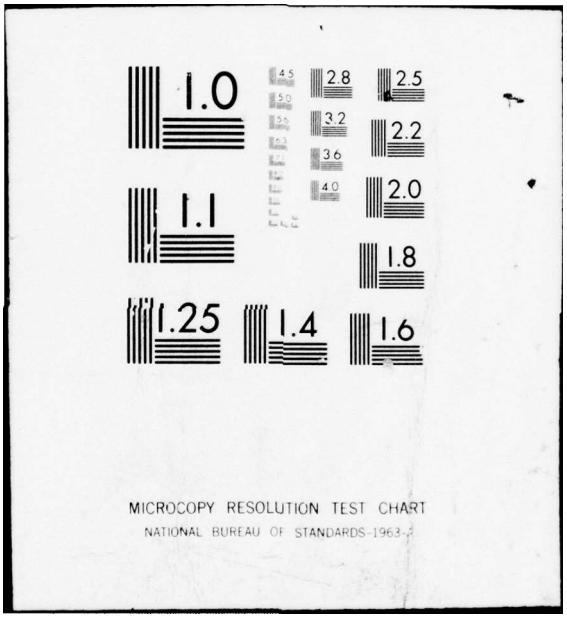
AD-A037 881 MINISTRY OF AGRICULTURE FISHERIES AND FOOD LOWESTOFT--ETC F/G 6/6
REPORT OF THE DIRECTOR OF MARINE FISHERY RESEARCH FOR THE YEARS--ETC(U)
FEB 73

UNCLASSIFIED NL

| OF |
AD
A037881

END

DATE
FILMED
4-77


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

ADA037881

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

(1)

REPORT OF THE DIRECTOR OF MARINE FISHERY RESEARCH

FOR THE YEARS 1969-1971

DDC
APR 7 1977
A

AU NO.
DDC FILE COPY

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

FISHERIES LABORATORY, LOWESTOFT, SUFFOLK

OFFICE OF NAVAL RESEARCH
LONDON
AUG 22 1974

REPORT OF THE

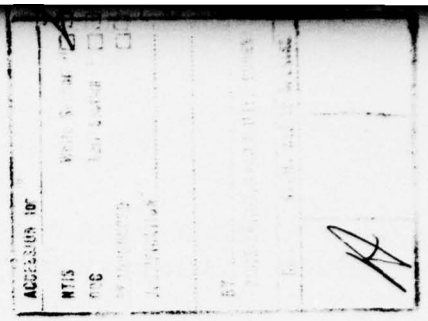
DIRECTOR OF FISHERY RESEARCH

1969-1971

DDC
APR 7 1977
A

FEBRUARY 1973

CONTENTS



	Page
INTRODUCTION	1
DEMERSAL FISHERIES	3
Distant-water resources	3
Near- and middle-water resources	4
Inshore resources	5
PELAGIC AND INDUSTRIAL FISHERIES	6
Stock monitoring	6
Industrial fisheries	6
Stocks to the south-west of Britain	7
Herring	8
SHELLFISH FISHERIES	10
Introduction	10
Lobsters	10
Crawfish	10
Crabs	11
Norway lobsters (Nephrops)	12
Shrimps	13
Cockles	15
Escallops and queens	16
Mussels	16
Oysters	17
GEAR RESEARCH AND FISH DETECTION	19
Gear research	19
Fish detection	21
FISH BIOLOGY	26
Blood types and biochemical variants applied to the definition of cod stock units	26
The causes of variability in recruitment to fish stocks	27
Offshore studies of the larval phase	27
Inshore surveys of nursery grounds	28
Marine production	28

Page

FISH BEHAVIOUR AND PHYSIOLOGY 29
Environmental factors and fishing 29
Migration of fish 29
The efficiency of the Granton otter trawl 30
Bait- and line-caught fish 30
The pineal eye and light 31
Fish muscle types and their use 32

MARINE FISH CULTIVATION 33
Introduction 33
Research at Lowestoft 33
Research at Port Erin 36

SHELLFISH CULTIVATION 39
Introduction 39
Molluscs 39
Prawns 40

MARINE POLLUTION 42
Monitoring of fish and shellfish 42
Toxicity testing 43
Dumping 43
Oil pollution 43
Investigations into specific proposals related to fisheries 46
Hydrographic aspects of marine pollution 46
Basic work 47

RADIOBIOLOGY 48
Introduction 48
Radiological control - inspection and monitoring 48
Radioecology 49
Radiobiology 51

HYDROGRAPHY 53
Near waters circulation 53
Dispersal of marine organisms 53
Sand and gravel extraction 55
The hydrography of the north-east Atlantic 55
The effects of climatic change on fisheries 57
Upwelling off north-west Africa 57

Page

COMPUTING AND STATISTICAL SERVICES 58
Demersal and pelagic fisheries 58
Biology 59
Hydrography 59
Gear research and fish detection 59
Radiobiology 59

PUBLICATIONS 60

PRINCIPAL RESPONSIBILITIES AND RESEARCH INTERESTS OF SENIOR MEMBERS OF THE SCIENTIFIC STAFF (1 FEBRUARY 1973) 75

INTRODUCTION

This Report provides a summary of the main lines of research pursued during the years 1969, 1970 and 1971 at the Laboratories at Lowestoft, Burnham-on-Crouch, Conway and Port Erin which make up the Directorate of Fishery Research of the Ministry of Agriculture, Fisheries and Food. It does not include the work done by the Ministry on salmon and freshwater fisheries, which forms the subject of a separate report.

The rather detailed form of presentation adopted in 1966, 1967 and 1968, which enabled the Reports for these years to be used as an account of progress in particular scientific investigations, has been abandoned in favour of a shorter, more plainly worded account designed to show the main lines of investigation being followed and their purpose, but giving only a very brief general indication of the results achieved. To obtain more detailed information, reference should be made firstly to the published scientific papers listed towards the end of the Report and secondly to the Director or appropriate Section Head at the Laboratory concerned.

A certain amount of domestic detail formerly included in the Reports, e.g. particulars of improved facilities or equipment available, has also been omitted; but a list of senior staff members, with a note of their particular interests and responsibilities, is included.

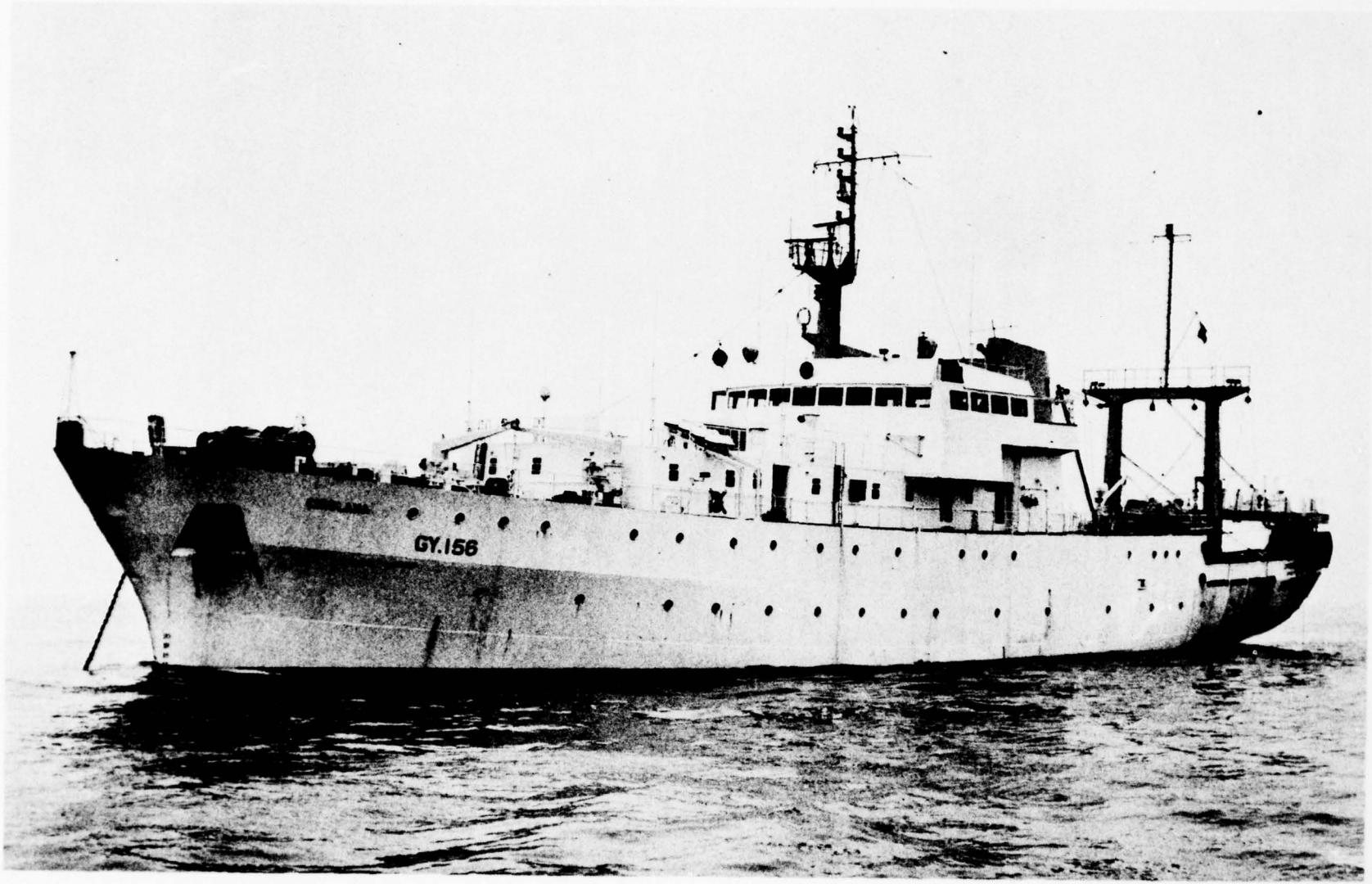


Figure 1 RV CIROLANA, the Ministry's new distant-water research vessel, which came into service in 1970.

DEMERSAL FISHERIES

The Demersal Fish Populations Section at Lowestoft (Head of Section - D. J. Garrod) monitors the status of all demersal (bottom-living) finfish resources of actual or potential value to the fishing industry in England and Wales, in order to provide advice to the Ministry on biological aspects of fisheries problems which may arise internally or with other countries. These activities relate to a total international production of some 8 million tonnes of demersal fish, with priority coverage of thirty major resources in seven areas of the north Atlantic, and an awareness of fishery trends on a global scale. The field is classified by sectors recognized by the fishing industry, viz.: Distant Water (long range), Near and Middle Water (medium range), and Inshore. The programme within each sector has two aspects, research on the ecology and factors underlying the changing abundance of fish stocks, and, arising from this, monitoring of the resources based upon information collected by the Inspectorate (Fisheries Division II) and aboard research vessels. The monitoring programme is fundamental to advice given to the Ministry at the national level, and internationally to the North-East Atlantic Fisheries Commission (NEAFC) and the International Commission for the Northwest Atlantic Fisheries (ICNAF) through their scientific advisory channels. The programme therefore contains a substantial element of international cooperative research. Relevant developments are also communicated to the fishing industry, for example in the annual publication 'Fishing Prospects' or by specially prepared Laboratory Leaflets, or simply by direct discussion with the vessel owners' associations, the processors, etc.

Distant-water resources

The Section makes a substantial contribution annually to detailed international reviews, on behalf of NEAFC and ICNAF, of all the major Arctic cod and haddock resources. This is effected mainly through the North-east Arctic Fisheries Working Group (covering the Barents Sea, Bear Island and Norway Coast fisheries), the North-west Fisheries Working Group (Iceland and Faroe), both sponsored by the International Council for the Exploration of the Sea (ICES), and the Assessment Sub-Committee of the ICNAF Standing Committee on Research and Statistics (this covers north-west Atlantic resources). The conclusions of these scientific working groups continue to serve as guidelines for current international discussions of regulation of the various fisheries and associated problems.

The monitoring programme also involves support work at sea in internationally coordinated research vessel surveys of the abundance of young-of-the-year fingerlings, to estimate forthcoming supplies of young fish in each area. These annual surveys are now established in the north-east Arctic (with the USSR and Norway) and at Iceland and Faroe (with Iceland, Germany and Norway). Further coordinated groundfish surveys are being developed in the north-west Atlantic under the auspices of ICNAF with participation by Canada and the USA. Each of these surveys is underpinned by research on appropriate methodology, electronic apparatus and automatic data processing routines.

Supporting research projects to which attention has been given in 1969-71 include:

(i) development to an operational level of simulation techniques for the assessment of complex fishery resources and the evaluation of management strategies with respect to the resources;

(ii) completion of a review of the selectivity characteristics of trawl cod-end materials (ICES/ICNAF Selectivity Working Group);

(iii) contributions to understanding of the relationship between size of spawning stocks and the number of young fish they can provide (ICES/ICNAF/FAO Symposium on Stock and Recruitment);

(iv) assessment of the plaice fishery at Iceland;

(v) preliminary quantitative estimates of the migration of cod from Greenland to Iceland;

(vi) analysis of the distribution and migration of coalfish at Iceland (in collaboration with an Icelandic scientist);

(vii) synopsis of the biology of haddock (for publication by FAO);

(viii) ad hoc appraisals of resources in south Atlantic and north-west African waters, in the Antarctic and at New Zealand, and to provide a base line for consideration of possible future redeployment of United Kingdom fishing vessels.

Near- and middle-water resources

Research designed to provide advice on the management of resources in this Sector is important in its own right, and the possibility that development in the control and management of Distant-Water fisheries may have repercussions in the Near- and Middle-Water Sectors has increased its urgency. Moreover, such studies can make an important contribution to the development of sound policies within the European Economic Community (EEC) and will be essential if the Law of the Sea Conference redefines the extent of territorial seas and exclusive fishing limits.

Projects receiving attention during the period 1969-71 include:

(i) a review of the biological basis of North Sea cod, plaice and sole resources, under the auspices of the appropriate ICES Working Groups;

(ii) national assessments and estimates of potential catches from sole resources in the Bristol Channel and Irish Sea which have been subject to increased exploitation in 1970 and 1971 by beam trawlers from other countries; supporting research has also been carried out on the mode of action of beam trawls (see section of report dealing with gear research);

(iii) an evaluation of the dab population in the southern North Sea and its role as a competitor with plaice; dabs are of little value for human consumption but they are fished to a small extent for reduction to fish meal;

(iv) a statistical analysis of the cause of year-to-year fluctuations in the success of cod-breeding in the North Sea; in recent years there have been some remarkably strong year-classes.

The last item will be integrated with an internationally coordinated young-fish survey scheduled for feasibility trials in 1972. This will follow the methods developed in Distant-Water areas and will have the same general purpose, i.e. to provide estimates of prospective catches of different species.

Research on the major resources is continuing in its second phase to define them in terms of component sub-stocks that contribute to the fisheries of different nations. The results will then be integrated in a multi-stock model of the North Sea fish production to investigate the implications of different management strategies that may arise through EEC or otherwise, for example the effect on English plaice fisheries of redeployment of Netherlands beam trawlers from sole to plaice. The broad programme of research aimed at defining and monitoring the potential harvest (quota) from each stock is being extended to westerly sea areas as research resources permit. Work is currently in progress on Irish Sea cod and whiting and Atlantic hake, the last-named in cooperation with France under the general auspices of ICES.

Inshore resources

Research into the potential production of inshore waters is being developed in anticipation of its increasing importance if there is any retrenchment in home-caught production as a result of regulations or resource problems limiting supplies from Distant Waters. The programme will also review inshore resources in relation to EEC policy on national fishery limits. Studies have been completed on the biology and population dynamics of major species exploited by inshore fleets off the south Devon and Cornish coasts. Comparable studies of the fisheries for dogfish, skates and rays are also complete or being prepared for publication.

The programme is now being extended to the north-east coast and East Anglia to determine the relative importance of different species, their nursery areas, migrations and distribution of the fishery in relation to the different belts of the exclusive fishery limit zone. Successful development of this programme depends very much on the Inspectorate being able to provide adequately detailed statistical information for inshore fishing activities.

PELAGIC AND INDUSTRIAL FISHERIES

The Pelagic Fish Populations Section of the Lowestoft laboratory (Head of Section - A. C. Burd) deals with 'pelagic' fish species (i.e. those which are primarily adapted to life in midwater) and 'industrial' fisheries, in which the catch is processed into fish-meal. The latter are often dependent upon pelagic species. Those which are currently the subject of research projects are herring, sprat, pilchard, mackerel, horse mackerel and sandeels.

Stock monitoring

This is a continuing project designed to provide up-to-date information on the state of pelagic or industrial fish stocks exploited by United Kingdom fishermen. Such information forms the basis upon which new or revised conservation measures can be formulated at national or international level. In addition, this project provides data for research into the dynamics of fish populations, using mathematical models.

Samples of fish from all major pelagic and industrial fisheries are collected at the ports and sent to the Lowestoft laboratory for analysis. At the laboratory, up to 12 separate characters (e.g. length, age, fecundity, fat content) may be measured, depending upon the species. With all species, however, the primary aim is to determine the age composition of the sample, and this, together with statistics (such as the total catch and the time spent fishing) collected from the vessels, provides information on, amongst other things, the mortality caused by fishing and the future prospects of the fishery. Such information is reported annually at international level in the ICES publication 'Annales Biologiques' and also at home in the Ministry's publication 'Fishing Prospects'.

Industrial fisheries

In the past, only comparatively small amounts of fish have been caught by United Kingdom vessels specifically for processing into fish-meal. In the last 3 or 4 years, however, some sections of the fishing industry have shown greater interest in this type of fishing, and industrial fisheries based on sprats and sandeels caught off the English east coast are now firmly established.

The main work on sandeels during the past 3 years has been a laboratory study of behaviour, designed to investigate their low availability in the fishery at night and also during the winter. Among the many interesting results from this work, it was found that there is a threshold light intensity below which the fish remain buried in the sand. Once this is reached, the fish will emerge, provided that the temperature is high enough. A full understanding of such questions would facilitate extension of the fishery and an increase in its efficiency. In 1969, observations were made on board an English vessel skippered by a Danish sandeel expert during a series of experimental sandeel voyages (Figure 2). The results, published as a Laboratory Leaflet, helped to create a favourable climate for the establishment of the fishery which followed in 1970.

Figure 2 A good haul of sandeels, taken during experimental fishing in the North Sea in May 1969.

Investigations into the great fluctuations in abundance in the sprat fisheries in the Thames, the Wash and off North Shields have continued. An analysis of 10 years' data from the Wash fishery from its start in 1959 (prompted by the results of a survey made by a Ministry research vessel in 1958) has been completed and published. It was found that the annual loss-rate averaged about 70 per cent, but that the fishery had no measurable effect on the stock. A large part of the loss-rate must therefore be due to natural factors such as emigration and predation.

Stocks to the south-west of Britain

Work has continued on the stocks of pelagic fish wintering in the western English Channel. These are particularly abundant, though lightly exploited. The species involved are mackerel, horse mackerel, pilchard and sprat. The principal aim of the work is to assess their fishery potential by means of stock-size estimates. This requires a knowledge of the egg production of the stock and the fecundity (number of eggs per female), and to this end two plankton egg surveys have been completed and a start made on the determination of fecundity in the horse mackerel. Other investigations on horse mackerel have suggested that there is a discrete stock, separate from a westerly stock,

which winters off the Eddystone and spawns during the summer in the southern North Sea. During exploratory fishing in January 1969, one of our research vessels achieved catch-rates of up to 8 tonnes per hour off the Eddystone.

Tagging of mackerel has continued and past results have been analysed and published. These results, together with other studies, suggest that there are two main stocks in the area. One stock overwinters off the Eddystone and spawns in the southern North Sea in summer (cf. horse mackerel), and the other spawns in the Celtic Sea in spring before dispersing to the north and east.

The seasonal fat cycle of sprats taken in the Tor Bay fishery has been examined in some detail. By this means it has been possible to distinguish two populations of sprat in this fishery. Catching normally begins in September and the fat levels decline as the season progresses. A sudden increase in catch-rate in January 1970 was associated with the influx of a new population having high fat levels and lower growth rates.

A project designed to investigate the environmental factors affecting the distribution of pelagic fish shoals in the Eddystone area has been started (January 1972).

Herring

During the past 3 years the main emphasis has continued to be placed on the achievement through ICES of international scientific agreement on the need for, and methods to be used in achieving, conservation of the North Sea herring stocks. To a great degree these analyses have depended upon the long series of catch, effort and biological data collected by the traditional North Sea herring fishing nations - the United Kingdom, Netherlands, Germany and Denmark. Though the catches of the first three countries now amount to less than 20 per cent of the total North Sea catch the dependence on their data for stock assessments has not decreased, because inadequate statistics are provided by the main catchers - Norway, Sweden and Denmark.

It has been established that the maximum sustainable yield from the North Sea is of the order of 700 000 tonnes. This level was exceeded in all years from 1963 to 1968. Subsequently catches have declined to around 500 000 tonnes, with no decrease in total fishing effort.

With the acceptance of the need for North Sea herring conservation by the North-East Atlantic Fisheries Commission, a system of closed periods for fishing was introduced as an interim measure in 1971. Similar regulations have been adopted for 1972 and 1973. Appraisal of the effects of any such regulations will depend upon the continuity of present data and the development of stock size assessments independent of catch per effort data.

A successful management programme would be expected to result in increased recruitment to the three main North Sea stocks. Recruitment has been monitored by young herring surveys in English coastal waters, and by internationally coordinated larval and young herring surveys. The results so far obtained appear to give usable forecasts of recruitment of 3-year-old fish to the adult stocks. It is expected that an expansion in this type of work will take place with the increased need for recruitment forecasting in a scientifically managed fishery.

Two new techniques aimed at stock identification have been developed. It appears that the numbers of white fibres in the musculature of herring can be used to separate Banks, Downs and Buchan and some longshore herring stocks. This character may be genetically determined.

As a second method of attack on this long-standing problem, the variation in fecundity between North Sea herring populations has been re-examined. A technique has been developed which distinguishes clearly between Banks and Downs stocks, the Bank herring being about twice as fecund as the Downs. As a character for identification of Bank and Downs fish, in a mixed catch, fecundity is of limited value, because it is weight-related and because comparisons need to be made with fish in exactly the same maturity stage. However, Bank and Downs fish differ considerably in length for age and this character has been combined with fecundity to obtain a fecundity index. The fecundity index is fecundity/length cubed. There is little or no overlapping within an age group between the respective distributions of this index for Bank and Downs herring. The character has been successfully used to estimate the relative strengths of recruiting Bank and Downs herring in the mixed catches of the North Shields fishery.

SHELLFISH FISHERIES

Introduction

The principal aim of the shellfish research programme is to provide scientific advice to the Ministry and to the Sea Fisheries Committees for the purpose of regulating the fisheries in such a way as to maximize the yield and give efficient conservation. Effects of changing patterns of exploitation and abundance are investigated and promising new methods of catching and cultivation are studied with the aim of improving efficiency. Predators, pests and diseases are investigated and control measures devised. The work is divided between the Fisheries Laboratory, Burnham-on-Crouch (Officer in Charge - P. C. Wood) and the Fisheries Experiment Station, Conway (Officer in Charge - Dr P. R. Walne).

Lobsters

Field studies have been made to elucidate the important aspects of pot design. Lobster pots with eyes ranging from $3\frac{1}{2}$ to 6 inches (8.9 to 15.2 cm) in diameter were fished in the Menai Straits to study the effect of eye size on pot efficiency. A pot of $4\frac{1}{2}$ inch (11.4 cm) eye diameter was the most efficient in this area. The experiments showed that pots may be very selective and suggested that the size distribution of pot-caught lobsters may not be representative of the population as a whole. This is important in studying changes in lobster fisheries and suggests that catch measurements alone may not be an adequate indicator of the state of the stocks.

Lobsters caught in the Menai Straits were marked and released to study growth rates; 31 recaptures showed that adult lobsters add a constant increment at each moult, as has been noted elsewhere. Lobsters in the Menai Straits added slightly larger increments than have been observed off Yorkshire and Cornwall.

In cooperation with the Natural Environment Research Council (NERC) Institute of Marine Biochemistry (Aberdeen), trials are being conducted on captive lobsters to study the effectiveness and basic characteristics of various baits. So far plaice, squid and mackerel appear to be equally attractive, whereas an extract of squid is less effective. This research into the important chemical qualities of lobster bait will be continued.

