Technical Report 6

ASPECTS OF THE ECOLOGY OF FISH AND COMMERCIAL CRUSTACEANS OF THE BLACKWOOD RIVER ESTUARY, WESTERN AUSTRALIA

ENVIRONMENTAL STUDY OF THE BLACKWOOD RIVER ESTUARY

a report to the
Estuarine and Marine Advisory Committee
of the
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Aspects of the ecology of fish and commercial crustaceans of the Blackwood River estuary, Western Australia.

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I INTRODUCTION

In January, 1970, dredging and mining claims for heavy minerals were pegged in and around the Blackwood River estuary in south-west Western Australia. In 1971, objections to this proposed mining, based on social, aesthetic and environmental grounds, were lodged with the Department of Conservation by citizen bodies and other State Government Departments.

As a result of these objections, and because of lack of scientific and soiological data about the area which could be used as a basis for making a judgement on the ecological and sociological effects of such a proposal, the Environmental Protection Authority "recommended that no mining be allowed on these claims and they not be listed for hearing in the Mining Warden's Court until further research be undertaken".

As part of the Government's acceptance of the above recommendations, the Environmental Protection Authority directed that a programme of investigation should include "a study of the ecology of the estuary and its environs, and lead to an assessment of the multiple uses of the estuary with respect to such factors as commercial fishing, bird life, tourism, recreation, the mining proposal and the aesthetic effects for local residents".

This aspect of the programme of investigation involved the study of the ecology of populations of fish and commercial crustaceans of the Blackwood River estuary.

Although there have been many studies of this kind carried out elsewhere in the world (Dahlberg, 1972; Dahlberg and Odum, 1970; Derickson and Price, 1973; Haedrick and Haedrick, 1974; Haertil and Osterberg, 1974; Mcerlean, O'Conner, Mihursky and Gibson, 1973; Mori, Tokunaga, Kuwaska and Fugiki, 1973; Oviatt and Scott, 1973; Perlmutter, Schmidt and Leff, 1967; Targett and Mc cleave, 1974; Richards and Castagna, 1970; Wallace, 1973; Webb, 1972 and Williams and Harcup, 1974), there have been very few documented from Australia (Bass Becking, Thomson *et al.*, 1959., Shine, Ellway and Hegerl, 1973.,Environmental Study, Port Phillip Bay, 1973.).

The only information available on the fish and crustacea of the Blackwood River estuary is a preliminary species list (Lenanton, 1974a). and some information on the commercial production from the estuary (W.A. Dept. Fish. Wildl. files).

In view of this paucity of information, and with the aims of the overall study in mind, the objective of this investigation was to study the seasonal abundance and distribution of the fish and crustaceans together with a study of the estuary's use as a nursery area for the young of the various species.

The intention of this paper is not to review the biology of all the species collected during the survey but rather to establish in general terms which group of species is most abundant in the estuary, and how members of this group are able to utilise this extreme estuarine habitat. However all available natural history data is presented for the information of the readers.

II DESCRIPTION OF THE STUDY AREA

The Blackwood River estuary is situated on the western extremity of the south coast of Western Australia between lat. 34° 15' and 34° 20'S, and long. 115° 08' and 115° 13'E. (Figure 1). It consists of a tidal river which winds across a coastal plain and discharges into a shallow lagoon situated behind a ridge of pleistocene (calcarenite) coastal dunes. The dunes restrict the estuary mouth to a narrow tidal channel which at its seaward end breaches a wave built barrier beach of mobile sands.

A detailed account of the study area, which includes the climate, geomorphology, hydrology, tides, currents and river flow, has been prepared by Hodgkin, 1975.

III MATERIALS AND METHODS.

Sampling equipment consisted of a 210 m beach seine (haul) net constructed of 2.54 cm mesh wings 100 meshes deep, and 1.58 cm grading into 0.95 cm mesh bunt; four set (gill) nets with lengths and mesh sizes of 19 m and 5.08 cm, 91 m and 5.71 cm, 93 m and 8.25 cm and 27 m and 10.16 cm respectively; plankton nets of 1.0 and 0.2 mm mesh, and a small 3.5 m head rope otter trawl with 5.0 cm mesh wings and cod end.

The estuary was arbitrarily divided into six sampling areas; Swan Lakes, Deadwater, Channel, Lagoon, Basins and tidal river. Collectively within these regions were situated eleven seine and plankton net and fourteen set net stations (Figure 1). Whenever possible all stations were sampled once during each field trip. Trawl netting was restricted to the deeper areas of the estuary (Figure 1) and was to be continued as a regular sampling technique only if initial trials proved successful. Bimonthly field trips commenced in March 1974 and concluded in March 1975.

