Fisheries Research Bulletin No. 23

Fish Eggs and Larvae of the Hauraki Gulf, New Zealand

by

J. Crossland

Fisheries Research Division

New Zealand Ministry of Agriculture and Fisheries

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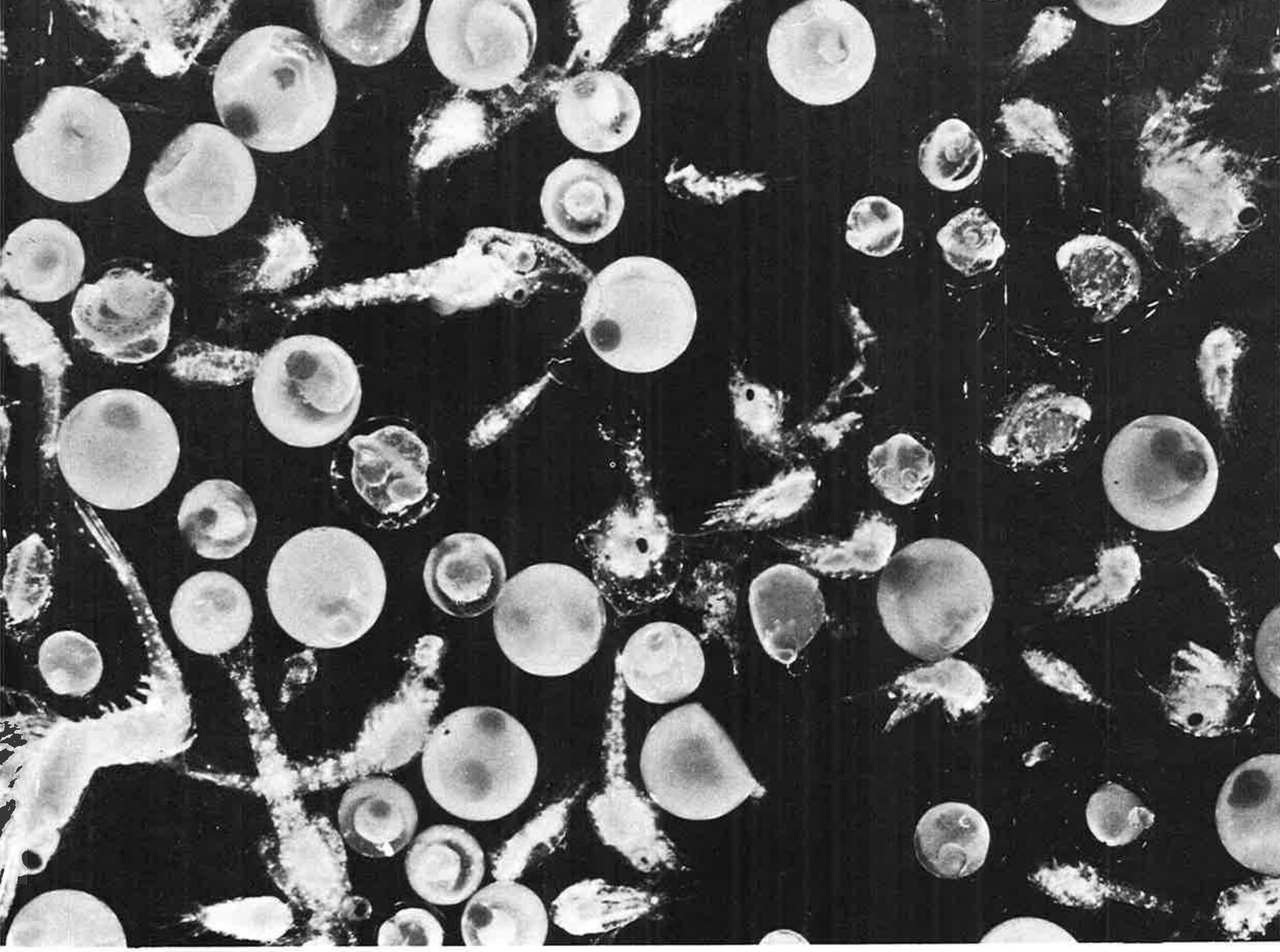

Frontispiece: Part of a rich haul of fish eggs from the spring plankton of the Hauraki Gulf.

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FOREWORD

JAMES CROSSLAND has already used the distribution and abundance of the eggs and larvae of snapper to assess the standing stocks of this most valuable species in New Zealand's most important commercial fishery. However, despite the rapid expansion of fishing effort over the past few years, our knowledge of the available resources, even in the Hauraki Gulf, has remained meagre.

The data in this bulletin not only add to our understanding of the other species in the Hauraki Gulf, but are an important prerequisite to our appreciation of its significance as a spawning or nursery ground for fisheries elsewhere. At the same time, this type of information will be of value as a background for integrated management of the total resources of the area in the future.

G. DUNCAN WAUGH,
Director, Fisheries Research Division

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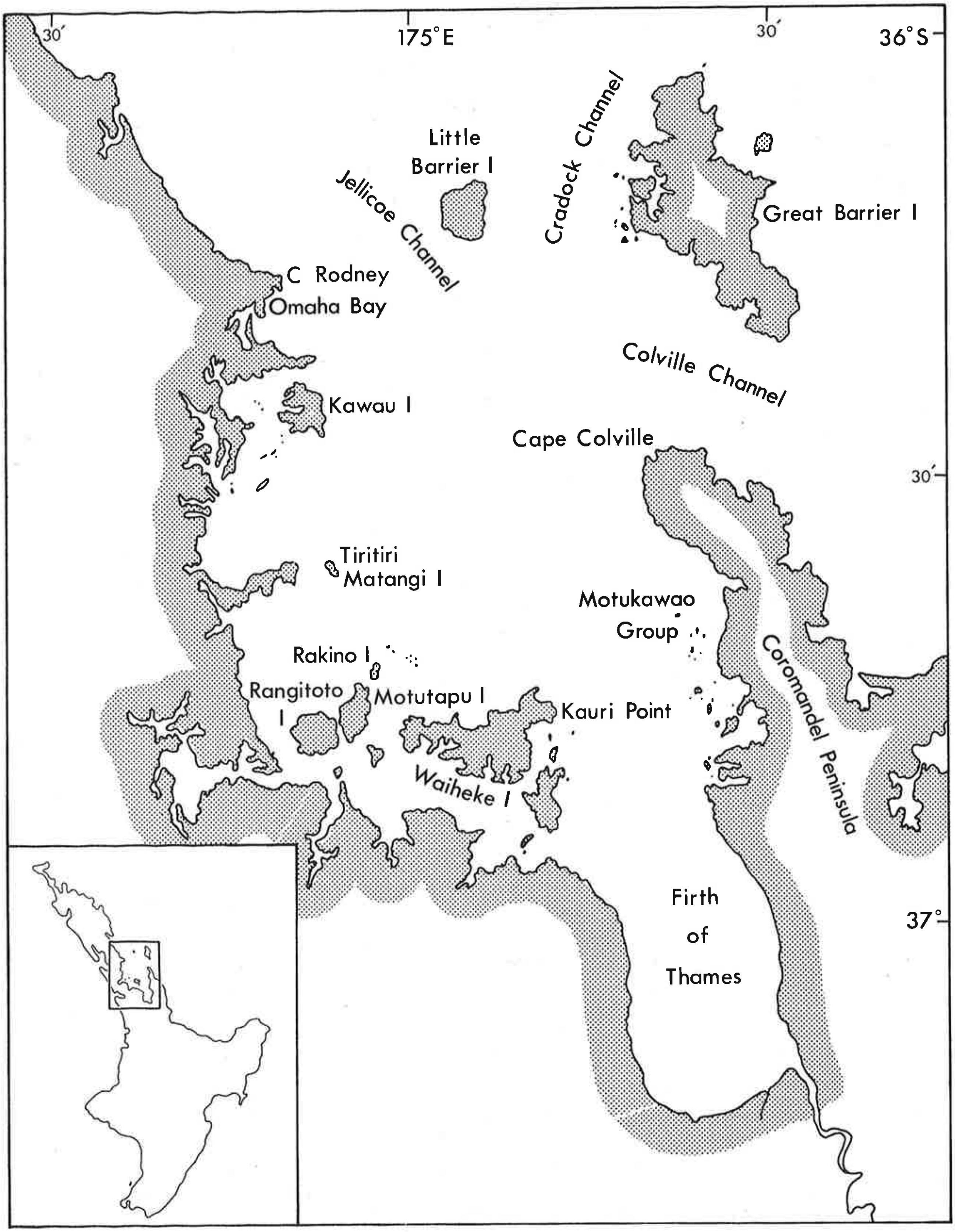


Fig. 1: The Hauraki Gulf, showing places mentioned in the text.

INTRODUCTION

The Hauraki Gulf, New Zealand's richest fishing ground, is a large, relatively shallow embayment with many islands and harbours (Fig. 1). It is an important spawning ground for many fish species, including snapper (*Chrysophrys auratus*), which dominates the commercial landings. During the spring-summer periods (October to January) of 1974–75 and 1975–76, 2-weekly plankton surveys were carried out with the aim of estimating the stock size of snapper based on egg counts (Crossland 1980). These surveys were specifically designed for sampling snapper eggs; however, many types of fish eggs and larvae were collected, identified, and counted. These data are presented in this bulletin.

There are few published accounts of ichthyoplankton surveys from New Zealand. In the Hauraki Gulf Cassie (1956a) studied the distribution of snapper eggs, and Colman (1973) studied the spawning of two species of flounder. Baker (1972) surveyed pilchard eggs and larvae in Tasman Bay, Robertson (1980) recorded the distribution of the eggs of 17 species off the Otago coast, and Colman (1979) studied the spawning of the sprat around the South Island. Additional information on the eggs and larvae of species mentioned in this bulletin is given in Elder (1966), Robertson and Raj (1971), Baker (1973), Robertson (1973), Castle and Robertson (1974), and James (1976). Robertson's (1975) key describes the planktonic eggs of 56 species of New Zealand fishes.

MATERIAL AND METHODS

SAMPLING AND SORTING

Plankton samples were taken by oblique tows of a cylinder-cone net at the stations shown in Fig. 2. Details of the net were: mouth area 0.25 m^2; cylinder 56 cm diameter by 150 cm long; cone slope length 185 cm; gauze 0.425-mm aperture with a porosity of 47%. The total filtering area was 2.225 m^2 and the filtering area/mouth area ratio was 8.9, made up of 5.35 in the cylinder and 3.55 in the cone. The volume of water sampled (range 50–300 m^3) was recorded with a digital flow meter, type 2030 by General Oceanics, Inc., which was mounted at a distance of a quarter the diameter from the rim of the net. Tows were made at a boat speed of 2 to 2.5 knots, with the net usually descending to within 2 to 4 m of the bottom.

Samples were preserved in 5% neutralised formalin. During sorting all fish eggs and larvae were counted. Initially plankton sorters removed all eggs and larvae and sorted them according to type. When the sorters were sufficiently experienced to identify the different kinds accurately, the common ones were counted *in situ* in the samples. Regular checks were made on the accuracy of identifications and sample counts. Large samples were divided with a Folsom splitter until a manageable fraction was obtained. In samples where eggs were abundant but larvae were not, eggs were subsampled, and the whole sample was sorted for larvae. Details of the dates of sampling, numbers of stations, and sea temperature data and further information on the sampling technique can be found in Crossland (1980).

IDENTIFICATION OF EGGS AND LARVAE

Robertson's (1975) key was useful in identifying many of the eggs. Other eggs and larvae were identified by building up a series of developmental stages from egg to larva to recognisable juvenile.

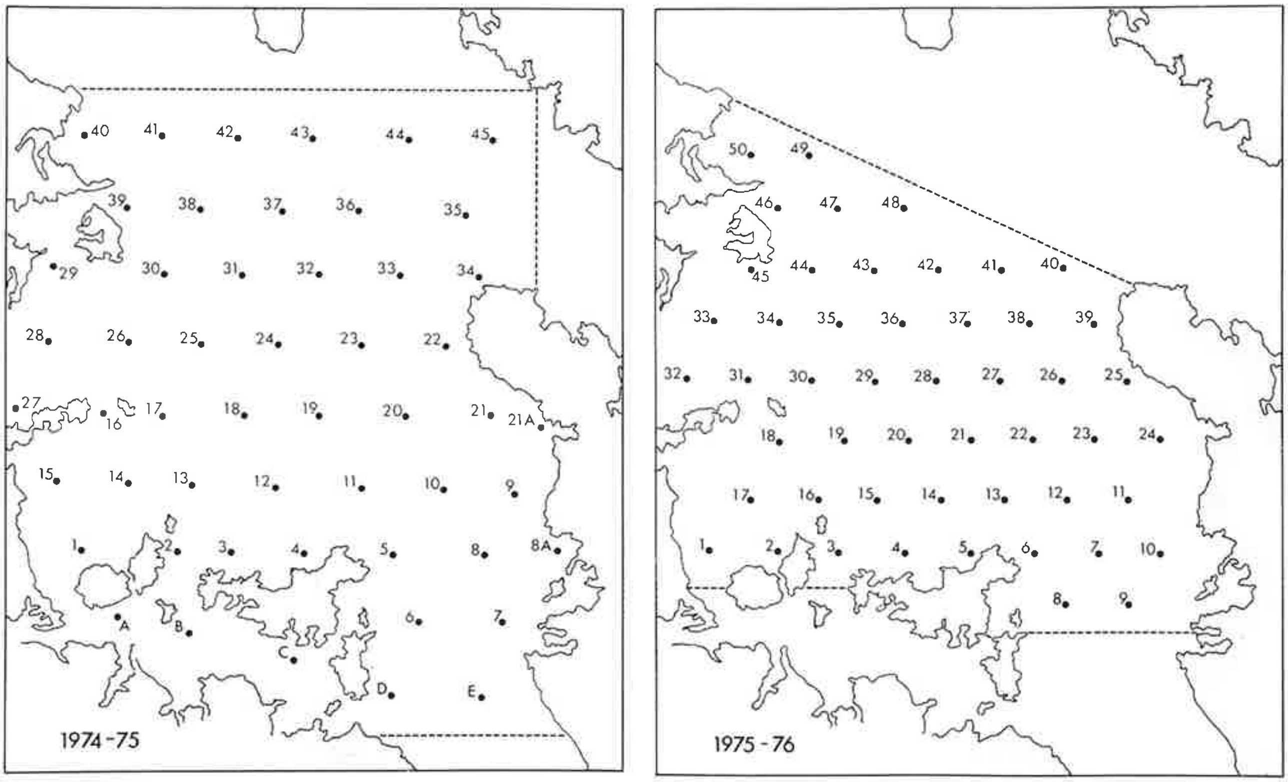


Fig. 2: Survey stations and study area. Left: 1974–75. Right: 1975–76.

Larvae of some species were identified by their similarity to those of related species which had been described from other parts of the world. Electrophoretic tissue analysis aided in identifying snapper larvae (Smith and Crossland 1977) and larvae of the spotted stargazer. The distribution and abundance of species occurring locally as adults were also considered.

DESCRIPTIONS OF EGGS AND LARVAE

This bulletin describes and illustrates eggs and larvae taken or refers to published accounts.

The descriptions of larvae are intended to highlight features which will allow recognition of the individual species; they are not meant to be detailed, stage-by-stage descriptions of larval growth and morphology. Most species can readily be distinguished. Exceptions are the two species of *Rhombosolea* and the two species of *Trachurus*, all of which may be present in the sampling area.

All descriptions and measurements apply to material which was preserved in 5% neutralised formalin. Measurements were made under a stereo microscope at a magnification of 62×. The length recorded for larvae was total length. The figures of eggs and larvae were also made by use of a stereo microscope and a drawing tube.

DATA PRESENTATION

This study was made on a more intensive scale (that is, at shorter time intervals and with stations closer together) than is common with ichthyoplankton surveys. The complete data, which are held in Fisheries Research Division library, give the counts recorded for each type of egg and larva for every sample taken; these were calculated as numbers per 100 m^3 (eggs) and numbers per 500 m^3 (larvae).

For some of the more common egg types the densities were integrated over the study area to give estimates of the total numbers present at one time on that cruise. This was done by multiplying each individual station volume (station area by mean depth) by its egg density and then summing over the whole study area. The calculations were adjusted for the slight variation in area between the 2 years. The method of integration is explained fully in Crossland (1980). The embryonic period was not known for any of the eggs; so it was not possible to calculate total egg production.

Distribution maps were plotted for the more common types of eggs and larvae as numbers below 10 m^2. Cruises not shown in the map series recorded fewer eggs and larvae than the minimum contour level for that species.

RESULTS

Both fish eggs and larvae were very abundant in the Hauraki Gulf. In 1974–75 the 330 samples contained 583 000 eggs and 55 000 larvae. In 1975–76, 589 000 eggs and 79 000 larvae were collected in 426 samples. The maximum number of eggs taken in one haul was 89 000, and that of larvae was 6000. For both years combined, only 2 samples contained no eggs, and 21 contained no larvae. The kinds of eggs and larvae recognised are shown in Table 1. Details of the distribution, seasonality, and abundance for eggs and larvae of each species are given below. The species have been placed in phylogenetic sequence according to Nelson (1976).

The relationship between spawning and temperature was also considered. For demersal species (for example, flounder or gurnard) the sea bottom temperature was used; for pelagic species (for example, anchovy or pilchard) the sea surface temperature; and for species occurring throughout the water column (for example, jack mackerel or ahuru) the mean of bottom and surface temperatures.

Family Engraulidae

Anchovy *Engraulis australis* (White, 1790)

Eggs. The anchovy egg is described and figured in Robertson (1975). Its elliptical shape makes it immediately recognisable, as the only other species known from New Zealand to have an elliptical egg, the carapid *Echiodon* sp., does not occur in the Hauraki Gulf.

The distribution of anchovy eggs for the 2 years (Fig. 3) showed a spawning centre within the study area. Anchovy eggs were common and occurred on all cruises in both years. During October spawning was light and took place in the southern part of the gulf near Waiheke Island and the northern part of the Firth of Thames. The main burst of spawning observed was during November in 1974, and December in 1975. The centre of spawning moved north to the central gulf-Kawau Island area as the season progressed, a similar pattern to that observed for snapper (Crossland 1980). Spawning was still taking place at the end of the sampling period in each year.

The relationship between temperature and spawning (Fig. 4) showed that spawning began when the sea surface temperature was about 16°C and was most intense at 19°–20°C. The number of eggs produced in the 1975–76 study period was about three times that of the previous year (Fig. 4). These figures have been integrated over the study area, but not over time, because the embryonic period of the anchovy is not known. Crude egg counts do not consider the effect of

TABLE 1: Kinds of eggs and larvae collected in the Hauraki Gulf, October to January in 1974–75 and 1975–76

Species	Eggs	Larvae
Anchovy (*Engraulis australis*)	+*	+
Pilchard (*Sardinops neopilchardus*)	+	+
Sprat (*Sprattus antipodum*)	+	−†
Moray eel Family Muraenidae	+	+
Sand eel *Gnathophis* sp.	+	−
Ahuru (*Auchenoceros punctatus*)	+	+
Garfish (*Hyporhamphus ihi*)	−	+
Roughy Family Trachichthyidae	−	+
John Dory (*Zeus japonicus*)	−	+
Seahorse (*Hippocampus abdominalis*)	−	+
Long-snouted pipefish (*Stigmatophora longirostris*)	−	+
Red gurnard (*Chelidonichthys kumu*)	+	+
Rockfish *Acanthoclinus quadridactylus*	−	+
Rockfish *A. trilineatus*	−	+
Jack mackerel *Trachurus novaezelandiae*	+	+
Jack mackerel *T. declivis*	+	−
Snapper (*Chrysophrys auratus*)	+	+
Yellow-eyed mullet (*Aldrichetta forsteri*)	+	+
Grey mullet (*Mugil cephalus*)	−	+
Spotty (*Pseudolabrus celidotus*)	−	+
Spotted stargazer (*Genyagnus monopterygius*)	+	+
Blennies: Family Blenniidae, Family Clinidae, Family Tripterygiidae	−	+
Graham's gudgeon (*Grahamichthys radiatus*)	−	+
Barracouta (*Thyrsites atun*)	−	+
Blue mackerel (*Scomber australasicus*)	+	+
Crested flounder (*Lophonectes gallus*)	+	+
Flounder *Rhombosolea plebeia* & *R. leporina*	+	+
Speckled sole (*Peltorhamphus latus*)	+	+
Leather jacket (*Novodon convexirostris*)	+	+
Porcupine fish *Allomycterus jaculiferus*	−	+
Three unidentified species	+	−

* Present.
† Absent.

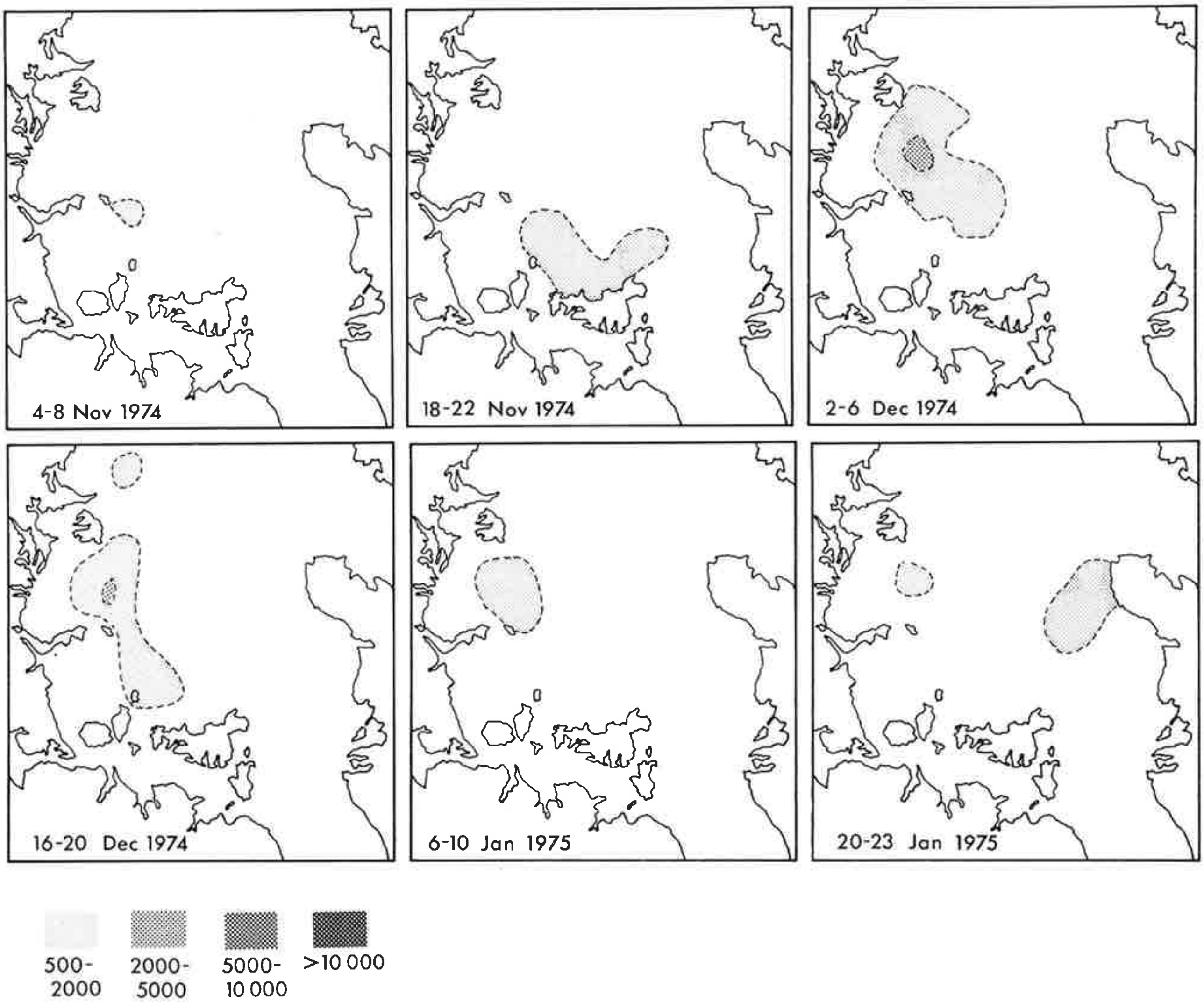


Fig. 3 (above and right): Distribution of anchovy eggs by cruises, 1974–75 and 1975–76.

temperature on development. The egg production shown in Fig. 4 has been adjusted on the basis that the development period is halved for a 10°C rise in temperature. This effect was found experimentally for snapper eggs from the Hauraki Gulf (Cassie 1956b).

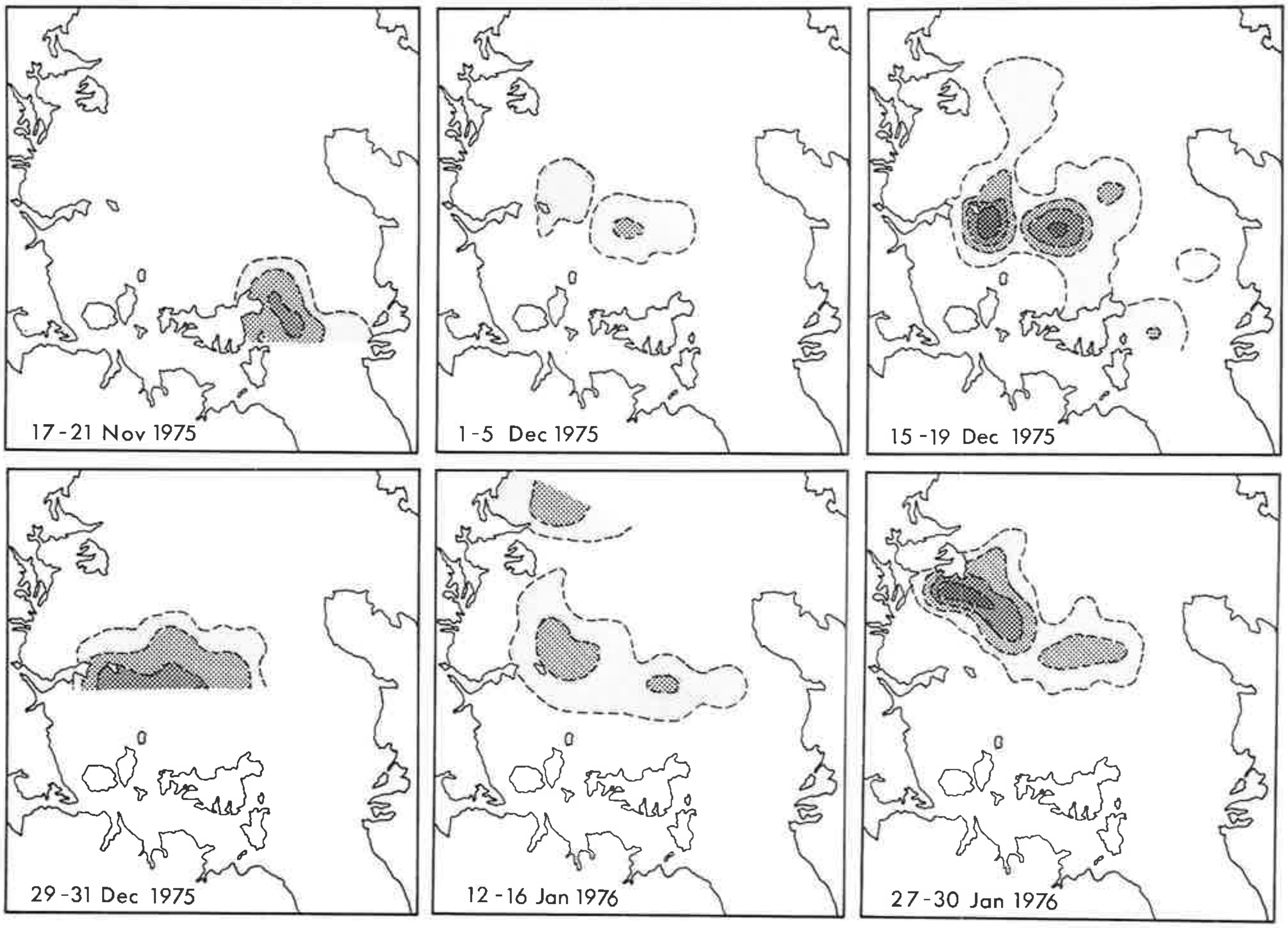
Larvae. The anchovy larva is described and figured in Baker (1972). It may readily be distinguished from larvae of the other New Zealand clupeoids pilchard (*Sardinops neopilchardus*) and sprat (*Sprattus antipodum*) by its underslung jaw and the relative positions of its anal and dorsal fins, which overlap. The latter feature is particularly useful for identification, even in small larvae.

