Fisheries Research Bulletin No. 21

Hydrology and the Quantitative Distribution of Planktonic Eggs of Some Marine Fishes of the Otago Coast, South-eastern New Zealand

by

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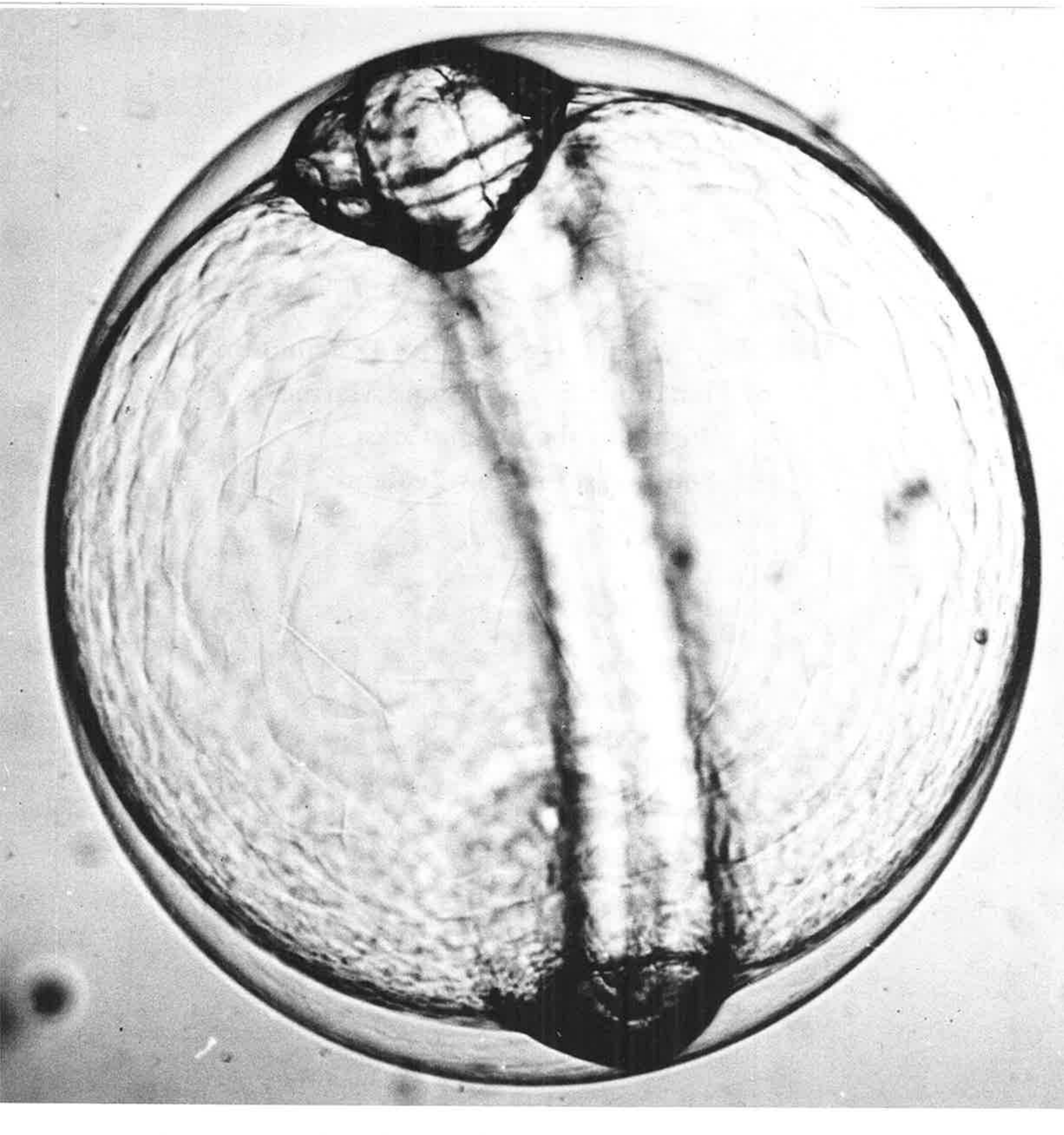

Frontispiece: The egg of the sprat (*Sprattus antipodum*), one of the most common planktonic eggs of the Otago coast.

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FOREWORD

BEFORE 1970 little was known of the eggs and larvae of New Zealand marine fishes. Dr Robertson helped to rectify this by describing many of them, and he now extends our knowledge by describing the distribution in time and space of the eggs of 17 species which occur off the south-east coast.

The distributional data indicate spawning areas and seasons as well as the hydrological affinities of the species; the quantitative data provide base lines against which future changes in stock density and recruitment may be measured. For these reasons alone, I am sure that this bulletin will remain a valuable reference source for many years.

G. DUNCAN WAUGH,

Director, Fisheries Research Division

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INTRODUCTION

The planktonic nature of marine teleost eggs was first observed by Sars (1879) during his investigations on the cod fisheries near the Lofoten Islands off Norway. Sars (pages 576–7) regarded his observations as a "peculiarity of the roe of codfish to which no parallel is found in any other fish". Since then, however, a great number of marine fish species have been found to have planktonic eggs and larvae.

During the 50 years after Sars's artificial fertilisation of cod eggs, the technique of releasing millions of fertilised eggs or hatched larvae was developed in many parts of the world in an attempt to replenish declining fish stocks. Throughout this period information was gathered on the spawning areas and early life histories of many coastal species of fishes, particularly fishes of the North Sea and the Atlantic coast of North America, where considerable effort was made to return fertilised eggs or hatched larvae to the sea. This practice was eventually discontinued because of lack of evidence of its success (Shelbourne 1964).

As well as providing basic information on the early life histories of marine fishes, studies on eggs and larvae have provided techniques for detecting the presence of commercial species, both exploited and latent (Murray and Hjort 1912, Smith, Ahlstrom, and Casey 1970), for estimating the recruitment potential of larvae (Saville 1959), and for the assessment of adult stock size (Buchanan-Wollaston 1923, 1926, Simpson 1959, Saville 1964, Ahlstrom 1968, de Ciechomski 1971b).

Buchanan-Wollaston (1923, page 14) considers surveys of egg abundance as "perhaps the most reliable means of estimating the adult stock of a fish in a particular area", and Ahlstrom (1966) regards larval surveys as the most effective technique available for fishery resource evaluation.

In spite of these comments, there are few examples of egg or larval surveys which have resulted in reliable estimates of adult stock size. Those that have been successful, in the North Sea and the Pacific Ocean off California, have depended on a broad background knowledge of the planktonic phases of the species concerned, the fecundity of the females, and the adult sex ratio.

Many general surveys and developmental studies on planktonic eggs and larvae of marine teleosts have been conducted in the Northern Hemisphere, but apart from the work of Gilchrist (1905, 1916), Matthews and de Jager (1951), Davies (1954, 1957), and de Jager (1955) in South African waters, Fischer (1959) and de Ciechomski (1971a) in South American waters, and Dakin and Colefax (1940) in Australian waters, there have been few similar studies in the Southern Hemisphere.

The earliest observations of this nature in New Zealand marine waters were made at the Portobello Marine Fish Hatchery (now the Portobello Marine Laboratory). The rearing of marine fish larvae for release was a primary function of the Portobello Marine Fish Hatchery at the turn of the century, when Anderton (1907) described and figured the eggs and yolk-sac larvae of several species occurring in Otago waters. Since this work there have been several New Zealand studies which either wholly or partly consider the egg and larval stages of individual fish species.

Rapson (1940) in his study on the biology of the lemon sole (*Pelotretis flavilatus* Waite) included a section on the egg and larval occurrence in the plankton of Tasman Bay and the Marlborough Sounds; Cassie (1956a, 1956b) described the distribution and development of the eggs of the snapper (*Chrysophrys auratus* (Forster)) in the Hauraki Gulf, and McKenzie (1961) has described the eggs and yolk-sac larvae of tarakihi (*Cheilodactylus macropterus* (Bloch and Schneider)) in her discussion of the East Cape fishery. In a study on the biology of the butterfish (*Coridodax pullus* (Forster)), Ritchie (1969) described the eggs and yolk-sac larvae; Baker (1972, 1973) has described the egg and larval stages of the New Zealand pilchard (*Sardinops neopilchardus* (Steindachner)) and the New Zealand sprat (*Sprattus antipodum* (Hector)). The egg and yolk-sac larval features and development of the sand flounder (*Rhombosolea plebeia* (Richardson)) were outlined by Robertson and Raj (1971), and James (1976) has described the eggs and larvae of trevally (*Caranx georgianus* (Cuvier)).

Fish larvae have been the subject of two plankton studies in New Zealand waters. Regan (1916) collected larval and post-larval fishes from 12 "Terra Nova" stations around the north of New Zealand and Elder (1966) studied the fish larvae of Wellington Harbour. Other major planktonic studies in New Zealand waters, (for example, those of Jillett (1971), Bradford

(1972), Wear (1965), and Roberts (1968)) discuss the eggs or larvae of fish as a whole, without separation into specific groups. However, Roberts mentions larvae of *Rhombosolea leporina* Günther and *Gasterocymba quadriradiata* (Rendahl).

Dakin and Colefax (1940) collected many fish eggs and larvae in south-east Australian waters, but identified only the southern anchovy (*Engraulis australis* (White)) and the pilchard *Sardinops neopilchardus*. Blackburn (1950) and Baker (1972) have also commented on the eggs of *E. australis*.

This brief review of existing information shows that though the planktonic phase of fishes has occupied past attention, little is known about the early life history of most of the marine fish species known to occur around New Zealand, particularly the numerous species living beyond the edge of the continental shelf. Such information is important in understanding their ecology and distribution, as well as providing insight into the evolution and systematic position of teleost species (for example, Marshall 1953, Orton 1957, Moser and Ahlstrom 1970). For many commercial or potentially commercial species egg and larval surveys are a powerful tool in stock size estimates.

This study considers quantitatively the seasonality, geographical range, hydrological affinities, drift, and vertical distribution of the planktonic eggs of fishes occurring in Otago waters. (Larvae were also collected, but are not considered here.)

SAMPLING AREAS

SEASONAL TRANSECTS

Three sampling areas were chosen in Otago waters — in Blueskin Bay, to the east of the Otago Peninsula, and in Otago Harbour (Fig. 1). These areas differed in average depths, bottom topography, distance from shore, and hydrological conditions. Any differences in the fish faunas of these areas were expected in the egg stages in the plankton. Otago waters are defined here as the area seawards of the coastline between Moeraki and Nugget Point out to the 1000-m isobath.

Blueskin Bay is a shallow open area exposed to the prevailing north-east wind and characterised by a slow counter-clockwise eddy of neritic water. Stations A–F (Fig. 1) were occupied monthly from April 1970 to April 1972.

The transect east of the Otago Peninsula was positioned to include stations in the shallow in-shore strip of neritic water, the subtropical northward flowing Southland Current, and the Subantarctic Surface Water as described by Jillett (1969). The bottom profile sloped from 20 m at the shoreward station to about 180 m at the shelf edge and then dropped steeply to about 1000 m at the outer station. The stations G–L (Fig. 1) were occupied from April 1971 to June 1972.

Otago Harbour is a shallow tidal inlet with an average depth of 2–3 m at low tide, when about half of its area consists of exposed mud flats. Tidal flows and freshwater run-off result in thermal and saline gradients along the length of the harbour. The stations M–R (Fig. 1) were positioned along the harbour's length in the narrow shipping channel. These stations were occupied monthly from April 1971 to June 1972.

All stations in the seasonal transects were worked from Otago University's research vessel *Munida*.

NON-SEASONAL TRANSECTS

Several plankton surveys were conducted along the Otago coast to collect further information on the distribution of fish eggs. These surveys were carried out in conjunction with a demersal fish trawling programme conducted by staff at the Fisheries Research Division with the research vessel *James Cook*. During these cruises all species of fish caught were examined for gonad maturity and any ripe eggs were preserved.

Three such surveys were undertaken (Fig. 2): in August 1971 (J10/71 — 39 plankton stations occupied with a WP-3 interim net), October 1971 (J14/71 — 14 plankton stations occupied with a ½-m cylinder-cone net), and February 1972 (J2/72 — 19 plankton stations occupied with the "Egg Net", see Table 1).

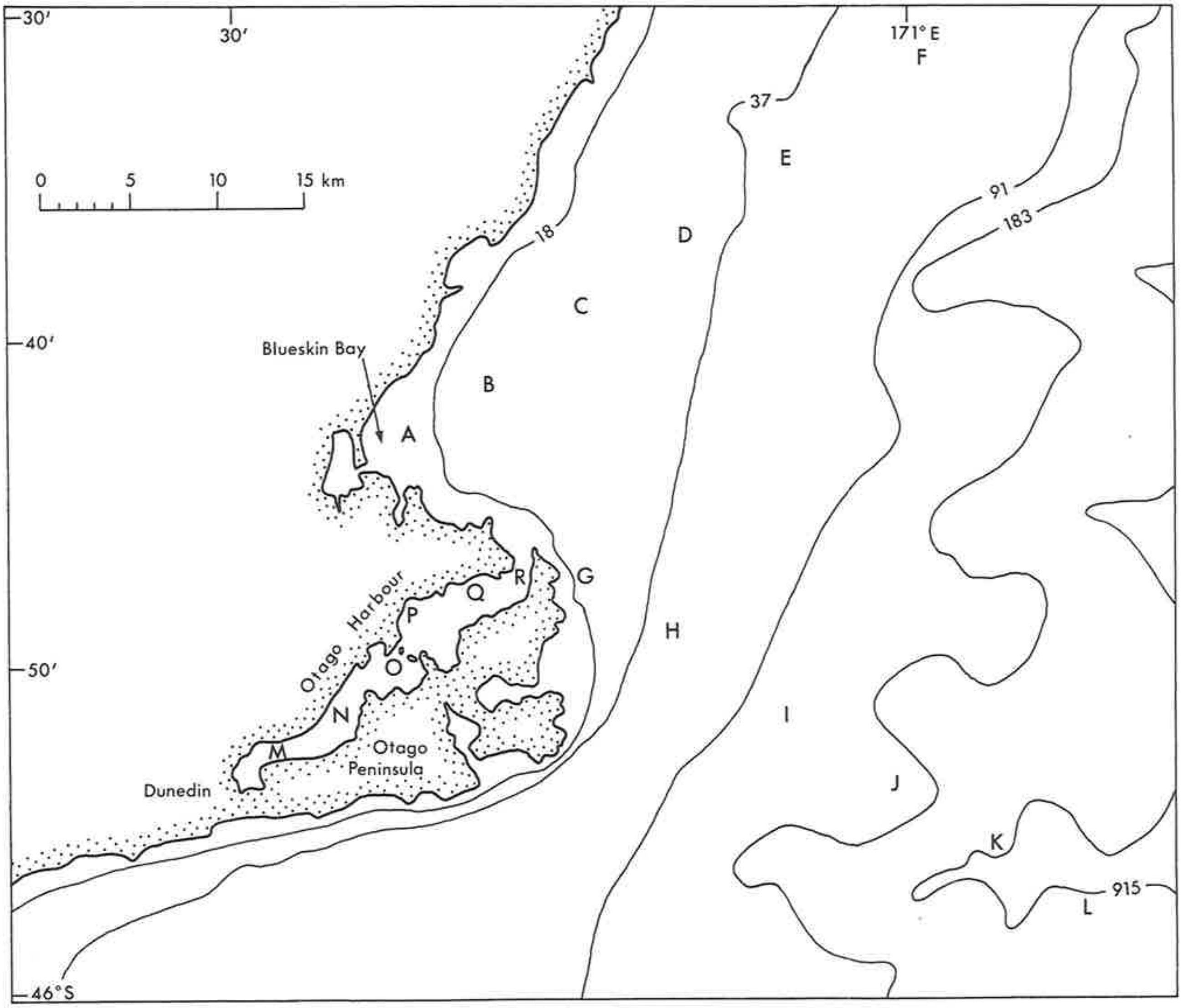

Fig. 1: Seasonally occupied stations off Otago.

TABLE 1: Types and principal features of plankton nets used in this study

Net	Shape	Depth of tow* (m)	Towing speed (knots)	Approx. vol. filtered (m^3)	Mouth area (m^2)	Total length (m)	Mesh size (mm)	Porosity	Open area ratio	Filtration efficiency (%)
Clarke-Bumpus	Cone	Surface 0-2	3-4	50	0.013	1.08	0.350	0.427	15.72	87
"Conical" net	Cone	Surface 0-2	3-4	500	0.170	1.35	0.688	0.510	3.50	80-87
WP-3 interim	Cylinder-cone	Surface 0-2	1-4	1 500	1.000	2.59	0.365	0.436	2.73	55-80
"Egg Net"	Cylinder-cone	Surface 0-2	3-4	500-1 000	0.275	5.00	0.365	0.417	15.42	90-105
Throttling "Egg Net"	Cylinder-cone	0-100	3-4	500-1 000	0.275	5.00	0.365	0.417	15.42	90-105

* All tows horizontal.

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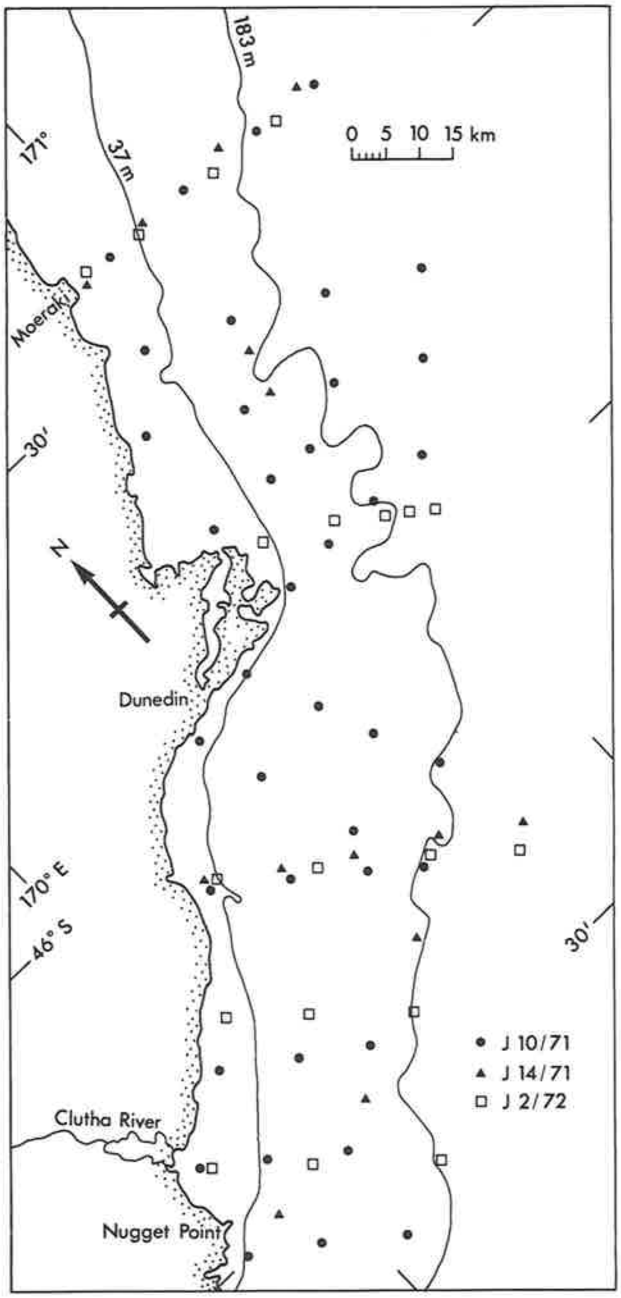

Fig. 2: Non-seasonal stations off the Otago coast.

METHODS

COLLECTION OF SAMPLES

Plankton

Planktonic teleost eggs are buoyant, and though they are often released at or near the sea bottom, under suitable hydrological conditions and during calm weather they ascend and accumulate close to the sea surface. Turbulence and variations in sea water density, however, result in eggs being distributed unevenly through the upper 150 m, with numbers being greatest near the surface (Ahlstrom 1969).

In a quantitative survey of planktonic eggs and larvae in which the primary aim is the assessment of the size of the breeding stock, it is essential that the entire vertical range of distribution is sampled. In such surveys vertical or oblique hauls are normally used (for example, Buchanan-Wollaston 1926, Simpson 1959, Ahlstrom 1968). Because of the tendency for buoyant eggs to accumulate at or near the sea surface, both vertical and oblique hauls often yield fewer eggs per cubic metre than horizontal surface samples. To provide a large sample of eggs, seasonal plankton tows in Otago waters were all taken immediately beneath the surface.

A variety of nets was used; their features are outlined in Table 1.

Two series of samples were collected from discrete depth intervals to help define the vertical distribution of the eggs.

Series 1, Blueskin Bay, 24 October 1972. A 57-cm diameter throttling net (identical to the "Egg Net", Table 1), fitted with internal and external TSK flow meters and a bathykymograph, was lowered backwards as the vessel moved ahead slowly until the required length of wire was out and then it was towed in a straight line at 3.5 knots for 30 minutes. At the end of the haul a messenger weight was passed down the wire to release the net mouth and actuate the throttling device before the net was recovered.

Six samples were taken, two at the surface and one each at 4 m, 6 m, 12 m, and 18 m. The bottom depth was 20 m.

The fish eggs were removed from each sample, counted, and identified if possible. Egg densities and relative proportions at each sampling depth were calculated.

Series 2, east of the Otago Peninsula, 12 October, 1972. The same net and method were used as in Series 1. Each haul was made parallel to the coastline. The bottom depths at the north and south ends of the hauls were 112 m and 120 m respectively, and the depths of sampling were 0.5 m, 12 m, 24 m, 41 m, and 84 m. The samples were treated as above.

Adult Fish

Many adult fish were collected at all seasons of the year by a variety of methods: bottom trawl, mid-water trawl, beach seine, set-net, set-line, hand-line, and speargun. Whenever running ripe females were caught, a sample of eggs was preserved in isotonic formalin, and if a running ripe male was taken an attempt was also made to fertilise eggs and observe development.

Many adult specimens were transported alive to the Portobello Marine Laboratory aquarium, where subsequent maturation of the gonads of several species enabled eggs to be collected and fertilised.

Observations on egg features from adult fish and plankton samples were used to compile an egg key which includes descriptions of all eggs discussed in this study (Robertson 1975).

TREATMENT OF SAMPLES

Freshly collected plankton samples were preserved by adding sufficient concentrated formalin, neutralised with 200 g/l of hexamine, to give about a 4%-5% solution. Occasionally there were large quantities of swarming or aggregating animals (mainly *Thalia democratica, Pyrosoma atlanticum, Nyctiphanes australis,* or *Munida gregaria*). When these occurred it was necessary to regard the sample as non-quantitative, and only a portion of the sample was kept for examination.

A low-power binocular microscope was used to separate eggs from the rest of the plankton. Usually the complete sample was examined and all eggs were removed.

In samples where eggs were very abundant, that is, 2000 per sample, subsamples were taken by use of a "Folsom Splitter" (McEwen, Johnson, and Folsom 1954). After removal from the rest of the plankton, the eggs were sorted into similar types, counted, and identified if possible by the features outlined in Robertson (1975).

Measurements of egg and oil droplet diameters were made to 0.025 mm with a graduated eyepiece on a binocular microscope.

HYDROLOGICAL OBSERVATIONS

To enable the recognition of water masses in which various fish species were spawning, and to define the basic environmental conditions in which their eggs developed, salinities and temperatures were taken at all seasonal stations in Otago waters and at all but a few of the non-seasonal stations.

Methods

Temperature readings and water samples for salinity determinations on the three transects were taken with a plastic water bottle fitted with two Negretti and Zambra protected reversing thermometers. Salinity samples were analysed with an "Autolab" inductive salinometer calibrated against Standard Copenhagen Sea Water.

The temperatures and salinity samples on the Blueskin Bay transect were taken at the surface and bottom at each station, and on the transect east of the Otago Peninsula they were taken at the surface and bottom or at 50 m when the depth was greater than 50 m. On the Otago Harbour transect temperatures and salinities were taken at 1.5 m, since tidal mixing was complete under most conditions.

At all non-seasonal stations salinities and temperatures were taken at the sea surface with a TSK casting bucket.

Five hundred plastic-coated drift cards (Olson 1951) were released in southern waters between Puysegur Point and Moeraki in October and November 1971 and January 1973.

HYDROLOGY

TEMPERATURE AND SALINITY

The main features of the surface waters around New Zealand have been summarised by Heath (1971a, page 15): "The New Zealand region contains two surface water types, namely Subantarctic Surface Water, which has its origin in the West Wind Drift south of New Zealand, and Subtropical Water which has its origin in the Trade Wind Drift north of New Zealand. These water types, which are definable by their characteristic temperature salinity relationships, meet in the Subtropical Convergence Region."

All surface current systems around New Zealand are subtropical in origin (Fig. 3). The south-east coast of the South Island is the least subtropical because of the cooling and diluting influence of adjacent Subantarctic Surface Water.

The hydrology off the Otago Peninsula was defined by Jillett (1969), who studied the seasonal temperature and salinity changes of shelf and slope waters. Jillett recognised three main surface water masses — neritic water, the Southland Current, and Subantarctic Surface Water — and a subsurface region of Antarctic Intermediate Water, each of which was distinguished by characteristic temperatures and salinities.

Seasonal Transects

Otago Peninsula Stations G–L (Figs. 4–7). The sea surface temperatures on this transect varied from 9.1° to 16.1°C. Temperatures were highest at the in-shore stations in late summer, with a tongue of warm water extending away from the coast throughout the summer.

Temperatures at the bottom near the coast, or at 50 m (where the bottom was deeper than 50 m), varied from 9.2° to 15.3°C. As with surface temperatures, the lowest readings were recorded in August 1971 and June 1972. The isotherms reflect the same pattern that occurred at the surface, except for the period July-October 1971, when an area of water warmer than that at the surface occupied the mid-shelf region.

Salinities at the sea surface ranged from 33.49‰ to 35.06‰. Two periods of dilution were apparent in October 1971 and June 1972; otherwise the variations were non-seasonal, with salinities being consistently high over the mid to outer shelf.

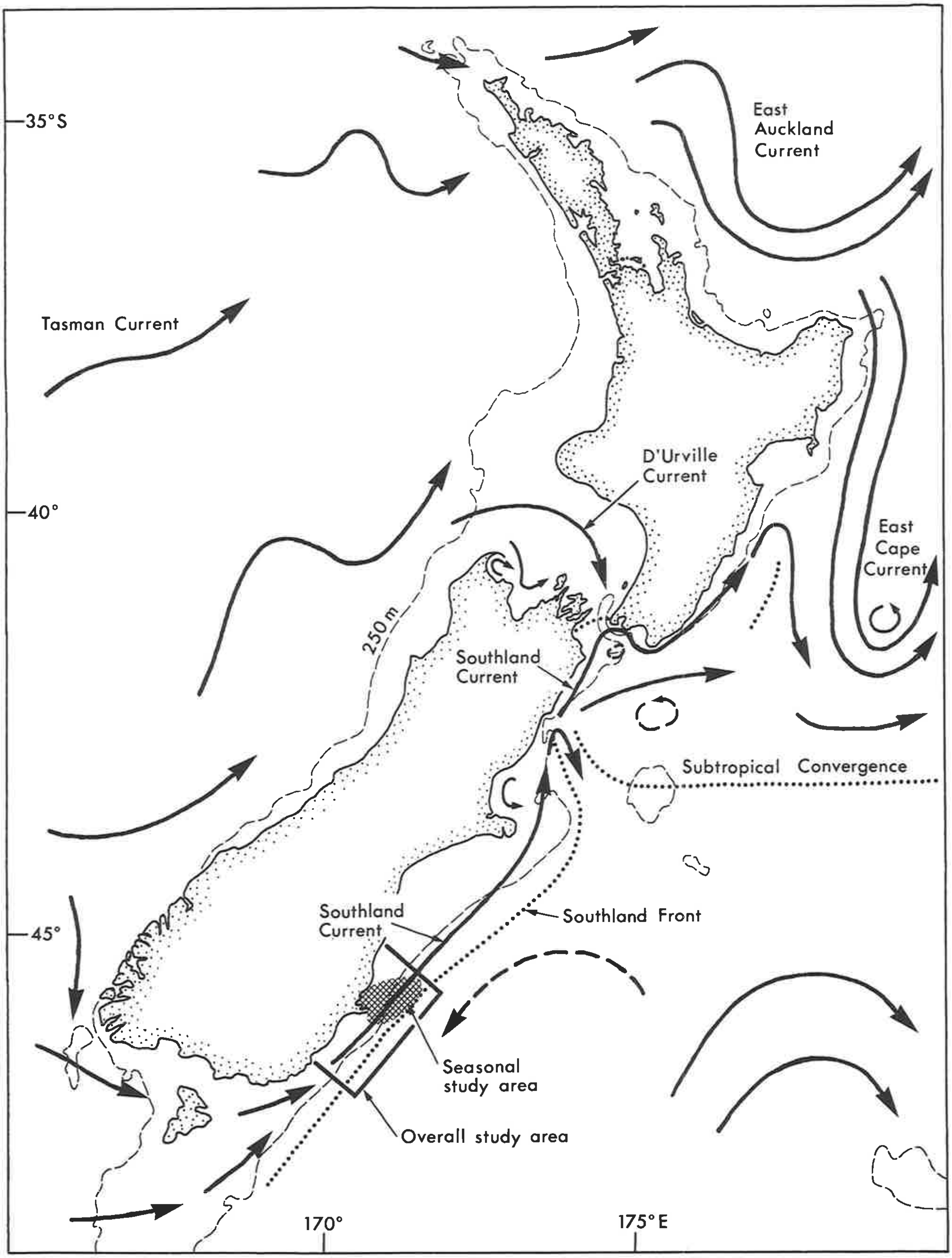

Fig. 3: Near surface oceanic circulation around New Zealand (after Heath 1971a).

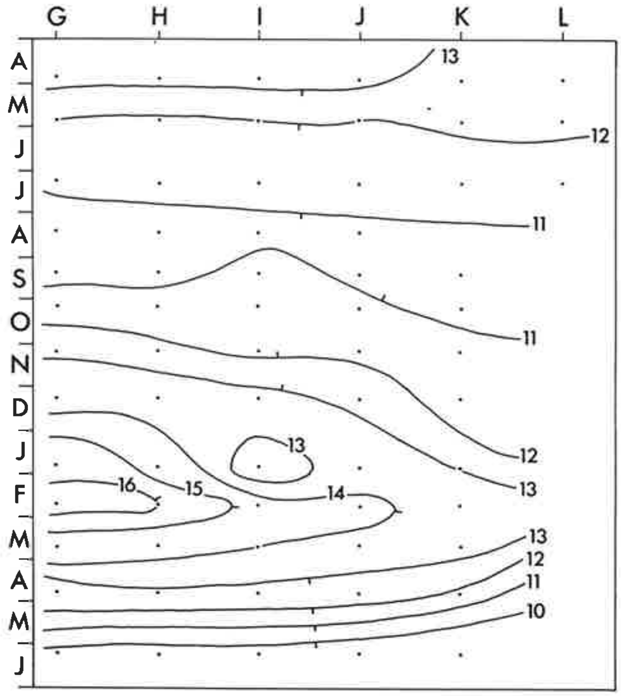

Fig. 4: Sea surface temperatures (°C) at stations G–L, April 1971 to June 1972.

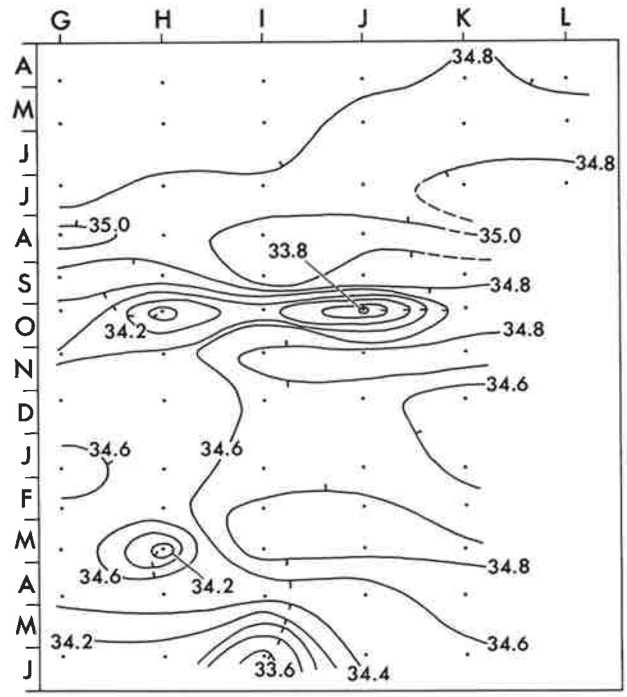

Fig. 6: Sea surface salinities (‰) at stations G–L, April 1971 to June 1972.

