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Development of FISHERIES RESEARCH IN NEW ZEALAND from 1965 to 1973

By G. Duncan Waugh

Fisheries Research Division
Occasional Publication No.10

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Introduction

THIS introduction summarises the events preceding the creation of the Fisheries Research Division and those which were of subsequent significance to its work. It also serves as a background to some more recent developments which are dealt with in subsequent sections.

Though the account is generally confined to the first 8 years of the division's existence, it is difficult to define a precise dividing point, particularly where continuing research programmes are described. There are therefore some references to projected work and some to work which was in hand in 1973 and about which papers were subsequently published.

Early administration

Until the early part of the twentieth century aquatic biological studies or collections of scientific material were made by various individuals, some of whom were associated with exploratory cruises in the South Pacific.

Within New Zealand the Marine Department, established in 1866, was given responsibility for fisheries in 1877, when a Fish Protection Act was passed to control fishing for certain marine species. In 1887 the department took over the administration of the Salmon and Trout Act of 1869 from the Department of Internal Affairs. The development of the Marine Department and of fisheries administration has been described by Martin (1969). Slack (1969b) has dealt with the history of the fishing industry, and Waugh (1973) has discussed more recent developments in the industry.

Until 1964 all administration of fisheries as well as research was carried out by a single Fisheries Division of the department. Occasional efforts were made to stimulate fishery production, and there was an increasing demand for more knowledge of the resources. However, pressure from parochial interests for local studies tended to preclude the limited scientific staff from undertaking any broadly based fundamental studies.

In 1963 an *ad hoc* committee of the National Research Advisory Council, recognising the need for longer-term studies on fish and fisheries which could provide a basis for rational management of the resources, recommended the creation of a separate Fisheries Research Division within the Marine Department. The division became a functional unit in early 1965 under the part-time acting directorship of J. W. Brodie, director of the New Zealand Oceanographic Institute, of the Department of Scientific and Industrial Research. At this time the fisheries management and administrative functions of the Marine Department remained with the Fisheries [Management] Division.

During the next 2 years, despite the burden of his dual responsibility, Brodie was able to establish guidelines for the work of the new Research Division, recruit some staff, and acquire basic items of equipment. However, it was inevitable that he could not devote all the necessary attention to developing the work of the division, and the absence of a permanent director was not conducive to any assurance of security for staff. The appointment of a full-time director in February 1967 helped to create a feeling of permanence, and the members of the team were better able to plan for the long-term projects that were expected of them.

Early research

Before 1965 emphasis in research had been on freshwater studies, particularly on the sports fisheries for salmon and trout. Work was done by Government staff and people associated with universities or with the Portobello marine station (Martin 1969). Early marine studies were aimed at assessment of fishing potential and fishing grounds and were supervised by L. F. Ayson, who was chief inspector of fisheries from 1899 to 1927. From then until 1946 A. E. Hefford fulfilled the dual role of chief inspector and director of fisheries research. From August 1946 to October 1960, though there were scientists on the staff, there was no formal director of fisheries research until K. R. Allen was appointed to this position.

Acclimatisation societies, which had been given statutory responsibility for developing and administering trout and salmon fisheries, represented an organised "pressure group" and this, plus the greater accessibility of fresh waters for study, probably explains why there was greater emphasis on freshwater research. Commercial fishermen, loosely organised, widely scattered, and fishing mostly for local markets, lacked the power to stimulate research. Furthermore, in a largely agrarian community where consumption of protein in the form of fish represented less than 4 percent of the intake per head of animal protein the degree of attention given to marine fisheries was meagre. Small quantities of fish were exported, but their contribution to the overall economy was of little significance. Coupled with this was the fact that the continental shelf is narrow (average width 19 km), which in turn led to the belief that fish stocks must be small and easily overexploited.

TABLE 1: Relative importance of the first 10 of the various fish species landed by New Zealand vessels in 1969 and 1973

Species	1969 Weight (cwt)	% of total catch	Species	1973 Weight (cwt)	% of total catch
Snapper	224 525	34.8	Snapper	278 211	31.6
Tarakihi	71 007	11.0	Trevally	97 366	11.1
Trevally	64 583	10.0	Tarakihi	74 159	8.4
Gurnard	55 594	8.6	Gurnard	73 235	8.3
Hapuku	22 092	3.4	Barracouta*	56 093	6.4
Flounder	21 408	3.3	Shark	31 708	3.6
Sole	19 170	3.0	Hapuku	25 830	2.9
Elephant fish	18 382	2.9	Eels*	25 314	2.9
Blue cod	14 941	2.3	Elephant fish	18 851	2.1
Pioke	13 578	2.1	Sole	16 966	1.9
	Total %	81.4		Total %	79.2

*Barracouta and eel landings increased significantly in 1973.

[*National Publicity Studios photo*

The acquisition of the deep-sea trawler *James Cook* was an important event in the development of the division, because it enabled marine research to be organised on a New Zealand-wide basis.

As pointed out by Slack (1969b), Hefford's frequently stated opinion about the limited size of the stocks, and the system of restrictive licensing which had been imposed to "conserve" the resources, militated against any real belief in a major expansion of the fisheries.

Changing attitude to marine fisheries and research

More than 40 species of marine fin fish are exploited, yet from 1960 to 1973 about 80 percent of the landed weights came from only about 10 species, and of these snapper, tarakihi, trevally, and gurnard contributed about 60 percent (see Table 1). Until 1965 significant research had been published on only one important commercial fish — the snapper (*Chrysophrys auratus*)—by Cassie (1955, 1956a, 1956b, 1956c, 1957), though some work had also been done on species of less importance, for example, lemon sole (*Pelotretis flavilatus*) by Rapson (1940), and useful biological observations are combined in Graham (1956). The only other marine species exploited

TABLE 2: Fisheries research publications issued between 1927 and 1973

Period (incl.)	Freshwater fisheries	Marine fisheries	Marine mammals	General	Total
1927-65	63	14	5	9	91
1966-69	37	23	9	3	72
1970-73	33	46	5	6	90
Total	133	83	19	18	253

before 1965 and on which published data existed were the whales (Gaskin 1963, 1964a, 1964b, 1964c, 1965).

From 1927 to the end of 1965, 91 papers and articles were published by research staff. Of these about 69 percent were concerned with fresh water, 25 percent with marine fish and shellfish, and 6 percent with marine mammals. In the next 4 years 72 papers were published and the proportion of freshwater publications was reduced to about 50 percent. In the 4 years immediately preceding 1973 there were 90 publications, of which about 39 percent were concerned with freshwater research (Table 2).

Two major events had changed the attitude to commercial fisheries. The first was the opening up in 1952 of a lucrative export market for rock lobsters in the United States. The subsequent rapid expansion of this fishery and the good earnings created an awareness of the value of our fishery resources. The second was the advent of Japanese distant-water fishing vessels off the coast from 1959 onwards. This confirmed a view, already held in some quarters, that there was a worthwhile resource that was inadequately exploited by local fleets.