The distribution of anchovy larvae (Fig. 5) differed from that of the eggs. The main concentrations of larvae were in the central and outer gulf, further north than the eggs. Large numbers of larvae occurred on the November cruises in 1974, when the numbers of eggs were low. This probably resulted from bursts of spawning which took place between sampling cruises and were thus not sampled, and it showed that even sampling at 2-weekly intervals may be insufficient to measure the egg production of the mobile, shoaling anchovy.

Family Clupeidae

Pilchard *Sardinops neopilchardus* (Steindachner, 1879)

Eggs. The development of the pilchard egg is described and figured in Baker (1972). These eggs



were present from the beginning of sampling in each year (October) until mid November in 1974 and mid December in 1975. They were seldom abundant, and on only one cruise (4–8 November 1974) was there a large spawning within the study area (Fig. 6).

Larvae. The pilchard larva is described and figured in Baker (1972). Small pilchard larvae are difficult to distinguish from larvae of the sprat *Sprattus antipodum.* Larvae longer than about 25 mm can be identified by the differences noted by Baker. Pilchard larvae have a melanophore below the eye and one at the base of the pelvic fin, and the last ray in the anal fin is elongated. These features are absent in sprat larvae. During this study all clupeid larvae large enough to be identified were pilchard; smaller larvae of the same type were, therefore, assumed to be pilchard also. Some error may be introduced by this, but since pilchard is very common in the Hauraki Gulf and sprat uncommon, the error will be small.

The distribution of larvae in both years (Fig. 7) showed that the main spawning areas of the pilchard

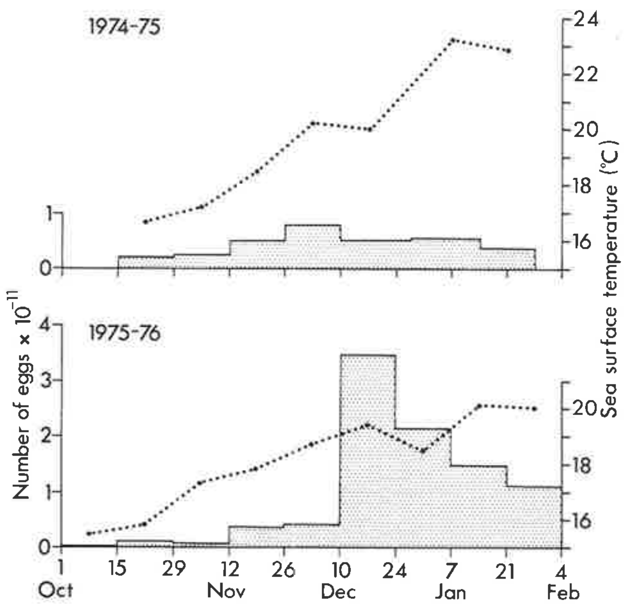


Fig. 4: Number of anchovy eggs within the study area at the time of sampling for each cruise, 1974–75 and 1975–76. Mean sea surface temperatures for each cruise are also shown.

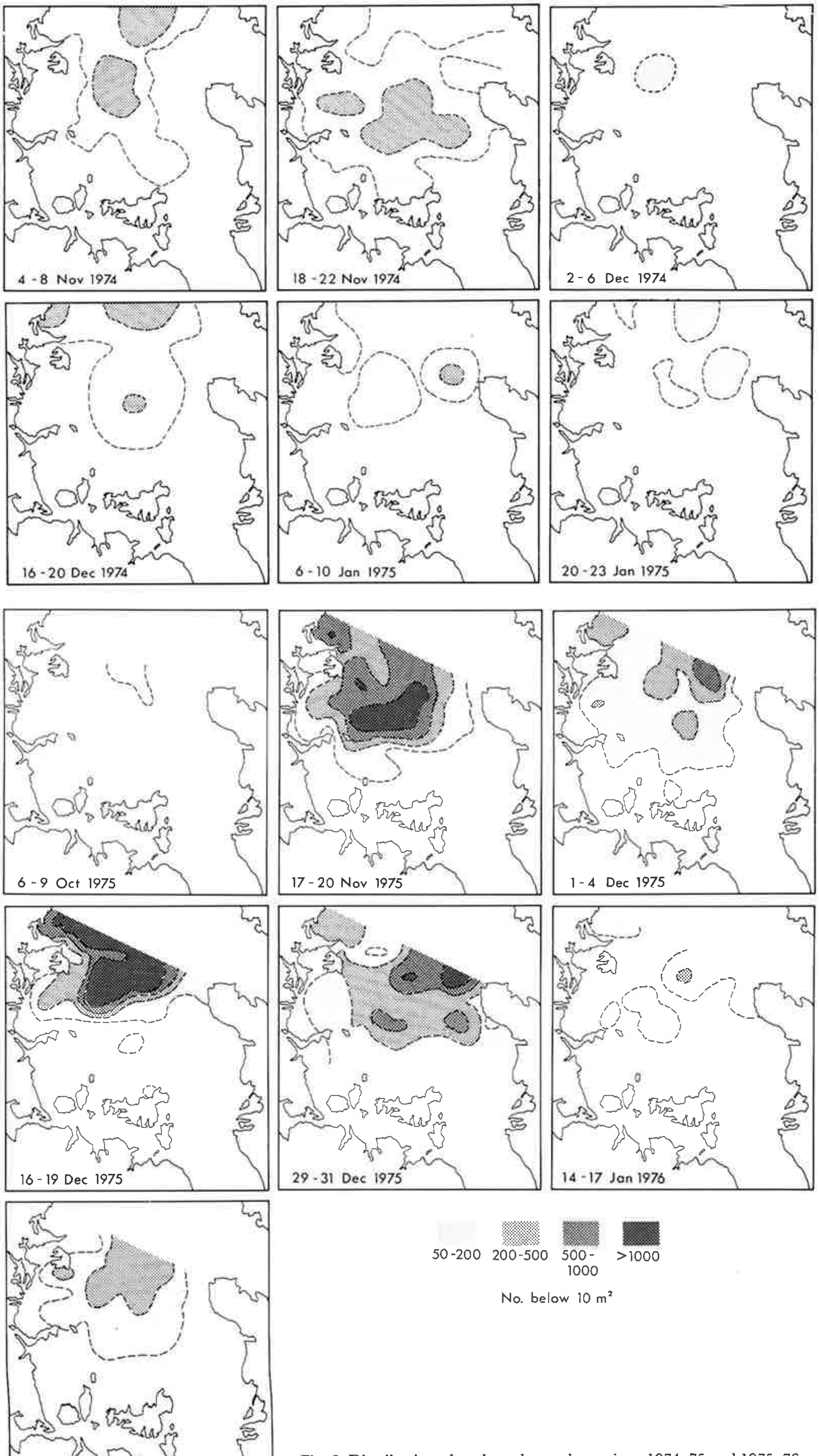


Fig. 5: Distribution of anchovy larvae by cruises, 1974–75 and 1975–76.

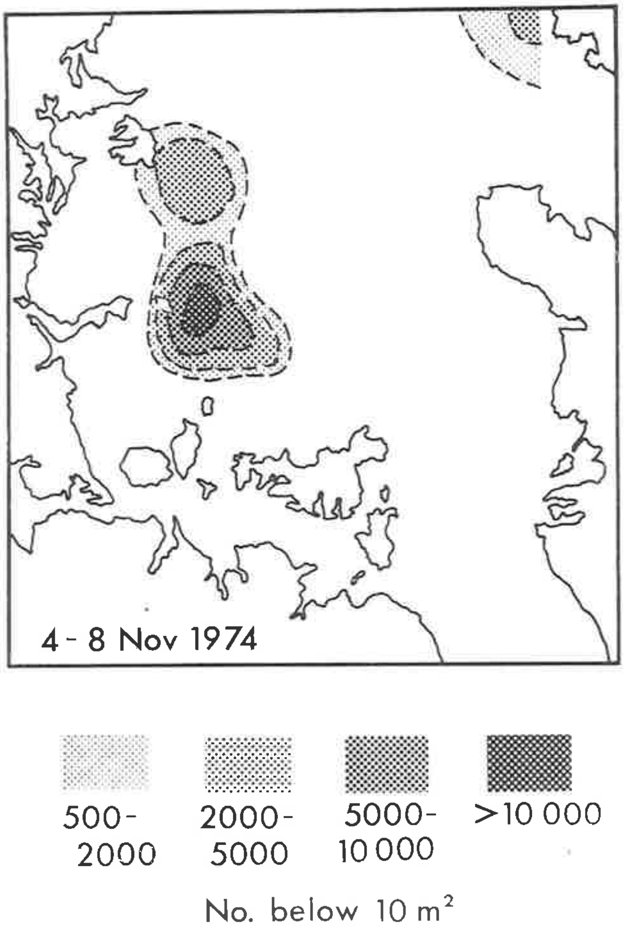


Fig. 6: Distribution of pilchard eggs, 4–8 November 1974.

were north of the study area, probably in the Jellicoe and Cradock Channels. The numbers of larvae taken in each cruise are shown in Fig. 8. A similar pattern was apparent in both years, but the peak lagged by 2 weeks in 1975–76, when temperatures were lower. Larval numbers reached a maximum in the first week of November in 1974, and in the third week in 1975. Peak spawning would therefore have taken place earlier, possibly in late October or early November.

These results can be compared with those of Baker (1972), who studied a population in Tasman Bay and found the breeding season to be November to February, with a peak in December-January; that is, some 6 weeks to 2 months later than in the Hauraki Gulf. The difference in latitude between Tasman Bay (41° S) and the Hauraki Gulf (36° 30′ S) is the probable reason for this. Baker found that most pilchard eggs were spawned when the sea surface temperature was between 16.0° and 16.4°c. It was difficult to make a direct comparison with temperature data from this study, because most spawning took place outside the study area; however, the sea surface temperatures at the outer stations were in the range 16.1°–17.8°c at the peak occurrence of larvae.

Sprat *Sprattus antipodum* (Hector, 1872)

Eggs. The sprat egg is described and figured in Baker (1973). These eggs were taken in only small numbers and occurred sporadically in time and space. Their cumulative distributions for the 2 years are shown in Fig. 9. The largest patch of eggs was found in late October 1975, off Kauri Point, Waiheke Island.

Larvae. Sprat larvae were not recognised in any sample, but they may have been confused with small (less than 25 mm) pilchard larvae.

Adult sprat are occasionally taken by bottom trawl in the Hauraki Gulf if a cod-end liner is fitted, but they do not appear to be abundant. Baker (1973) recorded sprat spawning in the Marlborough Sounds from July to January. Robertson (1980), sampling off the Otago coast, found that spawning lasted from May to November and peaked in June-August. In the Hauraki Gulf the sampling period was outside the main spawning season found by these workers. However, it is unlikely that major spawning took place in the winters of 1974 and 1975, because sprat larvae or juveniles would have been recognised in the samples.

Family Muraenidae

Moray eel (unidentified)

Eel eggs and larvae of a previously undescribed type were occasionally taken in the outer stations of the study area. Because of their close similarity to the eggs and larvae of moray eels from European waters (see Sparta 1939), they were identified as one of the species of morays found in New Zealand. The most commonly observed species locally is the yellow moray (*Lycodontis prasinus* (Richardson, 1847)).

Eggs. These eggs had a diameter of 3.9–4.5 mm; a wide perivitelline space (especially in early stages); and a finely segmented yolk with 6 to 40 oil droplets, 0.07–0.15 mm in diameter (Fig. 10). Eggs were first observed in mid December and were still present at the end of the sampling period in late January. The cumulative egg distribution for 1974–75 is shown in

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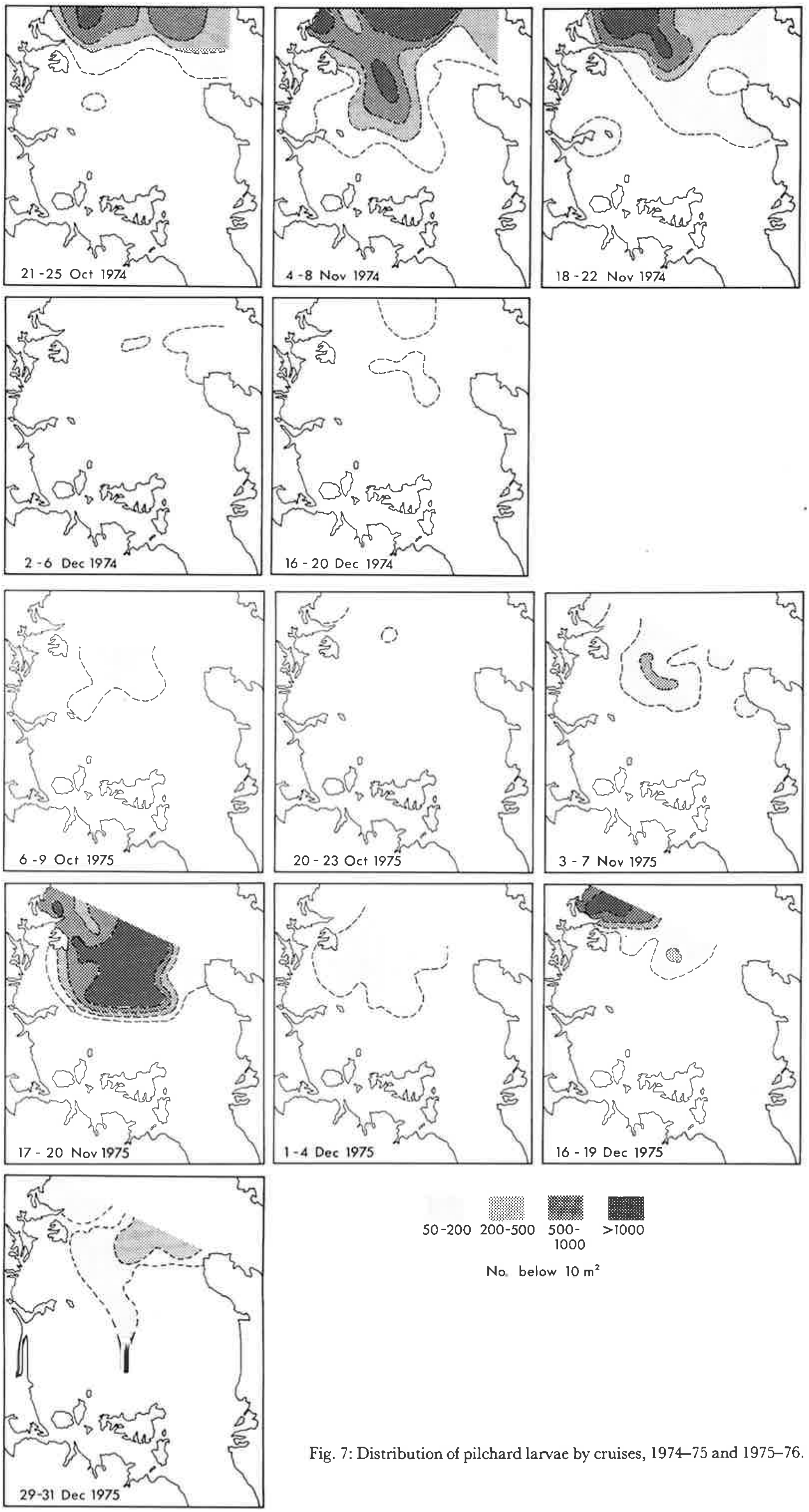


Fig. 7: Distribution of pilchard larvae by cruises, 1974–75 and 1975–76.

Fig. 11. Spawning appeared to be located mainly outside the study area, probably over the rocky bottom around Great and Little Barrier Islands, a habitat favoured by morays. Fewer eggs were taken in 1975–76 because the outer part of the Hauraki Gulf was not sampled.

Larvae. Five larvae were taken in 1974–75 and two in 1975–76; they were found close to the eggs. They were immediately recognisable by their long, slender shape and fearsome array of forward-pointing teeth (Fig. 12).

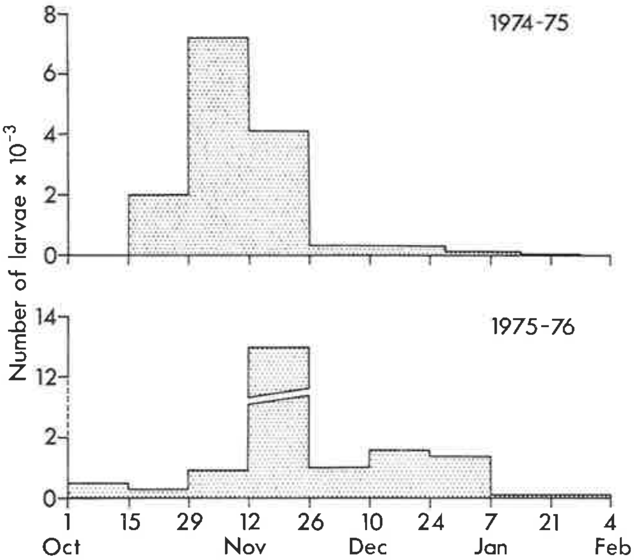
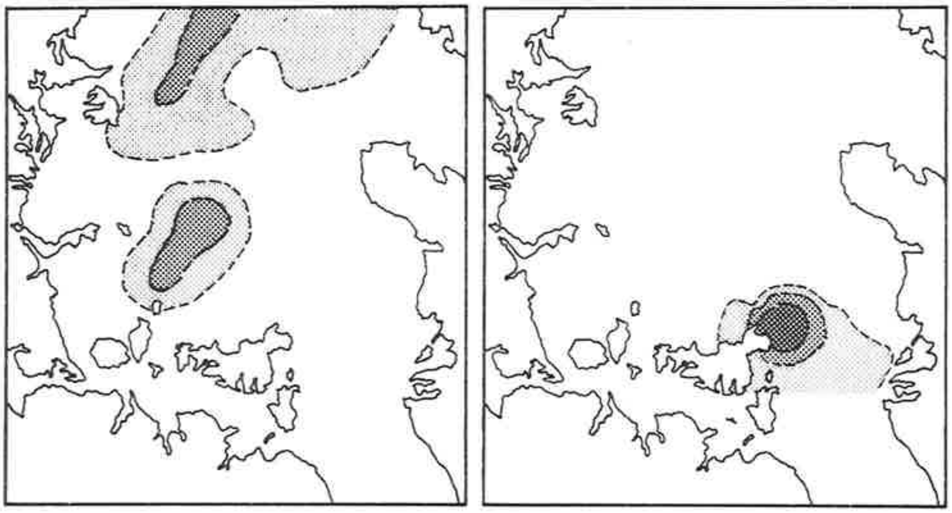


Fig. 8: Numbers of pilchard larvae taken by cruises, 1974–75 and 1975–76.



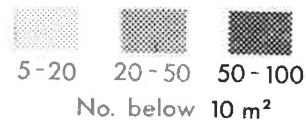


Fig. 9: Cumulative distribution of sprat eggs. Left: 1974–75. Right: 1975–76.

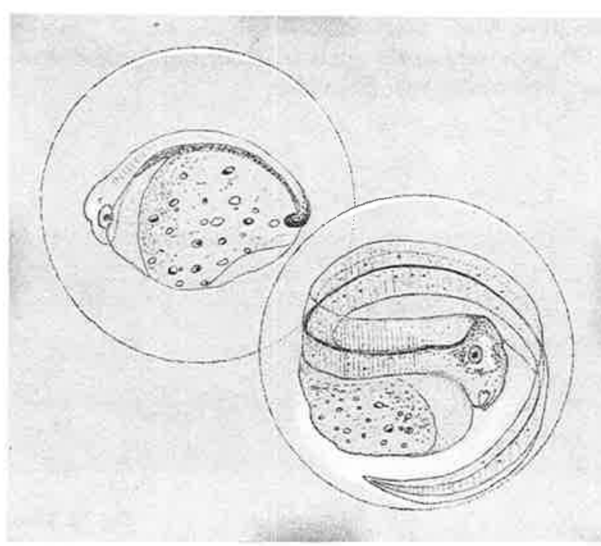


Fig. 10: Moray eel eggs.

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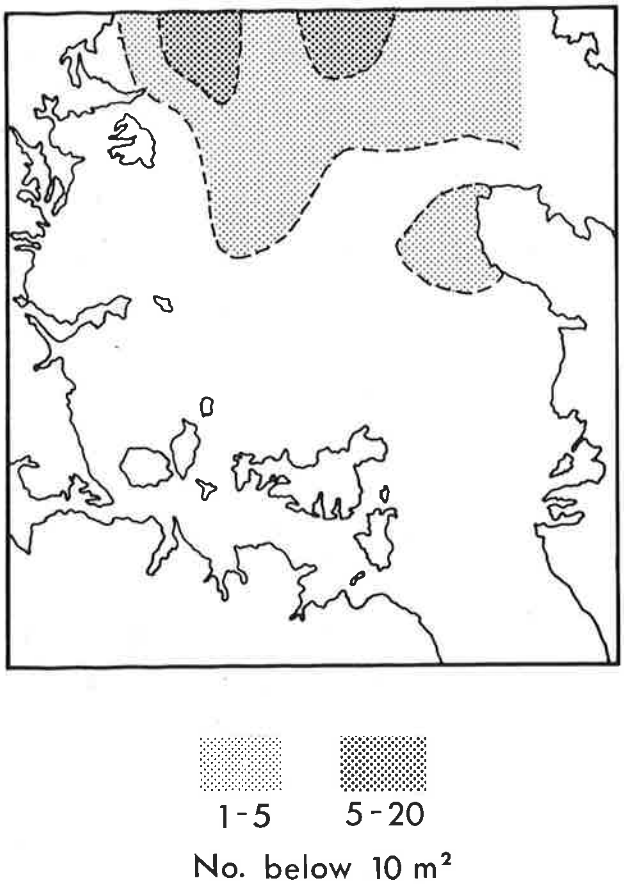


Fig. 11: Cumulative distribution of moray eel eggs, 1974–75.

Family Congridae

Sand eel *Gnathophis incognitus* Castle, 1963 or *G. habenatus* (Richardson, 1848)

Eggs. The egg of *Gnathophis* sp. is described and figured in Castle and Robertson (1974). Five eggs of this type were taken in one sample on 22 January 1975; two were at the early blastodisc stage and three had well-developed embryos.

Family Moridae

Ahuru *Auchenoceros punctatus* (Hutton, 1873)

Eggs. The ahuru egg is described and figured in Robertson (1975). The distribution of ahuru eggs for the 2 years is shown in Fig. 13. The centre of spawning was in the northern part of the Firth of Thames. Figure 14 shows seasonal changes in egg numbers for the 2 years and the mean sea temperatures in the spawning area. Few eggs were observed in 1974, but they were common during October and November 1975, when sea temperatures were lower than in the previous year. These findings are consistent with those of Robertson (1980), who found that in Otago waters ahuru were winter-spring spawners, preferring cool, low-salinity, in-shore waters.

Larvae. The main distinguishing features of the larvae are the large numbers of rays in the dorsal and anal fins, and in older larvae the single hair-like ray in front of the dorsal fin (Fig. 15). Small larvae have no particularly distinctive features and were recognised after building up a developmental series.

Ahuru larvae were common in the study area and were more abundant than the eggs, particularly in the first year. In 1974–75, 6800 were recorded, and in 1975–76, 9700. They were most numerous during October and November (Fig. 16), with a marked peak in November 1975, 2 weeks after the peak in egg numbers. The relatively high numbers of larvae and low numbers of eggs in 1974–75 indicated that spawning either took place mainly outside the study area (to the south) or before sampling began.

The distribution of larvae (Fig. 17) shows distinct and puzzling differences from that of the eggs. In both years few larvae were found in the immediate vicinity of spawning. In 1974–75 larvae were commonest in the eastern gulf, off the Coromandel Peninsula. In 1975–76 they were found both there and more widely spread over the central gulf.

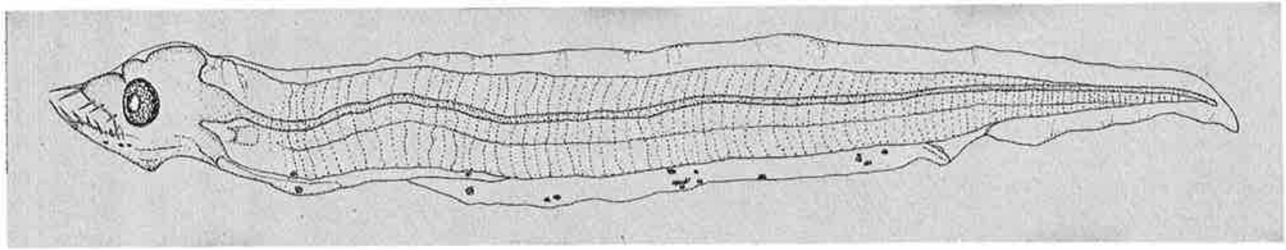


Fig. 12: Moray eel larva (9.6 mm).

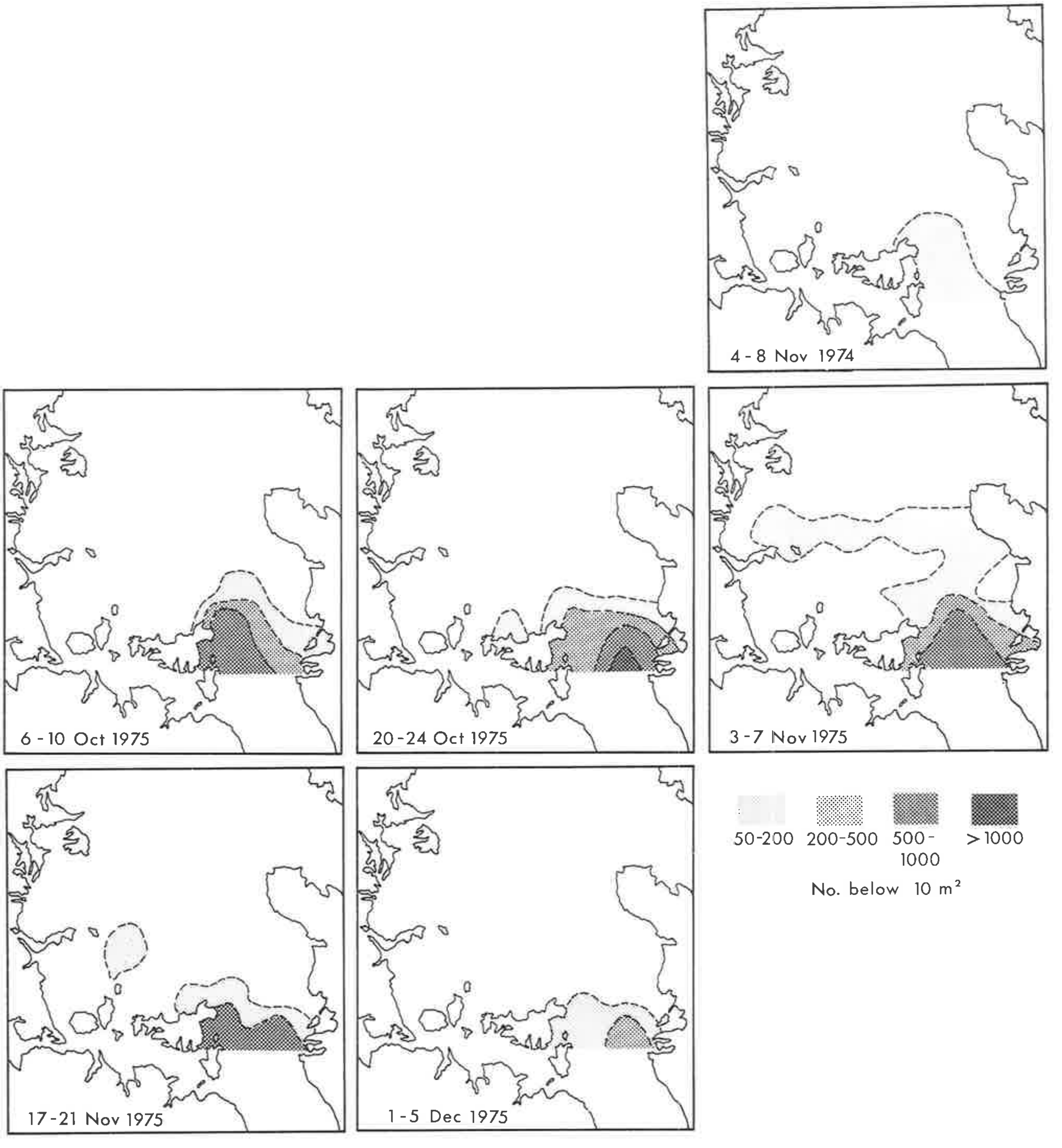


Fig. 13: Distribution of ahuru eggs by cruises, 1974–75 and 1975–76.

