of defining water quality are discussed in a report by Edmondson & Watts (1992). They stress that, not only do the unique set of conditions that represent water quality vary between one estuary and another, but also within any particular estuary on an hourly, monthly or annual basis in response to tidal cycles, climatic conditions, geomorphological processes and a variety of chemical reactions. Edmondson & Watts elaborate on these main features affecting estuaries; chemical reactivity, tidal movement and freshwater discharge. Briefly they summarise the main reaction as between the freshwater-seawater interface which cannot be geographically defined as its position is subject to state of tide, freshwater inflow and climatic conditions.

The chemical reactions in estuaries are very complex and are determined by the freshwater-seawater interface, and mixing that results in high turbidity and other factors. These are critically affected the tidal state, freshwater inflow, and climatic conditions which themselves are subjected to lunar and seasonal cycles.

The tidal amplitude and geomorphology of an estuary have a profound effect on water movement and thus the distribution and dispersal of suspended matter and pollutants. The differences of tidal range between spring and neap tides will influence the status of an estuary, both in the water distribution and the erosive forces resulting from the strength of currents.

Estuaries are drainage channels for freshwater run off from terrestrial riparian and lacustrian sources. The volume of freshwater is determined by the volume of precipitation in the catchment area which in turn has an impact on the spatial distribution of chemicals in the estuary. In areas where the estuary drains the melt waters from mountainous regions, the freshwater influence can also have a seasonal impact on water temperature.

These variables show the problem of defining water quality and in relating it to the wildlife distribution within an estuary. However, the problem has been tackled in a different way by the NRA in their 1991 classification of water quality in estuaries. Their indices assess the biological quality based on the ability of fish and benthic communities to survive, a pollution index, and one on water quality based upon dissolved oxygen. These factors are combined, on a points system, grading water as "good", "fair", "poor", and "bad" quality. Their data should be examined in conjunction with the BEC water quality determinands for estuaries and coastal waters (Edmondson & Watts, 1992)which reports on detailed surveys of twenty estuaries over a period of 10 years and review nutrients, heavy metals, DOE "red list" elements, BOD, dissolved oxygen, turbidity, salinity, and other components in the water column. Further information on the distribution of heavy metals in estuaries is given by Burt *et al.*, 1992.

The impact of water quality of fishes is not always easily defined as sublethal effects may result in the reductions in benthic communities, and as a consequence fish leaving an area. The effects on individual species is also highly variable. Generally the impact of pollution is a regional one and one where estuaries are particularly susceptible through the historic tendence for urbanised development and industry to locate on primary water sources. Fishes are particularly susceptible to low concentrations of oxygen that might result from bacteria oxygen demand (a consequence of effluent discharges). (Dethlefsen & Tiews, 1985; Alabaster *et al.*, 1991).

4. CONCLUSIONS

Estuaries and their wildlife are a central part of our natural heritage and provide a link between our great river systems and the rich and fertile coastal waters. However, it is their strategic position that has resulted in estuaries being subjected to intense pressure by interference, over exploitation, and as a means of disposing of unwanted industrial wastes. They have played a crucial role in providing safe shelter for our ships and fishing fleets and more recently a site for our water based leisure activities. They provide a focal point for urbanisation with the accompanying problems of waste and sewage disposal. Yet despite these pressures, estuaries contain some of our most scenically beautiful countryside and many are designated as SSSIs with full reserve status for sites of conservation importance (Davies *et al.*, 1990). Estuaries provide the boundary between rivers and the sea and reflect, in their fauna and flora, elements from both ecosystems as well as a number of organisms specially adapted to life in and around the estuary. The rich nutrients and organic debris that drains down rivers settles in the estuary and provides rich mud and sand flats that become colonised by many molluscs, crustacea and worms. It is these invertebrate communities that provide the feeding grounds for waders and wildfowl, and when the tide is high for estuarine fishes (Davidson *et al.*, 1991; Kennish, 1990).

Variation in the size and shape of an estuary has an impact on the fauna and during the present review of estuarine fishes this became apparent despite the variability in the quality of data for each estuary. Some estuaries, notably the Thames, Severn, Humber, Solway Firth, Tamar and Helford have been subjected to detailed surveys and provided a full and representative species list. However others, the Orwell, Ribble, and Duddon have not been examined in detail with respect to the fish fauna.