Captive lobsters have been marked in various ways to try to find an effective persistent tag for field studies. A Canadian 'sphyrion' tag is very promising; there have been 18 moults of lobsters with this tag with no loss of tags, no adverse effects on growth and no mortality. Heat branding was not satisfactory because the marks soon became indistinct, and an arrow tag tested was easily lost. The development of a design of persistent tag is of fundamental importance to studies of the population dynamics of lobsters and will continue.

Crawfish

Work on crawfish has been directed mainly to an investigation of allegations that the stock is in danger of overfishing because of the activities of divers.

Samples of crawfish measured from the Cornish fishery show that only large specimens are caught. Females generally range from 100 to 160 mm

carapace length, and males from 120 to 190 mm carapace length. In recent years there have been no marked changes in the size ranges, or in the average size of crawfish caught. A watch for size changes in the population which might be the results of exploitation will be maintained.

Crawfish marked with two types of tag have been released off Cornwall: firstly, a plastic disc (wired to the base of the antenna) which is lost at moulting, and, secondly, a plastic arrow (inserted between the joints of the tail) which is retained when the crawfish moults. The arrow tag can be used to study growth. With the exception of one tagging experiment off St. Ives, only about 10 per cent or less of the tags have been returned within a year of release. The low rate of tag return suggests that fishing is taking only a small proportion of the stock. In the St. Ives experiment mentioned over 20 per cent of the tags were returned, suggesting much heavier fishing. However, a subsequent experiment in that area is giving a much lower rate of tag return and suggests that the 20 per cent return was atypical. Further tagging experiments will not be undertaken unless the landings indicate that a change in the population has occurred.

A number of arrow-tagged crawfish have been returned after moulting. Most of these show increases in carapace length of only 0-3 mm. Nine crawfish returned after more than a year at liberty showed an average increment of less than 2 mm carapace length. These observations indicate that off Cornwall crawfish are very slow-growing.

It has been reported that very small crawfish occur deep in rock crevices off the west coast of Ireland. However, an extensive search, by a team of divers, of similar grounds in Cornwall in 1971 produced none; the location of young crawfish from which the Cornish stock is replenished therefore remains a mystery.

Crabs

South-west coast

Crab landings from this area now represent some 40 per cent of the total catch from England and Wales, and expansion in exploitation has led to fears that this population may become overfished. Therefore, in 1967, a study was begun to determine whether the existing minimum size regulations gave the best possible sustained yield. To make this assessment, considerable background knowledge is required, including details of the landings, the effects of fishing, natural mortality, and the growth and migrations of crabs in the area. Knowledge of general biology and behaviour is also important.

Information on the size of the crabs taken in the commercial fishery has been collected during monthly visits to the area, when scientific staff accompanied fishing vessels to sea. At the same time, the main periods of shell casting have been determined; it has been found that the moulting period extends from April to October and is not so well-defined as on the east coast, where moulting mainly occurs between July and September.

To obtain information on the growth and migrations, a series of tagging experiments, first commenced in 1968, has been completed. By the end of 1971, some 9 460 tagged crabs had been released in the south-west of England; all were marked with a special suture-tag, developed by the laboratory, which is not lost when the hard shell is cast at moulting. By the end of 1971, a total of 1 547

(16 per cent) tagged crabs had been recaptured and 224 (14 per cent) of these had moulted during their period of freedom. These recaptures showed how much crabs grow at each moult and also their migratory movements. From these and other observations, it is possible to make an estimate of the annual growth of each sex. On average, after one moult, a male crab having a shell width of $4\frac{1}{2}$ inches (11.4 cm) (the minimum size which can be landed) will reach $5\frac{3}{4}$ inches (14.6 cm), while a female crab will reach a size of $5\frac{1}{2}$ inches (14.0 cm). It is likely that, in Devon, crabs of both sexes which have shell widths of about $3\frac{1}{2}$ inches (8.9 cm) will reach the minimum legal size of $4\frac{1}{2}$ inches after a single moult. In general, migrations have been relatively limited, most crabs being recaptured within 10 miles (16 km) of their positions of release. However, some movements have occurred between the main crab-fishing areas of Devon and Cornwall, migrations of up to 70 miles (113 km) being recorded. The study has not yet been completed, but at the end of 1972 it is hoped that firm recommendations can be made for the efficient exploitation of these stocks.

East coast

The crab landings from the east coast of England between north Norfolk and the Border represent some 50 per cent of the landings in England and Wales. Between 1960 and 1967 a detailed investigation of these stocks was made to determine the level of exploitation. Recommendations were made that the existing minimum size limit of $4\frac{1}{2}$ inches shell width should be retained. During recent years, crab landings from this area have declined but this is mainly due to a lack of markets and a changeover to other more profitable fishing activities. However, a monitoring survey of these crab fisheries has been maintained by regular visits to the main ports in Norfolk, Yorkshire and Northumberland. The aim has been to assess whether or not there is any evidence of overexploitation. Samples of the landed catches have been measured, and information has been obtained on changing abundance on the various grounds in the form of catch-per-unit of effort data which relates the weight of crabs landed at the various ports to the number of traps fished. From these data the state of the stocks over a period can be assessed, since catch-per-unit of effort remains unaffected by day-to-day changes in the number of boats fishing. This investigation will be continued, but at the present time there is no evidence of overexploitation.

Norway lobsters (Nephrops)

The general study of the stocks of Nephrops off Northumberland has been continued. This fishery, based mainly on North Shields, lands some 50 per cent of the English catch. In recent years, some concern has been expressed within the fishing industry over the steady decline in catch rates and the increase in the proportion of small prawns being landed from the area. It was thought that these might be due either to a natural fluctuation in the size of the stock or to the result of fishing beyond the level that the stock could sustain.

Measurements of the landed catches show that, during the last few years, the proportion of small prawns in the landings at North Shields has increased. This is believed to be partly due to a change in the fishing pattern. In recent years, fishing has been concentrated in the early part of the season, when small Nephrops are normally most abundant, so accounting for the apparent reduction in size. A large proportion of these 'smalls' is rejected at sea but tests have

shown that if they are returned to the sea within $1\frac{1}{2}$ hours of being caught at least half will have a chance to survive. Therefore, at the present time further conservation measures do not appear to be justified. The general monitoring of this fishery will, however, be continued for a further two years.

Another important Nephrops fishery is found in the Irish Sea. A problem here concerns the use of small-meshed nets and the consequent capture of large numbers of undersized whiting. Trials are being made with a specially designed trawl having a double cod-end which releases undersized whiting, while still retaining commercial-sized whiting in the upper cod-end and Nephrops in the lower cod-end. Preliminary trials have been promising, and further development of this gear is planned during 1972.

Shrimps

Stocks of the pink shrimp (Pandalus montagui) around the English coast have declined drastically during the last decade and now only the Wash supports a viable fishery. Even in this area, landings are subject to large fluctuations. During the last five years, investigations have helped us to understand more about the biology of the pink shrimp, particularly the seasonal distribution, migrations and feeding patterns. Fluctuations in catches are now believed to be related to changes in the shrimps' behaviour rather than in abundance. It has been found that at certain times of the year the quantity of oil stored in the body increases and shrimps then spend a considerable period of the day in midwater. Here they are not caught by the usual methods of bottom trawling. The landings of shrimps could therefore be substantially increased if these stocks could be fished, and experiments are now going ahead to develop suitable midwater fishing gear.

This active research programme on pink shrimps has encouraged Wash fishermen to modernize their fishing and handling equipment. A demonstration of ship-borne oil-fired boilers (Figure 3), designed to replace the coal fires used to cook shrimps, resulted in their adoption by most of the King's Lynn vessels.

The population of deep-water shrimps (Pandalus borealis) in the Farne Deeps, Northumberland, has been surveyed annually. Six exploratory cruises have collected considerable data on the distribution, abundance and biology of this species. However, despite promising catch rates, this stock has not yet been much exploited by British vessels, although a small Danish and German fleet has trawled regularly on these grounds.

Like the pink shrimp, the main commercial fisheries for the brown shrimp (Crangon crangon) in the Wash, the Thames Estuary and Morecambe Bay are subject to wide annual fluctuations. Samples of shrimps from these areas have therefore been examined to study size composition and population structure and to determine the breeding cycle. During 1970, catches of brown shrimps declined in many coastal areas of north-west Europe, including Morecambe Bay, where a severe shortage of shrimps caused concern for the future of this important fishery. At that time, suggestions were made that poor landings might be associated with pollution, but catches began to improve in September 1971 and, by the end of that year, stocks were adequate for local needs. As a result of the investigation, it appears that the decline in this fishery, which mainly depends upon a single year-class, was due to poor recruitment in 1970. The reasons for this variation will be studied over a two-year period.

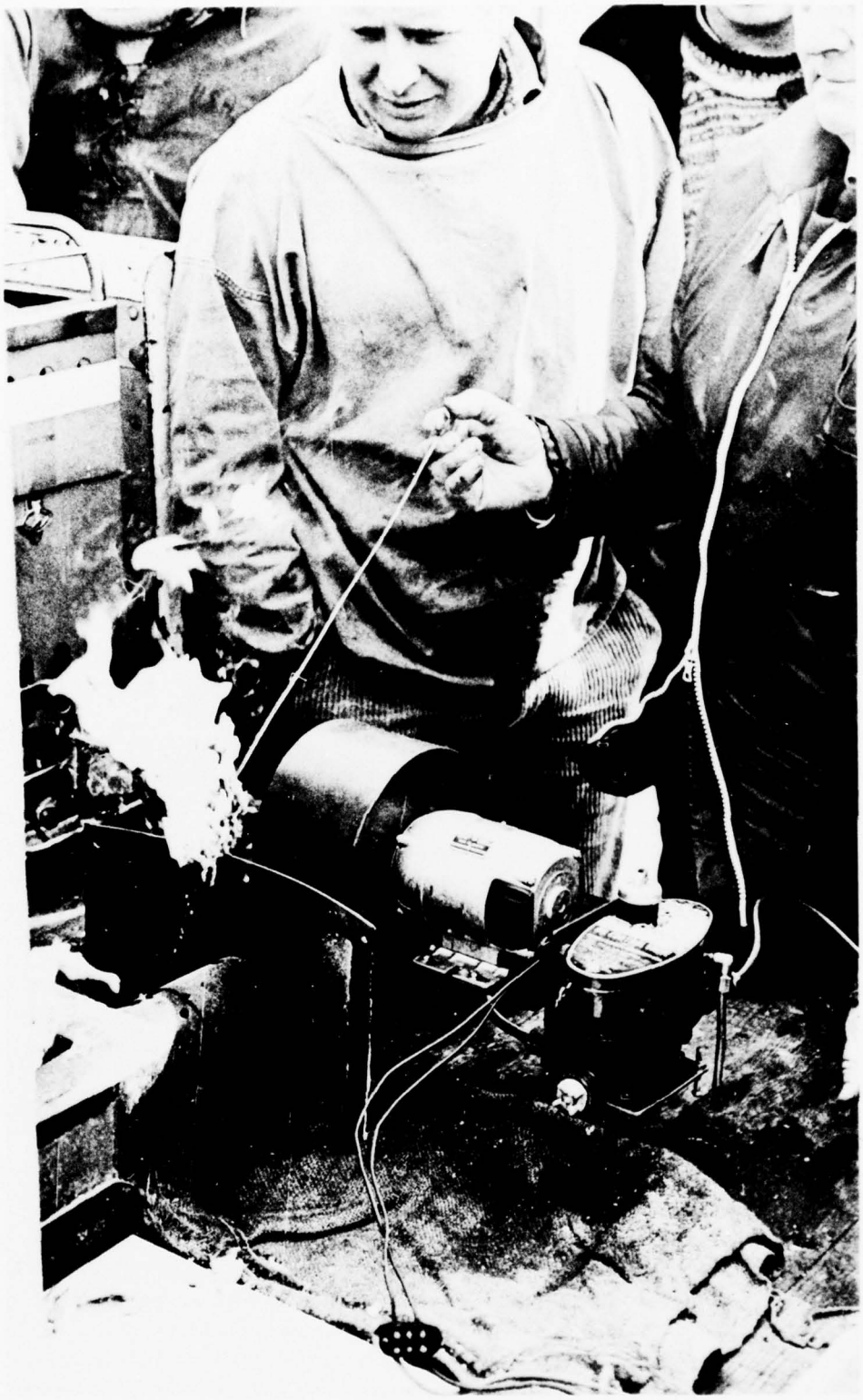


Figure 3 The adoption of these oil-fired boilers by the King's Lynn fleet has halved the cost of cooking shrimps.

Cockles

The success of the fisheries in the three main cockle-producing areas - the Wash, the Thames Estuary and the Burry Inlet (South Wales) - is dependent upon good year-classes. During the last three years, regular monitoring surveys have been made to assess the chief causes of these fluctuations, and to seek ways of promoting a steady annual yield. To achieve this objective, it has been necessary to assess the numbers of spat produced each year, their growth rate until they become large enough to be fished, and the extent and causes of natural mortality. All this is done by regular surveys of the cockle grounds and the analysis of large numbers of samples.

The main factors affecting yield were found to be variations in the initial strength and survival of each year-class. In 1969, high landings of cockles from the Burry Inlet followed a good settlement of spat in 1967. Poor landings in 1970 and 1971 were caused by the low level of spatfall in 1968 and heavy predation by oystercatchers. From the detailed study of the feeding habits of these birds, it has been found that oystercatchers take more cockles than are fished. A method of controlling these birds by cannon-netting has been developed but cannot be used because of objections by local ornithologists.

A study of the cooked meat yields from cockles taken from South Wales showed that these were greatest in the late summer and early autumn, and reached their lowest in January and February. Recommendations have been made to the fishermen on the best ways of taking advantage of these changes.

In the Thames Estuary the introduction of the continuous-lift hydraulic dredge developed by the White Fish Authority (WFA) has revolutionized the fishery. All traditional hand-gatherers have now turned to the dredge, and catches per boat have remained constant despite the extremely low density of the stocks. Total landings from this area have now risen due to the enlargement of the fleet and the exploitation of sublittoral stocks not previously harvested. Initial examinations showed that a large percentage of small cockles rejected by the dredge were damaged and fears were expressed about the long-term effects of dredging on the fishery. Detailed studies have shown that although this method of fishing is every efficient, it can also result in a high mortality of spat which become disturbed and washed out of the substrate if the grounds are continually worked. However, quantitative assessments show that the combined damage caused by dredging is still small when compared with that due to natural causes.

In 1970, an unexploited stock of over 10 000 tonnes of cockles was discovered on the Buxey Sands in the Thames Estuary. Studies during 1971 indicated that these stocks were subjected to a natural mortality of at least 50 per cent caused by overcrowding. Even by the end of 1971 these extensive cockle stocks remained unfished, but efforts to encourage the industry to utilize them have paid off and several vessels worked hydraulic dredges in the area in early 1972.

With a view to regulating the Wash fishery, cockle stocks in the area have been examined at regular intervals and the distribution of the stocks has been monitored. However, the unstable nature of the area and the high mortality of the young cockles makes long-term predictions difficult. Routine monitoring surveys of these stocks will, however, be continued in the future so that recruitment can be assessed.

Escallops and queens

As a result of new markets, mainly in the USA, important fisheries for queen scallops (Chlamys opercularis) have recently developed in the Clyde and off the Isle of Man. Stocks around the English and Welsh coasts have yet to be fully exploited and exploratory dredge surveys were therefore made off Whitby and Scarborough, around the Wash and off the Humber Estuary. However, poor catches were made using the traditional gear, although trawlers have reported some good hauls from particular areas of the east coast, suggesting that substantial stocks are available.

Tests of a specially designed queen dredge, using underwater observations, showed that the efficiency of this dredge was about 50 per cent, with many queens escaping the gear by swimming out of its path.

Surveys were made of the escallop stocks in the English Channel. One area in the eastern part was located where sufficient numbers of escallops were available for commercial fishing. Vessels from Newhaven have since exploited this stock with promising results. At the western end of the Channel an escallop stock off Plymouth was studied and growth rates established. Despite adequate stocks this bed is only lightly exploited, mainly because of poor demand for the size of escallop available.

Mussels

The main work, a four-year ecological study of settlement and productivity of seed beds in Morecambe Bay, was concluded in 1971. Since 1970 increasing effort has been devoted to utilization of these large resources for restocking, or initiating, fisheries elsewhere.

An annual seed crop cycle occurs on the stony Roosebeck grounds, near Barrow-in-Furness, where heavy winter and spring spatfall, and rapid development of settlements, culminates in almost total destruction by autumn storms. Up to 12 000 tonnes of 20 mm seed are available on the main (250 acre, approximately 100 hectare) bed for dredging and relaying from July to September.

A feasibility study began in 1970 into ways of utilizing Morecambe Bay mussel spatfall directly by gathering on collectors to set-up floating cultures in distant, more sheltered, waters. Spat can be caught in abundance during January-May on coir rope and fibrous, rubberized, matting placed on, or just above, the settling grounds. It should be possible to extend the catching season into July.

Viable hanging cultures resulted from ropes spatted before May and hung from a raft in the Menai Straits (Figure 4). Some transported populations attained 44-48 mm mean length, and gross yields of 17-19 kg per metre, within 9 months. The biological potential of this approach is apparent, but economic systems for spat capture and culture remain to be developed.

Surveys and condition examinations were made of mussel stocks in the Wash, and at Conway, Caernarvon and Bangor.

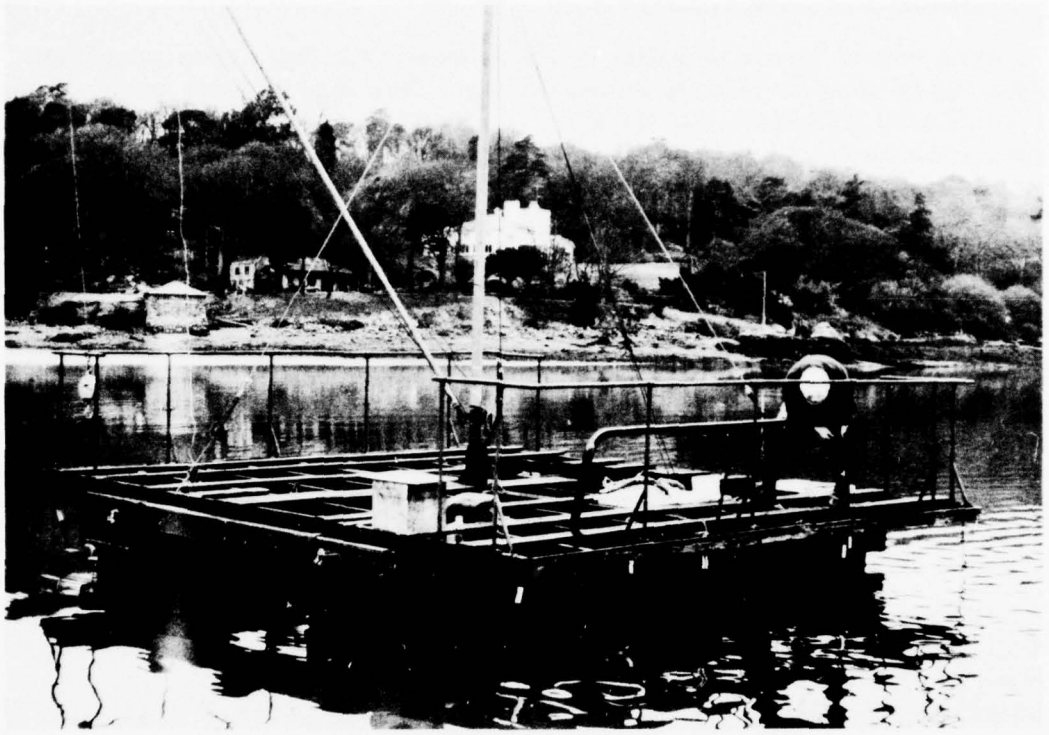


Figure 4 Mussel culture raft moored at Menai Bridge

Oysters

The weak state of the industry at the present time is mainly due to the continuing shortage of seed oysters. During the last three years research has been directed towards methods of using new sources of seed and means of improving natural settlement. With increasing demands for importation of seed of exotic species considerable attention has been directed to the risks of introducing new diseases, pests and predators.

Natural settlement

The River Fal in Cornwall is an important source of seed oysters for many English oyster beds. Work has been done to determine how natural spatfalls may be improved but, unfortunately, during the period of these investigations spatfalls have been generally low. Preliminary observations suggest that although production of larvae is often good, their subsequent growth and survival has been negligible; these problems are now being further examined. Along the east coast observations have been made in several important oyster-producing estuaries to monitor the production of young seed. During recent years production has been too low to replenish local stocks, and supplies of seed have had to be brought in from other areas.

Cultivation of small oysters

Experiments have been undertaken to determine whether oyster seed from Norway can be used for relaying in this country. This seed is small and fragile and is imported still attached to the twigs on which it settles. Special techniques are therefore required to handle them, and the trials showed that high mortality often occurred. This factor, and the high cost of handling, makes it unlikely that the British industry would use this type of seed for replenishing depleted oyster grounds.

The availability of large numbers of Japanese oysters (Crassostrea gigas) from British hatcheries has made it necessary to develop techniques for growing them in trays. Spat laid in trays at different tidal heights in the River Roach (Essex) and at Anglesey (North Wales) showed a positive correlation between the tidal level and time immersed and shell growth. There was however little difference between the meat yields of spat immersed for 90 and 100 per cent of the time.

Control of movement of shellfish

The Molluscan Shellfish (Control of Deposit) Order 1965 restricts the introduction from abroad and movements within Britain of shellfish which carry a risk of pests, predators and diseases. In 1968 the Order was extended to include the importation of oysters from France, following heavy losses there of Portuguese oysters due to 'gill disease'. Later, although oysters showing gill disease symptoms were found in Britain, the prohibition was maintained, because of the introduction into France of the Japanese oyster, and possible associated pests from Japan.

During the last few years there has been a substantial increase in the movements of molluscs, both within England and Wales and from abroad. Considerable effort has been involved in redefining the various problems concerning the spread of pests and diseases and, as a result, revised legislation will soon be introduced which will give more efficient control.

GEAR RESEARCH AND FISH DETECTION

Gear research

The small group engaged in gear research at Lowestoft (Head of Unit - A. R. Margetts) has been concerned in recent years with three main tasks: (1) the investigation of the effects of trawls on the sea bed, especially those fitted with heavy chains (the alleged damage by beam trawls fitted with multiple tickler chains is being considered by the North-East Atlantic Fisheries Commission), (2) the reaction of fish to a pelagic trawl, and (3) the development and testing of a hypothesis to account for the capture of fish by, and their escape from, a bottom trawl.

(1) Effect of trawls on the sea bed

Following complaints by fishermen about alleged damage to fishing grounds by trawling with heavy 'tickler chains' (chains across the mouth of the trawl to disturb flatfish in advance of the net as it is dragged along), in 1970 direct observations were made by Scuba divers on the effect of an inshore otter trawl. This was observed and photographed in action on fairly smooth sandy ground and on ground strewn with small boulders. It was used both with and without tickler chains. The track of the trawl was identifiable and the tickler chains and other chains were seen to dislodge some partially-embedded boulders and to roll them over once or twice (Figure 5).