The abandonment of restrictive licensing in 1963 cleared the way for expansion, and in 1968 the development of export targets for fisheries by the National Development Conference (1969) provided further impetus for development. However, these only re-emphasised the need for adequate data with which to plan for use of the resources.

For the Fisheries Research Division probably the most important event was the acquisition of the deep-sea trawler *James Cook* in July 1969 (Waugh 1969b). This provided the means by which marine research on a New Zealand-wide basis could be organised.

Objectives

THE TERMS of reference of the division, though never actually defined by the *ad hoc* committee of the National Research Advisory Council, were accepted as:

- To undertake fundamental studies on fish and fisheries of economic or potentially economic importance.
- To use the information obtained for proper scientific management of the fisheries.

Within these broad terms of reference priorities had to be assigned according to available expertise, and as more staff were recruited so fields of study were expanded.

Various considerations, including direct cash value, influenced decisions on topics and priorities, as the following examples show.

Commercial value. The rock lobsters, trawl fish, and, to a less extent, the dredge oyster fishery were economically the most significant, and most attention was paid to them first. The initial objective was to learn enough about the biology of the species to be able to interpret what was happening in the fisheries for them.

Recreational value. Trout and salmon fisheries are of considerable recreational value, with some attendant economic advantages through tourism. Commercial use of trout is prohibited, though some commercialisation of salmon is being contemplated. As indicated, work was already under way on some aspects of these species, but the programmes were developed to take into account the effects of changing environment on the fish. The toheroa is of more recreational than economic significance. Because it is a traditional delicacy associated with the New Zealand way of life and because stocks appeared to be in serious danger, a study was justified, particularly as there was an offer from industry to sponsor a fellowship.

Farming potential. Species such as rock oysters and mussels can be farmed and could be developed as significant economic species; so they, too, merited study. At the same time biological studies needed to be supplemented by environmental and chemical studies to ensure high-quality produce.

Scientific value. The indigenous freshwater fish, other than eels and whitebait, have no economic value, but many are unique to New Zealand. Some like the grayling are already extinct (Allen 1949) and others like the Canterbury mudfish are now very rare (Skrzynski 1968). The division, which has the only suitably equipped team to undertake studies on the unique fauna, has a moral responsibility for contributing to knowledge and providing sufficient data to help protect any endangered species.

Thus the work of the division embraces a wide variety of topics, not all of which are wholly industry oriented.

Staff

IN early 1965, after the selection of research personnel from the former Fisheries Division and before recruitment, the permanent staff of the division was 8 scientists and 9 technicians, plus the 3 officers of *Ikatere*, an editor, and clerical staff. At the end of 1969 staff had increased to 13 scientists, 23 technicians, 8 ships' officers for *James Cook* and *Ikatere*, an editor and assistant, a librarian and assistant, and administrative staff.

Apart from continuing recruitment of new staff the division was further expanded in 1971 by the transfer of the control of the Christchurch laboratory staff of 8 from Management to Research Division.

By the end of 1973 the total complement was 33 scientists, 52 technicians, 8 ships' officers, 5 library and editorial personnel, and 8 administrative staff. This very rapid expansion is not only a measure of the increasing emphasis being placed on the need to develop our fishery resources, but is also a recognition of the paucity of information that had existed through lack of earlier endeavour in the field.

Facilities

Laboratory accommodation

THE WELLINGTON staff are temporarily accommodated in old wooden houses converted for laboratory purposes largely by the scientists and technicians. In addition a small closed-circuit aquarium building has been constructed. Congestion within the buildings plus their scattered nature tends to militate against the integrated working of the team. However, plans are in hand for the erection of a laboratory on the shores of Wellington Harbour.

As an interim measure and to advance the work on shellfish an existing building has been acquired at Mahanga Bay for conversion to a shellfish hatchery. When this is completed the existing aquarium will be used exclusively for freshwater studies, particularly of fish diseases.

A new laboratory is to be built at Rotorua during 1974. It will be adjacent to the grass carp ponds, which have already been constructed on the Forest Research Institute's campus.

At Christchurch staff are housed in a temporary wooden building, but it is expected that eventually they, too, will be accommodated in a new laboratory. The Christchurch laboratory also maintains a small field station alongside the salmon trap on the Glenariffe Stream, a tributary of the upper Rakaia River.

Equipment and laboratory services

Equipment available is generally adequate for most studies and includes a wide range of normal laboratory instruments as well as specialised items such as a PDP 11 computer and an atomic absorption spectrophotometer. The workshop is well equipped and has the capacity to construct a wide variety of gear used for field and laboratory work.

Histological work is done in a well-equipped, though congested, laboratory. A photographic laboratory caters for the normal work of the division as well as X-ray photography for meristic and morphometric purposes.

Through the efforts of J. W. Brodie and of librarians the library is well able to service not only divisional staff but others interested in related fields of aquatic biology and ecology. Many of the journal holdings are unique to New Zealand, so that much work is involved through the national interloan system.

As shown in the list of references on page 33, there are, apart from the papers submitted to scientific journals, three major series of publications edited and produced in the division. These are the bulletin series, which is composed of substantive works by members of staff (see Gaskin 1968, McDowall 1968, Redfearn 1974), a series of

Four of the houses in which the division was accommodated in 1973. In the one on the left above were the library and editorial section and in the other were the administration section, laboratories, and workshop. The building on the left below housed the freshwater section and populations section. In the other were the demersal section, photographic section, and dive store.

Occasional Publications, which have no standard format and are of general information or intended for some servicing purposes (see Roberts, Baker, and Slack 1972, Eldon 1973), and a fairly new series of Research Information Leaflets, which are brief accounts of work presented in such a way as to inform and where necessary assist particular sections of industry (see Dinamani 1971a, Colman 1973b).

Vessels

Ikatere is a wooden side trawler built for research and patrol purposes by the Marine Department in 1940. The vessel is 19.2 m in length overall with a 4.5-m beam and draught of 2 m. Power is supplied by a 152-hp Gardner diesel engine. The vessel has been converted for stern trawling and is also used for trolling, dredging, plankton sampling, and hydrographic work.

Ikatere is based in Auckland and has a crew of five, including a sea-going technician, and accommodation for two scientific or technical personnel. Owing to her limited range and accommodation the vessel is used primarily for in-shore studies between North Cape and East Cape on the north-east coast of the North Island. However, occasionally *Ikatere* has worked the west coast as far south as the Marlborough Sounds in the north of the South Island. Because of her age and the lack of laboratory facilities and adequate working space, it is proposed to replace her with a more suitable craft.