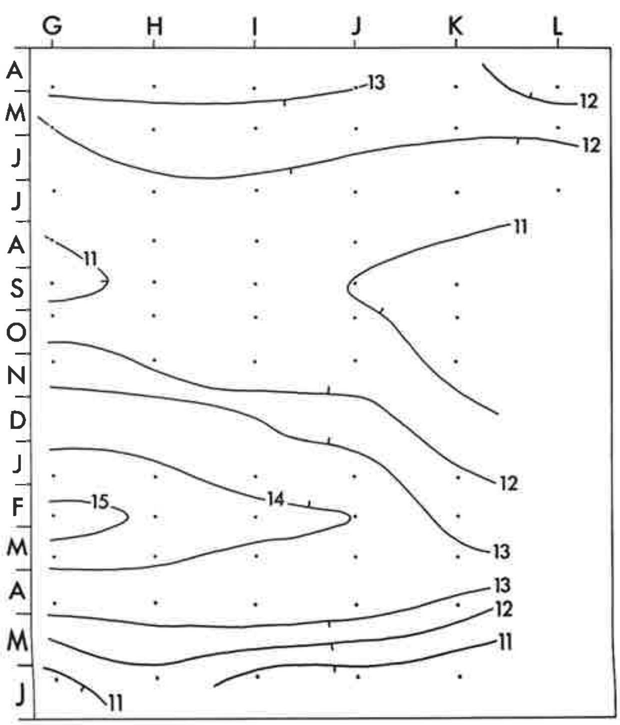

Fig. 5: Temperatures (°C) at the bottom at station G and at 50 m at stations H–L, April 1971 to June 1972.

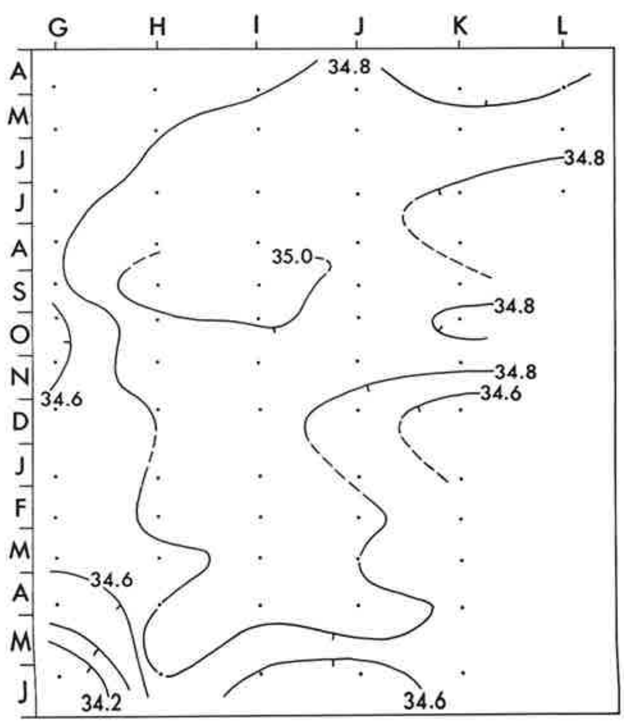

Fig. 7: Salinities (‰) at the bottom at station G and at 50 m at stations H–L, April 1971 to June 1972.

Subsurface salinities ranged from 34.03‰ to 35.07‰, and apart from some minor dilutions near the coastline, salinities were stable and showed no marked seasonal variations. Salinities were generally higher at the centre stations, H–J.

Discussion. These observations are consistent with Jillett's (1969) description of water masses off the Otago Peninsula. He defined the Southland Current as water with salinities and temperatures greater than 34.5‰ and 9.5 °C in winter, and greater than 34.6‰ and 12.0 °C in summer (Jillett 1969, Table 1). Such water of high salinity and temperature was present during the whole sampling period at stations H–K, that is, shallow to outer shelf. The maximum of 35.07‰ and other values higher than 35.00‰ in August-September 1971 were all higher than the maximum of 34.9‰ recorded by Jillett (1969). Temperatures in this study were also 1.0° to 1.5 °C higher than those observed by Jillett.

Jillett, using Garner's (1961) minimum Southland Current salinities, has described neritic water as having a salinity of less than 34.6‰ in winter and 34.7‰ in summer. This condition occurs over the inner shelf where Southland Current water is diluted by freshwater run-off. Neritic water is also characterised by variable temperatures. These are typically higher in summer and lower in winter than the water immediately off shore. The neritic layer, which is green, was often easily distinguished from the blue Southland Current water. The boundary between these water masses was often well defined and detected as a sharp deflection on a thermograph trace.

In Jillett's study Subantarctic Surface Water lay seawards of the Southland Current and was characterised by low salinities and temperatures, that is, less than 34.5‰ and 9.5 °C in winter and 34.6‰ and 12.0 °C in summer. Although areas of low temperature and salinity were observed at the outer stations east of the Otago Peninsula, these occurrences represented modified Southland Current water which had probably undergone temperature and salinity reduction through contact with Subantarctic Surface Water. None of the stations on this transect were positioned in true Subantarctic Surface Water.

Thus the conditions observed to the east of the Otago Peninsula were similar to those recorded by Jillett (1969) at his stations A, B, and C, with the Southland Current separated from the coast by a narrow strip of neritic water of variable temperature and salinity.

Blueskin Bay Stations A–F (Figs. 8–11). Sea surface temperatures in Blueskin Bay varied from 9.0° to 16.6 °C. Winter minima occurred in July-August in both 1970 and 1971; summer maxima occurred near shore in February-March. Temperatures at the sea bottom were similar to those at the surface. (The range was 9.1° to 16.6 °C.) Surface and bottom temperatures varied seasonally; fluctuations at stations A, B, and C were greater than at the outer stations.

Salinities at the surface varied from 33.80‰ to 34.91‰, with a range of 1.11‰. Fluctuations were seasonal, but conditions during the winter-spring of 1971 were quite the opposite from those during the previous winter and spring. The 1970 winter-spring was characterised by water of less than 34.40‰ extending seawards from the bay with a central minimum in October less than 34.00‰. In the 1971 winter-spring, however, water of high salinity extended coastwards and a central maximum occurred in July-September with salinities higher than 34.80‰. This was obviously an intrusion of non-neritic Southland Current water.

Sea bottom salinities in Blueskin Bay were similar to those at the surface, except that the coastward intrusion of high salinity water was slightly more extensive than at the surface.

Discussion. Blueskin Bay water is typically neritic, with salinities of less than 34.60‰ and temperatures which fluctuate beyond the expected range of the Southland Current.

Otago Harbour Stations M–R (Figs. 12 and 13). The Otago Harbour temperatures varied from a minimum of 6.5 °C in July 1971 to a maximum of 18.0 °C in February 1972. A thermal gradient frequently occurred along the length of the harbour, temperatures in the upper harbour being warmer in summer and colder in winter than in the lower harbour. The area of strongest temperature change was usually detected near the Quarantine Island-Goat Island channel about half way along the length of the harbour near station O.

Harbour salinities varied from 31.52‰ to 34.79‰, with a seasonal range of 3.27‰. As with temperatures, salinity gradients occurred along the harbour's length. Generally there was no seasonal reversal of the gradient, as upper harbour salinities were frequently depressed by freshwater run-off. In July-August 1971 high salinity water (34.70‰ to 34.79‰) was observed near the harbour entrance. This occurred when the Southland Current was closer in shore and more saline than usual (Figs. 6 and 7).

Discussion. As Otago Harbour is shallow and affected by freshwater run-off and by atmospheric

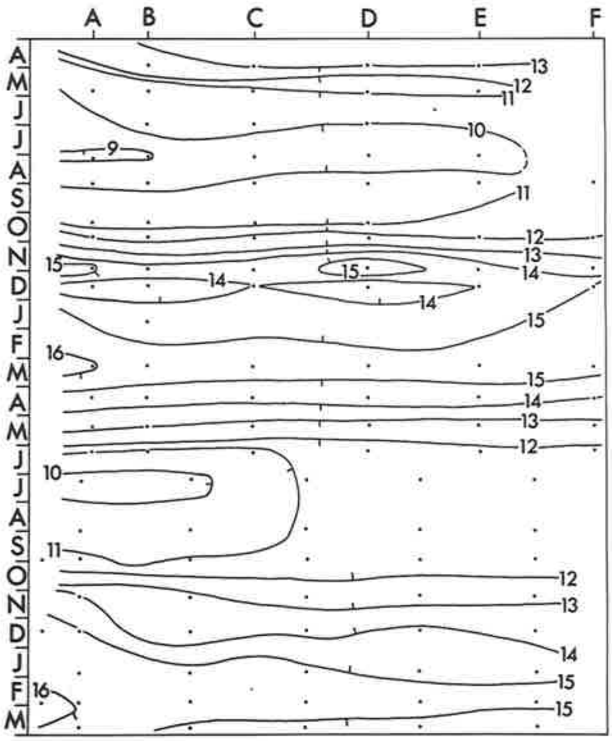

Fig. 8: Sea surface temperatures (°C) at stations A–F, April 1970 to March 1972.

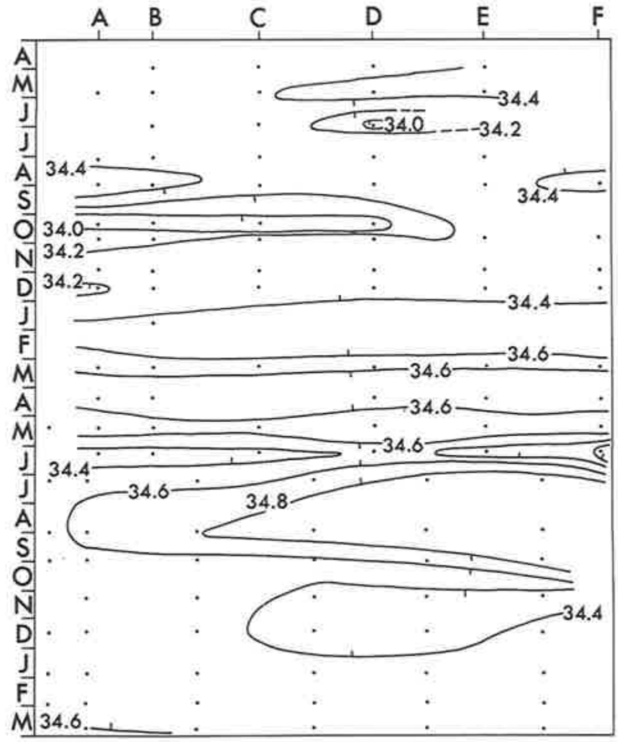

Fig. 10: Sea surface salinities (‰) at stations A–F, April 1970 to March 1972.

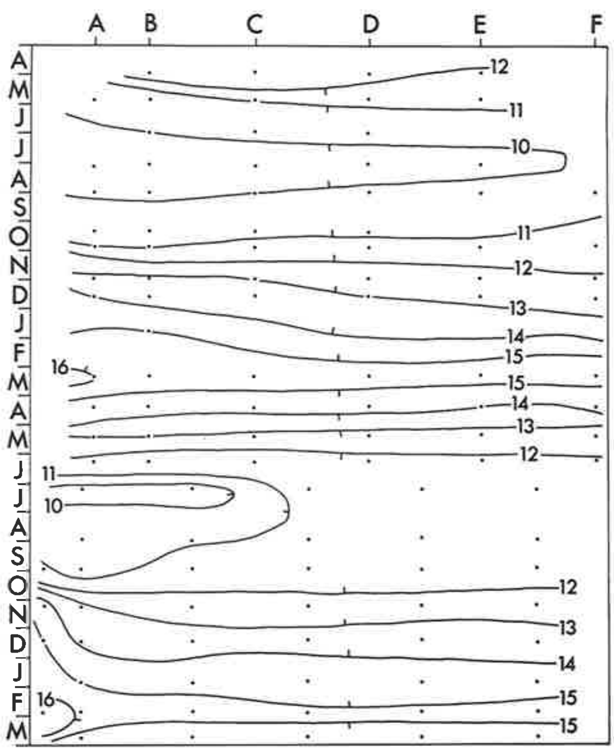

Fig. 9: Sea bottom temperatures (°C) at stations A–F, April 1970 to March 1972.

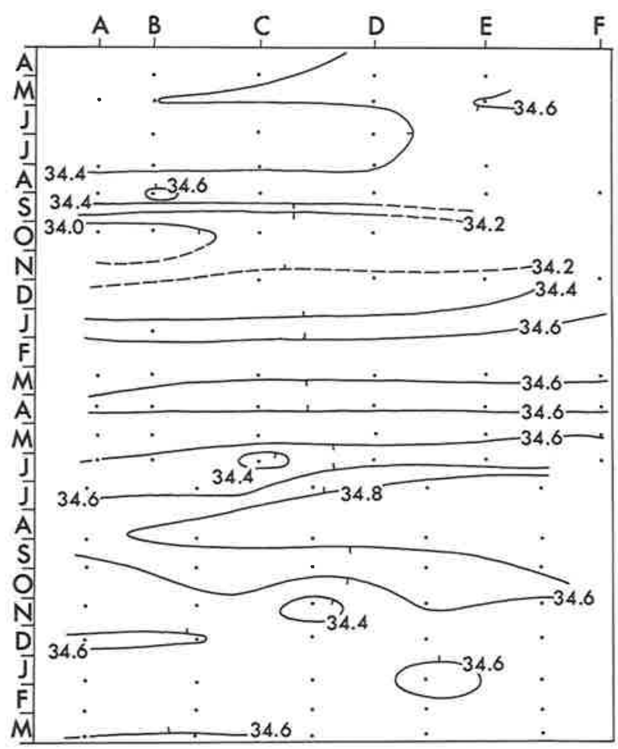

Fig. 11: Sea bottom salinities (‰) at stations A–F, April 1970 to March 1972.

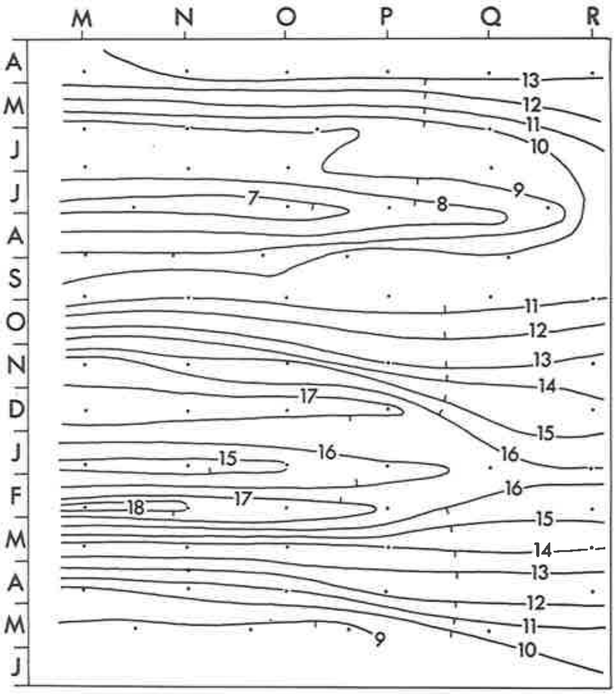

Fig. 12: Temperatures (°C) at stations M–R, April 1971 to May 1972.

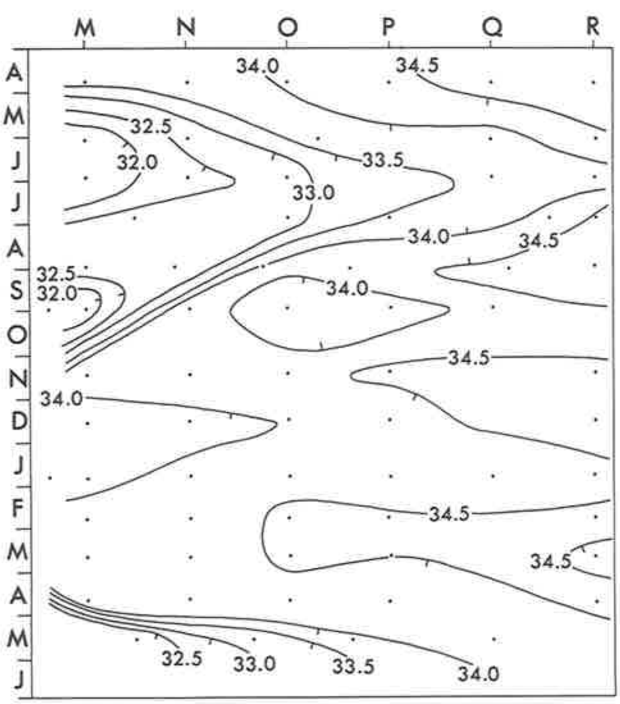

Fig. 13: Salinities (‰) at stations M–R, April 1971 to May 1972.

heating or cooling, it was to be expected that temperature and salinity would be more variable than in the other two transects. Furthermore, there were more pronounced thermal and saline gradients along the harbour than in either the Blueskin Bay or Otago Peninsula transects.

Skerman (1958) discussed the sea surface temperatures taken at the Portobello Marine Laboratory wharf in Otago Harbour from 1952 to 1955 and reported minima in July and maxima in January. The maximum annual range was 12.7 °C in 1953, which was greater than the range (11.3 °C) observed at station O in this study. Since his study was based on observations taken at a single point, Skerman was unable to comment on the gradients along the harbour. Such temperature and salinity gradients have been observed in Otago Harbour by Rainer (1969) and Jillett (pers. comm.). Slinn (1968) sampled at seven shore stations along the harbour and detected a salinity gradient of 2 ‰ between the inner and outer stations. He also measured daily salinities collected at the Portobello Marine Laboratory wharf during 1963. His monthly means ranged from 32.71 ‰ in July to 34.82 ‰ in January; that is, they were similar to the overall range observed during April 1971 to May 1972.

Conclusions. The three transects described above represent three different hydrological situations. The transect east of the Otago Peninsula is principally dominated by the high temperatures and salinities of the Southland Current, which is modified by fresh-water run-off and seasonal land temperature changes at its inner edge to form a neritic zone and is cooled at its outer edge by Subantarctic Surface Water.

The Blueskin Bay transect was neritic at most of its stations, with the western margin of the Southland Current occasionally influencing the other stations. Hydrological conditions in the bay were intermediate between those observed in Otago Harbour and those east of the Otago Peninsula. Harbour conditions were more extreme and much less stable than those of the other two areas (Table 2).

Non-seasonal Transects

Moeraki to Nugget Point (Cruise J10/71) (Figs. 14 and 15). The sea surface isotherms and isohalines along the Otago coastline indicate the position of the Southland Current, which occupies the mid to outer shelf, and an area of low temperatures representing the neritic zone west of the 10.2 °C isotherm. This zone was widest off the Clutha River mouth in the south. Cool Subantarctic Surface Water was detected at the seaward end of two of the lines of stations. Apart from an area of strong dilution extending north-east from

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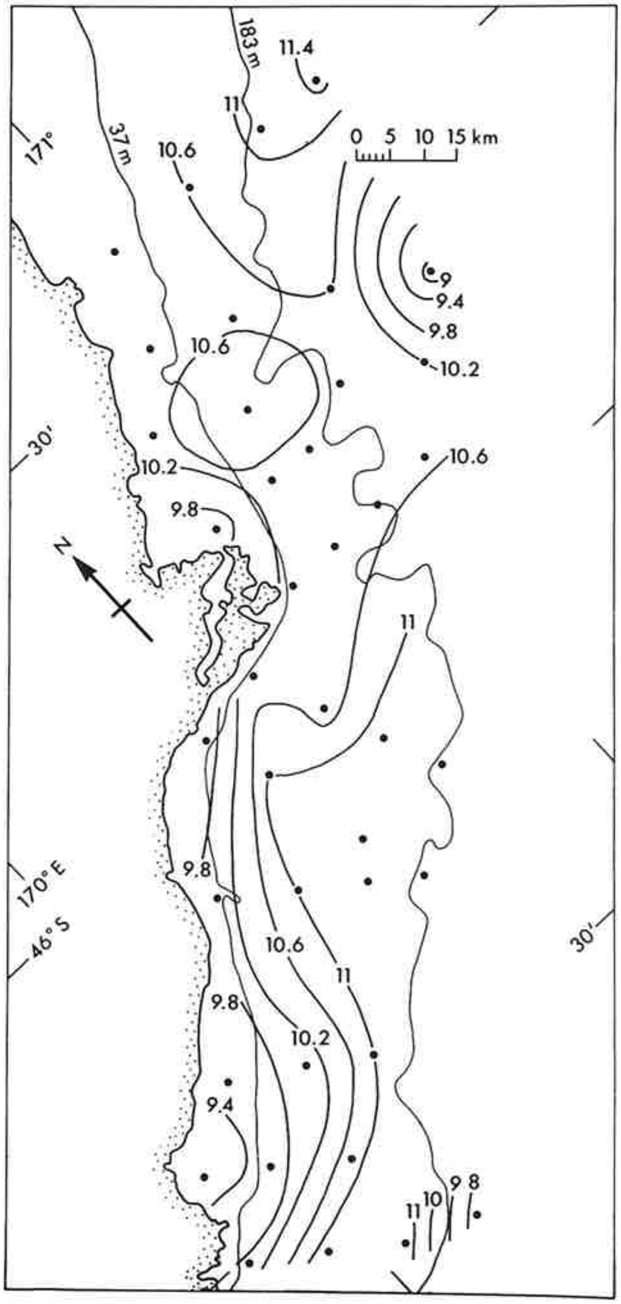


Fig. 14: Sea surface temperatures (°C) along the Otago coast, 11-14 August 1971 (Cruise J10/71).

the Clutha River mouth, the salinity was relatively high compared with values given by Jillett (1969).

The typical hydrology for the Otago coastline is clearly shown in surface temperature and salinity records from a transect running east from Nugget Point (Fig. 16); that is, the warm, high salinity Southland Current is bounded by neritic water in shore and Subantarctic Water off shore.

Discussion. These results demonstrate that the situation observed off the Otago Peninsula extends along the whole length of the Otago coastline from Moeraki to Nugget Point, and on two transects cool Subantarctic Surface Water was detected beyond the shelf edge. The steep temperature gradients observed at the outer ends of these two transects represent the Southland Front described by Burling (1961).

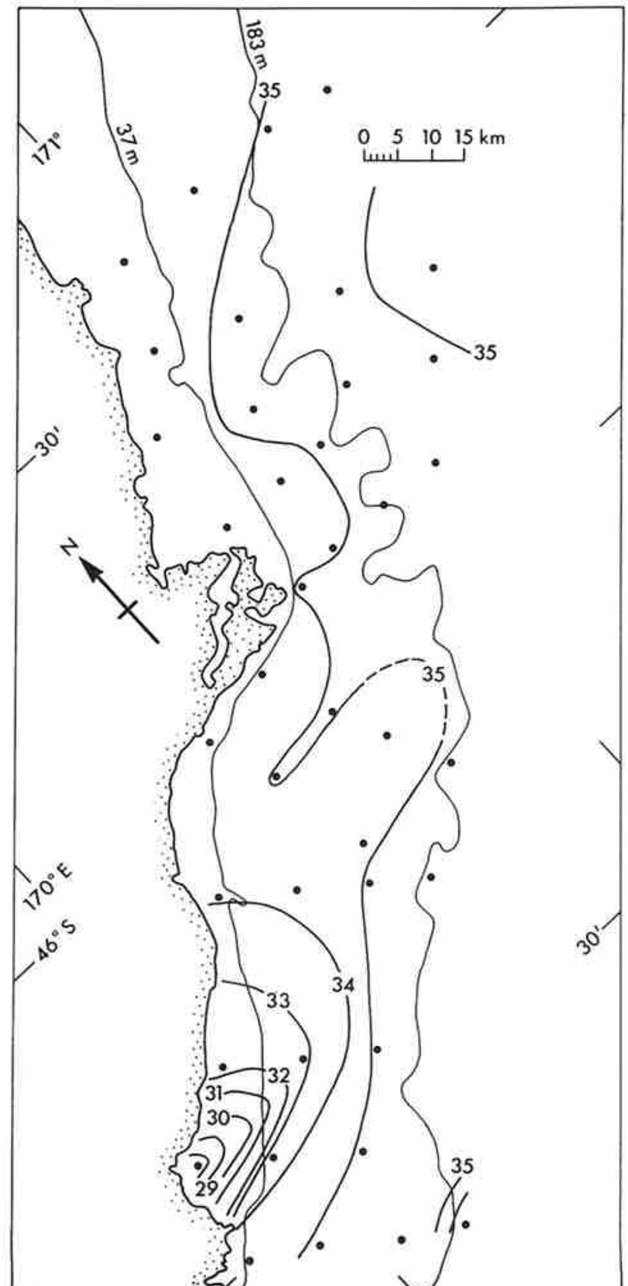


Fig. 15: Sea surface salinities (‰) along the Otago coast, 11-14 August 1971 (Cruise J10/71).

TABLE 2: Summary of temperatures and salinities on the three Otago transects

Transect	Depth (m)	Temperature (°C) Max.	Min.	Range	Salinity (‰) Max.	Min.	Range
East of Otago Peninsula	0	16.1	9.1	7.0	35.06	33.49	1.57
	50	15.3	9.2	6.1	35.07	34.04	1.03
Blueskin Bay	0	16.6	9.0	7.6	34.91	33.86	1.05
	bottom (10–50)	16.6	9.1	7.5	34.90	33.89	1.01
Otago Harbour	1.5	18.0	6.5	11.5	34.79	31.53	3.26

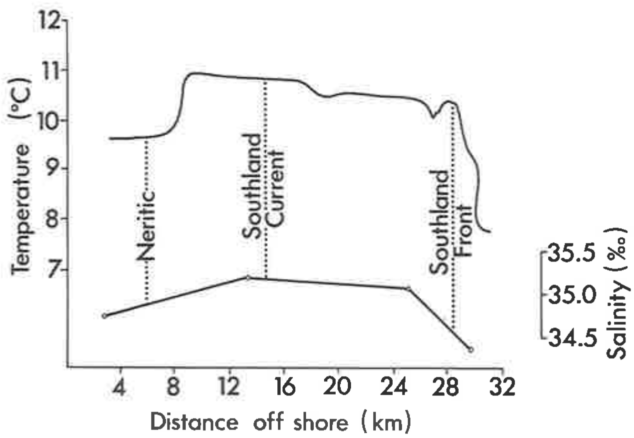


Fig. 16: Sea surface temperatures and salinities on an off-shore transect east of Nugget Point. (Temperatures continuously recorded on a thermograph.)

The in-shore surface water between Nugget Point and the Otago Peninsula was cooled and diluted by freshwater run-off from the Clutha River. Jillett (1969) demonstrated a close relationship between the Clutha River flow and in-shore salinity changes off the Otago Peninsula and suggested (page 359) that the Clutha flow "appears to have a primary influence on salinity depression in coastal waters and this influence is merely modified by outflow from smaller south-east coast rivers". Positive confirmation of this is provided by the sea surface isotherms in Fig. 15.

Moeraki to Nugget Point (Cruise J14/71) (Figs. 17 and 18). On both transects surface temperatures were fairly even across the shelf and dropped steeply beyond the edge. Mid-shelf temperatures on the southern transect were 1 °C higher than those further north off Moeraki. Salinities on both transects were highest (greater than 35.00 ‰) over the mid shelf. Low values due to run-off from the Taieri River were observed near the shore on the southern transect.

Discussion. During October 1971 the typical hydrological regime was present off the Otago coast. Warm, high salinity Southland Current water was dominant over the shelf, bounded by neritic water and Subantarctic Surface Water.

Moeraki to Nugget Point (Cruise J2/72) (Figs. 19 and 20). Sea surface temperatures were highest in shore and, unlike winter temperatures, summer values declined gradually from the inner to outer shelf. Sea surface salinities were much less variable than those observed previously and Southland Current water (salinity greater than 34.6 ‰) was present over most of the mid to outer shelf. An area of strong dilution was again observed near the Clutha River mouth.

Discussion. The observations on this cruise along the Otago coastline again confirmed the presence of the Southland Current over the mid to outer shelf, where surface temperatures and salinities were respectively greater than 12.0 °C and 34.6 ‰, the definitive values for Southland Current water off Otago in summer (Jillett 1969).

Conclusions. The hydrological observations made on these three cruises along the Otago coast in late winter and spring 1971 and summer 1972 have shown that conditions similar to those observed monthly off the Otago Peninsula also prevailed from Moeraki to Nugget Point. These observations have been combined to give a generalised hydrological situation for the sea surface off the Otago coastline (Fig. 21).

CURRENTS

The major current systems around New Zealand (Fig. 3) have been well defined in recent years (Brodie 1960, Heath 1968, 1969, 1971a, 1972, Ridgway 1970), and the velocities of some of these water movements have been measured by a variety of methods (Gilmour 1960, Sdubbundhit and Gilmour 1964, Houtman 1966, Heath 1968, 1969, 1971b, 1972).

Prevailing current systems are important in the lives of fishes. The adults often migrate against currents to spawning grounds, and the strength and direction of the currents have a strong influence on the subsequent fate of the planktonic eggs and larvae (Fulton 1897, Fraser 1958, Bishai 1960, Harden Jones 1968).

To provide an indication of the drift of the young planktonic stages of fishes the movement of water in the Otago study area was observed by use of a current meter and drift cards.

Results

Of the 500 drift cards released, 58 (11.6%) were recovered. All except two moved northwards (Fig. 22) and several were recovered such a short time after release that they provided an estimate of the minimum current velocity (Table 3). The average minimum velocity was 14.9 cm/sec.

Discussion. The observations made on water movements off Otago confirmed the presence of the Southland Current flowing northwards as was expected from the reports of Marshall (1931), Brodie (1960), Henderson (1967), Jillett (1969), and Heath (1972).

Current velocity measurements in coastal waters are complicated by tidal changes, coastal promontories, and irregularities in bottom topography, each of which increases the variability of observations. The current velocities measured off Otago were, however, comparable with those from other areas of New Zealand coastal waters.

TABLE 3: Minimum velocities of Southland Current surface water estimated from drift card recoveries

Position released (deg. min.)		Area recovered	Time from release to recovery (days)	Minimum distance travelled (naut. miles)	Minimum velocity	
Lat.(S)	Long.(E)				Naut. miles/day	cm/sec
46 22	170 22	Longbeach Otago	7.85	45	5.9	12.7
46 04	170 15	Longbeach Otago	8.28	36	4.4	9.4
46 08	170 22	Katiki Beach	9.98	53	5.3	11.4
46 08	170 22	Shag Point	9.00	48	5.3	11.4
46 08	170 22	Moeraki Beach	9.04	58	6.4	13.7
46 08	170 24	Shag Point	8.98	47	5.2	11.2
46 08	170 24	Shag Point	9.03	48	5.3	11.4
46 08	170 24	Shag Point	9.03	48	5.3	11.4
46 08	170 22	Katiki Beach	10.05	52	5.2	11.2
46 08	170 22	Katiki Beach	8.29	53	6.4	13.7
46 37	169 32	Warrington Beach	7.71	75	9.5	20.4
46 37	169 32	Karitane	7.62	76	10.0	21.4
46 37	169 32	Warrington Beach	7.54	75	9.9	21.2
46 37	169 32	Waitati	7.67	75	9.8	21.0
45 48	170 48	Pegasus Bay	18.24	210	11.5	24.7
46 28	169 52	New Brighton	32.42	263	8.1	17.4
46 28	169 52	Spencerville Pegasus Bay	42.31	265	6.3	13.5
46 42	169 10	Smithfield Beach	26.23	140	5.3	11.4

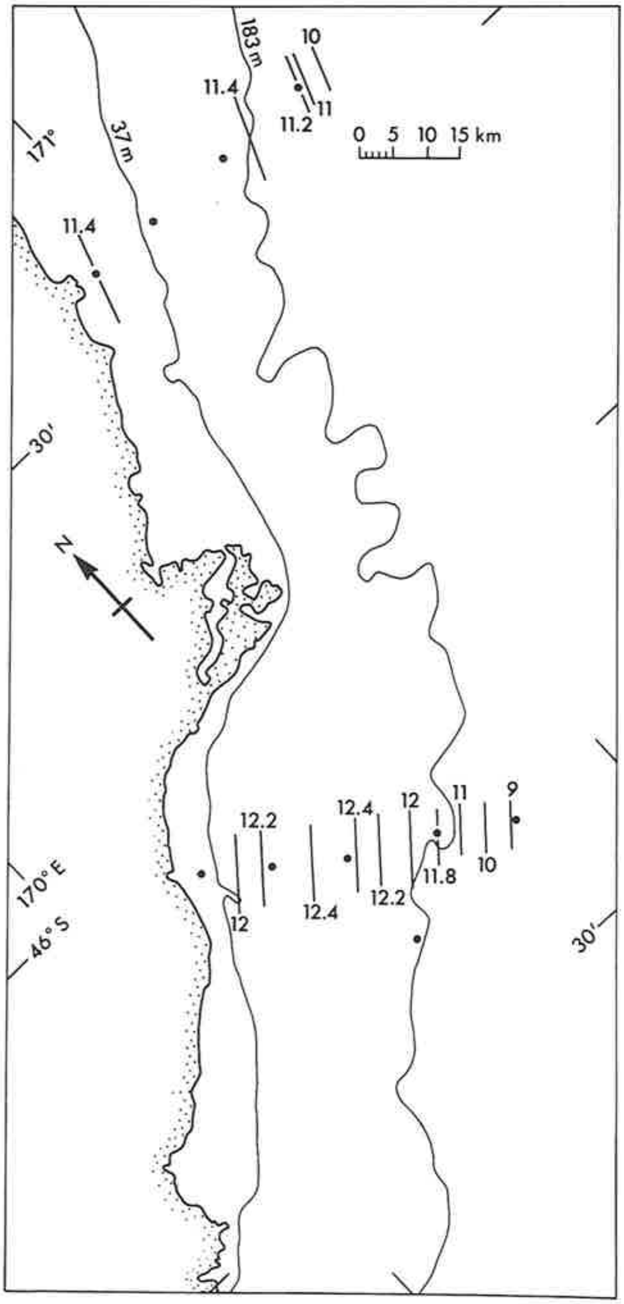


Fig. 17: Sea surface temperatures (°C) off the Otago coast, 13–15 October 1971 (Cruise J14/71).