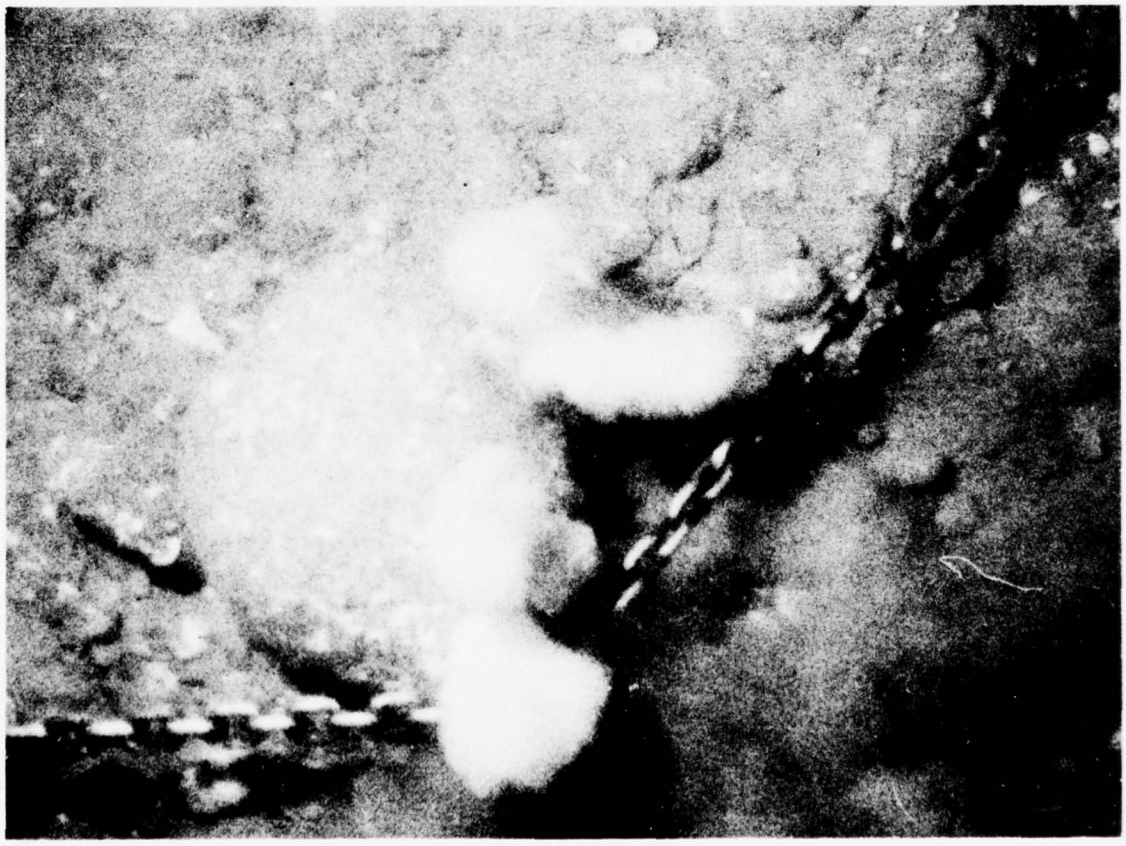


Figure 5 Otter trawl tickler chain in contact with a boulder.

In 1971 the investigation was extended to the study of the effect of a deep-sea beam trawl with four tickler chains; here attention was paid necessarily to the tracks made by the trawl. Divers' observations and photographs were supplemented by pictures from underwater television. Different degrees of bottom disturbance and different types of trawl tracks were noted on a variety of seabed types ranging from mud through sandy-mud to coarse sand and shell. The effects of an otter trawl and a beam trawl were essentially rather similar when both were fitted with tickler chains. In 1972 experiments are planned to observe the effects of a beam trawl with a large number of tickler chains and to measure the depth of bottom penetration by chains. Since this project was commenced, ICES has passed a recommendation stressing the need for such investigations and the reporting of results as a matter of urgency.

(2) The reaction of fish to a pelagic trawl

Fish in the path of a pelagic trawl have the opportunity of moving upwards, downwards, sideways or in front of it in order to escape rather than be caught; they may also be scared away by the trawler itself. Single-ship pelagic trawls have net mouth openings about 60 feet (18 m) square and the distance between otter-boards and net is commonly 200 feet (61 m). Consideration of these facts together led to the adoption of acoustic apparatus for observing what fish did in the vicinity of a pelagic trawl. A multi-transducer apparatus attached to the trawl has provided, in effect, an array of echo sounders facing in many directions, and records from these, correlated with echo sounder and sonar records from the towing ship, have enabled shoal movements relative to the trawl to be followed or deduced. Lively Shetland summer herring swam away from the trawl; spawning North Sea herring and Cornish pilchards have been seen to descend beneath a trawl and some have been caught. The installation in RV CLIONE of the sector-scanning sonar developed by the Admiralty Research Laboratory (the ARL Scanner) enabled fish and parts of a pelagic trawl to be viewed together directly in 1970. At the time suitable shoals of herring were not available but shoals of small fish, probably sprats, were seen to take evasive action at the approach of the trawl near the surface in daylight by rising above the headline as it came to within a few metres distance from them.

(3) The capture of fish by bottom trawls

Based on the results of lengthy comparative fishing experiments, a hypothesis had been developed earlier which attempted to explain bottom-trawl catch differences in terms of differences between the spreads of otter-boards and trawl net, the distances that the otter-boards were ahead of the net, the speed of movement of the trawl and the swimming speed of the fish. For testing this hypothesis, measurement of actual efficiencies of trawls by means of special acoustic apparatus is preferred to the necessarily lengthy and costly techniques of comparative fishing. Fish-counting apparatus, by means of which numbers of fish between the trawl otter-boards and between the net wing-ends may be compared, is being developed. The ARL Scanner can distinguish the main features of a trawl on the bottom. A first attempt to observe fish reactions to different parts of the gear and to relate these to whether or not the fish were caught was foiled by bad weather, but subsequently acoustic-tagged fish have been watched by the Scanner as they have been trawled for with another ship.

Fundamental to any gear investigation is the measurement of the fishing shapes of gear. In 1969, trawl-mounted instruments were used to measure the horizontal spread of a bottom otter trawl and how this changed with different rigs of tickler chains. Instruments were also used to measure the horizontal and vertical openings of pelagic trawls towed at various speeds. In 1970 and 1971 the fishing shapes and dimensions of a Granton bottom trawl, a single-boat pelagic trawl and purse seines were recorded by use of the ARL Scanner. This programme will be continued to include other gears and a wider variety of fishing conditions, thus providing a background catalogue of basic information about gear in action.

Other basic work is being done by giving assistance to a British Standards Institution technical committee; tests are being made so that appropriate loadings of mesh gauge springs may be ascribed to particular types of mesh, and a survey is being made of terminology of fishing gear prior to the drafting by the British Standards Institution of proposals for international use.

Fish detection

Although research and development work on fish detection at the Lowestoft laboratory is spear-headed by Instrumentation and Electronics Section (Head of Section - R. B. Mitson) the application of the techniques and instruments devised is a matter for the fish population specialists concerned with demersal and pelagic fisheries or the biologists investigating fish behaviour in relation either to fishing gear or to changes in environmental conditions. The following notes describe a few of the more important developments which have occurred during the period 1969-71.

ARL Scanner

We are greatly indebted to the Admiralty Research Laboratory for allowing us to fit this sonar in RV CLIONE in order to carry out work in fisheries research. We have done a substantial amount of development work. This included an entirely new stabilization system eliminating the effects of pitch, roll and yaw.

The sonar transmitter floodlights a volume of sea, 30^{o} in one plane by 10^{o} in the other, by transmitting an acoustic pulse which lasts 100 μs, two or four times per second. This gives a range resolution of 7.5 cm and maximum ranges of 366 and 183 m respectively. A receiver beam is swept over the same volume 10 000 times per second with a resolution of 0.33^{o}. With this beam sweeping in the horizontal plane, a plan position display is obtained of targets in midwater or of features on the sea bed. The mode of operation can be changed so that the beam scans in the vertical instead of in the horizontal plane. In this case the depth of a target can be obtained as well as a profile of the sea bed (Figure 6).

This equipment has been used for observing fishing gear, fish shoals and features on the sea bottom. Midwater herring trawls and bottom trawls of the type used by most British deep-sea trawlers have been observed in operation.

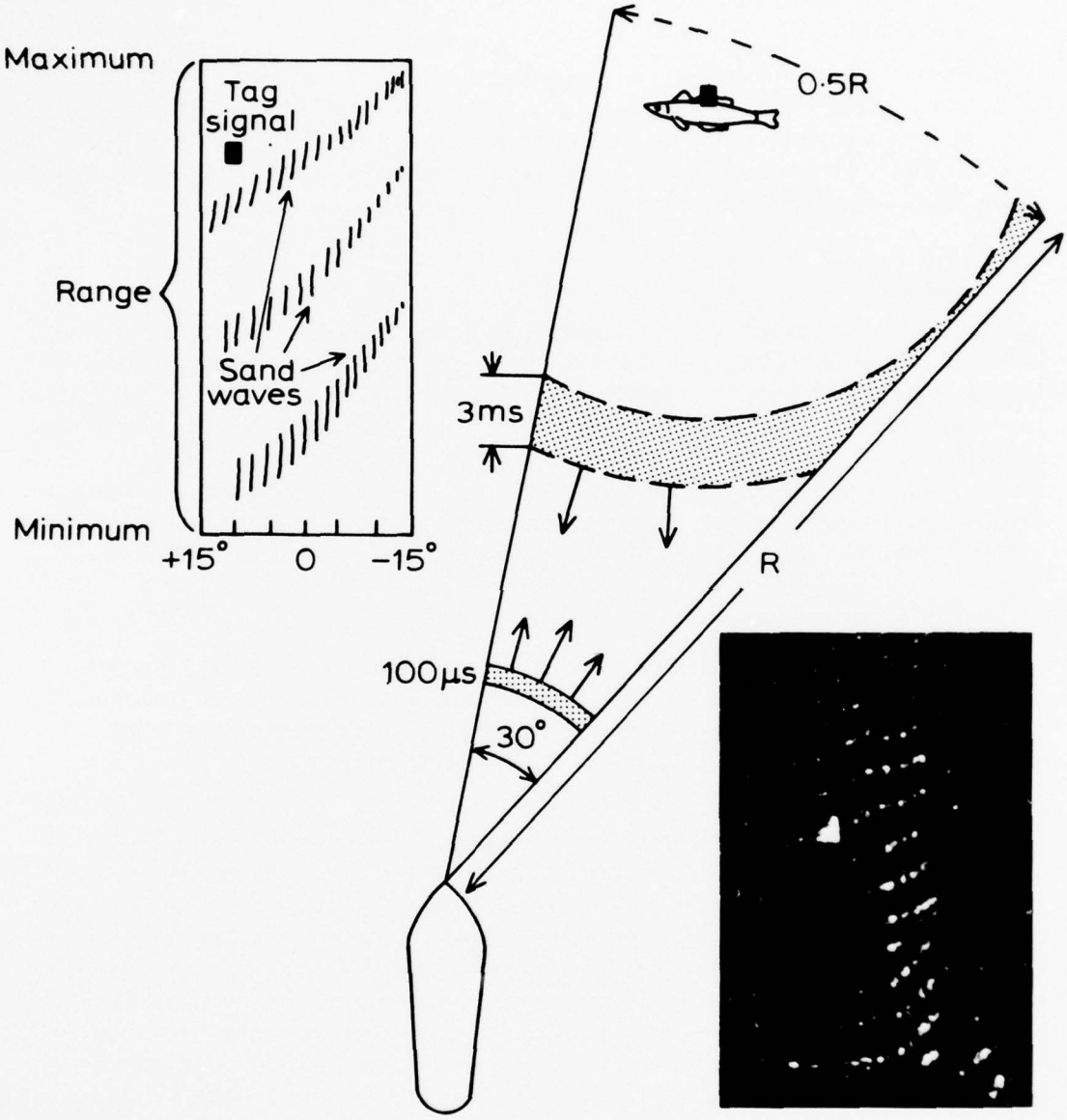


Figure 6 Diagrammatic representation of the operation of the ARL Scanner, used in conjunction with a transponding acoustic fish tag. On the right is a photograph of the actual scanner display showing the fish tag signal against a background of sandwaves.

By manoeuvring CLIONE close behind the towing trawler, trawls were seen from above, from behind and from the side at ranges up to 300 m. The details of each trawl were clearly discernible, e.g. towing warps, otter-boards, bridles, dan lenos, net and cod-end. Net shapes and relative positioning of various parts of the trawl were well shown. Development of this equipment is complete and its applications are increasing. It appears to be a most important addition to the equipment available for fisheries research. The design and manufacture of a version taking advantage of the most modern techniques of electronic instrumentation has become a matter of urgency.

Transponding acoustic fish tag

Although single fish can be detected and followed by the ARL Scanner without the use of acoustic tags, individuals cannot be identified. A transponding acoustic tag (Figure 7) has therefore been designed to assist in the study of fish behaviour, migration, reaction to fishing gear and movements relative to bottom features.

When the transponding principle is used, the pulse transmitted from the ARL Scanner is received by the tag and used to trigger its transmitter, thus sending a return pulse to the ship. This gives an accurate range measurement between the ship and the fish. The other measurements of importance are bearing and depth, both of which can be obtained with the necessary accuracy from the ARL Scanner display.

These acoustic tags have fully met their specification, which is summarized below:

Length	4 cm
Diameter	1 cm
Weight	3 g in sea water
Life	4 days when interrogated once per second 32 hours when interrogated four times per second
Range	500 m in sea water 1 500 m in fresh water
Depth	not yet tested beyond 100 m.

They have been attached to plaice (Figure 8) and cod for tracking exercises concerned with migration studies and more recently for studies of behaviour in relation to trawls.

The transponding acoustic tags are now manufactured to the MAFF design by Marconi Space and Defence Systems Limited. Work will continue for the next two years to enable parameters of interest in and around the fish to be measured and telemetered by the tag, e.g. direction of movement, heartbeat, etc.

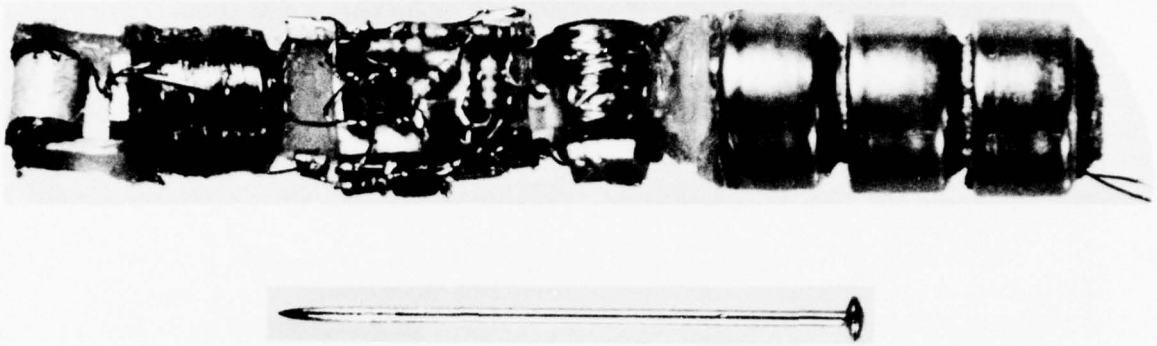


Figure 7 The transponding acoustic fish tag; its size is shown relative to that of an ordinary household pin which is 1 inch (2.54 cm) long.

Figure 8 The acoustic tag in process of being attached to a plaice.

Echo sounding

Considerable effort has been put into the development of apparatus for acoustic surveys of fish populations. Such surveys are becoming increasingly important as a means of estimating stock size and of predicting the abundance of a year-class of young fish, such as 0-group cod.

Work has proceeded on the processing of signals from fish received on echo sounders. This has mainly concentrated on the separation of the signals into single fish or shoals. Once such a distinction has been made, separate methods of processing can be used for obtaining estimates of the size of individual fish and relating these to the quantity of fish in a particular shoal. A discriminating system such as this allows distributions of different-sized fish to be obtained under normal surveying conditions with a research vessel. To obtain accurate estimates of fish size the echo sounders in use must be calibrated throughout a survey. This has been a serious problem because of the difficulty of positioning calibrating devices accurately beneath the ship, but it has been overcome by using towed transducers and fitting these to a calibration frame when necessary.

The use of higher frequencies in acoustic surveys of fish populations (i.e. 100 kHz or above) has many advantages. Examination of such frequencies has been made and an equipment constructed to work at 100 kHz. With its narrow-beam towed transducer it will be put into service in 1972 and should be an extremely powerful tool for the study of both demersal and pelagic fish stocks.

FISH BIOLOGY

The Biology Section at Lowestoft (Head of Section - Dr D. H. Cushing) has two main groups of projects in hand: (1) those described here, concerned with studies of the biology and ecology of fish, especially their younger stages, in support of current studies in population dynamics, and (2) those concerned with fish behaviour and physiology (described in the following section), which are of great importance to workers engaged in fishing gear research and fish cultivation. The boundaries between the two groups are not, however, precise.

Blood types and biochemical variants applied to the definition of cod stock units

In recent years the development of methods for the identification of distinct blood groups in fish has provided a new approach to objective identification of the stock units among commercial fish. An important aspect of this development has been that at long last simple genetic characteristics provide confirmation of the identification of 'stocks' as contemporary breeding units. The older methods relied upon the recapture of tagged fish and the measurement of body characteristics, which tend to be biassed by environmental effects.

At Lowestoft work in this field was concentrated at first on cod, although it is now being extended to other species in which there are stock-mixing problems to be disentangled, such as mackerel and hake. Close liaison is being maintained with workers elsewhere, particularly in northern Europe and North America, and a very useful degree of cooperative working has been quickly established.

In these investigations laboratory tests of fresh tissues collected from spawning cod populations are used to show the distributions of the products of genes. Alternative forms of a gene may control the substitution of a single amino-acid for another at one point in the construction of a protein molecule. Haemoglobin from cod blood provides an example and has been extensively used. Alternative haemoglobin types occur in predictable proportions in cod in different areas throughout the North Atlantic; these, together with other similar examples based on different tissues, are used for stock identification. In addition the numerical composition of types found in samples can be tested against certain well-established laws of genetic balance, to confirm stock unity or detect physical mixing of stocks.

This approach has shown the existence of numerous isolated cod stock units that are predictably found on banks throughout the North Atlantic where hydrographic conditions provide a mechanism for the maintenance of adult fish, eggs, larvae and juveniles within a discrete geographical area. The genetic observations have started to influence the deliberations of some international working groups concerned with stock assessments. For example, North Sea cod appear by these biochemical methods to be one race containing different spawning groups, rather than as several separate unit stocks. By contrast, at south-west Iceland the earlier and later spawners appear to belong to different races and this may be important in quantifying the relationship between cod stocks at Iceland and Greenland.

The causes of variability in recruitment to fish stocks

Much recent work, particularly that done at the Lowestoft laboratory, has confirmed the belief that the strength of a year-class of young fish is determined very early in life, mostly during the egg and larval phases. Thus, the general magnitude of recruitment to the fishable stock is determined at this stage and subsequent losses will usually have much less effect. Particular attention has been paid to disentangling the factors responsible for early losses, with the aim of providing a mechanism of predicting year-class strength from environmental factors and breeding stock size. The vital importance of determining whether severe reduction in stock size may jeopardize future recruitment does not need to be emphasized; it has come to be recognized as a central problem in fish stock management. Work on the survival of larvae and early juveniles seems destined to provide important clues to an understanding of this problem.

Offshore surveys of the larval phase

The studies undertaken at Lowestoft in the period 1969-71 were concentrated in the North Sea, where the large plaice stock provides very convenient and suitable material. Offshore surveys have been carried out with the Lowestoft multi-purpose high-speed plankton sampler on the known spawning grounds in the English Channel and southern and central North Sea to determine changes in the abundance and distribution of plaice eggs and larvae, and of their competitors and predators in the plankton community.

The effect of temperature on development and growth of the eggs and larvae of plaice, sole, lemon sole and turbot, and on the complete life-cycle of the planktonic crustacean Pseudocalanus elongatus was studied under controlled laboratory conditions. The results were used to interpret the ages of plaice eggs and larvae and the stages of Pseudocalanus in the samples taken from the sea and to estimate mortality in these stages more accurately. Stomachs of arrow-worms (Sagitta spp.) and a variety of young fish including cod, haddock and whiting were examined and the results suggest that young fish may be the main predators and the most likely cause of the mortality in larval fish. The population dynamics and biology of appendicularians were also studied in detail and their importance in the diets of plaice and sandeel larvae assessed. An attempt has been made to assess the losses of plaice larvae resulting from changes in the availability of their food.

The estimates of mortality and their dependence on food availability will be used to elucidate the relationship of recruitment to parent stock. Statistical and model studies have revealed that this relationship is a function of fecundity.

To improve the accuracy of the numerical estimates, work was carried out in collaboration with the National Physical Laboratory Ship Division to calibrate the high-speed plankton sampler for volume accepted. Measurements were also made of pressure and velocity gradients ahead of the sampler, which are potential avoidance clues for planktonic organisms. In the laboratory techniques have been developed, using infra-red radiation, for recording the behaviour of larval fish in relation to changes in environmental factors.

Inshore surveys of nursery grounds

Inshore surveys of sole spawning grounds along the east coast of England and in the Blackwater Estuary were made to estimate mortality in egg and larval stages. None of this mortality could be attributed to pollution. Again the interpretation of the field data was dependent on the controlled laboratory experiments carried out with this species.

In a special study of the plaice nursery grounds in Filey Bay on the Yorkshire coast, yearly fluctuations in population size, growth rates and mortality estimates were obtained for young fish. The young plaice in the bay were tagged in the autumn of 1970 and 1971 and approximately 20 per cent of these were recaptured within 12 months. The majority had moved north towards Whitby and Hartlepool and were rarely caught more than 20 miles offshore. Most of the undersized fish were recaptured within Filey Bay, indicating that small fish do not join adult stocks until they approach maturity.

In 1970-71 the distributions of eggs, larvae and young fish less than 2 years old (of all commercially important species) were mapped along the coasts of south and east England, and this work will be extended along the west coast in 1972 and repeated in subsequent years. In these inshore surveys eggs and larvae were sampled with small high-speed tow-nets and young fish with fine-mesh midwater trawls and beam trawls.

In all these studies continuous monitoring of temperature, salinity and transparency of sea water and special hydrographic studies on diffusion and currents were carried out. This information will help to explain the annual and seasonal variation in distribution and abundance of the young stages of fish. International cooperation was limited to exchange of samples with the Dutch fisheries scientists who carried out similar surveys in the eastern and central North Sea in 1971.

These surveys of young fish nursery grounds are also required in connection with the control of the disposal and dumping of polluting materials and as a basis for decisions on the need for additional conservation measures, especially in an EEC context.

Marine production

A model of production in the Southern Bight of the North Sea has been developed, associated with the studies of the variability of recruitment. The aim is to predict the timing of the production cycle, and hence the quantity of recruitment, from meteorological data. Measurements of the plant pigments chlorophyll and phaeophytin in the Southern Bight link the model with observations.

A study of the production of flagellates in the Barents Sea has shown that they can be cultured, though with some difficulty. An estimate of their quantity on certain cruises has been made. A routine method has been developed for estimating the chlorophyll content of very small algae with a fluorometer; up to 95 per cent of total chlorophyll in the water is composed of nanoplankton, less than 20 μm in diameter. Seasonal and annual variations in the quantity of flagellates can then be estimated. The importance of these studies lies in the value of the algae as food for larval fish.

FISH BEHAVIOUR AND PHYSIOLOGY

If we are to understand the movements of fish in relation to changes in the environment, for example in relation to light, temperature or current speed and direction, and to be able to predict their reaction to fishing gear, we must greatly improve our understanding of their physiology and behaviour. While advances in basic studies of physiology, e.g. the study of enzyme systems and neurophysiology, may be expected from the universities, the facilities necessary for the work required by fisheries scientists are often available only at the fisheries laboratories, where there is also the dual advantage of close contact with population specialists and hydrographers and an immediate appreciation of the likely practical applications of the results. The studies briefly described below are heavily dependent either upon special facilities available at Lowestoft or on information directly derived from our contacts with the fishing industry.

Environmental factors and fishing

Trawlers make high catches where fish are concentrated or when particular environmental factors made the fish more accessible, or vulnerable, to the gear. Temperature is an important concentrating factor and cod are often found piled up along the warm side of fronts between warm- and cold-water masses. This is well known on the Svalbard Shelf. Laboratory experiments have shown that cold water down to -1.3°C does not kill cod, and the fish are not adversely affected by sudden changes from 4 to 0°C. These results suggest that the reason for the cod being found on the warm side of the fronts is associated with the steepness of the temperature gradient rather than with the avoidance of water of a particular temperature. Similar concentrations may therefore be expected at other temperatures where such gradients occur, even in the relatively warm North Sea.

In the North Sea, catch-per-effort may vary by day and night and with wind direction. Analysis of log sheets kept by skippers confirms that in the Southern Bight of the North Sea less plaice are caught when the winds are northerly than when they are southerly. In the North Sea some hauls are five to ten times better than the average for the trip, and these big catches do not appear to be related to temperature or to weather. Steps are being taken to determine the positions and circumstances of these big hauls, which must be associated with exceptional concentrations of fish: we want to know where and why they occur.

