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THE SEVERN ESTUARY AND THE BRISTOL CHANNEL.(U)
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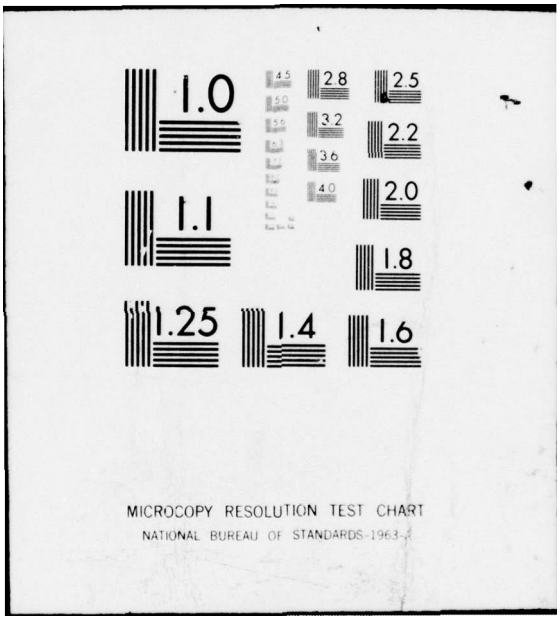
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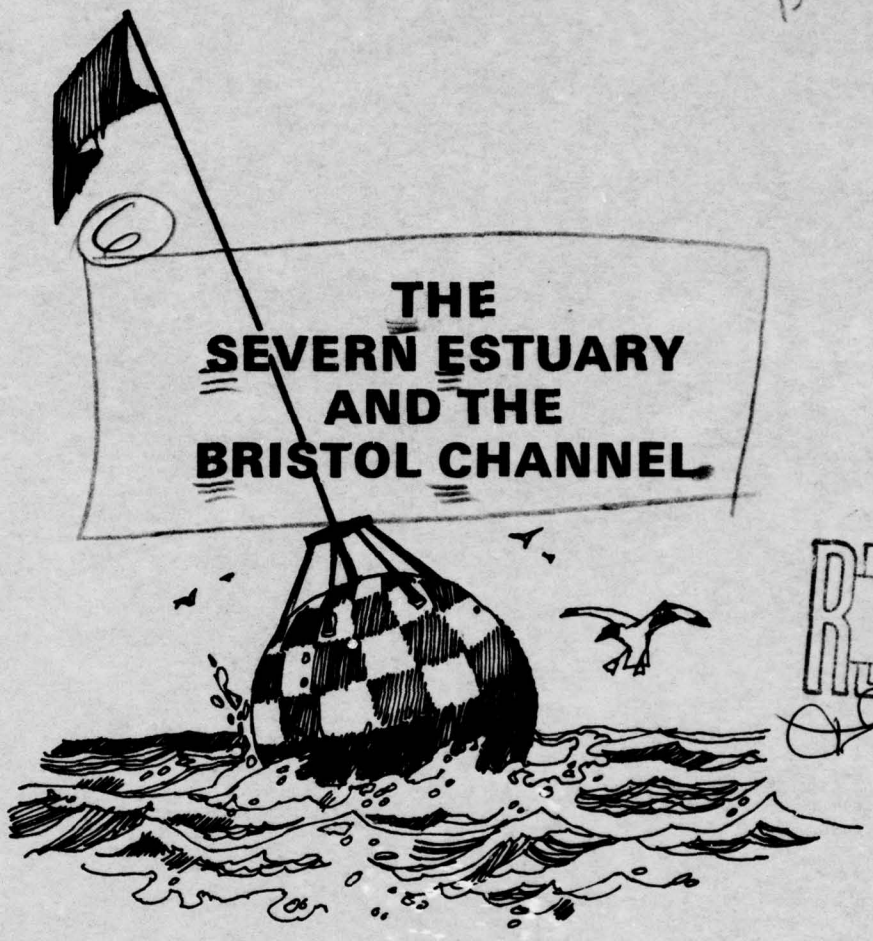

An Assessment of Present Knowledge

compiled by:

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Institute for Marine Environmental Research
Unit of Coastal Sedimentation

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THE NATURAL ENVIRONMENT RESEARCH COUNCIL

PUBLICATIONS SERIES C No. 9 DECEMBER 1972

14 Pub-Ser-C-9

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Aerial view of the Severn Estuary (photo Airviews Ltd).

PREFACE

Estuaries have attracted much attention recently and an increasing research effort is being directed to their problems. There are many reasons for this, stemming from the developing needs of new industries and new conurbations for marine access, for industrial and domestic water supply, or simply for new land sites. At the same time, estuaries are a major pathway by which materials reach coastal seas and, ultimately, the oceans. In its task of encouraging and executing research in the natural environment, the Natural Environment Research Council has underlined the need for more basic and background information about how estuaries work, what fauna and flora they support, and how estuarine systems are likely to respond to the uses we make of them.

Among British estuaries, that of the Severn, which together with other contributory rivers, develops into the more complex Bristol Channel, is one of the largest. Historically, it has played an important part in the development of the major industrial centres of Bristol, Gloucester, Newport, Cardiff and Swansea. Proposals for future development, notably expressed in the Severnside Feasibility Study (1971), suggest a much greater potential utilisation of the estuary and its hinterland. The geomorphological characteristics of the area, and especially the high energy conditions of the estuary, make it of singular scientific interest.

An initiative in promoting scientific study of the area was made, early in 1970, by the University of Bristol, with the formation of the inter-disciplinary 'Sabrina Group' which asked NERC for support of a number of research projects in the whole watershed area. As a part of its response to this initiative, but in this case limited to the estuary proper, NERC called a meeting on the 3rd December 1970 of representatives of the University of Bristol and of Council's component institutes engaged in estuarine research. The meeting was chaired by Professor R. W. Edwards, Department of Applied Biology, University of Wales, Institute of Science and Technology, and a member of Council. The meeting recognised that an essential first step in formulating a research programme was the collation and evaluation of existing information about the estuary.

Both 'Sabrina Group' scientists and those from NERC institutes contributed papers to cover the major aspects of the estuary and subsequently, University College, Swansea, were also involved in the exercise. Individual contributions were then compiled as a unified report. For the purposes of this report, the Severn Estuary was defined as the tidal part of the Severn River, downstream to a line. from Brean Down, through Flat Holm and Steep Holme to Lavernock Point. The seaward boundary of the Bristol Channel was taken as a line between Hartland Point, Lundy Island and Milford Haven.*

**A number of people have assisted, but particular mention should be made of Mr. D. Hamilton (University of Bristol.), Dr R. Kirby (UCS) and Dr G. W. Heath (IMER.).*

It is not the purpose of this review to assess the use of the natural resources of the area, nor to offer judgment or views on the control of activities, that might give rise to pollution or physical interference with the estuary. However, it is recognised that planning and control of such activities will require a sound basis of physical, chemical and biological knowledge. The report attempts a critical assessment of the information available; its conclusions show where present knowledge is inadequate and where further research is called for.

Since this report was completed (June 1972), two other reports of relevance have appeared. One of these is the Department of Environment's Report on 'Water Quality in the Severn Estuary and Recommendations for Future Investigation', prepared by the Water Pollution Research Laboratory. This 'desk study' has examined data on the water quality characteristics: freshwater flow, salinity, dissolved oxygen, biological oxygen demand, nitrogen compounds and some information on heavy metals content of muds. The aim of the reports is to formulate a predictive mathematical model for the distribution of pollutants which can assist management of the estuary. Focusing, as it does, on the upper end of the estuarine system and on the composition and flow of tributaries and effluent outfalls, the report does not overlap with the one presented here, the two being complementary. In addition, in pursuing the aim of model-making on the basis of physical and chemical data. the WPRL Report does not include considerations of a biological nature, other than those implicit in the oxygen demand.

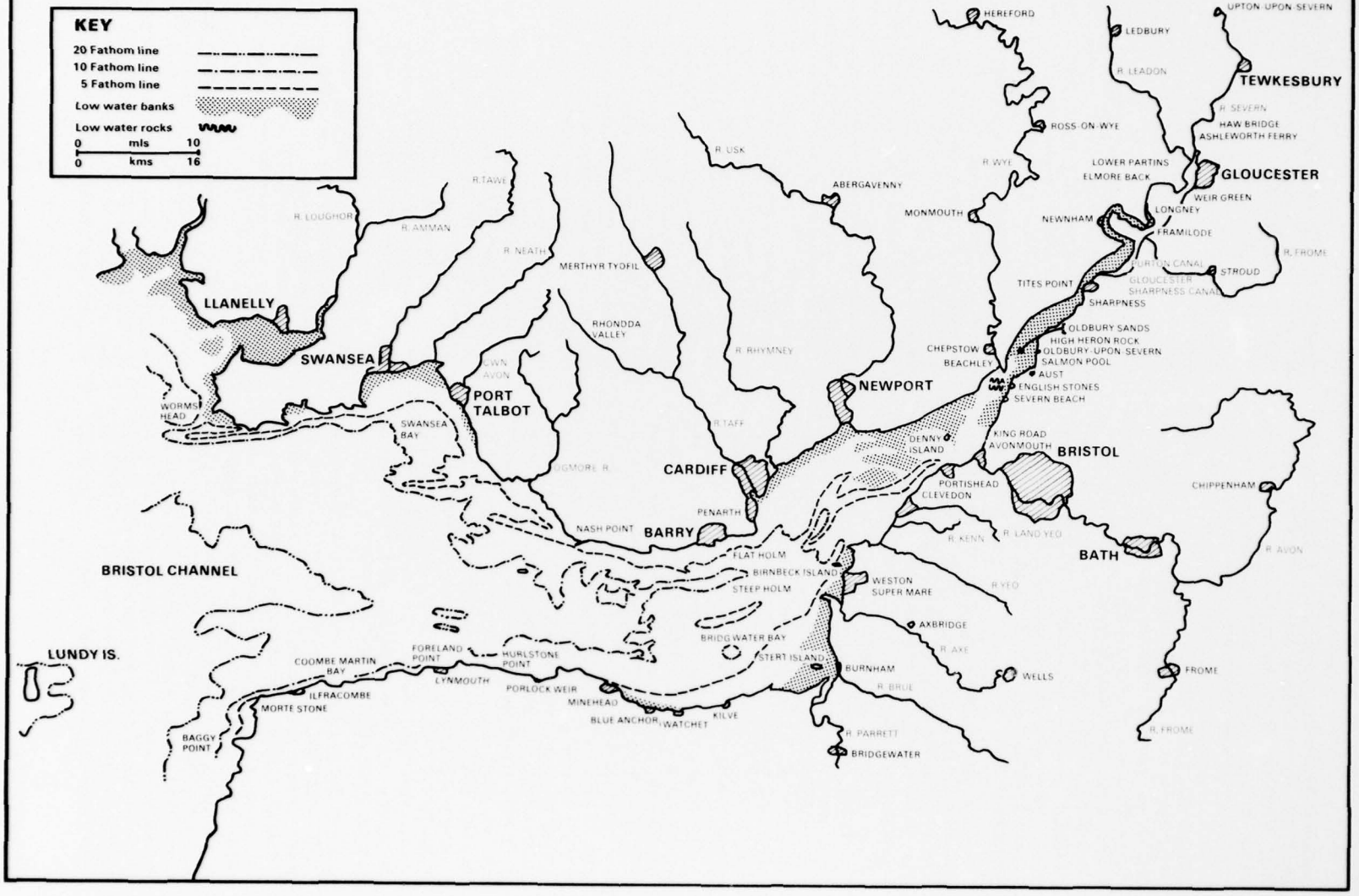
Secondly, the Royal Commission on Environmental Pollution has recently published a Third Report entitled 'Pollution in some British Estuaries and Coastal Waters' (Command No. 5054). In their conclusion to a most informative report on the state of our estuaries and coastal waters, the Commissioners stress the need for more background knowledge of estuarine systems, particularly the need for more knowledge and understanding of the long-term toxicity of pollutants in the aquatic environment, effective mathematical models, more knowledge of coastal hydrography, accumulation processes, and development of the use of biotic indicators of pollution.