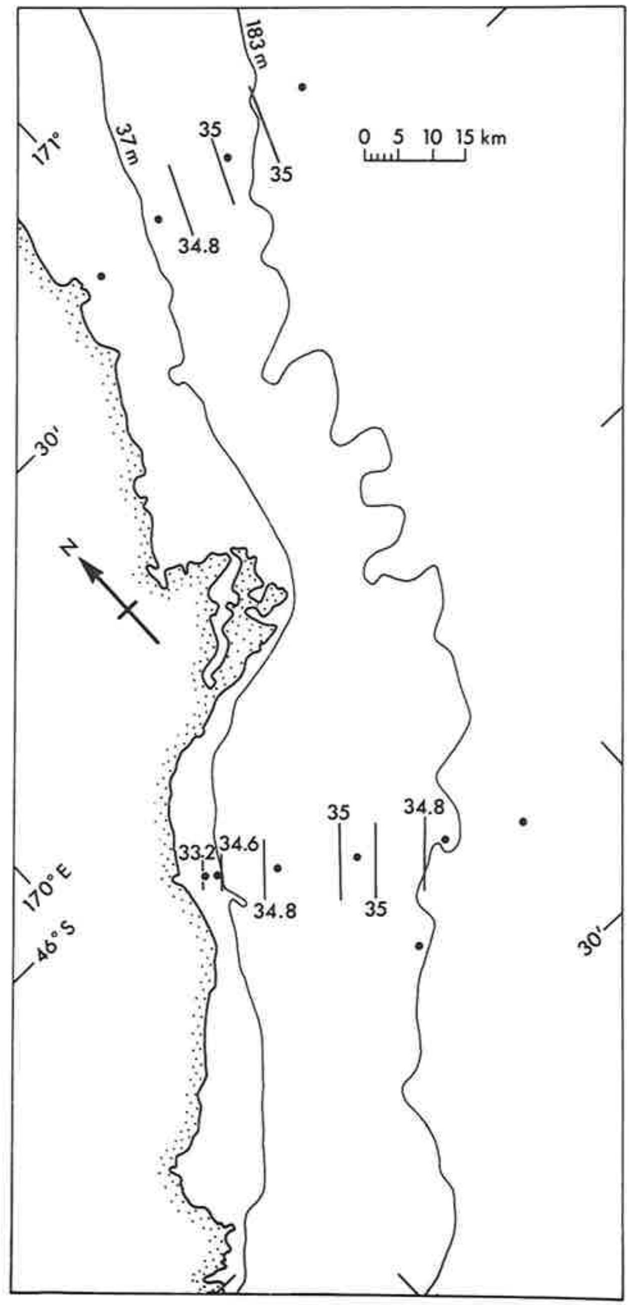


Fig. 18: Sea surface salinities (‰) off the Otago coast, 13–15 October 1971 (Cruise J14/71).

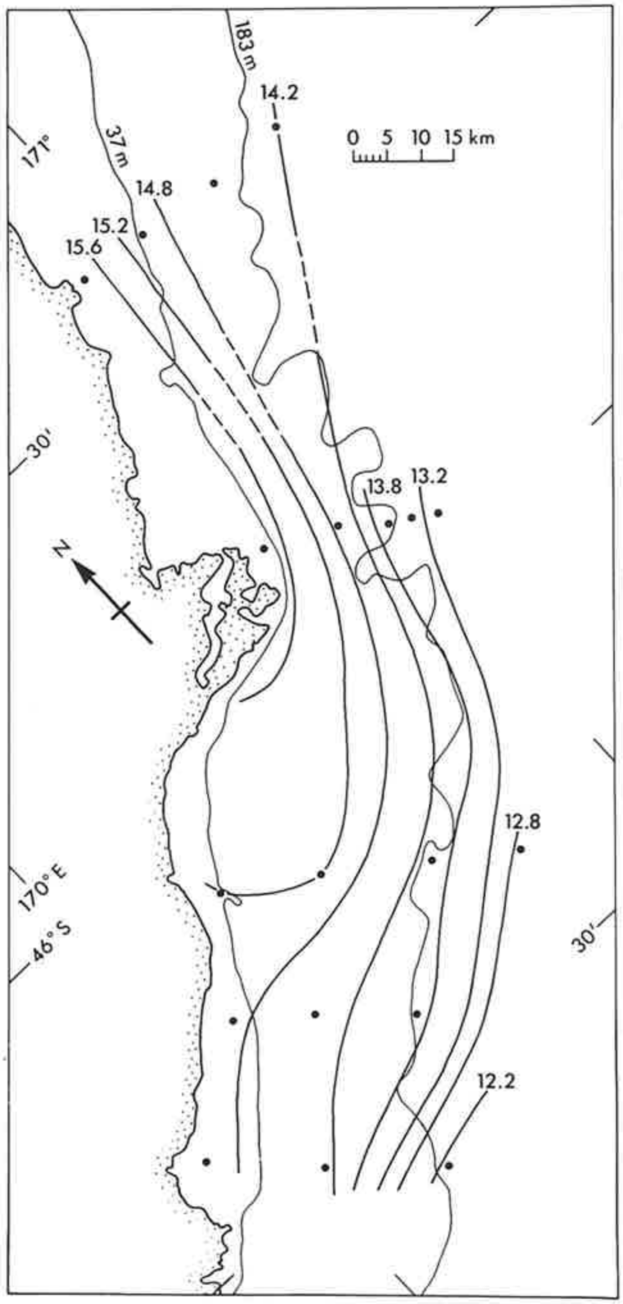


Fig. 19: Sea surface temperatures (°C) off the Otago coast, 26–28 February 1972 (Cruise J2/72).

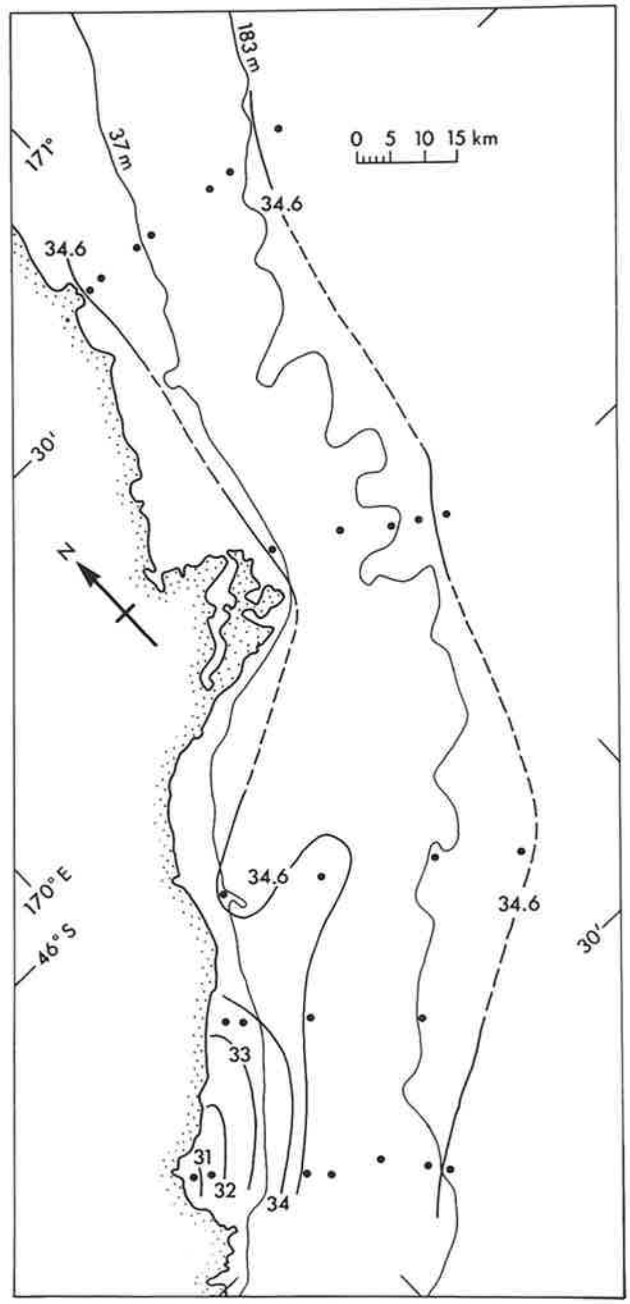


Fig. 20: Sea surface salinities (‰) off the Otago coast, 26–28 February 1972 (Cruise J2/72).

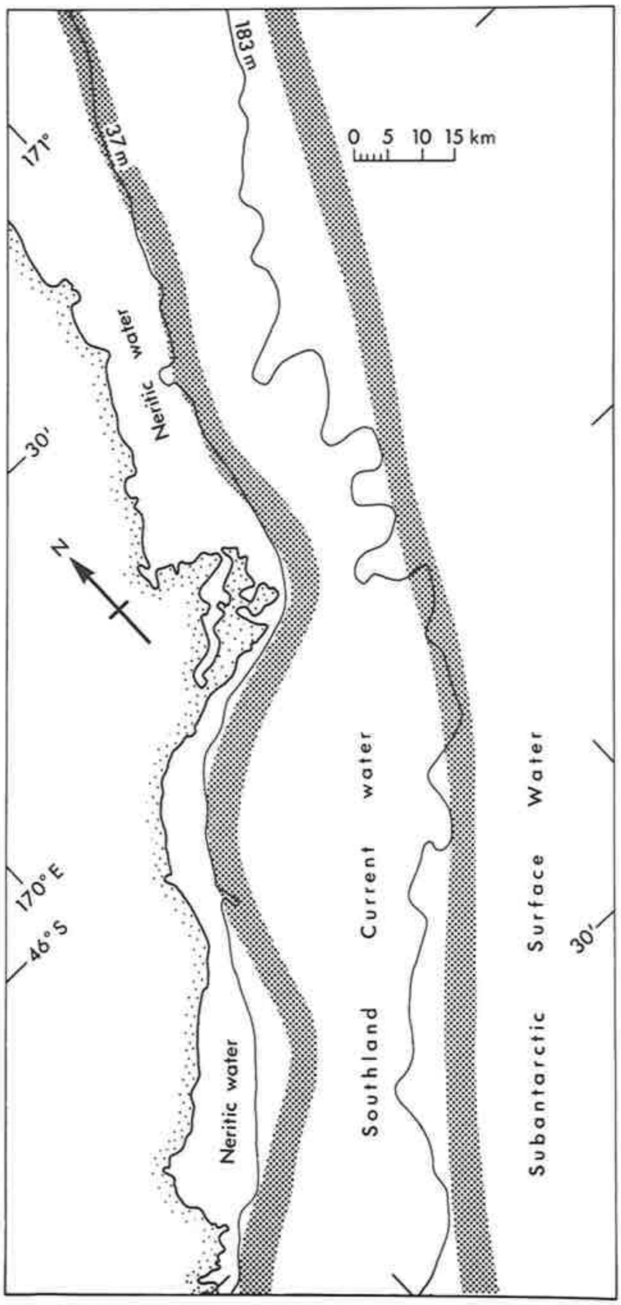


Fig. 21: A generalised view of the positions of the surface water masses off the Otago coast in winter and spring. Shaded areas represent thermohaline fronts.

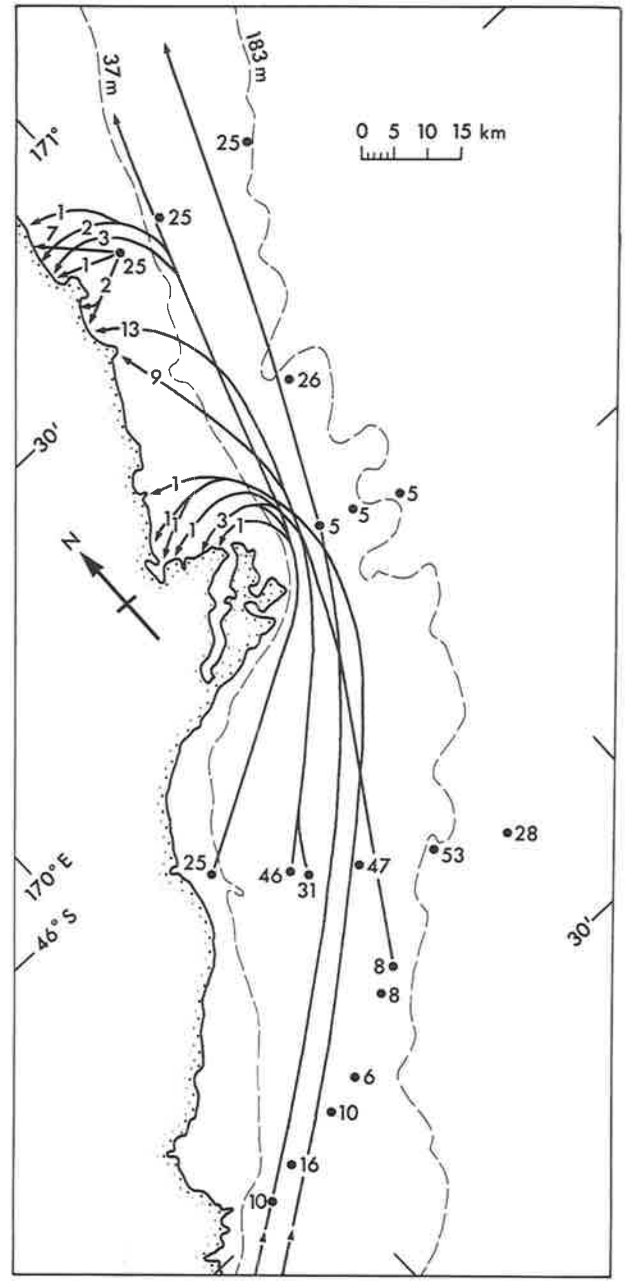


Fig. 22: Drift card release points, recovery points, and probable drift paths off the Otago coast. (Numbers of cards released and recovered.)

SEASONALITY, DISTRIBUTION, AND ABUNDANCE OF PLANKTONIC FISH EGGS

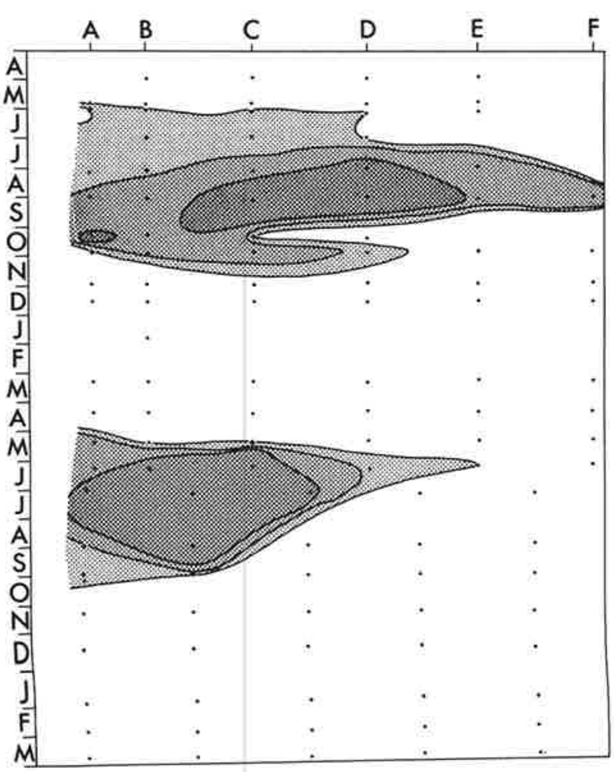
Family Clupeidae

Sprattus antipodum (Hector 1872) Sprat

In New Zealand waters sprat have been taken from the Auckland Islands to the Bay of Islands (Baker 1972). Two more species, *S. muelleri* (Klunzinger 1880) and *S. holodon* (Regan 1916), have been described from New Zealand. Svetovidov (1952) suggests that *S. antipodum* and *S. muelleri* may be synonymous and Whitehead (1964, page 327) considers that these two species are "perhaps doubtfully distinct . . .". Their synonymy is shown in Robertson and Moreland (in prep.), though a second undescribed species is present.

Baker (1973) has recently described and figured the developmental stages of the eggs and larvae of the sprat.

The seasonal occurrence of sprat eggs on the three Otago transects is shown in Figs. 23–25. Of the three areas Blueskin Bay was the most important. In the Blueskin Bay sample eggs were more abundant than in samples from Otago Harbour or east of the Otago Peninsula. The spawning season was well defined both in 1970 and 1971 in Blueskin Bay (Fig. 23), where eggs occurred from June to early November in 1970 and from May to early October in 1971. Spawning extended further seawards during the 1970 season than was observed in the 1971 season, probably because in 1970 sea temperatures were considerably cooler than in 1971. The presence of warm, high salinity Southland Current water during the 1971 season appeared to confine the centre of spawning activity to stations A, B, and C (Fig. 1). Comparison of Blueskin Bay egg density contours (Fig. 23) with seasonal isotherms (Fig. 8) shows that in both 1970 and 1971 the centre of spawning activity was confined by the 11.0°C isotherm.



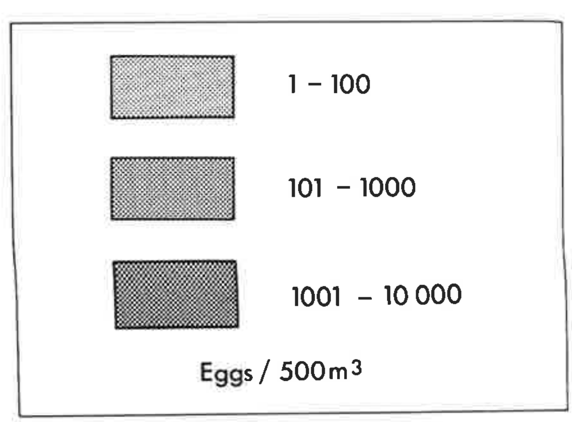


Fig. 23: Seasonal sea surface distribution of sprat (*Sprattus antipodum*) eggs at stations A–F, April 1970 to March 1972.

Small numbers of sprat eggs were collected at the inner stations on the transect east of the Otago Peninsula in April, May, July, and October of 1971 and in April, May, and June of 1972. The occurrences at stations H, I, and J in October 1971 (Fig. 24) were associated with the pocket of unusually low salinity shown in Fig. 6. Other occurrences were in neritic water close to the shore.

Sprat eggs were not common in Otago Harbour and were present only during June and July of 1971, when they were taken throughout the length of the harbour (Fig. 25). Eggs were also abundant in several of the surface plankton samples taken along the Otago coastline in August 1971 (Fig. 26). The centre of abundance was between Nugget Point in the south

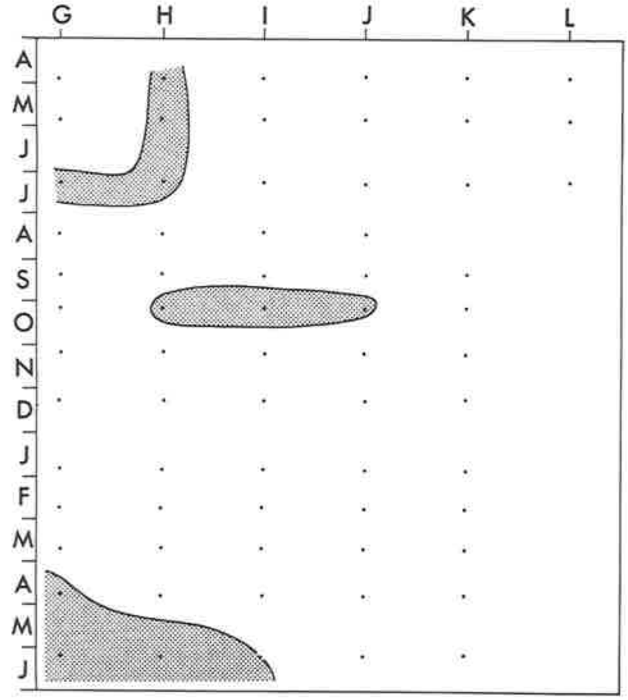


Fig. 24: Seasonal sea surface distribution of sprat (*Sprattus antipodum*) eggs at stations G–L, April 1971 to June 1972 (see key on page 28).

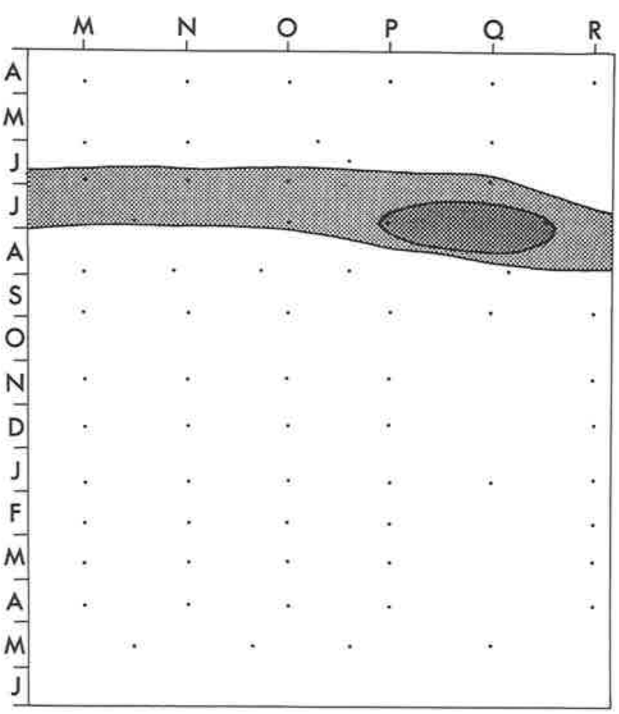


Fig. 25: Seasonal sea surface distribution of sprat (*Sprattus antipodum*) eggs at stations M–R, April 1971 to May 1972 (see key on page 28).

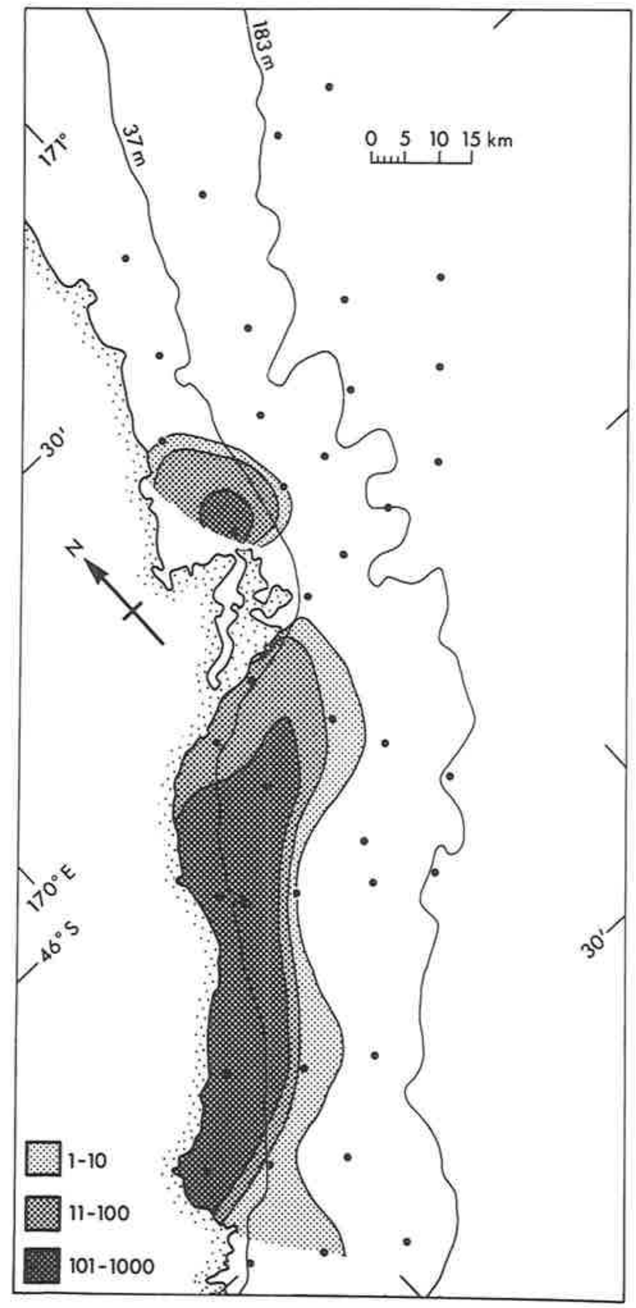


Fig. 26: Sea surface distribution of sprat (*Sprattus antipodum*) eggs off the Otago coast, 11–14 August 1971 (numbers per 500 m^3).

and the Otago Peninsula, with a smaller pocket of eggs occurring in Blueskin Bay. Sprat eggs were, however, absent from stations beyond the middle of the continental shelf. The spawning area obviously extended further south than the southern stations, since the southernmost samples contained eggs.

The distribution of eggs along the Otago coastline was centred in the cool, low salinity strip of water between Nugget Point and the Taieri River mouth,

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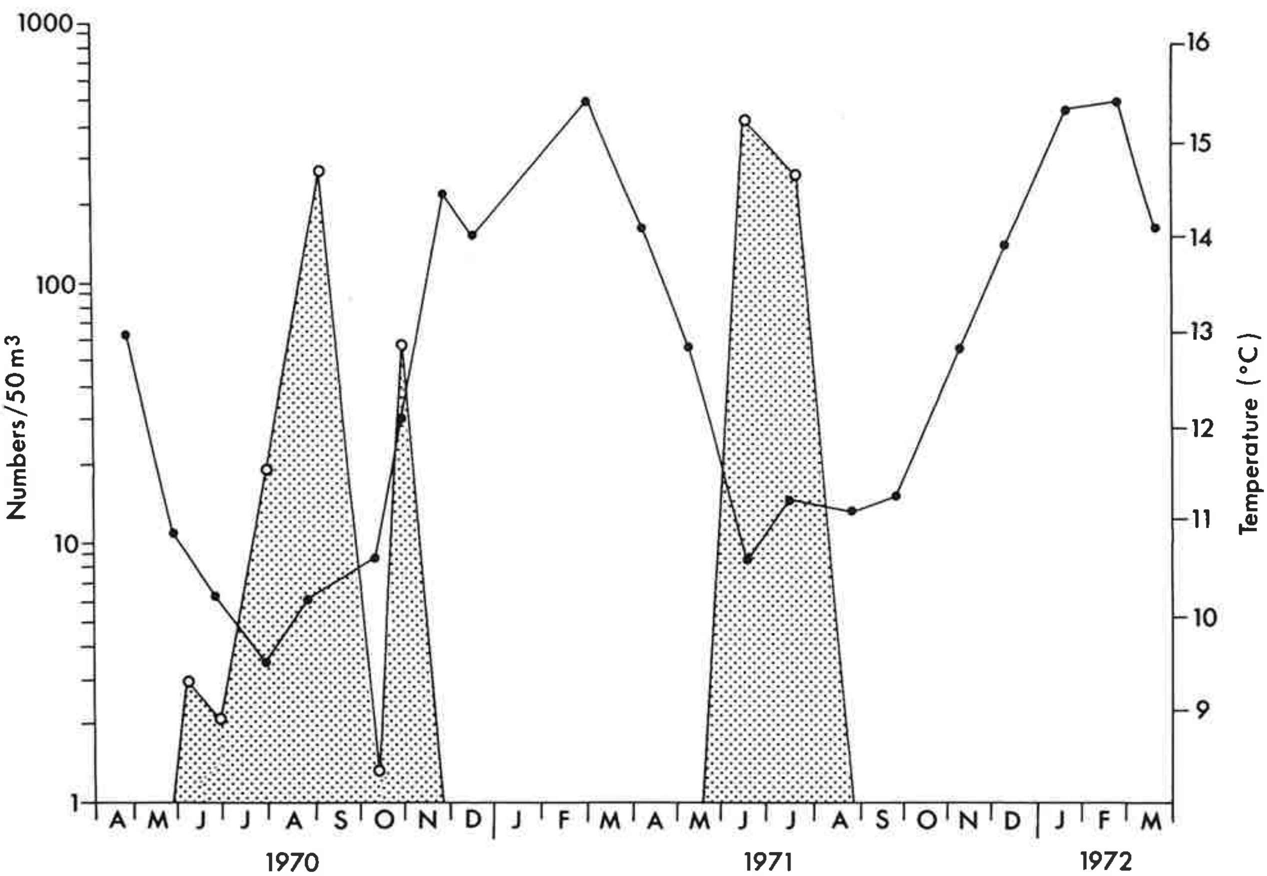

Fig. 27: Annual temperature cycle and sprat (*Sprattus antipodum*) egg numbers at station C, April 1970 to March 1972.

where salinities and temperatures were lower than in the rest of the area surveyed. The contours of egg density closely paralleled the isopleths for temperature and salinity shown in Figs. 14 and 15.

The relationship between sprat egg abundance and the annual temperature cycle is shown for Blueskin Bay station C in Fig. 27. Eggs first appeared at a temperature of 10.8 °C in 1970 and at 11.3 °C in 1971 as the temperature was falling. Numbers reached a maximum at the same time as, or shortly after, the seasonal temperature minimum. Eggs were present over a range of 10.8°–12.5 °C in 1970 and 11.3°–11.2 °C in 1971 at station C.

The ranges of temperature and salinity of waters in which sprat eggs were collected are given in Table 4. Included are values taken at the limits of distribution; these will obviously be beyond the limits of spawning. Comparison of the egg distributions with the corresponding hydrology figures shows the centre of abundance of the eggs (that is, the site of spawning) to occur in areas with a surface temperature range of 9.0°–10.4 °C and a surface salinity of less than 34.50 ‰.

Some samples enabled an estimation of the approximate time of spawning. On 31 August 1970, at 2025 hours and 2225 hours, sprat eggs at the 0-4-celled stage were taken at the surface in Blueskin Bay. As no data are available on the early development of sprat eggs, it was assumed that these eggs were from 1 to 3 hours old and that fertilisation had occurred in the period 1725–2125 hours. Similar observations were made in August 1971, when 8–32-celled eggs were taken at stations occupied at 2216 and 2248 hours. If an age of 4–6 hours is assumed, fertilisation would have occurred within the

TABLE 4: Temperature and salinity ranges at collection sites of sprat eggs

Area	Year	Temperature (°C)	Salinity (‰)
Blueskin Bay	1970	9.1-12.1	33.86-34.49
	1971	9.7-13.1	34.32-34.80
East of Otago Peninsula	1971	11.1-13.2	33.79-34.82
	1972	9.6-12.5	33.49-34.50
Otago Harbour	1971	6.5-18.3	31.74-34.70
Otago coast (J10/71)	1971	9.2-11.3	27.80-35.01

period 1616–1848 hours. Eggs were collected at all other times of day in the sprat spawning area, but none were at the 0–32-celled stage.

Discussion. Although the distributional range of adult sprat is extensive in New Zealand waters, plankton samples examined throughout the New Zealand region suggest that spawning is concentrated in central and southern waters. From a consideration of the hydrological conditions where its eggs were most abundant, sprat can be expected to spawn in neritic waters with temperatures of 9.0°–10.5°C and salinities less than 34.50‰. This would include neritic waters around most of the South Island in mid winter.

The spawning season is well defined in Blueskin Bay, Otago, where sprat is a winter-spring spawner. The season in the Marlborough Sounds area, however, lasts longer, as Baker (1973) reports winter to summer spawning. The spawning season may be longer where temperature and salinity are depressed by freshwater run-off during summer; for example, where south Otago waters are diluted and cooled by the Clutha River outflow.

There are few observations on the spawning of sprat. Parrott (1957) commented that spawning occurred in the open sea and suggested that the species was probably an autumn-winter spawner. Morgans (1966), after studying the length-frequency distribution of a large sample from Kaikoura, suggested that the species was a prolonged spawner, and Baker's (1973) observations confirm this. According to Lebour (1921), the spawning of *Sprattus sprattus* (Linnaeus 1758) near Plymouth may begin in January, with eggs being most abundant in February-March and dwindling in May; that is, *S. sprattus* is a winter-spring spawner like its southern counterpart. The night-time spawning of *S. antipodum* off Otago resembles that of *S. sprattus,* which spawns between 2200 and 0600 hours with peak activity between midnight and 0400 (Simpson 1971).