Migration of fish

Fish migrate for distances up to several hundreds - or even thousands - of kilometres when moving between their feeding, winter, and spawning areas. We do not know the behavioural or locomotory patterns characteristic of these movements: we do not even know what fish do when they move from one bank to another.

With the use of the ARL Scanner and acoustic transponding tags it has been possible to track single fish in the open sea for periods of up to 50 hours. During this time the position of the fish relative to the research ship and its depth in the water column are known with sufficient accuracy to reconstruct the movements of the fish throughout the track. Six experiments with plaice have been made off the East Anglian coast and five of these fish moved 30-50 km when kept under

constant surveillance. Four of the five fish moved north, coming off the bottom into midwater on a north-going tide and returning to the bottom at slack water. Those fish that went north stayed more or less in one position on the bottom during the south-going tide: by far the greater part of the northward movement was made in midwater on the north-going tide. One plaice which went south showed the opposite behaviour, staying in one position on the north-going tide and moving south in midwater on the south-going tide. So we can describe the locomotory behaviour of plaice when moving from one position to another. The next step is to determine the clues used by the fish in detecting slack water when leaving or returning to the bottom, and in making a distinction between north- and south-going tides.

The efficiency of the Granton otter trawl

The efficiency of the otter trawl, in terms of the proportion of the fish within its influence that are caught, is not known. This lack of knowledge is a serious hindrance to any research programme which aims to increase the catch-per-effort by improving the gear.

Sector-scanning sonar and the acoustic transponding tag provide the technical break-through to determine the efficiency of a trawl directly in a way which had hitherto been thought impossible. Single plaice fitted with an acoustic transponding tag were released and kept under surveillance by the ARL Scanner. After allowing the fish time to settle down, a research ship towing an otter trawl was directed to catch it. The whole fish-capture operation was followed by sonar in detail, and escape and herding movements of the fish were observed. The experiments with plaice have shown that the otter trawl used caught 65 per cent of the fish that lay within the otter-boards, and 75 per cent of the fish that lay directly in the path of the net. Some, but not all, of the fish between the boards and the wing-ends of the trawl moved into the path of the net. In all, 58 per cent of the plaice originally lying between doors and wing-ends were caught. These results suggest that there is room for improvement in the efficiency of this particular trawl.

Bait- and line-caught fish

There are over 800 liners in the United Kingdom fishing fleet, most of them small inshore boats under 12 m in length. The cost of bait, and the time spent baiting the hooks, are important items in the economics of the fishery. Whiting and other gadoids are attracted to lugworm, a popular bait, and by means of experiments in a specially-built apparatus and chemical analysis the chemical clue has been systematically whittled down to two amino-acids. Laboratory experiments suggest that the amino-acids are effective individually or in a mixture, and that the fish is attracted to them by its sense of smell (Figure 9). The next step in this work is to develop a practical artificial bait which can be soaked or impregnated with amino-acids and to test these against normal baits in a series of field trials.

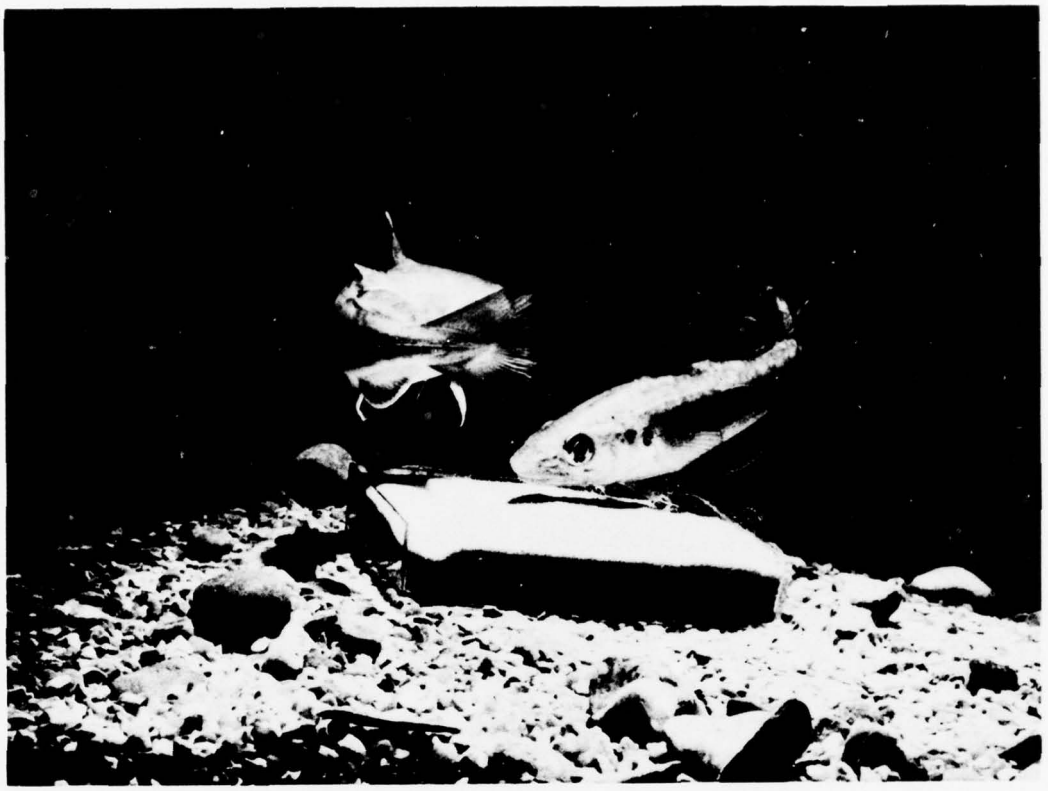


Figure 9 A fish feeding behaviour experiment.

The pineal eye and light

In fishes the paired eyes are not the only receptors for light: there is a median unpaired pineal eye, closely associated with the mid-brain, which appears to be light-sensitive and may have important functions in controlling growth, sexual development, and the timing of the migratory movements. In some fish - such as mackerel, spurdogs, cod and haddock - the overlying tissues are modified to allow more light to pass into the pineal area. In these species electrophysiological work has shown that the pineal eye is light-sensitive and that there are seasonal cycles of neurosecretion in the photosensitive cells. The growth and development of the gonads appears to be related to these secretions. These results show that light, acting through day-length and almost certainly detected by the pineal, is an important factor controlling sexual development, and possibly growth, in fishes. The application of these results is relevant to studies of migration and growth and thus to stock unity and fish farming. By modifying the day-length (that is, the photoperiod), perhaps in conjunction with doses of pineal extracts, it should be possible to delay or advance spawning dates by 2-4 months.

Fish muscle types and their use

The bulk of a fish is made up of muscle tissue in which there are two types of fibre: red and white. The colour difference reflects the better blood supply and greater proportion of respiratory pigment (myoglobin) in the red muscle. Red muscle fibres are generally smaller and contract more slowly than white fibres. These differences are related to function. When the fish cruises along at a steady speed it uses the red fibre system: when it accelerates to attack or escape it uses the white fibre system. This division of function and its relation to structure is not completely understood and the role of the two systems has been studied by observing the increase in fibre size when coalfish (saithe) have been kept swimming at various speeds for several weeks. This form of 'training' has shown that the white fibres do play some part in swimming even at slower speeds, and that the division of labour is not so rigid as had been supposed.

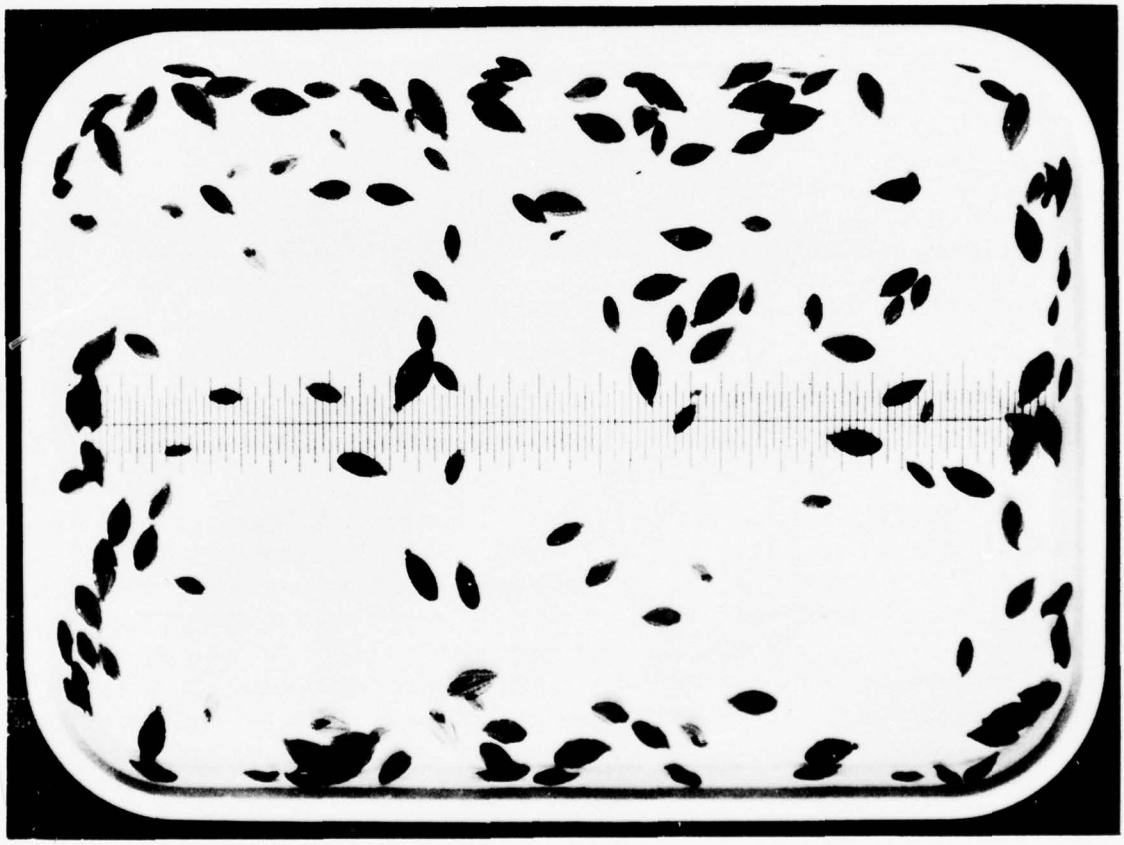


Figure 10 Sole reared to metamorphosis in the hatchery. The photographic method used to record material is also demonstrated.

MARINE FISH CULTIVATION

Introduction

Work on the artificial rearing of marine fish is in progress at both the Lowestoft Fisheries Laboratory (Head of Unit - Dr C. E. Purdom) and the Marine Laboratory, Port Erin, Isle of Man (Head of Unit - Dr J. E. Shelbourne).

Techniques for the cultivation of plaice are now well established but the low market price of this species is a barrier to its useful exploitation in artificial rearing systems. For this reason, work over the past three years has been directed towards the cultivation of turbot and sole, which are sufficiently valuable to justify commercial production. Some studies have also been made of lemon sole. Some basic work in genetics and fish nutrition has been done with plaice, since the results should have general application.

Research at Lowestoft

Hatchery techniques

The production of turbot and sole eggs, their incubation and the growth of larvae to metamorphosis have been studied. Sole have been reared through metamorphosis each year in small numbers (Figure 10), using rotifers for early feeding (up to 6 days after hatching) and brine-shrimp nauplii thereafter. In static conditions, sole can be reared to metamorphosis at densities of up to 800 fish per square foot of tank (approximately 8 000 per sq. m). Some problems have been encountered, particularly in relation to bacterial contamination of tanks, and the programme for 1972 will attempt to solve these and create conditions for pilot-scale production of fish for cultivation. Hatchery-reared sole born in 1968 matured in 1971 and produced viable eggs and spermatozoa.

A stock of mature turbot caught at sea was established in a temporary pool of 25 000 litres capacity. Natural spawning occurred sporadically, but for a regular supply of fertile eggs it was necessary to strip eggs and milt by hand for artificial fertilization. Eggs were successfully incubated at 12-13°C during 1969 but larvae were difficult to feed. In subsequent years, rotifers and mussel larvae were successfully fed to newly-hatched turbot larvae. First feeding was most successful if begun prior to yolk-sac absorption and at a temperature of 15-16°C. Under these conditions up to 80 per cent of larvae began to feed. After 10 days' feeding, the larvae measured 5.6-6.0 mm and began to take brine-shrimp nauplii. Many larvae were grown almost to metamorphosis, but continuous and heavy losses were experienced both in 1970 and 1971. The programme for 1972 includes the study of some factors which might be responsible for this high mortality. Flow systems will be examined and particular attention will be paid to suppressing bacteria and maintaining high oxygen levels.

Husbandry techniques

Growth trials with sole showed that fish could be reared to market size in about 2 years. Heavy mortalities occurred amongst small fish (5-15 cm in length) and these were due mainly to ciliate infestations which can be controlled with regular formaldehyde treatments. Reluctant feeding and slow growth were additional problems with sole and, in an attempt to improve on previous results, fish will be reared during 1972 on a reversed daylight schedule with feeding periods throughout the dark phase.

Figure 11 Two-year-old turbot in an experimental rearing tank.

Growth trials with small turbot (mean length 6 cm) taken from the beaches showed that these fish are ideal for cultivation. They feed voraciously on trash fish and at a temperature of 18°C reach a marketable size of 30 cm within 12 months (Figure 11). Survival of young fish after capture was very high and if sufficient numbers of 'wild' fish could be obtained without depleting natural stocks, a farming system rather similar to that practised in Japan for yellowtails would be feasible. Over a period of 16 months, 150 turbot reached a total weight of 121 kg and consumed approximately three times this weight of food.

Nutrition

Studies have been made on sole and Tilapia (a tropical freshwater fish suitable for experimental work) to investigate the nature and quantity of reserve materials in the fish body, the way they are deployed in growth and the manner in which they are replaced by feeding. A fat fish can weigh up to 50 per cent more than a lean one of the same length; some of the difference is due to differences in water content, but a fat fish may have twice the protein and ten times the fat content of a lean fish. Given ample food, a lean fish very rapidly 'fills out'. Large rations are not necessary to produce good growth in length but a high protein diet is required. This means that good growth can be achieved on low protein-rich rations with a short period of heavy feeding to fatten the fish.

Experiments with sole have shown that the ratio of weight to length can be a reliable guide to the composition of fish. This makes possible an assessment of the value of diets without killing fish for chemical analysis. Such trials will be continued in 1972 in addition to work on the relationships between feeding, reserve storage and the development of reproductive organs.

Genetic techniques

Experience in the poultry industry has shown the great advantage of stocking intensive rearing systems with genetically uniform material specially bred for the purpose. Although the application of modern genetic techniques to marine fish is in a very early stage, sufficient has been done at Lowestoft to demonstrate the potential benefits.

Methods for the manipulation of chromosomes in marine flatfish are being examined. A form of parthenogenesis developed earlier for the creation of inbred lines is still under study. Fish produced by this technique are now over 2 years old and are expected to mature in 1973. The process of inbreeding promotes genetic uniformity and results in the elimination of undesirable recessive genes and the fixation of advantageous ones.

A method has been developed for doubling the number of egg chromosomes by subjecting eggs to cold shocks just after fertilization. The result of this is that the two sets of egg chromosomes and the single set in the spermatozoon fuse to produce an embryo whose cells contain three sets of chromosomes instead of the normal two sets. Such triploid fish grow faster than diploids but, more importantly, they are sterile and therefore do not use energy in the development of reproductive organs.

Hybrids between plaice and flounder were reared and shown to be fertile. Back-crosses between female plaice and hybrid males were shown to be intermediate in form between their two parents, as were the hybrids themselves.

Other hybrids within the Pleuronectidae (plaice family) were also produced and future plans include the examination of plaice x halibut crosses. A stock of halibut was obtained in 1971 and has become established in a large tank. Male fish are expected to mature in 1972 or 1973 but females may require a little longer.

Research at Port Erin

The team at Port Erin has been particularly concerned with studies of factors in the environment most likely to influence the commercial production of flatfish (sole, lemon sole, turbot and plaice) during their early life (Figure 12).

Water conditions

Chlorine, used as an antifouling agent, can influence the survival and growth of captive flatfish in heated power-station effluent. Shortly after hatching, larval sole and plaice withstand no more than 0.02 mg/litre of free chlorine. Their tolerance increases to 0.07 mg/litre during development into juveniles 4 cm long but fish encountering higher chlorine concentrations are at great risk. The growth rate of juvenile fish is not slowed down until the chlorine level reaches 0.055 mg/litre. Sole are marginally less tolerant than plaice at all stages of development.

Ammonia, a soluble product of fish metabolism, occurs in the ionized and non-ionized state. The concentration of the toxic non-ionized fraction depends on total ammonia, temperature, pH and salinity. Fifty per cent of small flatfish die when non-ionized ammonia reaches a level equivalent to 0.70 mg/N/litre. This compares with 0.40 mg/N/litre for freshwater fish. In addition to superior innate resistance, marine fish are at less risk from equal ammonia release into the aquatic environment than freshwater fish, since high salinity reduces the toxic fraction. There is, however, a marked effect on the growth of juvenile flatfish at sub-lethal levels of ammonia.

Temperature studies on different flatfish species at all stages of development were started in 1971. Data are already available on the upper lethal limits of acclimatized and unacclimatized sole and plaice. Lower lethal limits will be investigated later and the work extended to lemon sole and turbot. Optimum temperatures for growth, and temperature effects on food conversion efficiencies, are also being investigated.

Food

The eggs of the brine shrimp (Artemia) imported from the USA can be incubated in warm sea water to produce an organism acceptable to larval sole and plaice, both of which have relatively large mouths. Lemon sole and turbot are too small to utilize brine shrimp at first-feeding, but lemon sole have been reared with 25 per cent survival on mussel larvae, rotifers and brine shrimp fed in succession as each organism becomes acceptable during the course of early development. Indigenous marine rotifers are easily cultured and can replace imported brine shrimp completely as an early food for plaice and sole, with no effect on survival rate. A 30 litre culture yields 1/3 million rotifers daily, sufficient to supply 4 000 plaice at first-feeding or 200 plaice at metamorphosis 10 weeks later.

Data have been obtained and published on the concentration of selected

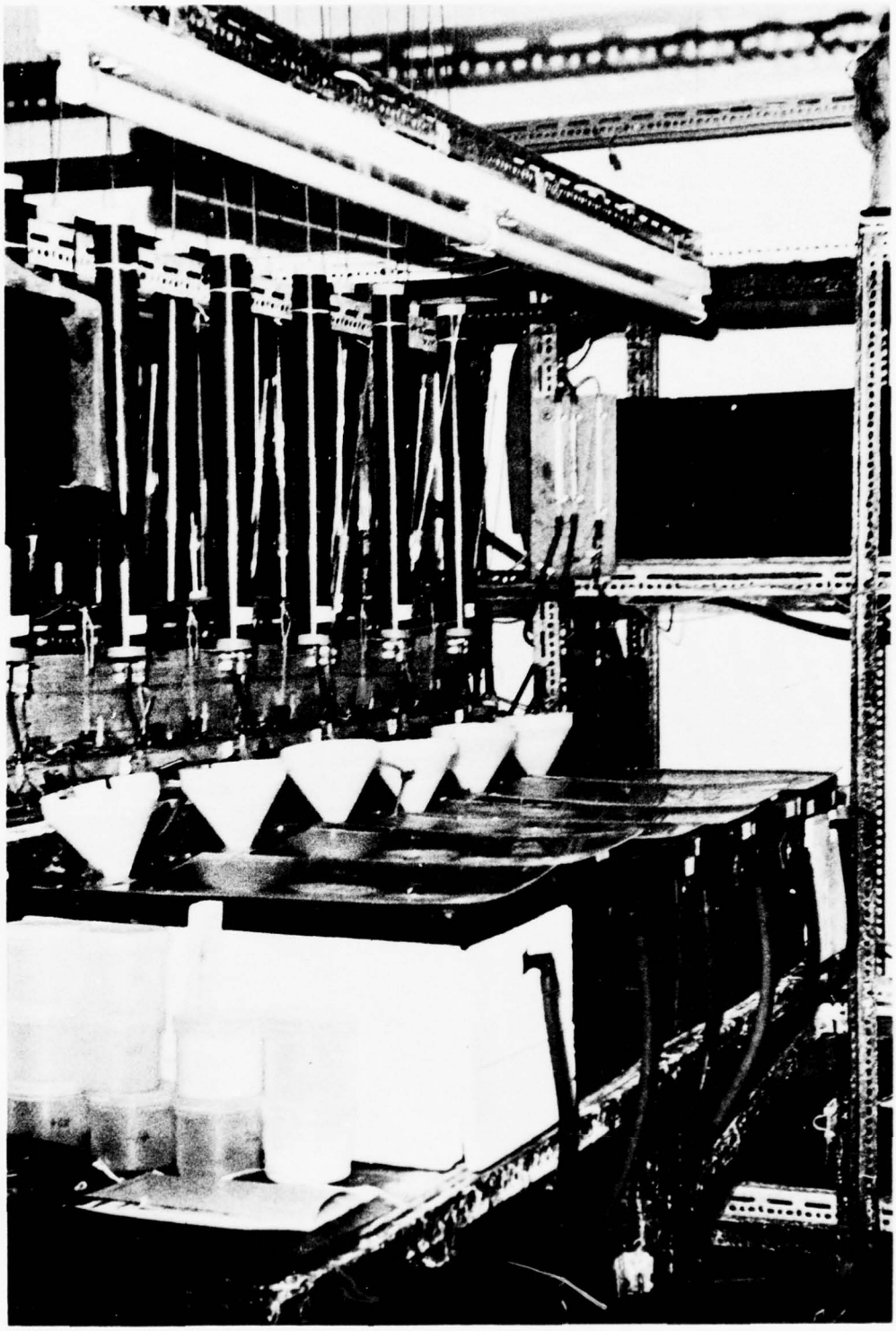


Figure 12 Apparatus used in the investigations on the effects of dissolved ammonia on the growth and survival of small flatfish at Port Erin.

For fast growth and good survival, young flatfish require a continuous supply of live food for 3 or 4 weeks after metamorphosis. Lumbricillus rivalis is an intertidal worm found in decaying seaweed; in the live state it supports excellent growth at a conversion rate better than 3:1 wet weight. The nutritional value of Lumbricillus is immediately and substantially reduced by deep-freezing or freeze-drying. Another worm, Enchytraeus albidus, is easier to cultivate but gives indifferent growth rates. A live mixture of 75 per cent Enchytraeus and 25 per cent Lumbricillus supports growth in young sole equal to that obtained by Lumbricillus alone. The brandling worm (Eisena foetida) found in farmyard manure is a useful live food for larger flatfish, and is already cultivated commercially. Foods such as waste fish and shellfish are also being evaluated, together with a balanced artificial food developed by the NERC Institute of Marine Biochemistry, Aberdeen.

Growth and space

The cost of providing space for captive stock will be a major item of fish-farm expenditure. How to use that space to the best advantage is fundamental to good farm management. We can assume that the growth rates of juvenile flatfish kept in equal-sized tanks with ad lib. food conditions will be influenced by population density; the bigger the population, the slower the growth. From our observations, the mean weight of a stock (W) varies inversely as a power of the population density (d); the trend can be generalized as $W = kd^{-n}$. The average growth performance of genetically equivalent sole populations kept at different densities in otherwise equal conditions has been studied, and the way in which the position and slope of the curves change with elapsed time provides a first clue to the rational management of tank space so as to achieve maximum output.

Tank size itself has a significant effect on the growth of larval flatfish at equivalent and tolerable population densities. Large (4 x 2 x 1 ft, approximately 1.2 x 0.6 x 0.3 m) tanks permit faster growth than small (2 x 1 x 1 ft, approximately 0.6 x 0.3 x 0.3 m) tanks during the early life of larval plaice, but this trend is reversed for a time once the fish metamorphose and take to a more sluggish life on the bottom.