James Cook, originally *Sea Harvester II*, was bought by the Marine Department in February 1969, converted for research purposes, and commissioned in her new role in June 1969. She is a steel stern trawler built by Aakers of Trondheim, Norway. Principal dimensions are overall length 42.1 m, beam 8.7 m, draught 2.6 m, and registered tonnage 210. Power is provided by a 1200-hp Lister Blackstone Trunk diesel engine. She has a crew of 13 plus a permanent sea-going technician. There is additional accommodation for six scientific staff. Most of the fishing work is done on the fully protected fish deck, where there is good "wet working" space, but there is also a small "dry" laboratory. On the trawl deck there is a hydrographic laboratory.

The vessel is equipped with radar, radio direction-finding equipment, two Simrad echo sounders operating on 34 and 17 kHz, and a Marconi fish detector. The main trawl winch, which is hydraulically operated, carries 2400 m of warp and in addition there are hydraulically operated winches for hydrographic and plankton sampling purposes. Besides the conventional lifesaving equipment and lifeboat the vessel has a 6-m tender, which is used for close in-shore studies and as a base for diving operations. During 1974 a Simrad EK 120 scientific sounder will be installed for stock assessment purposes and further laboratory and crew's quarters will be provided.

With her size and range the vessel is capable of covering all the fishing grounds now being exploited by the New Zealand fleet and of extending well beyond them.

Because of her limited range *Ikatere* is used mainly for in-shore studies between North Cape and East Cape.

Rukuwai is a 6-m open, aluminium-hulled vessel powered by a 150-hp outboard motor. The vessel was designed specifically as a trailer-borne diving tender for coastal and lake studies. She has no permanent crew, but is operated by two of the technical staff who are divers and also hold launchmaster's certificates. The vessel is equipped with an echo sounder and ship-to-shore radio.

Programmes for all three vessels are planned for each year towards the end of the preceding year and all are operated to a tight schedule, with little opportunity for introduction of supplementary work.

Several other small craft are also available and used for lake and estuarine studies.

Research Programmes

INCREASES in staff during the period enabled the activities of the division to be sectionalised during 1972, and in the following account research projects are dealt with by section. As well as describing the general scope of the work of the sections, the account makes particular reference to those studies which are of special significance to the fisheries. A full list of all published work is available in the division's Occasional Publication No. 1, which is periodically revised (Fisheries Research Division 1974).

Demersal fisheries

Principal emphasis continues to be placed on those bottom fish which contribute most to landings or have the greatest unit value. L. J. Paul, a member of the division from its inception, has accumulated biological data on the snapper *(Chrysophrys auratus)* in the Auckland area, on changes in year classes, and on the history of the Auckland fishery and has made some hydrographic observations in the Hauraki Gulf (Paul 1968a, 1968b, in press a, in press b). Colman (1972) contributed a paper on the feeding behaviour of snapper, and Vooren and Coombs (in press) have made a preliminary appreciation of the population dynamics of the species in the Gulf.

The rise in snapper landings from 8609 tonnes in 1965 to 11 400 tonnes in 1969 and 14 134 tonnes in 1973 not only reflected increased pressure by more and better equipped vessels but a real increase in available stocks (Paul 1970). However, the dependence of an expanding industry on good year classes and the presence of a high proportion of old fish inevitably raise the question of continued stability of the fishery (Paul in press a). Thus attention is now being paid to monitoring stock and recruitment on east and west coasts.

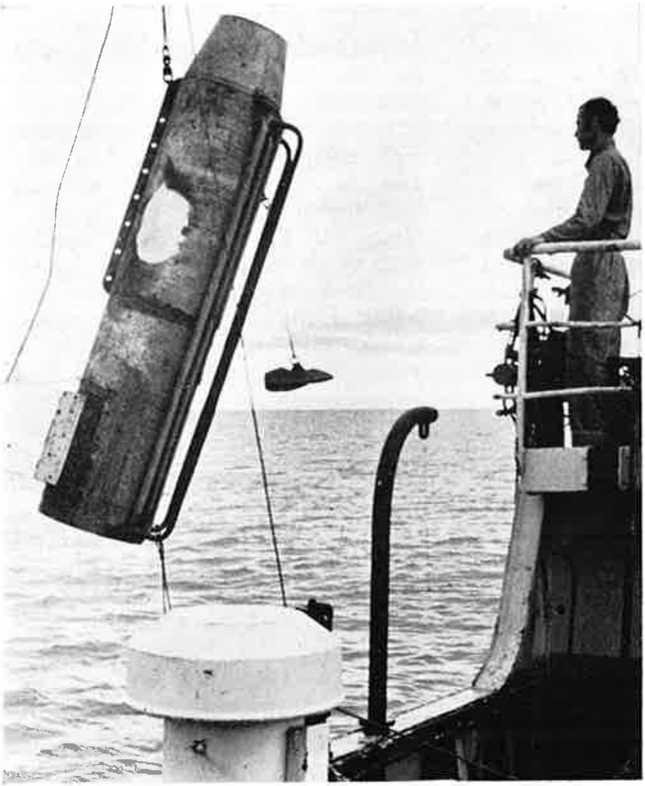
A detailed survey of the Hauraki Gulf, parts of which are closed to trawling, is being undertaken by R. D. Elder, and J. Crossland is studying migratory behaviour of the adults, many of which are believed to overwinter on rough, untrawlable ground to the north.

For several years tarakihi *(Cheilodactylus macropterus)* was the second most important demersal species in terms of landed weight and value. Few early data existed, but from 1967 to 1972 major effort was concentrated on the species by L. J. Tong and C. M. Vooren. At first their work was aimed at understanding the biology, including age-growth relationships and breeding as related to landings (Tong and Vooren 1972). As this work developed, more attention was devoted to the fishery, and Vooren's (1973) work on the East Cape stocks was the first attempt to establish the maximum sustainable yield for any New Zealand species. This work has been extended by an analysis of the statistics of the tarakihi fishery (Vooren 1974) and by further surveys in the East Cape area (Vooren and Tong 1973). At the same time attention has been drawn to the possible existence of several different stocks, but this will need to be confirmed.

The absence of young-of-the-year fish from the trawling grounds has made recruitment monitoring difficult, but the existence of nursery grounds such as those in Tasman Bay (Vooren 1972) for 1- and 2-year-old fish suggests that some prediction of future yields may be possible once it is known to which stocks such juveniles contribute.

Like the snapper, the tarakihi is a long-lived species (35 years or more) with a low natural mortality. Continued fishing on what may amount to an accumulated old stock emphasises the need to determine maximum sustainable yields. Though Gulland and Boerema (1973) have pointed out that management should not necessarily be based on this single concept, it is one that is easily understood and provides a good working basis for a more refined approach to future management of the resources.

Work on gurnard *(Chelidonichthys kumu)* was initiated by R. D. Elder in 1967. Some work had been done at Portobello on the early development of the species in 1906 (Anderton 1906), and more recently Staples (1972) published data on age and growth in the Canterbury area. Partly because of the availability of *Ikatere* in the Auckland area and partly because about 27 percent of



Collections of planktonic fish eggs and larvae are used for identification of spawning areas and spawning seasons as well as for estimating fish abundance. A "tin-tow net" or high-speed plankton sampler, which is shown being lowered over the side of the research vessel *James Cook,* is often used for the purpose.

the landings of this species are into Auckland, Elder was mainly concerned with the Hauraki Gulf-Bay of Plenty populations. Besides work on gurnard biology and migration his principal field of study has been the dynamics of the population and yield per recruit as these are likely to affect the further development of the fishery (Elder in press).