The estuaries and coastal areas reviewed yielded a total of 181 species of fish (Tables 1 & 3) from a total British marine fish fauna of 330. Of these, 41 were considered to be truly estuarine, being dependent at some time in their life cycle on the estuarine environment and in many cases showing some form of physiological adaptation towards estuarine life. In most cases this would be an ability to osmoregulate in water of variable salinity. Unfortunately, the boundary between marine and estuarine environments cannot easily be defined and a number of species could have been added to the estuarine fish lists. Yet again, other species use estuaries as nursery grounds while others like to aggregate in the mouths of estuaries to feed. Young labrids are often to be found occupying the mouths of estuaries before moving to coastal inshore waters. Some species that are considered fully estuarine like the flounder (*Platichthys flesus*) in the northern part of its distribution form populations that are fully marine, while other like the cod (*Gadus morhua*) contain individual populations that may depend on estuaries as nursery grounds. With such variety, definitions become difficult.

Despite the difficulty, Table 2 sets out the different categories of estuarine species that show most dependency on the estuarine environment. Of the 41 species listed, 21 are migratory, 8 anadromous, migrating up estuaries to spawn; and two, the eel (*Anguilla anguilla*) and flounder (*P. flesus*) are catadromous, migrating out of estuaries to spawn at sea. It is noticeable that the species diversity decreases moving up the estuary towards the freshwater influence and only six species were recorded as having tolerance of freshwater estuarine conditions compared with 39 at the marine end of the estuary. Many fishes in estuaries use them intermittently and only 22 are considered resident compared with eleven making seasonal migrations into the lower part of the estuary to breed and feed.

By far the largest fish component of the estuaries and coastal areas reviewed consisted of marine vagrants, of which there were 140 of the 181 species recorded. In some areas reviewed, a significant section of open coast was included, Holy Island to Farne Island coast, the Wash, Severn, Morecambe Bay, and the Solway Firth, and it is not surprising to find marine species present. However, others were also found to contain significant records of marine fishes, which serves to emphasise the importance of estuaries as feeding grounds for many species at different times of the year.

Table 4. shows the distribution of estuarine fishes between the 22 estuaries and coastal areas. The data presented clearly indicates the variability in the fish fauna between different areas. Thus, with a total possible of 41 species of estuarine fishes, only the Thames, Chichester and Langstone Harbours, Fal and Helford, Severn, Morecambe Bay and Solway Firth have 30 or more species. The reason appears to be that these areas have been subjected to detailed examination and particularly the Thames and Severn, where extensive bibliographies exist. It should also be noted that the Thames, Severn, Morecambe Bay, and Solway Firth contain a significant marine component in the estuary mouth and are considered to have a rich habitat diversity. By contrast, some areas have very low species diversity of estuarine fishes which either results from inadequate surveys of the area or impoverished environmental conditions. These include Holy Island to Farne Island coast, which has no major estuary and might not expect to yield a high estuarine fish fauna. In fact, 12 estuarine species were recorded, but only from a total of 31 species which clearly indicates a need for a fish survey of the region. This should be considered of some urgency in view of the important sea bird and seal colonies of the area which depend on local fish populations as food. By contrast the Solway Firth has 32 estuarine fishes in a total recorded fish fauna of 130 species. Paucity in species diversity was also shown by the Camel and Duddon Estuaries yet neither is subjected to excessive human impacts and the low numbers reflect a lack of a fish survey. The Wash might also be expected to yield a fish fauna larger than 22 species and is known to be an important nursery ground for several species.

Estuaries subjected to primary surveys and showing low species diversity generally showed a range of human impacts that could explain the low species numbers. Most important of these human impacts must be considered land reclamation which effectively removes the aquatic environment and often results in the degradation of what remains. The Orwell has lost tidal flats in land claim activities at Felixstowe and both the Orwell and Stour Estuaries are both subjected to extensive dredging operations. Further pollution of the estuary results from the dredging activities in the Orwell which increases the turbidity and has been shown to release TBTs from the disturbed sediments.

The Mersey and Ribble Estuaries show low fish diversity that is a consequence of chronic pollution. Indeed, the Mersey is currently rated as the most polluted estuary in Great Britain. Draining the intensively urbanised and industrialised north east of England the Mersey contains low oxygen levels that deplete the invertebrate fauna and deter the influx of fishes. While some pelagic species are recorded to enter the estuary at high water few move any distance up the river and anadromous species have nowhere to go in the upper estuary. Recently an increase in flounders (*P. flesus*) indicate some sign of improvement in water quality, but much remains to be done before a full and representative estuarine fish fauna returns.