On behalf of NERC, I would like to express the hope that this report, and others to follow, will contribute to the task of gathering relevant information to a single locus, of identifying gaps in knowledge and of stimulating the development of further research to provide a scientific base for the wise use of the estuary as a major natural resource.

December 1972

R. J. H. Beverton, Secretary of Council

THE SEVERN ESTUARY AND THE BRISTOL CHANNEL



1. SYNOPSIS

1.1. Boundaries of the Area—The Severn Estuary is funnel-shaped and extends from Upton-on-Severn to Flat Holm and Steep Holme, a distance of 90 miles (150 km). The Bristol Channel is 60 miles (100 km) long, is 8 miles (14 km) wide at the Holms and reaches a width of 45 miles (70) km at its western limit at Lundy Island. Nearly one sixth of the land area of England and Wales drains into the Severn Estuary, whilst the Bristol Channel receives only limited freshwater inflow.

1.2. Geology and Sedimentology—The coastline of the Bristol Channel is predominantly rocky, which contrasts with the generally unconsolidated sediments forming much of the coastline of the Severn Estuary. Although some preliminary mapping of the solid geology and the bedrock surface morphology has been carried out in both the Channel and Estuary more detailed knowledge, particularly in the Severn, is required. The nature of the unconsolidated sediments in the Severn Estuary and Bristol Channel is known only for limited areas.

The major channels are flanked by large shoals, some of which are known to be unstable. There are insufficient data relating to the causes and processes of this instability and equally little information is available on the nature of the extensive marginal tidal flats. Their role in the sediment budget of the estuary is unknown.

1.3. Water Movements—The estuary has the greatest diurnal tidal range in Britain—over 40 feet (12 m) at Avonmouth, a range of about 10 feet (3 m) between equivalent spring and neap tides, and a geographical variation in tidal range throughout the length of the estuary. Tidal stream velocities are known but the dynamics of the system, including circulation, salinity and temperature patterns are inadequately understood.

1.4. Chemistry—Materials carried into the Estuary in fresh water discharges are subjected to interaction with saline water. Resuspended sediments are important as buffers, stores and catalysts. Studies of these sediments and their organic and inorganic processes are vital to a sound chemical understanding of the capacity of the estuary to accept, degrade and tolerate the pollution load.

1.5. Biology—There is little information about biological aspects of the unconsolidated sediments of the Severn Estuary—particularly of those in the sub-littoral zone. Rather more is known about the benthos of the rocky intertidal surfaces, some sandy shores and certain sub-littoral regions of the Bristol Channel. Attached algae have hardly been studied.

The distribution of invertebrates reflects salinity regimes and suspended sediment content. Fish in the area are mainly known from records of commercial fisheries, dating from the fifteenth century. Some species have declined in recent times.

Marine plankton diminish in variety of species and abundance with distance upstream from the mouth of the estuary. Abundance appears to be influenced by the turbidity of the water.

Work on salt marshes has emphasised the important role of *Spartina* grass in retarding currents and thereby trapping sediments.

2. GEOLOGY AND SEDIMENTOLOGY

2.1. Geological Setting—The solid geology influences both the orientation and shape of the Bristol Channel and Severn Estuary. The present coastline in the Bristol Channel is predominantly solid rock while in the Severn Estuary/Bridgwater Bay, the coast is mainly unconsolidated sediments.

2.1.1. Bristol Channel—The land area adjacent to the Bristol Channel has been mapped by the Institute of Geological Sciences and other research workers, mostly on the scale of 1:10,560 and in parts on 1:2,500. Therefore the basic onshore geology is quite well known but data derived from boreholes on land allow only limited extrapolation offshore.

In contrast, only limited areas of the offshore surface geology have been mapped in comparable detail. To date, preliminary mapping of the solid geology in the Bristol Channel has been done by means of continuous seismic profiling, gravity coring, side-scan sonar, gravity, magnetic, and seismic-refraction techniques. This work has been carried out by the University College of Swansea, University College, London, and the National Institute of Oceanography.

2.1.2. Severn Estuary—The solid geology marginal to the estuary has been mapped by the Institute of Geological Sciences and other workers on the scale of 1:10,560.

Detailed studies have been made of certain areas, such as the M4 Severn Bridge, Severn Tunnel, Central Electricity Generating Board Tunnel, power station sites and other civil engineering sites.

Much more borehole information is available along the margin of the Severn Estuary than along the Bristol Channel, despite the disparity in the geographical size.

In the Severn Estuary solid rock is exposed on some wide shoals, on islands and in some tidal channels. The Unit of Coastal Sedimentation and the University of Bristol have carried out preliminary continuous seismic profiling and gravity coring surveys, between Avonmouth and the Holms. Some information is available from site investigation reports.

2.1.3. Morphology of the Bedrock Surface—The bedrock surface is mostly a buried channel system of Pleistocene to Recent age. This channel system extends beyond the limits of the present Severn Estuary/Bristol Channel. Continuous seismic profiling surveys, carried out by Swansea University, have produced an outline of the buried relief between the Holms and the Lundy/Caldy region, amplified by more detailed surveys of certain areas. This work is being supported by surface sediment sampling and bedrock coring. Preliminary seismic surveys have been carried out in the Severn Estuary.

2.2. The Unconsolidated Sediments—The sedimentary environment of the Severn Estuary and Bristol Channel is greatly influenced by the high energy conditions resulting from the high tidal velocities.

The thickness of offshore sediments is known only from the few geophysical records already obtained. The data are restricted in areal extent, as well as by the techniques and equipment used. Interpretation is tentative since it has not proved possible to calibrate these records by sampling in depth. There is a most marked contrast between the coastal and offshore sediment bodies in the two areas. In both areas, information is available from hydrographic surveys and a limited number of site investigations.

Only a little knowledge exists of the spatial distributions of lithologies on a regional scale and of the surface features of individual sediment bodies. Meaningful information is entirely inadequate for the regional assessment of sediment types, internal structures, geotechnical properties, mineralogy and the occurrence of natural and industrial tracers. The effects of biological activity (binding, pelleting, etc.) on the mobility of sediment in this area is largely unknown.

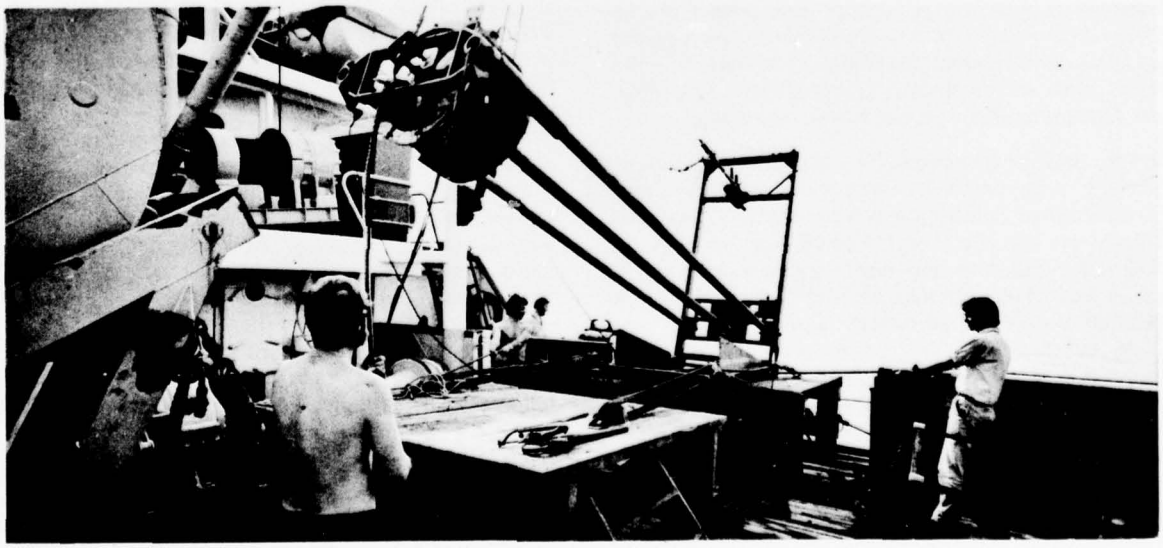
2.2.1. Bristol Channel—In the Bristol Channel unconsolidated sediments occur as linear banks resting on bedrock. There are also large sediment bodies in the major embayments. The linear sandbanks, some Gower beaches and superficial deposits in the Loughor Estuary, are being studied at University College of Swansea, particularly the spatial distribution of lithologies, sediment thickness and internal structures.

2.2.2. Severn Estuary—In the Severn Estuary unconsolidated sediments form banks and intertidal flats over the larger part of the estuary. A study of these sediments is in progress at the University of Bristol and supported by NERC. Some parts of the area have been under investigation since 1961 and the work is expected to continue for another 5–10 years. The Unit of Coastal Sedimentation has obtained vibrocore samples from Newport Deep and the Bridge area.

2.2.3. Morphology of the sediment surface—Knowledge of the seabed morphology is derived principally from hydrographic surveys, and comparison of these yields valuable information about changes. Care should be taken in using this information as only the most recent surveys are based on adequate positional control and in many cases these still lack the tidal datum control necessary for detailed comparisons. These limitations are particularly important in the Severn Estuary because of its very large tidal range. The Unit of Coastal Sedimentation and University of Bristol have undertaken side-scan sonar surveys in the navigable channel and these are proving a useful addition to hydrographic surveys.

2.2.4. Tidal Flats—Erosion and accretion occur at some places along the margins of the channel and

The Unit of Coastal Sedimentation's vibrocorer in use during a sedimentological survey in the Severn Estuary.



estuary, leading to long term changes. These changes form an integral part of the sediment movement pattern within the estuarine system. Pierce *et al.* (1970) have assessed the stability of some intertidal estuarine muds under experimental conditions. The influence of the flora and fauna on erosion and accretion of the tidal flats in the region of high energy is unknown : it could be important and should be assessed.

2.3. Mobility of Sediments—An historical analysis of some long term changes in the shape of the sea bed recorded in hydrographic surveys has been made from records obtained during the last 150 years (Hawkins, 1971).

The extreme tidal variations cause considerable transport of sediment both within the water mass and as bed load. Only an insignificant amount of definitive information exists on this topic.

Three artificial tracer tests in Swansea Bay, Newport Deep and Portishead, have added to our knowledge of sediment circulation, but these few tests have been of limited value. A study of suspended sediment transport and deposition has been carried out in Swansea Bay by the University College of Swansea.

Although there is considerable mobility of a wide range of sediment types, there is apparently a high degree of retention of sediment within the Severn Estuary. Information is required on the sediment budget, i.e. the rate of input of sediments and the loss, if any, to the sea. The effects of changes in salinity on the clay mineralogy are also imperfectly understood.

It is known from other estuaries that, in some cases, the morphology of the sea bed and sediment transport regime varies in response to single tidal cycles, with spring/neap alternations, with seasonal changes, with longer term fluctuations, and with effects from random meteorological causes. Little or no precise data are available for these changes in either the Bristol Channel or the Severn Estuary.

3. WATER MOVEMENTS AND OTHER PHYSICAL

3.1. Tides—The Severn Estuary has the greatest tidal range of any estuary in Britain. (See Table below.)

The predominantly semidiurnal tide has a mean spring range of 6 m at Milford Haven, increasing progressively up the converging estuary to 12 m at Avonmouth. Reliable harmonic constants exist for only six stations throughout this changing tidal regime.