With the completion of this initial project Elder's new study is of the total fishery in the Hauraki Gulf with a view to determining and coordinating studies on stock abundance of snapper, gurnard, flounder, and other fish and the way in which the fishery might be better managed.

Biological studies on the sand flounder *(Rhombosolea plebeia)* were started before 1965 by A. R. Mundy and finalised in an unpublished Ph.D. thesis presented to the University of Canterbury (Mundy 1968). The work was primarily concerned with age and growth relationships, migrations, and age at maturity, though some tagging was done for both migration studies and stock assessment purposes.

J. A. Colman began work on the flounder stocks of the inner Hauraki Gulf and Firth of Thames in 1968. He has described the growth, fecundity, and spawning behaviour of the two species *R. plebeia* and *R. leporina* (Colman 1973a) and more recently the importance of the central Gulf to these stocks and has given an explanation for fluctuating yields (Colman 1973b). In addition a detailed evaluation has been made of Mundy's tagging experiments to determine the significance of the Canterbury Bight-Pegasus Bay spawning grounds to the central east coast stocks of the South Island (Colman in prep.).

The taxonomic status of the sole *Peltorhamphus* has been studied by James (1972), who has also made observations on mesh selection of flatfish in the Otago trawl fishery (James 1970). In addition Tong and Elder (1968) have used some of the early data from the Marine Department for an analysis of distribution and abundance of demersal fish in the Bay of Plenty.

L. J. Tong, after a period overseas, has trained in the use of sounding techniques for rapid assessment of fish stocks, and the necessary equipment for use aboard *James Cook* is on order. In this project he will be working closely with members of the populations team.

Thus, within the period of this review, work progressed from purely biological studies of the major species, about which little or nothing was known, to first attempts to evaluate the fisheries for them. In the future even more attention will be given to the fisheries and at the same time new studies will begin on other species.

Pelagic fisheries

Before 1965 pelagic species were only lightly exploited, and the only fishery of any significance was for the pilchard *(Sardinops neopilchardus)* (Baker 1972). More recently markets have been developed for the trevally *(Caranx lutescens)*, which is now taken in substantial numbers by trawlers. The fish schools at the surface and is susceptible to bulk-catching methods such as purse seining, particularly in summer.

Substantial stocks of other species are reported to occur (Eggleston and Waugh 1974), and Japanese vessels exploit barracouta *(Thyrsites atun)* and horse mackerel *(Trachurus declivis)*, which they catch with high headline trawls. Tuna are also taken in international waters around New Zealand (Shingu 1965, 1967). Partly because of the example of Japanese and Russian exploitation and partly because of the development of processing techniques within New Zealand, there have been substantial increases in the local catches of several species, including those already mentioned.

The recommendation of the National Development Conference was for an increase in landings of pelagic species to weights at least equivalent to those of the demersal fisheries (National Development Conference 1969).

Early work on the tuna was done by York (1969), of the Fisheries Management Division, and it was on these high value species, particularly albacore *(Thunnus alalunga)*, that P. E. Roberts began work in 1969. Unlike other studies this work began as an investigation of the potential of the fishery and the seasonal and temporal distribution of the species. Biological observations have been confined to feeding behaviour and migratory patterns. The principal object was to devise fishing methods suitable for New Zealand vessels (Slack 1969a, Roberts 1971a, Roberts, Baker, and Slack 1972) and to predict where possible the occurrence of the fish (Roberts 1971b).

The albacore landings increased from 51 tonnes in the summer of 1969-70 to 455 tonnes in 1972-73 and there is every indication that

Measuring a trevally on one of the research vessels at sea.

the catches can be increased still further. However, most of the fish are immature 2- and 3-year-olds and though it appears that the present catch is insignificant in relation to the total stock off our coasts during summer, tagging studies have been started to determine fishing intensity and migration routes. These data will become important if international agreement is sought to control the take of these oceanic migratory species.

Most trevally have been taken by trawlers and most of the biological information on age and growth has been obtained from such samples since 1969 by G. D. James, who in addition has made some observations on growth and distribution of horse mackerel.

Purse seining by the Fisheries Management Division's vessel *W. J. Scott* and later by the J. Wattie Canneries vessel *Marine Countess* has provided useful material for analysis of age and size composition of various surface schooling species such as kahawai *(Arripis trutta)* and pilchard; trawl surveys and, later, midwater trawls from *James Cook* will provide samples of other species, such as barracouta. In addition the joint venture between the Government and the American company Starkist in which the crew of an American purse seiner is to study catch rates and distribution of skipjack *(Katsuwonus pelamis)* and mackerel during 1974 will yield useful data on the likely resources of these species.

D. Eggleston began research on kahawai and barracouta in early 1972 and has so far concentrated on biological data, age, growth, and fecundity studies. It is already apparent that kahawai is much longer lived (20 years) than was supposed from the Australian work (7 years) of Malcolm (1960), and this will obviously influence the approaches to the management of the stocks.

Eggleston is studying barracouta in collaboration with Ikeda, of the Japanese Far Seas Laboratory, Shimizu. The former is principally concerned with the younger, smaller, in-shore fish and the catches of local vessels, and the latter is dealing with the fish taken in deeper water by Japanese vessels. This species, which is caught at the rate of about 20 000 tonnes a year by foreign fleets, contributed only 1.9 percent of the weight landed by New Zealand vessels and ranked twelfth in order of importance in 1969, but by 1973 it contributed 6.4 percent of the catch and had risen to fifth in order of importance.

D. A. Robertson, after studying the eggs and larvae of some New Zealand marine teleosts under contract to the division (Robertson 1973), joined the pelagic team in 1973 and has continued his work on pelagic species and their fecundity with the object of using his earlier knowledge for stock estimation based on abundance and distribution of eggs and larvae of selected species. His next project is to be a study of the jack mackerel fishery.

Shellfish fisheries

Crustacea

C. B. Kensler joined the division in 1965 and before he left in 1968 had contributed several papers on the biology of the rock lobsters

[*National Publicity Studios photo*

Juvenile rock lobsters reared from the post-larval stage for studies on growth and behaviour under laboratory conditions.

Jasus edwardsii and *J. verreauxi*. This work was related to development of post-puerulus stages, fecundity, size at first maturity, and distribution (Kensler 1967a, 1967b, 1967c, 1967d, 1968). In addition he made some observations on the fisheries (Kensler 1969).