Disease

In pursuit of a disease-monitoring technique the histology of hatchery-reared fish is being compared with that of healthy wild fish. Consistent differences have been found in the appearance of liver sections. Normal bloodcell values (haemoglobin, red cell count and packed cell volume) for hatchery fish are lower than for wild fish; diseased hatchery fish have shown values down to one-third those of healthy stock. Minor outbreaks of hatchery disease have been brought under control; 1:4 000 formalin is effective against the common skin parasites Gyrodactylus and Entobdella, whilst terramycin, a broad-spectrum antibiotic, can be incorporated in food pellets to improve the condition of sole and plaice under bacterial attack. Fish embryos can be killed or weakened by the proliferation of bacteria on the egg shell. Penicillin and streptomycin treatment alleviates this condition, but efforts are being made to find an equally effective but cheaper chemical prophylactic; so far, formalin, Roccal, Lysol and chlorine have proved unsatisfactory.

In further work on radiation regimes in aquatic environments, the experi-

SHELLFISH CULTIVATION

Introduction

Research on artificial cultivation of molluscs and crustacea is concentrated at the Fisheries Experiment Station, Conway (Officer in Charge - Dr P. R. Walne), where the White Fish Authority also undertakes development of commercial rearing techniques.

Molluscs

During the last few years the commercial application of hatchery culture of bivalve molluscs has become established in Britain, with the main interest in the native oyster (Ostrea edulis) and the introduced Pacific oyster (Crassostrea gigas). Research was concentrated at first on the native oyster, since this is the most desirable species and the more difficult to rear. Stocks of seed are urgently needed to replenish depleted fisheries, and the export potential to Europe is considerable.

A study of the feeding conditions of the parent oysters immediately before spawning showed that these had a great influence on the vigour and survival of the larvae and of the juveniles after settlement. Breeding oysters held under hatchery conditions even with good flows of water steadily lose condition, and the importance of correct supplementary feeding has been clearly demonstrated. Cooperative studies with the NERC Unit of Invertebrate Biology at Menai Bridge have revealed substantial differences in the food reserves of different batches of oyster larvae which seem to be related to their viability. The main source of these differences seems to be in the conditions under which breeding stock are held in the hatchery, and future work will concentrate on defining those needed to ensure the production of strong larvae from the parent stock.

The quality of the pumped seawater supply available at Conway for larval rearing varies seasonally, with periods when hatchery production is interrupted because of poor survival and settlement of the larvae. Investigations of the chemical and biological reasons for this are being intensified; it appears that one of the causes is the seasonal blooming in the late spring of the alga Phaeocystis which produces a brown discoloration of the water throughout Liverpool Bay and along the North Wales coast during periods of settled weather. This blooming leaves behind an organic metabolite which appears to be toxic to oyster larvae. The suggestion by other workers that these seasonal interruptions in rearing success were due to the presence of residues of metals such as zinc derived from old mines in the Conway valley is not supported by the results of precise experiments using artificial sea water as the culture medium.

The increasing efficiency of hatcheries is posing substantial problems to be solved in the development of methods of handling very tiny juvenile oysters and clams before they can safely be planted on the sea bed. Extensive trials have been undertaken to define the conditions under which the juveniles can be kept until they are 1 or 2 years old. Increasing emphasis will be given to the rearing of older stages in trays in the sea.

The growth and survival of three species of hatchery-reared shellfish - Pacific oyster, quahog and palourde - have been compared at a number of sites in the United Kingdom. These are varieties of shellfish which can readily be

produced by British hatcheries but to which the industry and the public are unaccustomed. All have done well in several areas and substantial quantities of the Pacific oyster are now being exported. The market for much of the UK production of such shellfish may well be overseas, at least for some years.

Prawns

The initial research in prawn culture at Conway was concentrated on the requirements of the highly-priced but rather scarce native species - the English prawn, Palaemon serratus. Special attention was given to the development of a processed diet. Although the prawn was reared successfully it was found to be unsuitable in several ways for an intensive culture system, particularly because of its relatively slow growth rate. Consequently, during the period under review, attention has been directed to other species from different parts of the world, particularly a 'cold-water' prawn from British Columbia and a tropical prawn from Malaysia. Methods of culturing from the egg to a commercial size were developed for both species. These studies included assessments of larval food requirements and, for the juveniles, an examination of such items as different stocking densities, a range of temperatures and salinities, and a variety of natural and artificial diets.

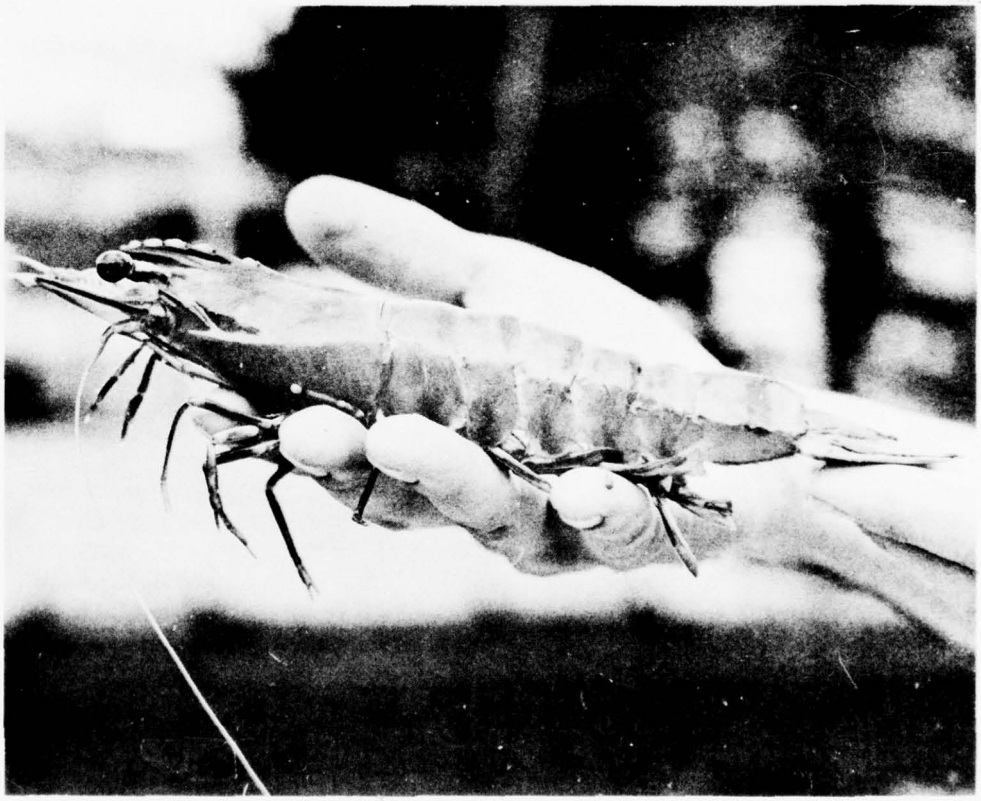


Figure 13 Penaeus monodon (the Philippine 'jumbo tiger shrimp') after culture for one year in the laboratory (weight 70 g).

A review of the results obtained led to the conclusion that the greatest promise for a soundly-based commercially-viable culture method lay with tropical prawns grown intensively in a close recirculation system. The prawn from Malaysia is rather aggressive and a search among other tropical species has been initiated, in order to identify the most promising form before undertaking further detailed biological work. One species from the Philippines (Figure 13) has shown great promise, because it has grown to commercial size at Conway in 3-4 months. Successful large-scale cultures of this type will need careful control of the chemistry of the recirculating system, and a programme to measure the tolerance of prawns to ammonia, nitrate and dissolved carbonaceous material is in progress at the same time as a study of the efficiency of biological filters to control the level of these factors.

MARINE POLLUTION

Research on marine pollution is centred at the Fisheries Laboratory, Burnham-on-Crouch (Officer in Charge - P. C. Wood), but hydrographic aspects have received special attention at Lowestoft where there is a Unit within the Hydrography Section concerned specially with pollution problems. Some help has also been provided by the analytical chemists and others at the Fisheries Radiobiological Laboratory.

The general aim of the work has been to establish the effects that man's activities in the sea may have on commercial fish and shellfish resources or on their quality. These activities include solid and liquid waste disposal through sewers and pipelines and by dumping, mineral and hydrocarbon extraction, and other engineering and development work in the coastal region. The purpose of the research work is to obtain knowledge which can be used as a basis for administrative decisions by the Ministry, by statutory bodies having pollution control powers in tidal waters (the Sea Fisheries Committees and River Authorities), and by other Departments concerned (Department of the Environment, Department of Trade and Industry, Department of Health and Social Security). Liaison is also maintained with industry and others with commercial interests in the sea.

In order to establish the effect of a specific proposal, chemical, physical, biological and hydrographic studies are made, either in the laboratory or in the field. Full advantage is taken of cooperation with other Departments, and bodies working in related fields.

Monitoring of fish and shellfish

For the last five years, in cooperation with the Department of Agriculture and Fisheries for Scotland (DAFS), a continuing programme has been undertaken to monitor the presence of persistent substances in fish and shellfish landed at British ports. Concentrations of metals, pesticide residues and other organic substances have been determined twice yearly in representative samples of commercial species taken from traditional British fishing grounds, including distant and middle waters, and coastal and estuarine regions. Special attention has been directed towards coastal areas where the presence of potentially hazardous substances is expected because of concentrations of industry or adjacent large conurbations. During the period of the investigations, no general increase has been detected in metals, pesticide residues, or other organic substances. During 1971, a special investigation was made into the distribution of mercury in fish and shellfish; the results formed a significant part of the First Report of the Working Party on the Monitoring of Foodstuffs for Mercury and other Heavy Metals (HMSO). Current investigations pay special attention to lead and cadmium and the results will be published by the Ministry in further reports.

More recently these investigations have been expanded as part of the baseline study to determine the distribution of persistent substances in the North Sea mounted by ICES in its International Study of the Pollution of the North Sea and its Effects on Living Resources and their Exploitation.

In cooperation with DAFS, the presence in shellfish of toxins dangerous to man and derived from blooms of marine algae, especially dinoflagellates, is

monitored along the north-east coast each year during the summer months. Early stages of toxicity are reported to DHSS and may lead to restrictions on the marketing of mussels and other shellfish; this work will be continued.

Toxicity testing

Reliable methods for the assessment of the toxicity of polluting substances are an important part of the equipment of any laboratory concerned with pollution control. As in fresh water, acute toxicity can be expressed as the concentration of a poison capable of killing 50 per cent of the test organisms in 48 or 96 hours (48 or 96 hours LC_{50}). The test may be carried out in static or flowing water and for the latter purpose a special piece of apparatus has been developed at the Burnham-on-Crouch laboratory (Figure 14). Tests can if necessary be maintained for one month or longer to establish the effects of long exposure to low levels of pollutants. A variety of test organisms may be used, ranging from single-celled algae to mature fish. Those most commonly employed in routine work at Burnham are brown shrimps, cockles, oysters, plaice and a common inshore fish Agonus cataphractus. Experiments have also been made with the larvae of oysters, brown shrimps and plaice which show that these early stages in the life cycle are substantially more sensitive to some poisons, such as metals, than the adults. This conclusion has great practical importance since the young stages often occur in estuaries and shallow coastal waters where pollutants are likely to be most concentrated.

A further method of particular value in field surveys is to expose fish or shellfish of known history in cages in the area where pollution is being studied and to observe survival, for example in relation to exposure during different parts of a tidal cycle. In this way a picture has been built up of the spread of toxic pollutants from particular outfalls, e.g. in the Humber.

Dumping

Special investigations are made to support the Ministry's voluntary system for the control of dumping of industrial wastes and of sewage sludges at sea. Applications to dump at sea are made by local authorities and industry, and after determination of the composition of the waste, its toxicity and persistence, the distribution of fisheries and the dispersal characteristics of the proposed disposal area, recommendations are made. A very large part of marine dumping carried out from England and Wales is now subject to such control. The experience gained from this work has provided a valuable basis for the internationally agreed convention to control dumping in the north-east Atlantic signed in Oslo in February 1972. It is anticipated that this programme will continue and expand as statutory powers come into effect in 1973.

Oil pollution

The effects of oil pollution on fisheries have been assessed by a cooperate study with DTI and the oil industry. A standard method for the estimation of toxicity of oil and detergents has been developed in cooperation with the Warren Spring Laboratory (DTI), and has enabled industry to produce a family of detergents of low toxicity. These are now being manufactured and widely distributed

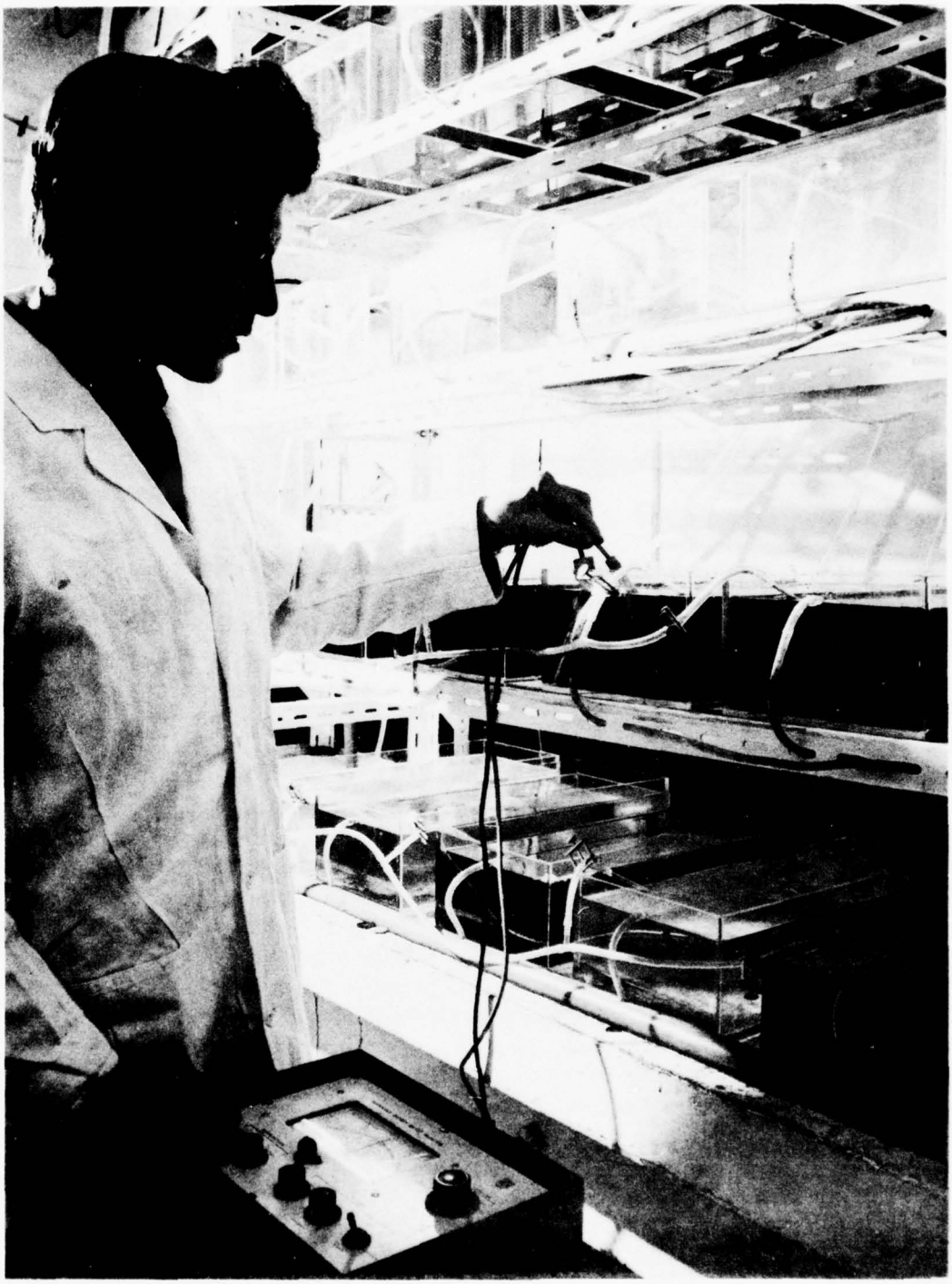


Figure 14 Measuring dissolved oxygen concentrations in the continuous-flow toxicity-testing apparatus used at the Burnham-on-Crouch laboratory.

and allow modern detergents to be applied in situations where the older more toxic ones could not be used.

In cooperation with DTI, tests are being made to assess the effect on fishing gear and on fish of oil sunk by mineral substances (Figure 15). The effect of long-term exposure to sunken oil is being determined in the laboratory. First results indicate that oil sinking should not be used except in an emergency following a major oil spill.

Figure 15 Oil on the hands of a fisherman and on the net which he has just hauled.

As a result of concern following North American experience, investigations are now being made, in cooperation with the Torry Research Station and the Laboratory of the Government Chemist, to assess the presence of fractions of mineral oil in fish and shellfish. Special attention is being directed to potentially carcinogenic substances, to the distribution of oil fractions in fish and shellfish from coastal areas, and to the study of fish given measured doses of oil in their food. The rate of removal of oil fractions from tainted fish and shellfish on return to clean waters is also being determined.

These investigations provide the biological basis upon which DTI recommends to local authorities how oil should be treated. The programmes briefly described above will probably require a further 18-24 months to complete. In addition it is anticipated that the routine monitoring of commercial species of fish and shellfish for the presence of mineral oil fractions will start within the next 12 months.

Investigations into specific proposals related to fisheries

The effects of sewage effluents on molluscan shellfish are being studied with particular reference to the spread of disease. Methods for the detection of sewage organisms in shellfish and coastal waters are being constantly improved. Advice is given to local authorities, DOE and DHSS on the standards of sewage treatment necessary to prevent pollution of shellfish beds. Methods of shellfish purification have been evolved and are now in use on a commercial scale in many areas for the removal of sewage bacteria from contaminated molluscs. Advice on the design, construction and approval of these installations is given to industry, the local authorities and DHSS, and the working of existing plants is supervised.

The effects of gravel extraction on fisheries, and the rate of infill of excavated areas are being assessed in cooperation with the Hydrography Section of the Lowestoft laboratory. The Crown Estate Commissioners are advised on fishery aspects of new applications for exploitation. Such applications may involve interference with fish spawning and feeding grounds or locally important trawling areas, destruction of shellfish beds and other adverse effects.

The consequences of proposed and established dumping operations are being examined. The effects of offshore dumping of large amounts of inert mineral wastes (fly ash, china clay and colliery wastes) on pot and trawl fisheries have been assessed off the Cornish and north-east coasts; the effects on fisheries of sewage sludge dumping are being examined in the Thames Estuary and Liverpool Bay; and the effect of the dumping of mixed industrial wastes in Liverpool Bay and off Morecambe Bay is also being studied.

The consequences of disposal of industrial wastes through coastal pipelines are being assessed in the Humber and the Swale (Kent), where the local River Authorities are being advised; these are both areas in which measurable damage to fisheries has already occurred. Off the Yorkshire coast, where a substantial outfall will discharge mineral waste from a potash mine, advice on the methods needed to monitor the potash effluent is being given to DOE, the local planning authority and the developer. In addition to these specific proposals, many requests for advice related to coastal discharges are received from Sea Fisheries Committees and River Authorities. Some of these can be dealt with on the basis of existing knowledge without the need for special field investigations.

Although many of these programmes will be completed during the next 1-2 years, we must anticipate that a steady stream of such specific proposals will continue and will require similar investigations. Increased public concern over marine pollution is expected to lead to a demand for higher standards and with it an increase in the work load of the Burnham-on-Crouch laboratory.

Hydrographic aspects of marine pollution

During the period 1969-71 a number of proposals have arisen for pollutant discharges where the prediction of the consequences of the discharge, and particularly its probable effect on the local fishery, could not be made reliably without hydrographic studies.

Specific problems dealt with include:

(a) the discharge of waste from potash mining off the north-east Yorkshire coast (in collaboration with the United Kingdom Atomic Energy Authority (UKAEA) and the Fisheries Radiobiological Laboratory);

(b) the discharge of china clay waste off the south Cornish coast near St. Austell;

(c) the dumping of sewage sludge in the Liverpool Bay area of the Irish Sea (as part of the programme of a DOE Working Group).

Smaller investigations have been made in connection with proposed discharges of sewage to the Swale, the Solent and off Lowestoft, and of methanol off Mablethorpe. In the latter case, a desk study was found to be adequate, but investigations have usually involved the use of moored current meters to determine the residual circulation, releases of the dye Rhodamine B to measure dispersal produced by random water movement, and other hydrographic observations. Off the north-east Yorkshire coast the study has also involved the use of a radioactive tracer to determine the rate of dispersal of particulate matter in sea water.

Over the next two years work will include the analysis of results already obtained, and investigations in connection with three main proposals: the dumping of sewage sludge off the Tyne, and in the Thames Estuary, and the dispersal of chalk waste from the Channel tunnel project. It is hoped to obtain measurements of long-term inshore water movements at a number of positions on the English east coast.

Investigations have also been conducted to determine the distribution of dissolved organic material in Liverpool Bay and the distribution of heavy metals, such as zinc, copper, manganese and cadmium, in the southern North Sea, a particular aim being the establishment of base lines against which any future variability can be measured. Heavy metal concentrations have been found to be generally low offshore, with some increase towards coastlines. Additional surveys of trace metals are planned over the next two years, and dissolved organic material is being considered as a possible index of sewage pollution. This work forms part of the ICES Study of Pollution of the North Sea.

Basic work

Many of these programmes require the support of more basic studies, which are normally undertaken as part of the advisory programme. Thus the development of analytical techniques for the estimation of important chemical pollutants, the estimation of long-term sub-lethal effects of toxic substances on physiology, behaviour and breeding success, and the changes in communities of bottom-dwelling marine organisms in response to waste disposal are typical of the studies which must first be carried out if the practical implication of a specific proposal can be fully understood. It is anticipated that there will be a continuing need for a programme of such basic studies to support the day-to-day advice which is given. Particular attention must be given to the effects of long-term exposure to low levels of pollutants.

RADIOBIOLOGY

Introduction

The Fisheries Radiobiological Laboratory (Head of Section - A. Preston) provides advice and services on radiological protection in an environmental context, primarily to serve the Ministry in discharging its responsibilities under the Radioactive Substances Act 1960 for the control of radioactive waste disposal to surface waters and the sea. The laboratory also provides advisory and technical services to the Scottish Office, and monitoring is undertaken for the Channel Islands authorities and for the Republic of Ireland. The routine control activities are supported by a research programme concerned with the behaviour of natural and artificial radioactivity and the possible consequences of radioactive contamination of the environment for public health and natural resources.

Radiological control - inspection and monitoring

This work is divided into inspection, monitoring and radiological site (discharge) assessment.

Statutory inspection requirements have been met through regular visits to all the major nuclear sites in England and Wales where there is a fisheries interest, and annual reports or other documentary material have been prepared and issued to the appropriate authorities.

Monitoring, on a scale adjusted to individual discharge requirements, has been undertaken at the majority of sites in England and Wales, and also on behalf of the authorities in Scotland, the Channel Islands and the Republic of Ireland.

In addition to routine surveillance, through environmental and effluent monitoring, special site assessments have been made to determine discharge limits for new establishments or to amend those at existing establishments. An authorization has been issued for Wylfa, which commenced operation in 1971, and an agreement on discharges from HM Dockyard, Devonport is imminent. Site assessments have been completed for Hinkley Point, where a second nuclear power station is approaching completion, and for Trawsfynydd, where amendment to the authorization is needed due to changing effluent composition. A detailed re-evaluation of discharge limits for Windscale has been undertaken and is likely to lead to revision of the authorization. The need for this latter review arises from changing effluent composition and the emergence and increasing importance of two other exposure pathways - external exposure and fish consumption - in addition to the long-standing major route of public radiation exposure via Porphyra seaweed and laverbread.

Radiological site assessments involve the conduct of local fish consumption and habits surveys, some of which have been made as part of the specific site assessments already detailed, but others - at Chapelcross, Sizewell, Bradwell, Chatham and Dounreay - were made as part of a regular programme to ensure the current validity of all data used in radiation protection programmes (Figure 16). New nuclear power stations are under construction at Hartlepool and Heysham, and preliminary surveys have also been made there.

Figure 16 Measurement of beta-radiation dose of fishing nets.

This stringent control continues to keep environmental contamination and the consequent public radiation exposure well within acceptable limits at all sites; indeed, in most cases the margin of safety is considerable, with exposure of the public much less than 1 per cent of the dose limits recommended by the International Commission on Radiobiological Protection (ICRP).