A possible explanation for the disjunctive egg and larval distributions is that the larvae were carried by water movements from the spawning area and were not sampled until they reached a size large enough to be retained by the plankton net. The newly hatched larva from the small ahuru egg (0.525–0.600 mm diameter) is unlikely to exceed 1.5 mm total length and the smallest larvae taken were about 4 mm long. However, ahuru juveniles, some up to 45 mm long, were sometimes taken and were the largest ichthyoplankton caught during this survey. Adults seldom exceed 120 mm and are suspected to live off the bottom. Graham (1956) found that ahuru fed principally on a surface-living copepod.

Family Exocoetidae

Garfish *Hyporhamphus ihi* Phillips, 1932

The early development of the garfish is described and figured in Graham (1956). This species has adhesive, demersal eggs.

Larvae. Two larvae (measuring 10.6 and 11.0 mm) were taken in 1975, and one (measuring 11.3 mm) in 1976. In both years they were taken in the northern central gulf in late January. The heavily pigmented garfish larva is distinctive (Fig. 18), with a prominent double row of round pigment spots along its back. The lower jaw projects beyond the upper.

Family Trachichthyidae

Roughy (unidentified)

Larvae. During December and January, larvae (Fig. 19) identified to this family were taken occasionally at the outer stations of the study area.

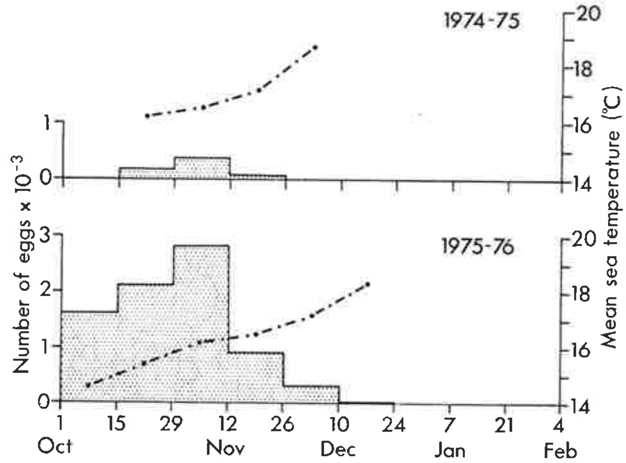


Fig. 14: Numbers of ahuru eggs taken by cruises, 1974–75 and 1975–76. Mean sea temperatures in the spawning area are also shown.

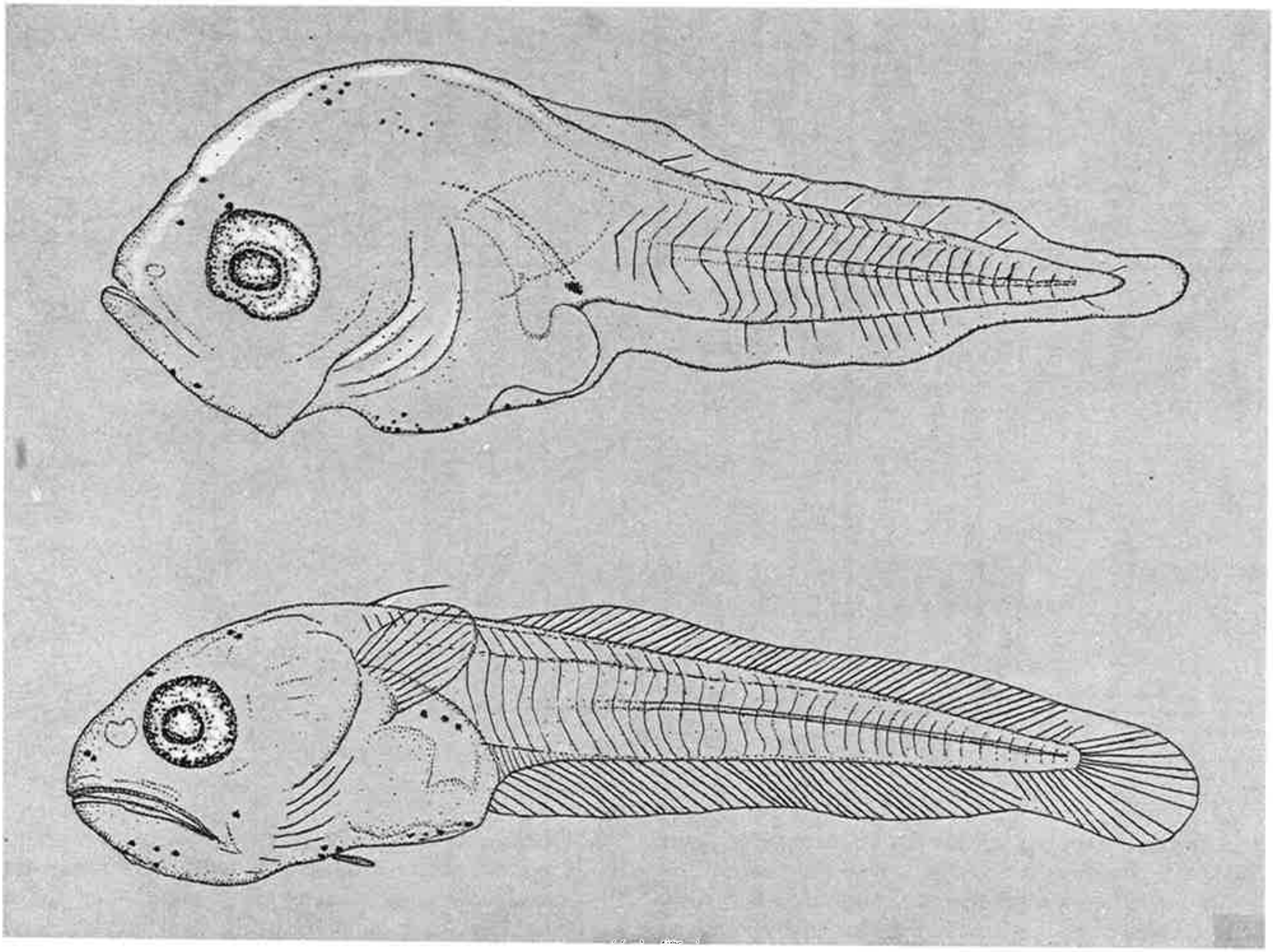


Fig. 15: Ahuru (*Auchenoceros punctatus*) larvae (5.6, 12.8 mm).

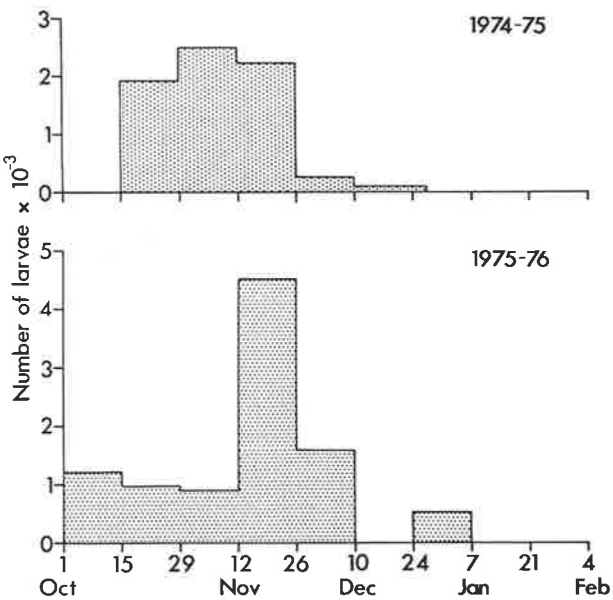


Fig. 16: Numbers of ahuru larvae taken by cruises, 1974–75 and 1975–76.

They may have been larvae of the slender roughy (*Optivus elongatus*, (Günther, 1859)), the most common species of roughy observed by divers along rocky coastlines in northern New Zealand (Doak 1972). Most larvae were small (3.5–4.5 mm long). The largest was 8.3 mm and the skin on the dorsal surface of its head and body was covered with tiny spines.

Family Zeidae

John Dory *Zeus japonicus* (Richardson, 1845)

The eggs of this species have been described (Robertson 1975), but were not taken in this study. A single juvenile 11.9 mm long was taken in the outer gulf on 16 January 1976.

Family Syngnathidae

Small juveniles of the seahorse (*Hippocampus abdominalis* Lesson, 1818) and the long-snouted pipefish (*Stigmatophora longirostris* Hutton, 1872) were occasionally recorded.

Family Triglidae

Red gurnard *Chelidonichthys kumu* (Lesson and Garnot, 1826)

Eggs. The red gurnard egg is described and figured in Mito (1963) and Robertson (1975). Red gurnard eggs were taken on every cruise during both years, but were never abundant. The cumulative egg distribution was remarkably similar in both years (Fig. 20) and showed the main spawning centre to be at the northern edge of the study area or still further to the north. The seasonal variation in egg numbers for 1974–75 indicated a spring spawning peak in October, but in 1975–76 peak egg numbers occurred in December (Fig. 21). However, in both years the sea bottom temperatures in the spawning area were similar at peak spawning (15.6°C in 1974–75 and 15.7°C in 1975–76). Elder (1976) considered that the time of peak spawning was influenced by temperature, through its effect on the maturation rate of the gonads.

Larvae. Early stages of the red gurnard larva are figured in Mito (1963). The cumulative distributions of larvae (Fig. 22) showed a pattern of dispersal

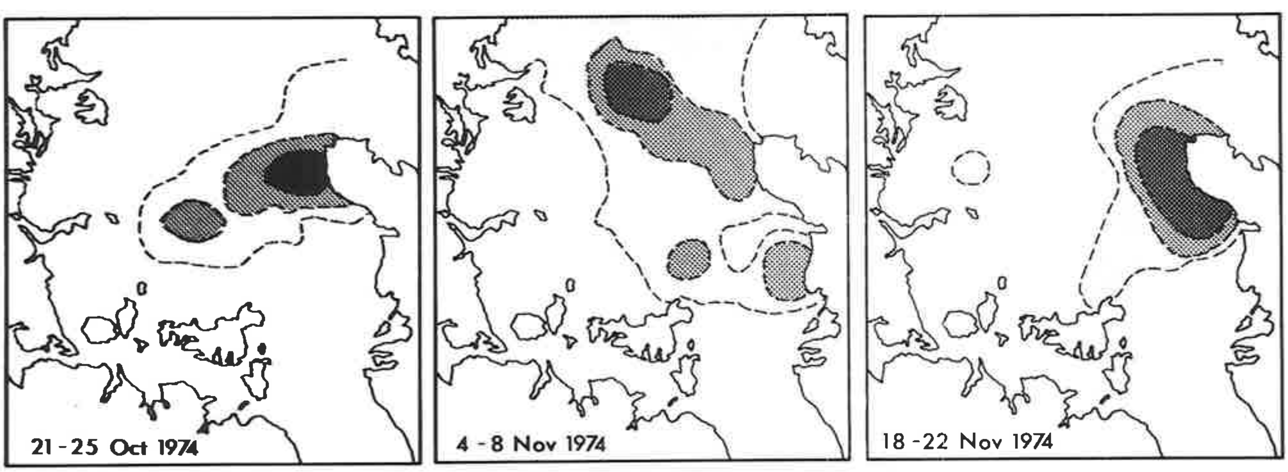


Fig. 17: Distribution of ahuru larvae by cruises, 1974–75 (see key on following page).

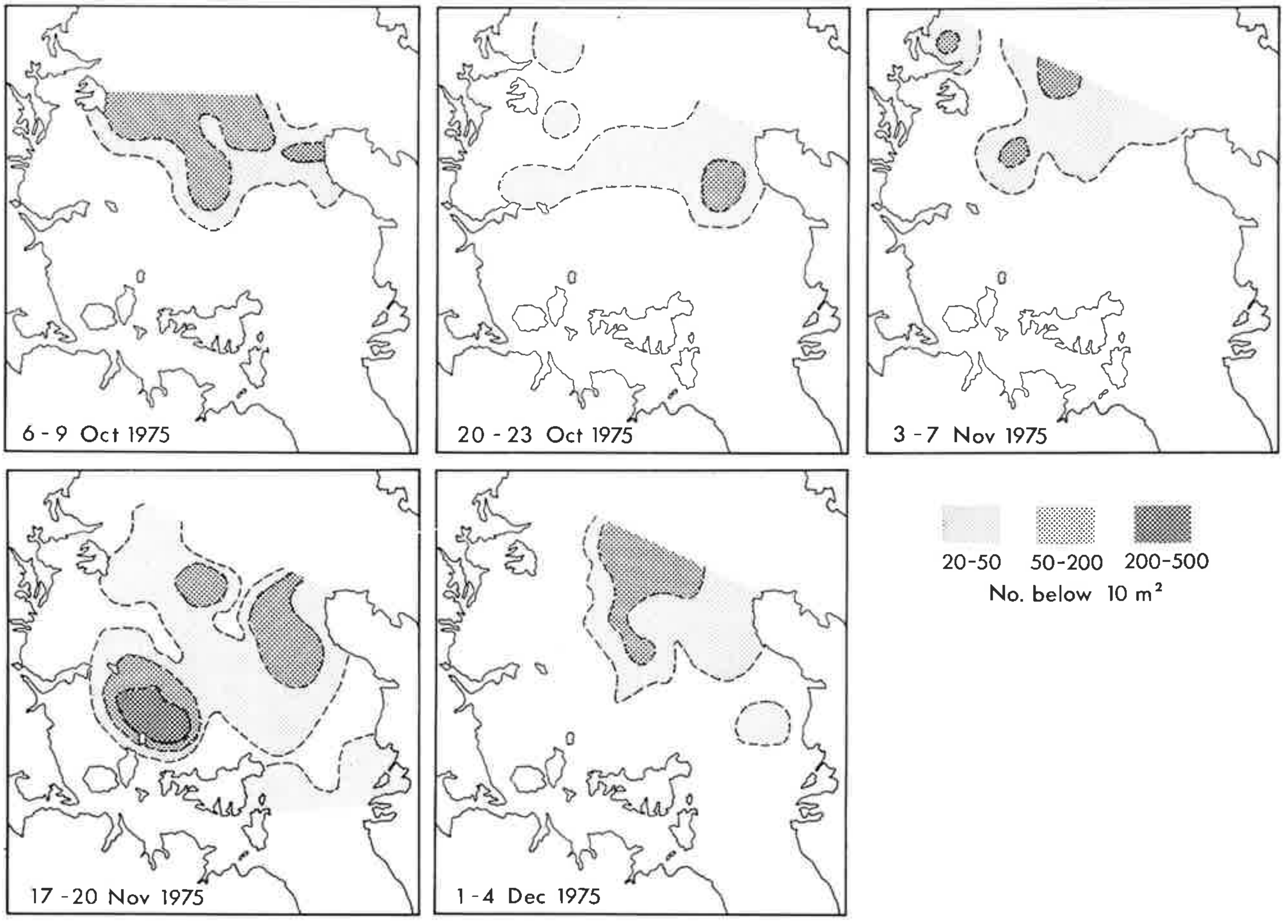


Fig. 17 (continued): Distribution of ahuru larvae by cruises, 1975–76.

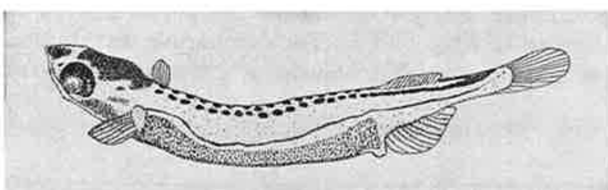
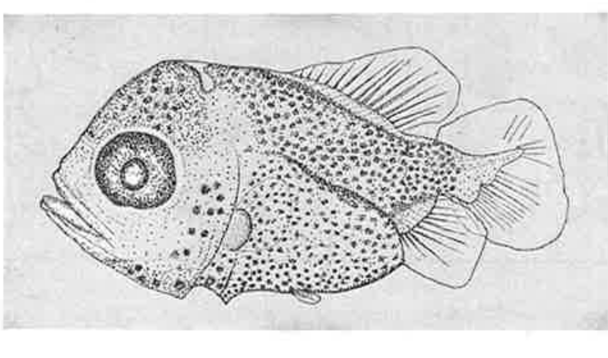


Fig. 18: Garfish (*Hyporhamphus ihi*) larva (11.3 mm).

southwards from the spawning area; this was more marked in 1974–75, perhaps because spawning began earlier that year (see Fig. 21). These findings concur with those of Elder (1976), who postulated that larvae drifted south after a northward, contranatant migration of adult red gurnard from the inner Hauraki Gulf to a spawning ground in the Cradock and Colville Channels.



Family Acanthoclinidae

Rockfish *Acanthoclinus quadridactylus* (Bloch and Schneider, 1801) and *A. trilineatus* (Griffin, 1933)

Jillett (1968) described the early life history of *A. quadridactylus*, a small littoral fish which lays demersal eggs. The adults of both *A. quadridactylus* and *A. trilineatus* are described and figured in Griffin (1933).

Fig. 19: Roughy (Family Trachichthyidae) larva (5.3 mm).

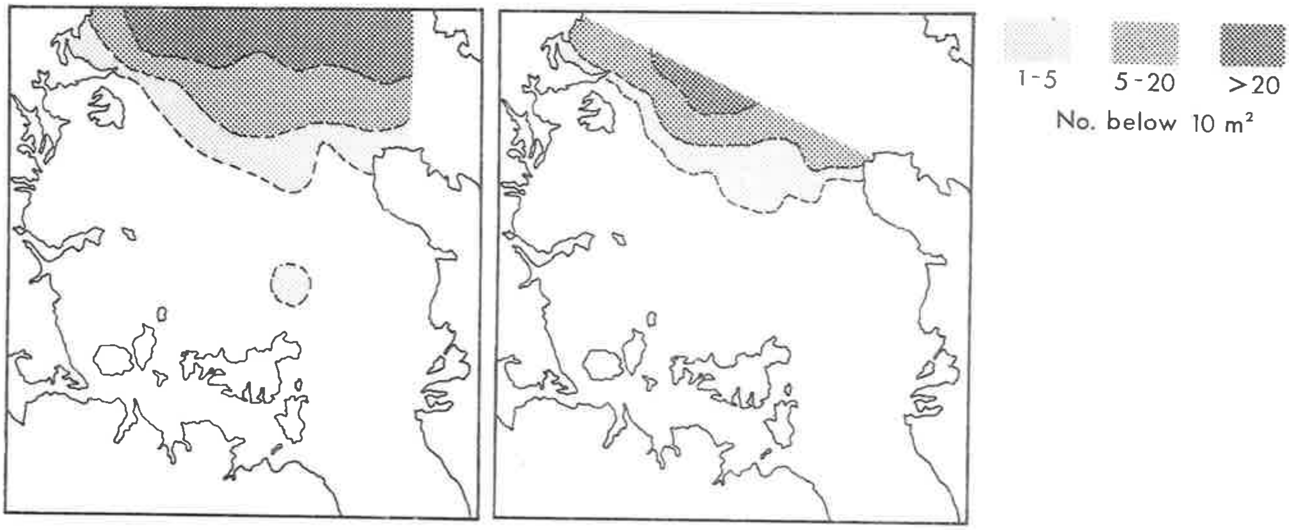


Fig. 20: Cumulative distribution of red gurnard eggs. Left: 1974–75. Right: 1975–76.

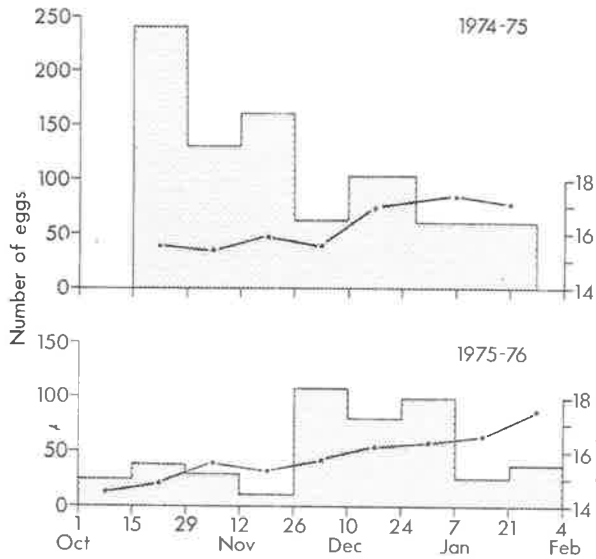


Fig. 21: Numbers of red gurnard eggs taken by cruises, 1974–75 and 1975–76. Mean sea bottom temperatures in the spawning area are also shown.

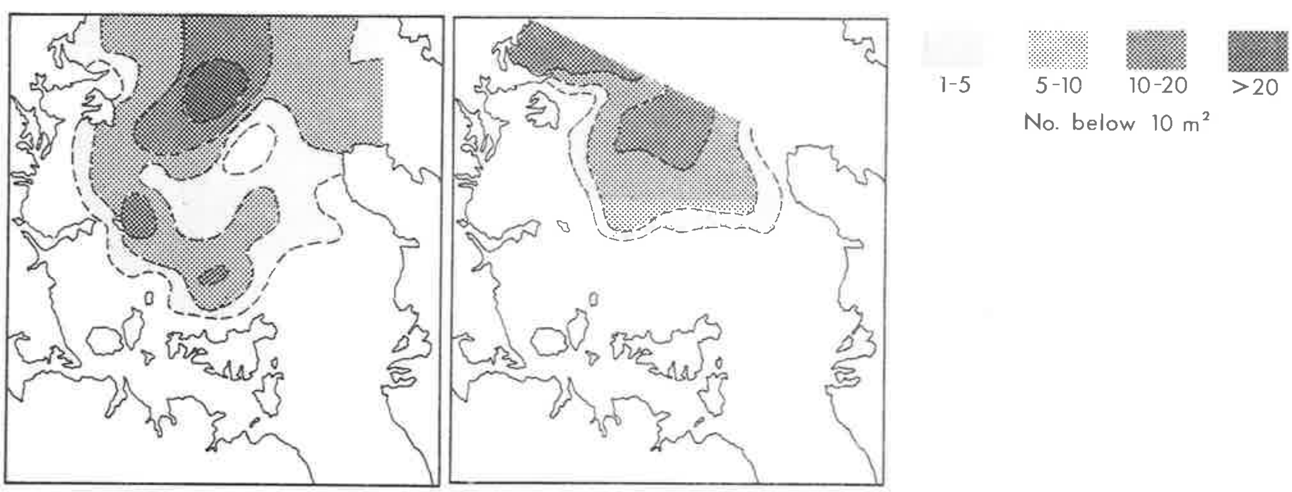


Fig. 22: Cumulative distribution of red gurnard larvae. Left: 1974–75. Right: 1975–76.

Inset 3

Larvae. Small larvae of *A. quadridactylus* up to 5.5 mm long are figured in Jillett (1968). Larvae of the two species were not recorded separately during this study. The illustrated specimen (Fig. 23) is *A. trilineatus*, which has more dorsal and anal fin rays than *A. quadridactylus* and a more slender body. The larvae are heavily pigmented with dark brown spots.

The cumulative distribution for the 2 years (Fig. 24) showed the larvae to be well dispersed, but with the largest numbers usually recorded close to land. Larvae were collected on all cruises in both years, except the last cruise in 1974–75. Their numbers declined steadily as the sea temperature increased. More larvae were collected in 1975–76 than in the previous year, which was warmer. These results are consistent with Jillett's findings that *A. quadridactylus* is a winter spawner, with peak spawning in September and October. (Jillett considered September and October as winter.)

Family Carangidae

There are two species of *Trachurus* (jack mackerel) found in New Zealand waters (Stephenson and Robertson 1977). *Trachurus novaezelandiae* is abundant in in-shore waters in northern New Zealand. *Trachurus declivis* usually lives further off shore and is found throughout New Zealand. The eggs of both species are described in Robertson (1975), but this study and recent findings of Robertson (pers. comm.) have shown these descriptions to be inaccurate.

Jack mackerel *Trachurus novaezelandiae* (Richardson, 1843)

Eggs. The eggs of *T. novaezelandiae* (= *T. mccullochi*) are described in Robertson (1975) as having a diameter of 0.720–0.820 mm, a segmented yolk, and a single oil droplet. During this study eggs conforming to this description were not taken, but an egg slightly larger than this was regularly caught and was very abundant. The likely causes of this size discrepancy

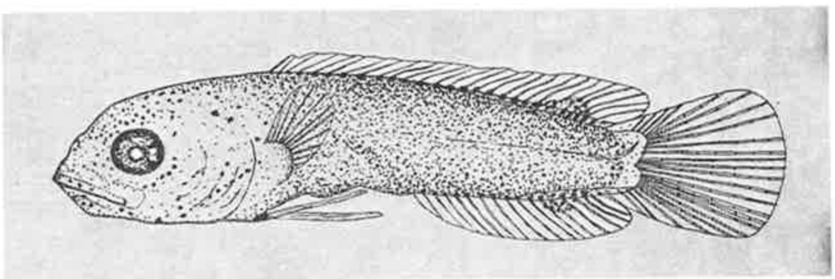


Fig. 23: Rockfish *Acanthoclinus trilineatus* larva (10.0 mm).

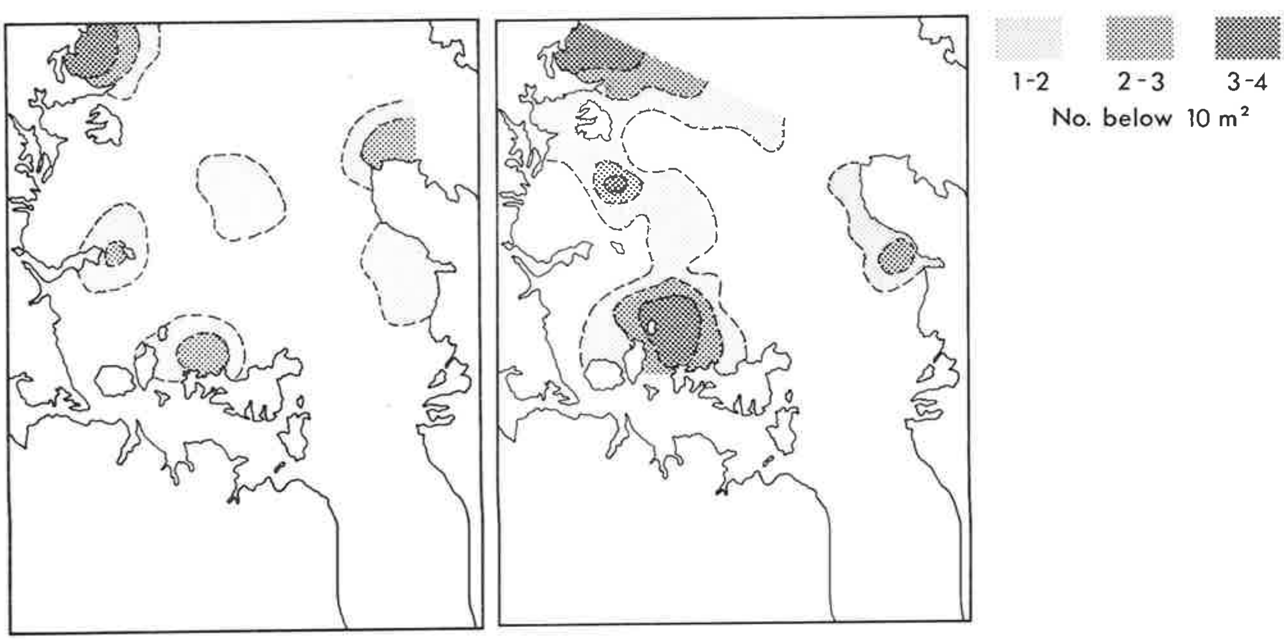


Fig. 24: Cumulative distribution of rockfish larvae. Left: 1974–75. Right: 1975–76.

are that Robertson's measurements were of unfertilised eggs which were probably not fully mature, and that a slight increase in size normally occurs at fertilisation.