Between 1968 and 1972 J. H. R. Lesser studied the distribution and abundance of the larval stages in the plankton and prepared a description of the early life history of *J. edwardsii* (Lesser 1974). He also collected scyllarid larvae, which are being described by Atkinson and Boustead (in prep.).

R. F. Coombs also began work in 1968 on adult behaviour and on the fishery, particularly in the Chatham Islands.

In mid 1973 J. D. Booth and J. L. McKoy started studies on catchability, moult frequency, and territorial behaviour and began to survey selected regional fisheries to establish catch per unit of effort and size composition of the stocks.

From 1970 to 1972 P. M. Hine surveyed New Zealand waters for various prawn species to extend the work begun by Pike and Cooper (1969). Effort was finally concentrated on *Metanephrops challengeri*, and the distribution and early life history have been described (Hine in prep. a, in prep. b). However, the scattered nature of the populations, the depths at which they occurred (deeper than 350 m), and the fairly low catch rates suggested that stocks were insufficient to support a unit fishery based on present technology, and the project was discontinued.

Mollusca

The fishery for dredge oysters *(Ostrea lutaria)* in Foveaux Strait is in many respects unique and has

Diving is a prerequisite in the collection of data for some studies, such as in Foveaux Strait, where dredge oyster densities are being measured.

Spat settlement in northern waters is an important phase of the division's work on rock oysters. During summer collectors are set up at different tidal levels to give an indication of settlement density and period.

been described by Sorensen (1968). H. J. Cranfield, who transferred to the Fisheries Research Division at the outset, made numerous observations on the distribution, spatfall, intensity of settlement, and ecological relationships on the beds (Cranfield 1968a, 1968b, 1970) and continued his work on larval behaviour of oysters *(Ostrea edulis)* during a period overseas (Cranfield 1973a, 1973b, 1973c).

In present work attempts are being made to determine the levels of recruitment, the standing stocks on the beds, and possible methods of augmenting the population by returning shell from the shucking houses. From 1969 to 1971 R. W. Hickman studied growth rates and condition of the oysters in various parts of the strait and began some studies on farming.

Preliminary observations on settlement and growth of rock oysters *(Crassostrea glomerata)* were begun in 1967 by G. D. Waugh and were followed up from 1969 by P. Dinamani, who has described the incidence of a competing form of *Ostrea* sp. and the larval development of *C. glomerata* (Dinamani 1971a, 1973) as well as the reproductive cycle (Dinamani 1974). As this species is farmed, the major effort is devoted to understanding ways of increasing productivity and distribution and intensity of spatfall and of improving the quality of the animals.

The unexpected appearance of the Japanese oyster, *C. gigas,* has been described (Dinamani 1971b) and observations on the natural spread of the species are being made. Whether it will prove to be a source of additional production or an undesirable competitor with *C. glomerata* is still a matter for conjecture.

Toheroa (*Paphies* (*Mesodesma*) *ventricosa)* are subject to very wide fluctuations in population density (Greenway 1969a) and though early biological observations had been made by Rapson (1954), there were insufficient data to determine whether or not the species was in danger of overexploitation. Meredith Bros. and Company Ltd., of Auckland, kindly offered a 3-year fellowship tenable in the division from 1968 to 1971. This was taken up by P. Redfearn, who then joined the permanent staff.

Studies have been made of toheroa distribution and growth, intensity and distribution of spatfall, mechanisms of colonisation of the beds, and mortality (Redfearn 1974). From these studies it has become apparent that the major causes of population fluctuation are environmentally induced and that with present-day technology there is little chance that the population can be substantially and permanently augmented or adequately protected. Though some further biological research on larval rearing and on adult behaviour will be done as opportunity permits, other work on toheroa has been discontinued.

From mid 1973 Redfearn joined R. W. Hickman, who since 1971 has been working on the green-lipped mussel *(Perna canaliculus).* These mussels have a high growth rate (Greenway 1969b) and seem to have a good farming potential (Waugh 1968, 1969a). The principal tasks are to determine those parts of the New Zealand coast which will give the best yields in growth and quality, the most suitable areas for spatfall, and the most suitable methods of spat collection. In addition regional and seasonal changes in condition and onset of maturity are being studied.

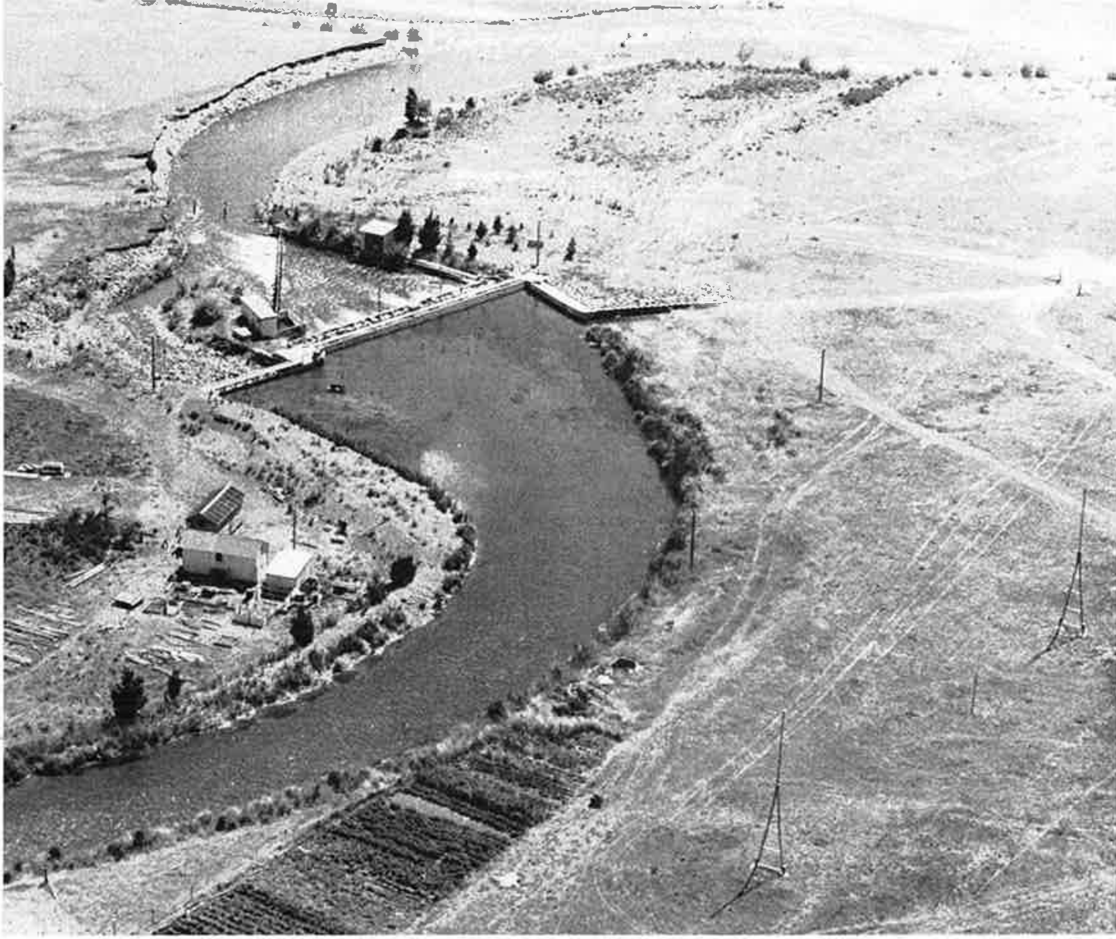
Shellfish are a potential problem because of their ability to concentrate heavy metals. S. A. Nielsen, a National Research Advisory Council post-doctoral fellow, joined the division in late 1971 and has investigated the occurrence of such elements as lead, mercury, copper, zinc, cadmium, and cobalt in mussels, oysters, toheroa, and scallops from a wide variety of localities and at various depths all around the coast. Industrial pollution is generally very low, but there are significant local variations, presumably associated with natural deposits, in the levels of the elements in the shellfish (Nielsen 1975, Nielsen and Nathan 1975).