Tidal stream observations are scanty; the tidal streams are generally rectilinear, lead the elevation by $2/2\frac{1}{2}$ hours, generally reach 5–7 knots in the main channels and up to 10 knots in The Shoots. Estimates of tidal friction by Taylor (1921) and Grace (1936) are the only theoretical studies known. The bulk of tidal data reside at the Tidal Branch of the Hydrographic Department and the Institute of Coastal Oceanography and Tides.

Very little is known of (i) the distribution of shallow water tides, (ii) the vertical structure of tidal streams and variability of non-tidal currents, (iii) tidal heights in mid-channel.

No comprehensive scientific study has been mounted of the tidal regime in the area. Coriolis effects remain to be determined but are unlikely to be substantial.

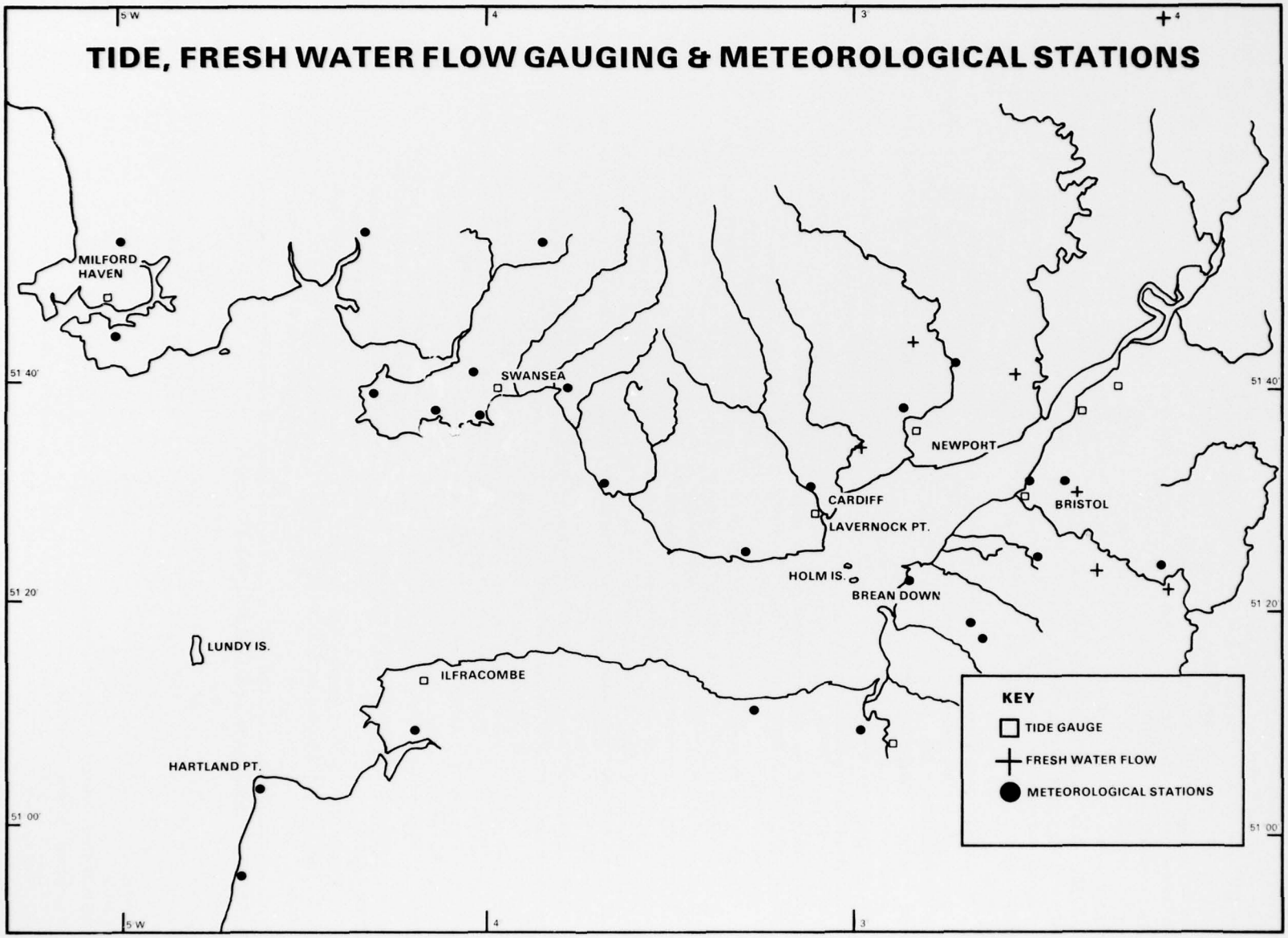
3.2. Storm Surges—The natural causes and frequency of positive surges in the area are quite well known (Heaps, 1967), and would be accurate with little extension for most major studies; no studies have been made of negative surges. Seven surges exceeding 1.8 m at Avonmouth occurred between 1920 and 1955, generated by secondary depressions travelling eastwards over Ireland (Lennon, 1963a). Dynamic amplification seems important. The converging nature of the Bristol Channel further amplifies and sharpens surges which are mainly generated seaward of the Channel.

3.3. Surface Waves—Very little data exist for the area. The National Institute of Oceanography have done some work off Land's End and from the Helwick Light Vessel (Draper and Fricker, 1965). A little work has also been done in conjunction with port and power station development (Hartland Point, Hinkley Point, Oldbury, Newport), but only to check conditions for construction. Maximum wave height recorded at Helwick in the period September 1960–February 1961 inclusive was 10.4 m with most frequent height 3.0 m and period 5–6 secs.

Tidal Range in some estuaries around Great Britain (metres)

Estuary	Port	LAT	MLWS	MHWS	HAT	MSTR
Severn	*Avonmouth*	*−0·34*	*0·58*	*12·90*	*14·15*	*12·31*
Mersey	Liverpool	−0·68	0·46	8·86	9·80	8·38
Forth	Leith	−0·18	0·68	5·40	5·94	4·79
Humber	Immingham	−0·58	0·34	6·68	7·46	6·37
Thames	Sheerness	0·30	0·58	5·73	6·16	5·15
Southampton Water	Southampton	−0·30	0·46	4·54	4·94	4·08

From Table 5 Admiralty Tide Table. Vol. 1, 1970
LAT – Lowest Astronomical Tide—MLWS – Mean Low Water Springs: MHWS – Mean High Water Springs: HAT – Highest Astronomical Tide: MSTR – Mean Springs Tidal Range.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LAVERNOCK PT.
BRISTOL
HOLM IS.
BREAN DOWN
LUNDY IS.
ILFRACOMBE
HARTLAND PT.
KEY
TIDE GAUGE
FRESH WATER FLOW
METEOROLOGICAL STATIONS

3.4. Temperature, Salinity and Suspended Solids Distribution—Cooper (1967) has shown that at the entrance to the Bristol Channel it is possible to distinguish not only gradients of salinity and temperature, but also of phosphate, etc. Similar gradients may be expected in the middle and upper reaches of the Channel and seasonal variations are also probable. The delineation and extent of these will help to determine dispersion patterns. The studies of Bassindale (1943), extending from Avonmouth to The Holms, include data on temperature, salinity, suspended solids, pH and dissolved oxygen and hence their relationships to water mixing. The Hydraulics Research Station in collaboration with the Central Electricity Generating Board have collected and analysed extensive data on the conditions in the neighbourhood of some of their power stations.

The 1927 Admiralty Survey gives salinity and suspended solids at four stations between Avonmouth and Sharpness. Salinity charts for the area, particularly above English Stones, have been prepared by H.R.S. while the Ministry of Agriculture, Fisheries and Food have recorded salinities in the Bristol Channel and above the Severn Bridge.

All these recordings are largely unco-ordinated.

3.5. Circulation Patterns and Mixing—C.E.G.B. and H.R.S. have used temperature measurements (and hydraulic model studies) at the Berkeley and Oldbury power stations to give an indication of water mixing. Radioactive tracer experiments have been used to study channel stability, in Newport Deep (British Transport Docks Board), Swansea Bay and off Portishead (British Steel Corporation). The H.R.S. report for the I.C.I. Avonmouth outfall includes float tracking, current metering and suspended solids records close to the mouth of the River Avon. Recently the Water Pollution Research Laboratory has been assessing available information with a view to predicting large-scale effluent dispersion patterns (WPRL, 1972).

Notwithstanding these activities, we still have only an elementary understanding of the hydrodynamics of the Bristol Channel/Severn Estuary.

3.6. Hydraulic Model Studies—Gibson's model (Gibson, 1933) for tidal power studies reproduced the Severn Estuary and River Severn. While designed to a very small scale, and with severe vertical scale distortion, it was deemed adequate for the study, although a larger model was advocated for siltation studies. H.R.S. used a much larger and more satisfactory model of the Estuary above English Stones, for C.E.G.B. cooling water studies. This model was subsequently employed also for local sedimentation studies. The H.R.S. has also constructed models of restricted locations for specific studies, e.g. the approaches to Avonmouth Docks, but no large models have been built of the areas below English Stones.

3.7. Monitoring Stations (See map opposite).—Permanent automatic tide gauges exist at Milford Haven*, Swansea*, Cardiff, Newport (up-river), Narlwood Beacon (HW only), Berkeley Jetty, Avonmouth, Bridgwater (up-river), and Ilfracombe*. There is a gap in this chain from Ilfracombe to St. Mary's, Scillies*. At present, Port of Bristol Authority maintains the Clevedon gauge, although the future of the pier is in doubt.

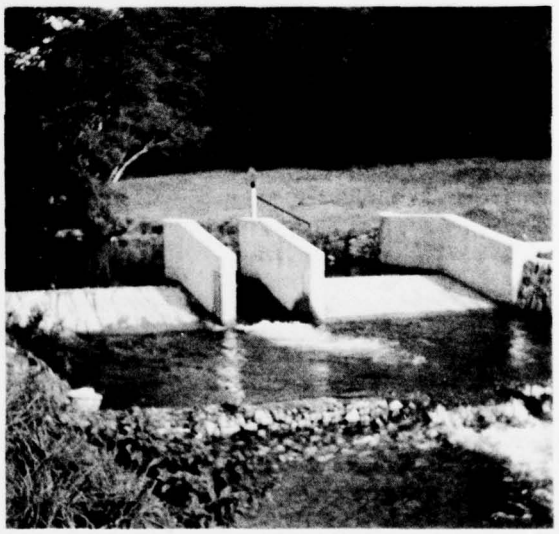
Stations monitoring freshwater flow into the Severn estuary and Bristol Channel are shown below.

River	*Station*
Bristol Avon	Bath
Severn	Bewdley
Avon	Evesham
Stour	Kidderminster
Chew	Compton Dando
Salwarpe	Hartford Hill
Parrett	Chiselborough
Usk	Chain Bridge
Teme	Tenbury Wells
Leadon	Wedderburn Br.
Ebbw	Rhiwderin
Frome	Frenchay
Wye	Cadora
Taff	Tongwynlais

Some 30 land meteorological stations in the vicinity of the Severn Estuary and Bristol Channel complete climatological returns. Specific features, particularly rainfall, are recorded by local authorities, by schools and by individuals; most of these are daily gauges, the results from which are largely uncorrelated.

A detailed study of dynamic rainfall is in progress in the Gloucester/Cheltenham area using autographic gauges and incorporating daily gauges (Waller and Shaw, 1970).

A river gauging station.



*Stations in national tide gauge report

4. CHEMISTRY

4.1. Chemical and Biological Oxygen Demands (C.O.D. and B.O.D.)—Measurements of this type are made in the tributary rivers by the River Authorities but there is little published information for the estuary itself.