The eggs shown in Fig. 25 had a diameter of 0.78–0.88 mm; a narrow perivitelline space; a segmented yolk (segmentation irregular and not always distinct, in the early stages more noticeable just below the blastodisc) (see Fig. 25 top); and a single, yellowish oil droplet, 0.20–0.27 mm in diameter, situated anteriorly in late stage eggs. The embryo was stout bodied with numerous prominent melanophores along the dorsal surface.

These eggs were considered to be those of *T. novaezelandiae* for the following reasons:

1. They had the typical carangid egg features of segmented yolk; single, anterior oil droplet; and relatively undeveloped embryo at hatching.

2. An embryological series was built up and the late stage embryos were indistinguishable from yolk-sac larvae of *T. novaezelandiae.*

3. Measurements of 100 unfertilised eggs from a ripe specimen of *T. novaezelandiae* gave the following results: diameter 0.775–0.865 mm (mean 0.825 mm); oil droplet 0.191–0.250 mm diameter (mean 0.226 mm) (Robertson pers. comm.).

4. The eggs are not those of trevally (*Caranx georgianus* (Cuvier, 1833)), another carangid known to occur in the Hauraki Gulf. Although of a similar size, the trevally egg has an unpigmented embryo (James 1976).

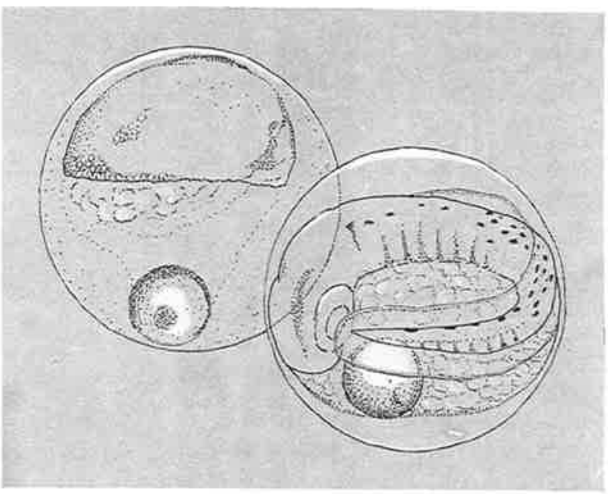


Fig. 25: Jack mackerel *Trachurus novaezelandiae* eggs.

The egg distribution (Fig. 26) showed the Hauraki Gulf to be an important spawning area for *T. novaezelandiae.* Most spawning occurred in the western side of the gulf, a few miles off shore, and in depths greater than 30 m. Spawning extended from Rakino Island in the south to Cape Rodney in the north, with the densest patches of eggs east of Tiritiri Matangi and Kawau Islands, the areas in which snapper eggs were also most abundant (Crossland 1980). In 1974–75 there was another important spawning area off the south-west shore of Great Barrier Island; this part of the gulf was not sampled in 1975–76.

The seasonal changes in egg production are shown in Fig. 27. The figures have been adjusted for temperature effect (as described for anchovy eggs) and the numbers in the 1974–75 season are for an area equivalent to that sampled in 1975–76. The observed egg production was similar in both years. Peak spawning occurred in mid November in 1974, when the mean sea temperature was 17.3°C, and in mid December in 1975 at a mean sea temperature of 17.9°C.

Larvae. The larvae of *T. novaezelandiae* (Fig. 28) are similar to those of *T. symmetricus* (Ahlstrom and Ball 1954) from the north-eastern Pacific. They show the distinctive carangid feature of three rows of melanophores on each side, one each along the dorsal and ventral margins of the body and one along the lateral line. They can readily be distinguished from the larvae of trevally because the latter are more darkly pigmented and have a deeper body (James 1976).

The distribution of larvae (Fig. 29) was similar for both years. Larvae were found close to the eggs for the corresponding period, but were displaced a few miles to the north-east, further into the central gulf. Larval numbers (Fig. 30) showed a distinct peak in November of each year. In 1974 this coincided with the peak in egg numbers, but in 1975 it occurred a month before the egg peak. This could be the result of a large spawning inside the study area between sampling periods, or it could have resulted from a spawning to the north of the study area, with the larvae carried south by currents (compare with pilchard and gurnard).

Jack mackerel *Trachurus declivis* (Jenyns, 1841)

Eggs. Robertson's (1975) description gives the egg diameter as 1.1–1.3 mm. This was based on a poorly preserved sample and is inaccurate. A more recent sample of 100 artificially fertilised eggs had a diameter

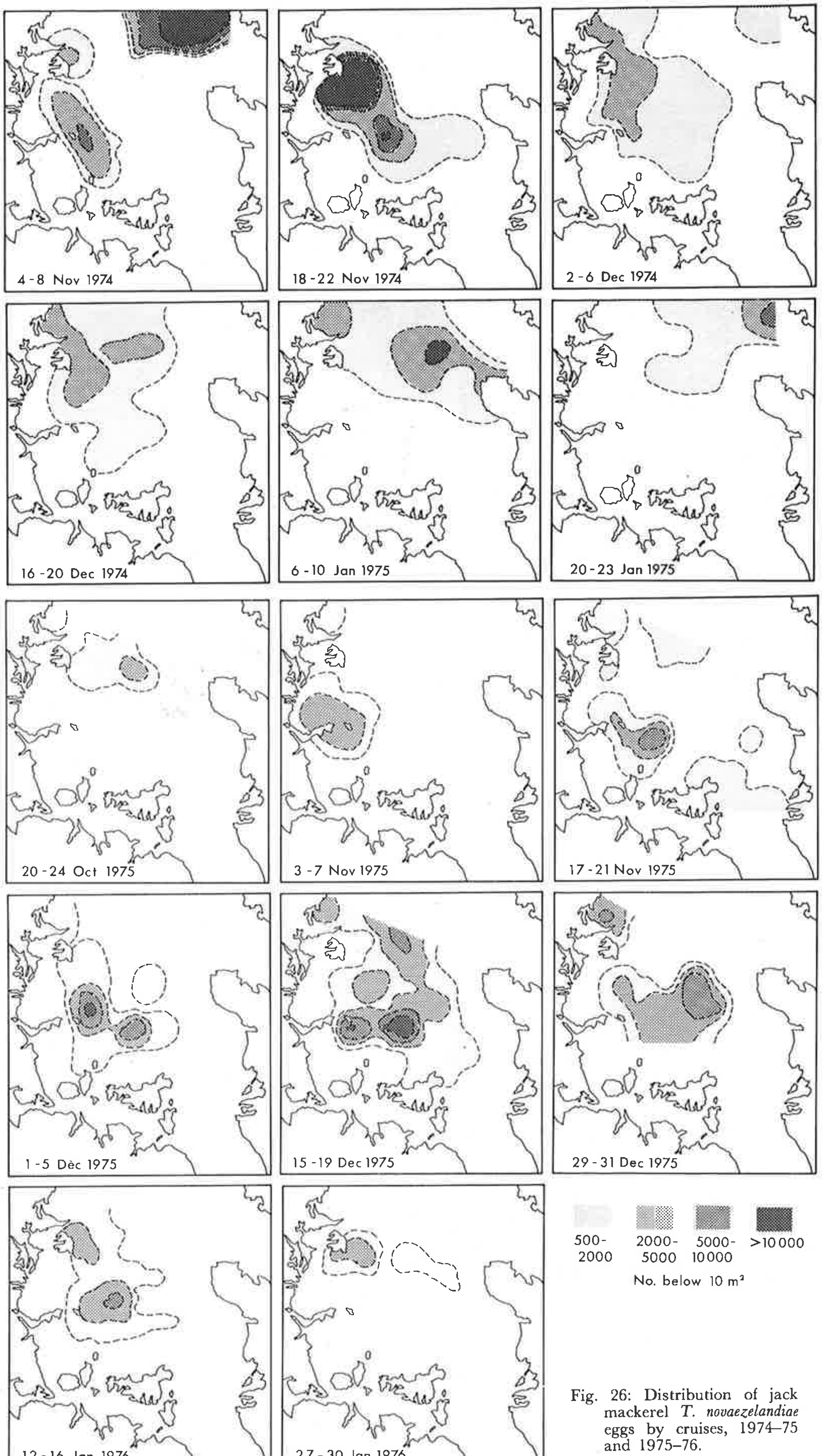


Fig. 26: Distribution of jack mackerel *T. novaezelandiae* eggs by cruises, 1974–75 and 1975–76.

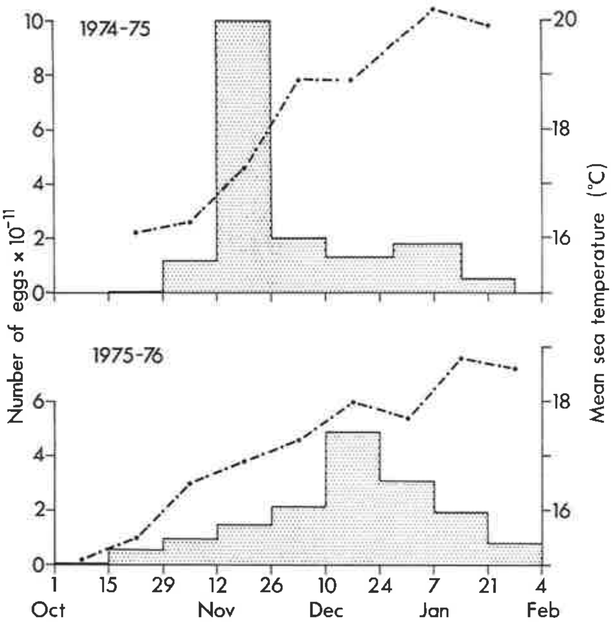


Fig. 27: Number of jack mackerel *T. novaezelandiae* eggs within the study area at the time of sampling for each cruise, 1974–75 and 1975–76. Mean sea temperatures for each cruise are also shown.

range of 0.970–1.030 mm (mean 0.998 mm) and a segmented yolk with an oil droplet of 0.238–0.302 mm (mean 0.266 mm) diameter (Robertson pers. comm.). Eggs conforming to this description were occasionally recorded in the Hauraki Gulf. They ranged in size from 0.95 to 1.02 mm diameter and had an oil droplet of 0.23–0.29 mm diameter. The late stage embryo was more slender and much more lightly pigmented than that of *T. novaezelandiae* (Fig. 31). Cumulative egg distributions for the 2 years are shown in Fig. 32.

Larvae. The larvae of *T. declivis* are probably so similar to those of *T. novaezelandiae* that separation of the two species may only be possible by biochemical means. Stephenson and Robertson (1977) could not distinguish juveniles of the two species if they were shorter than 35 mm standard length. Because the eggs of *T. declivis* were only rarely recorded, and nearly all adult jack mackerel observed in the Hauraki Gulf are *T. novaezelandiae*, all *Trachurus* larvae were assumed to be *T. novaezelandiae.*

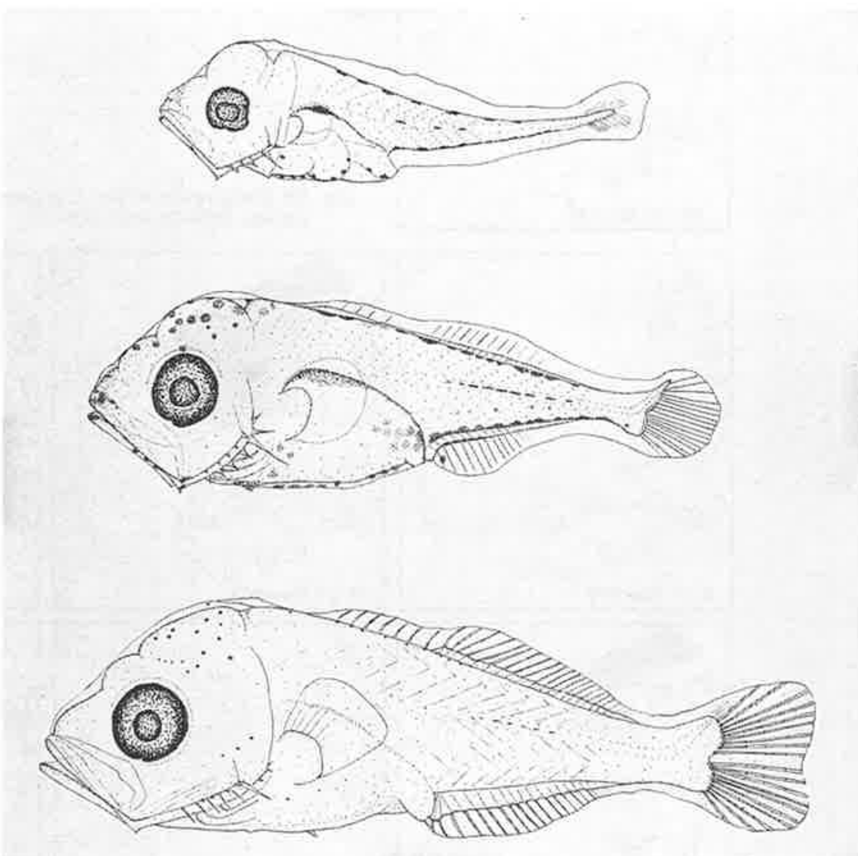


Fig. 28: Jack mackerel *Trachurus novaezelandiae* larvae (4.4, 7.6, 8.9 mm).

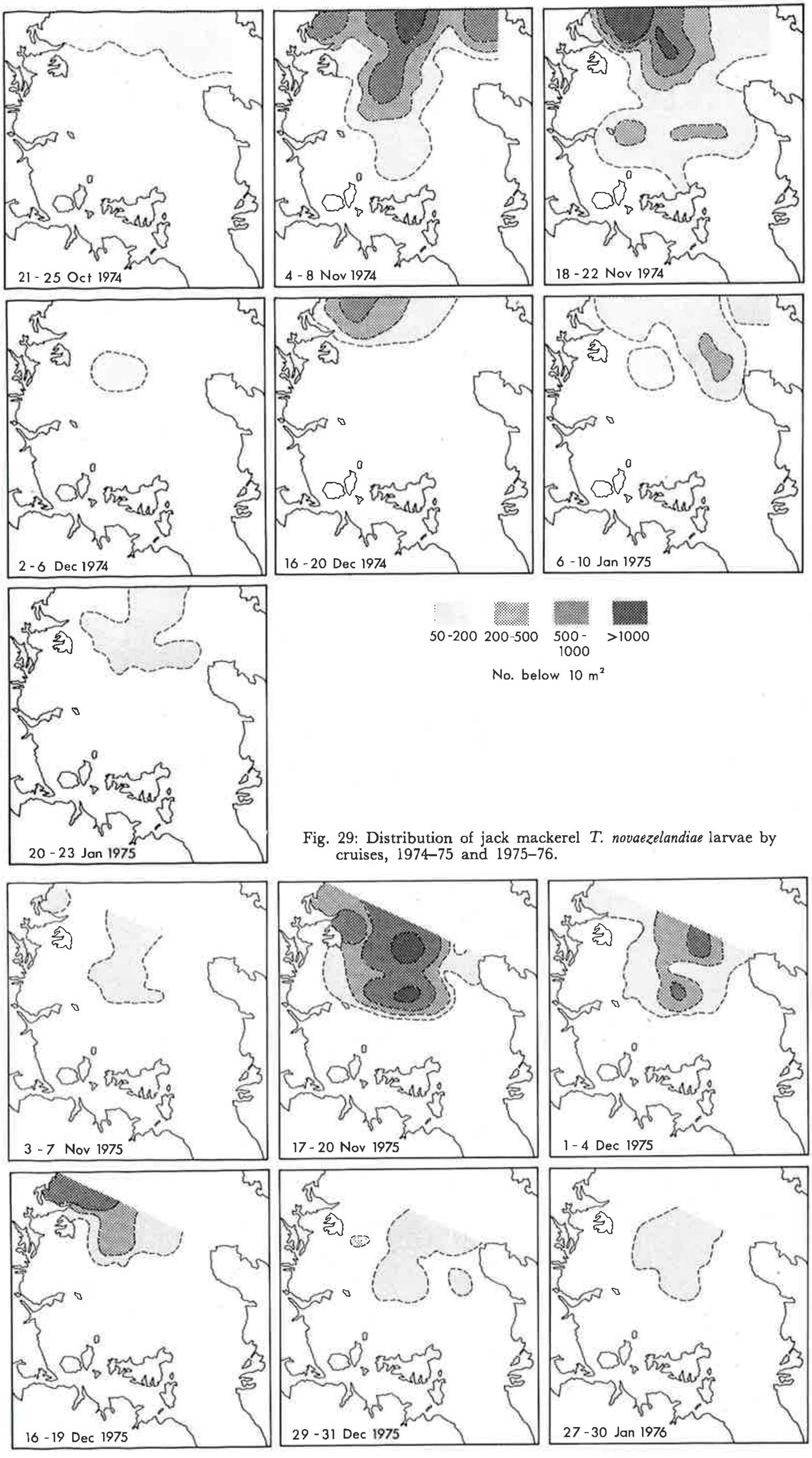


Fig. 29: Distribution of jack mackerel *T. novaezelandiae* larvae by cruises, 1974–75 and 1975–76.

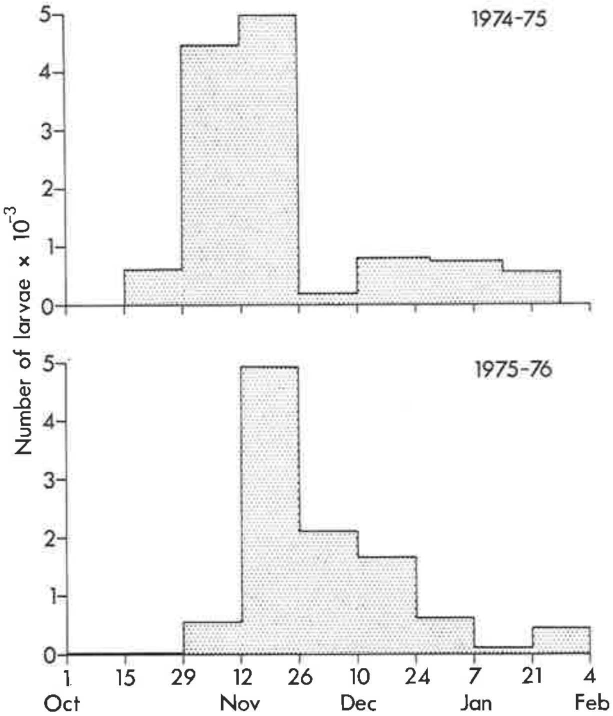


Fig. 30: Numbers of jack mackerel *T. novaezelandiae* larvae taken by cruises, 1974–75 and 1975–76.

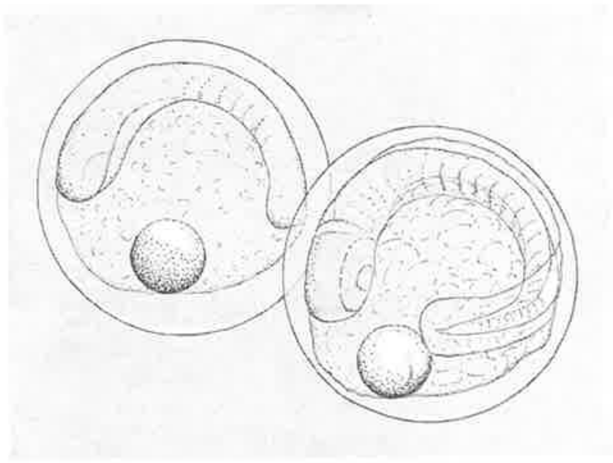


Fig. 31: Eggs of jack mackerel *Trachurus declivis.*

Family Sparidae

Snapper *Chrysophrys auratus* (Forster, 1801)

Eggs. The snapper egg is described and figured in Cassie (1956b) and Crossland (1980). The distribution and abundance of snapper eggs in the Hauraki Gulf have been described previously (Crossland 1980). They were the most abundant of all egg types.

Larvae. The early stage larva up to a length of 3.2 mm is described and figured in Cassie (1956b). The patches of yellow pigment he observed in living specimens were not apparent in preserved samples, and the absence of distinctive features in small snapper larvae made initial identification difficult. Gradually a series was built up and it showed that the most useful identifying character, before the development of the fin ray pattern, was the presence of two pigment spots on the ventral surface of the gut (Fig. 33 top). These larvae were confirmed to be snapper by electrophoretic analysis of their enzyme patterns and comparison with those of the adult (Smith and Crossland 1977). Larvae large enough to be identified by their fin ray count (that is, larvae more than 10 mm long) were rarely taken.

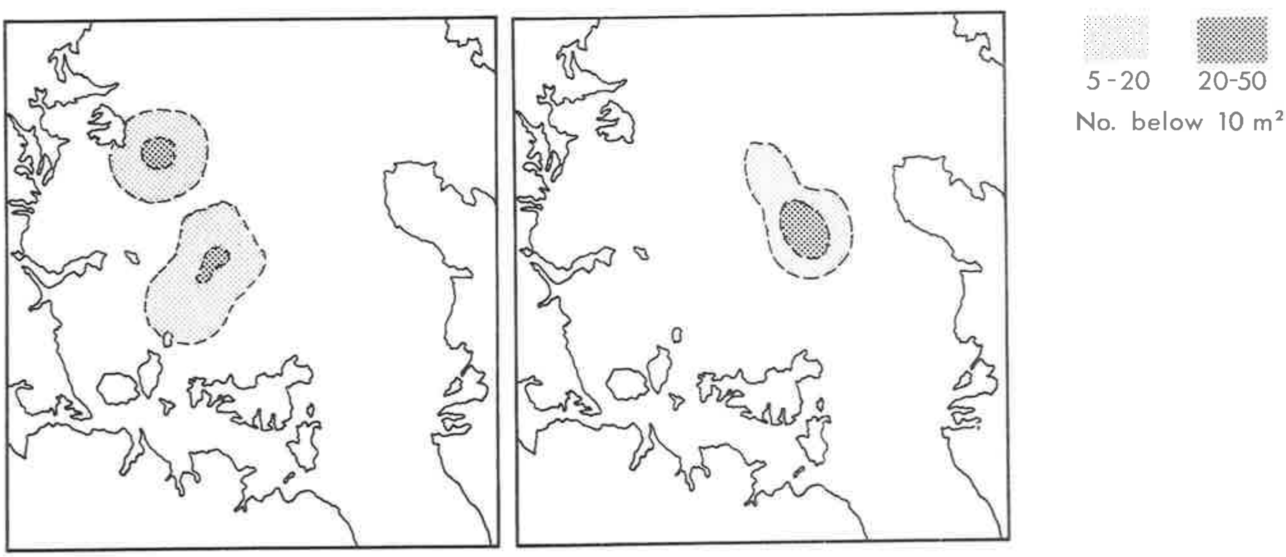


Fig. 32: Cumulative distribution of jack mackerel *T. declivis* eggs. Left: 1974–75. Right: 1975–76.

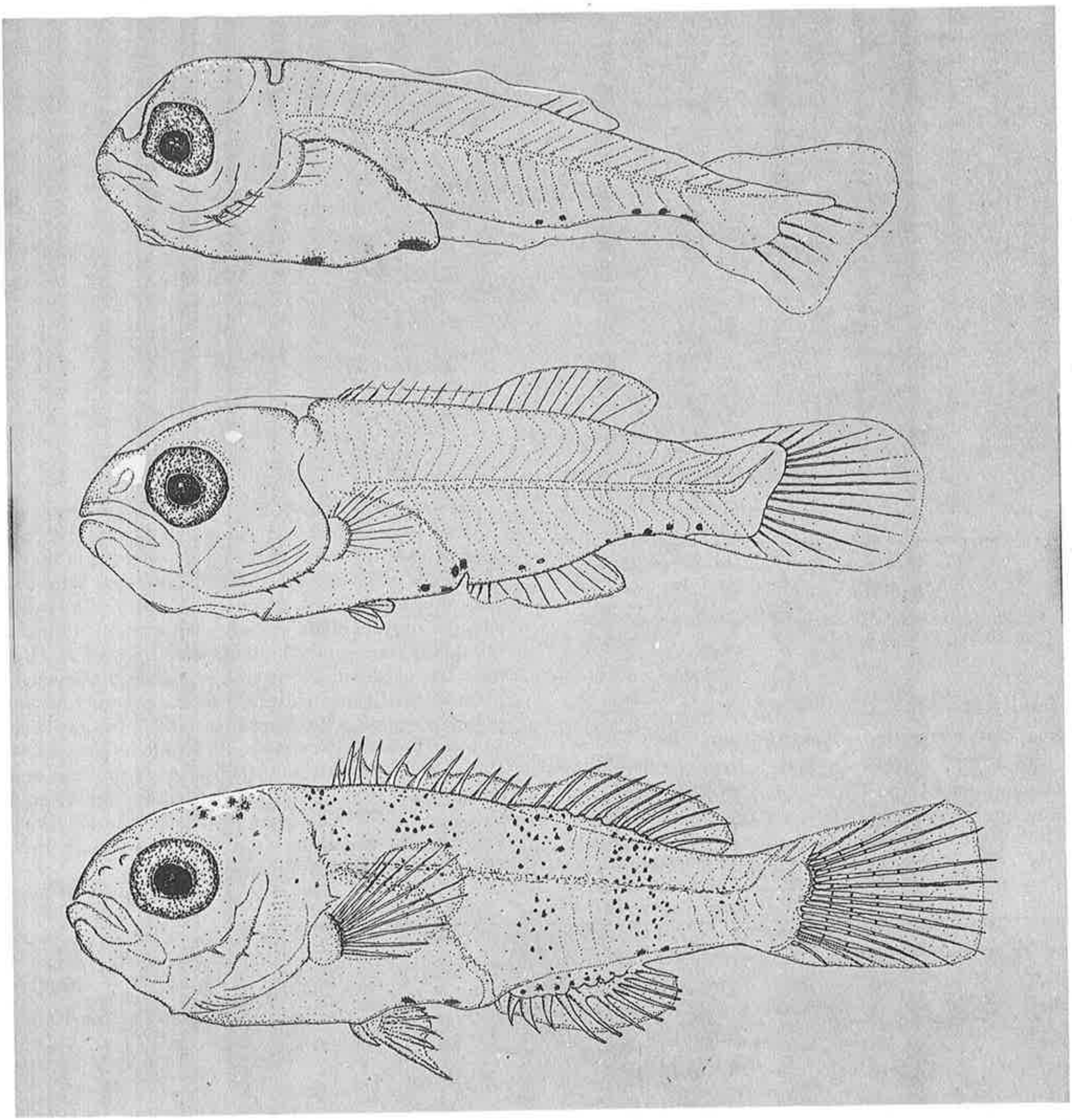


Fig. 33: Snapper (*Chrysophrys auratus*) larvae (5.6, 9.7, 13.5 mm).

The distribution of snapper larvae was patchy in 1974–75 (Fig. 34), and they were not abundant (Fig. 35). In 1975–76 they were much more common, and more evenly distributed, mainly over the central gulf (Fig. 34). Consideration of these facts alone would lead to the conclusion that spawning was much heavier in 1975–76 than 1974–75, yet the opposite was true (Crossland 1980). A study of egg mortality in the 2 years indicated that it was lower in 1975–76 than in the year before and that about the same number of eggs survived to hatch in each year.