Freshwater fisheries

The freshwater team is split among the Wellington, Rotorua, and Christchurch laboratories, but the work is co-ordinated from Wellington, and for the purposes of this review it is more convenient to discuss topics rather than deal with the laboratories in order.

Work on water quality in relation to the trout fisheries had been started by G. R. Fish at Rotorua before 1965 (Fish 1963a, 1963b,

Studies on freshwater fish populations being undertaken with the use of electric fishing equipment in the Hinaki Stream, Wairarapa.



General view of the salmon trap on the Glenariffe Stream, a tributary of the Rakaia River.

1968), but from 1967 to 1971 his major limnological work dealt with nutrient budgets for Lakes Rotorua and Rotoiti, the former in an advanced state of eutrophication (Fish and Chapman 1969, Fish 1975, Fish and Andrew 1971), but other lakes have also been studied (Fish 1970).

A. M. R. Burnet, who had studied the ecology of New Zealand freshwater eels and trout and developed electric fishing techniques in the Marine Department during the early 1950s (Burnet 1952, 1959, 1961, 1967, 1968, 1969a, 1969b), remained with the Fisheries Management Division in Christchurch until the end of 1970, when he transferred to the Research Division in Wellington. He has complemented Fish's work on New Zealand lakes and extended understanding of associations of primary productivity, nutrients, and trout (Burnet and Wallace 1973). Monitoring the environment, often in isolated situations, presents considerable difficulty, and much of his recent time has been devoted to developing remote sensing and recording equipment.

At Christchurch a team of technicians (the technical field service), whose services were paid for by acclimatisation societies, had been employed to undertake surveys of angling waters. M. Flain had been associated with this work, particularly on Lake Coleridge (Flain in prep. a, in prep. b), and its subsequent extension into monitoring the runs of quinnat salmon (*Oncorhynchus tshawytscha*), with specific observations at the trap built on the Glenariffe Stream (Flain 1972).

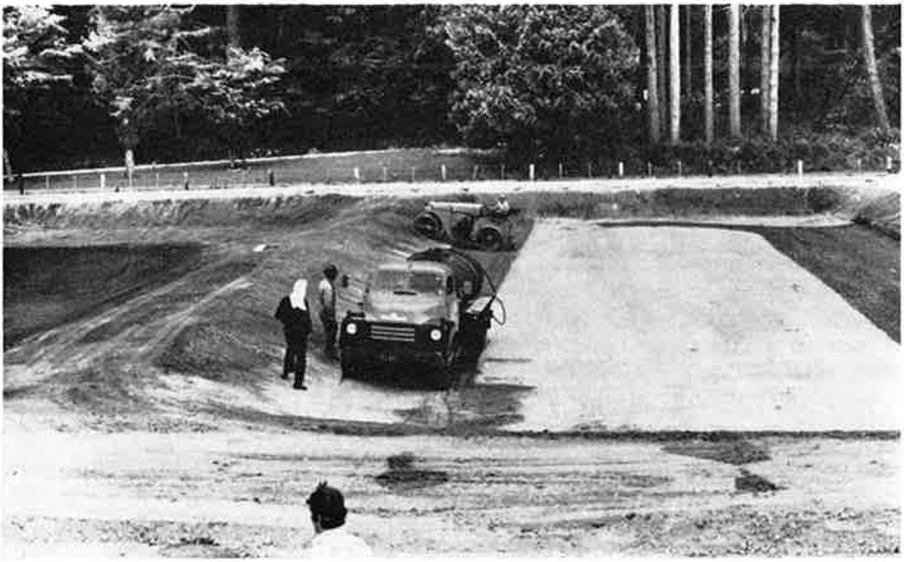
With the transfer of the Christchurch laboratory from Fisheries Management Division to Fisheries Research Division in 1971, the technical field service became part of the research team, with the principal task of assisting in an understanding of fluctuations in the salmon runs and means of augmenting the populations. In this work Flain was joined in 1972 by J. V. Woolland, who has been studying the behaviour of fry and juveniles and the influence of the size and age of the down-stream migrants on the magnitude of the subsequent adult run. Other work is associated with attempts to monitor the total salmon population of the Rakaia River and the angling pressure on the stocks.

The work of the laboratory recently became diversified with the appointment to the team of P. R. Todd, who undertook a Ph.D. study on eels as a National Research Advisory Council fellow, to work on population dynamics of eels and the impact of the rapidly developing commercial fishery on other components of the freshwater fauna, particularly the salmonids. This work will be complemented by that of D. J. Jellyman, formerly a Marine Department bursar, who joined the Wellington team to work on natural recruitment and on eel farming.

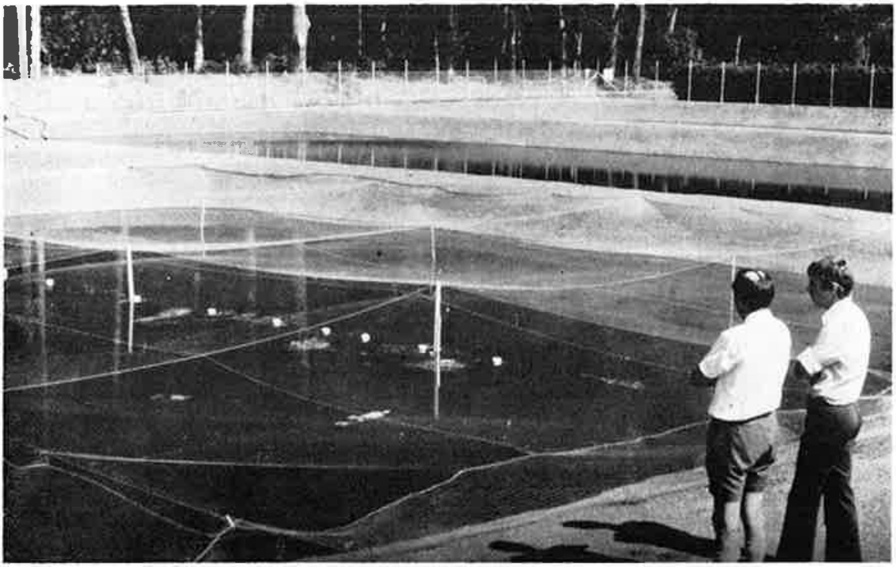
The impact of changed land use and land management practices on the quality and productivity of inland waters and their contained fauna, a topic of increasing significance, has been studied by C. L. Hopkins, who was one of the original members of the division in Wellington, but who moved to the Christchurch laboratory in late 1973. Apart from this work (Hopkins 1970, 1971b) he has also investigated the biology of the freshwater crayfish *(Paranephrops)* (Hopkins 1966, 1967a, 1967b), which may be suitable for farming.