Radioecology

The behaviour of artificial radioactivity in the natural environment is studied in order to improve the predictive capability of the laboratory in the conduct of radiological site assessments. Three large-scale radioecological surveys of the Irish Sea were made during 1969, 1970 and 1971, with samples of sea water, suspended matter and bottom sediment being taken from a large network of stations. The results will be used to examine the total budget of ruthenium-106 and caesium-137 in the north Irish Sea, but studies of this kind also afford an opportunity to trace the pattern of water movements. Contour diagrams of the standing concentrations of caesium-137 in sea water during the years of the surveys demonstrate the variable influence of incoming Atlantic water upon the circulatory pattern of the north Irish Sea.

Data have been obtained and published on the concentration of selected heavy metals in British Isles coastal waters. The results show that there are some areas where significant contamination exists, and the eastern Irish Sea appears to have the highest concentrations of most metals. However, data from most regions show that the concentrations of the metals examined are not significantly higher than those in the open Atlantic Ocean adjacent to the British Isles. The sampling of seaweeds strongly suggests that concentrations of most metals, including those in polluted areas, have changed little over the 10 years up to 1970.

Over the period 1969-71 observations have been made of the concentrations of radioactive caesium in lake water, bed sediment and fish taken from Lake Trawsfynydd, Merionethshire. The lake receives radionuclides discharged in the liquid effluents of a nuclear power station. The relationships between the discharge rate of caesium-137 and concentrations in lake water, lake bed and fish flesh have been examined to establish maximum permissible discharge rates for the caesium radionuclides and other constituents of the liquid effluent. The concentration factor (caesium-137 fish flesh/caesium-137 lake water) has been compared with that obtained in the period when the only source of radioactive caesium in the lake was from nuclear weapon-test fallout. Measurements of the concentration factor for stable caesium are in progress for comparison with the results obtained with caesium-137 derived from fallout and from reactor operation.

Routine monitoring has increasingly shown the importance of the reconcentration of radionuclides by marine and estuarine sediments, and some work has been started on the mechanisms involved. Several parameters, such as the size range of the particles in a sediment, and the salinity of the supernatant water, influence the degree of uptake, and attempts have been made to measure their importance. Standard techniques have been developed to measure the particle size distributions of sediments, and now permit a full size frequency analysis to be made in one operation.

In the sand and silt size ranges, the uptake of radioactivity is closely related to the surface area of the material in the sample. Below this size the picture is not so simple, and the uptake pattern is modified by the presence of clay minerals and organic colloids; work is in progress to find any component showing a particular affinity for the important fission product nuclides. Attempts are being made to separate the organic components by flotation in heavy liquids and to fractionate the various inorganic minerals by zonal centrifuging prior to identification by X-ray diffraction and estimation of radioactive content by autoradiography.

The laboratory has participated in international intercalibration programmes, determining trace elements in sea water as part of the US Geochemical Ocean Sections survey, and also radionuclides in an intercomparison exercise conducted by the International Atomic Energy Agency (IAEA). Collections of sea water and seaweed for this latter work were made as part of an IAEA contract, and investigations into the stability of radionuclides in seawater samples were also financed, in part, by the Agency. More recently the laboratory has participated, within the framework of ICES, in an intercalibration exercise for trace metals in sea water as part of the International Study of Pollution of the North Sea.

Radiobiology

Studies pursued include: (a) the dynamics of radionuclide uptake and loss in marine and freshwater organisms, to provide basic information in relation to site assessment requirements and, in some instances, to provide data of use in heavy metal pollution studies; and (b) assessment of possible radiation damage to marine resources through both experimental investigations and assessment of radiation experienced in the environment.

(a) During the period under review, work with caesium in fish has been completed, and that for the plaice and ray published. The accumulation from water of the radionuclides of selected heavy metals (zinc-65, manganese-54, iron-59 and cobalt-58) by plaice, trout and rays has been followed at tissue level over periods up to 180 days, and has been studied in relation to the drinking rates of the fish and their total body water flux as determined by tritiated water injections. Comparisons have also been made with the stable element levels in the tissues, and an assessment was made of the relative sizes of the body pools of these elements. More precise estimates on the biological half times of these nuclides have been obtained from excretion studies, both from animals that have accumulated their radioactive body burdens from water labelling and from injections. The water contribution to metal uptake in fish has been found, in fact, to be very small and, although labelled food experiments have not been undertaken, experiments to determine the percentage of absorption of nuclides from the gut both in vitro and in vivo are under way.

Various invertebrate species have also been studied for the same nuclides and, in the mussel, uptake from water has been followed at tissue level, together with changes in stable element levels. Autoradiographic techniques have been used to obtain information on tissue localization. Mussels labelled with cobalt-58 have been fed to starfish, and the subsequent subcellular distribution of the isotope was followed in the starfish organs. Such experiments are intended to illustrate, at a cellular level, the different metabolic pathways of food and water intake.

As a prerequisite to an understanding of heavy metal accumulation from water, experiments have also been undertaken to indicate the changes in heavy metal distribution in aquaria and the validity of nuclides as tracers.

(b) In order to assess radiation exposure in the Windscale effluent discharge area, 3 580 plaice were marked with a combined radiation dosimeter/Petersen disc tag, and released off Windscale; of these, 1 053 (29 per cent) have been recaptured, and the dosimeters from 970 have yielded useful data. The results broadly confirm the estimates of dose rate derived from calculations made on the basis of the known levels of radioactivity in the sea bed, although it is clear that the natural behaviour and migrations of the fish combine to reduce the average dose rate received by the population. From a consideration of the combined results of the dosimeters on the upper and lower surfaces of the plaice, it is concluded that the mean dose rate to the gonad is 250 μrad h^{-1}. Although this is approximately twenty-five times greater than the dose rate from the natural background radiation, it is much lower than the dose levels required to produce somatic effects in individual fish or genetic effects in the population.

In further work on radiation regimes in aquatic environments, the experiments with plaice eggs to provide data on which to base radiation dosimetry models have been extended to herring and lobster eggs.

An experimental approach to the effects of continuous irradiation on the breeding performance of fish is being made, using pairs of guppies (Poecilia reticulata), a small, live-bearing tropical fish. These are maintained under conditions of continuous irradiation at dose rates of 1.7, 0.5 and 0.25 rad h^{-1}. Performance in terms of brood production rate, brood size and sex ratio of offspring is being followed. At the highest dose rate the brood size is very small, and the adult fish soon become sterile. At the lower two dose rates the brood rate is only slightly changed from that for the controls, but the brood size is significantly reduced. The experiment is continuing.

HYDROGRAPHY

The general purpose of the work of the Hydrography Section of the Lowestoft laboratory (Head of Section - H. W. Hill) can be defined as the measurement and interpretation of the physical and chemical parameters in the sea which have a bearing on fisheries problems. Much work is, however, done on marine pollution problems and this has been described in the appropriate section of the Report.

The main areas of work in the three years 1969-71 have been:

Near waters circulation

Arrays of recording current meter stations (Figure 17) have been moored for periods varying from a few days to a year, in the North and Irish Seas, to discover the mean residual current circulation in the area of the arrays, i.e. the current pattern on which the tidal streams are superimposed. Most of the work during these years has been in the Irish Sea, where techniques have been developed and equipment proved. It has been found that the main residual currents in the northern part of the Irish Sea, during most of the year, can be contoured for the surface and bottom layers, but it has become clear that a real understanding of the circulation and its variability, sufficient to permit a degree of prediction, can only be achieved by a coordinated programme of observational data and mathematical modelling. To this end a joint programme was carried out in 1971 involving the Fisheries Laboratory, the Institute of Coastal Oceanography and Tides (ICOT) and the Oceanographic Departments of Liverpool University and the University College of North Wales at Bangor.

Since January 1971 the main effort has been switched from the Irish Sea to the North Sea, where the laboratory maintains three long-term current measuring stations as part of an Anglo-German-Dutch-Belgian cooperative project, and two stations on oil rigs in conjunction with the Shell and AMOCO companies. Short-term arrays of current meters and other hydrographic observations have been made to supplement the long-term stations, and a mathematical model is being written of the circulation of the southern North Sea, which will use these current data as one input parameter. Phase I of the international network will continue until December 1972.

Dispersal of marine organisms

Studies of fish stocks have sometimes needed estimates of the dispersal rates of eggs and larvae. These have included oyster larvae in the estuaries of the Roach, Crouch and Fal, and plaice eggs and larvae in the southern part of the North Sea. In each case an attempt has been made to identify and measure the types of water movement that produce dispersal of the eggs and larvae.

The tracer Rhodamine B has been used to estimate diffusion rates and these data have been supplemented by other hydrographic observations and, particularly, current measurements using moored meters. The plaice egg and larval distributions themselves have also been used to estimate dispersal rates, but in the case of the oyster this type of information has proved to be too sparse to use in this way. In the Fal Estuary the hydrographic results have suggested a good location for a stock of parent oysters.

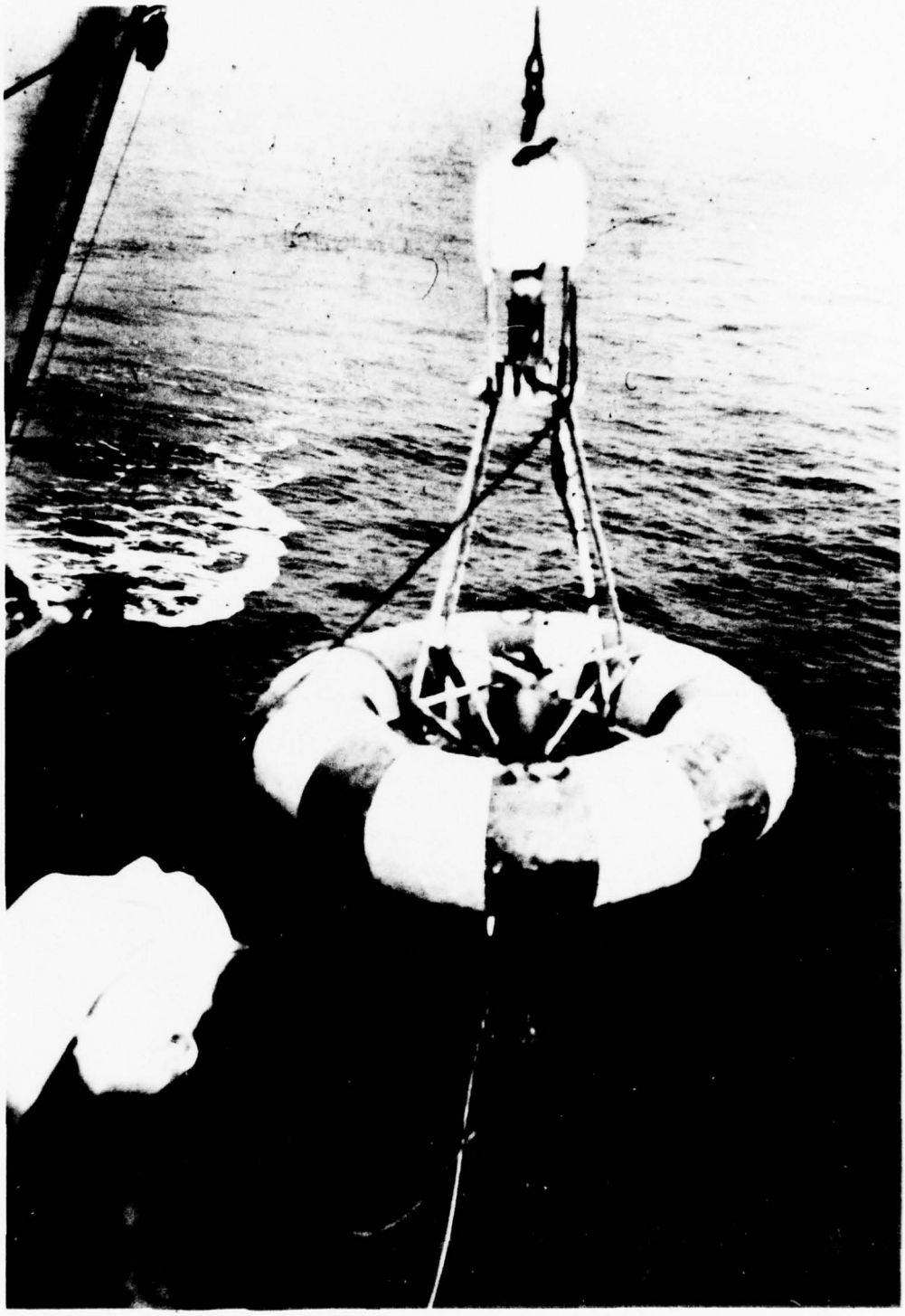


Figure 17 Launching the surface marker at one of the long-term current-measuring stations in the North Sea.

This work is leading to the production of a mathematical model, representing dispersal by largely random water movements in an area such as the Southern Bight, which will be of value both in biological studies and in pollution investigations.

Sand and gravel extraction

Since 1963, marine production of sand and gravel has risen by 17 per cent per year to a total of 13 million tonnes in 1970, representing 11.8 per cent of the total United Kingdom production. As mentioned above, the Ministry is consulted by the Crown Estate Commissioners in assessing the desirability of granting dredging licences for specific inshore areas, and since November 1970 the Lowestoft and Burnham laboratories have conducted research into the effects of marine dredging on fisheries. The principal grounds for concern lie in the possibility that dredging operations might destroy the feeding and spawning grounds of economically important fish species or may render the area permanently untrawlable. Accordingly, the research programme aims to investigate the nature of the physical and, in conjunction with the Burnham laboratory, the faunal disturbance caused by different dredging methods, and to establish base lines for assessing the recovery times of a dredged sea bed in areas of different water depth, current speed and sediment type.

Observations consistent with these aims have been made during a survey in the Shipwash-Gabbard area in the southern North Sea and during three surveys of a test site located on the Shingle Banks off Hastings (Figure 18); the NERC Unit of Coastal Sedimentation participated during the first of these surveys. The ARL Scanner has proved a valuable tool in this programme of work. It is envisaged that the Hastings programme will be completed to the stage of producing a first draft report during 1972 but additional observations from other areas will be continued during 1973. The initial results suggest that the rate of infilling of pits, dredged in gravel or shingle, will be very slow under the tidal current speeds normally experienced around our coasts.

The hydrography of the north-east Atlantic

The first comprehensive survey undertaken by the laboratory (in collaboration with DAFS and the Ministry of Defence (MOD) (Navy)) of the physical and chemical oceanography of the waters immediately to the west of the United Kingdom was completed in 1969 and should be ready for publication in 1972. Much basic information about the area has been obtained and short-term local winds have been shown to have large effects upon the transport of water, even reversing the general northerly movement on occasion. Amongst other results, it was shown that the flow towards the north-west European fishing grounds, at depths of 50-200 metres, was not a direct continuation of the Gulf Stream water, but had come northwards close to the continental shelf after mixing with Gulf of Gibraltar water.

Analyses of United Kingdom weather ship observations support the latter point by demonstrating that the North Atlantic Drift approached to within 180 miles of the Irish continental shelf, but subsequently turned north-westwards away from the British Isles. Work from this joint MAFF, MOD (Navy) and Meteorological Office project should reach draft report stage early in 1973.

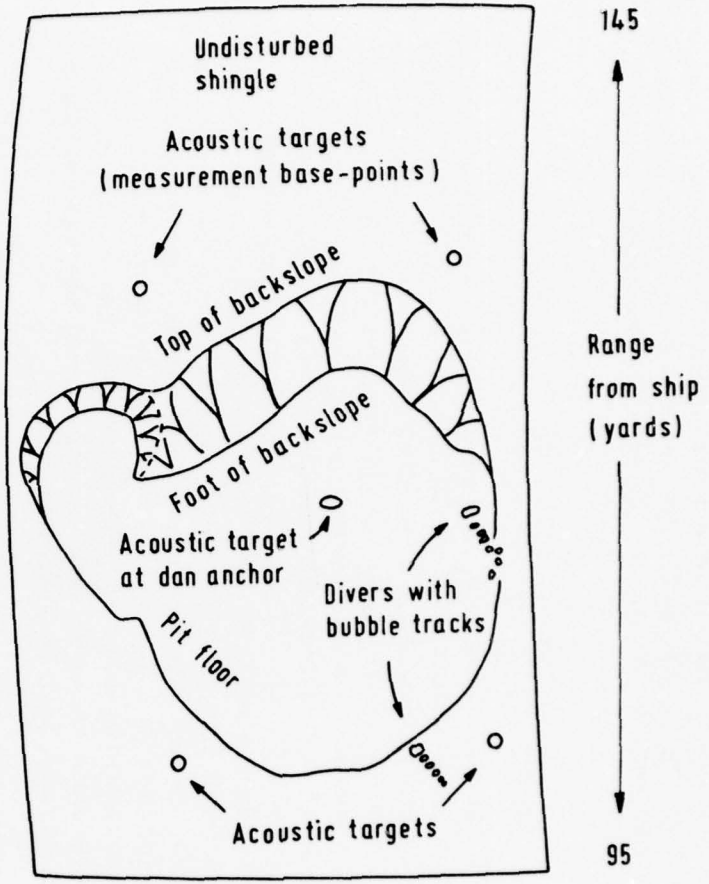


Figure 18 Experimental pit, Hastings, dredged July 1971.

A partially closed circulation of water around Rockall Bank may account for the apparently self-contained fish stocks there, and results from a number of cruises will be published in 1973. The physical mechanism is not entirely clear, partly because of the uncertainty about deep-water movements in the vicinity. Observations made further north in 1971 give clear indications of dense south-flowing water on the bottom, and additional work will be carried out in 1972 to study this circulation further.

The effects of climatic change on fisheries

Meteorological records during this century have provided increasing evidence of climatic changes over several different time-scales. These have been responsible for inducing significant changes in the marine environment, often with important fishery implications. Specifically, these changes may alter the distribution or development rate of marine organisms, including fish larvae and fish of economic importance, and they may also influence the timing of phytoplankton and zooplankton production cycles. Thus, by their effects on the relationship between the production of fish larvae and the production of their food, such changes may induce fluctuations in the abundance of major fish stocks. Recent research has aimed at identifying the major connected trends in the atmosphere and ocean over the present century, with special reference to conditions on the major North Atlantic fishing grounds. To a large extent the inter-decadal trends of long-term climatic change, and the shorter-term inter-annual fluctuations, have now been identified and their relationship to biological events of the types mentioned above has been empirically described. Over the next two years it is hoped to provide a more detailed description of the environmental effects on specific stocks of fish.

The laboratory operates a routine sampling network, providing sea surface temperature and salinity data, using lightvessels, coastal stations, merchant vessels and ocean weather ships. This collection of data provides a valuable description of long-term changes in the marine climate for comparison with biological records and for other purposes. Since the beginning of 1971, regular bottom temperature observations have been made on a routine basis by our research vessels in the seas around the United Kingdom, as part of an ICES project to understand long-term changes.

Upwelling off north-west Africa

The coastal waters off north-west Africa are particularly fertile sea areas, due to the process called upwelling, and hence are able to support a large fishery. Upwelling, which is primarily caused by the North-East Trades, results in the enrichment of surface waters by nutrient salts and the subsequent growth of a large plant and animal population. During 1969 an investigation was made within a small area near Cape Blanc, using a survey vessel from MOD (Navy). The rate at which oceanographic conditions change was measured over both time and distance. Very large variations in water structure were observed and this appears to be a relatively common feature of such upwelling areas. The results of this survey, which are about to be published, form part of a series of similar investigations made off the coast of west Africa by this laboratory during earlier years. Upwelling is a widespread phenomenon and the principles emerging from these studies will have other applications.

COMPUTING AND STATISTICAL SERVICES

The major task of this group (Head of Unit - J. G. K. Harris) is to provide a data-processing service to the remainder of the laboratory; hence much of the work is covered by other sections of the report. This account is therefore limited to the work of developing new computer systems.

Demersal and pelagic fisheries

Collection and tabulation of fisheries statistics

A new system for recording fish-landing statistics has been designed to enable more detailed information to be recorded concerning fishing trips split between two or more fishing grounds. The new system is designed for processing on the Ministry's ICL 1907 computer in Guildford to produce tabulations showing quantity and value of fish landed at different ports and from different fishing grounds. Programming was nearing completion by the end of 1971 and collection of data on the new forms commenced on 1 January 1972.

Historical file of fish-landing statistics

A historical file is being compiled on magnetic tape to provide an easily accessible record for all fish landings made in England and Wales from 1940 to the present day. When completed this file will become a major source of data to scientists investigating fish population dynamics.

Fish sampling program

Work is scheduled to start in 1972 on a comprehensive computer system designed to improve on the current Fish Sampling Program on the Elliot 803 computer. As an interim measure a program has been developed for raising age-length keys according to sample length distributions. This program is now used extensively, and has cut considerably the manual work involved in this exercise.

Fish-tagging program

A computer system is being developed for processing all fish-tagging experiments. Magnetic-tape files of all fish tagged will be produced and updated as tagged fish are recaptured. The system will also produce printed lists of tagged fish for circulation to interested organizations, replacing the existing manual preparation of such lists. The system will eventually incorporate a suite of programs for applying to the data on the file such analyses as scientists in the laboratory may require.

It is also intended that many tagging experiments carried out in the past will be put through the new system to build up a historical file of tagging experiments so that old experiments may be subjected to further analysis. This system is expected to become operational during 1972.

Biology

Plankton survey system

A computer system is under development for processing the data collected on regular plankton surveys made in the southern North Sea. The system produces a magnetic tape file of all species counted in the plankton samples at each station of each cruise. This file can be processed to tabulate distributions for each species for each cruise or can be linked with a contouring program to produce contoured distribution maps.

The system has operated successfully on a survey in which only a limited number of species were counted, and is now being expanded to produce the full working system.

Hydrography

Current meter data processing

A computer system was under development during 1971 for processing data collected by Plessey moored current meters. The program detects and smooths irregularities in the data, calculates velocity, direction and temperature or pressure and also calculates hourly and tidal means of these quantities. The results are transferred to a historical file on magnetic tape for further processing in the future.

The program was under test at the end of 1971 and will commence routine working early in 1972.

Gear research and fish detection

Transformation of ARL Scanner pictures

A program has been developed which uses a pencil-follower, computer and graph-plotter to transform pictures from the Scanner films of plots of range against angle to true views of the area under scan. The program has been operational since mid-1971.

Radiobiology

Analysis of gamma-spectra by least squares fit

A program was developed during 1969-70 to analyse gamma-spectra by a least squares fit of standard spectra. The system commenced operation in October 1970 and now processes some 20-40 samples a week, recording the results on a historical file on magnetic tape.

PUBLICATIONS

NOTE: Where there is more than one author and not all of them are MAFF, the names of the MAFF author(s) are underlined.

1969

Anderson, K. P., Burd, A. C., Popp Madsen, K., Saville, A., Schubert, K. and Zijlstra, J. J. Report of the North Sea young herring working group. Coop. Res. Rep. int. Coun. Explor. Sea (A), No. 14, 1-87.

Arnold, G. P. The orientation of plaice larvae (Pleuronectes platessa L.) in water currents. J. exp. Biol., Vol. 50, 785-801.

Arnold, G. P. A flume for behaviour studies of marine fish. J. exp. Biol., Vol. 51, 671-679.

Arnold, G. P. The reactions of the plaice (Pleuronectes platessa L.) to water currents. J. exp. Biol., Vol. 51, 681-697.

Bannister, R. C. A. and Flatman, S. Forty-year-old plaice landed. Fishg News, Aberd., No. 2911, p.6.

Bayne, B. L. The gregarious behaviour of the larvae of Ostrea edulis L. at settlement. J. mar. biol. Ass. U.K., Vol. 49, 327-356.

Berry, Nancy J. Herring recruits racial surveys - a summary of computer programs. Coop. Res. Rep. int. Coun. Explor. Sea (A), No. 14, Appendix 2, 4 pp.

Birkett, L. The nitrogen balance in plaice, sole and perch. J. exp. Biol., Vol. 50, 375-386.

Birkett, L. Calorimetry: modification of a standard bomb for small heat outputs. J. Cons. perm. int. Explor. Mer, Vol. 32, 437-440.

Blacker, R. W. Chemical composition of the zones in cod (Gadus morhua L.) otoliths. J. Cons. perm. int. Explor. Mer, Vol. 33, 107-108.