How can the five times greater number of larvae in 1975–76 be explained? The relative scarcity of snapper larvae (even in 1975–76) compared with the larvae of other species whose eggs were much less

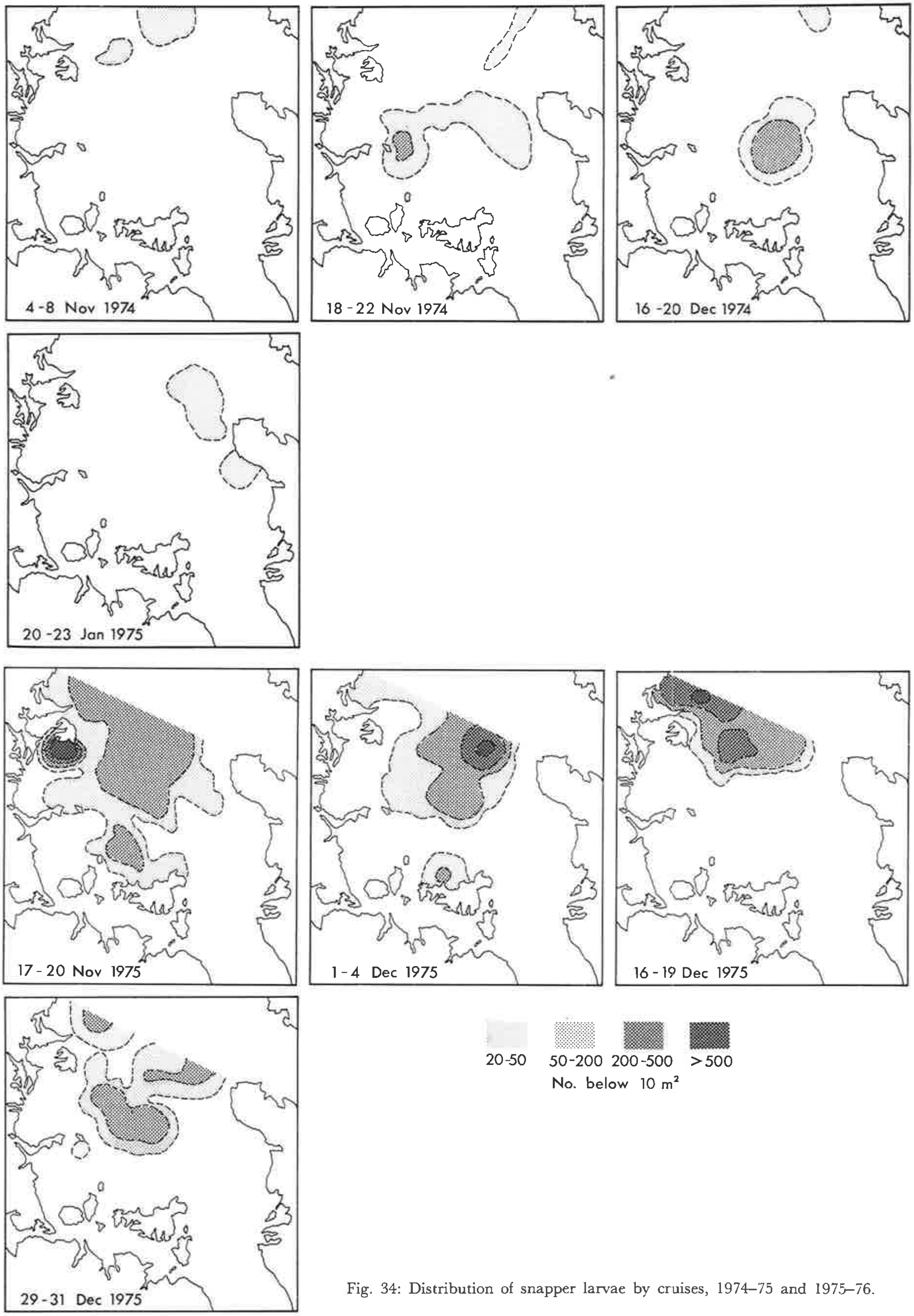


Fig. 34: Distribution of snapper larvae by cruises, 1974–75 and 1975–76.

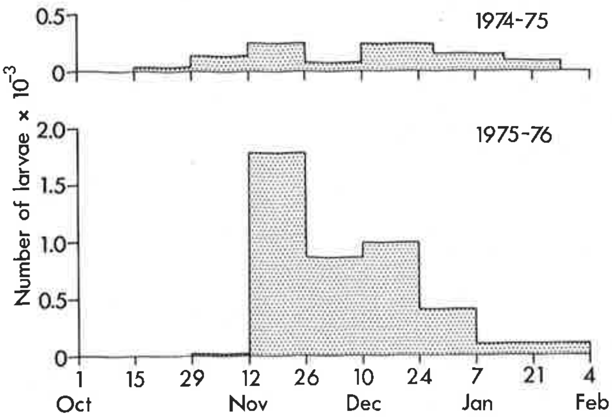


Fig. 35: Numbers of snapper larvae taken by cruises, 1974–75 and 1975–76.

abundant (such as jack mackerel) indicates that the snapper larva has a short pelagic phase. Cassie (1956b) observed that newly hatched snapper larvae preferred the bottom of their container. If the demersal habit is quickly adopted, the larvae collected in the plankton may be mainly those displaced by currents or tidal movements. Thus the chances of sampling them will depend not only on their actual abundance, but also on the effects of the prevailing weather or the state of the tide. One sample in November 1975 taken off the south shore of Kawau Island, where tidal movements are more pronounced than in open water, contained more larvae than the total for the whole of the previous year. This is also the only locality in which Cassie (1956b) recorded snapper larvae in any numbers.

Family Mugilidae

Yellow-eyed mullet *Aldrichetta forsteri* (Valenciennes, 1836)

Eggs. The egg of the yellow-eyed mullet is described in Cassie (1956b). Eggs of this species were taken in the inner gulf throughout the study period, but never in large numbers. They ranged in size from 0.84 to 0.93 mm diameter. The number of oil droplets varied from 3 to 13. Late stage eggs were never recorded; most eggs were at the stage shown in Fig. 36. The cumulative egg distributions for the 2 years (Fig. 37) showed a spawning centre east of Tiritiri Matangi Island. Eggs were more abundant in 1974–75 than in the following year.

Larvae. Larvae of this species are very dark, because of many small melanophores over the whole of the body and head (Fig. 38). In older larvae and small juveniles the pigmentation merges to form a uniform, dark grey background.

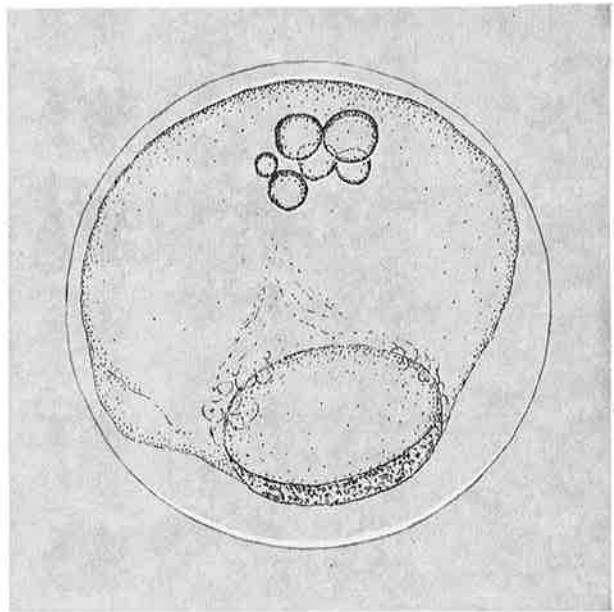


Fig. 36: Yellow-eyed mullet (*Aldrichetta forsteri*) egg.

Larvae, and juveniles up to 33 mm long, were recorded throughout the study area, but were taken only occasionally. The occurrence of juveniles during the early part of the study period indicated that spawning also occurred during late winter and that the yellow-eyed mullet has an extended breeding season.

Grey mullet *Mugil cephalus* Linnaeus, 1758

A single juvenile 11.5 mm long was recorded in mid January 1976. It was very similar to juvenile yellow-eyed mullet, but could be distinguished by its having only 8 anal soft rays (compared with 12 in the yellow-eyed mullet); both species have 3 spinous rays.

Family Labridae

Spotty *Pseudolabrus celidotus* (Forster, 1801)

Eggs of this common littoral fish, which are described in Robertson (1975), were not recorded during this study.

Larvae. Larvae (Fig. 39) were recorded in small numbers between October and the beginning of December and were three times as abundant in 1975–76 as in the previous year. This species may be a winter spawner in northern New Zealand.

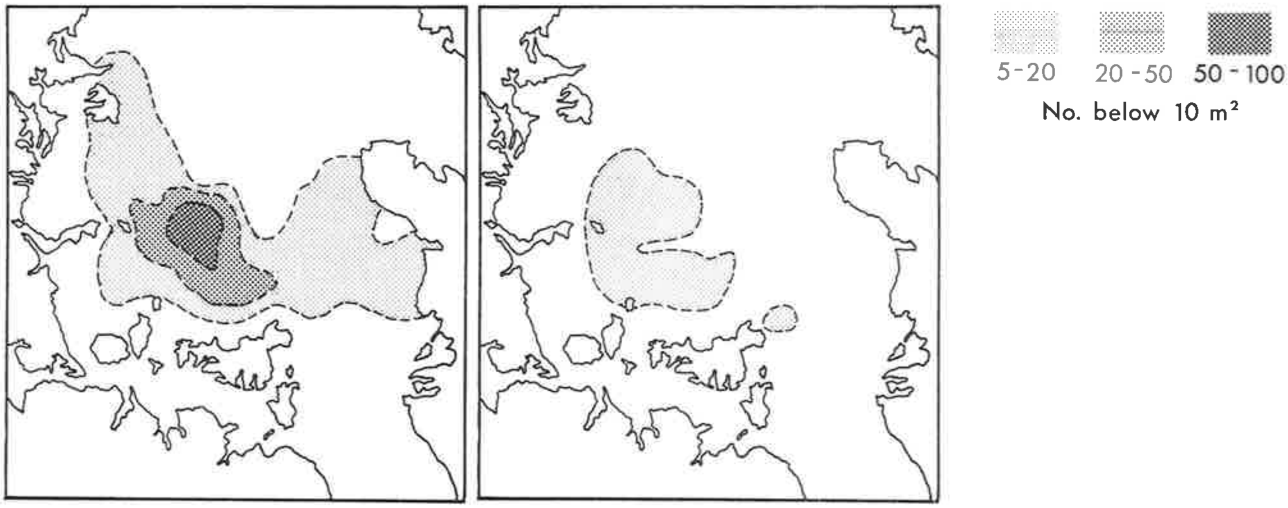


Fig. 37: Cumulative distribution of yellow-eyed mullet eggs. Left: 1974–75. Right: 1975–76.

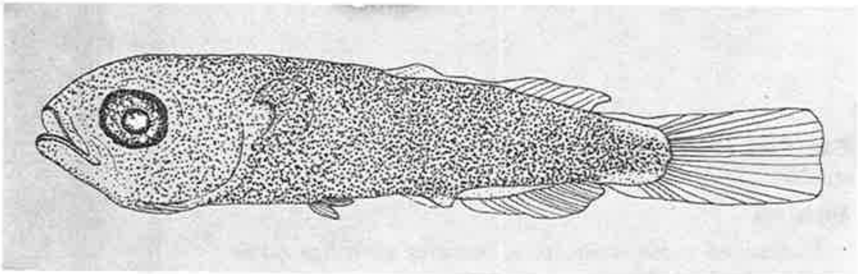


Fig. 38: Yellow-eyed mullet (*Aldrichetta forsteri*) larva (10.5 mm).

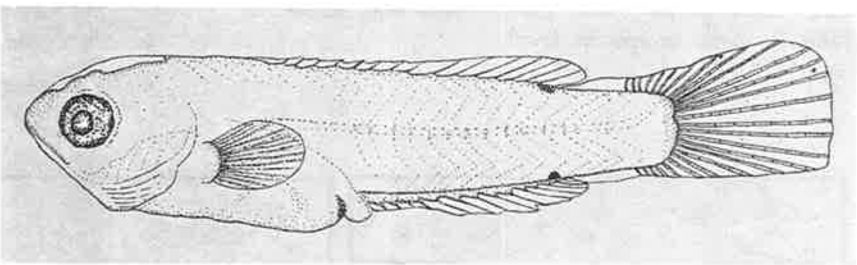


Fig. 39: Spotty (*Pseudolabrus celidotus*) larva (13.2 mm).

Family Uranoscopidae

Spotted stargazer *Genyagnus monopterygius* (Bloch and Schneider, 1801)

Eggs. The spotted stargazer egg is described in Robertson (1975) (diameter 1.800–2.000 mm; non-segmented yolk; three to nine oil droplets). Eggs with a size range of 1.79–1.96 mm and multiple oil droplets were recorded in both years (Fig. 40 top). During sorting a developmental series of these eggs was built up and it showed that as the egg matured the oil droplets coalesced, so that by the middle stages (Fig. 40 centre) there were only two or three larger droplets, and in the late stages only a single, posteriorly placed droplet remained (Fig. 40 bottom). The late stage embryo was spotted with numerous melanophores; there were also some on the surface of the yolk. The dorsal median fin fold was strongly developed and began at the front of the head.

Spotted stargazer eggs were recorded consistently during October and November of each year, but in only small numbers; from December onwards they were rare. Their distribution (Fig. 41) was patchy and widespread, consistent with the occurrence of this species.

Larvae. These were identified by building up a developmental series (Fig. 42). The smallest larva (top) was consistent with the most advanced embryo (Fig. 40 bottom). The adult fish has a small barbel on the chin, and this was observed in the largest larva taken (Fig. 42 bottom), which also showed the characteristic forward placement of the pelvic fins. Although no specimen was developed far enough to allow comparison of fin ray counts, biochemical tests confirmed the identification. Electrophoretic tissue analysis by my colleague P. J. Smith on one of these larvae and on adult spotted stargazer detected a glucosephosphate isomerase (GPI) locus of similar mobility in both. These loci are good species markers because of electrophoretic variability of phenotypes (Avise and Kitto 1973, Dando 1974).

The cumulative distribution of larvae is shown in Fig. 43. They were less scattered than the eggs, commonest in the central gulf during both years, and taken at all times during the study period.

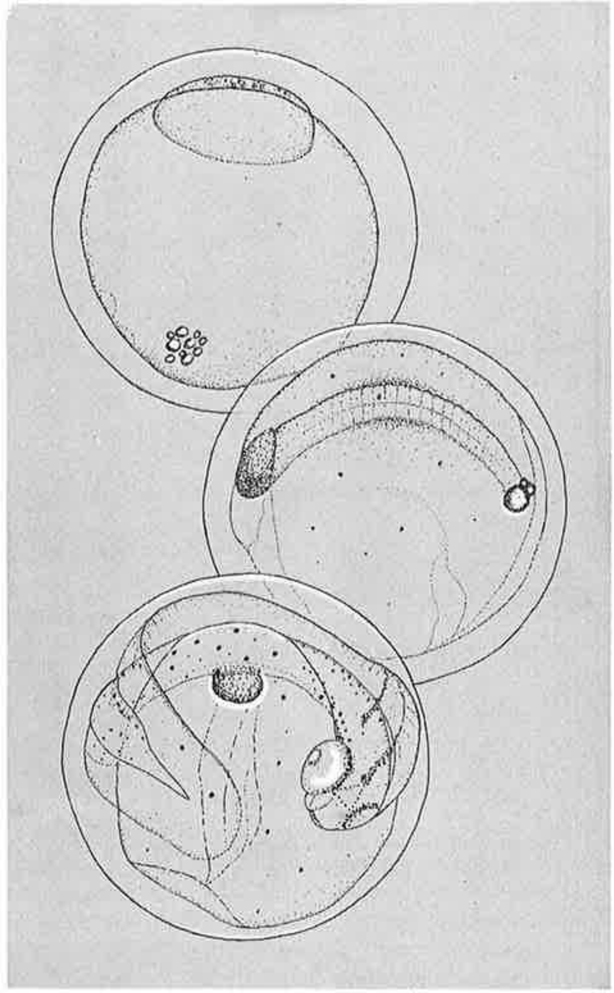


Fig. 40: Spotted stargazer (*Genyagnus monopterygius*) eggs.

Families Blenniidae, Clinidae, and Tripterygiidae

Blennies

Larvae of these ubiquitous families of fishes (the adults of which lay demersal eggs) were a common component of the ichthyoplankton. Most were small (less than 8 mm), and no attempt was made to identify them to species level.

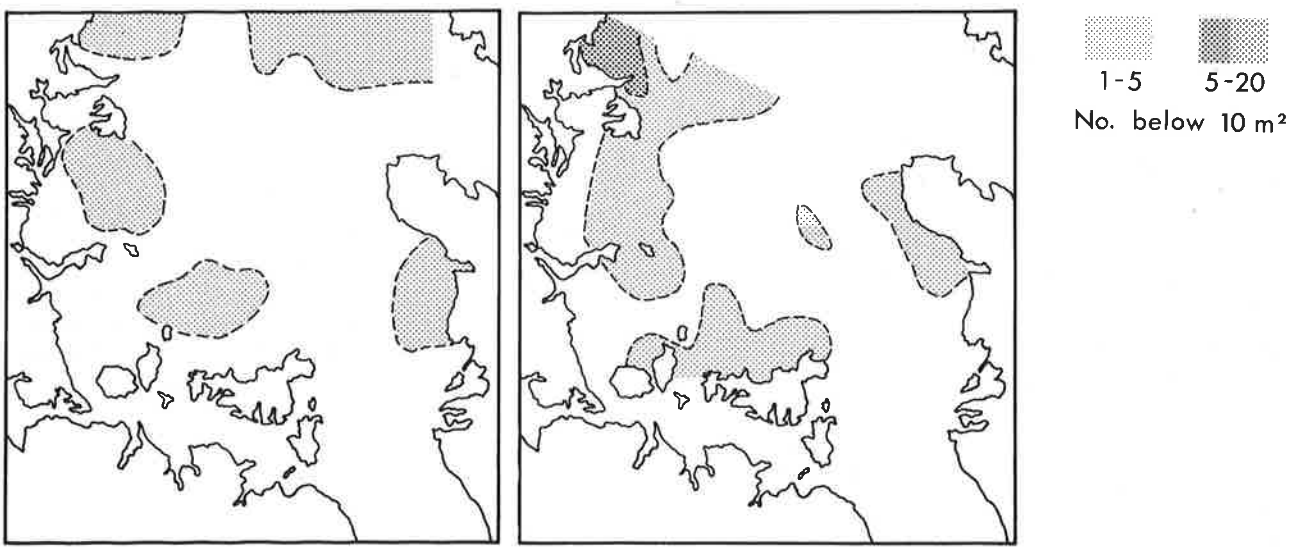


Fig. 41: Cumulative distribution of spotted stargazer eggs. Left: 1974–75. Right: 1975–76.

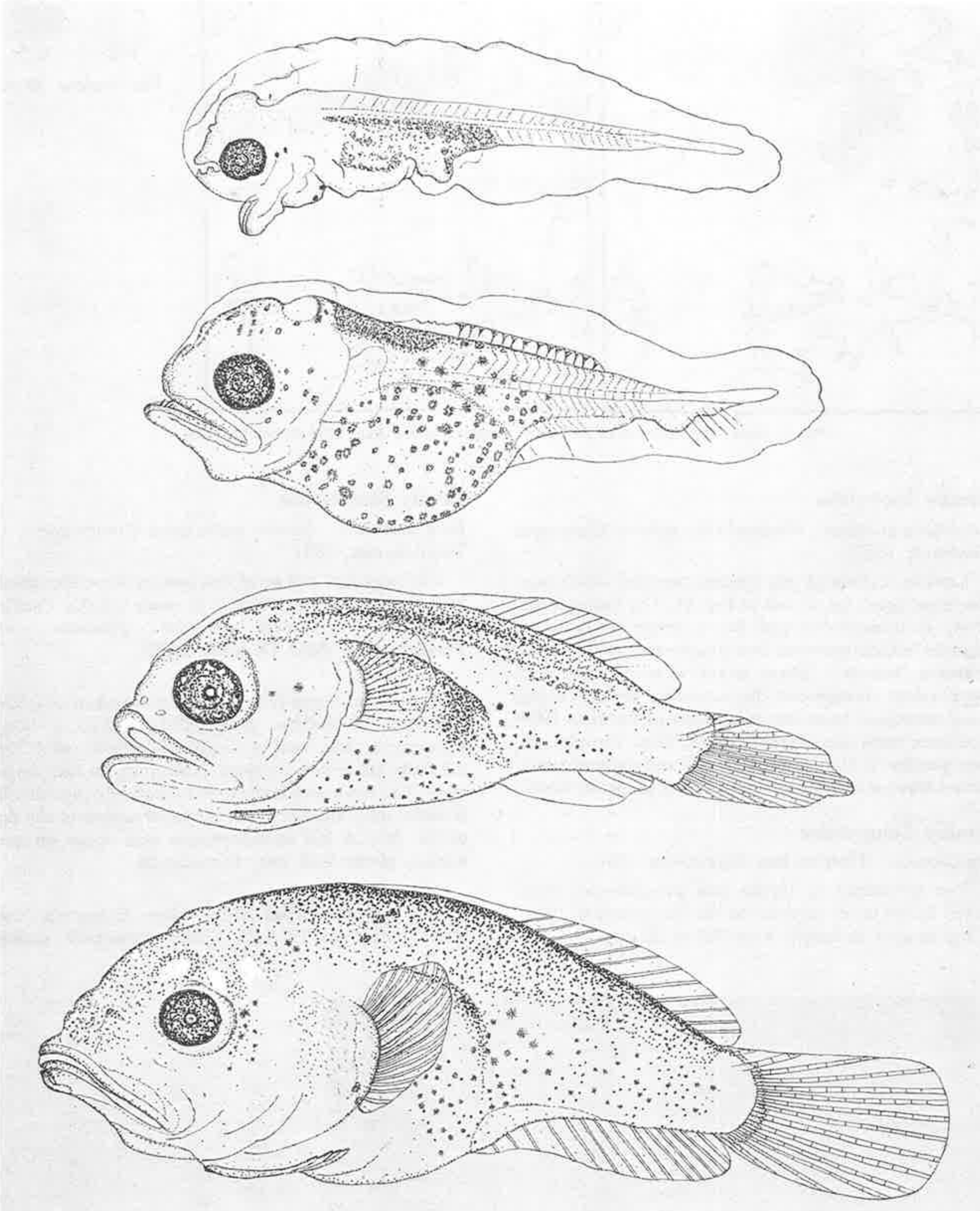


Fig. 42: Spotted stargazer (*Genyagnus monopterygius*) larvae (5.6, 7.2, 13.8, 20.0 mm).

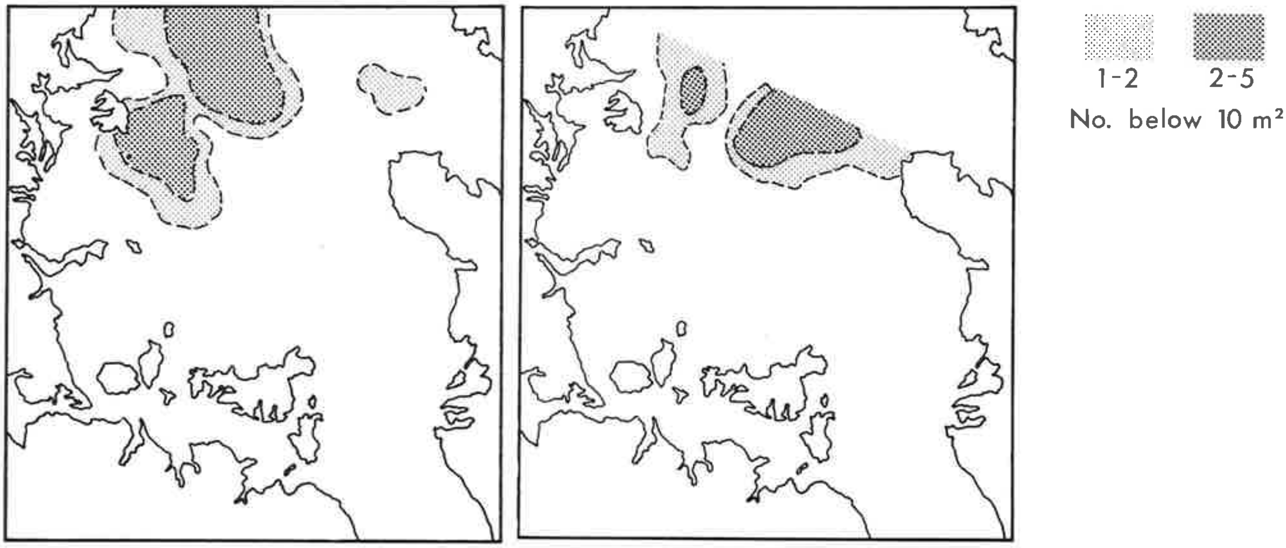


Fig. 43: Cumulative distribution of spotted stargazer larvae. Left: 1974–75. Right: 1975–76.

Family Eleotridae

Graham's gudgeon *Grahamichthys radiatus* (Quoy and Gaimard, 1837)

Larvae. Larvae of this species (another which lays demersal eggs) are shown in Fig. 44. The young larva (top) is transparent and has a conspicuous swim bladder which becomes less prominent as the larva matures (bottom). These larvae were common and were taken throughout the sampling period, being most abundant from late November onwards in 1974 and from early December in 1975. Their distribution was similar in both years (Fig. 45) and extended in a broad band across the northern half of the study area.

Family Gempylidae

Barracouta *Thyrsites atun* Euphrasen, 1791

Ten specimens of larvae and pre-juveniles were taken in the outer stations on the first cruise in 1974. They ranged in length from 7.5 to 25 mm.

Family Scombridae

Blue mackerel *Scomber australasicus* Cuvier and Valenciennes, 1831

The eggs and larvae of this species were identified from their close similarity to those of the Pacific (Japanese) mackerel *Scomber japonicus* (= *Pneumatophorus diego*) (Kramer 1960).

Eggs. These eggs (Fig. 46) had a diameter of 1.05–1.20 mm; a narrow perivitelline space; a non-segmented yolk; and a single oil droplet of 0.26–0.33 mm diameter, situated posteriorly in late stage eggs. The advanced embryo is moderately pigmented dorsally and laterally, from the head almost to the tip of the tail. A few melanophores also occur on the surface of the yolk near the embryo.

Blue mackerel eggs were taken throughout the study period in 1974–75. Their abundance varied

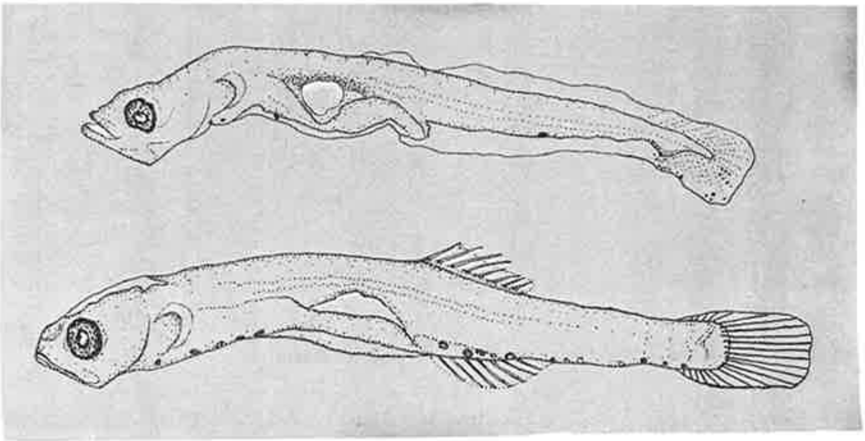


Fig. 44: Graham's gudgeon (*Grahamichthys radiatus*) larvae (4.9, 12.2 mm).