R. M. McDowall, another of the original members of the division, has been particularly concerned with native freshwater fishes. He has studied the commercial fishery for whitebait (McDowall 1968) and has unravelled the affinities, derivations, and distribution of most of the fish fauna (McDowall 1964a, 1970). He has also described some life histories (McDowall 1964b, 1965a, 1965b). Hopkins (1971a), Eldon (1968, 1969, 1971), and Ots and Eldon (1975) have also contributed to these studies.

One of the problems possibly associated with increased enrichment of waters has been wider growth of aquatic weeds, particularly introduced species such as *Lagarosiphon major*, which interfere with recreational use of lakes and rivers (see Chapman and Bell 1967). Preliminary work on the feeding behaviour of grass carp *(Ctenopharyngodon idella)* had been undertaken at the University of Auckland, and in 1971



Grass carp ponds under construction on the Forest Research Institute campus. Because of the porous nature of the pumice soil the ponds were excavated and then sealed with bitumen.



Ponds complete and used for weed preference studies. The ponds were covered with netting to exclude predators and reduce the chance of transferring disease outside the area until quarantining was completed.

a consignment of these fish was imported to Rotorua from Hong Kong for study as biological control agents for nuisance weeds (Waugh 1970). At that time D. J. Edwards was appointed to Rotorua to deal with the quarantining of the fish, their behaviour, and their interaction with the native and exotic fauna and to carry through a phased evaluation of the fish for possible release into natural waters (Edwards 1974, Edwards and Hine 1974). This work is necessarily long term and is planned to last until at least 1977.

The quarantine studies on grass carp, the lack of knowledge of parasites and diseases in the native fishes, the proposal to farm trout in New Zealand, and the outbreak of whirling disease in an Otago trout hatchery (Hewitt and Little 1972) all emphasised the need for more, and more detailed, studies of disease in the aquatic environment. P. M. Hine began this work in 1972, and a disease diagnostic and research unit has since been established in Wellington (Hine 1973, Hine and Boustead 1974). Some studies have been made on marine species, but most attention has been given to freshwater species and though trout farming is banned through a change in Government policy, problems in trout hatcheries and in the farming of eels have caused considerable work. Fortunately, none of the extremely serious viral diseases of salmonids of the Northern Hemisphere has been introduced to New Zealand and it is important both to know the health status of the local stocks of fish and to develop ways of protecting them.

Populations section

The acquisition of a PDP 11 computer for data logging and, as more recently developed, for additional computational work has enabled the populations section to undertake research in population dynamics, to investigate the overall effects of fishing on the stocks, and to advise other members of staff on experimental design and data interpretation.

In 1966 a catch sampling programme was established (Waugh 1967) to study the trawl fisheries in general, with particular reference to a few species all around the New Zealand coast. For various reasons, notably the lack of good computer facilities, it was not possible to arrange analysis of the data collected until late 1972, when adequate services were provided through the Government Computer Centre.

The section was formally established in 1972 under R. F. Coombs, who had been appointed in 1968 to study rock lobsters. Since that time he has been instrumental in planning for a new fisheries return system which has obviated the need for the catch sampling programme and which at the same time will provide more worthwhile data for research, management, and industry purposes.

R. L. Allen, who transferred to the division in late 1972, has analysed the catch sampling data (Allen 1975) and with I. F. West, appointed in late 1973, is now engaged in developing a shed sampling programme to complement the data which are to be provided by industry from 1 January 1974.

TABLE 3: Research contracts supported by the Marine Department and subsequently the Ministry of Agriculture and Fisheries. (As contracts are of up to 3 years' duration, those made after 1970 are not yet complete.)

Year began	University	Topic	Thesis or manuscript complete	Formally publ'ed
October 1965	University of Canterbury	Taxonomy and distribution of New Zealand freshwater fishes	Yes	No
March 1966	University of Otago	Phytoplankton productivity in Tomahawk Lagoon, Lake Waipori, and Lake Mahinerangi	Yes	Yes
March 1966	Victoria University of Wellington	Biology and life history of the pilchard	Yes	Yes
April 1966	University of Auckland	Productivity of Lake Rotorua	No	No
November 1966	University of Auckland	Lake weed problems and associated phytoplankton cycle, Lake Rotorua	No	No
September 1968	University of Auckland	The benthic ecology of the entrance to Whangateau Harbour, Northland, New Zealand	Yes	No
February 1969	Victoria University of Wellington	The biology of *Perna canaliculus* and *Mytilus edulis*	No	No
October 1969	University of Canterbury	The biology of the Canterbury mudfish, *Neochanna burrowsius,* and the related *Galaxias vulgaris*	Yes	No
March 1970	University of Otago	The egg and larval development of New Zealand fish species, with particular reference to the tarakihi, *Cheilodactylus macropterus,* in New Zealand fisheries waters	Yes	No
July 1970	Victoria University of Wellington	New Zealand bivalve larvae with observations on adults and hydrology of Bay of Islands and Wellington Harbour	Yes	No
April 1971	University of Canterbury	Life history and biology of the red cod, *Pseudophycis bacchus*	No	No
January 1972	University of Canterbury	The biology of New Zealand Durvilleaceae	No	No
April 1973	Victoria University of Wellington	The biology of the New Zealand scallop and possibility of raft culture	No	No
April 1973	University of Auckland	Nutrient cycle and energy throughput of grass carp and other introduced fishes	No	No
August 1973	University of Canterbury	Population dynamics, production, and yield estimates for paua, *Haliotis iris*	No	No
October 1973	University of Auckland	The distribution of submerged aquatic weed in Lake Rotoma	No	No

In the meantime C. Bolland, appointed in 1971, has been working particularly on analysis of flounder tag returns with J. A. Colman and with M. Flain and J. V. Woolland on the analysis of salmon runs and the design of the sampling procedures for both adults and salmon fry at the Glenariffe trap. R. F. Coombs has continued his surveillance of the Chatham Islands rock lobster fishery and retains an interest in the behaviour of the species (Coombs 1972), particularly in relation to development of models for the fisheries in several localities.