Blacker, R. W. English observations on rare fish in 1968. Annls biol., Copenh., Vol. 25, 257-259.

Blacker, R. W. Rare or unusual fish, 1968. Suffolk Natural History, Vol. 15, Part 1, 62-63.

Boyd, H., Jamieson, A. and Hall, J. G. Fertilization rate and embryonic survival in dairy cows in relation to transferrin and J. antigen groupings of sires and dams. J. Reprod. Fert., Vol. 18, 317-323.

Bridger, J. P. The behaviour of demersal fish in the path of a trawl. Fish. Rep. F.A.O., No. 62, Vol. 3, 695-715.

Brown, C. G. Exploratory fishing for crabs in the English Channel, 18-22 May, 1969. Shellfish Inf. Leafl. Fish. Lab., Burnham, No. 15, 4 pp., 2 tables, 3 figs (mimeo).

Cushing, D. H. Models of the productive cycle in the sea. Morning Review Lectures of the Second International Oceanographic Congress, Moscow, 1966, 103-115, UNESCO, Paris, 1969.

Cushing, D. H. The estimation of fish abundance. F.A.O. Fish. tech. Pap., No. 83, 57-61.

Cushing, D. H. The regularity of the spawning season of some fishes. J. Cons. perm. int. Explor. Mer, Vol. 33, 81-92.

Cushing, D. H. Migration and abundance. pp. 207-212 in "Perspectives in Fisheries Oceanography". Bull. Jap. Soc. Fish. Oceanogr. Special number 1969.

Cushing, D. H. The fluctuation of year-classes and the regulation of fisheries. FiskDir. Skr., (Ser. Havunders.), Vol. 15, 368-379.

Cushing, D. H. Acoustic fish counting. Oceanology International 69 Conference; Technical Sessions, Day 4, Session C (pages unnumbered).

Cushing, D. H. Upwelling and fish production. F.A.O. Fish. tech. Pap., No. 84, 40 pp.

Cushing, D. H. (Abstract) The dates at which fish spawn. Proc. Challenger Soc., Vol. 4, Part 1, p. 33.

Cushing, D. H. The use of echo sounders and scanners in the study of fish behaviour. Fish. Rep. F.A.O., No. 62, Vol. 2, 115-130.

Dickson, R. and Lee, A. Atmospheric and marine climate fluctuations in the North Atlantic region. Prog. Oceanogr., Vol. 5, 55-65.

Doddington, T. C. and Jones, S. R. Temperature observations at English and Welsh coastal stations during 1968. Annls biol., Copenh., Vol. 25, 46-48.

Dunster, H. J., Kenny, A. W., Neal, W. T. L. and Preston, A. The British approach to environmental monitoring. Nucl. Saf., Vol. 10, No. 6, 504-513.

Dutton, J. W. R. Gamma-spectrometric analysis of environmental materials. Tech. Rep. Fish. radiobiol. Lab., Lowestoft, FRL 4, 18 pp.

Ellett, D. J., Jones, S. R. and Read, G. Surface temperature and salinity observations at English sampling stations during 1968. Annls biol., Copenh., Vol. 25, 34-46.

Fryer, G. and Iles, T. D. Alternative routes to evolutionary success as exhibited by African cichlid fishes in the genus Tilapia and the species flocks of the Great Lakes. Evolution, Vol. 23, 359-369.

Garrod, D. J. Empirical assessments of catch/effort relationships in North Atlantic cod stocks. Res. Bull. int. Commn NW. Atlant. Fish., No. 6, 26-34.

Garrod, D. J. Market sampling 1968. MAFF, 18 pp. (mimeo).

Garrod, D. J. Market sampling 1969. MAFF, 18 pp. (mimeo).

Garrod, D. J. and Parrish, B. B. United Kingdom Research Report, 1968. Redbook int. Commn NW. Atlant. Fish., Part II, 118-120.

Hancock, D. A. Oyster pests and their control. Lab. Leafl. Fish Lab., Lowestoft, No. 19 (New Series), 30 pp.

Holden, M. J. Selectivity experiments on the Grand Bank of Newfoundland in 1967. Redbook int. Commn NW. Atlant. Fish., 1969, Part III, 109-113.

Holden, M. J. Review of "Theory of fish population dynamics" by G. V. Nikolski. New Scient., Vol. 44, No. 678, p. 521.

Holden, M. J. Summary of fishing prospects. Fishg News, Aberd., No. 2908, p. 7.

Holden, M. J. and Jones, B. W. The effect of a Polish type chafer on cod-end selectivity for haddock. Coop. Res. Rep. int. Coun. Explor. Sea (B), 1968, Appendix 2, 47-50.

Horsted, Sv. Aa. and Garrod, D. J. A yield per recruit function for sub-area 1 cod. Redbook int. Commn NW. Atlant. Fish., 1969, Part III, 17-21.

Iles, T. D. and Holden, M. J. Bi-parental mouth brooding in Tilapia galilaea (Pisces, cichlidae). J. Zool., Vol. 158, 327-333.

Jefferies, D. F. and Preston, A. Summary of field studies in the United Kingdom. pp. 67-71, In: Proc. Seminar on Marine Radioecology, Cherbourg, 3-6 December 1968. Organization for Economic Cooperation and Development and European Nuclear Energy Agency, 150 pp.

Johnson, P. O. The English sprat fisheries, results of the 1968/69 season. Annls biol., Copenh., Vol. 25, 222-230.

Jones, F. R. Harden Observations on the behaviour of fish made with the bifocal sector scanner. Fish. Rep. F.A.O., No. 62, Vol. 3, 667-670.

Jones, F. R. Harden and Hester, F. New developments in sonar techniques. F.A.O. Fish. tech. Pap., No. 83, 63-70.

Key, D. Methods of cultivating small oysters. Shellfish Inf. Leafl. Fish. Lab., Burnham, No. 14, 12 pp., 6 figs (mimeo).

Lee, A. J. (Abstract) The variability of the Atlantic current in the Norwegian Sea. Proc. Challenger Soc., Vol. 4, Part 1, 54-55.

Lee, A. J. and Folkard, A. R. Factors affecting turbidity in the southern North Sea. J. Cons. perm. int. Explor. Mer, Vol. 32, 291-302.

Margetts, A. R. Catching clupeoid fish by pelagic trawl. Fish. Rep. F.A.O., No. 62, Vol. 3, 499-508.

Margetts, A. R. Gear research without disturbing the environment. Oceanology International 69 Conference; Technical Sessions, Day 3, Session E (pages unnumbered).

Margetts, A. R. Comparative and experimental fishing methods for studying fish behaviour in the natural environment. Fish Rep. F.A.O., No. 62, Vol. 2, 131-138.

Mitchell, N. T. Monitoring of the aquatic environment of the United Kingdom and its application to hazard assessment. Environmental Contamination by Radioactive Materials, IAEA, Vienna, 449-462.

Mitchell, N. T. Radioactivity in surface and coastal waters of the British Isles 1968. Tech. Rep. Fish. radiobiol. Lab., Lowestoft, FRL 5, 39 pp.

Mitson, R. B. The structure and functioning of sonar equipment. F.A.O. Fish. tech. Pap., No. 83, 17-33.

Mitson, R. B. Instrumentation in fisheries research. Underwat. Sci. Technol. J., Vol. 1, No. 3, 116-123.

Mitson, R. B. (Abstract) Development and application of the triton acoustical counter. Proc. BCF Acoustical Workshop, 25-27 Nov. 1968, 27-28.

Preston, A. Aquatic monitoring programmes. Environmental Contamination by Radioactive Materials, IAEA, Vienna, 309-324.

Preston, A. and Dutton, J. W. R. The application of neutron activation analysis to the study of trace elements in United Kingdom coastal waters. International Symposium on the Application of Neutron Activation Analysis in Oceanography, held in Brussels, June 1968. NATO, Paris, 117-142.

Preston, A. and Jefferies, D. F. Aquatic aspects in chronic and acute contamination situations. Environmental Contamination by Radioactive Materials, IAEA, Vienna, 183-211.

Preston, A. and Jefferies, D. F. The ICRP critical group concept in relation to the Windscale sea discharges. Hlth Phys., Vol. 16, 33-46.

Purdom, C. E. Radiation-induced gynogenesis and androgenesis in fish. Heredity, Lond., Vol. 24, Part 3, 431-444.

Purdom, C. E. and Wyatt, T. Racial differences in Irish Sea and North Sea plaice (Pleuronectes platessa). Nature, Lond., Vol. 222, 780-781.

Ramster, J. W. and Hill, H. W. Current system in the northern Irish Sea. Nature, Lond., Vol. 224, 59-61.

Reeve, M. R. The suitability of the English prawn Palaemon serratus (Pennant) for cultivation - a preliminary assessment. Fish. Rep. F.A.O., No. 57, Vol. 3, 1067-1073.

Reeve, M. R. The laboratory culture of the prawn Palaemon serratus. Fishery Invest., Lond., Ser. 2, Vol. 26, No. 1, 38 pp.

Reeve, M. R. Growth, metamorphosis and energy conversion in the larvae of the prawn, Palaemon serratus. J. mar. biol. Ass. U.K., Vol. 49, 77-96.

Reynolds, N. The settlement and survival of young mussels in the Conway fishery. Fishery Invest., Lond., Ser. 2, Vol. 26, No. 2, 24 pp.

Riley, J. D. New fish from old. Spectrum: Brit. Sci. News, No. 61, 5-6.

Riley, J. D. Hibridacion entre especies marinas. Industrias pesq., Vigo, Ano. XLIII, Num. 1013, 388-389.

Riley, J. D. and Thacker, G. T. New intergeneric cross within the Pleuronectidae, dab x flounder. Nature, Lond., Vol. 221, 484-486.

Rolfe, M. S. Escallops off Plymouth. Shellfish Inf. Leafl. Fish. Lab., Burnham, No. 13, 6 pp., 2 tables, 7 figs (mimeo).

Shelbourne, J. E. Marine cultivation techniques in Japan. Proc. Challenger Soc., Vol. 4, Part 1, 18-19.

Wheeler, A. and Blacker, R. W. Rare and little-known fishes in British seas in 1966 and 1967. J. Fish Biol., Vol. 1, 311-331.

Wood, P. C. The production of clean shellfish. Lab. Leafl. Fish. Lab., Lowestoft, No. 20 (New Series), 10 pp.

Wood, R. J. and Parnell, W. G. The English herring fisheries in 1968. Annls biol., Copenh., Vol. 25, 180-185.

Woodhead, P. M. J. Influence of oestradiol 3-Benzoate upon the plasma content of calcium and vitamin A aldehydes in the cod, Gadus morhua. J. mar. biol. Ass. U.K., Vol. 49, 939-944.

Woodhead, P. M. J. Effects of oestradiol and thyroxine upon the plasma calcium content of a shark, Scyliorhinus canicula. Gen. comp. Endocr., Vol. 13, No. 2, 310-312.

Wooster, W. S., Lee, A. J. and Dietrich, G. Redefinition of salinity. Deep-Sea Res., Vol. 16, 321-322; Limnol. Oceanogr., Vol. 14, No. 3, 437-438. Nouvelle definition de la salinité. Cah. Océanogr., Année XXI, No. 6, 539-542.

1970

Baker, C. W. and Mitchell, N. T. Investigations of liquid effluent from CEGB nuclear power stations, 1969. Tech. Note Fish. radiobiol. Lab., Lowestoft, No. 6, 3 pp., 2 figs.

Bannister, R. C. A. The biology and population dynamics of the plaice (Pleuronectes platessa L.) at Iceland. Ph.D. thesis, University of East Anglia, 100 pp.

Bedford, B. C. Cod - 'question-and-answer' form article. Angling Times, 5 March 1970.

Benko, Yu. K., Dragesund, O., Hognestad, P. T., Jones, B. W., Monstad, T., Nizovstev, G. P., Olsen, S. and Seliverstov, A. S. Distribution and abundance of 0-group fish in the Barents Sea in August-September 1965-1968. Coop. Res. Rep. int. Coun. Explor. Sea (A), No. 18, 35-76.

Bennett, D. B. Tagged crabs. Angling Times, 29 July 1970.

Bennett, D. B. and Brown, C. G. Crab investigations in south-west England. A progress report. Shellfish Inf. Leafl. Fish. Lab., Burnham, No. 18, 12 pp.

Birkett, L. Experimental determination of food conversion and its application to ecology. pp. 261-264, In: Steele, J. H. (Ed.) Marine Food Chains, Proc. Symp. held at Univ. Aarhus, Denmark, 23-26 July 1968. Oliver and Boyd, Edinburgh, 552 pp.

Blacker, R. W. English observations on rare fish in 1969. Annls biol., Copenh., Vol. 26, 279-280.

Cole, H. A. Review of "Pollution and Marine Ecology" by T. A. Olsen and F. J. Burgess (Eds.). J. appl. Ecol., Vol. 7, No. 1, 205-206.

Cole, H. A. Fish farming. IFST Proc., Vol. 3, No. 3, 86-90.

Cushing, D. H. The use of sonar and echo sounders in fisheries research. Fish. Rep. F.A.O., No. 62, 115-130.

Cushing, D. H. Pelagic food chains. pp. 69-73, In: Steele, J. H. (Ed.) Marine Food Chains, Proc. Symp. held at Univ. Aarhus, Denmark, 23-26 July 1968. Oliver and Boyd, Edinburgh, 552 pp.

Cushing, D. H. and Dickson, R. R. Productivity in the North Atlantic. Proc. Challenger Soc., Vol. 4, Part 2, p. 71.

Dare, P. J. The movements of oystercatchers (Haematopus ostralegus Linnaeus) visiting or breeding in the British Isles. Fishery Invest., Lond., Ser. 2, Vol. 25, No. 9, 137 pp.

Davies, G. Mussels as a world food resource. Proc. Symp. on Mollusca, Mar. Biol. Ass., India, Part III, 873-884.

Dickson, R. R. and Doddington, T. C. Hydrographic conditions off Spitsbergen in the summers of 1968 and 1969. Annls biol., Copenh., Vol. 26, 26-32.

Dickson, R. R., Midttun, L. and Mukhin, A. I. International 0-group fish surveys in the Barents Sea 1965-1968. Section 1: The hydrographic conditions in the Barents Sea in August-September 1965-1968. Coop. Res. Rep. int. Coun. Explor. Sea (A), No. 18, 3-24.

Dutton, J. W. R. The determination of radiocaesium in sea and fresh waters. Tech. Rep. Fish. radiobiol. Lab., Lowestoft, No. 6, 9 pp.

Ellett, D. J., Dixey, D. J. and Horwood, J. W. Surface temperatures and salinity conditions in the vicinity of Rockall Bank, October 1968 to November 1969. Annls biol., Copenh., Vol. 26, 36-43.

Ellett, D. J. and Martin, J. H. A. (Abstract) The physical oceanography of the Rockall Channel. Proc. Challenger Soc., Vol. 4, Part 2, 89-90.

Folkard, A. R. Hydrographic investigations in the English Channel and southern North Sea, January 1969, and Irish Sea, November-December 1969. Annls biol., Copenh., Vol. 26, 82-85.

Folkard, A. R. and Jones, S. R. Surface temperature and salinity observations at English sampling stations during 1969. Annls biol., Copenh., Vol. 26, 54-68.

Folkard, A. R. and Jones, S. R. Temperature observations at English and Welsh coastal stations during 1969. Annls biol., Copenh., Vol. 26, 69-70.

Foster, J. J. and Bridger, J. P. Some British comparative fishing experiments conducted over the period 1963-1968. Rep. 8th Int. Working Group for Fish. Technol., Meeting, Lowestoft, 29-30 April 1969, Contrib. No. 7, 57-75.

Garrod, D. J. United Kingdom Research Report, 1969. Subareas 1-3. A. Status of the fisheries. Redbook int. Commn NW. Atlant. Fish., Part II, p.147.

Garrod, D. J., Holden, M. J. and Simpson, A. C. Fish and shellfish production in the United Kingdom: the future outlook. Proc. Marketing Conference.

Gulland, J. Food chain studies and some problems in world fisheries. pp. 296-315, In: Steele, J. H. (Ed.) Marine Food Chains, Proc. Symp. held at Univ. Aarhus, Denmark, 23-26 July 1968. Oliver and Boyd, Edinburgh, 552 pp.

Hancock, D. A. Abstract from verbal presentation of "Problems with edible molluscs". Proc. malac. Soc. Lond., Vol. 39, No. 2/3, 243-246.

Hancock, D. A. An experiment with overcrowded cockles (Cardium edule). Proc. Symp. on Mollusca, Mar. Biol. Ass., India, Part III.

Harding, D. The fisheries of the Bangweulu region of Zambia. J. appl. Ecol., Vol. 7, No. 1, p.2P.

Harvey, B. R. and Morrell, C. Radiochemical analysis of biological materials. Tech. Note Fish. radiobiol. Lab., Lowestoft, No. 5, 14 pp.

Harvey, B. R. and Sutton, G. A. Liquid scintillation counting of nickel-63. International Journal of Applied Radiation and Isotopes, Vol. 21, 519-523.

Hill, H. W. (Abstract) Current systems of the northern Irish Sea. Proc. Challenger Soc., Vol. 4, Part 2, 63-64.

Hill, H. W. Measuring currents on fishing grounds. Fishg News, Aberd., No. 2958, p.7.

Holden, M. J. The feeding habits of Alestes baremose and Hydrocynus forskali (Pisces) in Lake Albert, East Africa. J. Zool., Vol. 160, Part 1, 137-144.

Holden, M. J. Summary of the fishing prospects in distant, middle and near waters for English and Welsh vessels. Fishg News, Aberd., No. 2960, p.2.

Holden, A. V. and Portmann, J. E. Monitoring organo-chlorine residues. Mar. Pollut. Bull., Vol. 1, No. 3, 41-42.

Howell, B. R. and Shelton, R. G. J. The effect of china clay on the bottom fauna of St. Austell and Mevagissey Bays. J. mar. biol. Ass. U.K., Vol. 50, 593-607.

Jamieson, A. Cod transferrins and genetic isolates. pp. 533-538, In: Proc. XI European Conference on Animal Blood Groups and Biochemical Polymorphism, Warsaw, 2-6 July 1968. Dr W. Junk N.V., Publishers, The Hague, 607 pp.

Jefferies, D. F. Exposure to radiation from gamma-emitting fission-product radionuclides in estuarine sediments from the north-east Irish Sea. pp. 205-216, In: Environmental surveillance in the vicinity of nuclear facilities. Proc. Mid-year Tropical Symposium of the Health Physics Society, Jan. 1968, W. C. Reinig (Ed.). Charles C. Thomas, Springfield, Illinois, 465 pp.

Jefferies, D. F., Steele, A. K. and Wastell, C. Devonport Local Habits Survey 1970. Tech. Note Fish. radiobiol. Lab., Lowestoft, No. 4, 5 pp.

Johnson, P. O. The Wash sprat fishery. Fishery Invest., Lond., Ser. 2, Vol. 26, No. 4, 77 pp.

Johnson, P. O. and Hulme, T. J. The English sprat fisheries: results of the 1969-70 season. Annls biol., Copenh., Vol. 26, 240-248.

Jones, A. Some aspects of the biology of the turbot (Scophthalmus maximus L.) with special reference to feeding and growth in the juvenile stage. Ph.D. thesis, University of East Anglia, 145 pp.

Jones, B. W. and Mackie, I. M. An application of electrophoretic analysis of muscle myogens to taxonomic studies in the genus Merluccius. Comp. Biochem. Physiol., Vol. 32, 267-273.

Jones, F. R. Harden Review of "The Natural History of Sharks" by T. Lineaweaver III and R. H. Backus. Nature, Lond., Vol. 227, No. 5254, p. 206.

Jones, F. R. Harden and Scholes, P. Antifreeze, cold water and cod (Gadus morhua Linn.). Proc. Challenger Soc., Vol. 4, Part 2, p. 59.

Jones, P. G. W. Review of "Marine Chemistry" by R. A. Horne. Deep Sea Res., Vol. 17, p. 1027.

Jones, P. G. W. and Folkard, A. R. Chemical oceanographic observations off the coast of N.W. Africa with special reference to the process of upwelling. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer, Vol. 159, 38-60.

Kenny, A. W. and Mitchell, N. T. United Kingdom waste - management policy. pp. 69-90, In: Management of Low- and Intermediate-level Radioactive Wastes, IAEA, Vienna, 814 pp.

Key, D. Further results from experiments on the culture of small oysters. Shellfish Inf. Leafl. Fish. Lab., Burnham, No. 17, 12 pp.

Lee, A. J. The currents and water masses of the North Sea. pp. 33-71, In: Barnes, H. (Ed.) Oceanography and Marine Biology, Vol. 8. Allen and Unwin, London, 628 pp.

Lee, A. J. Hydrographic conditions in the ICNAF area in 1969. Annls biol., Copenh., Vol. 26, 11-12.

Macer, C. T. and Boon, T. W. The fishery for sandeels off the English east coast in 1969. Annls biol., Copenh., Vol. 26, 265-267.

Macer, C. T. and Burd, A. C. Fishing for sandeels. Lab. Leafl. Fish. Lab., Lowestoft, No. 21 (New Series), 9 pp.

Margetts, A. R. and Bridger, J. P. Some guiding rules for the conduct of comparative fishing experiments. Rep. 8th Int. Working Group for Fish. Technol., Meeting, Lowestoft, 29-30 April 1969, Contrib. No. 12, 111-113.

Mitchell, N. T. Radioactive waste disposal from Windscale. Mar. Pollut. Bull., Vol. 1, No. 11, 172-174.

Mitchell, N. T. Radioactivity in surface and coastal waters of the British Isles 1968. Tech. Rep. Fish. radiobiol. Lab., Lowestoft, No. 5, 39 pp.

Mitson, R. B. and Cook, J. C. Shipboard installation and trials of an electronic sector scanning sonar. Proc. Conf. on Electronic Engineering in Ocean Technology, Univ. Coll. Swansea, 21-24 September 1970. IERE Conf. Proc. No. 19, 187-210.

Portmann, J. E. The toxicity of 120 substances to marine organisms. Shellfish Inf. Leafl. Fish. Lab., Burnham, No. 19, 10 pp.

Portmann, J. E. The effect of china clay on the sediments of St. Austell and Mevagissey Bays. J. mar. biol. Ass. U.K., Vol. 50, 577-591.

Preston, A. Concentrations of iron-55 in commercial fish species from the North Atlantic. Mar. Biol., Vol. 6, No. 4, 345-349.

Preston, A. and Dutton, J. W. R. Review of methods for the determination of selected cobalt nuclides in marine materials. Reference Methods for Marine Radioactivity Studies, IAEA, Monaco, 1970. pp. 223-241, In: Tech. Rep. Ser. No. 118, 284 pp.

Price, N. B., Calvert, S. E. and Jones, P. G. W. The distribution of iodine and bromine in the sediments of the south-western Barents Sea. J. mar. Res., Vol. 28, No. 1, 22-34.

Purdom, C. E. Gynogenesis: a rapid method for producing inbred lines of fish. Fishg News int., Vol. 9, No. 9, 29-32.

Shelbourne, J. E. Marine fish cultivation: priorities and progress in Britain. pp. 15-36, In: McNeil, W. J. (Ed.) Marine Aquiculture. Oregon State Univ. Press, Corvallis, Oregon, 172 pp.

Shelton, R. G. J. Dispersant toxicity test procedures. pp. 187-191, In: Proc. Joint API/FWPCA Conf. on Prevention and Control of Oil Spillages (American Petroleum Institute/Federal Water Pollution Control Administration), 15-17 December 1969.

Shelton, R. G. J. Dust for oiled beaches. Mar. Pollut. Bull., Vol. 1, No. 9, p. 132.

Shelton, R. G. J. and Laverick, M. S. Receptor hair structure and function in the lobster, Homarus gammarus (L.). J. exp. mar. Biol. Ecol., Vol. 4, 201-210.

Simpson, A. C. Molluscan resources. Section Q in: Gulland, J. A. (Comp.), The Fish Resources of the Oceans. F.A.O. Fish. tech. Pap., No. 97, 218-250.

Simpson, A. C., Howell, B. R. and Warren, P. J. Synopsis of biological data on the shrimp, Pandalus montagui (Leach) 1814. Fish. Rep. F.A.O., No. 57, Vol. 4, 1225-1249.