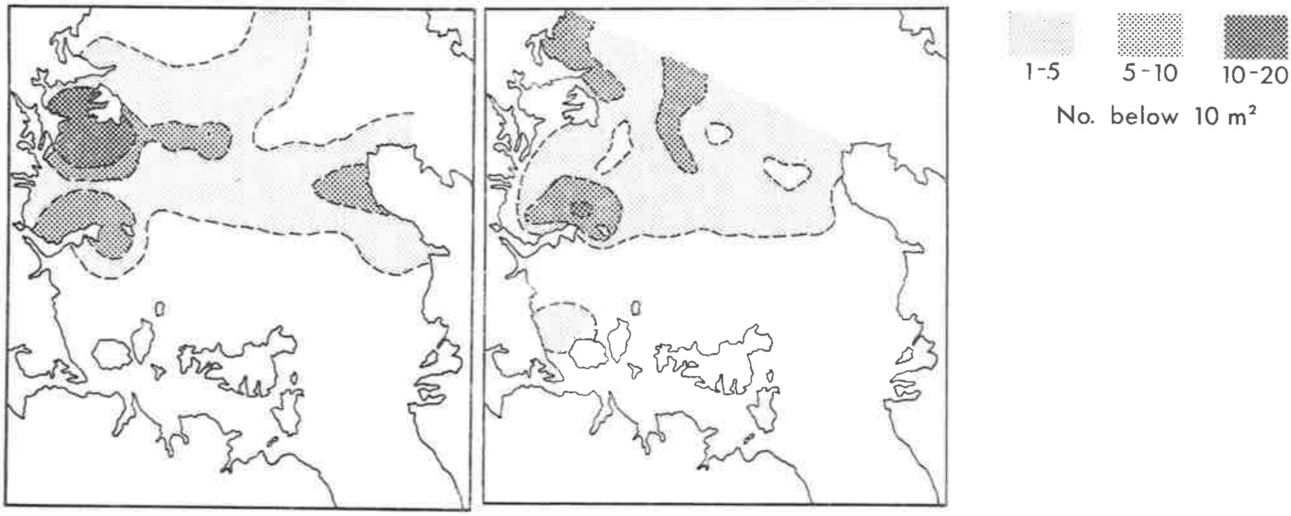


Fig. 45: Cumulative distribution of Graham's gudgeon larvae. Left: 1974–75. Right: 1975–76.

greatly from cruise to cruise (Fig. 47), which is to be expected with this highly mobile schooling fish. The spatial distribution (Fig. 48) showed the main spawning area to be outside the study area or on its northern periphery. In 1975–76 this part of the gulf was not sampled and blue mackerel eggs were less common, being taken in large numbers only during one cruise.

Larvae. Blue mackerel larvae (Fig. 49) are characterised by a patch of round melanophores on top of the head and dense pigmentation on the sides of the visceral cavity. These features distinguish them from snapper larvae, which they superficially resemble in the early stages. Details of pigmentation are remarkably similar to those of the Pacific mackerel described by Kramer (1960). However, larvae of *S. australasicus* are more slender and have less developed fin rays than *S. japonicus* larvae of comparable length. The largest larva recorded was 19 mm long.

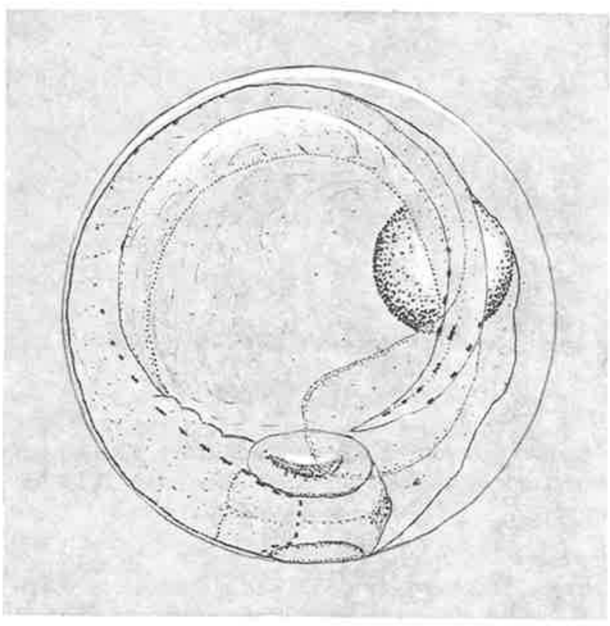


Fig. 46: Blue mackerel (*Scomber australasicus*) egg.

Blue mackerel were among the most abundant larvae in plankton from the outer stations; on several occasions over 1000 were taken in one sample, and a maximum of 2704 was recorded. The seasonal variation in larval numbers (Fig. 50) showed two marked peaks in both seasons. I was not able to determine whether these were caused by chance during sampling or were a significant feature of the spawning of this species. The distribution of larvae (Fig. 51) was similar in both years and was centred close to the observed spawning areas, but dispersed further south into the central gulf.

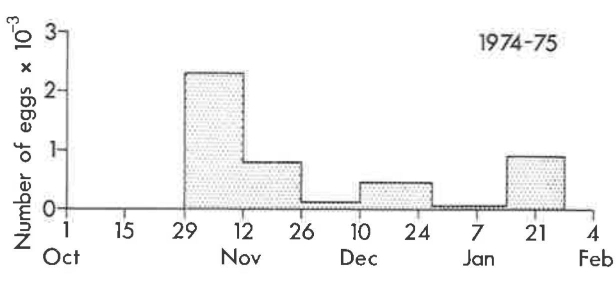


Fig. 47: Numbers of blue mackerel eggs taken by cruises, 1974–75.

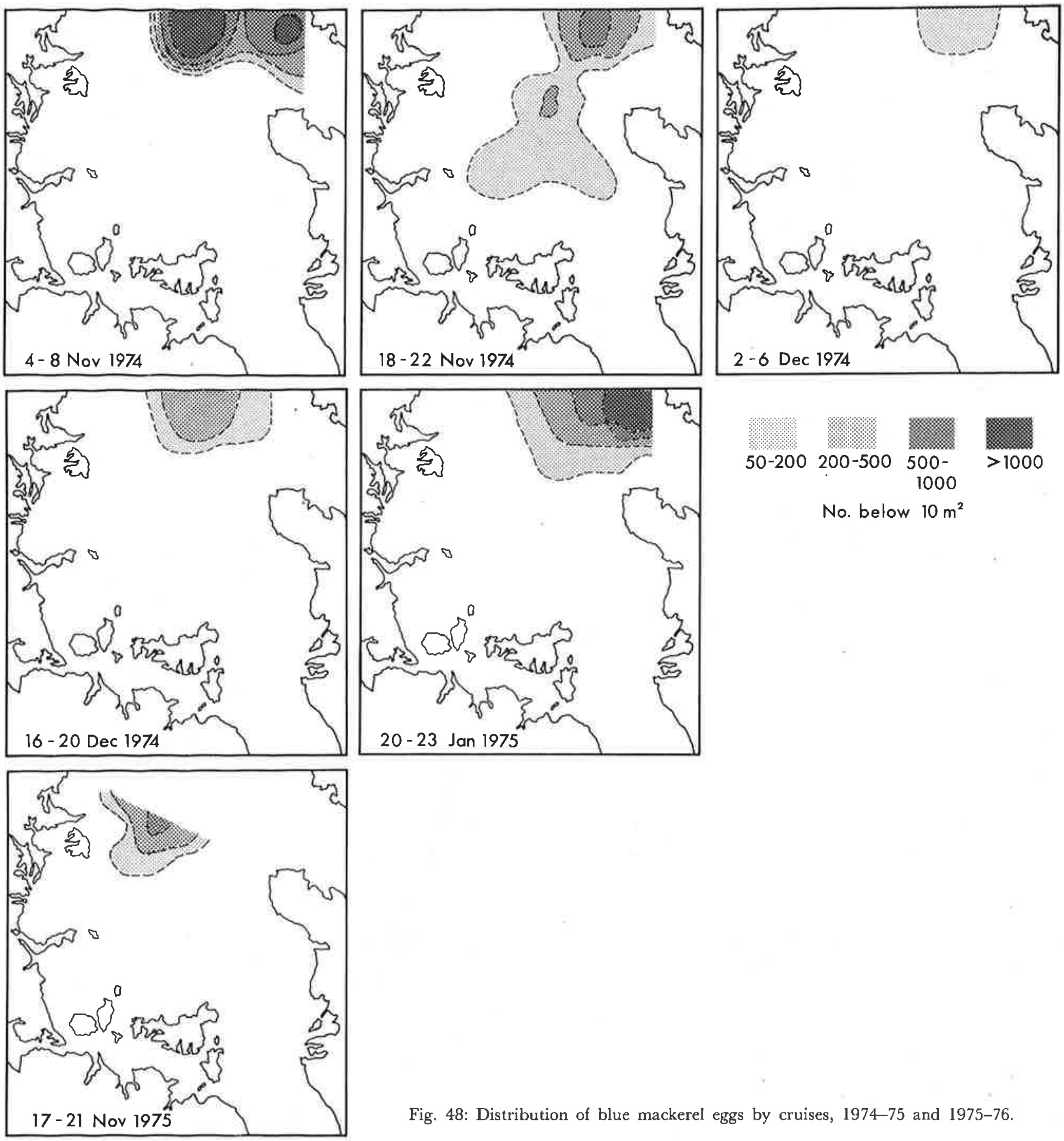


Fig. 48: Distribution of blue mackerel eggs by cruises, 1974–75 and 1975–76.

Family Bothidae

Crested flounder *Lophonectes gallus* Günther, 1880

The eggs of this species have not previously been described from New Zealand, and the larvae have been described only in an unpublished account (Robertson 1973). Eggs and larvae were identified by building up an embryological and larval series. They closely resemble those of the related species witch (*Arnoglossus scapha* (Bloch and Schneider, 1801)) (see Robertson 1975 for eggs and Robertson 1973 for larvae).

Eggs. These eggs (Fig. 52) had a diameter of 0.81–0.88 mm; a non-segmented yolk; and a single oil droplet of 0.12–0.16 mm diameter. Crested flounder eggs were taken at the outer stations on every cruise in

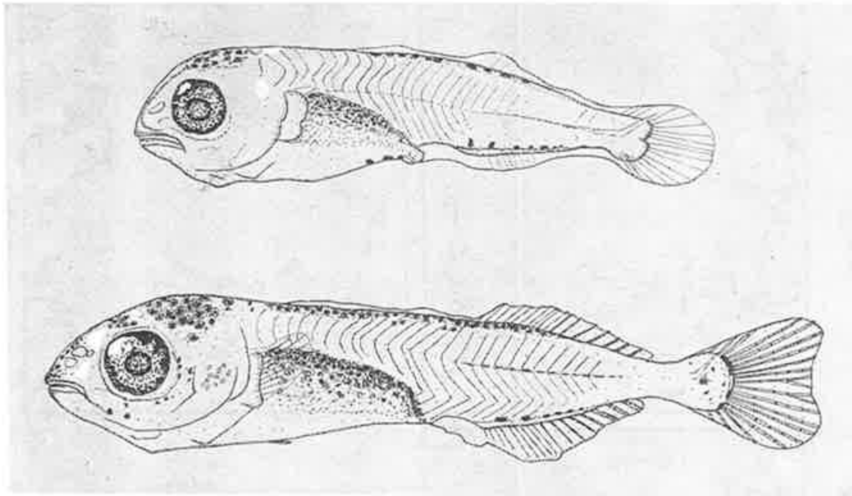


Fig. 49: Blue mackerel *(Scomber australasicus)* larvae (9.4, 14.4 mm).

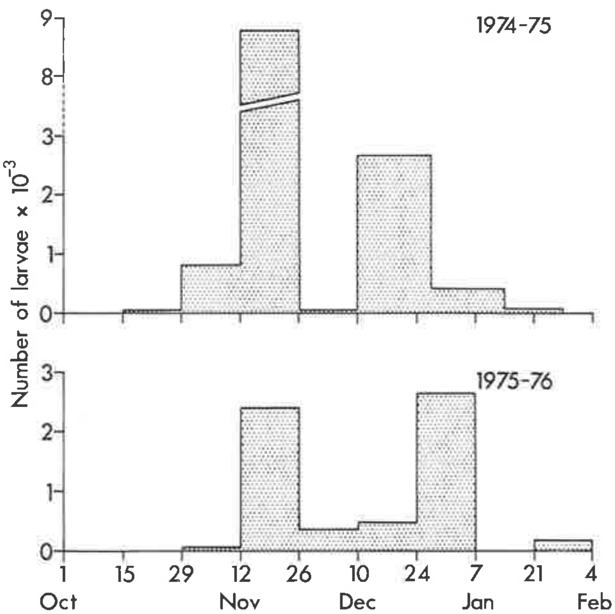


Fig. 50: Numbers of blue mackerel larvae taken by cruises, 1974–75 and 1975–76.

1974–75, but were never common except at one station off the south-west shore of Great Barrier Island (Fig. 53). The spawning area appears to be north of the study area.

Larvae. The young larva (Fig. 54 top) is quickly recognisable by a prominent band of black pigment near the tail and by the bifid whisker on top of the head. (Sometimes only a single ray was present, possibly as a result of damage.) Larger larvae are transparent and every detail of the viscera and structure of the gills is visible. They also have the bifid whisker. These features also apply to the larvae of the more southerly distributed *A. scapha.* However, the bothid larvae taken in this study were positively identified as those of *L. gallus* by their fin ray counts. *Lophonectes gallus* has 87 to 93 dorsal rays and 71 to 77 anal rays; *A. scapha* has 111 to 126 and 87 to 99 respectively (Norman 1934). The largest larva recorded was 14 mm long, at which size metamorphosis had not begun.

Unlike the eggs, larvae of crested flounder were at times abundant, particularly in 1975–76, when as many as 152 were recorded in a sample. The larval distribution (Fig. 55) shows dispersion south into the central gulf from the northern spawning centre. This was more marked in 1975–76, when larvae were common as far south as Tiritiri Matangi Island. Although larvae were taken on all cruises in both years, their numbers varied greatly, and periods of abundance did not correspond in the 2 years. In 1974–75 larvae were common on the first three cruises (October and November); in 1975–76 they were rare on the first three cruises, suddenly became abundant on the fourth cruise (mid November), and continued to be so until the end of December.

The thin, leaf-life form of the crested flounder larva indicates that it is a weak swimmer and is probably more truly planktonic than many other fish larvae and thus more affected by water movements. This, with its long larval period, means that it can occur in samples taken a considerable distance from the spawning site.

Family Pleuronectidae

Three members of this family are commonly found in the Hauraki Gulf: the sand flounder (*Rhombosolea plebeia* Richardson, 1843), the yellow-belly flounder (*R. leporina* Günther, 1873), and the speckled sole (*Peltorhamphus latus* James, 1972). The development of

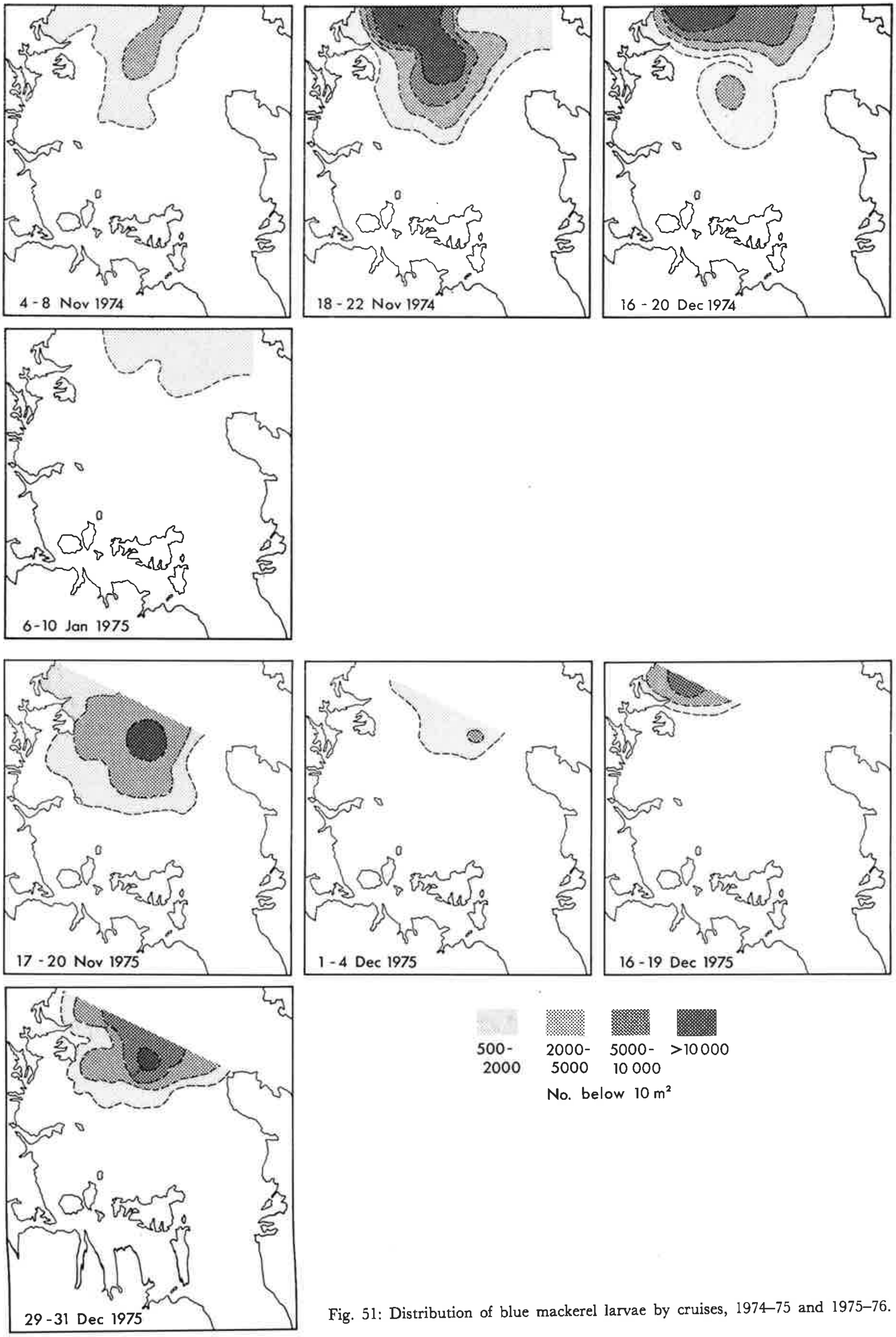


Fig. 51: Distribution of blue mackerel larvae by cruises, 1974–75 and 1975–76.

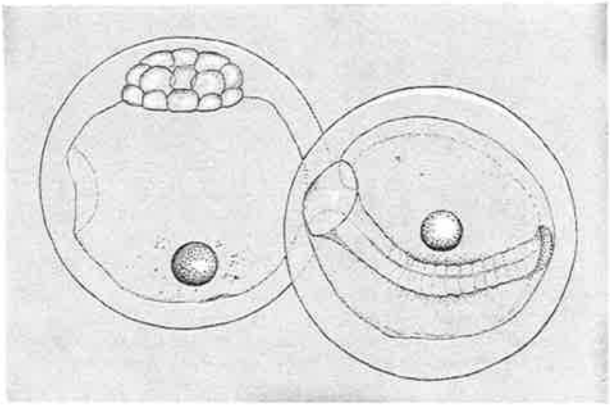


Fig. 52: Crested flounder (*Lophonectes gallus*) eggs.

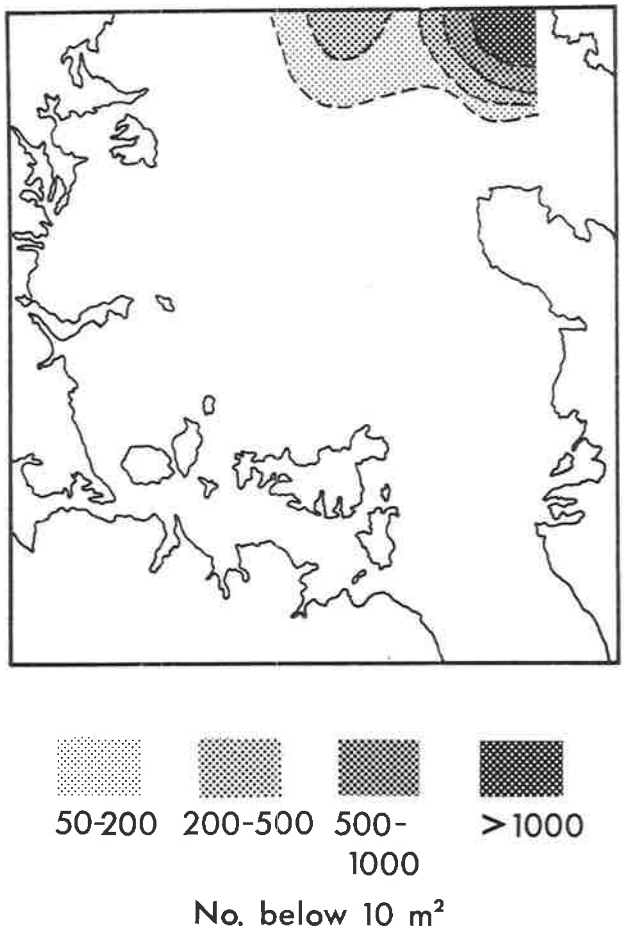


Fig. 53: Cumulative distribution of crested flounder eggs, 1974–75.

the sand flounder egg is described and figured in Robertson and Raj (1971); the egg of the yellow-belly flounder is very similar (Robertson 1975). Eggs of these two species could not be distinguished in plankton samples by Colman (1973) who studied their spawning in the Hauraki Gulf. The eggs of *P. latus* have not been described, but are probably similar to the eggs of the other two species of *Peltorhamphus* given in Robertson (1975); these are similar both to each other and to flounder eggs. The eggs of the three pleuronectid species from the Hauraki Gulf were therefore classed together.

Eggs. The distribution of pleuronectid eggs (Fig. 56) showed that spawning was concentrated in the northern part of the Firth of Thames; this confirmed the findings of Colman (1973). However, particularly in 1974–75, there were additional spawning areas north of Waiheke Island and between Motutapu Island and Tiritiri Matangi Island. In 1975–76 patches of eggs were encountered in or to the east of Omaha Bay. If the distributions of flounder and sole larvae (Figs. 59 and 62) are studied in conjunction with the egg distribution, it appears that those eggs found north and east of Waiheke Island are a mixture of flounder and sole; eggs from between Motutapu Island and Tiritiri Matangi Island, mainly flounder; and eggs from Omaha Bay, sole.

Pleuronectid eggs were taken throughout the sampling period (Fig. 57). They were most abundant during October and November and their numbers then were greater than those recorded at any time by Colman (1973); however, differences in sampling methods may have influenced the results. The peaks in egg numbers occurred during the first week of November in 1974 and the third week in 1975. The sea bottom temperature in the spawning area was 15.5°c at peak spawning in 1974 and 15.9°c in 1975. Colman found that egg numbers were low from December to April. Eggs were also less abundant during December for the 2 years in this study, but the numbers were still appreciable, especially since the data in Fig. 57 were not adjusted for the effect of temperature on the embryological period.

***Rhombosolea* larvae.** Larvae of the two flounder species could not be distinguished from each other; but their dark brown appearance, caused by numerous round melanophores (Fig. 58), easily distinguished them from the relatively unpigmented sole larva (see Fig. 61). Flounder larvae over 6 mm long were seldom taken; most were 3 to 4 mm.

The distribution of larvae (Fig. 59) showed them to be most abundant at the northern end of the Firth of Thames and north of Waiheke Island. In 1974–75

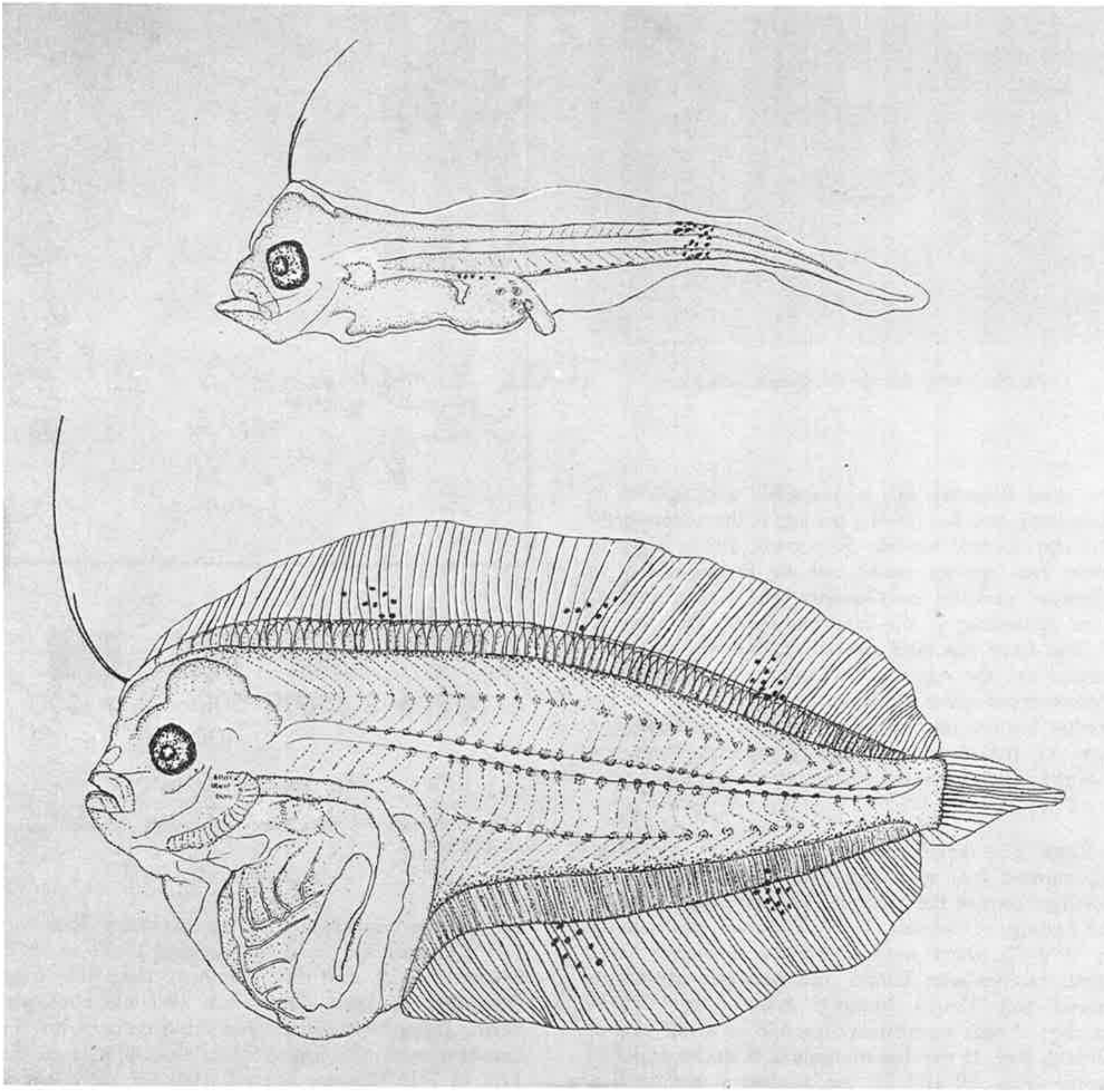


Fig. 54: Crested flounder (*Lophonectes gallus*) larvae (5.0, 14.0 mm).