Family Sternoptychidae

Maurolicus muelleri (Gmelin 1789)

The cosmopolitan subtropical sternoptychid *Maurolicus muelleri* is widespread and abundant around New Zealand. Seasonality and distribution of *M. muelleri* eggs along the Otago coast are shown in Figs. 28 and 29. Temperature and salinity ranges at these collection sites were 10.5°–10.9°C and 34.90‰ –35.10‰ respectively.

Discussion. The eggs of *M. muelleri* are common and widespread around New Zealand. Although the spawning period off Otago appeared to be restricted to

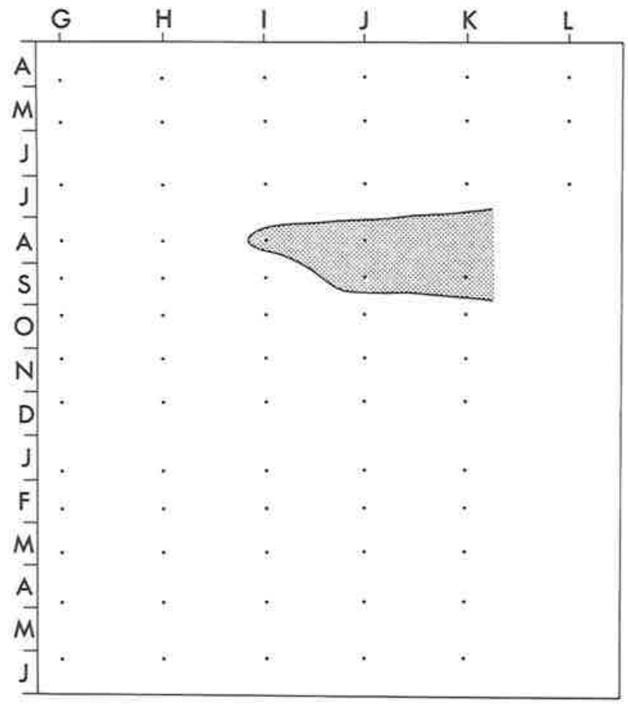

Fig. 28: Seasonal sea surface distribution of *Maurolicus muelleri* eggs at stations G–L, April 1971 to June 1972 (see key on page 28). (After Robertson 1976.)

August and September, it continues until March in North Island waters (Robertson 1976). Surface samples, however, are inadequate as a reliable indicator of spawning of this species, which releases its eggs at depths greater than 250 m, from which they may not ascend as far as the surface.

Family Moridae

Auchenoceros punctatus (Hutton 1873) Ahuru

The ahuru, *Auchenoceros punctatus,* is a small member of the family Moridae; mature adults range in length from 8 to 15 cm. This species occurs seasonally in Otago waters and was taken by Waite (1911) in the Canterbury Bight, Pegasus Bay, and south of Poverty Bay in the North Island. It has also been collected at Cape Campbell and in the Thames Estuary (Graham 1953).

The eggs of ahuru were the smallest taken in this study (0.525–0.600 mm in diameter, Robertson 1975). The seasonal occurrence of ahuru eggs in the three Otago transects is shown in Figs. 30–32. Of these three areas Blueskin Bay is the most important, and here the spawning period was well defined, beginning in June and lasting until November or December. Eggs were most abundant in the plankton from late June to late September (that is, mid winter to mid spring). Spawning in 1971 was not as extensive as in the previous year

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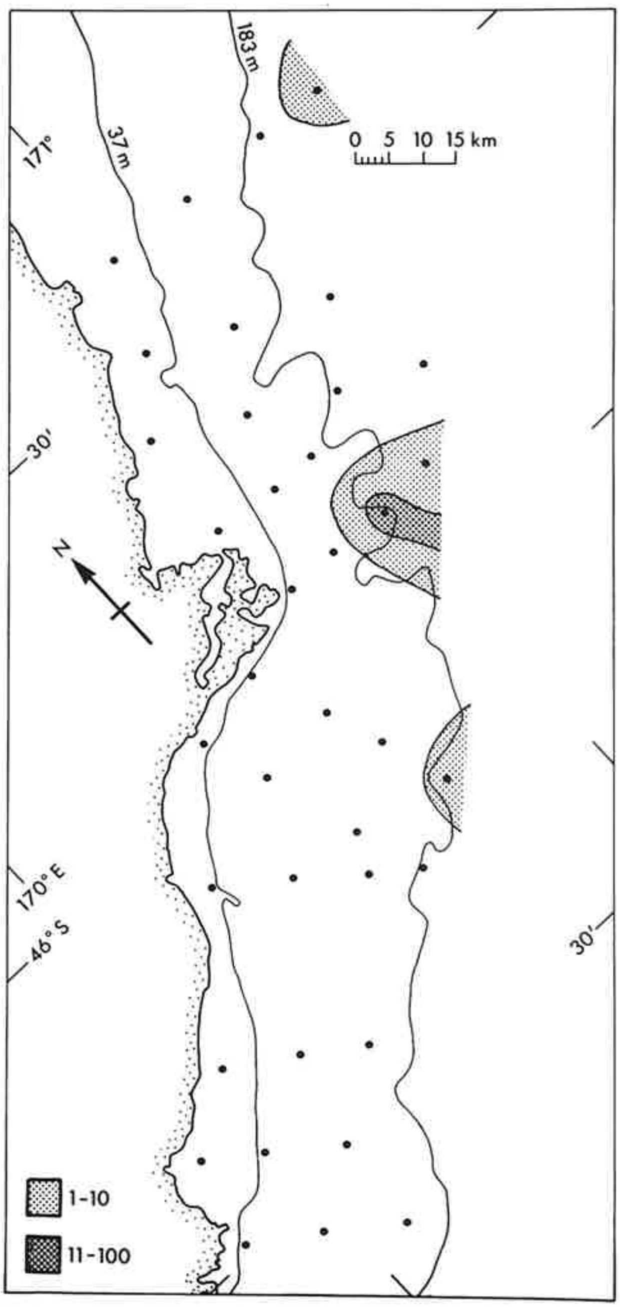


Fig. 29: Sea surface distribution of *Maurolicus muelleri* eggs off the Otago coast, 11–14 August 1971 (numbers per 500 m³). (After Robertson 1976.)

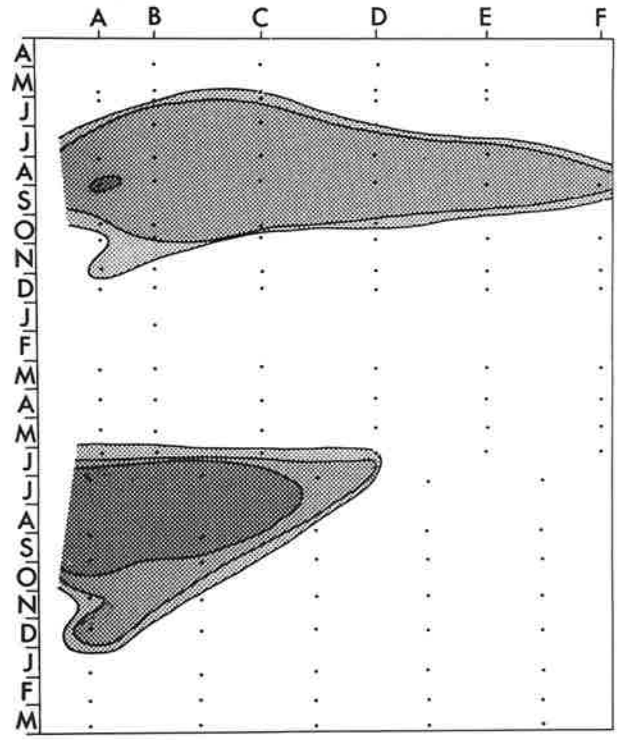


Fig. 30: Seasonal sea surface distribution of ahuru (*Auchenoceros punctatus*) eggs at stations A–F, April 1970 to March 1972 (see key on page 28).

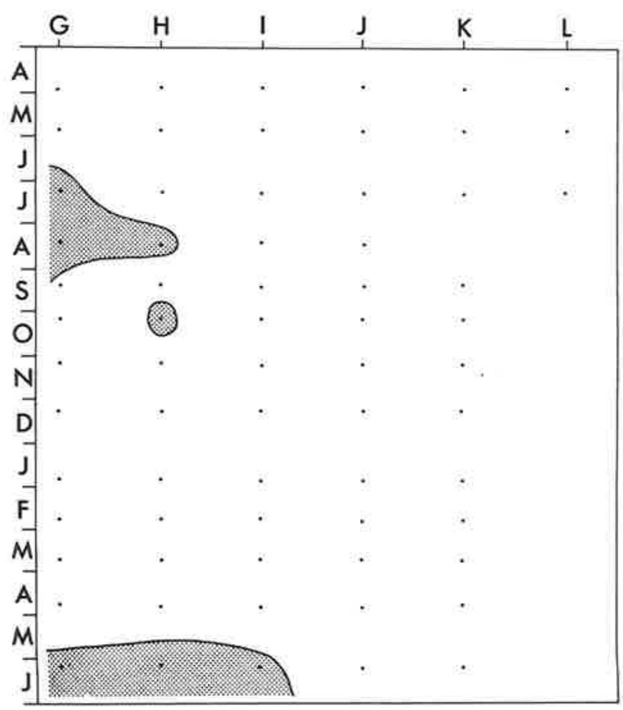


Fig. 31: Seasonal sea surface distribution of ahuru (*Auchenoceros punctatus*) eggs at stations G–L, April 1971 to June 1972 (see key on page 28).

and was apparently associated with the warming influence of Southland Current water. The outer limit of the eggs in Fig. 30 corresponds with the 11 °C isotherm in Fig. 8. Although eggs did not occur along the full length of the Blueskin Bay transect in 1971, eggs at the surface were ten times more abundant at stations A–C for the period July to September than for the same period in 1970.

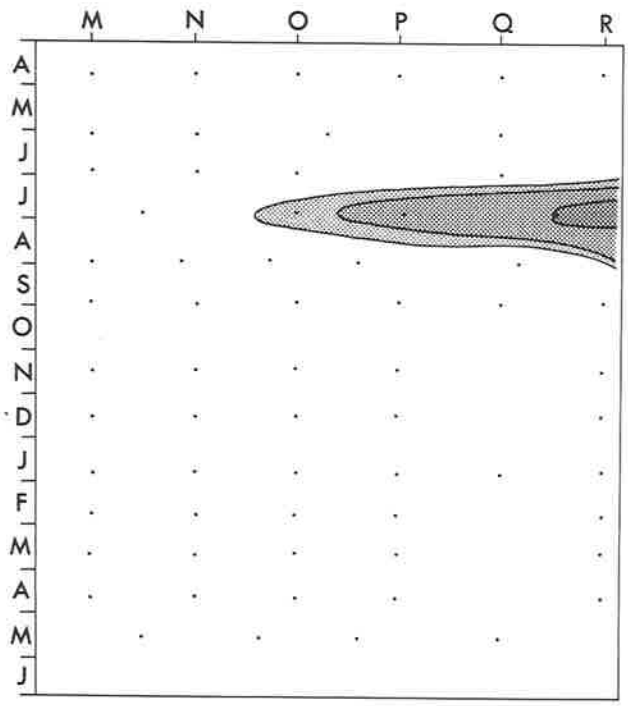


Fig. 32: Seasonal sea surface distribution of ahuru (*Auchenoceros punctatus*) eggs at stations M–R, April 1971 to May 1972 (see key on page 28).

On the transect east of the Otago Peninsula (Fig. 31) there were only a few ahuru eggs at the surface at the inner stations during July, August, and October 1971 and in June 1972.

In Otago Harbour eggs were collected in July 1971 (Fig. 32). These were late stage eggs and would have entered on the tide from Blueskin Bay.

During the peak of the 1971 spawning season plankton stations were occupied from Moeraki in the north to Nugget Point in the south. Spawning was centred in the zone of neritic water close to the shore line (Fig. 33) and eggs were most abundant where the water was coolest and the salinity lowest. The egg number contours between Otago Peninsula and Nugget Point are closely parallel to the temperature and salinity isopleths (Figs. 14 and 15). It is possible that the adults select water of such neritic attributes in which to spawn. No eggs were taken in the northernmost transects, which suggests that the spawning area in Blueskin Bay is localised and does not extend northwards. The presence of eggs in the southern transect indicates that spawning also occurs southwards along the coast.

The temperature and salinity ranges for areas of occurrence of ahuru eggs are given in Table 5.

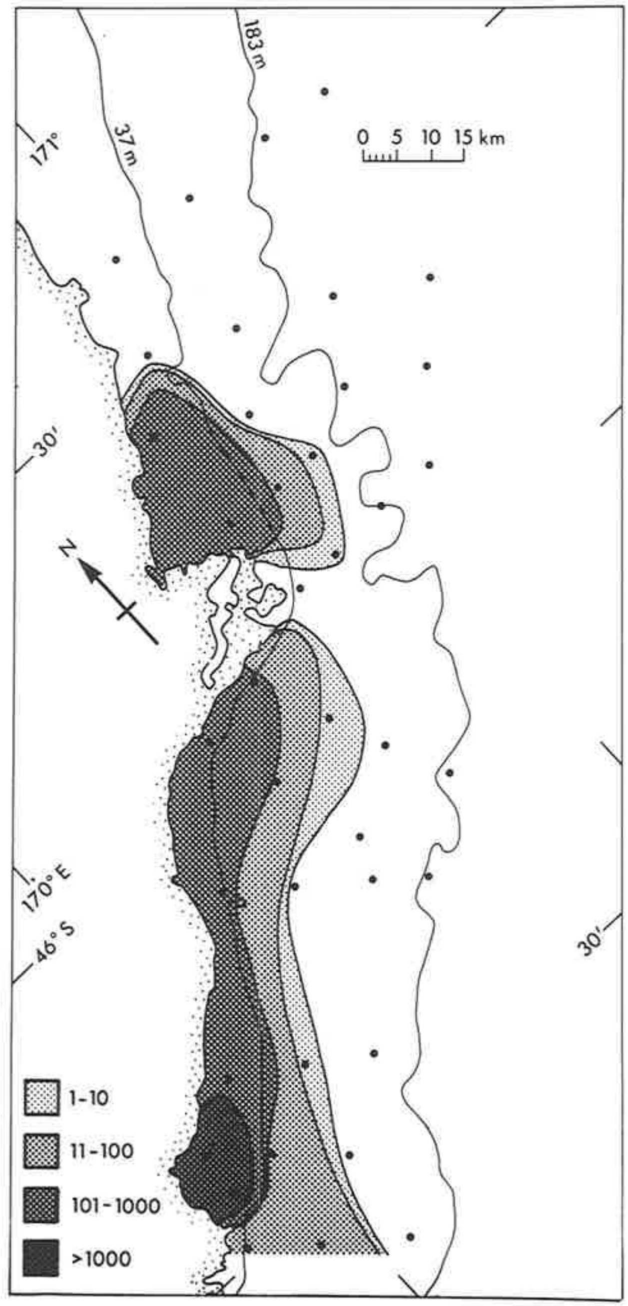


Fig. 33: Sea surface distribution of ahuru (*Auchenoceros punctatus*) eggs off the Otago coast, 11–14 August 1971 (numbers per 500 m^3).

In Blueskin Bay spawning was first detected in early June as the temperature was declining. The temperature at first sighting of ahuru eggs was 10.5 °C in 1970 and 10.7 °C in 1971. Numbers of eggs then increased as the temperature decreased, with the maximum number of eggs occurring when temperatures were lowest in late July-early August (Fig. 34). At station B no eggs were taken after the temperature increased beyond 11.5 °C in 1970 and 11.1 °C in 1971.

TABLE 5: Temperature and salinity ranges at collection sites of ahuru eggs

Area	Year	Temperature (°C)	Salinity (‰)
Blueskin Bay	1970-72	9.0-15.0	33.86-34.85
East of Otago Peninsula	1971	9.6-11.6	33.49-35.02
Otago Harbour	1971	6.5-10.6	32.75-34.70
Otago coast (J10/71)	1971	9.2-11.0	28.00-35.00

During August 1971 recently fertilised eggs were collected at two stations. The eggs at these stations were assumed to be 2–5 hours old (8–32 cells). At the two stations the mid times of sampling were 2230 and 2354 hours; thus the eggs would have been fertilised during the period 1730–2154 hours. (Sunset was at 1730 hours and the bottom depth 30 m.)

Discussion. There is no literature on the spawning of ahuru and no record of eggs or larvae being collected in New Zealand waters. However, several areas other than Otago are likely to provide conditions suitable for the spawning of this species. Such areas would include bays on the south coast of the South Island, Canterbury Bight, and Tasman and Golden Bays. Ahuru is a winter-spring spawner in southern New Zealand waters and the adults appear to have a definite preference for the cool, low salinity water close to the coastline, where spawning activity, as indicated by egg numbers, peaks during mid to late winter when temperatures are lowest. The time of day when spawning occurs is suggested to be between sunset and midnight in these in-shore waters. Development to hatching takes about 134–139 hours and yolk-sac absorption a further 123–127 hours at 10.0 °C (Robertson 1973). During this period the eggs or larvae drift in surface waters.

Family Macrouridae

Genus *Coelorhynchus* Giorna 1803

Coelorhynchus australis (Richardson 1839) and *C. aspercephalus* (Waite 1911) are two common and widespread members of the genus in New Zealand waters. They are occasionally taken by bottom trawl on the shelf, especially on the east coast of both islands (Waite 1911). They are, however, much more abundant in trawls taken beyond the edge of the shelf on the slope and off-shore plateaus.

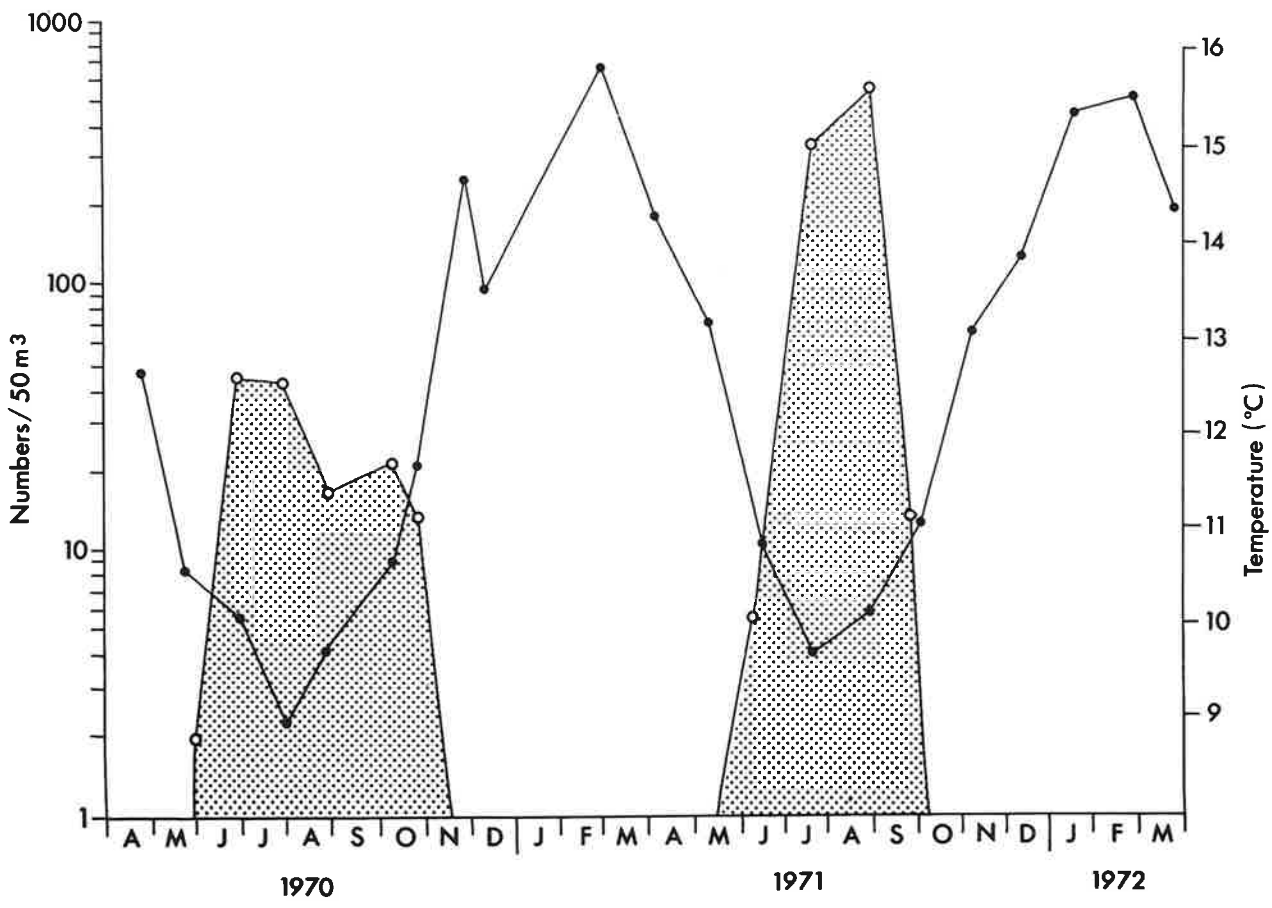


Fig. 34: Annual temperature cycle and ahuru (*Auchenoceros punctatus*) egg numbers at station B, April 1970 to March 1972.

Mature ripe female specimens of both species were collected by bottom trawl in August 1971 in a depth of 585 m off the Otago coast. The eggs of both species had a unique surface sculpturing consisting of raised hexagonally arranged extensions of the chorion (Robertson 1975).

On the seasonal transect east of the Otago Peninsula eggs of *C. aspercephalus* were collected during September, October, and November 1971 at stations I, J, and K over the outer shelf (Fig. 35). Distribution of eggs of *C. aspercephalus* off the Otago coast during August and October 1971 (Figs. 36 and 37) indicates that small numbers were present at the surface near or beyond the edge of the shelf north-east of the Otago Peninsula. Eggs were absent from samples over the shallow to mid shelf, and no adults were taken in bottom trawls in this region.

Temperature and salinity values of surface waters in which the eggs of *C. aspercephalus* were taken are given in Table 6.

Discussion. The structure of the chorionic surface of the eggs of *C. australis* and *C. aspercephalus* is very distinctive and though it was unlike that of any other eggs recognised in this study, there appears to have been some confusion in the early literature on the true identity of planktonic eggs assigned to macrourids. The egg figured by Ehrenbaum (1905 and 1909, page 303, Fig. 108a) almost certainly belongs to *Maurolicus muelleri*. This figure was originally produced by Emery (1879, quoted by Sanzo 1933) and subsequently reproduced by several other authors (Sanzo 1933).

The fact that *C. aspercephalus* spawns from late winter to late spring is consistent with at least one of the few observations made elsewhere on the spawning of macrourids. *Coryphaenoides acrolepis* is reported to spawn from February to May (late winter to late spring) off California (Matsui, quoted by Phleger 1971). Marshall (1965), on the other hand, has

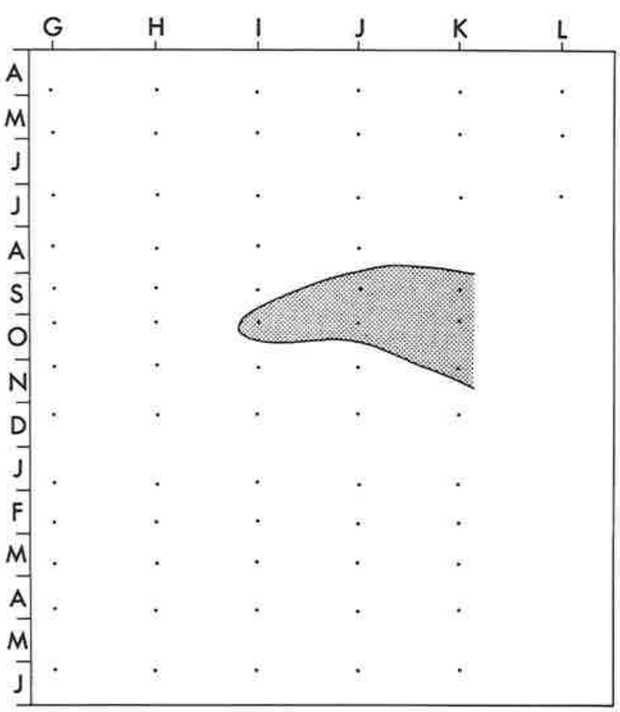


Fig. 35: Seasonal sea surface distribution of *Coelorhynchus aspercephalus* eggs at stations G–L, April 1971 to June 1972 (see key on page 28).

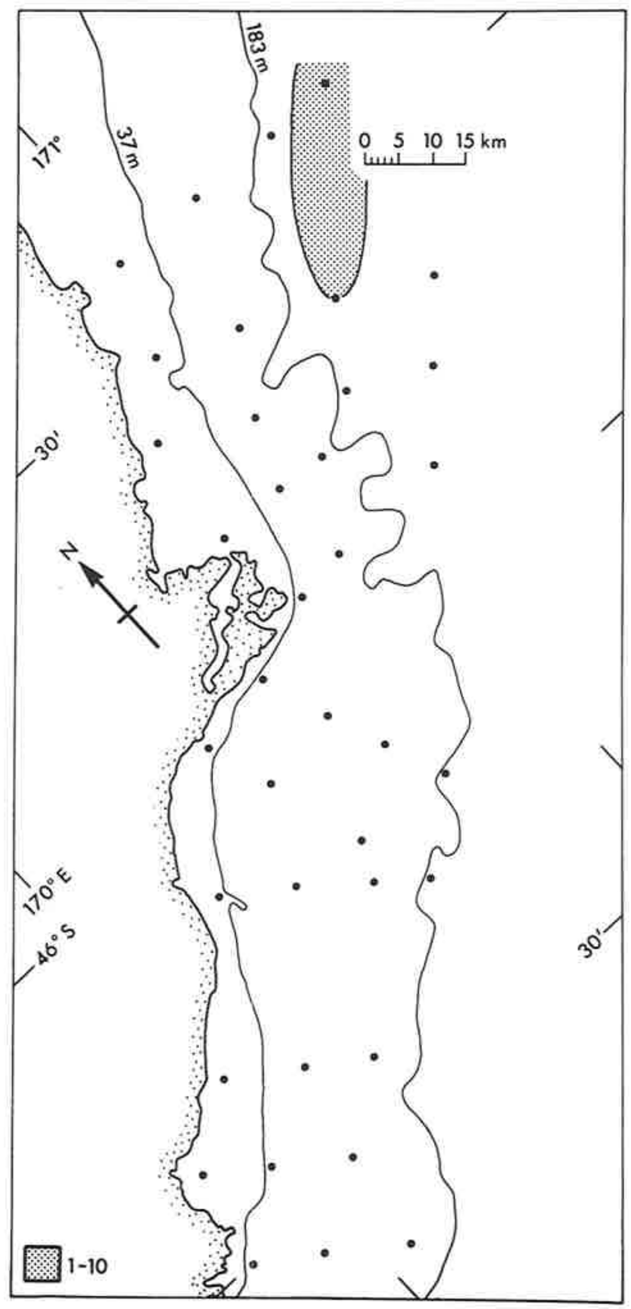


Fig. 36: Sea surface distribution of *Coelorhynchus aspercephalus* eggs off the Otago coast, 11–14 August 1971 (numbers per 500 m^3).

TABLE 6: Temperature and salinity ranges at collection sites of *Coelorhynchus aspercephalus* eggs

Area	Year	Temperature (°C)	Salinity (‰)
East of Otago Peninsula	1971-72	11.0-12.0	34.75-35.00
Otago coast	1971 August	10.6-11.5	35.00-35.02
Otago coast	1971 October	11.2-11.8	34.80-35.01

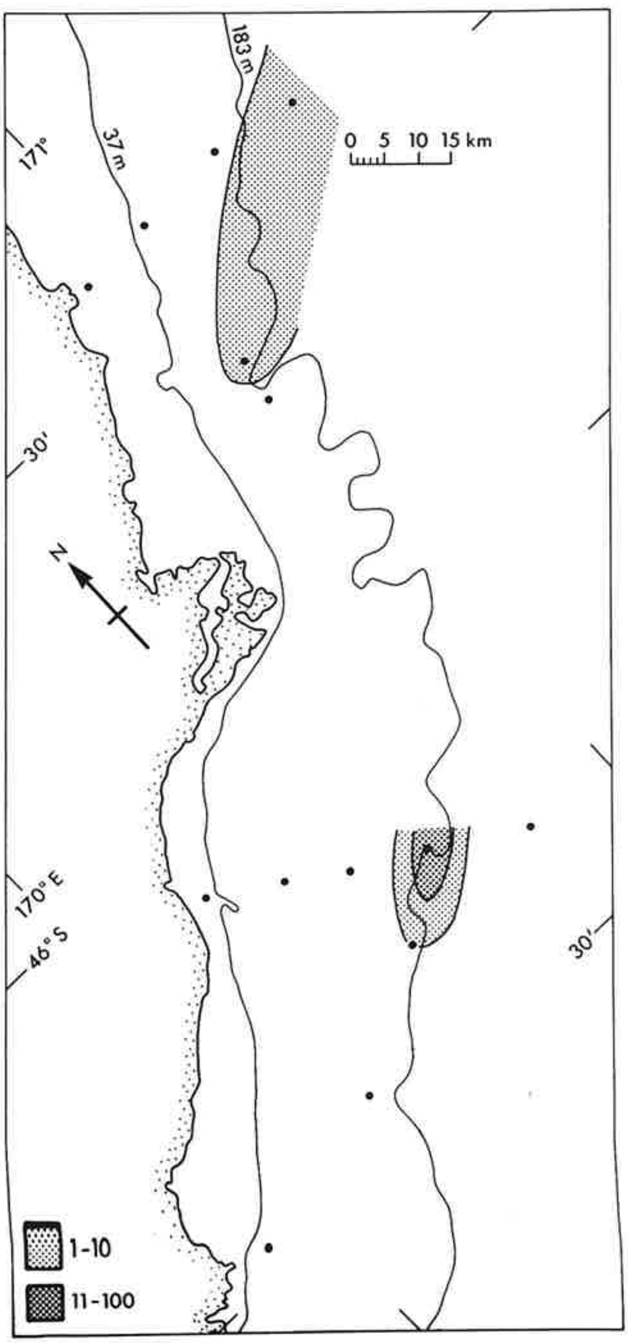


Fig. 37: Sea surface distribution of *Coelorhynchus aspercephalus* eggs off the Otago coast, 13-15 October 1971 (numbers per 500 m^3).

suggested that *C. rupestris* is a summer and autumn spawner in the Norwegian Sea.

In general the early life history of macrourids is poorly known. Phleger (1971) regards this as being "primarily due to the difficulty of collecting eggs and larval stages".

Family Triglidae

Chelidonichthys kumu (Lesson and Garnot 1826) Red Gurnard

There are three species of gurnard known from New Zealand: *Chelidonichthys kumu, Pterygotrigla picta* (Günther 1880), and *Lepidotrigla brachyoptera* (Hutton 1872). Of these three species, *C. kumu* (red gurnard) is the commonest and largest and is commercially important. All three are widespread in New Zealand waters and *C. kumu,* at least, is more abundant in the northern part of its range (Shuntov 1970); *C. kumu* is also known from Australia, South Africa, and Japan, and it has been reported from Chinese waters (Scott 1962). Anderton (1907) and Mito (1963) have described the early development of the red gurnard, but until the recent studies on growth (Staples 1972) and on age and growth, reproduction, and population dynamics (Elder 1972) very little was known about the biology of this species in New Zealand waters.

Red gurnard eggs were absent from seasonal samples and from cruise J10/71 (August 1971) along the Otago coast. Eggs were present, however, over the mid shelf off Moeraki and the Taieri River in October 1971 (Fig. 38). In February 1972 eggs were again present off Moeraki and also between the Clutha and Taieri River mouths to the south and west of the Otago Peninsula (Fig. 39). Temperatures and salinities of surface waters at the collection sites of red gurnard eggs in October 1971 were 11.5°-12.5°C and 34.70‰-35.02‰ and in January 1972 they were 14.9°-15.2°C and 33.00‰-34.70‰.

Discussion. The occurrence of red gurnard eggs off Otago and in most of the areas sampled by Robertson (1973) suggests that this species spawns around all or most of the New Zealand coastline. In Otago waters eggs were found in spring and summer. This is consistent with the observations of Elder (1972), who examined the seasonal gonad condition of adult red gurnard in the Hauraki Gulf. Elder concluded that the spawning season extended through spring and summer with a peak in early summer. A few ripe adults were present throughout most of the year. The earlier spawning observed in 1969-70 was attributed to the earlier occurrences of high temperatures in that season.

Anderton (1907) artificially fertilised red gurnard eggs taken in March off Otago and observed the development through to yolk-sac absorption. The eggs took 7 days to hatch at an average temperature of 9 °C and survived for a further 12 days. Mito (1963) observed development of specimens from Japanese waters and reported hatching after 96 hours at 13.4°–17.0 °C and yolk-sac absorption 96 hours after hatching. Thus in New Zealand waters the period of drift before commencement of feeding would be at least 8 days.