4.2. Sediment Composition—In general, the concentrations of chemicals other than soluble ionic species, are likely to be much lower in estuarine waters than in the highly adsorptive muds. Some measurements have been recorded for pesticides in the estuarine muds, and there is information for pollutants such as cyanide and phenol, in the possession of the River Authorities.

4.3. Nature of Sediments—The sediments are important from the chemical standpoint for undoubtedly they act as buffers, stores, catalysts and sites for microbial, microfaunal and mesofaunal activity.

The few available analyses of the muds show them to be alkaline, reducing and high in clay minerals such as illite and kaolinite. There is no comparative survey of the chemistry and microbiology of the muds around the estuary.

4.4. Chemistry of Water/Sediment Interaction—This is largely the field of colloid science for which there is considerable literature on the behaviour of minerals in relation to pH, salinity changes, etc. The various phenomena are incompletely understood and each environmental situation requires individual assessment. Studies underway at Bristol University (Chemistry, Geology and Geography) are concerned with the physical and chemical processes leading to the flocculation, precipitation and deposition of sediment, using the mouth of the Wye as a test-site. An investigation into the adsorption and release of humic acids and other organics is proceeding.

4.5. Ecochemistry of the Estuary—The Bassindale papers were an early attempt to assemble a range of information covering physical, chemical and biological disciplines and the formulation of a view of the working of the Severn Estuary as a whole. Little chemical information was available at that time (1943) and this remains true today. The paucity of data makes it difficult to distinguish man-made pollutants and their chemical and biological degradation products from naturally occurring substances. The ability of certain organisms to rework, concentrate, synthesise or dispose of metal ions or organic compounds has been amply demonstrated in the literature. Any model of the Severn Estuary ecosystem would need to encompass these factors, but at the present time even the basic information on the nature, abundance and inter-relationships of the various chemical components of this model is not available. The River authorities monitor several sites in the tributary rivers, in general to measure a few compounds and ions such as NH_4^+, CN^-, phenol, Cl^- and, occasionally metals, such as arsenic, lead, zinc and cadmium. The Severn River Authority recently expanded its estuarine analysis programme.

4.6. Pollutants—Pollutants are probably the most extensively recorded of the man-induced factors, though they are measured mainly in the rivers rather than the estuary. No overall view of the situation in the Severn Estuary is available to our knowledge. Large volumes of both raw and treated domestic sewage enter the estuary through sewer outfalls while sewage sludge and other solid wastes are dumped within the Bristol Channel. These sources and the outfalls of industrial complexes such as those at Avonmouth, Newport, Cardiff, Milford Haven and along the coasts near Swansea and Port Talbot, are identifiable "hot spots". *E. coli* counts have been recorded for some specific sites along the estuary.

Pollutants of agricultural origin, such as pesticides and herbicides, enter the estuary in the river flows, but must also be contributed via atmospheric "fall-out", especially when crop-spraying is followed by rapid transport of particulate material during storms. Effluents from mines, tips and old smelting enterprises (e.g. in the lower Swansea valley) will also add to the pollutant load. Major accidents have led to oil and chemical spills both direct into the estuary and into the sewerage system. Warmed water is discharged from several Central Electricity Board power stations, (nuclear:— Berkeley, Oldbury, Hinkley Point) and coal-fired (Uskmouth). Large amounts of ash from coal-fired stations reach the estuary (e.g. Uskmouth). Stack discharges may also give variable levels of contamination, dependent on atmospheric conditions.

4.6.1. Fate of Pollutants—The opinion is held widely that pollutants in an estuary are carried out to sea on the outgoing tide. However, the complex hydrography of the estuary results in some areas of little net transport or dispersion. More important is the retarding effect caused by the adsorption by the muds and subsequent retention within the estuary for unknown periods. It is probable that pollutants are degraded more rapidly at one site than at another, and that incorporation into food chains differs from one site to another. Again, individual pollutants are known to vary greatly in their ease of degradation, though few studies have been made of the degradation of pollutants under environmental conditions.

4.6.2. Heavy Metals—Major industrial activity involving heavy metals both past and present, inevitably contaminates the environment. The Avonmouth complex and industries located near Swansea process large quantities of metalliferous ores and the effects of their discharges can be observed in both terrestrial and aquatic environments. Limited, but

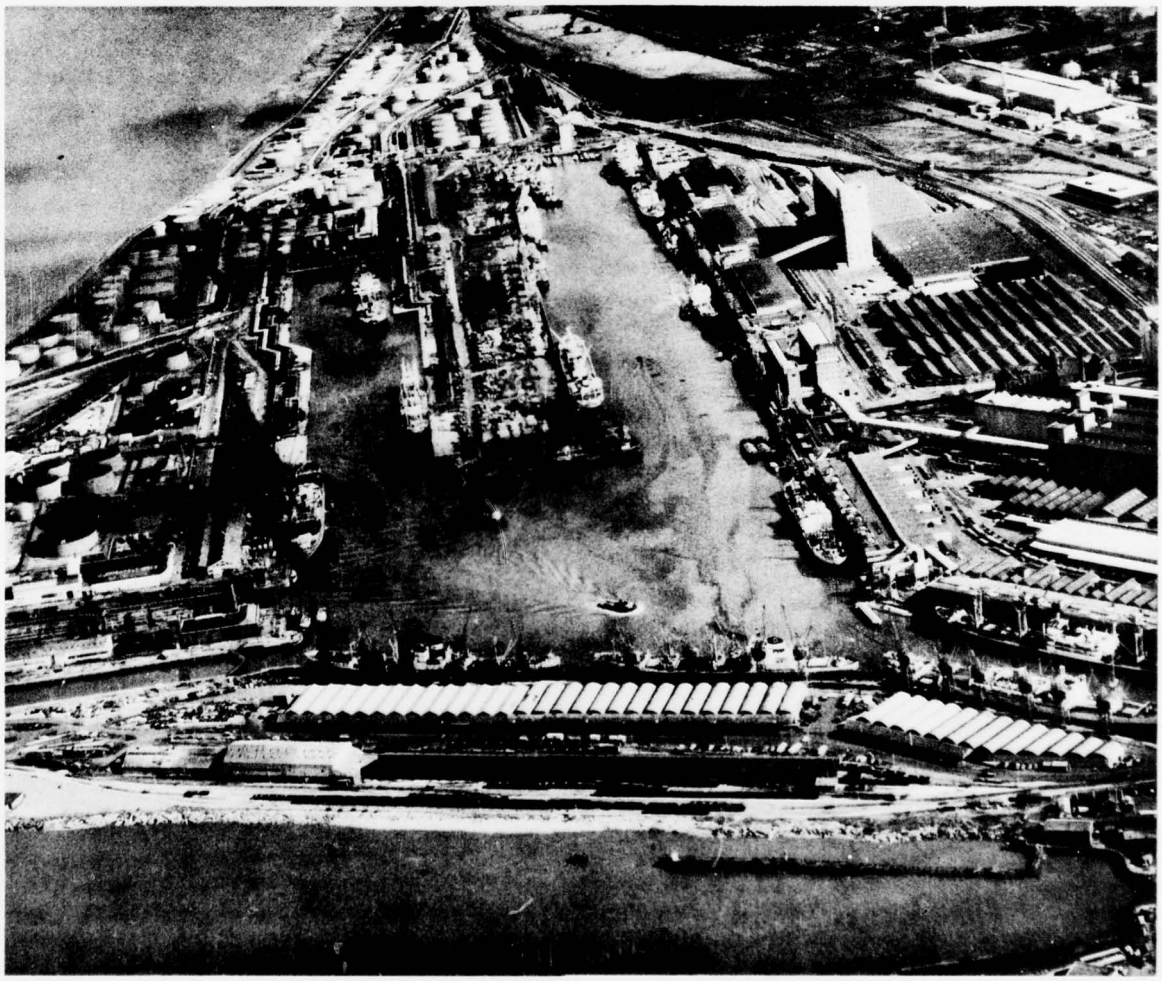
significant, data (Butterworth 1970) are available for concentrations of copper, cadmium, nickel, lead and zinc in water samples, in sediments and in selected organisms gathered from the English shore, taken from points extending from the Severn Bridge at Aust down to Hartland Point in Devon. The high values (e.g. 800 ppm dry weight Zn for *Fucus vesiculosis* at Severn Beach and 900 ppm Zn and 500 ppm Cd for *Patella vulgata* at Portishead) near Avonmouth fall off towards the rural coastline of the West.

Data for heavy metal concentrations in commercial fish and shell fish species taken within the estuary have been reported by the Ministry of Agriculture, Fisheries and Food (H.M.S.O., 1971 & 1972).

4.6.3. Pesticides and Herbicides—Some data are available for the concentration of chlorinated hydrocarbons (dieldrin, DDT) in water and mud of the River Severn but values are variable due to dramatic seasonal changes, for this river drains areas of intense agriculture and horticulture such as the orchards of Worcestershire and Herefordshire. At one point on the Severn, over one year the levels of dieldrin ranged from 73 to 4313 ng/l (parts per 10^{12}). Bristol University Agricultural and Horticultural Research Station at Long Ashton has long-term measurements on the throughput of DDT in an orchard in relation to levels in nearby stream, pond and river. Very few data are available for the estuary. Work is in progress at Bristol on the fate of DDT and other pesticides when deposited in the sediment; biodegradation is rapid although the metabolic products may also be toxic. Unfortunately, almost nothing is known of the microbiology of the estuary and its tributary rivers.

4.6.4. Oil—Over two million tons a year of petroleum products are carried in the estuary and oil spills have occurred. The slicks are difficult to track and deal with owing to the tidal streams, fast currents, mud flats, sand banks, etc.

Shipping and industry at Avonmouth (photo Airviews Ltd).



5. BIOLOGY

5.1. Plankton—5.1.1. Severn Estuary—The only published study is that of Rees (1939) in the estuary near Cardiff. He used one collecting station, but because of the movement of water up and down stream at various states of the tide, he effectively sampled from various regions of the water body a series of points along the channel. As is to be expected, the diatoms were almost entirely marine, and showed patterns of horizontal and seasonal distribution. The abundance of phytoplankton was low compared with that of the open sea, and this could have been caused by the opacity and turbulence of the water. Nutrients were not found to be limiting, and there was no evidence of a spring maximum as is usual in the sea.

5.1.2. Bristol Channel—Diatom counts and chlorophyll estimations (Moyse & Knight-Jones, 1966) suggested that the spring phytoplankton outburst is progressively later and smaller as one moves eastwards down the Bristol Channel. Incipient peaks appeared to be destroyed in windy weather. High turbidity must result in shallow compensation depths with production confined to the top few metres. Not surprisingly, minor spring peaks corresponded with calm weather. Some attention has been given to the plankton production of the Queen's Dock, Swansea, which is warmed by a power station effluent as well as being subject to oil spillages. The water off the Devon coast is much clearer, but conditions there are not well known.

5.1.3. Milford Haven—A regular series of plankton samples was taken in 1970 for comparison with a similar series taken in 1959/60 (Dias, 1961).

5.2. Fish and Fishery Data—5.2.1. Severn Estuary—Commercial fisheries here are long established, and mostly function as fixed-net fisheries, this method being facilitated by the extreme range of the tide. Records for these fisheries date back to the fifteenth century, and therefore pre-date all other biological records. The reports indicate that in recent times many fish have decreased in numbers, e.g. lampreys and herring. There are still profitable fisheries which take mainly sprats and salmon, although the catch of the latter is very variable.

Little is known of the details of fish movements within the Estuary, and the last analysis of the Weston fishery was made as long ago as 1941 (Lloyd, 1942).

5.2.2. Bristol Channel and Milford Haven—Records from the fishing ports of Swansea and Milford Haven provide the most extensive information. Besides these, the bionomics of flat fish populations in certain areas have been monitored in recent years (Ryland, in prep.), and the breeding population of herring in the upper reaches of Milford Haven has been the subject of a bionomic study (Nelson-Smith, 1964).