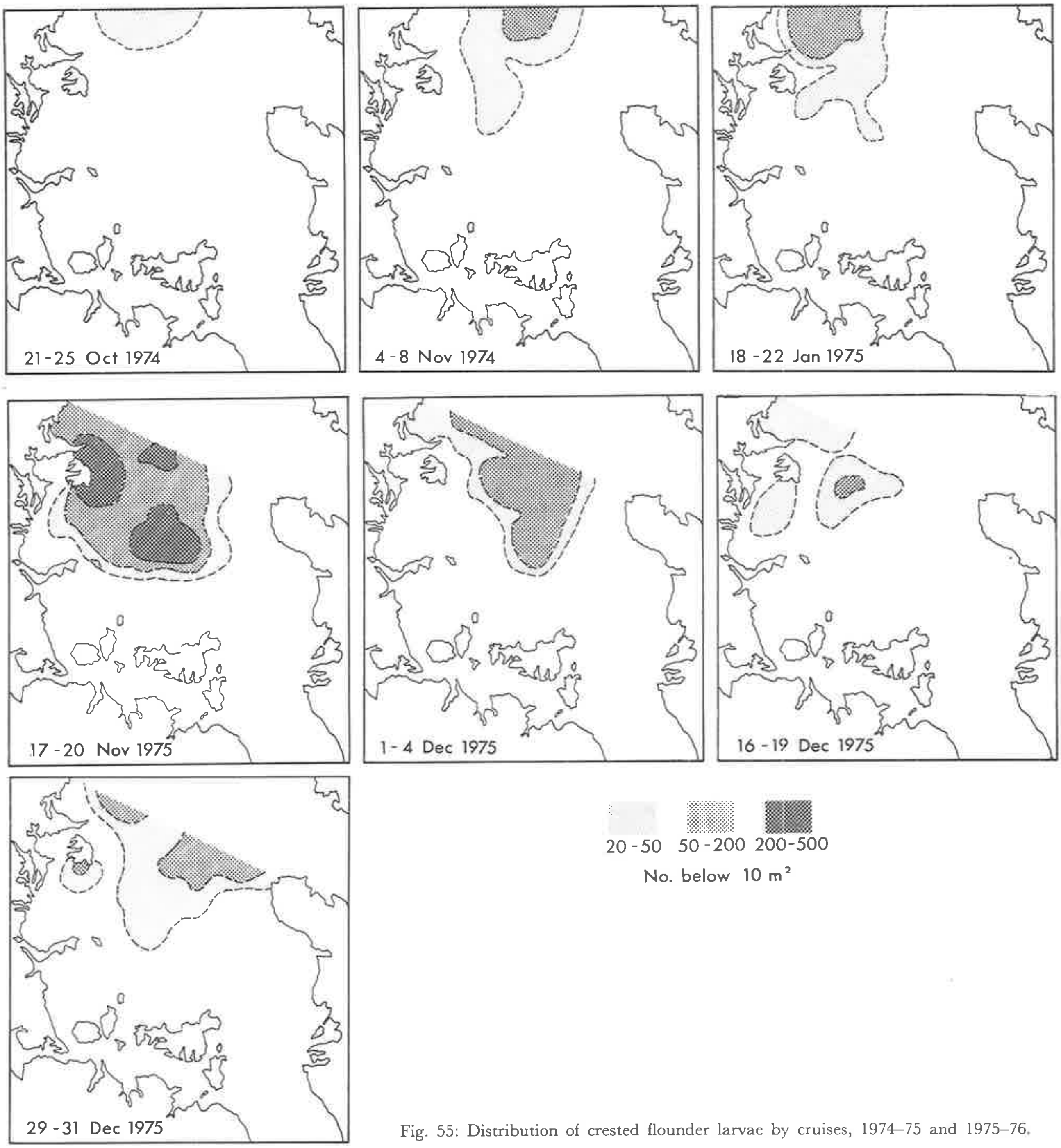


Fig. 55: Distribution of crested flounder larvae by cruises, 1974–75 and 1975–76.

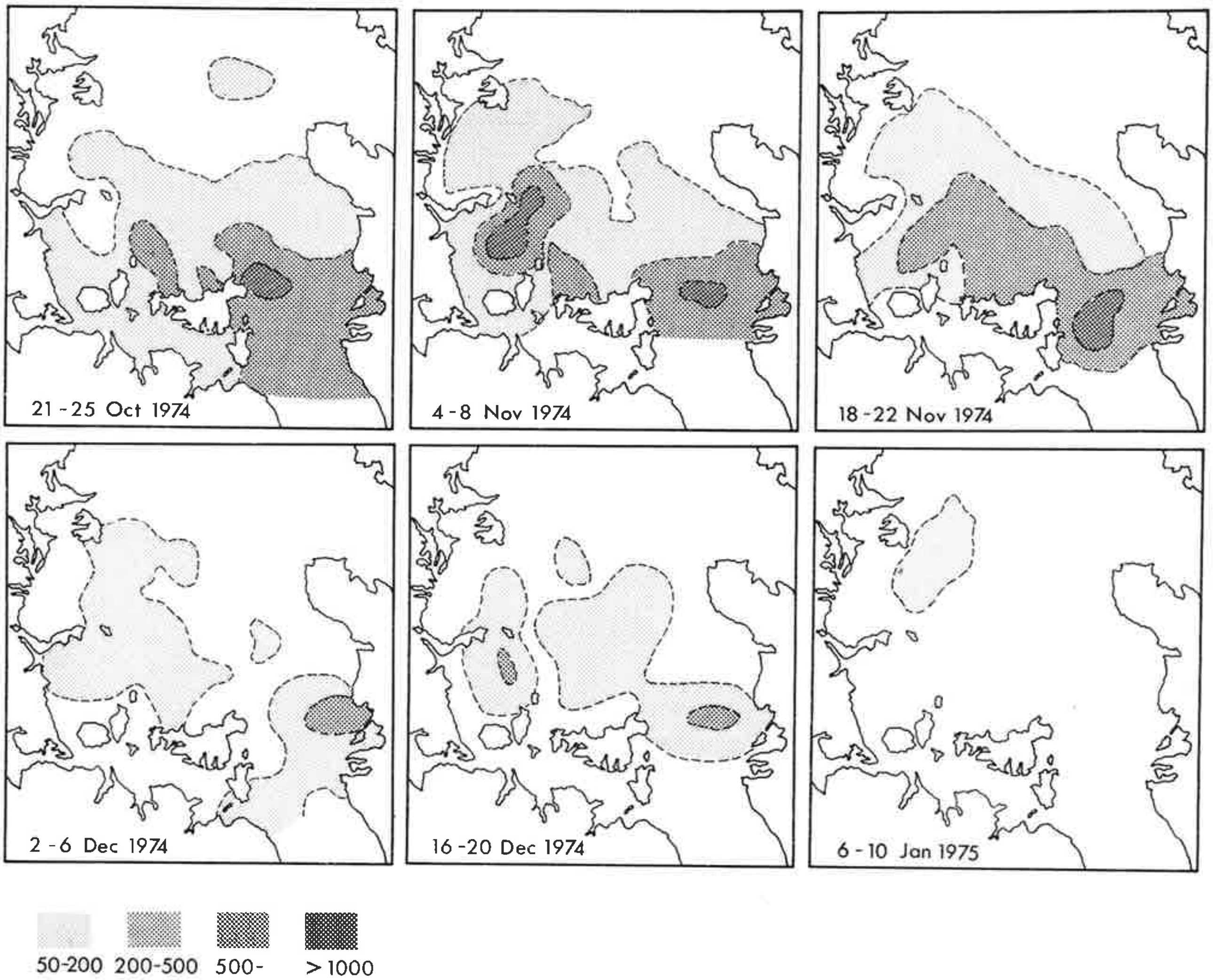
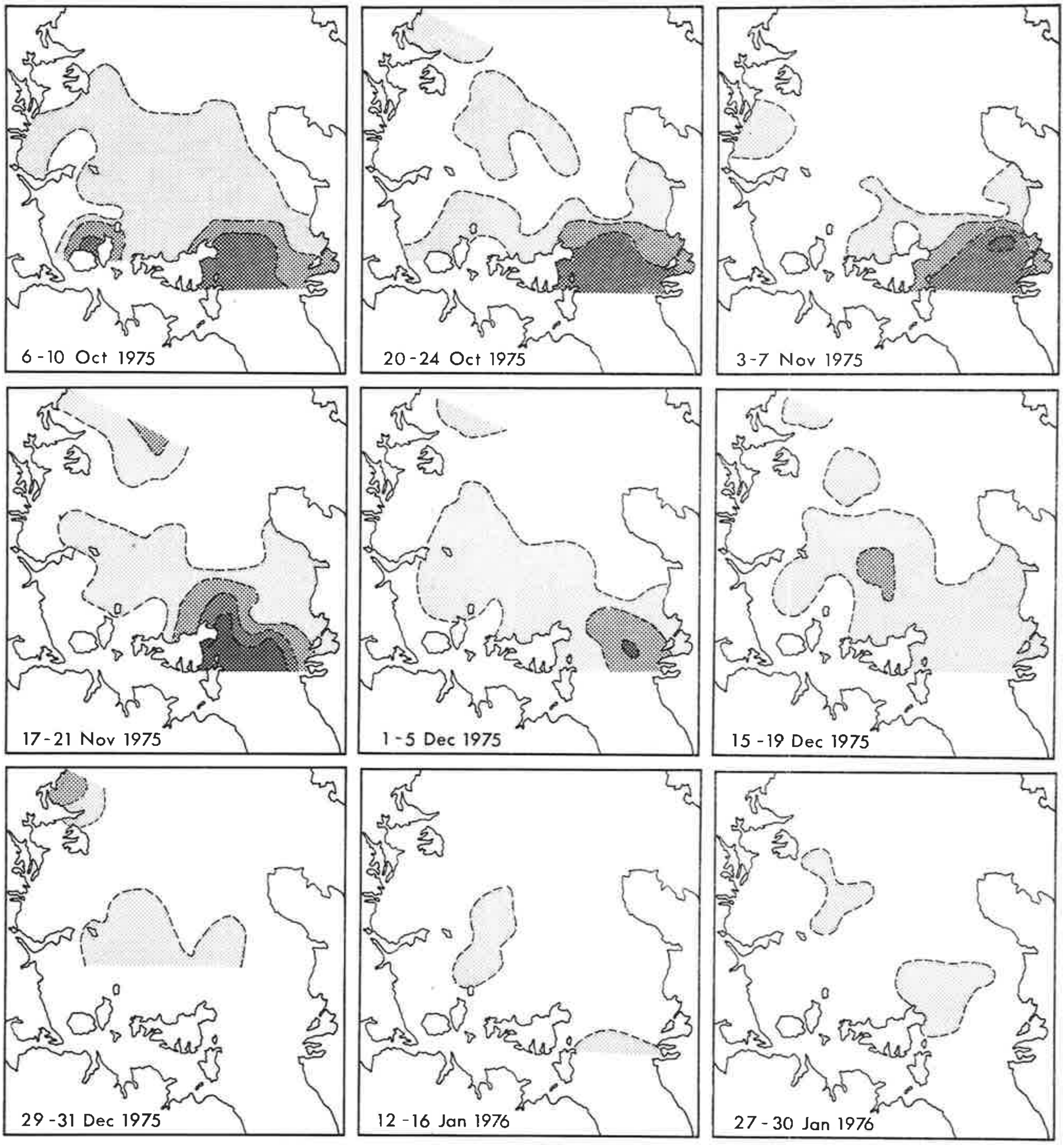


Fig. 56: (above and right): Distribution of pleuronectid eggs by cruises, 1974–75 and 1975–76.

they were also common around Rangitoto Island and Motutapu Island. Larvae were most abundant during November in each year (Fig. 60) and this abundance corresponded to the peaks in egg numbers. Since the presence of larvae is an indicator of past spawning, the smaller numbers observed during October, particularly in 1975, perhaps signify that peak spawning for flounders occurred during the study period, not at some time before sampling began.

***Peltorhamphus* larvae.** All sole larvae taken during this study were identified as those of *Peltorhamphus latus.* Adults of this small species are abundant in the Hauraki Gulf, but *P. novaezeelandiae* is only rarely observed, and the third species, the southerly distributed *P. tenuis* James, 1972, has not been recorded from this area. In addition, larvae with developed median fins gave ray counts in agreement with those for *P. latus* recorded by James (1972). The specimen in Fig. 61 (bottom) had 87 dorsal rays and 56 anal rays. Small larvae (Fig. 61 top), which did not have any obvious flatfish features, were recognisable by an area of small spots on the belly.

The distribution of speckled sole larvae (Fig. 62) was similar in both years, but differed from that of flounder larvae. Most sole larvae were recorded in the eastern gulf, with the main centre of abundance to the west of the Motukawao Group; larvae were rare in the Firth of Thames. The larval distribution pattern indicates a spawning centre to the north of that for flounders. However, since sole larvae were taken up to


6-10 Oct 1975
20-24 Oct 1975
3-7 Nov 1975
17-21 Nov 1975
1-5 Dec 1975
15-19 Dec 1975
29-31 Dec 1975
12-16 Jan 1976
27-30 Jan 1976

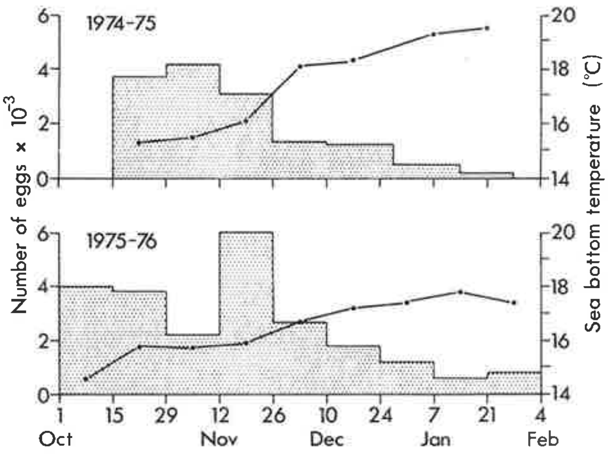


Fig. 57: Numbers of pleuronectid eggs taken by cruises, 1974–75 and 1975–76. Sea bottom temperatures for the spawning area are also shown.

a length of 11 mm, they have a longer planktonic stage than flounders and thus may be recorded further from their spawning site.

The longer planktonic stage may also be the reason why sole larvae were more numerous than flounder larvae; over the 2 years almost four times as many sole larvae were recorded. Larvae were most abundant in November 1974 (Fig. 63), when there was a distinct peak. In 1975 they were less abundant and their occurrence was more evenly spread over the study period.

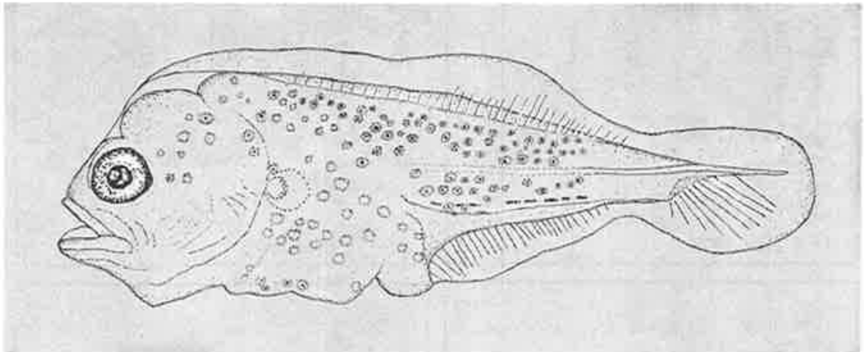


Fig. 58: Flounder *Rhombosolea plebeia* or *R. leporina* larva (5.3 mm).

Fig. 59: Cumulative distribution of flounder larvae. Left: 1974–75. Right: 1975–76.

Family Balistidae

Leather jacket *Novodon convexirostris* (Bloch and Schneider, 1801)

Eggs. The leather jacket egg is described in Robertson (1975). (The egg has a diameter of 0.650–0.725 mm; a non-segmented yolk; and a single oil droplet of 0.150 mm diameter.) Eggs with a size range of 0.64–0.74 mm and a single oil droplet of 0.13–0.18 mm diameter were commonly taken during this study and were assumed to be those of the leather jacket. These eggs (Fig. 64) had a remarkably clear yolk, surrounded by a perivitelline space which was 0.06–0.08 mm in the early stages, but much less in later stages. In the advanced egg the oil droplet was placed posteriorly. The embryo was transparent, the only pigmentation being two lines of inconspicuous dorsal melanophores.

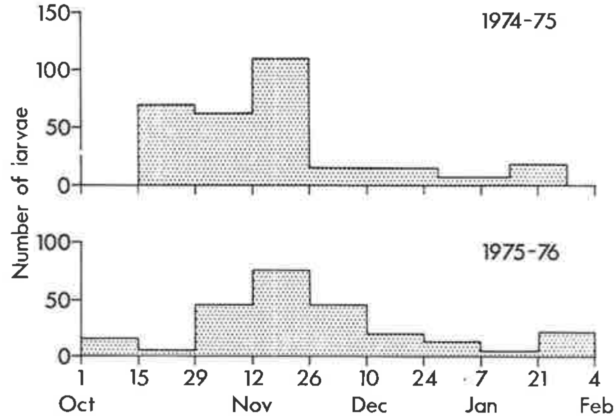


Fig. 60: Numbers of flounder larvae taken by cruises, 1974–75 and 1975–76.

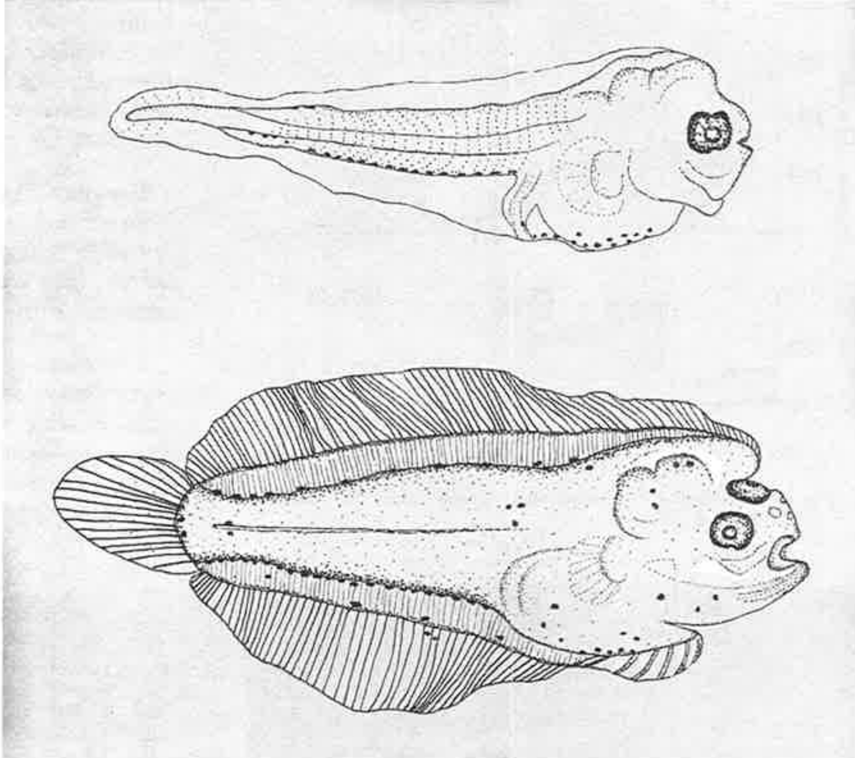


Fig. 61: Speckled sole (*Peltorhamphus latus*) larvae (4.2, 10.0 mm).

Leather jacket eggs were one of the commonest types and were taken on every cruise in both years. The seasonal variation in egg production (Fig. 65) has been adjusted for the effect of temperature and is for an equivalent area in both years, so that production in the 2 years can be directly compared. Leather jacket was a spring spawner in the Hauraki Gulf, with a peak in egg numbers during October, and thereafter a steady decline in spawning intensity as the sea temperature rose. The egg distribution in 1974–75 showed spawning to be centred in the central and northern parts of the study area, with eggs rare in the south of the gulf, particularly later in the season. This is consistent with the distribution of adults observed from trawling in the area. In 1975–76 spawning was again heaviest in the northern half of the study area,

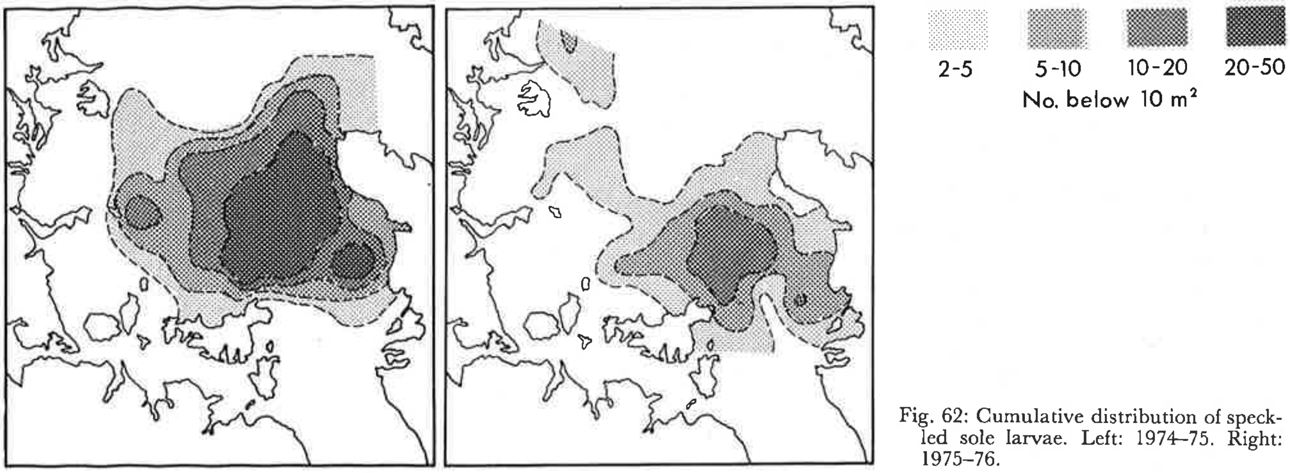


Fig. 62: Cumulative distribution of speckled sole larvae. Left: 1974–75. Right: 1975–76.

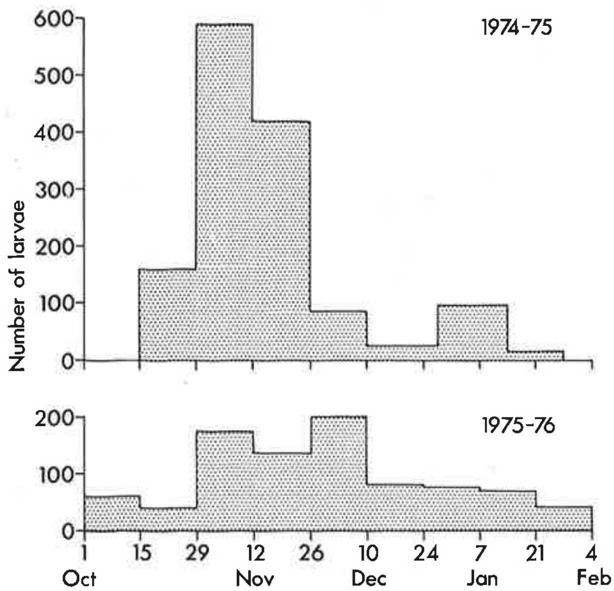


Fig. 63: Numbers of speckled sole larvae taken by cruises, 1974–75 and 1975–76.

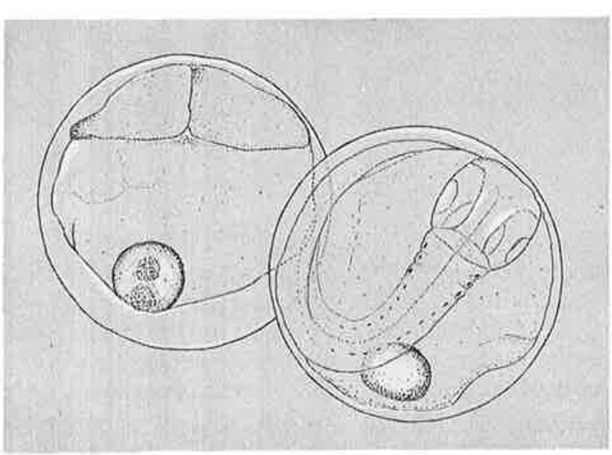


Fig. 64: Leather jacket (*Novodon convexirostris*) eggs.

but there was another centre near the entrance of the Firth of Thames (Fig. 66). The numbers of leather jacket eggs were much greater than was expected from the quantity of this species which is taken during fishing in the Hauraki Gulf. The species is known to be common close in shore, particularly among weed-covered rocks (Graham 1956, page 376). Possibly this is its habitat for much of the year, and it only moves off shore for spawning.

Larvae. The leather jacket larva is recognisable from an early stage by the prominent dorsal spine and the band of pigment near the tail (Fig. 67 top). Older larvae (Fig. 67 bottom) are unmistakably junior versions of the adult.

The number of larvae taken in both years was low, particularly compared with the abundance of the eggs. A wide range of sizes, up to juveniles 25 mm long, was taken. The cumulative distributions for the 2 years are shown in Fig. 68. In both years the larvae were commonest close to the spawning centres.

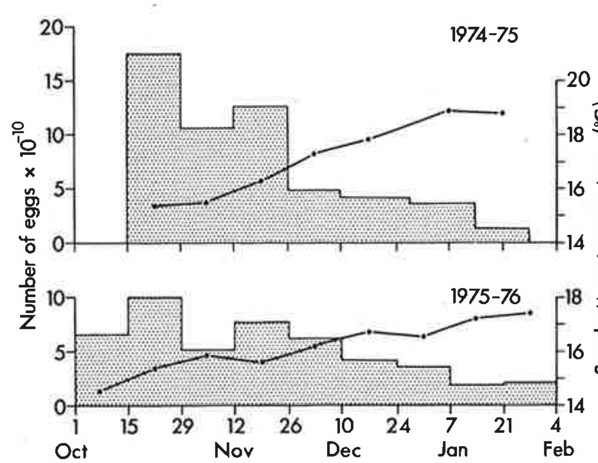


Fig. 65: Number of leather jacket eggs within the study area at the time of sampling for each cruise, 1974–75 and 1975–76.

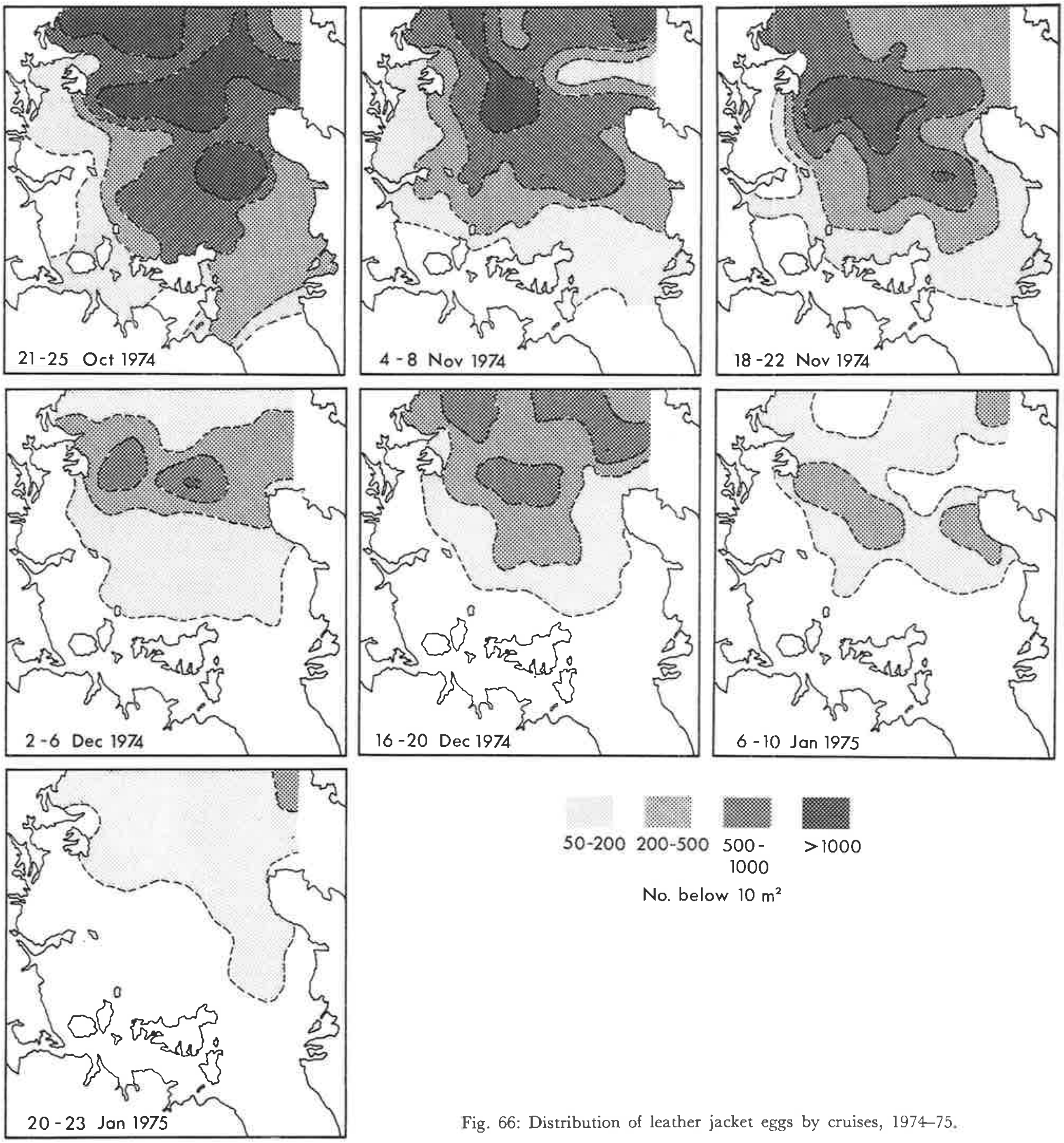


Fig. 66: Distribution of leather jacket eggs by cruises, 1974–75.