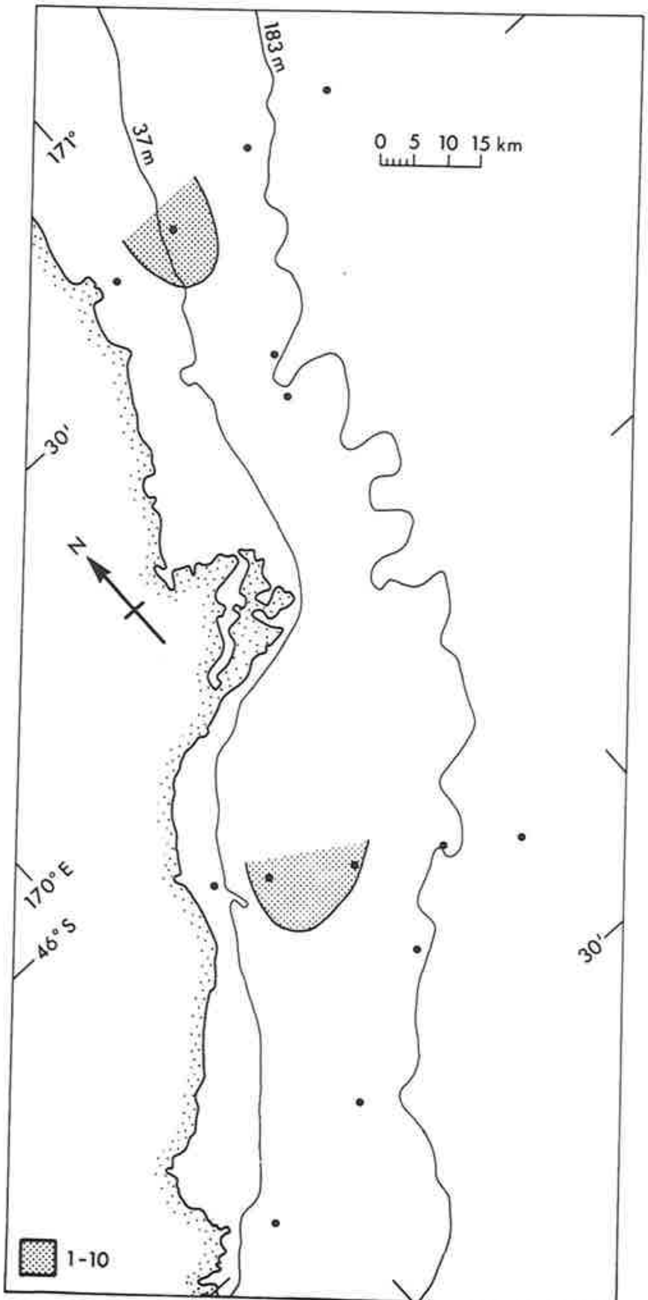


Fig. 38: Sea surface distribution of red gurnard (*Chelidonichthys kumu*) eggs off the Otago coast, 13–15 October 1971 (numbers per 500 m^3).

The summer spawning of red gurnard has also been reported in Otago waters by Thomson and Anderton (1921) and in South African waters (Gilchrist 1916). North-eastern Atlantic gurnards, for example, *Prionotus carolinus* and *P. evolans-strigatus,* also spawn throughout the summer (Kuntz and Radcliffe 1917, Marshall 1946) as do those in British waters, for example, *Trigla gurnardus, T. lucerna,* and *T. cuculus* (Ehrenbaum 1905 and 1909, Hefford 1910).

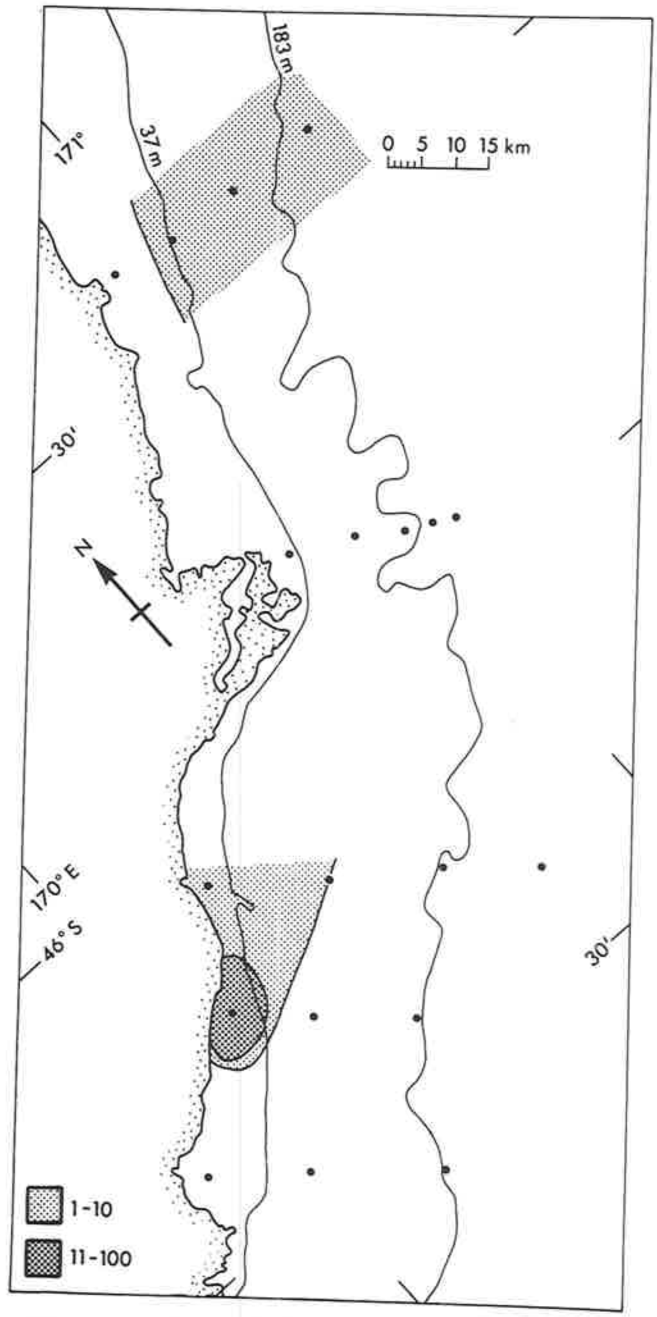


Fig. 39: Sea surface distribution of red gurnard (*Chelidonichthys kumu*) eggs off the Otago coast, 26–28 February 1972 (numbers per 500 m^3).

Family Congiopodidae

Congiopodus leucopaecilus (Richardson 1846) Southern Pigfish

The southern pigfish is common in rocky bays and shallow shelf waters around the South Island, especially south of Banks Peninsula and also around the islands along the southern margin of the New Zealand plateau. Waite (1911) reported that this species was "extremely common where it occurred, and was obtained at depths between 13 and 50 fathoms". None were netted by Waite north of Pegasus Bay.

The eggs of the southern pigfish are described by Robertson (1974) and were present in surface plankton samples collected on all three transects in Otago waters (Figs. 40–42). Eggs were present along the Blueskin Bay transect from August to October in 1970 and during August and September in 1971 (Fig. 40). On the transect east of the Otago Peninsula eggs were taken at the inner stations G, H, and I during August, September, and October 1971. In Otago Harbour eggs were taken from the harbour basin to the entrance and the early developmental stages of some of the eggs indicate that they were fertilised in the harbour.

The ranges of temperature and salinity of surface waters where pigfish eggs were present are shown in

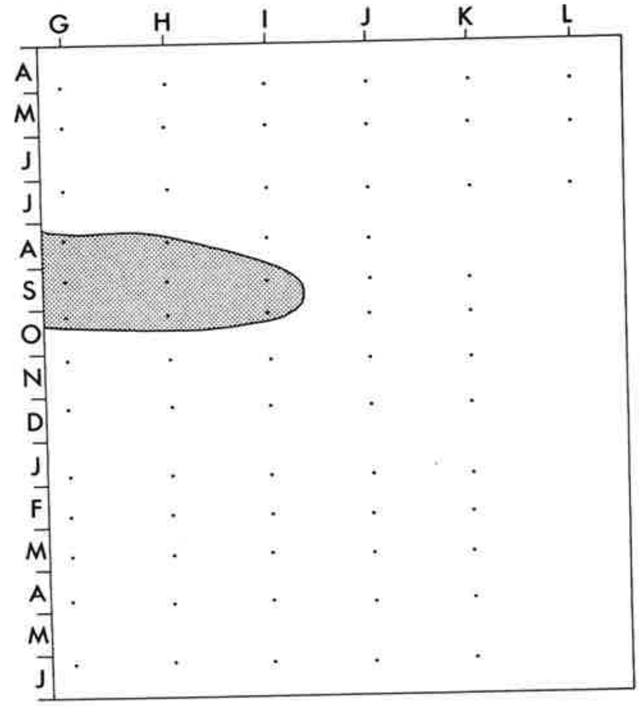


Fig. 41: Seasonal sea surface distribution of pigfish (*Congiopodus leucopaecilus*) eggs at stations G–L, April 1971 to June 1972 (see key on page 28).

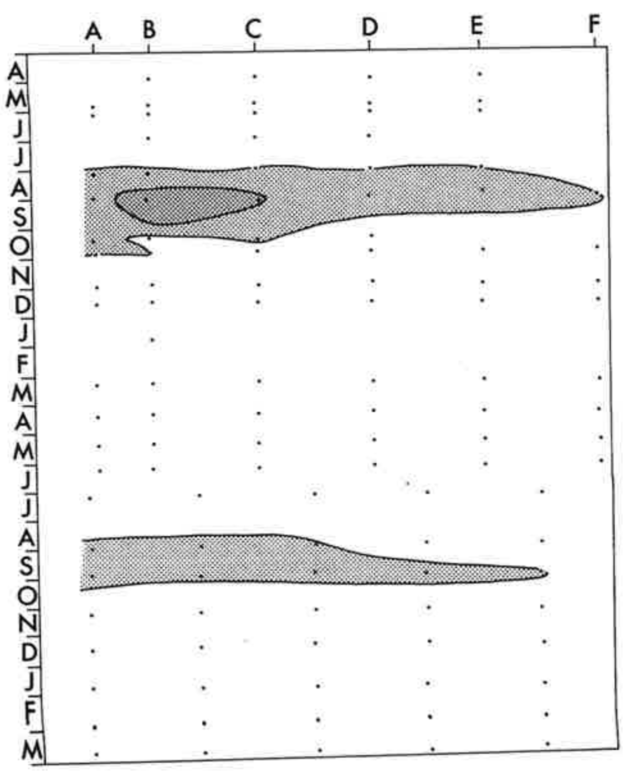


Fig. 40: Seasonal sea surface distribution of pigfish (*Congiopodus leucopaecilus*) eggs at stations A–F, April 1970 to March 1972 (see key on page 28).

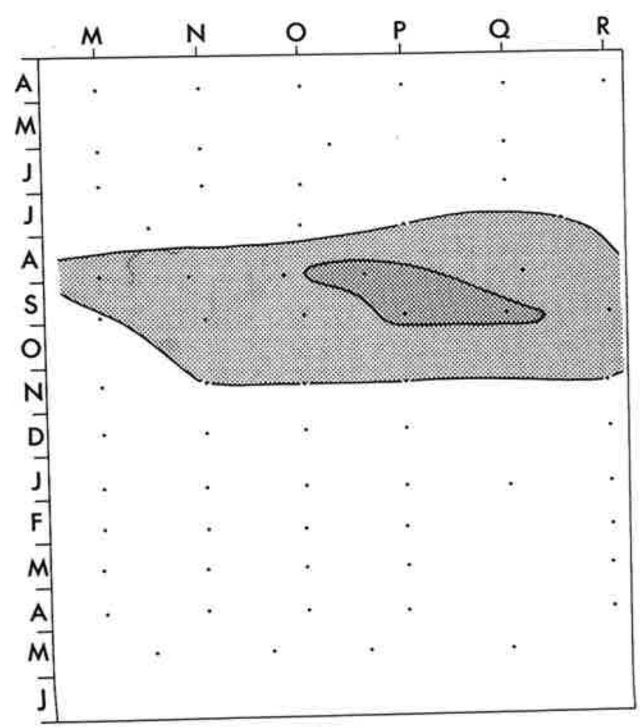


Fig. 42: Seasonal sea surface distribution of pigfish (*Congiopodus leucopaecilus*) eggs at stations M–R, April 1971 to May 1972 (see key on page 28).

TABLE 7: Temperature and salinity ranges at collection sites of pigfish eggs

Area	Year	Temperature (°C)	Salinity (‰)
Blueskin Bay	1970	9.0-12.0	33.86-34.49
	1971	10.2-11.2	34.51-34.91
East of Otago Peninsula	1971	10.8-11.6	33.92-35.02
Otago Harbour	1971	7.3-15.4	32.63-34.79

Table 7. The values for salinity greater than 34.60‰ represent situations where Southland Current water extended into the spawning area or where late stage eggs had drifted into the Southland Current.

Eggs of the southern pigfish appeared in the plankton close to or shortly after the seasonal temperature minimum (Fig. 43); that is, spawning occurred at Blueskin Bay station B while the temperature rose from 9.0° to 10.0°C in 1970 and from 10.2° to 11.1°C in 1971.

Discussion. The observed winter-spring spawning of the southern pigfish off Otago agrees with the only previous observations on the spawning of this species by Anderton in 1904. Anderton artificially fertilised ripe southern pigfish eggs at the Portobello Marine Fish Hatchery in September 1904 (Thomson and Anderton 1921). These eggs were incubated at 6°C and were reported to have hatched 1 month after fertilisation. Hatching at 11.5°C occurred after 14 days in a study of the developmental energetics of the southern pigfish (Robertson 1974).

Family Latridae

Mendosoma lineatum Guichenot 1849 Telescope Fish

First described from Chilean waters, the telescope fish has been seen around New Zealand in Milford Sound, Cook Strait, and Otago waters (Graham 1953) and also around Stewart Island (Doak 1972). Several large schools were observed by divers off the Otago Peninsula in 1972, yet none were taken by trawl, set-net, or hand-line during this study. Although the description (Robertson 1975) of the egg of this species is based on a single intact egg from a spent female, the absence of similar eggs from all other fish examined supports this tentative identification.

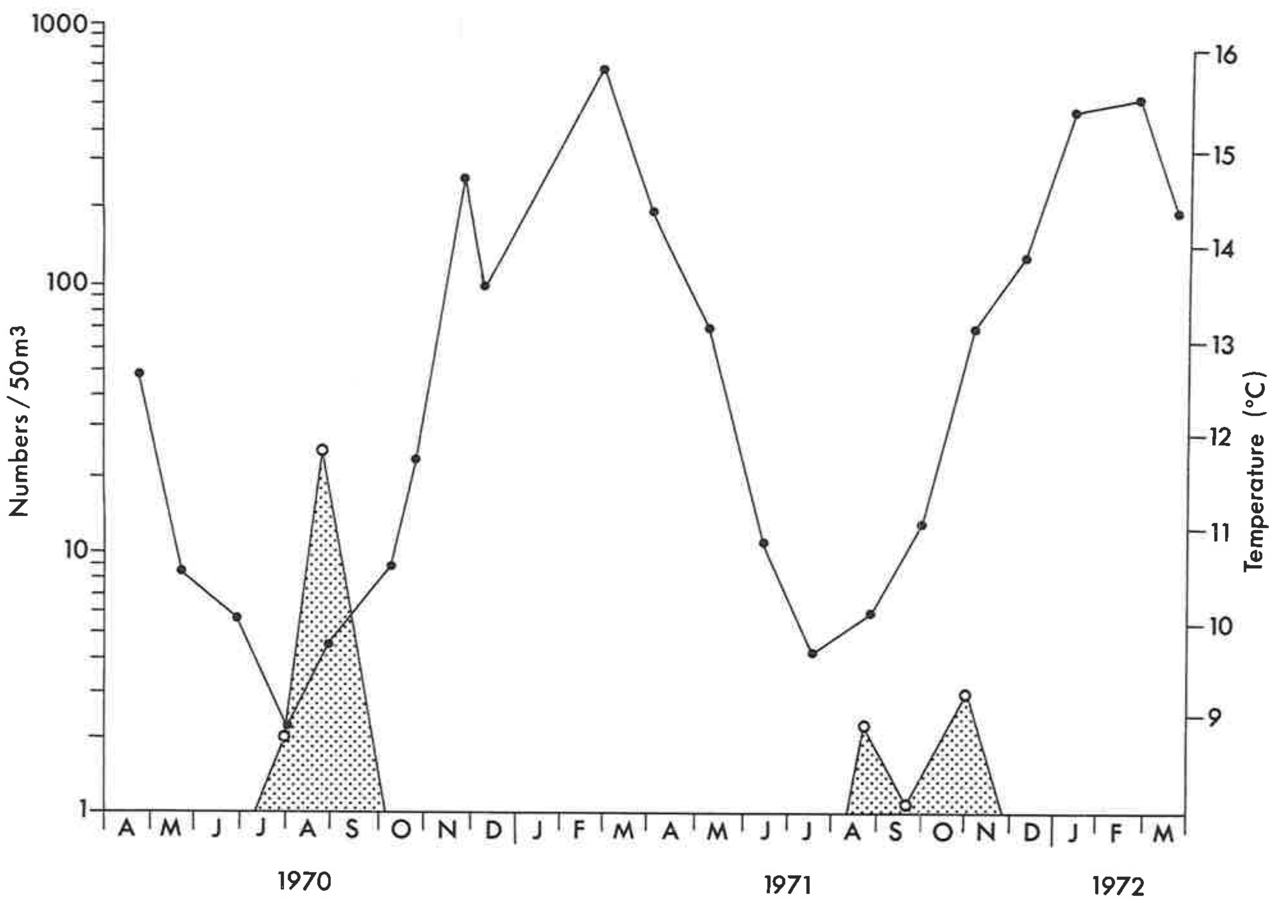


Fig. 43: Annual temperature cycle and pigfish (*Congiopodus leucopaecilus*) egg numbers at station B, April 1970 to March 1972.

The eggs assigned to the telescope fish were taken sporadically in the surface plankton on the Blueskin Bay transect in spring, summer, and autumn (Fig. 44), particularly at the outer stations. On the transect east of the Otago Peninsula a less scattered seasonal distribution pattern was observed (Fig. 45), with eggs occurring from August to March 1971 at stations G–K across the shelf. Eggs of the telescope fish were also widespread along the Otago coastline from Moeraki to Nugget Point in August 1971 (Fig. 46), with distribution centred in the Southland Current.

The ranges of temperature and salinity of waters in which telescope fish eggs were taken were principally typical of Southland Current water, though a small number of eggs also occurred in water of neritic properties (Table 8).

Discussion. The seasonal occurrence of the eggs of telescope fish suggests that the fish is primarily a late winter to late summer spawner in Otago waters and may spawn all year round. The absence of eggs from the Otago Harbour and inner Blueskin Bay stations, coupled with their presence at the outer end of the Blueskin Bay transect and off the Otago Peninsula, suggests that this species prefers exposed coastal waters rather than bays as spawning areas.

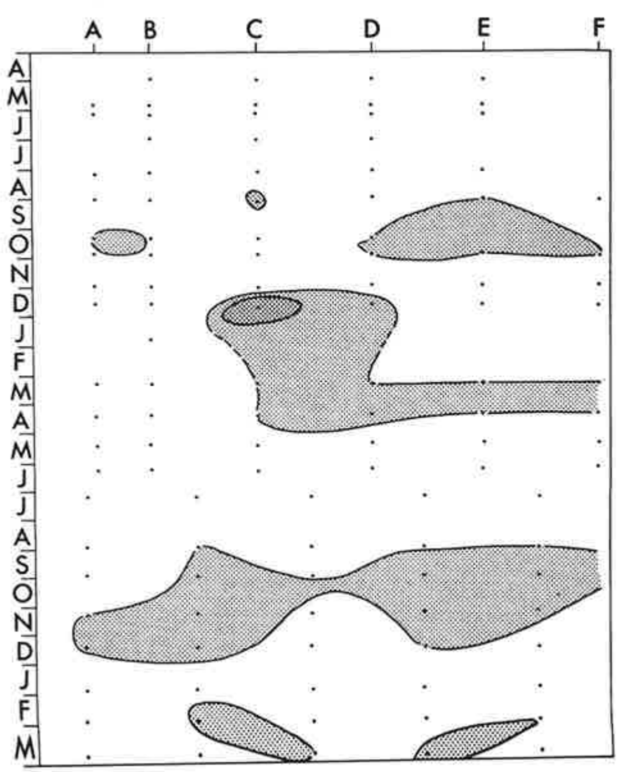


Fig. 44: Seasonal sea surface distribution of telescope fish (*Mendosoma lineatum*) eggs at stations A–F, April 1970 to March 1972 (see key on page 28).

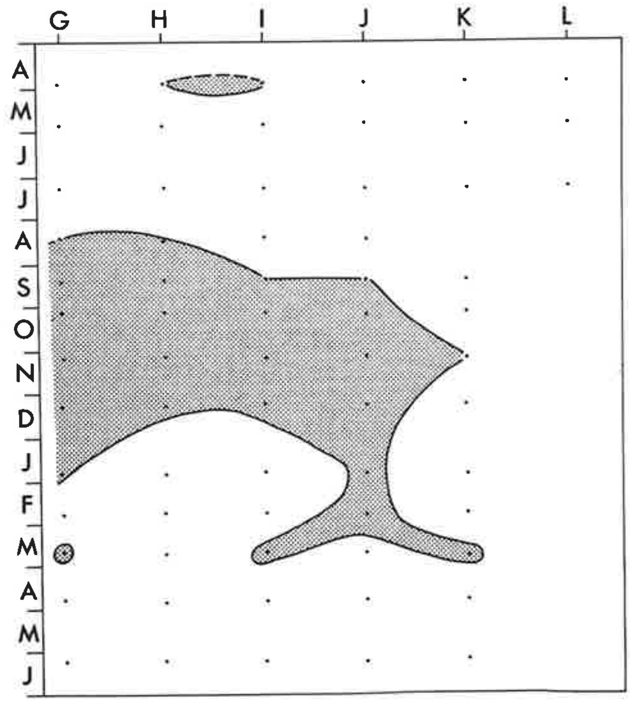


Fig. 45: Seasonal sea surface distribution of telescope fish (*Mendosoma lineatum*) eggs at stations G–L, April 1971 to June 1972 (see key on page 28).

TABLE 8: Temperature and salinity ranges at collection sites of telescope fish eggs

Area	Year	Temperature (°C)	Salinity (‰)
Blueskin Bay	1970	10.2-14.0	33.89-34.32
	1971	10.2-15.9	34.37-34.91
East of Otago Peninsula	1971	10.3-14.4	33.79-35.06
Otago coast (J10/71)	1971	9.5-11.2	32.00-35.02

Family Labridae

Pseudolabrus celidotus (Forster, *in* Bloch and Schneider 1801) Spotty

The spotty occurs in shallow coastal areas and is probably the commonest and most widespread member of the genus *Pseudolabrus* in New Zealand waters.

In 1970 spotty eggs were collected in the surface plankton from all stations on the Blueskin Bay transect (Fig. 47). The eggs were present from August to December 1970 and were most abundant at stations C, D, and E in September. They were less abundant in 1971, when the distribution was restricted to stations A and B presumably by the intrusion of Southland Current water during this period. Eggs were also

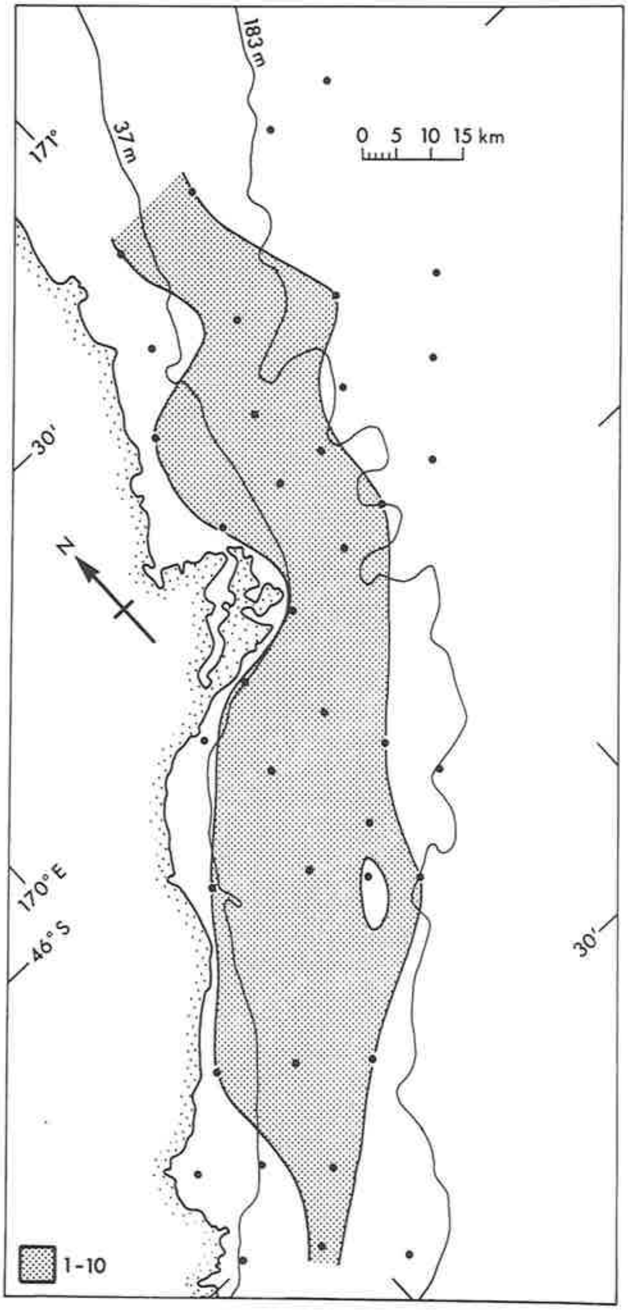


Fig. 46: Sea surface distribution of telescope fish (*Mendosoma lineatum*) eggs off the Otago coast, 11-14 August 1971 (numbers per 500 m³).

present in Otago Harbour at stations P, Q, and R in November and December of 1971. None were taken on the transect east of the Otago Peninsula.

Temperature and salinity ranges at the collection sites are given in Table 9.

In both 1970 and 1971 eggs appeared in the plankton shortly after the temperature had passed the annual minimum (Fig. 48). At station B in Blueskin Bay eggs were present while the temperature increased from 9.9°C in August to 14.7°C in December 1970, and from 10.2°C in early September to 13.9°C in December 1971.

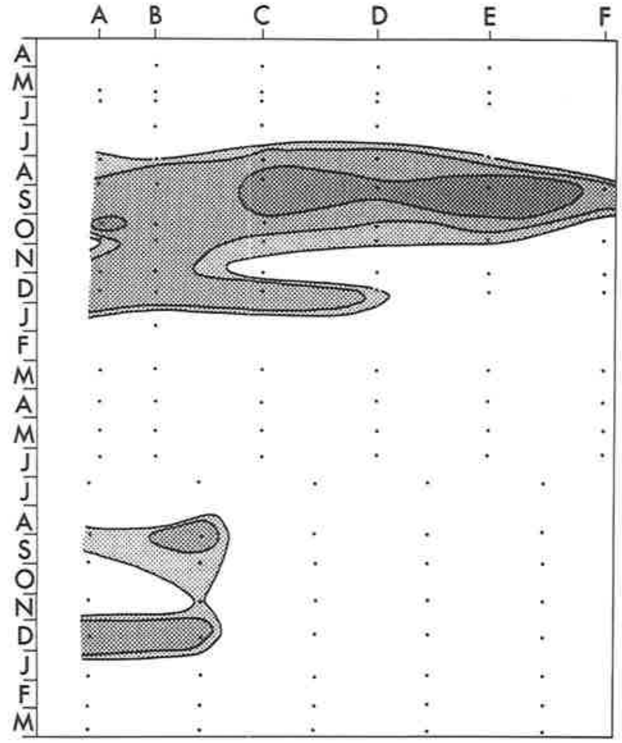


Fig. 47: Seasonal sea surface distribution of spotty (*Pseudolabrus celidotus*) eggs at stations A-F, April 1970 to March 1972 (see key on page 28).

Discussion. From observations of courtship displays and increased frequency of aggressive encounters between males, Doak (1972) concluded that spawning occurred during August-September. This is in general agreement with the observed spawning season in Otago waters, where spawning began in late winter (August) and continued until late spring-early summer (December), after which no spotty eggs were collected. The statement by Webb (1973) that eggs of the spotty are demersal is incorrect, since recently fertilised eggs were quite buoyant and remained so until hatching, both in the laboratory and in the sea.

TABLE 9: Temperature and salinity ranges at collection sites of spotty eggs

Area	Year	Temperature (°C)	Salinity (‰)
Blueskin Bay	1970	9.0-15.1	33.86-34.49
	1971	10.2-15.0	34.41-34.80
Otago Harbour	1971	13.3-17.1	34.29-34.57

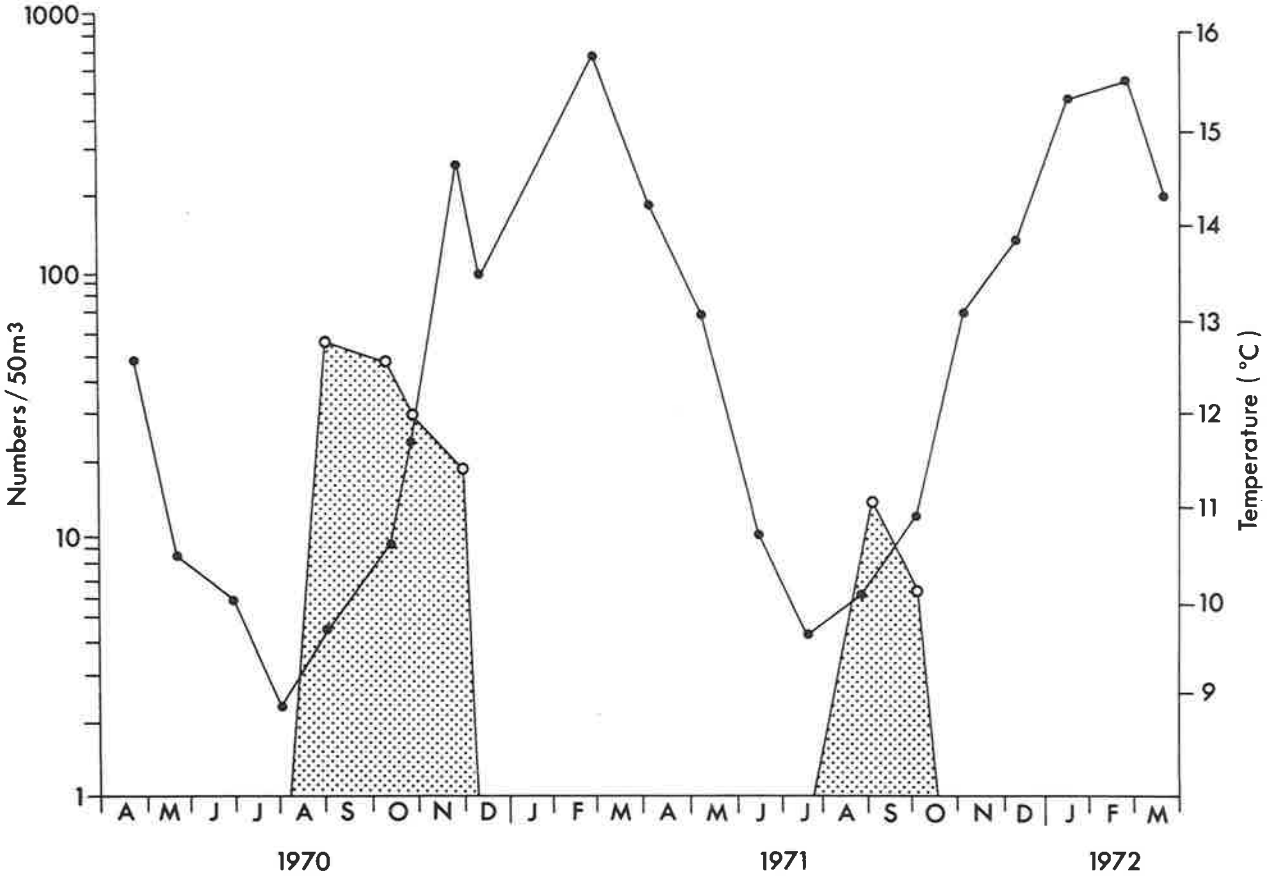


Fig. 48: Annual temperature cycle and spotty (*Pseudolabrus celidotus*) egg numbers at station B, April 1970 to March 1972.

Pseudolabrus fucicola (Richardson 1840) Banded Parrotfish or Banded Wrasse

Another of the six New Zealand species of *Pseudolabrus,* the banded parrotfish is widespread in coastal waters (Doak 1972) and generally inhabits shallow rocky areas.