5.3. Sub-littoral Benthic Studies—The vast area of unconsolidated sediment in both the Bristol Channel and the Severn Estuary has been largely ignored by biologists because of the practical problems of sampling. University College, Swansea, has undertaken trawling and dredging studies but these have so far been confined to some special communities. Several autecological studies (see below) of individual invertebrates have entailed sampling over extensive areas. The shallow-water benthos of the Bristol Channel has also been studied in some sheltered areas by aqualung diving (Bailey *et al.*, 1967).

5.4. Intertidal Areas: Rocky Shores—These are the only environments to be investigated biologically in any detail.

5.4.1. Severn Estuary—General studies of the fauna and its distribution have been made (Bassindale 1941–1943). These accounts give a good picture of the factors correlated with the distribution of the fauna, i.e. mainly the salinity regimes and suspended silt. The fauna diminishes in variety of species from Ilfracombe, where it appears to be typically marine, to the reaches of the River Severn below Gloucester where no marine forms are found. Some species may be limited by the lack of appropriate food in the Estuary (Berry & Crothers, 1970). Over the last 30 years, student projects and some scattered observations have extended the information on species distribution along the southern shore, but this information is not available in any systematic way.

There is no information about the distribution of algae except for the observations made in primarily zoological investigations.

5.4.2. Bristol Channel and Milford Haven—Extensive general studies of the fauna of Milford Haven (Moyse & Nelson-Smith, 1963; Nelson-Smith, 1964, 1967) included quantitative recording of dominant shore animals and plants. Some shores have been re-surveyed more recently (Crapp, 1969, 1971) in connection with pollution studies.

Sea urchin, elephant hide sponge and dead man's fingers (photo Roger Swifen).

Cockle fishers on the Burry Inlet Cockle Fishery (photo MAAF, Lowestoft).

5.5. Intertidal Areas: Mud and Sand Shores—

5.5.1. Severn Estuary—Detailed studies of the extensive upstream mudflats of the Estuary are totally lacking, even though they occupy there the greatest fraction of the intertidal surfaces. Some brief investigations have been carried out, notably one by Haderlie & Clark (1959), that enabled the definition of marine, transitional and estuarine zones. This study also points out the importance of investigating the unconsolidated substrate in estuaries, simply because this occupies the greater part of such environments; rocky shores are to a great degree uncharacteristic here, and their fauna is therefore unreliable as an indicator of different zones. Detailed studies of the ecology of the mud-flats are lacking, except for one short preliminary examination, which highlights the importance of the 'micro-fauna' (Rees, 1940).

Even less is known about the benthic microflora. The only study refers to the Avon banks at Bristol (Round and Palmer, 1966).

5.5.2. Bristol Channel and Milford Haven—Further west the fauna of seventeen sandy shores of the north bank has been surveyed recently (Withers, in press) including that of some sublittoral sediments. A general survey of the meiofauna of intertidal sands in the Gower area has been made (see Hickman, in prep.).

5.6. Intertidal areas: Salt Marshes—The various stages of succession in a salt marsh which developed at Berrow between about 1910 and 1920 were followed, up to about 1942, by which time the marsh had considerably decreased in size. More recent work, as might be expected with the planting of many marshes with *Spartina,* and the subsequent spread of this species, has concentrated on studies of *Spartina* marsh (Ranwell, 1964). This work was carried out in Bridgwater Bay, and there appears to be no general survey of the marshes in the Channel and the Estuary, either describing their distribution or the composition of the flora.

There are surprisingly few papers dealing with zoological aspects of the large areas of salt marsh; one exception is that of Brough *et al.* (1960). A great deal of what was once 'general salt marsh' is now *Spartina* marsh, which appears to carry a sparse fauna.

Special attention has been directed to the susceptibility of salt marshes to oil damage (Baker, 1971).

5.7. Autecological Studies—A small selection of such studies of individual species appears in the bibliography. Certain taxonomic groups have been well-studied, but only in a few cases (e.g. Gee & Knight-Jones, 1961) do these studies seek to plot the detailed distribution of an animal over the whole area.

Observations by many zoologists have contributed to the revised Dale Fort Marine Fauna (Crothers, 1966), particularly from the upper reaches of Milford Haven and in certain specialist groups.

5.8. Pollution Studies—Studies on oil pollution have been concentrated in Milford Haven. Here the sensitivity of individual invertebrate species to oil and to emulsifiers has been examined (Nelson-Smith, 1968; Crapp, 1971). Attempts have been made to correlate changes in field populations of invertebrates with known oil pollution, both short-term and chronic.

The capacity of salt marshes to trap oil and to recover from the effects of both oil and emulsifiers has been investigated in detail (Baker, 1971).

The effects of domestic sewage have not been examined, but a limited study has been made of the effects of the effluent from an intensive dairying unit on a small rocky bay in South Pembrokeshire.

5.9.—Higher Vertebrates—There is an extensive literature about the birds of the whole area, and a few papers on the aquatic mammals, but it is beyond the scope of the present review to assess these adequately. Clearly predation by several carnivorous species must play a part in the population stability of lower forms, as in the case of oystercatcher predation on the cockle fishery of South Wales (Davidson, 1967).

6. GENERAL CONCLUSIONS

This assessment indicates that there is an inadequate knowledge of the estuary as a single natural system. Knowledge is insufficient either for the scientific understanding of the dynamics of the hydrosphere, the sediments and the biosphere of this estuary, or as a basis for planning economic expansion in the area in such a way as to reconcile its increased use with maintenance of the Estuary as a natural resource.

We have only an elementary understanding of the dynamics of a water body influenced by exceptional tides and currents, large fresh-water inflows, and high concentrations of suspended solids. Data on tides (especially away from the shore) on currents and on waves, are inadequate. As a result, the circulation, mixing and diffusion patterns taking place in the Estuary cannot be evaluated fully.

A large reservoir of mobile, sandy and muddy sediment is known to be present in the Estuary and similar material also occurs in the Bristol Channel. Quantitative information on the tidal excursion and settling sites of the sediments is required (a) to understand the mechanisms of channel and harbour siltation (b) for the investigation of pollution.

The need for adequate knowledge of the mineralogy, physics, chemistry and biology of the unconsolidated sediments is urgent because these sediments provide chemically unstable substrates which both adsorb and release pollutants and which are the sites of pollutant degradation and nutrient release prior to utilization by the phytoplankton.

Although the organisms of the Severn Estuary and Bristol Channel have been subjected to a good deal of autecological study, surprisingly few studies have been related to the overall estuarine ecosystem. A survey of the present distributions of the flora and fauna with quantitation of existing pollutant residue levels, would at least provide a base line for comparison of future changes.

The Severn Estuary and Bristol Channel are characterized by a wide range of environmental conditions. An integrated study of the water, the sediments and the organisms will lead to a fuller understanding of estuarine systems. Such a study should be carried out bearing in mind academic, governmental and commercial interests. A fuller understanding of this environment is vital for the conservation and intelligent exploitation of this important natural resource.

CONSOLIDATED BIBLIOGRAPHY OF REPORTS AND PUBLICATIONS

Abdullah, M. I., Royle, L. G. & Morris, A. W. 1972. Heavy metal concentrations in coastal waters. Nature, Lond., *235*, 158–160.

Allen, J. 1942. Scheme of improvement for the R. Parrett in Somerset; an investigation with the aid of a tidal model. J. Instn Civ. Engrs, *19*, 85–99.

Anderson, J. G. C., 1968. The concealed rock surface and overlying deposits of the Severn Valley and Estuary from Upton to Neath. Proc. S. Wales Inst. Engrs, *83*, 27–47.

————and Blundell, C. R. K. 1965. The sub drift rock surface and buried valleys of the Cardiff district. Proc. Geol. Ass., *76*, 367–377.

ApSimon, A. M., Donovan, D. T. and Taylor, H. 1961. The stratigraphy and archaeology of the late glacial and post glacial deposits at Brean Down, Somerset. Proc. speleol. Soc., *9*, 67–135.

Bailey, J. H., Nelson-Smith, A. and Knight-Jones, E. W. 1967. Some methods for transects across steep rocky channels. Underwater Ass. Report for 1966–67.

Baker, J. M. 1971. Studies on salt marsh communities; 16–18. In: The ecological effects of oil pollution on littoral communities. E. B. Cowell (ed.) Institute of Petroleum, London.

————**and Crapp, B. G.** 1971. Predictions and recommendations; pp. 217–220. In: The ecological effects of oil pollution on littoral communities. E.B. Cowell (ed.) Institute of Petroleum, London.

Banner, F. T., Brooks, M. and Williams, E. 1971. The geology of the approaches to Barry, Glamorgan. Proc. Geol. Ass. *82*, 231–48.

Bassindale, R. 1941. Studies on the biology of the Bristol Channel. IV. The invertebrate fauna of the southern shores of the Bristol Channel and Severn Estuary. Proc. Bristol Nat. Soc. Ser. 4, *9*, 143–201.

————1942a. Studies on the biology of the Bristol Channel. VIII. An account of collecting stations, and corrections to the fauna list. Proc. Bristol Nat. Soc., Ser. 4, *9*, 304–315.

————1942b. Studies on the biology of the Bristol Channel. VII. The distribution of amphipods in the Severn Estuary and Bristol Channel. J. Anim. Ecol., *11*, 131–144.

————1943a. Studies on the biology of the Bristol Channel. XII. A comparison of the varying salinity conditions of the Tees and Severn estuaries. J. Anim. Ecol. *12*, 1–10.

————1943b. Studies of the biology of the Bristol Channel. XI. The physical environment and intertidal fauna of the southern shore of the Bristol Channel and Severn Estuary. J. Ecol. *31*, 1–29.

————1943c. Studies on the biology of the Bristol Channel. XIII. The Intertidal fauna of Porlock Bay. Proc. Bristol Nat. Soc., Ser. 4, *9*, 386–399.

————1947. Zoological notes. *Elminius modestus* and *Craspedacusta sowerbii*. Proc. Bristol Nat. Soc. *27*, 223–4.

————1955. Fauna. In "Bristol and its Adjoining Counties", (ed. C. M. MacInnes and W. F. Whittard), Bristol: Br. Ass. Advtmt. Sci.

————1957. Local barnacles. Proc. Bristol Nat. Soc. *29*, 381–392.

Bays, L. R. 1969. Pesticide pollution and the effects on the biota of Chew Valley Lake. Proc. Soc. Wat. Treat. Exam., *18*, 295–326.

Beckinsale, R. P. and Richardson, L. 1964. Recent findings on the physical development of the lower Severn valley. Geogrl. J., *130*, 251–278.

Beechley, F. W. 1861. Remarks upon the tidal phenomena of the River Severn. London.

Begg, J. H. 1969. Bristol to achieve full sewage treatment. Munic. Engng, Lond., *141*, 687–698.

Berry, R. J. and Crothers, J. H. 1970. Genotypic stability and physiological tolerance in the dog-whelk (*Nucella lapillus*). J. Zool., *162*, 293–302.

Bielby, G. H. 1960. The biology of river pollution with reference to the Bristol Avon River Board. J. Proc. Inst. Sew. Purif., *59*, 298–306.

Boley, G. M. 1942. The vegetation of Berrow, North Somerset. 1. The salt-marsh community. Proc. Bristol Nat. Soc., Ser. 4, *9*, 427–433.

————1943. The vegetation of Berrow, North Somerset. 2. The sand dune succession. Proc. Bristol Nat. Soc., Ser. 4, *9*, 510–520.

Bolton, H. 1903. On the occurrence of a shell bearing gravel at Dunball Island. Proc. Bristol Nat. Soc., N.S., *10*, 241–244.

Boulenger, G. A. 1906. Zoology: Fishes. In: The Victoria History of the Counties of England. A History of Somerset, Vol. I, 54–56. (ed. W. Page).