All regular seine net samples were taken during the day on an incoming or high tide. An area of 7018 m^2 was swept by the seine net at each sampling station. Set nets were positioned at the appropriate station just before sunset and collected just after sunrise the following day.

Plankton net samples of larval fish were taken from surface, and when possible, sub-surface waters. At each station the 1.0 mm net was towed for a distance of 100 metres. The 0.2 mm net was only used at several of the stations. Each tow was at a constant speed and of 2 minutes duration. Whenever possible temperature and salinity were recorded after each sample had been taken. Unless otherwise indicated, all plankton tows were made between 1800 and 2200 hours.

Trawl net shots were performed during the day, at speeds and times varying between 1 and 3 knots and 1 and 2 minutes respectively.

The individuals of each species taken in the seine and set net catches were measured (total length cm) and collectively weighed (kg). Whenever possible, the gonads were macroscopically examined, and their condition recorded. Length, weight, scale and gonad samples were taken from *Sillago schomburgkii*, *Sillago punctata*, *Mylio butcheri* and *Chrysophrys unicolor* to facilitate more detailed biological analysis, such as determination of age structure and spawning time of the populations. All fish eggs, larval and juvenile fish were sorted from other material, collected in the plankton tows, identified, counted and preserved in 3% buffered formalin solution. Trawl caught species were identified and counted. Whenever possible crustaceans were measured and weighed.

The measurement of physical parameters was made after the completion of each seine net sample. Temperature (^{o}C) and salinity (^{o}/oo) were measured with a Beckman induction salinometer, dissolved oxygen (% saturation) was measured with an Electronic Instruments Ltd Model 1520 portable dissolved oxygen meter, then converted to mg/l. using the following formula (Richards and Corwin, 1956).

Dissolved oxygen (mg/l) =

$$\frac{(\text{Dissolved oxygen \% sat.})\,(332.4 - \{\text{Sal. } ^{o}/oo\ 1.1854\})}{100\ (\text{Temp. } (^{o}C) + 33.5)}$$

Both instruments were calibrated regularly. A turbidity index (in metres) was obtained with a secchi disk. Records were also kept of the depth (m), the state of the tide and time of day (24 hr. clock).

An index of relative abundance for each species was estimated for each of the five*sampling areas (Figure 1) by averaging the catch (numbers) per haul for all hauls made in each of these areas each field trip. If it is assumed that (i) each species of fish was randomly distributed throughout each of the sampling areas at the time of sampling each month, and (ii) the catchability of each species of fish at all stations remains constant throughout the year, then an index of relative abundance for each species for the whole estuary can be calculated for each trip by weighting the average catch per shot for each sampling area by the actual area (ha) of shallow banks (<2 m. mean low water), and summing them for the whole estuary. The yearly mean index of relative abundance was calculated for each species by averaging the values determined for each of the seven field trips. The data from seine and set nets were treated separately. (It was later found that assumption (ii) was unacceptable).

IV RESULTS

The location of all sampling stations throughout the estuarine system is presented in Figure 1. Topographical records and other necessary sampling station parameters within each area are presented in Tables 1 and 2 (a) respectively. Hydrological Station data recorded from Swan Lakes and the Deadwater, are presented in Tables 2 (b) and 2 (c) respectively.

Temperature and salinity data are presented as isotherm and isohaline diagrams respectively in Figure 2.

A list of all species of fish and crustaceans recorded during the survey is presented in Table 3. The catch of each species taken from seine and set nets, expressed both in numbers and weight is presented in Tables 4 (a) and (b) and 5 (a) and (b) respectively.

The yearly mean index of relative abundance for both the more abundant (index >1.0) and less abundant (index <1.0) species from both seine and set nets is presented in Tables 6 and 7. There was insufficient biological data available to be used as a basis for the identification of the immature or juvenile size-range of most of the species being considered in this study. However, from the length frequency data collected, and other available biological data, the length range of 0+ year old fish was therefore able to be determined. The abundance of 0+ year old fish was considered to be the best available index of juvenile abundance.

* For the purpose of this calculation Swan Lakes and Deadwater were considered as one sampling area.