Eggs of the banded parrotfish have been positively identified in the plankton only from the Blueskin Bay area. They may have occurred in the more widespread sampling in August 1971, but could not be distinguished from several kinds of similar eggs which were present in samples taken on that cruise. There was a marked seasonality in the occurrence of eggs of this species in the Blueskin Bay transect (Fig. 49). In 1970 spawning was centred near station C in late October. Two insignificant occurrences were observed in August. Spawning in 1970 extended from early August to late November, and in 1971 it lasted from

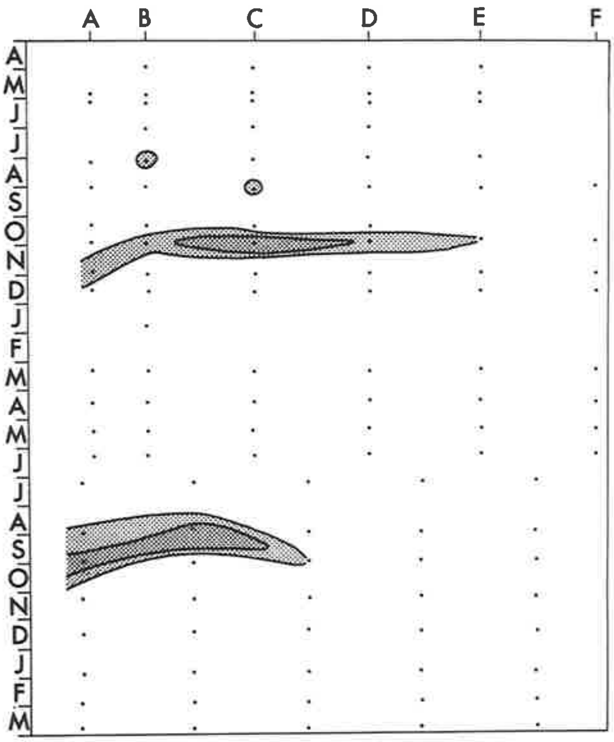


Fig. 49: Seasonal sea surface distribution of banded parrotfish (*Pseudolabrus fucicola*) eggs at stations A–F, April 1970 to March 1972 (see key on page 28).

late August to early October, with egg numbers being highest at stations A and B. Banded parrotfish eggs first appeared when the temperature was at its minimum or shortly afterwards (Fig. 50) and were present over a temperature range of 1.4°C (9.2°–10.6°C). The ranges of temperature and salinity of water containing banded parrotfish eggs are shown in Table 10.

Discussion. The banded parrotfish spawns during spring in neritic Otago waters, though the spawning season may be longer in northern waters, as Doak (1972) reports taking a ripe female in July at Poor Knights Islands. These observations, plus those of fishermen set-netting in Foveaux Strait, who report running ripe females in October, suggest that spawning probably occurs around the whole of New Zealand wherever the habitat is suitable for adults; that is, near rocky areas where bladder kelp *Macrocystis pyrifera* is abundant.

The successful development of hybrid yolk-sac larvae (Robertson 1973) from a cross between *P. celidotus* eggs and *P. fucicola* sperm raises the possibility of such hybrids occurring in nature, since running ripe adults of both species may be caught at the same place and time. Differences in spawning times and mating habits probably contribute to the normal isolation of the species, though evidence for this is lacking and will depend on observations of spawning behaviour by divers. There are no previous reports of cross fertilisation in New Zealand labrids; however, Hagström and Wennerberg (1964) cross fertilised labrid gametes from six Mediterranean species and also from four Norwegian species and concluded (page 52) that there were "almost no barriers to cross fertilization between the species of Labridae tested. It is also evident that most of the crosses may be reared up to free-swimming larvae." Hagström and Wennerberg found 10 hybrids in a sample of 1000 labrids; however, no such hybridisation has been observed in New Zealand labrids.

TABLE 10: Temperature and salinity ranges at collection sites of banded parrotfish eggs

Area	Year	Temperature (°C)	Salinity (‰)
Blueskin Bay	1970	11.8-15.1 (Aug 9.0)	34.16-34.34
Blueskin Bay	1971	10.2-11.2	34.51-34.80

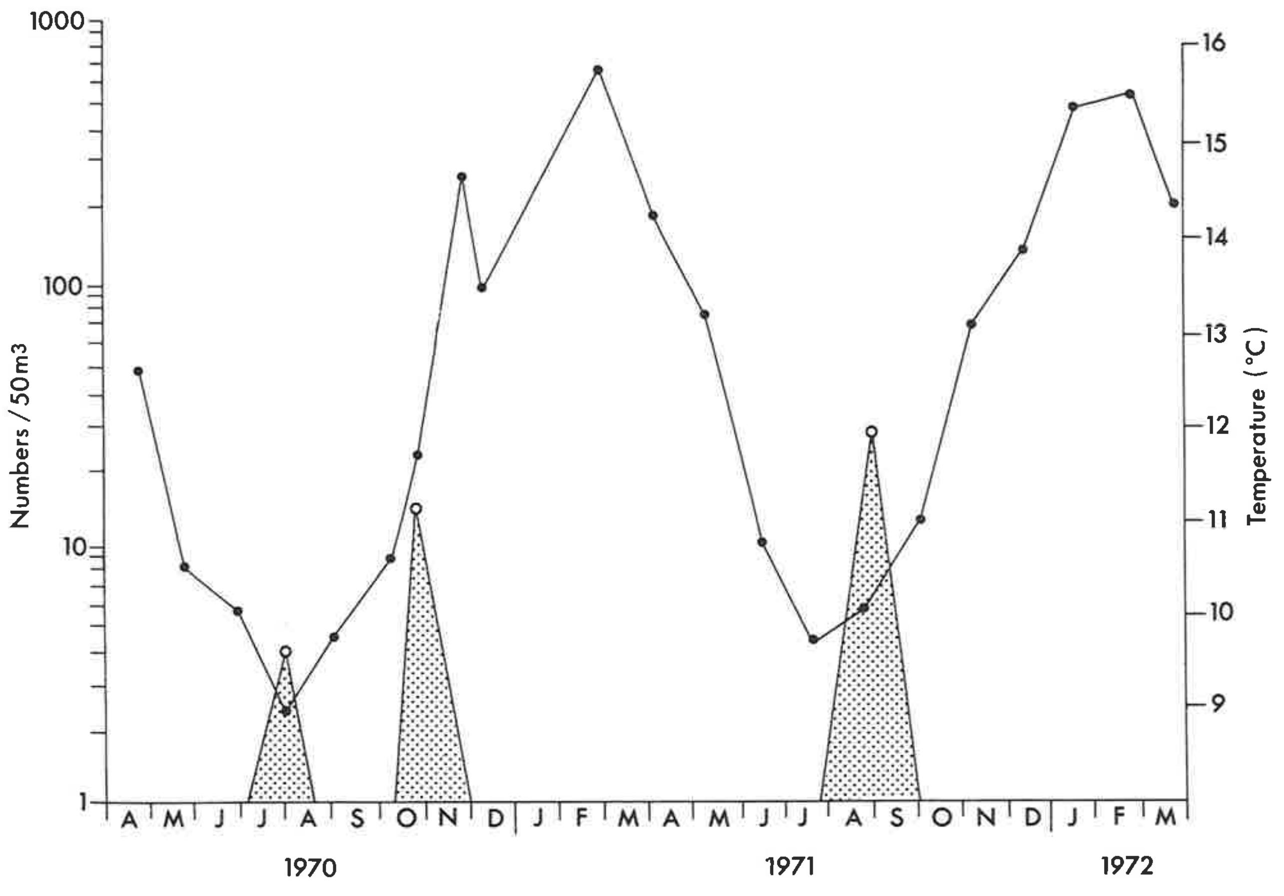


Fig. 50: Annual temperature cycle and banded parrotfish (*Pseudolabrus fucicola*) egg numbers at station B, April 1970 to March 1972.

Family Mugiloididae

Parapercis colias (Bloch 1801) Blue Cod

The blue cod is one of two members of this Indo-Pacific genus known from New Zealand waters (Cantwell 1964), where it is widespread and common in rough rocky areas, especially south of Cook Strait. This species occurs from the shore to the shelf edge and is sought by fishermen both for the commercial market and for rock lobster bait, particularly in Fiordland waters. The second member of the genus known from New Zealand waters, *P. gilliesii* (Hutton 1879), is rarely caught.

Blue cod eggs appeared seasonally in Blueskin Bay (Fig. 51), where they were taken at the outer stations from late August to December in 1970, with highest numbers being present in December. However, in 1971 they were scarce in Blueskin Bay and were taken only at three stations in November and December. East of the Otago Peninsula blue cod eggs were taken from July to December in 1971 over the mid to outer shelf, numbers being highest in October. None were collected at the inner station (Fig. 52). In August 1971 blue cod eggs were widespread over the mid to outer shelf between Moeraki and Nugget Point (Fig. 53) with a centre of abundance off the Otago Peninsula along the edge of the shelf. The situation was similar in October 1971, when egg numbers were again highest over the outer shelf (Fig. 54).

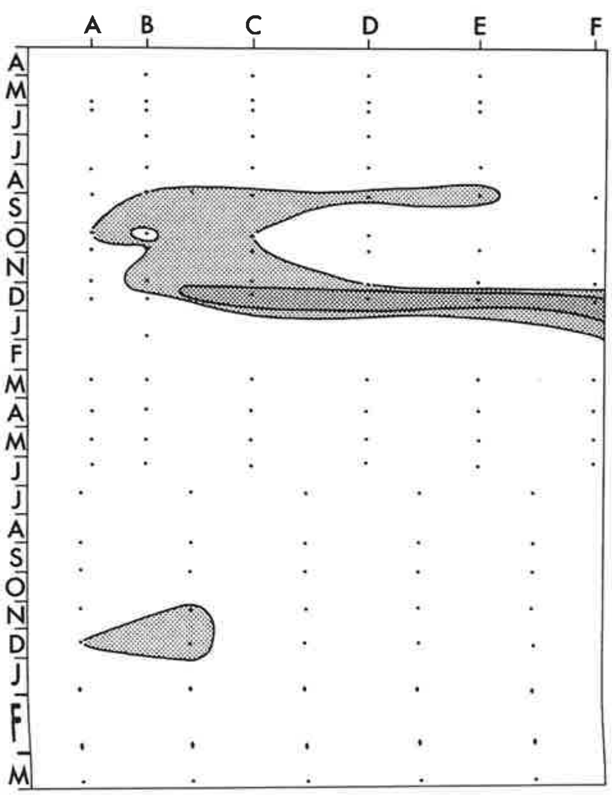


Fig. 51: Seasonal sea surface distribution of blue cod (*Parapercis colias*) eggs at stations A–F, April 1970 to March 1972 (see key on page 28).

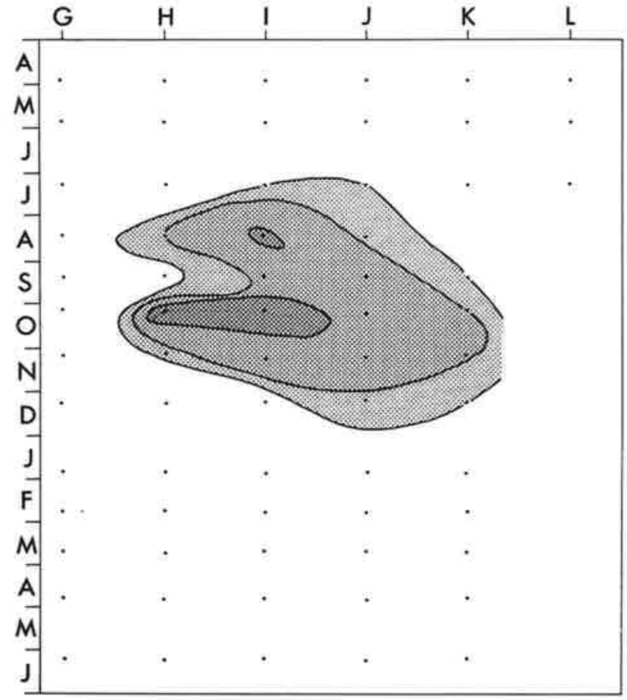


Fig. 52: Seasonal sea surface distribution of blue cod (*Parapercis colias*) eggs at stations G–L, April 1971 to June 1972 (see key on page 28).

The ranges of temperature and salinity of surface waters in which blue cod eggs were collected are given in Table 11.

Although the eggs were collected in neritic as well as Southland Current water, the centre of abundance, particularly of those at early stages of development, was in water of Southland Current properties where they must have been fertilised. This was further confirmed by the presence of running ripe adults only in Southland Current water.

Discussion. The spawning of blue cod in southern New Zealand waters extends from late winter to early summer and occurs in deep outer shelf Southland Current water. Since blue cod is so widespread in southern waters, especially around Stewart Island and

TABLE 11: Temperature and salinity ranges at collection sites of blue cod eggs

Area	Year	Temperature (°C)	Salinity (‰)
Blueskin Bay	1970	9.9-15.9	33.93-34.37
	1971	13.1-13.9	34.41-34.53
East of Otago Peninsula	1971	10.5-12.8	33.79-35.05
Otago coast	1971 August	9.6-11.2	32.95-35.02
Otago coast	1971 October	11.2-12.5	34.74-35.02

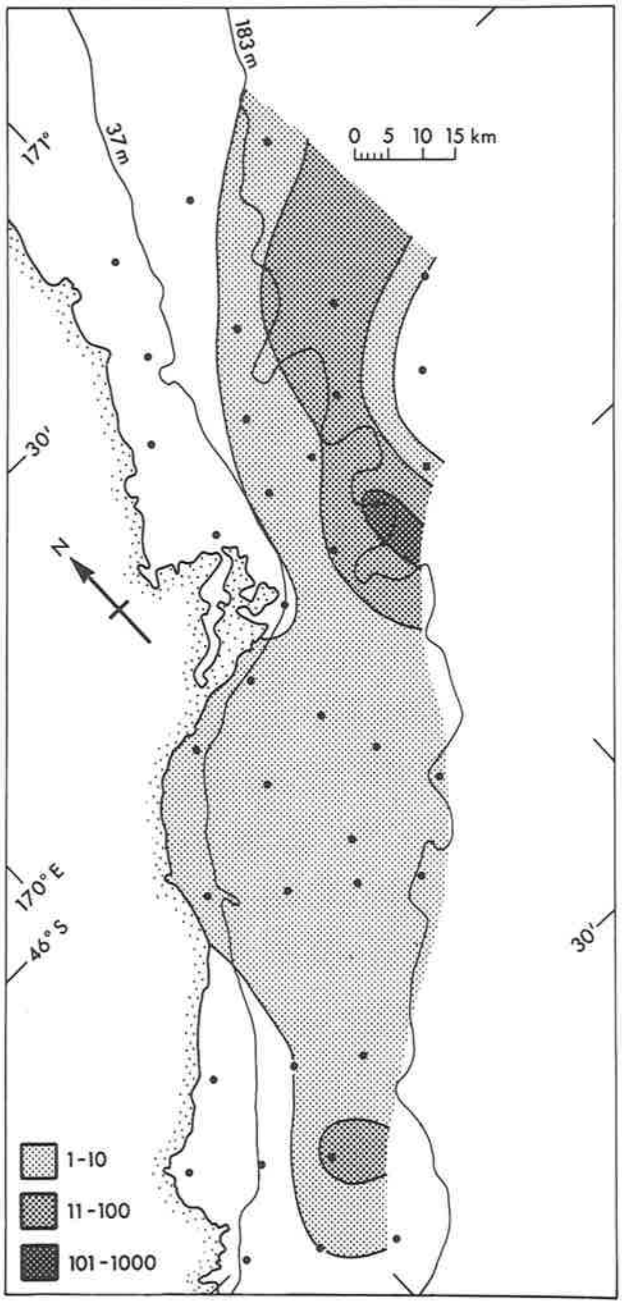


Fig. 53: Sea surface distribution of blue cod (*Parapercis colias*) eggs off the Otago coast, 11–14 August 1971 (numbers per 500 m³).

Fiordland, spawning probably occurs at suitable depths (mid to outer shelf) off shore from these areas as observed off Otago. Spawning is possibly preceded by a migration from in-shore to deeper off-shore waters.

The only previous observations on the spawning and development of blue cod are those of Anderton, who fertilised eggs from specimens in the tanks at the Portobello Marine Fish Hatchery in late October-early November of 1904 (Thomson 1906). Hatching time was not reported, but since a late stage embryo 116 hours old was figured, hatching presumably occurred shortly afterwards. The temperature of incubation was given as 7.4 °C, but this may be incorrect, since Otago Harbour temperatures in late October are generally about 13°–14 °C, and the developmental rates were similar to those observed by Robertson (1973) at 11.5°–12.5 °C.

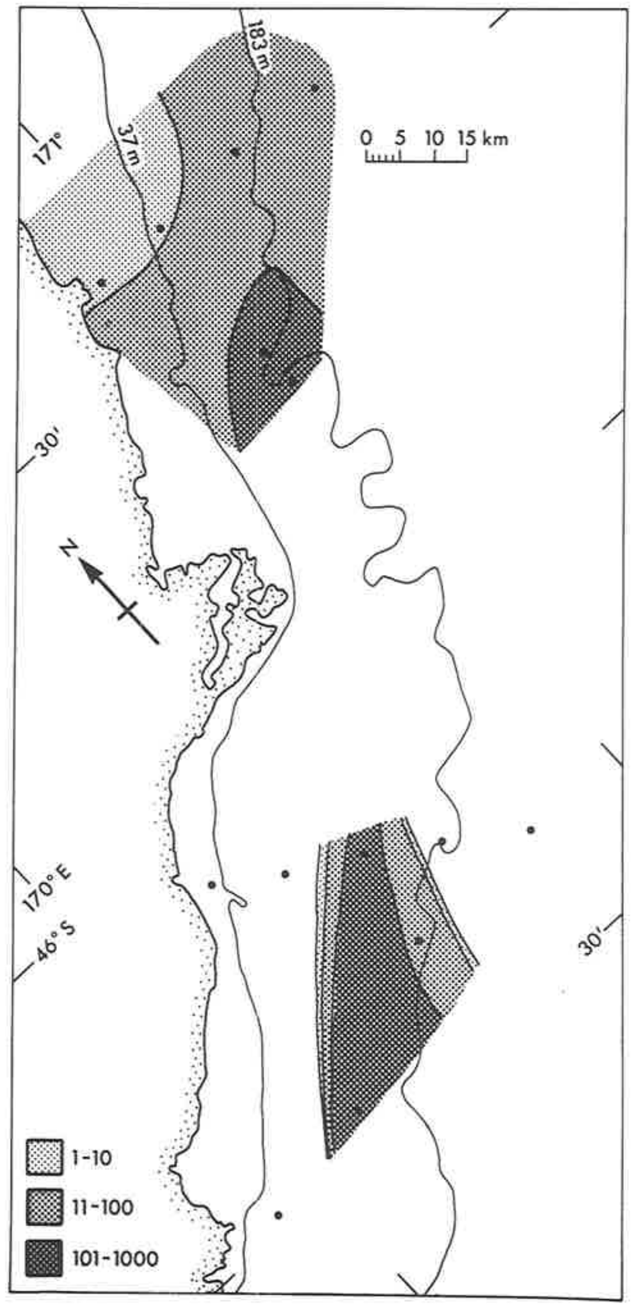


Fig. 54: Sea surface distribution of blue cod (*Parapercis colias*) eggs off the Otago coast, 13–15 October 1971 (numbers per 500 m³).

Family Centrolophidae

Seriolella brama (Günther 1860) Warehou

The genus *Seriolella* is coastal and restricted to the cool temperate waters of the Southern Hemisphere. *Seriolella brama* is one of three New Zealand members of the genus which also occur in Australian waters (Haedrich 1967). Around New Zealand warehou is the shallowest occurring of these species and is widespread, especially over the shelf around the South Island, where it is often taken by bottom trawl in depths from 20 to 200 m.

Warehou eggs were taken commonly in the surface plankton off Otago. On the three seasonal transects they were taken only east of the Otago Peninsula, where a few scattered occurrences were noticed in August, September, and November 1971 and in January and March 1972. Eggs were present at the mid-shelf stations H, I, and J and there was an occurrence at station K (Fig. 55). During the survey of the Otago coastline in August 1971 most warehou eggs occurred south of the Otago Peninsula, their distribution being centred over the middle of the shelf (Fig. 56). The highest egg densities were observed at the southern end of the sampling area and no eggs were taken in the cool, low salinity water near the coast or at the outer stations. Two months later in October warehou eggs were still present over the mid to outer shelf (Fig. 57) and again in February a similar pattern of egg distribution was observed (Fig. 58).

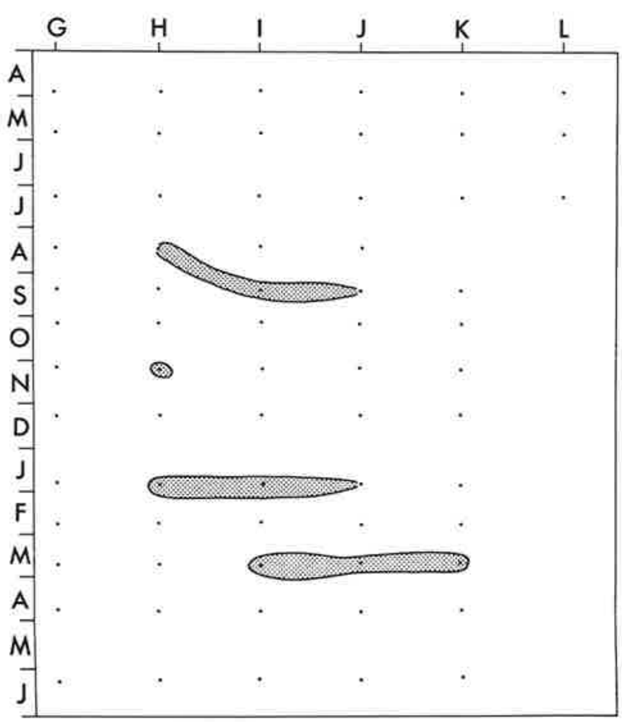


Fig. 55: Seasonal sea surface distribution of warehou (*Seriolella brama*) eggs at stations G–L, April 1971 to June 1972 (see key on page 28).

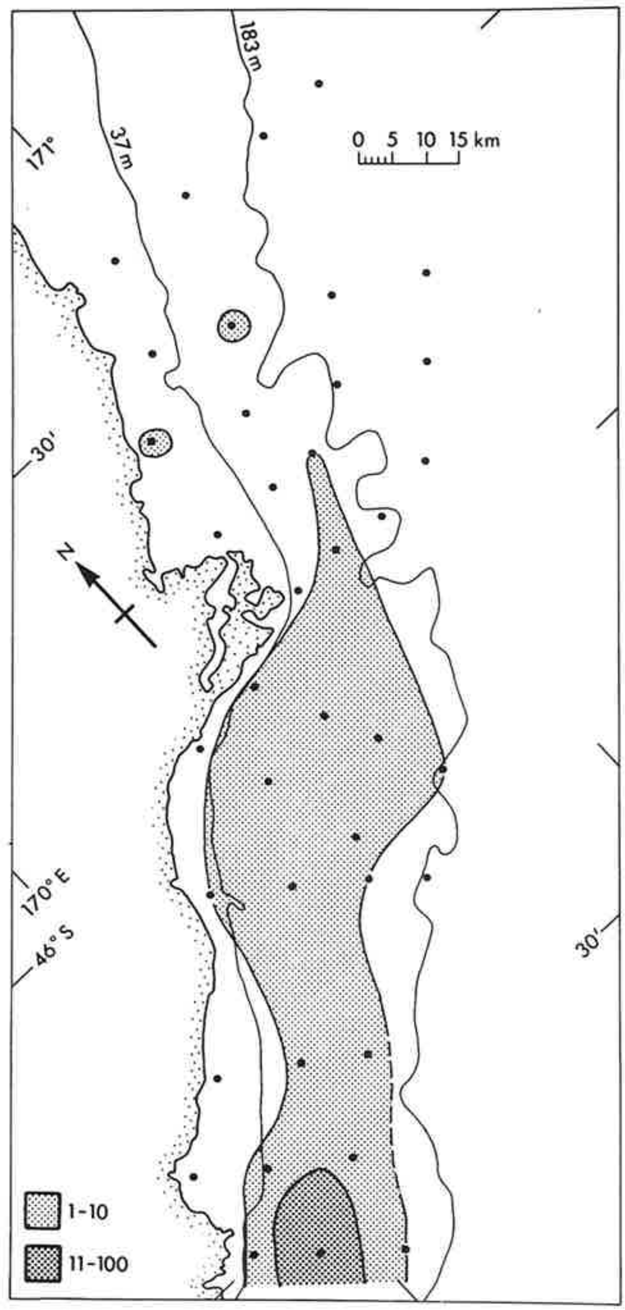


Fig. 56: Sea surface distribution of warehou (*Seriolella brama*) eggs off the Otago coast, 11–14 August 1971 (numbers per 500 m^3).

The ranges of temperature and salinity of surface water in which warehou eggs were taken are given in Table 12.

Although the eggs were occasionally present in neritic water, they were usually collected in water of Southland Current properties. The distribution of eggs at the surface was generally centred in Southland Current water, with egg density contours lying closely parallel to the isopleths for temperature and salinity.

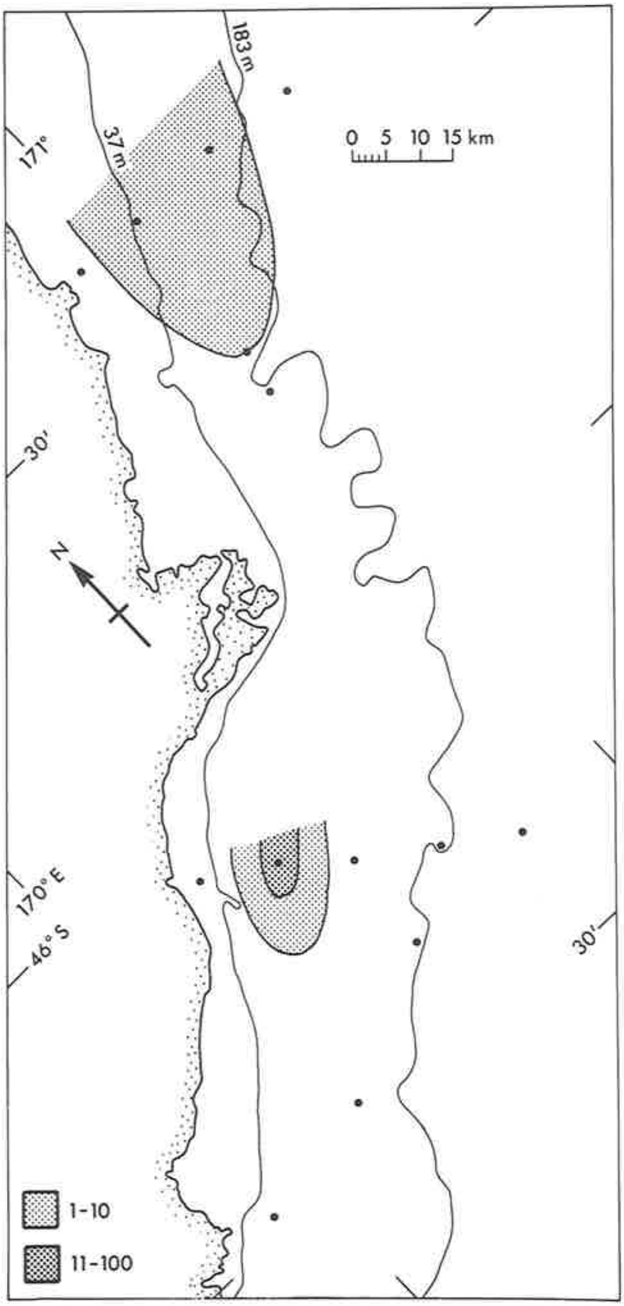


Fig. 57: Sea surface distribution of warehou (*Seriolella brama*) eggs off the Otago coast, 13–15 October 1971 (numbers per 500 m³).

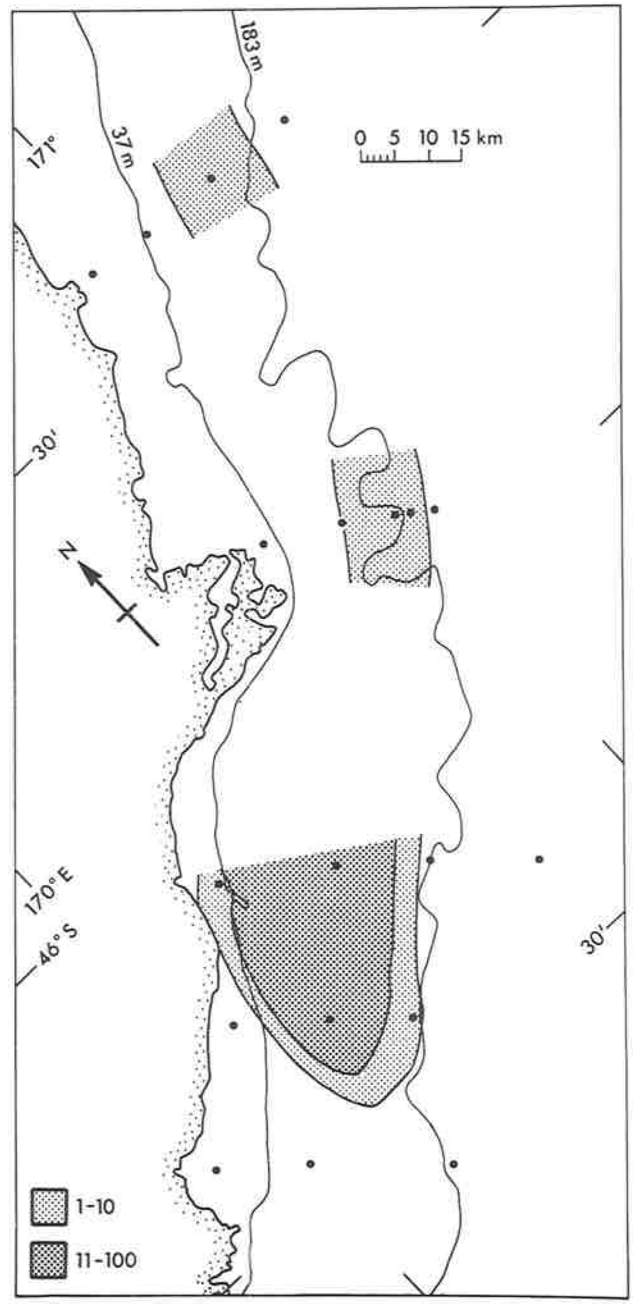


Fig. 58: Sea surface distribution of warehou (*Seriolella brama*) eggs off the Otago coast, 26–28 February 1972 (numbers per 500 m³).

Discussion. The warehou appears to be primarily a spring spawner, with spawning activity starting in late winter and continuing through until late summer. Spawning activity was detected on the east coast from Nugget Point to Castlepoint (Robertson 1973) and probably extends over mid-shelf waters around the South Island and southern end of the North Island. The presence of juveniles in Otago waters in summer suggests spawning around Stewart Island or Fiordland, and the presence of ripe fish east of Stewart Island confirms this.

Family Bothidae

Arnoglossus scapha (Bloch and Schneider 1801) Witch

There are about 24 known species in the genus *Arnoglossus* from the Atlantic coasts of Europe and Africa and from the Mediterranean and Indo-Pacific regions (Norman 1934). *Arnoglossus scapha* is known

TABLE 12: Temperature and salinity ranges at collection sites of warehou eggs

Area	Year	Temperature (°C)	Salinity (‰)
East of Otago Peninsula	1971	10.5-14.7	34.66-35.06
Otago coast	1971 August	9.6-11.2	33.20-35.02
Otago coast	1971 October	11.2-12.3	34.70-35.00
Otago coast	1972 January	13.8-15.2	34.56-34.90

only from New Zealand, where Waite (1911) regards it as "the commonest and most widely distributed of the flatfishes of New Zealand, and yet, unfortunately, the least valuable." Witch are found at all depths on the continental shelf and often occur in high numbers where no other flatfish are taken. Another species, *A. boops* (Hector 1875) has been described from New Zealand waters, but Norman (1934) believes that it may be identical with *A. scapha.*

Witch eggs were present in the surface plankton east of the Otago Peninsula from August 1971 to April 1972 (Fig. 59). The seasonal peak of spawning occurred during September, October, and November in 1971 at the mid-shelf stations H, I, and J. Eggs were absent from the inner station except for a single occurrence in August. During August 1971 witch eggs were widespread and abundant off the Otago coast; they extended from Moeraki in the north to Nugget Point in the south. Their distribution was centred over the mid shelf with numbers highest off the Otago Peninsula (Fig. 60). Eggs were few or absent at the inner and outer stations where salinities and temperatures were low. In October 1971 fewer stations were occupied off the Otago coast, but witch eggs were

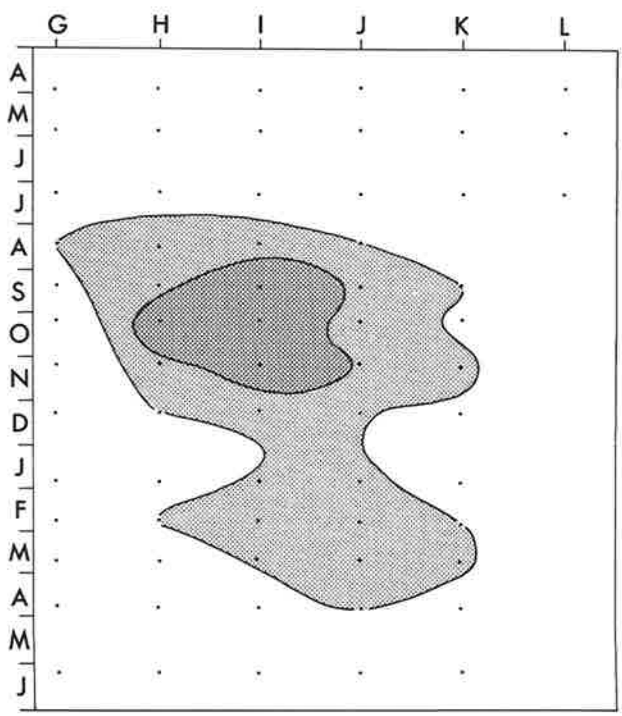


Fig. 59: Seasonal sea surface distribution of witch (*Arnoglossus scapha*) eggs at stations G–L, April 1971 to June 1972 (see key on page 28).