The number of species found in an estuary depends upon the habitat diversity, estuary size, structural complexity, tidal amplitude, freshwater runoff and other factors, and where no other influence is involved between 30 and 40 estuarine fish might be present. However, there are very few estuaires without some significant anthropogenic factors that have a bearing on the estuarine ecosystem and upon its fish fauna. These human impacts are presented in Table 5 and show the overall extent of human activities. The table does not show the seriousness of each impact or the ways in which they degrade the environment. In the long term, land reclamation is the most serious impact as it irreversibly destroys and removes the aquatic environment. Further, it is an accumulative process, and may eventually result in the destruction of the whole ecosystem. The Dee, Wash, Orwell and Ribble have all been subjected to extensive land reclamation activities and the Orwell in particular is seriously threatened by proposals to extend the docks at Felixstowe (Davidson *et al.*, 1991)

The importance of our estuarine resource to coastal fish populations should be stressed as they provide nursery areas for juvenile fishes, including sole, plaice, sprat, cod, dab, flounder, bass, herring and other species. The importance of estuaries as nursery areas is recognised by the MAFF who have applied control measures to reduce danger to young bass populations. The productivity of the lower estuary and estuarine mouth provides rich feeding grounds upon which many species depend.

The large number of marine vagrants identifies the estuary as a seasonal feeding area for many species (see Tables 1 & 3). The presence of adult fish in estuaries has been the basis for many important fisheries,perhaps most valuable of which is for salmonids that migrate into estuaries. Particularly important are the Solway Firth, Severn, Morecambe Bay, Dee, Exe, Taw/Torridge and Camel, although the overall signs are of decreasing fishery either resulting from over-exploitation or from pollution deterring the salmon runs.

Many estuaries have traditional local fisheries for flatfish, bass, cod, herring and eels including the Wash, Humber, Blackwater & Colne, Thames, Langstone and Chichester, Poole, Exe, Taw/Torridge, Severn, Dee and Solway Firth. The overall trend in estuarine fishes is one of decline, but for many species information is not available and where it is may show contradictory signs. There are signs of improvement in fish stocks in the Thames and Blackwater.

On all estuaries there is evidence of increases in domestic and industrial discharges. The impact however depends critically on what treatment is given to the effluent prior to release. The most serious impact overall in estuarine fishes results from the deoxygenation of the water, killing invertebrate and fish communities. In most cases these conditions are caused by the release of untreated sewage into the estuary. In winter months, with high precipitation in the freshwater catchment area, sewage and other pollutants will be flushed from the estuary. However, in estuaries with a low freshwater input, or in summmer when precipitation is low, sewage remains in the estuary causing eutrophication and an increase in the bacteriological oxygen demand. The result is long term oxygen depletion and a dramatic reduction in species diversity (ie. Mersey, Ribble and Dee). Secondary factors occur with the formation of algal mats, proliferation in *Ulva lactuca* and, in summer months, the formation of algal blooms in the lower estuary and inshore areas. Industrial and agricultural effllluents may cause serious downgrading of water quality and may result in an impoverished fish fauna. Occasional accidental spills of chemicals (aluminium sulphate in the Camel [1988], aldrin and dieldrin in the Taw [1985]), slurry sludge in the Tamar (1992) and oil spills in the Orwell and Stour Estuaries, and Chichester, Langstone and Poole Harbours may result in significant fish kills.

Clearly pollutants must be treated at source and tougher legislation is needed to prevent untreated sewage and industrial waste being discharged into estuaries.

The Thames provides an example of what can be achieved with a will and the resources to carry out the necessary clean-up operation. In the mid 19th century the Thames was so polluted few fish could survive and only eels were recorded to move upstream. This situation, continued until the 1950s and 1960s when moves were set in place to decontaminate the river. The result has been a resounding success and oxygen levels in the river are high and it now has a total fish fauna of over 100 species of which 38 are considered estuarine. This sets an example that needs to be studied and applied to other estuaries. Already signs of improvement are appearing in the Humber, but much more needs to be done before the Dee and the Mersey are able to show a return of a diverse estuarine fish community.

This review clearly shows that the estuarine fish resource is as varied and important as the avian fauna that use estuaries, and in economic terms far more important. However, relatively few full studies have been carried out on the fish fauna by which to compare the state of an estuary, its water quality and physical and geomorphology environment. Where data exist, as with the Thames and Humber, it is clear that the fish diversity in estuaries is an important index of environmental recovery. Thus an estuary with full estuarine fish fauna will also have a water quality that is likely to match EC directives on water quality and meet biological criteria. As over large areas fish and estuarine birds depend upon the same invertebrate food resources, the need for improving water quality is paramount for the health of the whole ecosystem. Estuaries are also important for commercial fisheries, providing nursery areas and feeding grounds for a wide variety of estuarine and coastal species. It is interesting to note that while fisheries activities will reduce the total species biomass of an estuary, there is little evidence it significantly reduces species diversity.