As a research tool the PDP 11 is being developed for integration with remote sensing equipment for rapid analysis of environmental parameters and for analyses of echo sounder records which will be used for stock assessment purposes. This work is novel and may enable fish schools not only to be counted but to be identified.

Research contracts

To facilitate research in a variety of fields the division has sponsored several studies at universities (Table 3). Some of the studies, though completed to the thesis level, still await more formal publication. It is believed that whenever possible the information obtained, because of its environmental or biological importance, should be published and so made readily available to others interested in the particular field. The rewriting and re-presentation of theses for publication can become a burden to the student and, in collaboration with the universities, ways are being sought to simplify this approach.

Future Developments

THE GENERAL biology of the principal species for which there are established fisheries in the Northern Hemisphere was understood at the turn of the century, so that the further development and/or management of these fisheries has been on the basis of this background knowledge. Because such knowledge was not available in New Zealand, there has been a need to learn about the biology of the most important species and at the same time quickly develop rational management plans for the wise use of the resources these represent.

Though this situation has called for urgent reappraisal based on limited data, there is the advantage that many of the population theories and fishery models have already been developed overseas and can be applied in New Zealand. Thus, though we have been slow in getting to grips with the problem, there is an opportunity for more rapid assessment of the needs for management of the resources.

Stocks of some species, for example, rock lobsters, dredge oysters, snapper, tarakihi, flounder, and gurnard, are, or soon will be, exploited at or near their sustainable yield level. There will be a need to monitor recruitment in these species and refine our assessments of the sizes of the stocks so that desirable yields can be more accurately determined and industry advised or prepared accordingly. Equally, management of the fisheries and the stocks needs to be developed to ensure that maximum benefit, whether economic or recreational, accrues to the community.

Some demersal species, such as hapuku (*Polyprion oxygeneios*) and blue cod *(Parapercis colias)*, which are line caught and have a high unit value, are as yet unstudied, but are subject to considerable variation in yield (Rapson 1956). Work will be necessary on such species and the fisheries for them. Others which are under-utilised—sharks, rays, and the like—will also need to be studied, though with some of these species there are other problems, such as high natural mercury levels.

Most of the pelagic species, from the large oceanic tunas to the small coastal sprats, are underexploited and besides the development of catching methods and methods of rapidly assessing the resources, ways will have to be found of utilising some of these fish. Some species, such as kahawai, though used extensively in Australia, are new on the world markets. Others for which markets could be developed, for example, squid, are being exploited by foreign fleets (the squid catch in the New Zealand area in 1972-73 by 60 Japanese vessels was 14 000 tonnes), but have hardly been fished by the local fleets, largely because of lack of markets and incentives for this form of fishing. However, other techniques may prove equally successful and more economical, and if so, work will need to be done on the desirable yields.

The rock lobster fishery presents a different problem. Here there is a ready market for a high-priced commodity. Gulland (1973) has pointed out that with such fisheries worthwhile economic yields to industry can continue beyond the level of the maximum sustainable yield. Therefore more intensive studies should be made of the fishery for the rock lobster, which may already be overexploited. If this is so and if management measures are required to control or limit effort, Government and industry should have some forewarning of the necessity for such measures.

Where possible stocks should be augmented by farming. However, as in other forms of farming, economic stability will depend on an adequate and regular supply of seed. The establishment of the shellfish hatchery at Mahanga Bay will open the way for studies on those species such as oysters, mussels, scallops (*Pecten novaezelandiae*), and paua (*Haliotis iris*) which may be capable of being farmed and for which an assured supply of seed is essential. Certainly the very much indented coastline and overall lack of pollution suggest that aquaculture could be substantially increased.

The hatchery project also opens the way for the possible introduction and evaluation of exotic species. Economically valuable crustaceans other than rock lobsters are uncommon on the New Zealand continental shelf and in the coastal bays and inlets. Their absence is probably more a feature of the country's early geographical isolation than of lack of suitable habitats; we may therefore be able to contemplate prawn fishing and/or farming.

The farming of marine fin fish, unless carried out in conjunction with that of other high-value species, is less likely to be a profitable proposition. Work is already in hand to develop ways of enhancing the natural runs of salmon, and there is the possibility that sufficient can be produced for commercial fishing as well as for better angling.

A further difficulty to be resolved with the salmon fishery is the conflict in the use of water. The waters of the most productive salmon rivers of the east coast of the South Island are also in great demand for electricity-generating purposes and for irrigation. Therefore minimum flow requirements for the natural spawning of the fish will need to be defined or more and better salmon hatcheries will have to be developed, with attendant improvements in techniques.

Eel farming has been established, but more efficient methods of feeding and growing the species will have to be found as well as more effective ways of combating disease. Because of the total dependence of the industry on the on-shore migrating glass eels for basic stock we will have to know the minimum stocks of adult spawning migrants that should be allowed to leave fresh water. Whether the Japanese experience of declining glass eel runs is due to too great a reduction in the numbers of spawning adults or to pollution inhibiting on-shore migrations or causing mortalities is as yet unknown, but it does point to the need for care in exploiting, even for farming purposes, a natural population.

Fortunately, levels of industrial and bacterial pollution in the marine and freshwater environments are generally low, though they may well increase. Overenrichment of inland waters as a result of more intensive use of fertiliser is, however, causing further serious problems. In the marine environment pollution by domestic and animal wastes can seriously impede the development of shellfish farms, and the possibility of the harmful effects of herbicides and pesticides on the quality of fish and shellfish is always likely to cause concern. Therefore pollution and hydrographic studies will become more essential if fisheries and farms are to be developed to produce high-quality produce.

With open-water fisheries any interpretation of natural and fishing mortalities and of yields depends on accurate effort statistics. Preliminary moves were made in late 1973 to introduce a new system of fishery returns. These will need to be developed and refined and fishermen convinced of the advantage of providing prompt and accurate returns.

Conclusion

The rapid expansion of the fisheries research effort is a measure of the increasing importance being attached to the full use of a national natural resource. It is also a recognition of the lack of past information and the need to retrieve this situation as quickly as possible.

The foregoing account outlines the range and complexity of the work in hand and what will have to be done in the future. The resources of the oceans are not unlimited, and we must be in a position to use them wisely. Increases in human population and the demand for protein will quickly exceed the capacity of the conventional fish stocks to provide the necessary food (Gulland 1973). More attention will then have to be paid to using the less conventional species and more effort devoted to augmenting supplies by intensive culture.

Effective management depends on good scientific advice and the willingness of the management authority to utilise or seek such advice before determining the most suitable ways of regulating effort in the interests of the producer and consumer. The aim of the Fisheries Research Division is to provide such advice based on as accurate data as can be made available at the time.

Inevitably the standards of accuracy will vary with the availability of data and the time spent in working with the species or the resource. Nevertheless considerable progress was made in fisheries research from 1965 to 1973, and it is expected that much greater progress will be made in the future.

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