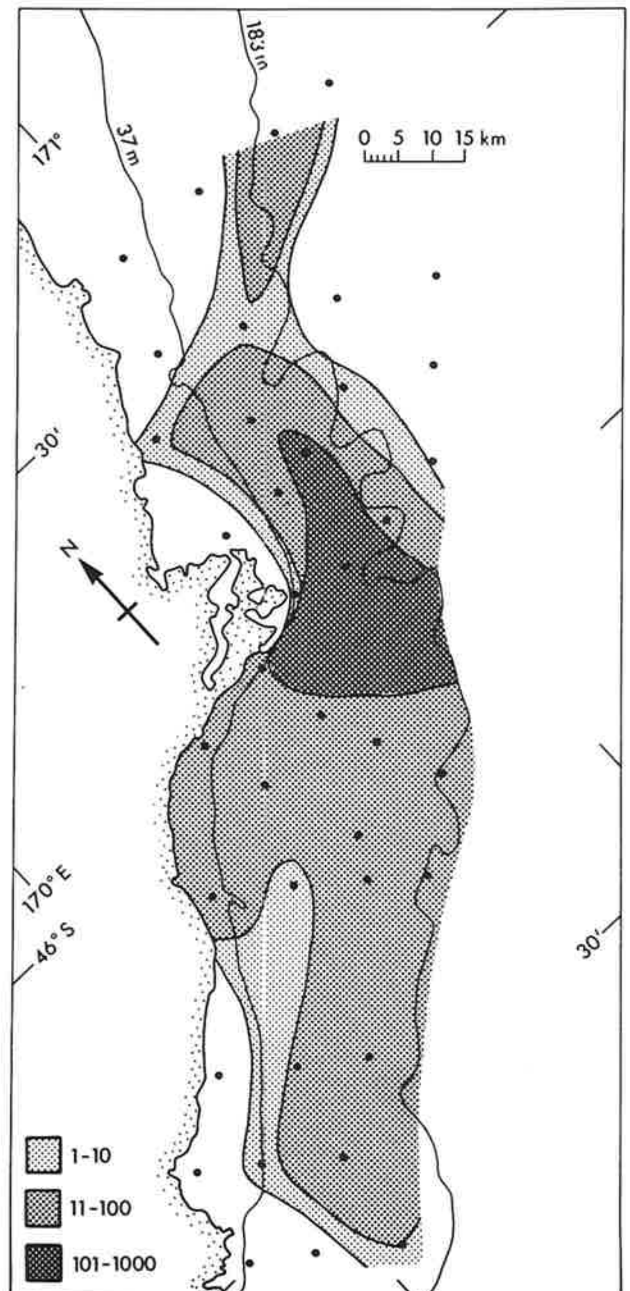


Fig. 60: Sea surface distribution of witch (*Arnoglossus scapha*) eggs off the Otago coast, 11–14 August 1971 (numbers per 500 m³).

again centred over the mid to deep shelf, with few or no eggs taken at the in-shore stations (Fig. 61). Eggs were less abundant, but distribution was similar in February 1972.

The ranges of temperature and salinity of surface waters where witch eggs were collected are shown in Table 13.

Egg numbers, when compared with temperature and salinity isopleths for the same cruises or areas, are obviously highest in Southland Current waters.

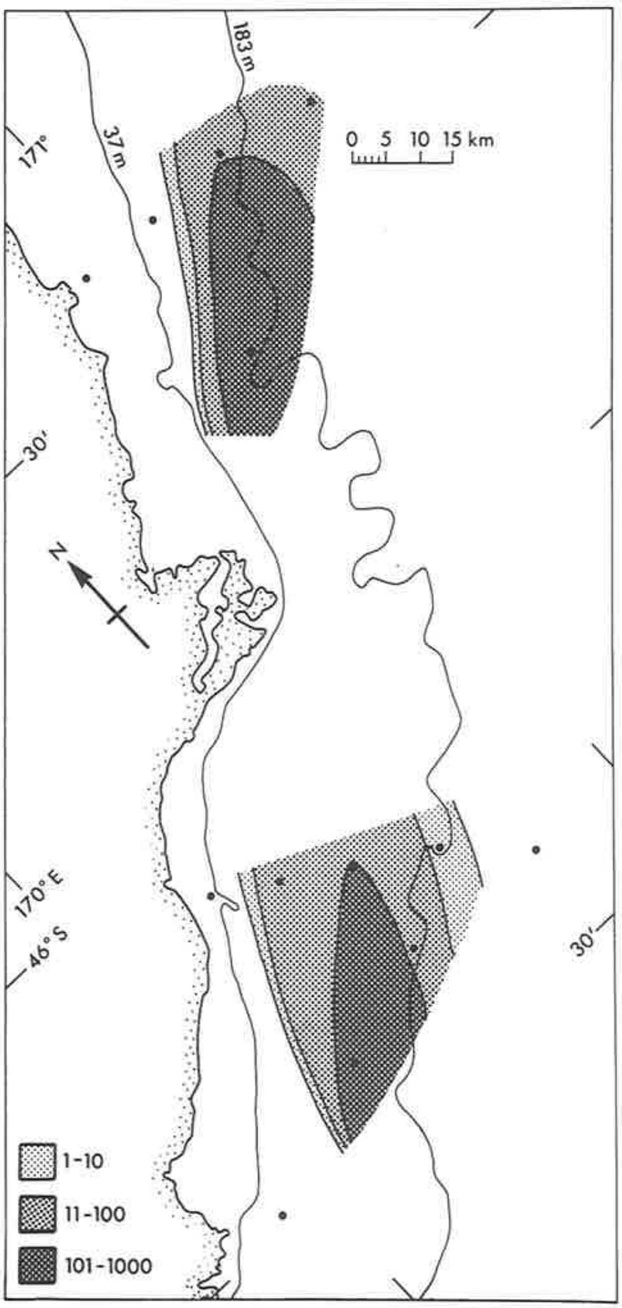


TABLE 13: Temperature and salinity ranges at collection sites of witch eggs

Area	Year	Temperature (°C)	Salinity (‰)
East of Otago Peninsula	1971	11.2-16.0	33.80-35.00
Otago coast	1971 August	9.6-11.2	33.00-35.02
Otago coast	1971 October	11.4-12.4	34.70-35.00

Discussion. The witch has a long spawning period in southern New Zealand waters. It lasted from August to April in 1971–72; that is, from late winter to early autumn with a peak in spring. The geographical spawning range probably extends over mid-shelf waters around the South Island and the southern end of the North Island, since no early stages were collected north of Castlepoint (Robertson 1973). The eggs of witch are similar to described eggs from other members of the genus *Arnoglossus*. Those described by Ehrenbaum (1905 and 1909) from the North Sea, and Marinaro (1971) from the Mediterranean, are all within the size range 0.52–0.78 mm and have a single small oil droplet. Anderton (1907) described eggs attributed to *Caulopsetta scapha* (a synonym of *A. scapha*, according to Norman (1934)) as having a diameter of 1.7 mm and containing many small oil droplets. This does not correspond with the egg characteristics described in Robertson (1975), but from Anderton's description of the adult it is obvious he was describing eggs of *Colisteum guntheri* (Hutton 1873) and not those of *A. scapha* as named.

The apparent preference of adult witch for Southland Current water in which to spawn and the prolonged planktonic life of the pre-juveniles (Robertson 1973) make it a potentially useful planktonic indicator species for Southland Current water, especially near Castlepoint, where mixing with East Cape Current water may result in temperature and salinity values which are difficult to interpret. Colton (1961) has used the presence of pre-juveniles of *Bothus ocellatus* as an indicator of the intrusion of tropical Gulf Stream water into the Georges Bank area in the north-west Atlantic. The advantage of this indicator species was that the hydrological conditions did not always detect the presence of tropical Gulf Stream water over Georges Bank. This event would be detected, however, if pre-juveniles of *B. ocellatus*, a typical inhabitant of tropical Gulf Stream water, were present in plankton samples.

Fig. 61: Sea surface distribution of witch (*Arnoglossus scapha*) eggs off the Otago coast, 13–15 October 1971 (numbers per 500 m^3).

Around New Zealand the complete geographical range of spawning and the usefulness of witch as an indicator species will be determined by future plankton sampling.

Family Pleuronectidae

Rhombosolea plebeia Richardson 1843 Sand Flounder

The sand flounder is one of four members of the genus *Rhombosolea* found around most of the New Zealand coast in shallow sandy areas, where it is sought by commercial fishermen. The development of eggs and yolk-sac larvae of the sand flounder has been described by Robertson and Raj (1971).

No major spawning activity of sand flounder was detected in this study. Eggs were taken in Blueskin Bay at stations A, B, and C in November and December 1970; highest numbers were at station B in December. In 1971 there was evidence of spawning activity in Otago Harbour in September, October, and November (Fig. 62), but in the same season eggs were present at only two of the inner stations in Blueskin Bay in early December.

The temperatures and salinities of surface waters containing sand flounder eggs are shown in Table 14.

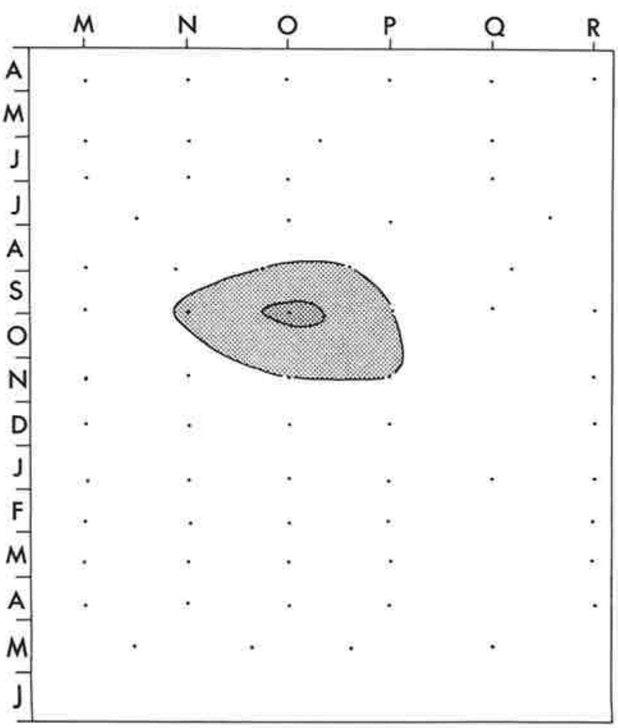


Fig. 62: Seasonal sea surface distribution of sand flounder (*Rhombosolea plebeia*) eggs at stations M–R, April 1971 to May 1972 (see key on page 28).

TABLE 14: Temperature and salinity ranges at collection sites of sand flounder eggs

Area	Year	Temperature (°C)	Salinity (‰)
Blueskin Bay	1970	13.5–15.1	34.20–34.30
	1971	13.9–15.0	34.41–34.43
Otago Harbour	1971	9.6–15.1	33.34–34.57

Discussion. The presence of planktonic eggs and running ripe sand flounders in in-shore neritic waters from September to December is to some extent consistent with other reports. Anderton (1907) reported spawning of sand flounder in holding ponds at the Portobello Marine Fish Hatchery on 9 October in both 1905 and 1906. In August 1906 he successfully fertilised eggs and observed their development through to yolk-sac absorption.

The spawning of sand flounder and yellow-belly flounder (*R. leporina*) in the Hauraki Gulf was studied by Colman (1973), who took running ripe sand flounder from March to December, the highest percentages occurring from June to November. Running ripe yellow-belly flounder were taken from July to December, with most occurring in September-October. Colman also collected planktonic eggs in the Hauraki Gulf and though there was some uncertainty about the identity of the eggs attributable to the two *Rhombosolea* species, the egg numbers were consistent with the observations on gonad condition.

The spawning period of both species in the south and the north seems to be centred on the spring months, spawning activity lasting longer in the north where it begins in early winter.

Genus *Peltorhamphus* Günther 1862 Soles

A recent revision of the New Zealand genus *Peltorhamphus* has resulted in the description of two new species, *P. tenuis* James 1972 and *P. latus* James 1972, and the redescription of *P. novaezeelandiae* Günther 1862. The last species is the commercially important "common sole", which is widespread around New Zealand and is most abundant in the southern part of its range. *Peltorhamphus tenuis* and *P. latus* occur wherever the habitat is suitable around most of the New Zealand coastline; *P. tenuis*, the least abundant of the three, occurs more commonly in South Island waters (James 1972).

Eggs were collected from ripe females of *P. novaezeelandiae* in July-August 1970 and 1971 in Blueskin Bay and from a single ripe female of *P. tenuis* taken in the same area in July 1971. Since the eggs of

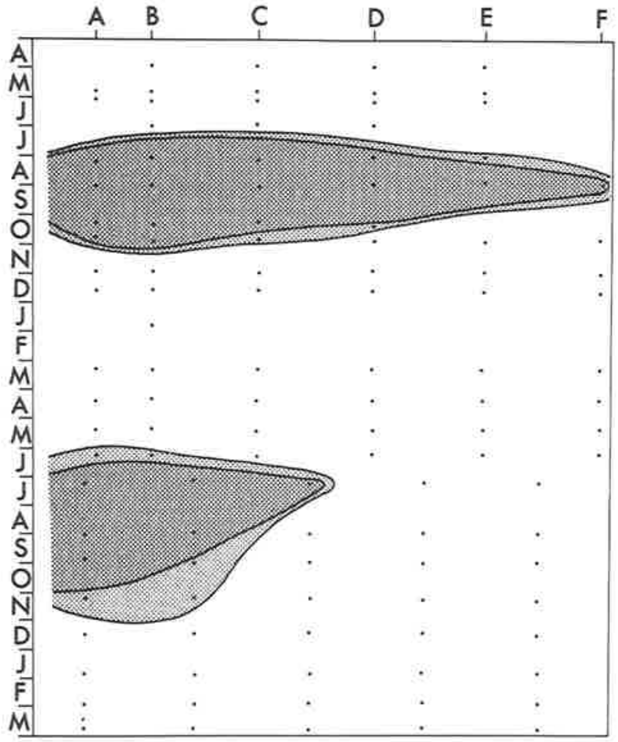


Fig. 63: Seasonal sea surface distribution of sole (*Peltorhamphus* spp.) eggs at stations A–F, April 1970 to March 1972 (see key on page 28).

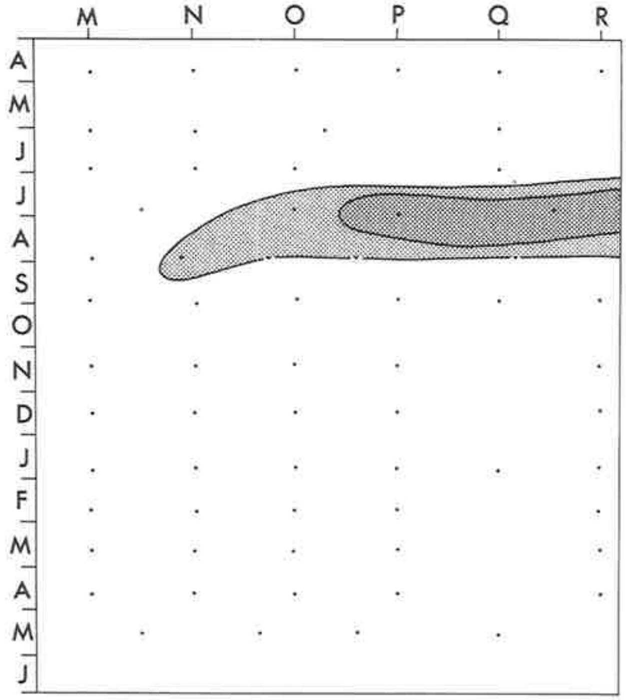


Fig. 64: Seasonal sea surface distribution of sole (*Peltorhamphus* spp.) eggs at stations M–R, April 1971 to May 1972 (see key on page 28).

these two species were very similar (Robertson 1975), and because ripe adults of both species were present in the same areas at the same time, it was not possible to be certain about the specific identity of the eggs of either species. For these reasons the eggs are referred to as sole eggs.

Sole eggs were abundant in Blueskin Bay during July to October in both 1970 and 1971 (Fig. 63). In both seasons the distribution was approximately contained by the 11.0 °C isotherm, and as with other species spawning in Blueskin Bay, the 1971 spawning area was restricted to the inner stations, presumably by the influence of the Southland Current water which extended further shorewards into Blueskin Bay in 1971.

Sole eggs were absent from the stations east of the Otago Peninsula, but occurred in Otago Harbour during July and August 1971 (Fig. 64). It seems likely that these eggs were brought into the harbour by the tide, as no early stages were taken and the numbers were highest near the harbour entrance.

Sole eggs were also abundant at the in-shore stations along the Otago coast in August 1971. The distribution pattern (Fig. 65) clearly shows the centre of abundance near the coastline, and when compared with Figs. 14 and 15 this area is seen to correspond with the relatively cool, low salinity strip of neritic water. As in the egg distribution of other species spawning in this zone, the contours of egg density are closely parallel to the isopleths for temperature and salinity, which indicates a close relationship between them and egg abundance. Numbers of eggs were highest off the Clutha River mouth where salinities and temperatures were lowest. The presence of sole eggs in the southernmost transect suggests that the spawning area continues south beyond Nugget Point. The ranges of temperature and salinity of surface waters where sole eggs were taken are shown in Table 15.

In 1970 and 1971 in Blueskin Bay sole eggs were first observed in the plankton as the sea surface temperatures approached the annual minimum in July

TABLE 15: Temperature and salinity ranges at collection sites of sole eggs

Area	Year	Temperature (°C)	Salinity (‰)
Blueskin Bay	1970	9.0-12.1	33.84-34.49
	1971	9.7-14.0	34.53-34.80
Otago Harbour	1971	6.5-10.6	32.27-34.70
Otago coast	1971	9.2-11.2	28.00-35.00

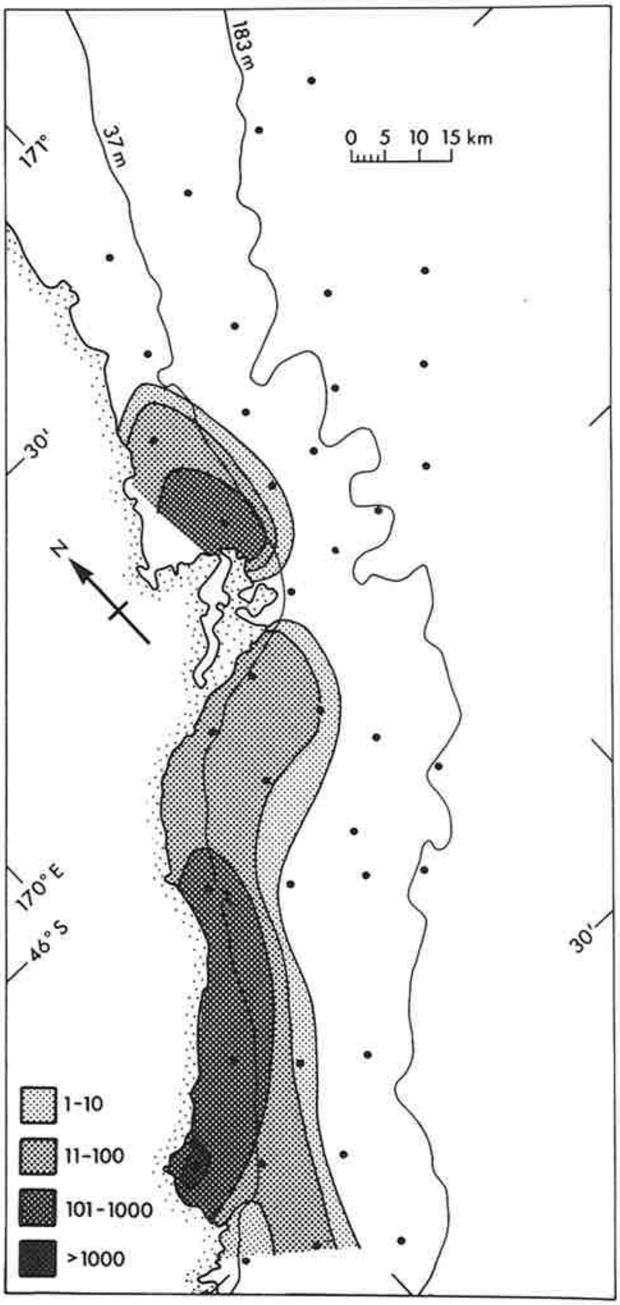


Fig. 65: Sea surface distribution of sole (*Peltorhamphus* spp.) eggs off the Otago coast, 11–14 August 1971 (numbers per 500 m³).

(Fig. 66). The eggs were present at station B in 1970 over a temperature range of 9.1°–12.1°C and in 1971 from 9.8°–13.1°C. Spawning began as water temperatures fell from 10° to 9°C.

Sole eggs at the 4–32-celled stage were present at one station in Blueskin Bay with a mid occupancy time of 2344 hours. Although there are no data available on the early development of these eggs, spawning had obviously occurred in the few hours preceding midnight. The bottom depth at this station was 30 m and the surface temperature 9.6°C.

Discussion. In south-eastern South Island waters the spawning season of *Peltorhamphus* spp. lasts from mid winter to late spring and though the extent of spawning was not defined, this genus can be expected to spawn in shallow neritic water around the South Island. This winter-spring spawning is in agreement with the findings of James (1969), who reported that spawning activity as defined by gonad condition lasted from July to December with a peak in August-September. He also collected planktonic eggs with *Peltorhamphus* features from 26 June to 26 November 1968, maximum numbers occurring in July-August.

The three *Peltorhamphus* species are generally taken in the same areas as the sand flounder, *Rhombosolea plebeia,* and the yellow-belly flounder, *R. leporina,* and since their eggs overlap both in size and number of oil droplets, they are difficult to distinguish. Since the eggs of *P. novaezeelandiae* and *P. tenuis* were observed to have an average of 4 oil droplets, with no more than 6, and sand flounder eggs had up to 13 oil droplets, all eggs were assumed to be sole eggs if none with more than 6 oil droplets occurred in a sample. Very few samples contained eggs attributable to sand flounder and only six ripe females of this species were taken during an extensive trawling programme in Blueskin Bay during 1970–72. Although ripe females of *P. novaezeelandiae* were common in winter-spring in the same area, only a single ripe female yellow-belly flounder was taken in the same period. Yellow-belly flounder were rare in the area. It is therefore probable that the eggs with 1–6 oil droplets and a diameter of 0.575–0.675 mm were correctly identified as *Peltorhamphus* spp.

As Colman (1973) pointed out, Thomson and Anderton (1921) may have confused *P. novaezeelandiae* with the recently described species *P. tenuis* and *P. latus,* as the size of their smallest ripe specimen was 14 cm. There was, however, no uncertainty about the identity of adult *P. novaezeelandiae* observed in this study.

Pelotretis flavilatus Waite 1911 Lemon Sole

Pelotretis flavilatus, the lemon sole, is distributed widely throughout shallow shelf waters of the North and South Islands and Chatham Islands, with centres of abundance in such areas as Nugget Bay, Tasman Bay, Pegasus Bay, and the South Taranaki Bight (Waite 1911), where it is sought by commercial trawlers.

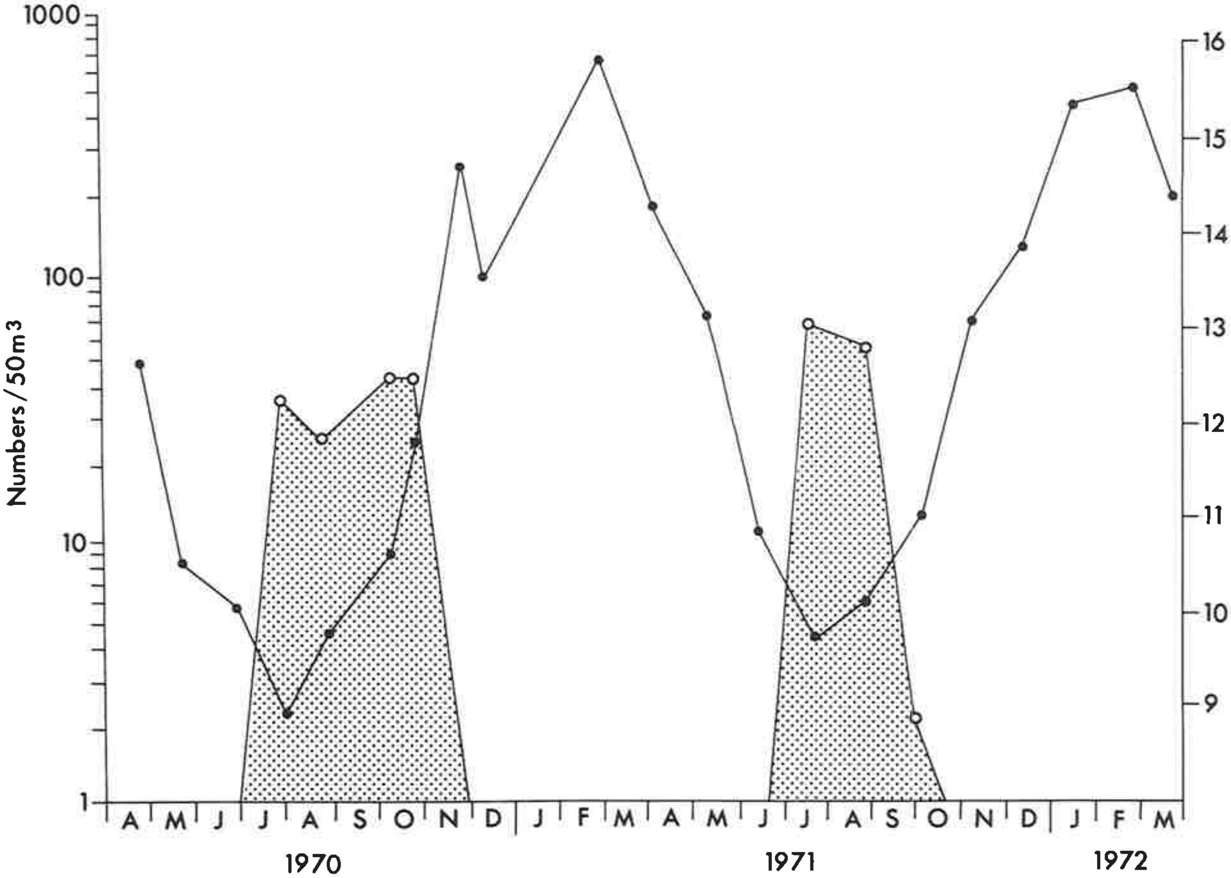
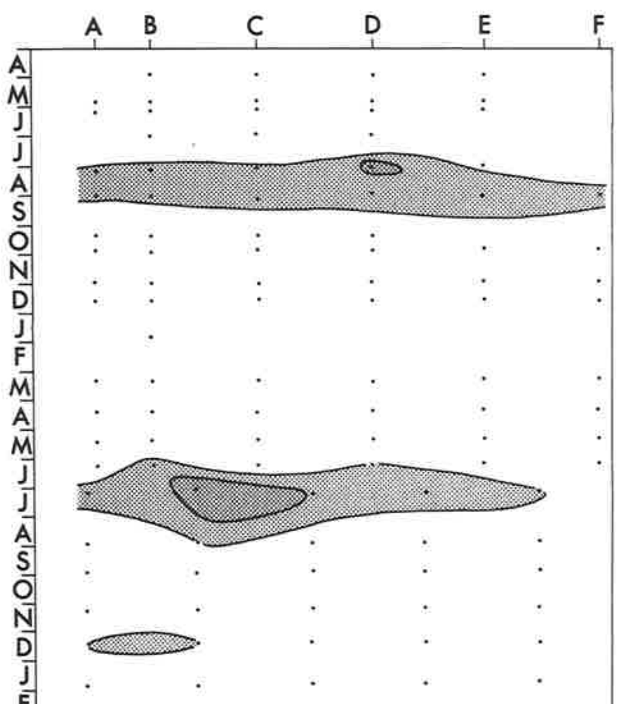


Fig. 66: Annual temperature cycle and sole (*Peltorhamphus* spp.) egg numbers at station B, April 1970 to March 1972.



Very few lemon sole eggs were collected in the seasonal samples taken in Blueskin Bay (Fig. 67), and during the 1971 season eggs were present in the outer half of Otago Harbour (Fig. 68). The latter were late stage eggs probably brought into the harbour with the tide. The distribution of lemon sole eggs along the Otago coast during August of the 1971 spawning season was centred near the coastline between the Otago Peninsula and Nugget Point (Fig. 69). The Blueskin Bay spawning area appeared to represent the northern extremity of a larger area of spawning centred to the south of the Otago Peninsula. The distribution pattern in Fig. 69 is open at the southern end, which indicates that further spawning activity was occurring to the south of the area studied. All lemon sole eggs collected at two of the night-time stations on cruise J10/71 (mid occupancy times of 2230 and 2344 hours) were at the 2-16- or 2-32-celled stages. Fertilisation would therefore have taken place in the preceding few hours between sunset (1730 hours) and 2200 hours.

Fig. 67: Seasonal sea surface distribution of lemon sole (*Pelotretis flavilatus*) eggs at stations A–F, April 1970 to March 1972 (see key on page 28).

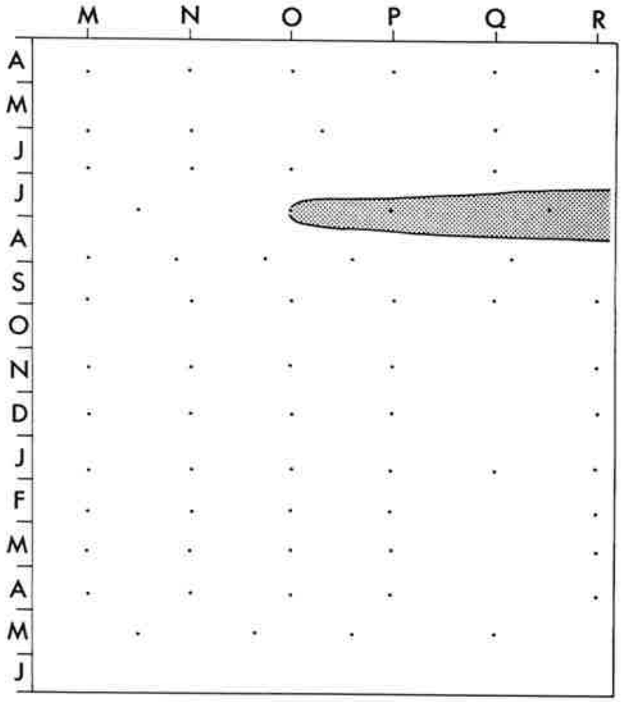


Fig. 68: Seasonal sea surface distribution of lemon sole (*Pelotretis flavilatus*) eggs at stations M–R, April 1971 to May 1972 (see key on page 28).

There appears to be a close relationship between salinity and/or temperature and egg distribution both seasonally and geographically. Seasonally the sea surface and bottom isotherms (Figs. 8 and 9) and contours of egg density (Fig. 67) are closely parallel. Geographically the area of highest egg density (Fig. 69) lies in the narrow coastal zone of cool, low salinity water and abundance contours are closely parallel to isotherms and isohalines in this area (Figs. 14 and 15).

The relationship between egg numbers and the annual temperature cycle for Blueskin Bay station B (Fig. 70) was similar to that observed for other species spawning in the bay. In both 1970 and 1971 the presence of eggs coincided with the annual temperature minimum. At this station in 1970 eggs were present over a temperature range of 9.0°–9.7°C and during 1971, 10.8°–9.7°C (temperature falling). The overall ranges of temperature and salinity of surface waters in which lemon sole eggs were collected are shown in Table 16.

Discussion. Thomson and Anderton (1921) detected spawning activity in adult lemon sole in Otago waters in August 1905 and again in July 1920. Similar results were obtained by Rapson (1940), who studied spawning through several seasons. Rapson took plankton tows in Tasman Bay and Marlborough Sounds from 1936 to 1939. During the same period he examined the gonads of the adults and was able to determine that the spawning season extended over a period of 6 months, usually beginning in June and continuing until December, August being the most important month.