Bowers, A. B. and Naylor, E. 1964. Occurrence of *Atherine boyeri* Risso in Britain. Nature, Lond., *202*, 318.

Bowers, E. A. 1969. *Cercaria bucephalopsis haimeana* (Lacaze-Duthiers, 1854). (Digenea: Bucephalidae) in the cockle, *Cardium edule* L. in South Wales. J. Nat. Hist. *3*, 409–422.

Bracher, R. 1929. The ecology of the Avon banks at Bristol. J. Ecol., *17*, 35–81.

Brooks, M. and Thompson, M. S. The geological interpretation of a gravity survey of the Bristol Channel. J. geol. Soc. Lond., (in press).

Brough, M. C., Delhanty, J. E. and Thompson, T. E. 1960. An ecological study of a brackish water pool on a saltmarsh at Lamby, near Cardiff. Trans. Cardiff Nat. Soc., *90*, 4–19.

Brown, W. R. 1880. The relative value of tidal and upland waters in maintaining rivers, estuaries and harbours. Minut. Proc. Instn. civ. Engrs, *66*, 1–85.

Burton, J. C. 1969. Desiccation and intertidal zonation in *Littorina* sp. Bios, *3*, 58–65.

Butterworth, J. S. 1970. The determination of heavy metals in the Severn Estuary. M.Sc. Thesis, No. 1884, Univ. Bristol.

Butterworth, J., Lester, P. and Nickless, G. 1972. Distribution of heavy metals in the Severn Estuary. Mar. Pollut. Bull., *3*, 72–74.

Carr, A. P. 1964. Coastal changes at Bridgwater Bay. Proc. Bristol Nat. Soc., *31,* 91–100.

Cartwright, D. P. 1966. Discharges to estuarine waters. J. Instn. munic. Engrs, *93,* 28–29.

Caseley, J. C. and Luckill, L. C. 1964. The effect of some residual herbicides on soil nitrifying bacteria. Rep. agric. hort. Res. Stn. Univ. Bristol, p 78.

Charbonnier, H. J. 1906. Zoology: Mammals. In: The Victoria History of the Counties of England. A History of Somerset, Vol. I. (ed. W. Page).

Codrington, T. 1989. On the submerged rock valleys in S. Wales, Devon and Cornwall. Q. Jl. geol. Soc. London., *54,* 251–278.

Cole, H. A. 1949. Swansea Bay-Mumbles area oyster fishery, and on the possibilities of reviving oyster culture in the River Cleddau, Pembrokeshire. Report of the South Wales Sea Fisheries District Committee. 1–14.

————1953. The possibilities of reviving oyster culture in Milford Haven. Report of the South Wales Sea Fisheries District Committee. 1–14.

————**and Baird, R. H.** 1953. The American slipper limpet (*Crepidula fornicata*) in Milford Haven. Nature, Lond., *172,* 687.

Cole, S. D. 1912. The sea walls of the Severn. Printed for private circulation.

Cooper, L. H. N. 1967. The physical oceanography of the Celtic Sea. Oceanogr. mar. Biol., *5,* 99–110.

Cowell, E. B. and Crothers, J. H. 1970. On the occurrence of multiple rows of 'teeth' in the dog-whelk, *Nucella lapillus* (L.). J. mar. biol. Ass. U.K., *50,* 1101–1111.

Crampton, C. B. 1959. Heavy minerals in certain old red sandstone and Silurian limestones of Monmouth. Nature, Lond., *183,* 485.

Crapp, G. B. 1969. Oil pollution in Milford Haven. Nature, Wales *2,* 131–137.

————1971. Zoological studies on shore communities; pp. 102–207. In: The ecological effects of oil pollution on littoral communities. E. C. Cowell (ed.) Institute of Petroleum, London.

————**and Whyte, D.** 1970. Oiled beaches successfully cleaned. Mar. Pollut. Bull., *1,* N.S., 77.

————, **Withers, R. G. and Sullivan, C. E.** 1971. Investigations on sandy and muddy shores; pp. 208–216. In: The ecological effects of oil pollution on littoral communities. E. B. Cowell (ed.) Institute of Petroleum, London.

Crisp, D. J. 1958. The spread of *Elminius modestus* Darwin in north-west Europe. J. mar. biol. Ass. U.K., *37,* 483–520.

————, **Bailey, J. H. and Knight-Jones, E. W.** 1967. The tube-worm *Spirorbis vitreus* and its distribution in Britain. J. mar. biol. Ass. U.K., *47,* 511–521.

Crisp, D. J. (ed.) 1964. The effects of the severe winter of 1962–63 on marine life in Britain. J. Anim. Ecol., *33,* 165–210.

Croll, B. T. et al. 1969. Organo-chlorine insecticides in water. Proc. Soc. Wat. Treat. Exam., *18,* 255–294.

Crothers, J. H. (ed.) 1966. Dale Fort Marine Fauna (second edition). Fld. Stud., *2,* Suppl.

Darbyshire, M. 1963. Wave measurements by the National Institute of Oceanography, pp. 285–291 in Ocean Wave Spectra, Prentice Hall, New Jersey.

Davidson, P. E. 1967. A study of the oystercatcher (*Haematopus ostralegus* L.) in relation to the fishery for cockles (*Cardium edule* L.) in the Burry Inlet, South Wales. Fishery Invest., Lond., Ser. 2, *25,* No. 7.

Davies, D. 1961. A study of the brackish and marine Copepoda of south and north Wales. Thesis, Zoology Dep., Univ. College, Cardiff.

Davis, H. H. and Tetley, G. 1943. Studies on the biology of the Bristol Channel XV. The Severn geese. Proc. Bristol Nat. Soc., Ser. 4, *9,* 494–509.

De Turville, C. M. and Jarman, R. T. 1965. The mixing of warm water from the Uskmouth power stations in the estuary of the River Usk. Air Wat. Pollut., *9,* 239–251.

Dias, N. S. 1961. Studies on the plankton of Milford Haven. M.Sc. Thesis, Univ. Wales.

Dillwyn, L. W. 1848. Materials for a fauna and flora of Swansea and the neighbourhood. Rees: Swansea.

Dobbie, C. H. 1955. Investigation of Monmouthshire moors. Report on drainage and sea defences. Welsh Agric. Land Sub-Commission, HMSO, London.

Donovan, D. T. 1961. Geology of the Bristol Channel. Proc. 4th Conf. Geol. Geomorph. S.W. England, Penzance. Roy. Geol. Soc., Cornwall, 17–18.

————, **Savage, R. J. G., Stride, A. H. and Stubbs, A. R.** 1961. Geology of the floor of the Bristol Channel. Nature, Lond., *189,* 51–52.

Draper, L. and Fricker, H. S. 1965. Waves off Land's End. J. Inst. Navig., *18,* p 2.

Dreghorn, W. 1967. Geology explained in the Severn Vale and Cotswolds. David and Charles, Newton Abbot.

Ellis, H. M. 1964. Treatment of polluted water and effluents. Effluent Wat. Treat. J., *4,* 284–286.

Ellis, T. S. 1909. Lower Severn Valley, River and Estuary from the Warwickshire border to the Bristol Avon. Proc. Cotteswold Nat. Fld. Club, *16,* 241–63.

Evans, D. J. The Quaternary geology of part of the northern Bristol Channel. Ma. Geol. (in press).

Evans, R. G. 1949. The intertidal ecology of rocky shores in south Pembrokeshire. J. Ecol., *37* 122–139.

Fret*er, V. and Graham, A. 1954. Observations on the ‹ pisthobranch mollusc *Actaeon tornatilis* (L.) J. mar. biol. Ass. U.K., *33,* 565–585.

Gee, J. M. 1963. On the taxonomy and distribution in south Wales of *Filograna, Hydroides* and *Mercierella* (Polychaeta, Serpulidae). Ann. Mag. Nat. Hist., Ser. 13, *6,* 705.

————**and Knight-Jones, E. W.** 1962. The morphology and larval behaviour of a new species of *Spirorbis* (Serpulidae). J. mar. biol. Ass. U.K., *42* 641–54.

Gibson, A. H. 1933. Construction and operation of a tidal model of the Severn Estuary. Severn Barrage Committee Report. Economic Advisory Council, HMSO, London.

Gosse, P. H. 1853. Rambles on the Devonshire coast. Van Voorst, London.

————1856. Tenby: a seaside holiday. Van Voorst, London.

Grace, S. F. 1936. Friction in the tidal currents of the Bristol Channel. Mon. Not. R. Astr. Soc. geophys. Suppl., *3,* 388–395.

Green, J. 1957. The growth of *Scrobicularia plana* (Da Costa) in the Gwendraeth Estuary. J. mar. biol. Ass. U.K., *36,* 41–7.

H.M.S.O. 1971. "Survey of Mercury in Food". Report of a working party on the Monitoring of Foodstuffs for Mercury and other Heavy Metals; first report.

H.M.S.O. 1972. "Survey of Lead in Food". Report of a working party on the Monitoring of Foodstuffs for Mercury and other Heavy Metals; second report.

Haderlie, E. C. and Clark, R. B. 1959. Studies on the biology of the Bristol Channel XIX. Notes on the intertidal fauna of some sandy and muddy beaches in the Bristol Channel and Severn Estuary. Proc. Bristol Nat. Soc., *29,* 459–468.

Ham, J. 1837. On the mud deposited by the tidal waters of the Severn, Usk and Avon. Rep. Br. Ass. Advmt Sci., 76–77.

Hancock, D. A. and Urquhart, A. E. 1966. The fishery for cockles (*Cardium edule* L.) in the Burry Inlet, S. Wales. Fishery Invest., Lond., Ser. 2, *25,* No. 3.

Hansard No. 842 Vol. *808* Dec. 1970, 1753–1772 (Severn Pollution Debate).

Harvey, C. E. 1968. Distribution and seasonal population changes of *Campecopea hirsuta* (Isopoda: Flabellifera). J. mar. biol. Ass. U.K., *48,* 761–767.

————1969. Breeding and distribution of *Sphaeroma* (Crustacea: Isopoda) in Britain. J. Anim. Ecol., *38,* 399–406.

Hawkins, A. B. 1962. The buried channel of the Bristol Avon. Geol. Mag., *99,* 369–374.

————1967. The geology of the Portbury area. Proc. Bristol Nat. Soc. *31,* 421–428.

————1969. Post-glacial sea level changes in the Bristol Channel (Abstract). Proc. Ussher Soc., *2,* 86–87.

————1971. New work on the Quaternary of the Severn estuary. Proc. geol. Soc., No. 1664, 303–4.

————1972. The late Weichselian and Flandrian transgression of S.W. Britain. Quaternaria (in press).

————1972. Sea level changes around S.W. England. Colston Papers (in press).

————**and Kellaway G. A.** 1971. Field meeting at Bristol and Bath. New evidence for glaciation. Proc. Geol. Ass. *82,* 267–292.

————**and Sebbage, M. J.** 1972. The reversal of sand waves in the Bristol Channel, England. Mar. Geol., *12,* M7–M9.

Heaps, N. S. 1967. Storm surges. Oceanogr. mar. Biol., *5,* 111–118.

————1968. Estimated effects of a barrage on tides in the Bristol Channel. Proc. Instn. civ. Engrs. *40,* 495–509.

Hickman, N. Studies on the meiobenthos of intertidal and sub-littoral sands around Gower (in preparation).

Holdich, D. M. 1968. Reproduction, growth and bionomics of *Dynamene bidentata* (Crustacea: Isopoda). J. Zool., *156,* 137–153.

Holmes, E. M. 1906. Botany: Marine algae. In: The Victoria History of the Counties of England. A History of Somerset. Vol. *1,* 54–56 (ed. W. Page).