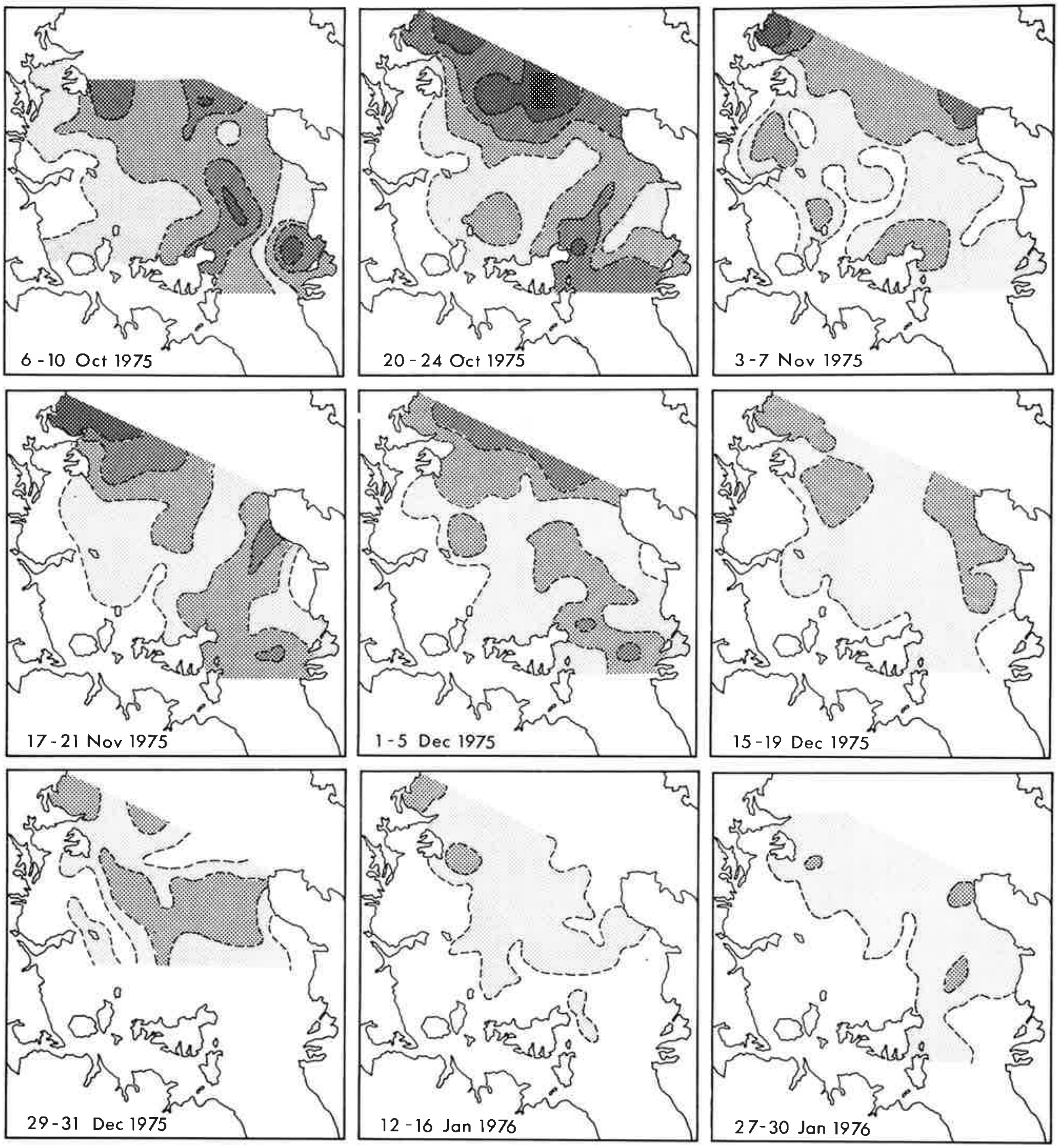


Fig. 66 (continued): Distribution of leather jacket eggs by cruises, 1975–76 (see key on previous page).

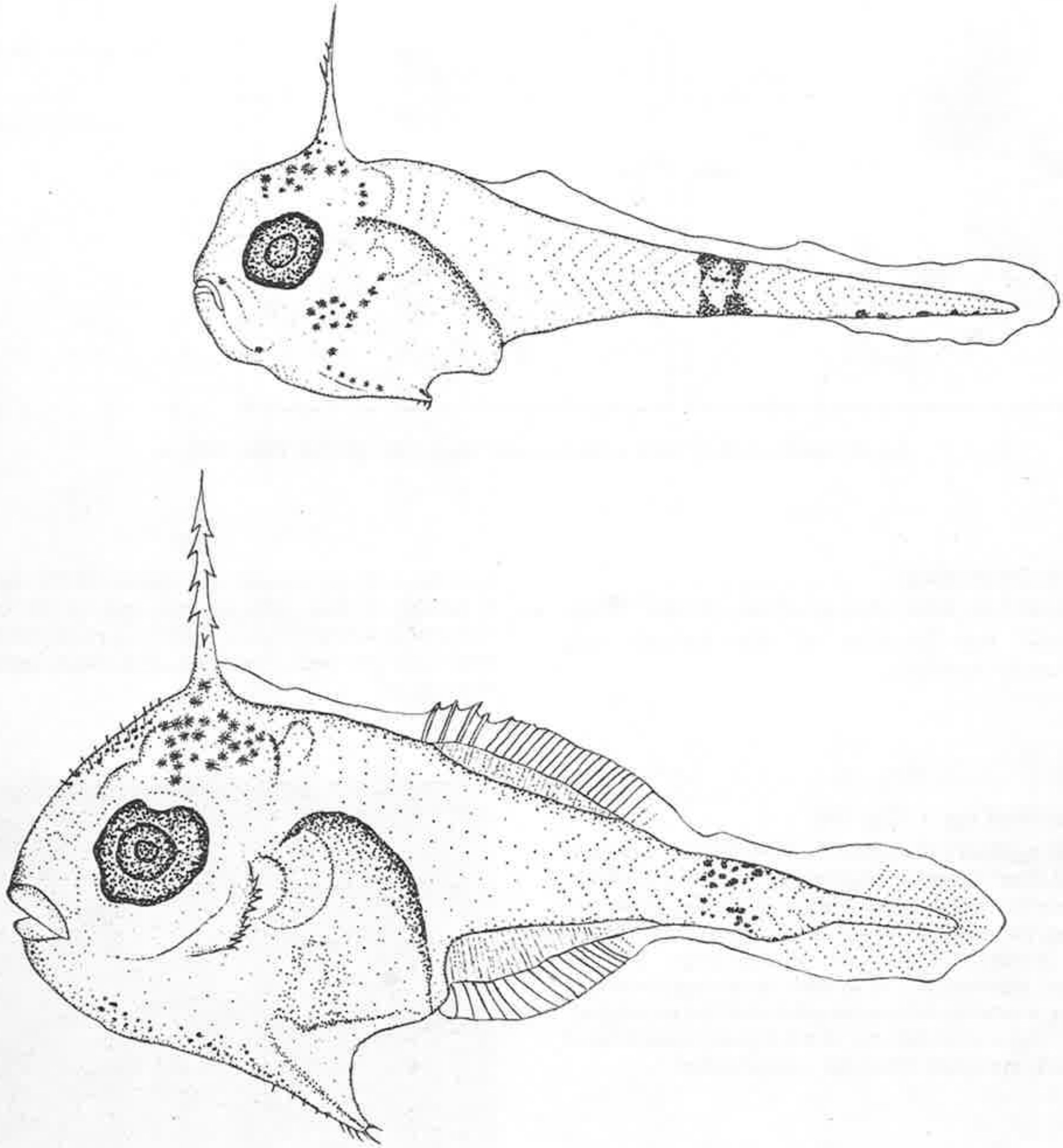


Fig. 67: Leather jacket (*Novodon convexirostris*) larvae (4.5, 6.7 mm).

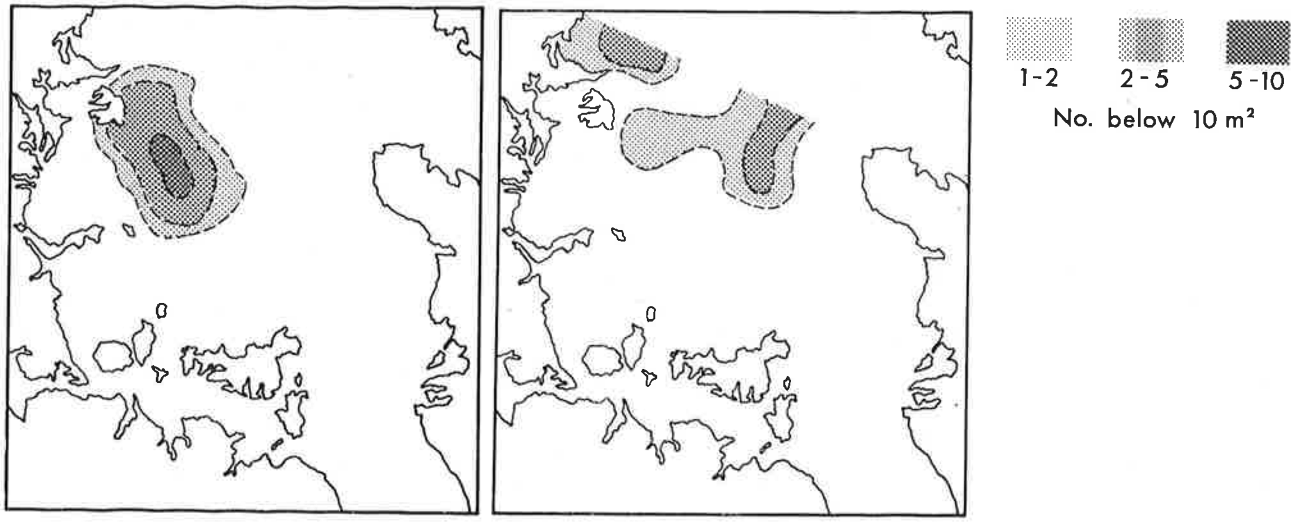


Fig. 68: Cumulative distribution of leather jacket larvae. Left: 1974–75. Right: 1975–76.

Family Diodontidae

Porcupine fish *Allomycterus jaculiferus* (Cuvier, 1818)

Larvae and juveniles of this species were occasionally recorded.

Unidentified egg 1 (Fig. 69)

This egg had a diameter of 0.80–0.89 mm; a narrow perivitelline space; a segmented yolk; and a single, pale yellow oil droplet, 0.20–0.25 mm in diameter. During the early stages of development this egg was very conspicuous because of the large, strongly marked segmentation of its yolk; as the egg developed the segmentation became smaller and less prominent. Later stages were difficult to distinguish from those of the jack mackerel *Trachurus novaezelandiae.*

Eggs of this type were taken on every cruise during both years except the first October cruise in 1975. They occurred irregularly, but occasionally were very abundant, with a maximum of 8972 being taken in one sample during January 1976. They frequently occurred with large hauls of jack mackerel eggs and were found mainly in the central gulf. The spawning pattern indicates that these eggs are from a schooling species not very common in the study area. The egg characteristics are those of a carangid fish. One possibility is that they may be those of the trevally, whose eggs have a diameter range of 0.76–0.86 mm and an oil droplet of 0.20–0.25 mm diameter, but only a moderately segmented yolk (James 1976). Another possibility is that they are the eggs of the koheru (*Decapterus koheru* (Hector, 1875)), a carangid whose eggs have not been described, and which occurs in this region.

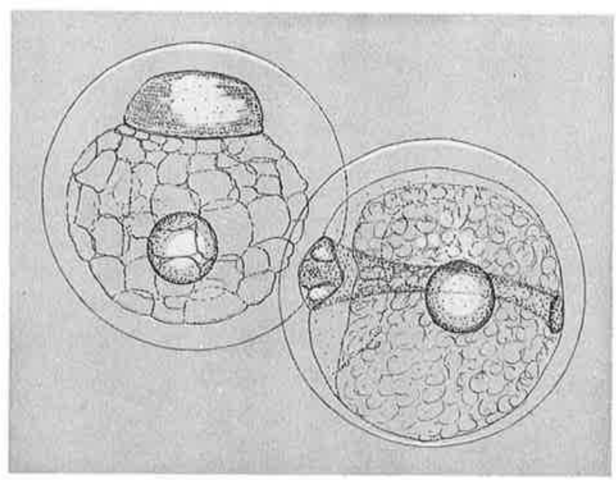


Fig. 69: Unidentified egg 1.

Unidentified egg 2 (Fig. 70)

This egg had a diameter of 1.12–1.22 mm, a very narrow perivitelline space, a segmented yolk, and no oil droplet. The advanced embryo is darkly pigmented.

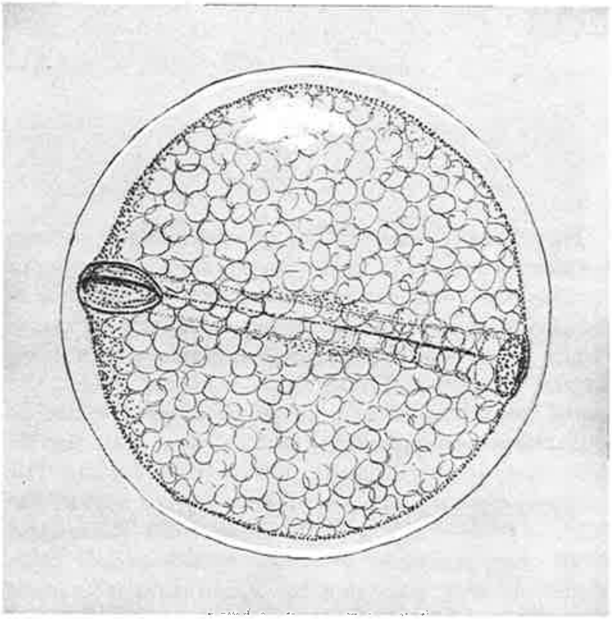


Fig. 70: Unidentified egg 2.

This egg was taken regularly at the outer stations, but never in large numbers. It was most abundant in November and December. It may be the egg of a roughy, the larvae of which were occasionally taken (see page 22).

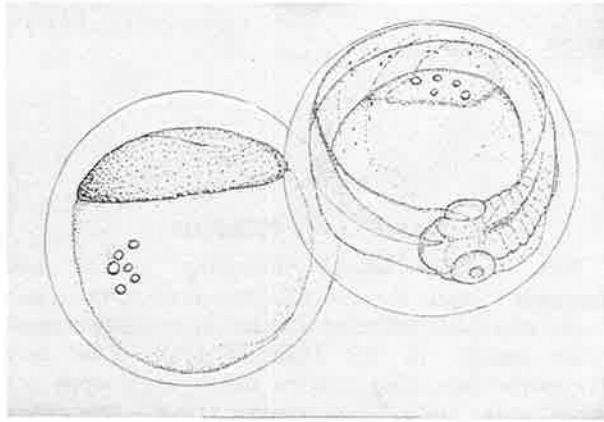


Fig. 71: Unidentified egg 3.

Unidentified egg 3 (Fig. 71)

This egg had a diameter of 1.02–1.12 mm; a narrow perivitelline space (0.08 mm); a non-segmented yolk; and two to eight oil droplets, with a maximum diameter of 0.05 mm.

This egg was very rare and was taken only at the outer stations. It is similar to, but slightly smaller than, the egg of the latrid *Mendosoma lineatum* Guichenot, 1849 described in Robertson (1975).

DISCUSSION

SAMPLING PERIOD

The October-January sampling period was designed to cover the spawning season of snapper, but it also effectively included the main spawnings of most other species in the Hauraki Gulf. The only commonly occurring species whose eggs were not taken were: John Dory, parore (*Girella tricuspidata* (Quoy and Gaimard, 1824)), spotty, and blue maomao (*Scorpio violaceus* (Hutton, 1873)). John Dory is known to spawn at this time of year (Robertson 1975); it must do so elsewhere. Parore probably spawns outside the sampling grid, in muddy, estuarine areas, its favoured habitat. Spotty and blue maomao are thought to be winter spawners.

EFFECT OF TEMPERATURE ON SPAWNING

Temperature was probably the most important environmental factor affecting spawning in the Hauraki Gulf during this study. Table 2 gives a summary of the spawning seasons and preferred temperatures for the principal species. The effect of temperature on spawning became apparent only because there was a noticeable difference in temperature between the 2 years. The effect of lower temperatures in 1975–76 was to delay spawning by some 2 to 4 weeks. This was observable both over all (Fig. 72) and for individual species, where this could be determined (Table 2). The sea temperatures at peak spawning were closely similar for the two seasons, with a mean difference of 0.4°c for six species.

The effect of temperature on the number of eggs spawned was not so easy to determine. The number of stations and volume of water sampled on corresponding cruises of each year were approximately the same. Figure 72 shows the crude egg numbers to be similar for the 2 years. However, this may not reflect the actual situation. Apart from the direct effect of temperature on embryonic period, there may also be differences in egg mortality between the 2 years. For snapper, egg mortality over the embryonic period was 64% in 1974–75 and 26% in 1975–76 (Crossland 1980). Egg mortality probably results mainly from predation and unfavourable environmental conditions. It is therefore likely to be similar for different species.

If it is assumed that rates observed for snapper apply for other species, it appears that lower temperatures reduced egg production (Table 3) for snapper, jack mackerel, and leather jacket (the figures are derived from egg numbers integrated over the study area as described previously). Anchovy, however, showed higher production in the colder year. This is a short-lived species, and egg production is more likely to be affected by changes in population size between years than it is in the other three species, whose populations are more stable.

During this study all sampling was done in a period of rising temperature. Consequently, spawning was first observed in the south and west of the gulf, those areas quick to warm up early in the spring. An exception was the spawning of the leather jacket, but this was because the species was not so abundant in

TABLE 2: Spawning season and temperatures for the principal species in the Hauraki Gulf. Brackets indicate that spawning may begin earlier, or continue later, than the months shown

Species	Spawning season	Preferred spawning temperature (°C)	Dates of spawning peaks and temperatures (°C) 1974–75	1975–76
Anchovy (*Engraulis australis*)	Nov-(Jan)	18.5–20.5 SS*	2–6 Dec 20.2	15–19 Dec 19.4
Pilchard (*Sardinops neopilchardus*)	(Oct)-Nov	16.0–18.0 SS	–†	–
Ahuru (*Auchenoceros punctatus*)	(Oct)-Nov	14.0–17.0 MS‡	–	3–7 Nov 16.2
Red gurnard (*Chelidonichthys kumu*)	(Oct)-(Jan)	15.0–16.5 SB§	21–25 Oct 15.4	1–5 Dec 15.6
Jack mackerel *Trachurus novaezelandiae*	Nov-Jan	16.5–18.5 MS	18–22 Nov 17.3	15–19 Dec 18.0
Snapper (*Chrysophrys auratus*)	Oct-Jan	15.0–17.0 SB	18–22 Nov 16.3	1–5 Dec 16.2
Spotted stargazer (*Genyagnus monopterygius*)	(Oct)-Nov	15.0–16.5 SB	–	–
Blue mackerel (*Scomber australasicus*)	Nov-(Jan)	–	–	–
Flounder *Rhombosolea plebeia* & *R. leporina*	(Oct)-Dec	14.0–17.0 SB	4–8 Nov 15.5	17–21 Nov 15.9
Speckled sole (*Peltorhamphus latus*)	Oct-Dec	14.0–17.0 SB		
Leather jacket (*Novodon convexirostris*)	(Oct)-Dec	14.0–17.0 SB	21–25 Oct 15.4	20–24 Oct 15.5

* Sea surface.
† Insufficient data.
‡ Mean sea.
§ Sea bottom.

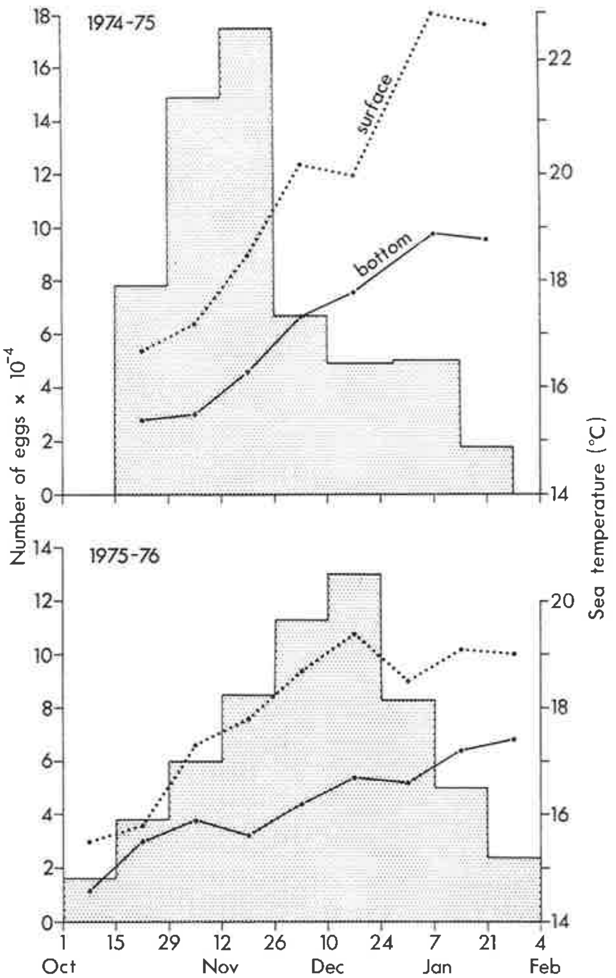


Fig. 72: Numbers of eggs of all species taken by cruises, 1974–75 and 1975–76. Mean sea bottom and sea surface temperatures are also shown.

the south. During the season, as the northern and central gulf became warmer, the centres of spawning moved there. This was true for snapper (Crossland 1980), anchovy, and jack mackerel. During the study period, the area of coolest water coincided with the area of least abundance of fish eggs. This cool water lay on the eastern side and extended, tongue-like, south from Cape Colville towards the Firth of Thames.

TABLE 3: Comparative egg production for 1974–75 and 1975–76

	1975–76 production as % of 1974–75 production	
Species	Observed	Adjusted for egg mortality
Snapper	62	46
Jack mackerel	100	72
Leather jacket	67	48
Anchovy	300	218

EFFECT OF WATER MOVEMENTS ON DISTRIBUTION OF LARVAE

In the enclosed, inner Hauraki Gulf, tidal movements are more important than long-shore currents. The tidal streams run in reciprocal directions on flood and ebb, with the general set of the flood tide being to the south-south-west, but modified in places by the shape of the land. Tidal streams run most strongly off Cape Colville, through the channels between the many islands of the gulf, and, to a smaller extent, in and out of the Firth of Thames.

In the outer gulf, on the northern periphery of the study area, water movements are more affected by oceanic influences, particularly the East Auckland Current (Paul 1968). This current, which sets in a south-easterly direction across the northern part of the gulf, enters through Jellicoe and Cradock Channels and passes out through the Colville Channel. There is a general tendency for currents to set inwards near large bays, and this probably occurs in the Hauraki Gulf.

Water movements are also affected by the wind, if it blows strongly and from the same direction for any length of time. To study the possible effect of wind-induced water movements, twice-daily wind data from Tiritiri Matangi Island were analysed. During the two study periods of October to January, the total amount of wind was similar, but there were differences in the proportion from each quarter (Fig. 73). In 1974–75 the cumulative total of wind speed from the two southerly quadrants was 1818 knots; in 1975–76 it was 2807, an increase of 60%. For the October to December period, those months when larvae were most abundant, the difference was more marked: 1241 knots in 1974, and 2240 in 1975, an increase of 80%. Despite these differences, there was no apparent effect on the distribution of larvae.

It is difficult to predict the individual effects on larvae of tides, winds, and currents, because of their complexity and the lack of detailed knowledge, particularly about subsurface drift. However, empirical observations showed there were three distinct patterns of larval movement in the study area.

The first pattern of larval drift showed a north or north-west movement of larvae of those species whose spawning was centred in the Firth of Thames. The centre of larval occurrence was about 5 nautical miles to the north of the eggs for flounder, 10 to the north-west for speckled sole, and 10 to 20 north and north-west for ahuru.

The second pattern was a north or north-east dispersal for those species whose spawning was concentrated in the western part of the central gulf, along the arc from Waiheke to Tiritiri Matangi to Kawau Islands. The centre of larval occurrence was 10 nautical miles to the north of the eggs for snapper, 10 to 15 north and north-east for jack mackerel, and 7 north-east for anchovy.

The third pattern was a southward movement of larvae from spawning centres near the northern periphery of the study area. Pilchard and crested flounder larvae were centred about 20 nautical miles from their supposed spawning grounds (to the north of the study area), gurnard larvae 10 to the south, and blue mackerel 15 to the south or south-west. With blue mackerel the situation was more complex because, though the main egg concentrations were in the Cradock and Colville Channels, the larvae were centred in the north-west corner of the study area. However, these larvae probably dispersed from an unlocated spawning ground in the Jellicoe Channel to the north. Larvae from the known spawning centre may disperse eastwards through the Colville Channel.

The larval movements deduced from these observations are consistent with a clockwise circulation of water in the Hauraki Gulf, presumably under the impetus of the East Auckland Current after it strikes the western side of the Coromandel Peninsula and is deflected southwards.

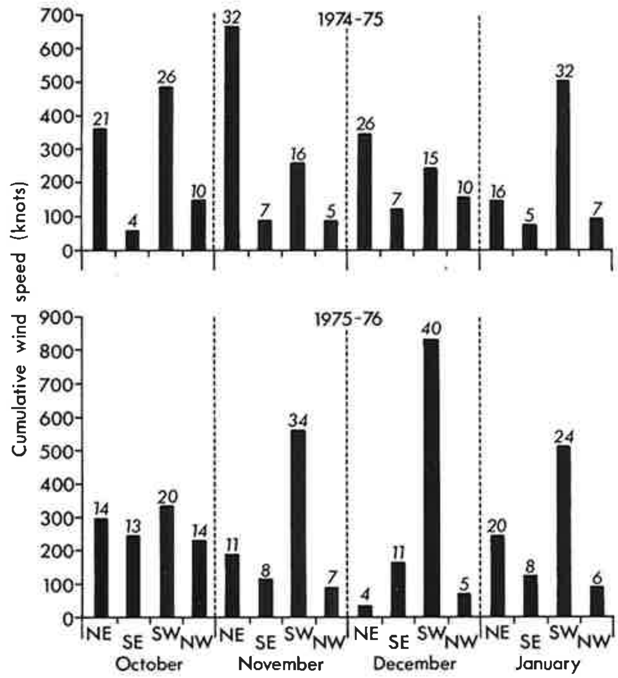


Fig. 73: Monthly cumulative wind speed by quadrant from twice-daily observations at Tiritiri Matangi Island, Hauraki Gulf. Number of occurrences shown in italics; seven calm observations in each 4-month period. (Source: New Zealand Meteorological Service.)

SUMMARY

The results of 2-weekly plankton cruises in the Hauraki Gulf from October to January for 1974–75 and 1975–76 are presented. About 50 stations were sampled on each cruise by oblique tows of a cylinder-cone plankton net with a mouth area of 0.25 m^2. All fish eggs and larvae were sorted and counted. Totals of 583 000 eggs and 55 000 larvae were collected on 7 cruises in 1974–75, and 589 000 eggs and 79 000 larvae on 9 cruises in 1975–76. Nineteen kinds of eggs and 27 of larvae were recognised. Figures are given of all eggs and larvae not previously illustrated in the published literature. The distribution, abundance, and seasonality of each species are discussed separately. The effects of temperature on spawning, and water movements on the distribution of larvae, are also considered.

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