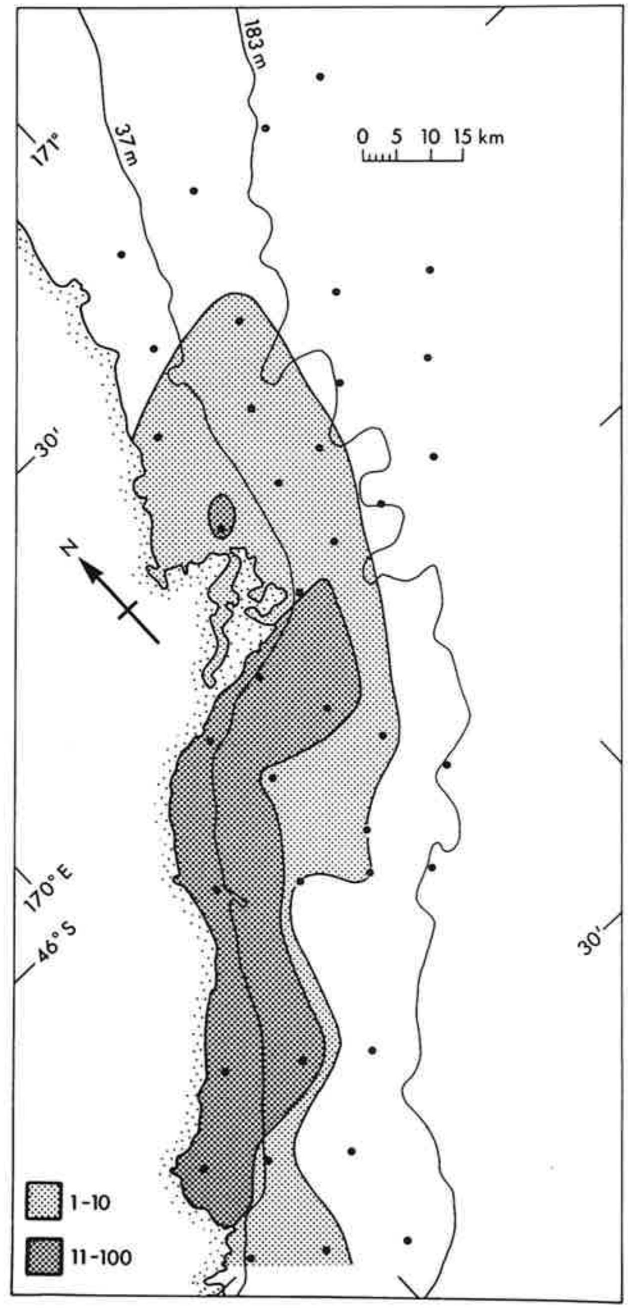


Fig. 69: Sea surface distribution of lemon sole (*Pelotretis flavilatus*) eggs off the Otago coast, 11–14 August 1971 (numbers per 500 m³).

In Otago waters lemon sole is a winter-spring spawner. The eggs occur in the plankton close to shore

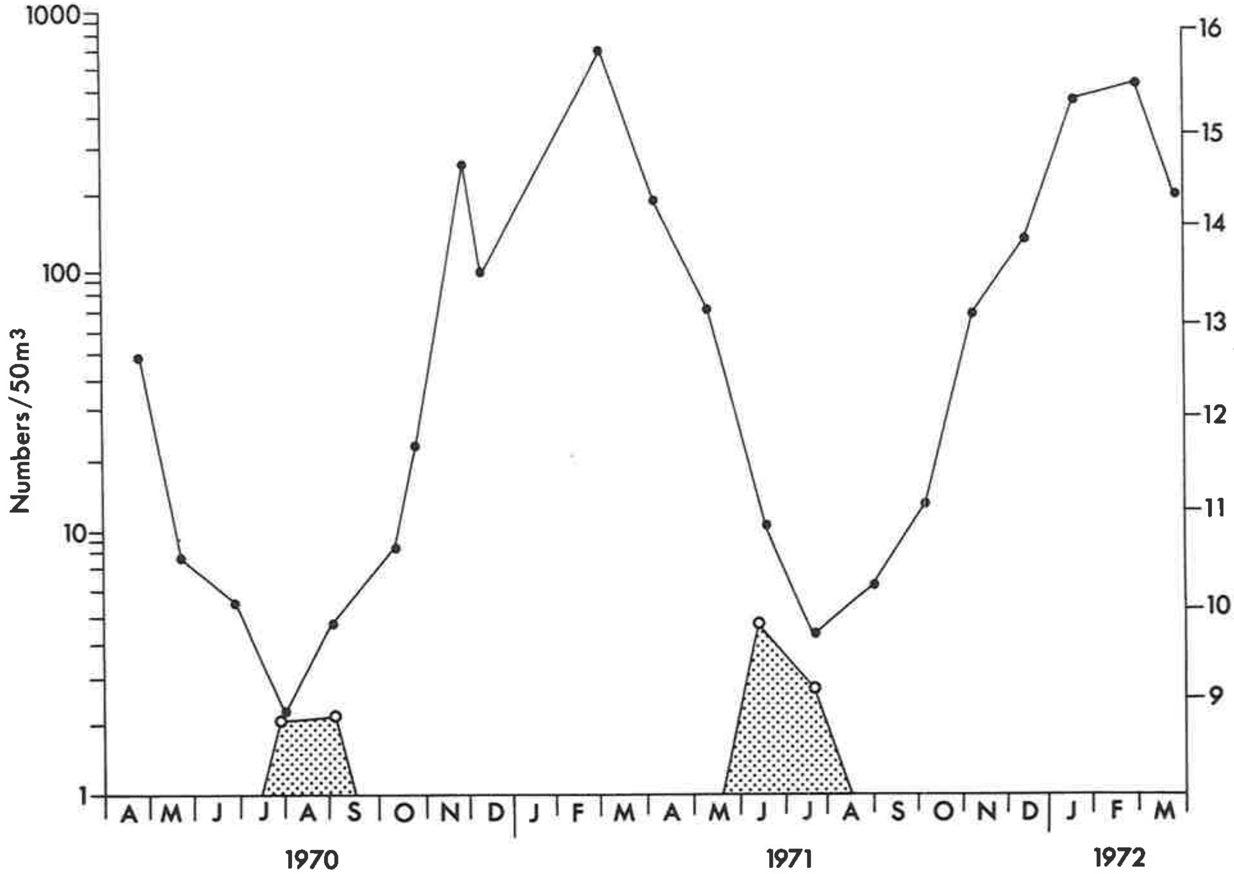


Fig. 70: Annual temperature cycle and lemon sole (*Pelotretis flavilatus*) egg numbers at station B, April 1970 to March 1972.

in neritic water from June to September. This concentration of eggs in waters of definite characteristics is a reflection of the preferential selection by the adults of water of particular attributes in which to spawn. Once released, the eggs, and later, the larvae, will tend to remain in that water mass and will leave it only by wind-induced surface drift or by mixing at the interface of two water masses (for example, neritic and Southland Current water).

TABLE 16: Temperature and salinity ranges at collection sites of lemon sole eggs

Area	Year	Temperature (°C)	Salinity (‰)
Blueskin Bay	1970	9.0-10.4	34.37-34.49
	1971	9.7-11.4	34.24-34.87
Otago Harbour	1971	6.5-10.6	32.75-34.70
Otago coast	1971	9.2-11.2	28.00-35.00

VERTICAL DISTRIBUTION OF PLANKTONIC FISH EGGS

A knowledge of the vertical distribution of planktonic eggs and larvae of marine fishes is essential when planning quantitative surveys designed to estimate indirectly the size of adult breeding stocks. Under calm conditions, as, for example, in a container of sea water, eggs of most marine fishes float immediately beneath the surface. At sea the vertical distribution of planktonic fish eggs is influenced by several factors, including depth of fertilisation, egg density, vertical density structure of the sea water column, and the degree of tidal or wind-induced turbulence.

The factors influencing the vertical distribution of larval stages include those mentioned above, but more important is larval response to light intensity, temperature, and food availability (Silliman 1943).

The following results are based on two series of horizontal samples from different depths.

RESULTS

The general features of the two series are summarised in Table 17.

Series 1

The eggs of several species were present in all of the samples taken at different depths in Blueskin Bay. The vertical distributions of the more common species are summarised in Fig. 71, and the data used to prepare this figure are given in Table 18. There is a gradation from the situation of sprat, where 72% of the eggs were at the surface, with numbers tapering off to 2% at 18 m, through to the situation of "sole" eggs, which were evenly distributed throughout the water column. Sole eggs included a small proportion of sand flounder eggs. The eggs of the pigfish, ahuru, and spotty were all intermediate in their vertical distribution compared with sprat or sole. When the data for all species present were combined, 52% of the eggs occurred at the surface; numbers tapered off to 6% at 18 m, the bottom of the sampling range.

Series 2

Egg densities were low in the samples taken east of the Otago Peninsula (Table 19). Only four of the nine species were identified. Since numbers of each species were too small to present meaningful vertical distribution diagrams, the data for all eggs have been combined (Fig. 72). Sixty percent of all eggs were taken at the surface. The relative numbers per standard haul indicate that they were distributed evenly at all depths from 15 to 84 m.

DISCUSSION

The two vertical series of samples were from neritic and Southland Current water masses. In the shallow in-shore waters of Blueskin Bay, where tidal and wind-induced turbulence prevent any appreciable vertical stratification, the five common kinds of eggs were distributed from the surface to the bottom sampling depth. Their predominance at the surface was probably due to two factors:

1. Conditions were calm at the time of sampling, which would allow the eggs to accumulate at the surface.
2. The most abundant eggs belonged to sprat, a pelagic species in which fertilisation probably takes place at or near the surface.

The presence of 60% of the eggs at the surface in Series 2 was probably due to their buoyancy and to the calm conditions.

The vertical distribution of fish eggs in Otago waters was similar to that observed in Loch Fyne, Scotland by Williamson (1899), off California by Silliman (1943)

TABLE 17: Hydrological features at the two vertical distribution sampling sites

Sampling site	Date	Bottom depth (m)	Max. depth sampled (m)	Surface temp. (°C)	Bottom temp. (°C)	Surface salinity (‰)	Bottom salinity (‰)	Water type
Series 1	24/10/72	20	18	12.1	12.1	34.55	34.56	Neritic
Series 2	12/10/72	112-120	84	11.2	11.1	34.89*	34.89*	Southland Current

* From Jillett's (1969) station B in October.

TABLE 18: Vertical distribution Series 1: Egg numbers and percentages at different depths in Blueskin Bay

Depth (m)	Volume filtered (m^3)	Filtration efficiency (%)	Pigfish No./500 m^3	Pigfish %	Sprat No./500 m^3	Sprat %	Ahuru No./500 m^3	Ahuru %	Sole No./500 m^3	Sole %	Spotty No./500 m^3	Spotty %	Blue cod No./500 m^3	Blue cod %	Lemon sole No./500 m^3	Lemon sole %	Total (all species) No./500 m^3	Total (all species) %
0–0.5	872	–*	21	42	3 304	72	144	30	325	23	585	30	2	12	1	10	4 382	52
4	816	–	14	28	506	11	102	21	307	22	550	28	5	30	5	52	1 489	17
6	804	94	6	12	368	8	85	18	289	21	420	22	6	36	3	31	1 177	14
12	883	89	4	8	326	7	113	23	257	18	236	12	3	18	0	0	939	11
18	800	91	5	10	94	2	43	9	241	17	156	8	1	4	1	7	541	6
			50		4 598		487		1 419		1 947		17		10		8 528	

* Not measured.

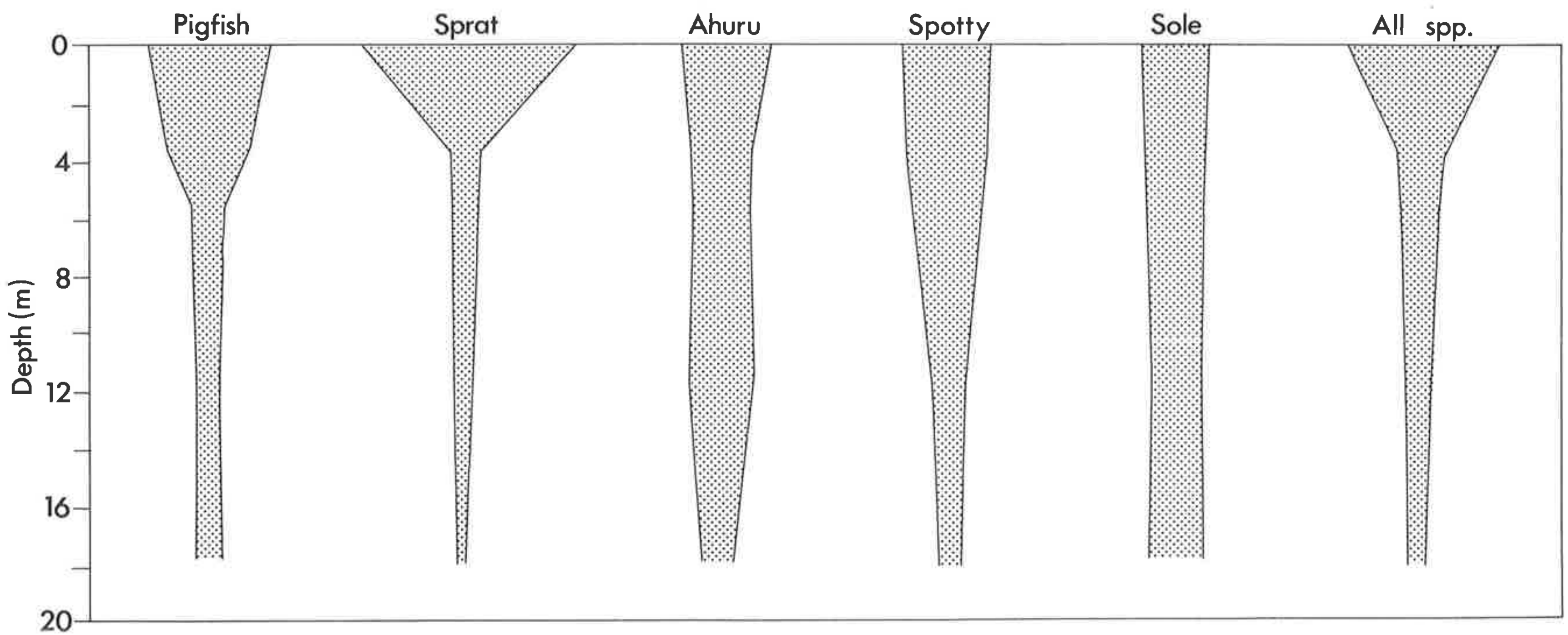


Fig. 71: Vertical distribution of eggs in Blueskin Bay.

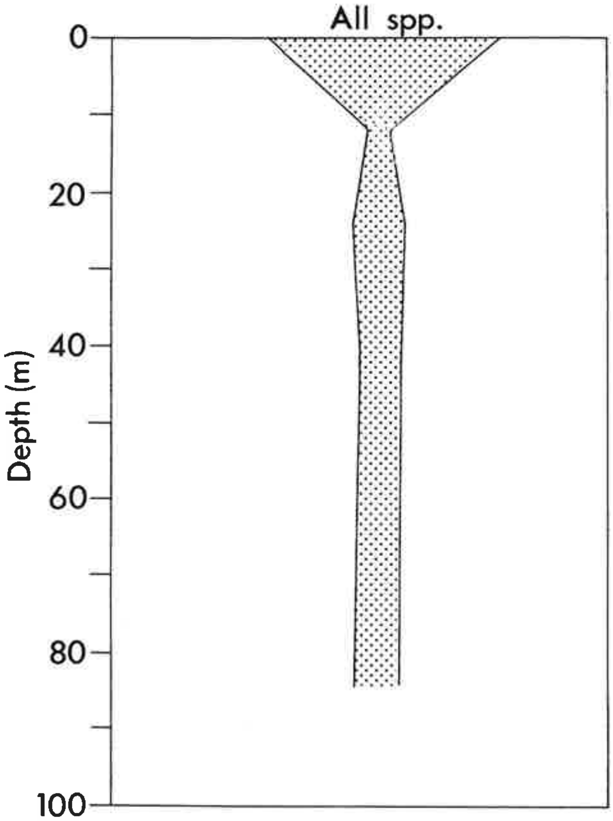


Fig. 72: Vertical distribution of eggs east of the Otago Peninsula.

and Ahlstrom (1959), in Long Island Sound by Williams (1968), and in the Gulf of Marseilles by Aboussouan (1964). Silliman (1943) found eggs of *Sardinops caerulea* to be most abundant in the upper mixed layer above the thermocline. A similar conclusion was reached by Ahlstrom (1959) after an extensive survey which included 22 series of hauls from different depths.

Although Ahlstrom confirmed that the extent of the vertical range of eggs and larvae was between the surface and 125 m, with eggs being predominant at the surface, he also comments (page 134) that within this depth range "all of the more common kinds of fish eggs and larvae showed marked differences in vertical distribution from series to series".

Both Silliman (1943) and Ahlstrom (1959) sampled in waters deeper and further off shore than those sampled in this study. However, Williams (1968) took comparable samples in Long Island Sound to a maximum depth of 30 m. The range of vertical distribution patterns observed by Williams for in-shore spawners was very similar to those observed in Blueskin Bay. Most of the more abundant kinds of eggs observed by Williams were, like the New Zealand sprat, concentrated near the surface; very few were near the bottom.

TABLE 19: Vertical distribution Series 2: Egg numbers and percentages at different depths east of the Otago Peninsula

Depth (m)	Volume filtered (m^3)	Filtration efficiency (%)	Total No./500 m^3	%
0-0.5	835	93	18.0	59.9
12	1 061	97	1.4	4.7
24	770	-*	4.6	15.2
41	837	91	3.0	9.9
84	647	90	3.1	10.3
			30.1	

* Not measured.

In the Blueskin Bay series the two egg types without oil droplets, pigfish and sprat, were both more abundant near the surface than the other species, which all contained one or more oil droplets. Although the oil droplet must contribute to the buoyancy, it is obviously not a prerequisite for the egg types which are more common at or near the surface. There was no difference in vertical distribution between the eggs with and without oil droplets collected from different depths in Long Island Sound by Williams (1968).

The buoyant nature of fish eggs was also observed by Aboussouan (1964), who sampled in the Gulf of Marseilles and demonstrated that the eggs of the pilchard *Clupea pilchardus* and anchovy *Engraulis encrasicholus* were almost invariably predominant at the surface throughout their spawning seasons and declined in numbers with increasing sampling depth. Few eggs were taken in his deepest samples (50 m).

If these observations can be regarded as typical, they show that at least for eggs in in-shore neritic waters, sampling at the surface gives an adequate representation of both numbers and kinds of species present in the water column, but since a vertical gradient of egg numbers exists for some species, surface sampling is inadequate for providing an estimate of the total numbers of eggs present in a given area. Such an estimate could be obtained only by sampling the entire vertical range of the eggs.

DRIFT OF PLANKTONIC FISH EGGS

From the moment of fertilisation a fish egg drifts passively with the current. At the same time, by eddy diffusion processes, there is an increase in the distance between individual eggs from one spawning (that is, the number per unit volume decreases (Hirano 1965)). Even after hatching, passive drift must continue beyond yolk-sac absorption until the young fish is some centimetres long and able to make appreciable movements against the current.

The total distance drifted by the early stages will depend on the variations in current velocity caused by differences in position with respect to the main flow and by winds, tides, or bottom topography. Although the velocity is variable, it is of interest to calculate the approximate distance drifted by the young stages of various species, since the distance may give an indication of the extent of adult spawning migrations and the fate of the eggs or larvae.

Although the actual rate of drift cannot be determined, an approximation can be obtained by use of the velocity values for the Southland Current observed over the shelf off Otago. The value used (14.9 cm/s) is the average of the mean velocity at 20 m measured by current meter off the Otago coastline and the mean minimum surface velocity obtained from drift card recoveries.

The length of time for which a fish species remains planktonic obviously varies from one species to another and with temperature and food availability. As an approximation, a figure of 100 days was used by Fraser (1958) for fish in the North Sea. Since New Zealand waters are warmer than the North Sea, a value of 90 days is used here as an estimated average drift period for most species of fish. The distance travelled during a period of 90 days at an average speed of 14.9 cm/s is 1161 km or 626 nautical miles, and if this distance was linear and parallel to the coastline, it would equal the distance between Nugget Point and Mahia Peninsula. Some possible distances drifted by various species as eggs and yolk-sac larvae at a speed of 14.9 cm/s are shown in Table 20.

Many fish exhibit a contranatant spawning migration with a subsequent down-stream drift of eggs and larvae to nursery areas where large numbers of young fish develop into juveniles. During the period of drift, eggs and larvae have been considered by many authors (for example, Fulton 1897, Walford 1938, Fraser 1958, Bishai 1960, Colton and Temple 1961) to be vulnerable to mass mortality due to the vagaries of water movements, particularly around island systems washed by oceanic currents. The maintenance of benthic invertebrate populations by the retention of planktonic larvae in insular eddy systems is discussed by Orton (1937) and Boden (1952) and that of fish populations by Saville (1965). Saville considered the effect of changes in wind-induced surface currents on the larval populations of several species of fish and concluded that only on rare occasions in relatively small or isolated areas, such as Faroe or Georges Banks, could abnormal wind conditions displace the planktonic eggs or larvae to the extent of diminishing the year class strength. The effects of currents on year class strength of species inhabiting off-shore fishing grounds such as the Georges Bank, where it seems that under average conditions most eggs and larvae are carried away, are not understood. It is not yet apparent how various species, such as the haddock (*Melanogrammus aeglefinus*), which are planktonic to a length of about 10 cm, are able to remain in the area without being swept away by the currents (Colton and Temple 1961).

The situation around New Zealand is such that all of the major current systems transport water roughly parallel to the coastline for some hundreds of kilometres. These current systems (Fig. 3) create small localised eddies in the bays in the lee of coastal projections such as the Otago Peninsula, Banks Peninsula, Kaikoura Peninsula, Farewell Spit, and Mahia Peninsula. That these eddies are important for larval survival is borne out by the fact that many such bays are well known nursery areas for a wide range of fish species.

Eggs spawned in shallow, sheltered bays will probably travel less distance in relation to their point of origin than those released in the Southland Current,

TABLE 20: Possible distances drifted at hatching and at yolk-sac absorption for various fish species

Species	Total distance drifted (km) At hatching	At yolk-sac absorption
Sprattus antipodum	64	-*
Auchenoceros punctatus	74	142
Chelidonichthys kumu	51	101
Congiopodus leucopaecilus	133	165
Pseudolabrus spp.	64	164
Parapercis colias	74	111
Seriolella brama	49	106
Rhombosolea plebeia	63	131

* No data available.

and they may possibly spend their entire developmental period within an eddy system in a bay (for example, Pegasus Bay). The tendency of many oceanic and coastal currents to exist as moving eddies rotating about their centres suggests that though young stages of fish may drift about 1161 km in 90 days, this movement would almost certainly not be parallel to the coastline. However, the complete absence of eggs of many in-shore spawners from samples taken beyond the mid shelf indicates that the eggs were either retained within the eddies in bays or that their drift was perhaps parallel to the coastline.

Until a greater understanding is gained of current flow rates and the behaviour of eggs and larvae in the water systems, as well as of the rate of circulation within the eddies and the rate of flow around New Zealand, only crude estimates of the extent of drift can be made.

CONCLUSIONS

The examination of planktonic eggs from Otago waters has enabled the definition of the spawning areas and spawning seasons of local fish species. The proportion of egg types recognised varied with samples taken from different localities: for example, a total of 16 different species was represented in the Otago Harbour samples and of these 13 species were identified; of the 21 kinds collected in Blueskin Bay 15 were identifiable; of the 59 species collected east of the Otago Peninsula 16 were identifiable. The unrecognised eggs were usually represented by very small numbers per sample.

The most significant general conclusion emerging from this study is the close relationship frequently observed between the distribution and abundance of eggs of different species and the prevailing hydrological conditions. Thus some of the young stages of the fish species which were recognised can be grouped with respect to their spawning areas (Table 21).

Within each of these areas the various species probably exhibit further differences; for example, flatfish spawn at or near the bottom, and sprat spawn at or near the surface. Although the category "oceanic spawners" is the smallest, in reality it would exceed the other two in numbers of species, even if the members of the family Myctophidae were the only addition. The single species in this category is a reflection of both the coastal nature of sampling and the difficulty in identifying the eggs of oceanic species.

The affinities of different species for different water masses is apparent in the ranges of temperatures and salinities of the surface waters in which the eggs were collected. The extent to which changes in hydrological conditions may influence the distribution of the eggs and perhaps the spawning adults is particularly evident in the differences observed in Blueskin Bay between 1970 and 1971 spawnings of sprat, ahuru, spotty, and sole (see Figs. 23, 30, 47, and 63). The shoreward intrusion of the warm, high salinity Southland Current in winter and spring of 1971 restricted the occurrence of eggs of the above species to the inner Blueskin Bay stations. The importance of the zone of neritic water for these species and others is apparent also in Figs. 26, 33, 65, and 69, in which the centres of abundance occur in the neritic zone. This is true also for anchovy *Engraulis australis* in the low salinity surface waters of the Fiordland sounds (Robertson 1973).

The hydrological observations off Otago emphasise the influence of run-off from the major rivers (for example, Clutha River) on the temperature and salinity of the neritic zone. In view of the importance of the neritic zone as a spawning site for a number of species, both commercial and non-commercial, the effects of hydro-electric developments on the seasonal dilution of coastal waters is a topic worthy of future consideration, particularly in Nugget Bay and Doubtful Sound. The latter area is now subjected to the increased outflow of considerable quantities of fresh water, which may be reflected in the survival of the young stages of fish spawned in the fiord (for example, anchovy and tarakihi, (Robertson 1973)).

A further geographical distinction can be made with respect to the Otago coast. A number of species (for example, anchovy, frostfish, pilchard, and tarakihi) have been observed (Robertson 1973) to spawn over a wide geographical area which excluded the east coast water over the shelf south from Banks

TABLE 21: Areas of spawning of some fish species of the Otago coast

Neritic spawners	Southland Current spawners	Oceanic spawners
Shallow shelf (0-40 m)	Mid to deep shelf (40-200 m)	Over deep water (>200 m)
Sprattus antipodum	*Coelorhynchus aspercephalus**	*Maurolicus muelleri*
Auchenoceros punctatus	*C. australis**	
Congiopodus leucopaecilus	*Chelidonichthys kumu*	
Pseudolabrus celidotus	*Mendosoma lineatum*	
P. fucicola	*Parapercis colias*	
Rhombosolea plebeia	*Seriolella brama*	
Peltorhamphus novaezeelandiae	*Arnoglossus scapha*	
P. tenuis		
Pelotretis flavilatus		

* Probably slope spawners.

Peninsula to Dusky Sound (that is, including Otago waters). Several other species were, however, more abundant in this southern area (for example, sprat, ahuru, blue cod, witch, and sole). This division is probably a reflection of the cooling influence of Sub-antarctic Surface Water, which extends north to about Banks Peninsula on the east coast of the South Island. The south-east coast is often depicted as lying south of the Subtropical Convergence, but in this area the Southland Front can be regarded as the Subtropical Convergence; thus the South Island would be north of the Subtropical Convergence, though the narrow Southland Current is considerably cooled along the east coast and is the least subtropical of all New Zealand waters.

The consistent seasonal occurrence of the eggs and larvae of various species in waters of distinct characteristics presents the possibility of the use of the more abundant species as indicators. For example, the presence of sprat eggs could be useful as a seasonal indicator of neritic water; witch and warehou eggs might prove useful indicators of Southland Current water, particularly where mixture with other water masses has obscured the origin of the water or where hydrological data are lacking.

Although some spawning activity was detected all year round in most New Zealand areas sampled by Robertson (1973), there was a definite seasonal fluctuation in numbers of species spawning, the highest numbers occurring in spring (Fig. 73). This was particularly obvious in each of the areas observed off Otago, where the numbers of species spawning began to increase in mid winter and peaked in spring-summer, with numbers of species spawning and egg numbers both being highest in September and October. Seasonal peaks in fish egg or larval abundance have been reported during spring-summer in Wellington Harbour (Wear 1965), Hauraki Gulf (Jillett 1971), and off Kaikoura (Bradford 1972), but none of these studies considered the number of species present. The observed peak in numbers of species spawning in spring coincides with the annual peak in primary production which occurs in September-October (Bradford 1972). The larvae will therefore be developing at the time of year when the food supply is greatest.

Qasim (1955), in his review on the seasons and durations of the breeding cycles of Northern Hemisphere fishes, suggests (page 151) that "the breeding cycles may be so regulated that the larvae hatch during the season which is most favourable for finding planktonic food . . .". On the north-western

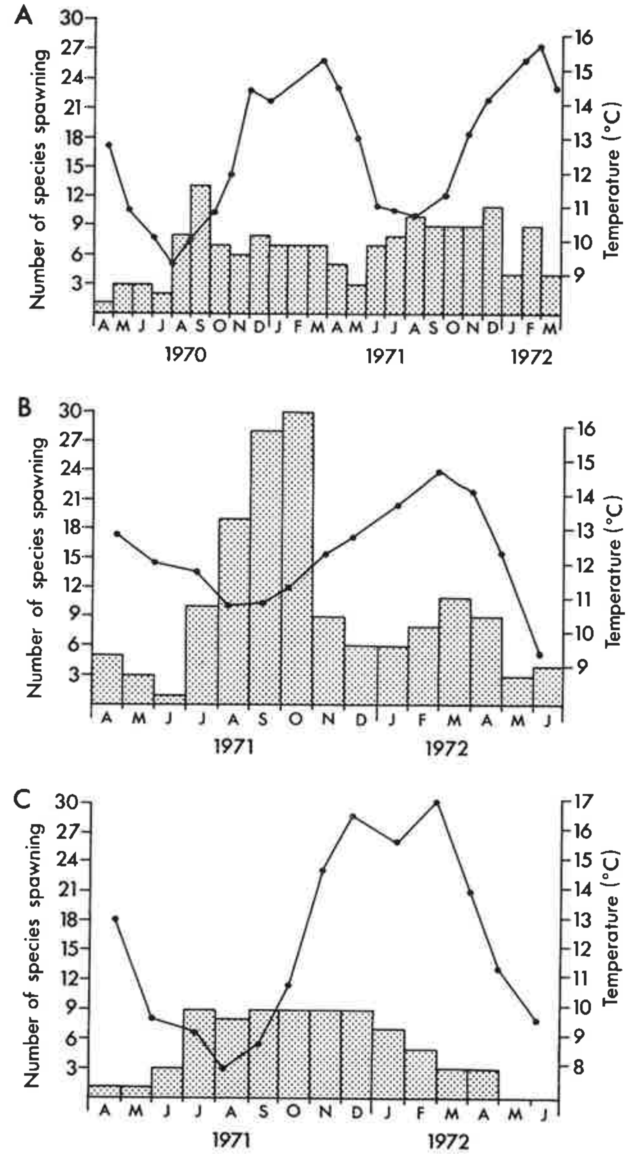


Fig. 73: Numbers of fish species spawning at different times of the year on each of the three Otago transects. A: Blueskin Bay (A–F). B: East of the Otago Peninsula (G–L). C: Otago Harbour (M–R).

Atlantic coast Richards (1959) reported an increase in number and variety of eggs and larvae throughout the spring, with a summer peak, and similar situations were observed around the British Isles (McIntosh and Masterman 1897), in the Bay of Biscay (Arbault and Lacroix-Boutin 1969), in the Mediterranean off Algeria (Marinaro 1971), in the Gulf of Marseilles (Aboussouan 1964), in the Adriatic (Varagnolo 1964), and in the south-west Atlantic (de Ciechomski 1971a). Thus a spring-summer spawning season is characteristic of many coastal temperate region fish species.

Too few seasonal observations have been made in northern New Zealand waters to allow definite statements regarding the north-south differences in spawning seasons; however, north-south differences in temperature would be expected to influence the time and duration of spawning activity.

The areas of spawning described here for Otago waters probably represent a portion of much broader spawning areas for the species considered. However, for species of current or latent economic potential, for example, common sole, lemon sole, blue cod, sprat, and warehou, this study provides some of the basic information necessary in the planning of future stock assessment programmes which might include egg or larval surveys.

SUMMARY

Concurrent examination of hydrological conditions and planktonic eggs off Otago has enabled the definition of the spawning seasons, spawning areas, and hydrological affinities of 17 fish species. The egg distributions reflect the presence of aggregations of spawning adults in water masses of definitive hydrological properties.

Observations on the vertical distribution showed that eggs in in-shore waters are most abundant at the sea surface.

The hydrology off the Otago Peninsula was shown to be typical of the Otago coast from Nugget Point to Moeraki; that is, the warm, high salinity Southland Current was bounded on the east by cool, low salinity Subantarctic Surface Water and on the west by low salinity neritic water which was cooler in winter and warmer in summer than the Southland Current.

Drift cards showed a strong northward flow of shelf waters.

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