Hope-Simpson, J. F. and Willis, A. J. 1955. Vegetation. In "Bristol and its Adjoining Counties", (ed. C. M. MacInnes and W. F. Whittard). Bristol: Brit. Ass. Advmnt Sci.

Horner, L. 1816. Sketch of the geology of the south western part of Somerset. Trans. geol. Soc., *3,* 339–394.

Howard, T. 1875. On the River Avon: its drainage area, tidal phenomena and dock works. Advmnt Sci., Bristol, 175–184.

Howells, W. R. 1964. The macrofauna of the intertidal soils of the Towy Estuary, Carmarthenshire. Ann. Mag. Nat. Hist., Ser. 13, *7,* 576–607.

Huxtable, D. N. 1971. The coelenterates of the Gower Peninsula. Bios, *5,* 62–72.

Hyde, H. A. 1936. On a peat bed at the East Moors, Cardiff. Trans. Cardiff Nat. Soc., *69,* 39–48.

James, B. L. 1968a. The distribution and keys of species in the family Littorinidae and of their digenean parasites in the region of Dale, Pembrokeshire. Fld Stud., *2,* 615–650.

————1968b. The characters and distribuiton of the subspecies and varieties of *Littorina saxatilis* (Olivi, 1792) in Britain. Cah. Biol. mar., *9,* 143–165.

James, D. G. 1971. Seismic refraction studies in parts of south Wales and the Bristol Channel. Ph.D. thesis, Univ. Wales.

Jarvis, J. and Wyer, D. 1969. Studies on the pycnogonid *Nymphon gracile* from Mumbles Head. Bios, 46–52.

Jones, D. A. 1970. Factors affecting the distribution of the intertidal isopods *Eurydice pulchra* Leach and *E. affinis* Hansen in Britain. J. Anim. Ecol. *39,* 455–472.

Jones, E. D. 1882. Description of a section across the River Severn based upon borings and excavations for Severn Tunnel. Proc. Geol. Ass., *7,* 339–351.

Jones, J. R. E. 1951. An ecological study of the River Towy. J. Anim. Ecol. *20,* 68–86.

Jones, M. B. 1970. The distribution of *Pariambus typicus* var. *inermis* Mayer (Amphipoda, Caprellidae) on the common starfish *Asterias rubens* L. Crustaceana, *19*, 89–93.

————**and Naylor, F.** 1971. Breeding and bio nomics of the British members of the *Jaera albifrons* group of species (Isopoda: Asellota). J. Zool., *165*, 183–199.

Jones, O. T. 1930. Some episodes in the geological history of the Bristol Channel region. Rep. Brit. Ass. Advmnt Sci., 57–82.

Kendall, O. D. 1936. The coast of Somerset, 1, Proc. Bristol Nat. Soc., Ser. 4, *8*, 186–208.

————1939. The coast of Somerset, 2, Proc. Bristol Nat. Soc., Ser. 4, *8*, 497–506.

Khan, M. A. 1970. On the morphology and biology of a new arhynchodine thigmotrichid ciliate (Protozoa) from the dog whelk *Nucella lapillus*. J. Zool., *161*, 39–47.

Kidson, C. 1960. The shingle complexes of Bridgwater Bay. Trans. Inst. Br. Geogr., *28*, 75–87.

————1963. The growth of sand and shingle spits across estuaries. Z. Geomorph. *7*, 1–22.

————1964. The physiographic evolution of the Severn estuary. 4th Int. Harbour Conf. Antwerp. 1–11.

————**and Carr, A. P.** 1961. Beach drift experiments at Bridgwater Bay, Somerset. Proc. Bristol Nat. Soc., *30*, 163–180.

King, P. E. 1970. Sea spiders in Glamorgan. Nature in Wales, *12*, 24–31.

————**and Jarvis, J. and Wyer, D.** 1972. Distribution and seasonal occurrence of littoral and sub-littoral pycnogonids in the Bristol Channel (in preparation).

————**and Osborn, A.** 1969. Oyster Dredging. Gower, *20*, 1–5.

————**and Stabins, V.** 1971. Aspects of the biology of a strand-living beetle, *Eurynebria complanata* (L.). J. nat. Hist., *5*, 17–28.

————**and Wyer, D.** 1972. Relationships between some British littoral and sub-littoral bryozoans and pycnogonids (in press).

————1972. Species of the pycnogonid genus *Endeis* occurring in British waters (in press).

Kulasing, P. 1969. Holocene tidal sediments at Ogmore, Glamorgan. Ph.D. thesis, Univ. Wales.

Lesse, C. E. and Vernon, W. F. 1960. Basal gravel in the alluvium near Severn Beach. Proc. Bristol Nat. Soc., *30*, 139–143.

Lennon, G. W. 1963a. The identification of weather conditions associated with the generation of major storm surges along the west coast of the British Isles. Q. Jl. R. met. Soc., *89*, 381–394.

————1963b. A frequency investigation of abnormally high tidal levels at certain west coast ports. Proc. Instn. civ. Engrs, *25*, 451–484.

Lester, P. 1970. Determination of zinc in selected marine organisms. M.Sc. thesis No. 1891, Univ. Bristol.

Lewis, S. 1936. Birds of the island of Steep Holm. Br. Birds, *30*, 219–223.

Llewellyn, L. C. 1965. Some aspects of the biology of the marine leech *Hemibdella soleae*. Proc. zool. Soc. Lond., *145*, 509–528.

Lloyd, A. J. 1938. Occurrence of burbot in the estuary of the River Severn. Nature, Lond., *142*, 1118.

————1941. Studies on the biology of the Bristol Channel. V. The marine fish fauna of the southern shores of the Bristol Channel. Proc. Bristol Nat. Soc., Ser. 4, *9*, 202–230.

————1942. Studies on the biology of the Bristol Channel. IX. A survey of the fishing industry at Weston-super-Mare during the winter of 1940–41. Proc. Bristol Nat. Soc. Ser. 4, *9*, 316–327.

————**and Yonge, C. M.** 1947. Studies on the biology of the Bristol Channel. XVII. The biology of *Crangon vulgaris* in the Bristol Channel and Severn Estuary. J. mar. biol. Ass. U.K., *26*, 626–661.

Lowton, R. J., Martin, J. H. and Talbot, J. W. 1966. Dilution, dispersion and sedimentation in some British estuaries, pp. 189–206. In: Disposal of Radioactive Wastes into Seas, Oceans and Surface Waters. IAEA Vienna.

Lunn, W. 1898. Report on the River Parrett floods prevention. Bridgwater.

————1912. Flood prevention and obstructions in the River. Bridgwater.

————1919. Flooding in districts: Report and estimates by Mr. Lunn for improvements in the River Parrett, Tone, Brue, Axe, King's Sedgemoor Drain and Carey River. Bridgwater.

Luxton, M. 1967. The ecology of saltmarsh Acarina. J. Anim. Ecol. *36*, 257–277.

Matthews, L. H. 1923. Notes on the fauna of the Bristol Channel. Proc. Bristol Nat. Soc., Ser. 4, *6*, 46–48.

————1934. The sea fish and fisheries of the Bristol district. Proc. Bristol Nat. Soc. Ser. 4, *7*, 442–462.

————1940. Studies on the biology of the Bristol Channel. VI. The marine mammals of the Bristol Channel. Proc. Bristol Nat. Soc., Ser. 4, *9*, 231–250.

————1942. Studies on the biology of the Bristol Channel. X. The catches of a Somerset fish weir. Proc. Bristol Nat. Soc., Ser. 4, *9*, 328–334.

————1943. Studies on the biology of the Bristol Channel. XIV. Elvers in the Severn. Proc. Bristol Nat. Soc., Ser. 4, *9*, 400–405.

Millichamp, R. I. & Staite, E. M. 1967. Salmon catches on the Rivers Usk and Wye. Ass. River Auths Yr Book, 1967, 112–116.

Milner, N. J. 1971. Studies on bass populations. Bios, *5*, 98–107.

Ministry of Housing. 1960. River Severn Basin hydrological survey.

Moore, H. C. 1892. The tidal wave in the Wye and Severn. Trans. Woolhope Nat. Fld. Club 1890–2, 316–324.

Morgan, C. L. 1887. The Severn Tunnel section. Proc. Bristol Nat. Soc., N.S., *5,* Engng Section, 82–94.

Morris, C. P. 1961. A study of some naked marine gastropod molluscs. Thesis, Zoology Dept., Univ. College, Cardiff.

Moyse, J. 1971. Settlement and growth pattern of the parasitic barnacle *Pyrgoma anglicum.* pp. 125–141. IVth European mar. Biol. Symp. D. J. Crisp (ed.) Cambridge Univ. Press, Cambridge.

————**and Knight-Jones, E. W.** 1966. Biology of Cirripede larvae. Symposium on Crustacea, Mar. biol. Ass. India, *2,* 595–611.

————**and Nelson-Smith, A.** 1963. Zonation of animals and plants on rocky shores around Dale, Pembrokeshire. Fld. Stud., *5,* 1–31.

————**and**————1964. Effects of the severe cold of 1962–63 upon shore animals in South Wales. In: The effects of the severe winter of 1962–63 on marine life in Britain. D. J. Crisp (ed.), J. Anim. Ecol. *33,* 165–210.

McLean, R. C. and Hyde, H. A. 1924. The vegetation of Steep Holm. J. Bot., Lond., *62,* 167–175.

Naylor, E. 1956. Biological effects of a heated effluent in docks at Swansea, S. Wales. Proc. zool. Soc. Lond., *144,* 253–268.

————1957. Introduction of a grapsoid crab, *Brachynotus sexdentatus* (Risso), into British waters. Nature, Lond., *180,* 616–617.

————1960. A North American xanthoid crab new to Britain. Nature, Lond., *187,* 256–257.

————1962. Seasonal changes in a population of *Carcinus maenas* (L.) in the littoral zone. J. Anim. Ecol., *31,* 601–609.

————1963. Tidal and seasonal migrations of the shore crab *Carcinus maenas* (L.). Rep. Proc. Challenger Soc. *3,* No. 15, 32.

————1965. Effects of heated effluents upon marine and estuarine organisms. Adv. mar. Biol. *3,* 63–103.

————1971. Zoology, pp. 101–118. In: "Swansea and its Region". Br. Ass. Advmnt Sci. Univ. College, Swansea.

————**and Haahtela, I.** 1966. Habitat preferences and interspersion of species within the superspecies *Jaera albifrons* Leach (Crustacea: Isopoda). J. Amin. Ecol. *35,* 209–216.

————**and Quenisset, D.** 1964. The habitat and life history of *Naesa bidentata* (Adams). Crustaceana, *7,* 3, 212–216.

Nelson-Smith, A. 1964. The herring of Milford Haven. Rep. Proc. Challenger Soc. *3,* No. 15, 26–27.

————1967a. Marine biology of Milford Haven. The distribution of littoral plants and animals. Fld. Stud., *2,* 407–434.

————1967b. Oil, emulsifiers and marine life. J. Devon Trust Nature Conserv., July, 29–23.

————1968a. The effects of oil pollution and emulsifier cleansing on shore life in south-west Britain. J. appl. Ecol. *5,* 97–107.

————1968b. A classified bibliography of oil pollution, pp. 165–196. In: The Biological Effects of Oil Pollution on Littoral Communities. J. D. Carthy and D. R. Arthur (eds.), Fld. Stud. *2,* Suppl.

————1968c. Biological consequences of oil pollution and shore cleansing. *Ibid.*

————1968d. Effects of oil and emulsifiers on shores in South-West Britain. Rep. Proc. Challenger Soc. *3, 20,* 60–61.

————1971. Ecology and the pollution of estuaries. Iron and Steel, *44,* 469–472.