Records of presence or absence of a species from water of known salinity, made from seine net sample data enabled the determination of the range of salinities experienced by each species. They were then able to be classified (Remane, 1971) as either stenohaline-marine (* seawater to 30 $^{o}/oo$), euryhaline (seawater to 3 $^{o}/oo$) or stenohaline-freshwater species (< 3 $^{o}/oo$ to freshwater). Then depending on the degree of euryhalinity displayed by each species in the euryhaline group, they were further divided into euryhaline I (seawater - 15 $^{o}/oo$), euryhaline II (seawater - 3 $^{o}/oo$) and euryhaline III (seawater - < 3 $^{o}/oo$). The salinity classification assigned to each species and the percentage of 0+ year old seine and set net caught fish in the catch is presented in Tables 6 and 7.

Size composition data for all those species where there was sufficient animals taken to enable some trends to be established are presented in Figures 3 - 22. The data for some species taken by set nets are possibly biased toward the size range of fish able to be taken by those nets, and as such may not be truly representative of the size range of fish present in the estuary.

The results of the larval fish sampling and trawling segments of the programme are summarised in Tables 8 and 9 respectively. A summary of the crustacean data collected during the study is presented in Table 10.

The total number of fish taken at all the set net sampling stations in the Channel area is presented in Table 11. Table 12 shows a comparison of catches from a day and night seine haul at Station 98. The high percentage of 0+ yr old fish caught at Station 02 is presented in Table 13. The number of species recorded from each of the sampling areas during each of the seven sampling trips is presented in Table 14. All available natural history data related to spawning of the more abundant species is summarised in Table 15.

An annotated checklist of each species, with details of the number caught, length range as total length (T.L.), seasonal relative abundance (for more abundant species), occurrence (of less abundant species) and distribution throughout the estuary, range of salinity, temperature and dissolved oxygen encountered, spawning condition † and whether the species was represented in the samples as eggs, larvae, juvenile or adult is presented in Appendix 1.

Data collected during non-routine sampling is summarised in Appendix 2.

* Seawater salinity is considered to range between 35 $^{o}/oo$ - 40 $^{o}/oo$.

† Macroscopic observations of gonad condition of all species caught were recorded whenever possible.

Results of a seine net efficiency experiment are presented in Appendix 3.

To enable the comparison of fish populations present in the estuary in two consecutive winters, a further sampling trip was undertaken during July 1975.

Details of techniques used and results obtained from this trip are presented in Appendix 4. For the sake of continuity, the length frequency distribution of the different species caught during the survey have been added to the data collected in the initial one year survey (Figures 3-22).

V DISCUSSION

A Sampling techniques

Depending on its particular mode of behaviour, a fish species is usually sampled from protected estuarine and inshore marine environments, by means of either a seine net, set (mesh) net, or a small otter trawl. (McHugh, 1967; Richards and Castagna, 1970; Derickson and Price, 1973; Haedrich and Haedrich, 1974).

In an attempt to ensure that all species which occurred in the Blackwood River estuary were adequately sampled, all three of these gear types were used in the fish sampling programme. However, each type of gear had its particular limitations.

The seine net could only be hauled effectively over a relatively firm flat bottom, free from protrusions i.e. over flat sandy or sparsely weeded bottoms. Densely weeded or rocky bottoms, strong currents, tides or river flow reduced the effectiveness of the net. In a blind* haul, this net was usually best able to catch the less mobile species, including juveniles of a great many species which were recorded from the estuary (Figure 3-22). Provided that the mesh size of the seine net pocket or "bunt" was small enough to retain the smallest individuals of each species, and fish do not escape by jumping the cork-line or burrowing under the lead-line, this net was capable of catching the complete size range of each species of fish and commercial crustaceans present in the estuary.

* "blind" used in this sense means that the haul was made in an area where fish were likely to be, without actually knowing that a school or shoals of fish were present.

Set nets could be used effectively over most bottom types, the exception being areas covered with sunken trees and branches, such as those found in the riverine areas of the estuarine system. Provided they were correctly positioned and securely anchored, set nets were able to fish effectively under conditions of relatively strong currents generated by tidal action or river flow. However it was apparent that the size of the fish that were caught were limited by both mesh size and ply (diameter of the netting twine). Clearly a certain mesh size net can only catch (gill) a certain size range of fish (Gulland, 1975). However fish both larger and smaller than the size range able to be caught conventionally (i.e. gilled) by a given mesh size can tangle or "bridle" in the net constructed of very fine ply. Increasing the ply was found to reduce the chance of fish tangling of "bridling". Colour of the net is also important, nets of some colours being more easily visible to fish than others. Therefore provided the appropriate mesh size, ply and colour is chosen, set nets are usually capable of catching a relatively broad size range of a number of species of fish in areas where seine nets cannot be operated.