Estuarine fishes and their species diversity provide an important guide to the state of "health" of the aquatic estuarine environment. They are indicators of water quality and their absence often identifies serious pollution or other destructive forces on the estuarine environment. However, the movement of water through an estuary also provides a self-cleansing system such that pollutants can be flushed from the ecosystem making way for a rapid recovery. The return of the mobile fish fauna and the ability of the estuary to sustain a full and diverse fish population is a mark of recovery and is clearly seen in the Thames which in the last thirty years has shown a near complete restoration of its fish fauna.

5. RECOMMENDATIONS

Following the present review on the status of estuarine fishes it is recommended that:-

- Baseline surveys are carried out on all estuaries to determine the species composition and, where possible, the relative abundance of commercial and non commercial species of estuarine fish.

- A review be undertaken of the current fisheries activities and landing statistics to examine the role of estuaries as a fisheries resource.

- The detailed surveys of fish catches at power station water inlet screens are continued and recognised as the most detailed long-term data set available on selected estuaries.

- A monitoring programme be established to record and measure the species diversity of estuarine fishes by which to assess whether estuarine conditions meet with EC directives on species and habitat.

- Ongoing monitoring should be supported to identify the status of rare or threatened species and in particular those protected under national and international legislation, which include 5 estuarine species.

- Consideration should be put to identifying and maintaining estuarine habitat diversity.

- Data on estuarine fishes and recording programmes should be coordinated centrally with the British Marine Fishes Database.

- With the discharge of untreated sewage implicated in the reduction of fish diversity in estuaries pressure should be maintained on regional water authorities to provide treatment at sewage outflows.

- Pressure should be maintained to ensure industrial effluents are treated at source.

- Major developments on estuaries should be the subject of a detailed environmental impact studies and independent review.

6. ACKNOWLEDGEMENTS

In preparing this review of the status of estuarine fishes it has been necessary to consult with many organisations and individuals who have generously made information available. We should like to thank the following for their important contributions:

English Nature: Ms A. Moffat, Dr. R. Mitchell, Dr D. Laffoley, Dr. M Vincent.

Joint Nature Conservation Committee: Dr K. Hiscock.

National Rivers Authority: Dr C. Ashcroft (Anglian Region), Dr L.Bird (Yorkshire Region), Mrs S. Birdseye (HQ), Mr S. Bray (South West Region), Dr Buckley (Southern Region), Mr A. Churchward (Severn-Trent Region), Dr D. Cragg-Hine (North West Region), Mr R. J. Cranshaw (Southern Region), Mr L. Davis (Wessex Region), Ms. J. Driver (South West Region), Dr M Everard (HQ), Mrs J. Jupe (HQ), Dr J.H. Kalicki (Severn-Trent Region), Mrs R. Keenan (South West Region), Dr R. Linfield (Anglian Region), Dr D. Lowthion (Southern Region), Ms. S. Peaty (Northumbria Region), Dr R. M. Thomas (Thames Region).

Sea Fisheries Committees: Mr S.C. Amos (Eastern SFC), Mr C.F. Beach (Eastern SFC), Mr J. Friend (Devon SFC), Mr S.A. Holman (Sussex SFC), Mr T. Knight (Devon SFC), Miss J. Lancaster (Cumbria SFC), Mr R.G. Teague (Cornwall SFC), Mr H.F. Theaker (North Eastern SFC), Mr M.A. Whitley (Southern SFC).

City, Borough and District Councils: Mrs R. Calderwood (Ipswich), Mr M. Eteson (Preston), Mr G. Evans (Exeter), Mrs M.A. Ginger (Padstow), Mr P. Hodges (South Hams), Mr P.S. Hunt (Portsmouth), Mr D.J. Ingham (Carlisle), Mrs R. Whittington (Colchester), Mr D.M. Worthington (North Devon), Mr P.N. Wright (Berwick-upon-Tweed).

Fawley Aquatic Research Laboratory: Dr R. Bamber, Dr P. Henderson, Dr A. Turnpenny .

Cornish Biological Records Unit: Dr C. French, Mrs P. Thompsett, Mrs S. Turk.

National Federation of Sea Anglers: Mr C. Davies, Capt. D.C. Goodwin, Mrs J. McCormack, Mr D. Rowe.

Individual contributions from: Dr P. Gainey, Mrs J. Jones (Devon Wildlife Trust), Dr M. Ladle (Freshwater Biological Association), Dr P. Reay (University of Plymouth), Dr G. Bryan, Mr G. Burt, Dr P. Claridge, Dr W. Langston, Mr Fred Frettsome, Miss Jenny Weeks.

In addition we should particularly like to acknowledge the considerable help of Miss Sue Boxall, Mrs Sue Gale, Miss Karen Langley, Miss Linda Noble, Miss Kate Prudden, Miss Wendy Rigby whose contribution to data gathering and the preparation of the final report was essential.