Walker, M. Greer Growth and development of the skeletal muscle fibres of the cod (Gadus morhua L.). J. Cons. perm. int. Explor. Mer, Vol. 33, 228-244.

Walne, P. R. Disease in oysters. Central Office of Information.

Walne, P. R. Introducing new species of bivalves into Britain. Central Office of Information.

Walne, P. R. Present problems in the culture of the larvae of Ostrea edulis. Helgoländer wiss. Meeresunters., Vol. 20, 514-525.

Walne, P. R. Studies on the food value of nineteen genera of algae to juvenile bivalves of the genera Ostrea, Crassostrea, Mercenaria and Mytilus. Fishery Invest., Lond., Ser. 2, Vol. 26, No. 5, 62 pp.

Walne, P. R. The seasonal variation of meat and glycogen content of seven populations of oysters (Ostrea edulis L.) and a review of the literature. Fishery Invest., Lond., Ser. 2, Vol. 26, No. 3, 35 pp.

Walne, P. R. The growth of relaid quahogs (American hard clams) in England and Wales. Shellfish Inf. Leafl. Fish.Lab., Burnham, No. 16, 13 pp.

Waugh, G. D. Fisheries and fishery research in New Zealand. Proc. Challenger Soc., Vol. 4, Part 2, 82-84 (Special Lecture).

Wickins, J. F. Bigger prawns for your table. Central Office of Information.

Wood, P. C. The effects of pollution on marine organisms. pp. 55-63, In: Proc. Symp. on Water Pollution Control in Coastal Areas, Bournemouth, 19-21 May 1970. Inst. Water Pollution Control, London.

Wood, R. J. 0-group herring fisheries in 1969. Annls biol., Copenh., Vol. 26, 224-227.

Woodhead, D. S. The assessment of the radiation dose to developing fish embryos due to the accumulation of radioactivity by the egg. Rad. Res., Vol. 43, 582-597.

1971

Alderman, D. J. and Jones, E. B. Gareth Shell disease of oysters. Fishery Invest., Lond., Ser. 2, Vol. 26, No. 8, 19 pp.

Bannister, R. C. A. Prospects in the Lowestoft plaice fishery. Tech. Rep. Fish. Lab., Lowestoft, No. 1, 19 pp.

Bolster, G. Mackerel of the south-west. Lab. Leafl. Fish. Lab., Lowestoft, No. 23 (New Series), 18 pp.

Boon, Mrs M. J. Non-linear fluorometer response at very low concentration levels. Tech. Rep. Fish. Lab., Lowestoft, No. 2, 8 pp.

Bromley, P. J. Relationship between the wet weight condition factor and nitrogen and energy content in the common sole (Solea solea L.). J. Cons. perm. int. Explor. Mer, Vol. 34, 131-134.

Burd, A. C. Summary of the Report of the North Sea Young Herring Working Group. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer, Vol. 160, 172-174.

Burd, A. C. and Holford, B. H. The decline in the abundance of Downs herring larvae. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer, Vol. 160, 99-100.

Burd, A. C. and Wallace, P. D. The survival of herring larvae. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer, Vol. 160, 46-50.

Cole, H. A. Objectives of biological pollution studies. Proc. R. Soc., Series B, Vol. 177, 277-278.

Cole, H. A. Pollution of the seas. Chem. Br., Vol. 7, No. 6, 232-235.

Cushing, D. H. The dependence of recruitment on parent stock in different groups of fishes. J. Cons. perm. int. Explor. Mer, Vol. 33, 340-362.

Cushing, D. H. Upwelling and the production of fish. pp. 255-334, In: Adv. mar. Biol., Vol. 9, 567 pp.

Cushing, D. H. Review of "Vertical Distribution of the Oceanic Zooplankton" by M. E. Vinogradov. Akad. Nauk. SSSR. Inst. Okeanol., 1968. (Transl. - Israel Program for Scientific Translation, Jerusalem, 1970, 339 pp.). J. Cons. perm. int. Explor. Mer, Vol. 34, 136-138.

Cushing, D. H. Review of "Population, Resources, Environment. Issues in human ecology" by P. R. Ehrlich and A. H. Ehrlich. W. H. Freeman & Co. Ltd., Reading, 1970, 383 pp. J. Cons. perm. int. Explor. Mer, Vol. 34, 143-145.

Davies, G. and Dare, P. J. Research on mussels (Mytilus edulis) in Great Britain. F.A.O. Aquacult. Bull., Vol. 3, No. 2, Suppl., 3 pp.

Dickson, R. R. A recurrent and persistent pressure anomaly pattern as the principal cause of intermediate-scale hydrographic variations in the European shelf seas. Dt Hydrogr. Z., Jahrg. 24, Heft 3, 97-119.

Elder, H. Y., Garrod, D. J. and Whitehead, P. J. P. Natural hybrids of the African cichlid fishes Tilapia spirulus nigra and T. leucosticta: a case of hybrid introgression. Biol. J. Linn. Soc. Lond., Vol. 3, No. 2, 103-146.

Forster, J. R. M. Some methods of binding prawn diets and their effects on growth and assimilation. J. Cons. perm. int. Explor. Mer, Vol. 34, 40-57.

Forster, J. R. M. and Gabbott, P. A. The assimilation of nutrients from compounded diets by two species of prawn, Palaemon serratus Pennant and Pandalus platyceros Brandt. J. mar. biol. Ass. U.K., Vol. 51, 943-961.

Harding, D. and Arnold, G. P. Flume experiments on the hydrodynamics of the Lowestoft high-speed plankton sampler: I. J. Cons. perm. int. Explor. Mer, Vol. 34, 24-36.

Harding, D., Shreeve, E., Tungate, D. S. and Mummery, D. A net-changing mechanism for the Lowestoft multi-purpose sampler. J. Cons. perm. int. Explor. Mer, Vol. 33, 483-491.

Hepper, B. T. Cornish crawfish investigations. Lab. Leafl. Fish. Lab., Lowestoft, No. 22 (New Series), 21 pp.

Hepper, B. T. Notes on Geryon tridens (Decapoda Brachyura) from west of Ireland. J. nat. Hist., Vol. 5, 343-348.

Hepper, B. T. The Cornish crawfish. MAFF Current Topics, July 8th, 1971.

Hill, H. W. Seasonal movement of young plaice in the north-east Irish Sea. Fishery Invest., Lond., Ser. 2, Vol. 26, No. 7, 24 pp.

Holden, M. J. Review of "The Natural History of Sharks" by T. H. Lineaweaver III and R. H. Backus. Andre Deutsch, London, 1970, 256 pp. J. Cons. perm. int. Explor. Mer, Vol. 34, 146-147.

Holden, M. J. (Ed.) Report of the ICES/ICNAF Working Groups on Selectivity Analysis. Coop. Res. Rep. int. Coun. Explor. Sea (A), No. 25, 144 pp.

Holden, M. J. The significance of sexual dimorphism of the anal fin of Polypteridae. Nature, Lond., Vol. 232, No. 5306, 135-136.

Holden, M. J., Rout, D. and Humphries, C. The rate of egg-laying by three species of ray. J. Cons. perm. int. Explor. Mer, Vol. 33, 335-339.

Iles, T. D. Growth studies on North Sea herring. III. The growth of East Anglian herring during the adult stage of the life history for the years 1940-67. J. Cons. perm. int. Explor. Mer, Vol. 33, 386-420.

Iles, T. D. Ecological aspects of growth in African cichlid fishes. J. Cons. perm. int. Explor. Mer, Vol. 33, 363-385.

Jamieson, A. Review of "Richerche Immunologiche ed Elettroforetiche Sulla Systematica e Biologia dei Salmonidi" by S. Scagnetti and V. Parisi. Boll. Pesca Piscic. Idrobiol., Vol. 22, 1967, 121-147. J. Cons. perm. int. Explor. Mer, Vol. 33, 519-520.

Jamieson, A. and Howlett, G. A system of muscle esterase variants in the sprat (Sprattus sprattus). Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer, Vol. 161, 45-47.

Jamieson, A. and Jonsson, J. The Greenland component of spawning cod at Iceland. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer, Vol. 161, 65-72.

Jamieson, A., De Ligny, W. and Naevdal, G. Serum esterases in mackerel, Scomber scombrus L. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer, Vol. 161, 109-117.

Jamieson, A. and Otterlind, G. The use of cod blood protein polymorphisms in the Belt Sea, the Sound and the Baltic Sea. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer, Vol. 161, 55-59.

Jefferies, D. F. and Hewett, C. J. The accumulation and excretion of radioactive caesium by the plaice (Pleuronectes platessa) and the thornback ray (Raia clavata). J. mar. biol. Ass. U.K., Vol. 51, 411-422.

Jones, A. Fish culture in North America. Tech. Rep. Fish. Lab., Lowestoft, No. 3, 44 pp.

Jones, B. W. and Jonsson, J. Coalfish tagging experiments at Iceland. Rit. Fiskideild., Vol. 5, No. 1, 1-27.

Jones, F. R. Harden The response of a planarian Dendrocoelum lacteum to an increase in light intensity. Anim. Behav., Vol. 19, 269-276.

Jones, P. G. W. The Southern Benguela Current region in February 1966: chemical observations with particular reference to upwelling. Deep Sea Res., Vol. 18, 193-208.

Jones, P. G. W. and Folkard, A. R. Hydrographic observations in the eastern Irish Sea with particular reference to the distribution of nutrient salts. J. mar. biol. Ass. U.K., Vol. 51, 159-182.

Kirk, R. G. Reproduction of Lumbricillus rivalis (Levinsen) in laboratory cultures and in decaying seaweed. Ann. appl. Biol., Vol. 67, 255-264.

Lee, A. J. Fish flourish but scientists worried. Times, 19 October, p. VI.

Lloyd, I. J. Primary production off the coast of north-west Africa. J. Cons. perm. int. Explor. Mer, Vol. 33, 312-323.

Macer, C. T. The extension of economic fisheries into the deep ocean. pp. 247-253, In: Herring, P. J. and Clarke, M. R. Deep Oceans. Arthur Barker Ltd., London, 320 pp.

Mitchell, N. T. Radioactivity in surface and coastal waters of the British Isles 1969. Tech. Rep. Fish. radiobiol. Lab., Lowestoft, No. 7, 33 pp.

Mitchell, N. T. Control and disposal of radioactive waste in the United Kingdom. "Environmental Engineering Aspects of Pollution Control", Symp. of the Soc. of Environmental Engnrs, Olympia, 1971. London, The Society, pag. var.

Mitchell, N. T. Radioactivity in surface and coastal waters of the British Isles 1970. Tech. Rep. Fish. radiobiol. Lab., Lowestoft, No. 8, 35 pp.

Mitson, R. B. and Cook, J. C. Shipboard installation and trials of an electronic sector scanning sonar. Radio and Electron. Eng., Vol. 41, No. 8, 339-350.

Mitson, R. B. and Storeton-West, T. J. A transponding acoustic fish tag. Radio and Electron. Eng., Vol. 41, No. 11, 483-489.

Nichols, J. H. Pleuronectidae. Fiches d'identification des oeufs et larves de poissons. Fich. Ident. Oeufs Larves Poissons, Nos. 4-6, 18 pp.

Pentreath, R. J. and Jefferies, D. F. The uptake of radionuclides by I-group plaice (Pleuronectes platessa L.) off the Cumberland coast, Irish Sea. J. mar. biol. Ass. U.K., Vol. 51, 963-976.

Portmann, J. E. Monitoring for metals in marine animals. Mar. Pollut. Bull., Vol. 2, No. 10, 157-158.

Portmann, J. E. Risks of pollution from exploitation of the seabed. "Environmental Engineering Aspects of Pollution Control", Symp. of the Soc. of Environmental Engnrs, Olympia, 1971. London, The Society, pag. var.

Portmann, J. E. and Wilson, K. W. The toxicity of 140 substances to the brown shrimp and other marine animals. (2nd ed.). Shellfish inf. Leafl. Fish. Lab., Burnham, No. 22, 2 pp., tables.

Preston, A. The United Kingdom approach to the application of ICRP standards to the controlled disposal of radioactive waste resulting from nuclear power programmes. pp. 147-157, In: "Environmental Aspects of Nuclear Power Stations", Proc. Symp., New York, 1970, org. by IAEA and USAEC. Vienna, IAEA, 970 pp.

Preston, A. and Wood, P. C. Monitoring the marine environment. Proc. R. Soc., Series B, Vol. 177, 451-462.

Purdom, C. E. and Howard, A. E. Ciliate infestations: a problem in marine fish farming. J. Cons. perm. int. Explor. Mer, Vol. 33, 511-514.

Ramster, J. New light on the North Sea. Lowestoft Journal, 22 January; Grimsby Evening Telegraph, 27 January.

Reynolds, E. A constant geometry approach to in situ seabed gamma monitoring. Hlth Phys., Vol. 20, 241-251.

Riley, J. D. The Riley push net. pp. 286-290, In: Holme, N. A. and McIntyre, A. D. Methods for the Study of Marine Benthos. Inst. Biol. Progr., London, 334 pp. (IBP Handbook No. 16).

Romeril, M. G. The uptake and distribution of ^{65}Zn in oysters. Mar. Biol., Vol. 9, No. 4, 347-354.

Shelton, R. G. J. Oil pollution and commercial fisheries in Britain. pp. 377-379, In: Hepple, P. (Ed.) Water Pollution by Oil, Proc. Seminar, Aviemore, May 1970. Inst. Petroleum, London, 393 pp.

Shelton, R. G. J. Effects of oil and oil dispersants on the marine environment. Proc. R. Soc., Series B, Vol. 177, 411-422.

Shelton, R. G. J. Sludge dumping in the Thames Estuary. Mar. Pollut. Bull., Vol. 2, No. 2, 24-27.

Shelton, R. G. J. and Mackie, A. E. Studies on the chemical preferences of the shore crab, Carcinus maenas (L.). J. exp. mar. Biol. Ecol., Vol. 7, No. 1, 41-49.

Simpson, A. C. Diel spawning behaviour in populations of plaice, dab, sprat and pilchard. J. Cons. perm. int. Explor. Mer, Vol. 34, 58-64.

Symonds, D. J. and Pickett, G. D. The Buxey Sand - its potential as a cockle fishery. Shellfish Inf. Leafl. Fish. Lab., Burnham, No. 20, 4 pp., figs, tables.

Symonds, D. J. and Simpson, A. C. The survival of small Nephrops returned to the sea during commercial fishing. J. Cons. perm. int. Explor. Mer, Vol. 34, 89-97.

Tilis, D., Mourant, A. E. and Jamieson, A. Red-cell enzyme variants of Icelandic and North Sea cod (Gadus morhua). Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer, Vol. 161, 73-74.

Walker, M. Greer Effect of starvation and exercise on the skeletal muscle fibres of the cod (Gadus morhua L.) and the coalfish (Gadus virens L.) respectively. J. Cons. perm. int. Explor. Mer, Vol. 33, 421-427.

Walker, M. Greer, Mitson, R. B. and Storeton-West, T. J. Trials with a transponding acoustic fish tag tracked with an electronic sector scanning sonar. Nature, Lond., Vol. 229, No. 5281, 196-198.

Walne, P. R. The introduction of the Pacific oyster. MAFF Current Topics, 13 May.

Walne, P. R. and Spencer, B. E. The introduction of the Pacific oyster (Crassostrea gigas) into the United Kingdom. Shellfish Inf. Leafl. Fish. Lab., Burnham, No. 21, 8 pp., figs.

Williams, T. Keeping a tag on fish. MAFF Current Topics, 25 November.

Wood, R. J. Some observations on the vertical distribution of herring larvae. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer, Vol. 160, 60-64.

Wood, R. J. Whitebait herring on the English east coast. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer, Vol. 160, 166-171.

Wood, R. J. Autumn-spawning grounds of herring to the west of Scotland. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer, Vol. 160, 65-73.

Woodhead, D. S. The biological effects of radioactive waste. Proc. R. Soc., Series B, Vol. 177, 423-437.

PRINCIPAL RESPONSIBILITIES AND RESEARCH INTERESTS OF SENIOR MEMBERS OF THE SCIENTIFIC STAFF
(1 FEBRUARY 1973)

Chief Scientific Officer	H. A. Cole, CMG, DSc, FI Biol	Director of Fishery Research; fishery management, marine pollution; fish and shellfish cultivation
Deputy Chief Scientific Officers	A. J. Lee, DSC, MA	Deputy Director of Fishery Research; fishery management; North Atlantic hydrography; research vessel management
	A. Preston, BSc	Deputy Director of Fishery Research; marine pollution; control and monitoring of radioactive waste management; radiobiology: study of heavy metals and their radionuclides
Principal Scientific Officer	R. G. J. Shelton, BSc, PhD	Assistant to Dr Cole; marine pollution; ecological studies; biological effects

Demersal Fish Populations Section

Senior Principal Scientific Officer	D. J. Garrod, BSc	Head of Section; conservation of demersal fish stocks; fish population dynamics
Principal Scientific Officers	M. J. Holden, BA	Near-water demersal fisheries; ecology and population dynamics of marine fishes, and in particular of elasmobranchs
	R. W. Blacker, BSc	Biology of commercial fish; ageing techniques; distribution of fish; underwater photography
	B. W. Jones, BSc	Ecology and dynamics of exploited marine fish populations; hake

Demersal Fish Populations Section (continued)

Senior Scientific Officers	T. Williams	Biology of exploited marine fish populations; fish sampling; soles
	R. C. A. Bannister, BSc, PhD	Population dynamics and ecology of marine fishes, and in particular of flatfish
	J. G. Pope, BSc, FSS	Fish stock assessment; modelling and computer simulation

Pelagic Fish Populations Section

Senior Principal Scientific Officer	A. C. Burd, BSc	Head of Section; population dynamics and stock management of pelagic fish stocks, particularly herring
Principal Scientific Officers	G. C. Bolster, BA	Mackerel fisheries, particularly in waters off the south-west coast of Britain
	C. T. Macer, BSc	Industrial fisheries, especially for horse mackerel and sandeels
Senior Scientific Officers	R. J. Wood	Herring fisheries and their relationship with the abundance of larvae and juveniles
	P. O. Johnson, BSc, PhD	Sprat fisheries, particularly in the North Sea; acoustic surveys
	W. G. Parnell	Herring stock assessments

Biology Section

Senior Principal Scientific Officers	D. H. Cushing, MA, DPhil	Head of Section; fish population dynamics; production studies; fish detection
	F. R. Harden Jones, BSc, PhD	Fish behaviour in relation to migration and fishing gear; fish detection
Principal Scientific Officers	G. C. Trout, BSc	Seasonal pelagic behaviour of gadoids; cod migration and ecology; research vessel planning design and construction
	N. Reynolds, BSc, PhD	Taxonomy and ecology of nano-plankton; culture of algae and food organisms for fish larvae
	C. E. Purdom, BSc, PhD	Fish genetics and cytogenetics; fish cultivation
	A. Jamieson, BSc, PhD	Biochemical, serological and genetical identification of fish stocks
	L. Birkett, BSc	Fish growth and food conversion
	D. Harding, BSc	Plankton studies; ecology and population dynamics of larval fish; stock and recruitment; hydrodynamics of plankton samplers and instrumentation
Senior Scientific Officers	D. S. Tungate	Ecology of plankton populations; predation on fish larvae; design of plankton sampling gear and instrumentation
	J. D. Riley, BSc	Marine fish larval rearing; ecology of young fish in inshore and estuarine areas
	T. Wyatt, BSc	Population dynamics and production of plankton

Biology Section (continued)

Senior Scientific Officers	G. P. Arnold, MA, PhD	Fish behaviour in relation to currents and fishing gear; larval fish behaviour in relation to recruitment; hydrodynamics of plankton samplers and avoidance behaviour of plankton
	M. Greer Walker, MA, PhD	Fish locomotion; muscle physiology
	R. G. Kirk, BSc, PhD	Rearing of young flatfish, with special emphasis on food and feeding and the cultivation of live food organisms
	R. Alderson, BSc, PhD	Biology of larval and young flatfish in relation to the chemistry of the rearing environment
	B. R. Howell, BSc	Study of larval flatfish rearing, with special emphasis on food and feeding
	A. Jones, BSc, PhD	Marine fish cultivation; experimental studies on the growth of fishes, and the rearing and biology of fish larvae
	P. Scholes, BA	Fish physiology
	V. J. Bye, BSc	Fish neurobiology and endocrinology

Hydrography Section

Senior Principal Scientific Officer	H. W. Hill, BSc	Head of Section; hydrography of North Atlantic and UK waters; ocean circulation; fisheries hydrography
Principal Scientific Officers	J. W. Talbot, MSc	Estuarine and coastal hydrography; pollution studies

Hydrography Section (continued)

Principal Scientific Officers	J. W. Ramster, BA	Near-water physical oceanography; current measuring
	P. G. W. Jones, BSc, PhD	Chemical oceanography; trace metals; distant-water physical oceanography
Senior Scientific Officers	A. R. Folkard	Chemical oceanography; data processing
	D. J. Ellett	North-east Atlantic physical oceanography
	R. R. Dickson, MA, PhD	Influence of long-term environmental changes on fisheries; distant-water hydrography; effects of marine gravel dredging on fisheries
	G. C. Baxter	Hydrographic instrumentation
	J. A. Durance, MSc, PhD	Mathematical modelling of shallow-seas circulation

Gear Research and Fish Detection

Gear Research

Principal Scientific Officer	A. R. Margetts, MA	Head of Unit; fishing gear design and action; effect of gear on sea bed
Senior Scientific Officer	J. P. Bridger	Fishing gear design and action; effect of gear on sea bed

Fish Detection

Principal Scientific Officer	R. B. Mitson	Head of Unit; instruments for the measurement of physical oceanographic variables; application of acoustic techniques to survey fish stocks and estimate abundance; development and application of acoustic fish tags for tracking and telemetry of physiological variables

Computing and Statistics Section

Senior Scientific Officer	J. G. K. Harris, MA	Head of Section; data processing for fisheries research; stock and recruitment relations in fish populations

Radiobiological Section

Senior Principal Scientific Officer	N. T. Mitchell, BSc, PhD, ARIC	Head of Section; radiological control of radioactive waste disposal
Principal Scientific Officers	J. W. R. Dutton	Analytical chemistry of radionuclides and trace elements
	D. F. Jefferies	Radioecology and trace element ecology
Senior Scientific Officers	E. Reynolds	Nucleonics and instrumentation; instrument development
	D. S. Woodhead, BSc, PhD ARCS	Radiobiology; effects of chronic and acute irradiation of marine and freshwater organisms; environmental radiation dosimetry
	B. R. Harvey, BSc	Chemistry; development of analytical methods of analysis for trace elements and their chemistry in sea water
	J. A. Hetherington, BSc	Radiological inspection of nuclear sites; sediment interactions
	R. J. Pentreath, BSc, PhD	Radiobiology; kinetics of artificial radionuclides and heavy metal accumulation by fish and shellfish; radionuclide studies of marine food chains
	C. J. Barker	Radiobiology; effect of chronic and acute irradiation of marine and freshwater organisms

Shellfish and Inshore Section

Senior Principal Scientific Officer	P. C. Wood, BSc, Dip Bact	Officer in Charge, Fisheries Laboratory, Burnham-on-Crouch; exploitation of shellfish resources; sanitary control of shellfish; marine pollution
Principal Scientific Officers	E. Edwards, MI Biol, PhD	Shellfish resource development; crustacean fisheries biology
	J. E. Portmann, BSc, PhD	Marine pollution; dumping of wastes; monitoring of commercial species for persistent substances
Senior Scientific Officers	D. Key	Oyster biology and cultivation
	A. Franklin, BSc	Exploitation of molluscan resources; population studies; pests and predators
Principal Scientific Officers	P. R. Walne, DSc, FI Biol	Officer in Charge, Fisheries Experiment Station, Conway; physiological and experimental aspects of hatchery cultivation of bivalves
	B. T. Hepper, MSc, MI Biol	Crustacean biology
Senior Scientific Officers	P. J. Dare, BSc, PhD	Mussel population studies and mussel cultivation; bird pests
	B. E. Spencer, BSc	Bivalve hatchery operations and techniques
	J. R. M. Forster, BSc, PhD	Intensive prawn cultivation
	M. M. Helm, BSc	Biology of oyster larvae in relation to hatchery culture
	J. F. Wickins, BSc	Intensive prawn cultivation