The otter trawl was considered to be more suitable than the seine or set nets for sampling fish and crustaceans in the deeper areas of the estuary, particularly the Channel area (3), which was subjected to strong tidal action. However catch rates achieved in exploratory trawls were very poor (Table 9). Assuming that the gear was functioning properly, and capable of catching fish in the deeper areas, then from the results, it would appear that at the times of trawling, there were very few fish and commercial crustaceans in the deeper areas of the estuary.

Seine and set net catches on the shallow banks in the Channel area during the months when trawling was attempted (Tables 4(a) and (b)) were substantially greater than the trawl catches. Station 25, with an average depth of approximately 2 metres could be considered to be representative of the deeper channel area. Set net catches from this station were substantially lower than set net catches from either of the other set net stations in the channel (Table 11).

On the basis of the results obtained for the months July, September, November, January and March, the seine and set nets were chosen as the regular sampling gear, and the regular sampling stations were those located on the shallow banks (<2 m mean low water) (Table 1).

The relative contributions of the seine and set nets to the total catch of the more abundant species are presented in Figures 3-22. As planned, the seine nets caught mostly smaller and the set nets larger individuals of the species that were present in the estuary.

The species composition and catch rates of the seine did vary between day and night (Table 12). However because of the considerable practical difficulties associated with netting at night, all seine netting was done during the day.

Many fish, particularly the demersal species, usually moved onto the shallow banks to feed with the incoming tide. Therefore whenever possible, seine nets were hauled on the incoming to high tide.

Whereas one seine haul usually takes all fish present in the area swept by the net, set nets must rely on fish swimming into the net and becoming meshed. Therefore desirable netting conditions were those under which the visibility of the set net to fishes was at a minimum.

The larger more mobile fish such as Australian herring and tailor are usually actively feeding throughout the night. It was also during this time that the nets were assumed to be less visible to these fish. Therefore all mesh nets were set just before sunset and retrieved just after sunrise the following day.

The three species of commercial crustaceans recorded from the estuary (Table 3) were all able to be taken by the seine net if present in the area swept by the net. However all three species are relatively inactive during the daylight hours, tending to bury in the bottom sediments. In situations where the lead-line of the seine did not disturb the bottom sediments, all three species may have been able to escape capture.

Only the two species of crabs were able to be caught in the set nets by tangling in the mesh. The fact that set nets fished during the darkness hours, when the crabs were most active resulted in the greater number of crabs taken by means of this technique (Table 10).

Like the seine net, the trawl was able to catch all three crustacean species successfully (Table 10).

B. Relative abundance

The estimation of indices of relative abundance of each species within each sampling area (Table 1, Figure 1) required that the following two assumptions be satisfied.

Firstly, that each species of fish was randomly distributed throughout each of the sampling areas at the time of sampling each month. For non-schooling fishes, this implied that individuals were randomly distributed throughout each area. However for schooling species, this assumption implies a random distribution of individual schools, and random mixing of individuals between schools present in the area.

The distribution of juveniles of a number of species, such as *R. sarba, S. punctata* and some of the Gobiid species, which appear to have a preferred habitat of *Ruppia maritima,* rather than displaying a strong schooling behaviour, is likely to be random within that habitat. However it is doubtful whether the habitat is randomly distributed throughout the sampling area.

Larger individuals of a number of species such as *S. schomburgkii* and *A. forsteri* are known to display a marked schooling behaviour. It is possible that the distribution of these schools is random over the whole sampling area. There are some data available to show that interschool mixing of individuals does occur in *S. schomburgkii* (Lenanton, 1970) and *A. trutta esper* (Walker, pers. comm.) populations. However the available information does not indicate whether the mixing was random or non-random.

Secondly, the catchability of each species of fish at all stations was assumed to remain constant throughout the year. Given that a particular species was available i.e. the species was present in the estuary, then the main factors which determine the catchability of a species are the accessibility and vulnerability of that species (F.A.O., 1960).

A species is accessible to a seine net if it is located within the range of operation of that particular unit of gear i.e. a whiting is accessible to a seine if it is distributed over relatively flat bottom which can be fished with the seine net. However, at the instant of time of the seine haul, a whiting is only accessible if it is located within the swept area of that haul. The fish is then vulnerable if it is able to be caught by the particular unit of gear i.e. if the mesh size of the seine net is small enough to prevent fish swimming through the net, or the lead-line of the net disturbs the bottom in such a way so as to prevent the whiting burying in the bottom and escaping.