————1972. Coastal pollution. Proc. Conf. environ, Res., Cardiff, Wales, 1970 (Nature Conservancy). (in press).

————**and Gee, J. M.** 1966. Serpulid tubeworms (Polychaeta, Serpulidae) around Dale, Pembrokeshire. Fld. Stud., *2,* 331–357.

North, F. J. 1915. On a boring for water at Roath, Cardiff. Trans. Cardiff Nat. Soc., *58,* 36–49.

————1955. Evolution of the Bristol Channel. Nat. Museum of Wales.

Orton, J. H. 1924. An account of investigations into the cause or causes of the unusual mortality among oysters in English oyster beds during 1920–21. Part 1. Fishery Invest., Lond., Invest. Ser. 2, *6,* No. 3.

Palmer, J. D. and Round, F. E. 1965. Persistent, vertical-migration rhythms in benthic microflora. I. The effect of light and temperature on the rhythmic behaviour of *Euglena obtusa.* J. mar. biol. Ass. U.K., *45,* 567–582.

Pearce, D. W. 1964. Plankton of an artificially heated dock. Rep. Proc. Challenger Soc. *3,* No. 16, 24–25.

————1967. Studies on the plankton of the Bristol Channel, M.Sc. thesis, Univ. Wales.

Pierce, T. J., Jarman, R. T. and de Turville, C. M. 1970. An experimental study of silt scouring. Proc. Instn. civ. Engrs, *45,* 231–243.

Preston, A., Jefferies, D. F., Dutton, J. W. R. Harvey, B. R. and Steele, A. K. 1972. British Isles coastal waters: concentrations of selected heavy metals in sea water suspended matter and biological indicators – a pilot survey. Environ. Pollut., *3,* 69–82.

Price, K. R. 1969. River surveys, with special reference to the River Severn. J. Proc. Inst. Sew. Purif., *68,* 425–433.

Priestley, J. H. 1911. The pelophilous formation of the left bank of the Severn Estuary. Proc. Bristol Nat. Soc., Ser. 4, *3,* 9–25.

Plummer, B. A. G. 1960. Investigation into human influences on marsh development in the Burry estuary. M.A. thesis, Univ. Wales, two volumes.

Purchon, R. D. 1937a. An ecological study of the royal beach, and dock, at Portishead. Thesis, Zoology Dept., Univ. Bristol.

————1937b. Studies on the biology of the Bristol Channel. II An ecological study of the beach

and the dock at Portishead. Proc. Bristol Nat. Soc., Ser. 4, *8*, 311–329.

————1947. Studies on the biology of the Bristol Channel. XVII The littoral and sub-littoral fauna of the northern shores, near Cardiff. Proc. Bristol Nat. Soc., *27*, 285–310.

————1957. Studies on the biology of the Bristol Channel. XVIII The marine fauna of five stations on the northern shores of the Bristol Channel and Severn estuary. Proc. Bristol Nat. Soc., *29*, 213–226.

Ranwell, D. S. 1961. *Spartina* saltmarshes of southern England. I. The effects of sheep grazing at the upper limits of *Spartina* marsh in Bridgwater Bay. J. Ecol., *49*, 325–340.

————1964a. *Spartina* saltmarshes of southern England. II. Rate and seasonal pattern of sediment accretion. J. Ecol., *52*, 79–94.

————1939. The plankton in the upper reaches of the Bristol Channel. J. mar. biol. Ass. U.K., *23*, 397–425.

————1940. A preliminary study of the ecology of a mud-flat. J. mar. biol. Ass. U.K., *24*, 185–199.

Richardson, C. 1887. The Severn Tunnel. Proc. Bristol Nat. Soc., N.S., *5*, Engng Section, 49–81.

Roper, I. M. 1919. Local coastal erosion and its cure. Proc. Bristol Nat. Soc., Ser. 4, *5*, 46–51.

————1921. Report on the Conditions of *Spartina Townsendii* below Clevedon, Somerset. Proc. Bristol Nat. Soc., Ser. 4, *5*, 131–132.

————1923. *Spartina Townsendii* in west Gloucestershire. Proc. Bristol Nat. Soc., Ser. 4, *6*, 49–50.

Rossiter, J. R. 1967. An analysis of the annual sea level variation in European waters. Geophys. J. R. Astr. Soc., *12*, 259–299.

Round, F. E. 1966. A new diatom species from the River Avon. J. mar. biol. Ass. U.K., *46*, 187–190.

————and Palmer, J. D. 1966. Persistent, vertical-migration rhythms in benthic microflora. II. Field and laboratory studies on diatoms from the banks of the River Avon. J. mar. biol. Ass. U.K., *46*, 191–214.

Rutter, F. W. E. 1961. Is there a health risk in sewage polluted beaches? Munic. Engng., *138*, 50.

Ryland, J. S. 1973. Statistical analysis of spatial distribution patterns. Proc. Second Int. Conf. Bryozoa, I.B.A. Durham.

————Preliminary investigation of the population structures of plaice, dabs, sole and skate in Carmarthen Bay (in preparation).

Sandison, E. E. 1967. Respiratory response to temperature and temperature tolerance of some intertidal gastropods. J. exp. mar. Bio. Ecol. *1*, 271–281.

Seddon, B. 1964. Submerged peat layers in the Severn Channel near Avonmouth. Proc. Bristol Nat. Soc., *31*, 101–106.

de Silva, P. H. D. H. and Knight-Jones, E. W. 1962. *Spirorbis corralinae* n. sp. and some other Spirorbinae (Serpulidae) common on British shores. J. mar. biol. Ass. U.K., *42*, 601–608.

Skempton, A. W. 1970. The consolidation of clays by gravitational compaction. Q. Jl. geol. Soc. Lond. *125*, 373–411.

Smaldon, G. 1972a. Population dynamics and breeding biology of *Pisidia longicornis* and *Porcellana platycheles* (in pres).

————1972b. New records for the distribution of *Pleyrocrypta porcellanae* Hesse 1876 from S. Wales and S. Devon (in press).

Smith, S. T. 1967. The ecology and life history of *Retusa obtusa* (Montagu) (Gastropoda, Opisthobranchia). Can. J. Zool., *45*, 397–405.

Sollas, W. J. 1883. The estuaries of the Severn and its tributaries. Q. Jl. geol. Soc. Lond., *49*, 611–626.

Southward, A. J. and Crisp, D. J. 1956. Fluctuations in the distributions and abundance of intertidal barnacles. J. mar. biol. Ass. U.K., *35*, 211–229.

Spooner, G. M. 1947. The distribution of *Gammarus* spp. in estuaries. I. J. mar. biol. Ass. U.K., *27*, 1–52.

Srivastava, L. P. 1966. The helminth parasites of the five-bearded rockling *Onos mustelus* (L.) from the shore at Mumbles Head, Swansea. Ann. Mag. nat. Hist. Ser. 13, *9*, 469.

Stebbing, A. R. D. 1971. The epizoic fauna of *Flustra foliacea* (Bryozoa). J. mar. biol. Ass. U.K., *51*, 283–300.

————1973. Colony overgrowth and spatial competition. Proc. Second Int. Conf. Bryozoa, I. B. A. Durham.

Stebbing, T. R. R. 1906. Zoology. Crustacea. In: The Victoria History of the Counties of England. A History of Somerset, Vol. I, 126–134. (Ed. W. Page).

Strahan, A. 1896. On submerged land surfaces at Barry, Glamorgan. Q. Jl. geol. Soc., Lond., *52*, 474–489.

Stringer, A. Lyons, C. H., Pickard, J. A. 1969. The fate of pesticides. Rep. agric. hort. Res. Stn. Univ. Bristol, p. 98.

————**and Pickard, J. A.** 1963. The DDT content of soil and earthworms in an apple orchard at Long Ashton. Rep. agric. hort. Res. Stn. Univ. Bristol, p. 127.

————1968. The Distribution of DDT in orchards. Rep. agric. hort. Res. Stn. Univ. Bristol, p. 80.

Swain, A. and Newman, O. F. 1957. Hydrographical survey of River Usk. Fishery Invest., Lond. Ser. 1, *6*, No. 1.

Taylor, G. I. 1921. Tides in the Bristol Channel. Proc. Camb. phil. Soc., math. phys. Sci., *20*, 320–325.

Taylor, J. N. 1953. Illustrated guide to the Severn fishery collection. Folk Museum, Gloucester.

Tetley, H. 1938. A survey of Steep Holm. V. Vertebrates. Proc. Bristol Nat. Soc., Ser. 4, *8*, 464–467.

Thomas, M. D. 1968. Gravity surveys around the mouth of the Severn. Thesis, Univ. Wales.

Thompson, H. S. 1922. Changes in the coast vegetation near Berrow, Somerset. J. Ecol., *10*, 53–61.

————1924. The flora of Stert Island. J. Bot., Lond., *62*, 1–7.

————1928. The vegetation of Berrow Flats, Somerset. Proc. Bristol Nat. Soc., *7*, 35–40.
————1930. Further changes in the coast vegetation near Berrow, Somerset. J. Ecol., *18*, 126–130.
Vernon, J. D. R. and Walsh, T. P. 1965. The common gull in the Severn Estuary in relation to feeding areas, roost sites and behaviour. Proc. Bristol Nat. Soc. *31*, 173–184.
Waller, R. S. and Shaw, T. L. 1970. Drainage and flooding in the Gloucester Region. Civ. Engng. publ. Wks. Rev., *65*, 368–369.
Walker, 1888. The Severn Tunnel. London.
Water Pollution Research Laboratory. 1972. Water quality in the Severn Estuary and recommendations for future investigations. W.P.R. Report, No. 1276.*
**Note: This report has not been prepared for unrestricted circulation but* bona fide *requests from interested persons, to the Director, WPRL, will be regarded sympathetically.*
Welch, F. B. A., *et al.* 1960. Geology of the country around Monmouth and Chepstow. Mem. geol. Surv. U.K.
Williams, G. J. 1968. The buried channel and superficial deposits of the lower Usk and their correlation with similar features in the lower Severn. Proc. Geol. Ass., *79*, 325–348.
Williams, I. C. 1965. The infection of the gulls *Larus argentatus* Pont., *L. fuscus* L., and *L. marinus* L. with Cestoda on the coast of Wales. Parasitology, *55*, 237–256.
Williams, M. 1960. The drainage of the Somerset Levels. Cambridge University Press.
Wills, L. J. 1938. The Pleistocene development of the Severn from Bridgnorth to the Sea. Q. Jl. geol. Soc., Lond. *94*, 161–242.
Withers, R. G. 1972. Aspects of the ecology and biology of marine sand dwelling macrobenthos. Ph.D. thesis, Univ. Wales.
————The diet of juvenile plaice, *Pleuronectes platessa* L. and other predators of sand dwelling macrobenthos in Oxwich Bay (South Wales). (in press).
Yonge, C. M. 1937. Studies on the biology of the Bristol Channel. I. General introduction. Proc. Bristol Nat. Soc. Ser. 4, *8*, 310–311.
————1959. On the structure, biology and systematic position of *Pharus legumen* (L.). J. mar. biol. Ass. U.K., *38*, 277–90.
————**and Lloyd, A. J.** 1939. Studies of the biology of the Bristol Channel. III. The shore fauna of Steep Holm. Proc. Bristol Nat. Soc., Ser. 4, *8*, 474–478.

Other documents dealing with the Severn Area

Annual Reports of Severn River Authority
Annual Reports of Wye River Authority
Annual Reports of Usk River Authority
Annual Reports of Bristol Avon River Authority
Annual Reports of Avon Dorset River Authority
Annual Reports of Glamorgan River Authority
Annual Reports of Somerset River Authority
Port of Bristol Authority
Sabrina Project Information Booklet, University of Bristol, May 1971.
Severnside – a feasibility study. Central Unit for Environmental Planning HMSO, 1971.