It was suspected that the presence of dense weed in a hauling area decreased the efficiency of the seine net for a number of species i.e. decreased the vulnerability and hence catchability of those species. An experiment was performed to test this hypothesis (Appendix 3). The results of this experiment showed that most of the larger individuals were caught in the first haul, but that only a small percentage of the smaller individuals, particularly *R. sarba* (11%), *A. forsteri* (14%), *Atherinosoma spp.* (<1%), *F. lateralis* (11%), *F. tamarensis* (< 1%) and *L. olorum* (< 1%) were caught in the first haul.

It is likely that these fish avoided capture by hiding in the seagrass thereby allowing the lead-line of the seine to pass over them.

The catchability of each species at each station was not determined. However, it would seem reasonable to assume that the catchability of the above species in a densely weeded area was extremely low, compared with their catchability in an area with a clean sandy bottom.

The density of seagrass varied considerably throughout the year (Congdon and McComb, 1974). Therefore it is reasonable to assume that the catchability of seine caught species varies seasonally, and between stations at any one instant of time.

A species is accessible to a set net if it lies within the range of operation of a particular unit of gear i.e. an Australian herring is accessible to a set net if it is located within the estuary. However the fish is only vulnerable if it is able to be caught i.e. conventionally meshed or "bridled" in the gear.

Given that the structure of the net i.e. mesh size, ply, and colour is constant over the year, then the main factors which affect the vulnerability of the fish are water clarity, which influences the ability of the fish to see the net, and fish behaviour. For example, the lower winter water temperatures may reduce the level of activity of the fish thereby reducing the chance of them swimming into a net.

Therefore the vulnerability and hence catchability of the species taken by set nets would be likely to vary seasonally, but probably remain relatively constant between stations at any one instant of time.

In view of the foregoing discussion, the mean catch per shot calculated for all species from each sampling area can provide at best, extremely gross indices of relative abundance. Therefore this discussion will be confined to a comparison of the indices of relative abundance on an annual basis for all species caught by regular sampling techniques during the study. However the seasonal mean catch per shot for each sampling area for the fifteen more abundant species has been summarised graphically in Appendix 1. For the less abundant species, seasonal occurrence at each sampling station has been included in preference to the estimated index of relative abundance of each species (Appendix 1).

Indices of relative abundance calculated as the average from a number of stations within a sampling area, was believed to have provided better estimates of the relative abundance of species within that area than estimates obtained by averaging catches from repetitive samples taken from only one station within the sampling area. This fact was taken into consideration when designing the sampling system.

Indices of abundance obtained for a given species by the two units of sampling gear were quite different, because the seine net took all the fish in a swept area at one instant of time, while a set net fished all night, relying on fish swimming into it and being caught. Therefore without some basis for the intercalibration of the two methods, the index of relative abundance of a given species taken by both techniques cannot be compared. However the indices of relative abundance of all species taken by one method were able to be compared.

There were too few commercial crustaceans taken in the survey to allow the calculation of indices of relative abundance. Biomass estimates were not attempted because of the inprecise nature of the data. However the total catch in numbers (Tables 4(a) and (b)) and weight (Tables 5(a) and (b)) is presented to facilitate possible future attempts of biomass calculation.

C Factors affecting usage of the estuary

(i) Salinity

The various species taken were arbitrarily considered as either more or less abundant on the basis of whether the index of relative abundance for those species caught by seine or set net was greater or less than 1.0 respectively.

All the more abundant species taken during the survey were to some extent euryhaline, the most abundant of these displaying the greatest degree of euryhalinity (Table 6). It should be noted that the classification of each species as a salinity type was based only on the records of individuals of the different species from waters of known salinity over the period of the survey. In the cases where the percentage of juveniles of some species was very high (Tables 6 and 7), the salinity type would obviously relate primarily to the juveniles of that species.

Physiological experiments have not been conducted to determine whether the species are really able to osmoregulate in order to accomodate the range of salinity from which they were recorded. However at the very least they must have a temporary physiological tolerance to these salinities.

Of the group of seventeen more abundant species (Table 6), only *M. butcheri, F. tamarensis* and *A. bifrenatus* appear to be true estuarine species i.e. they were only recorded from within the estuary. *Atherinosoma sp.* * and *L. olorum* have both been recorded from inland saline waters throughout south-Western Australia (Mutton, 1973). The remaining thirteen species have all been recorded by the author from marine embayment situations. As expected, the less euryhaline and stenohaline-marine species comprised most of the group of less abundant species (Table 7). Most of these species were present in the lower estuary only when salinities approached those of seawater. A number of fish in these groups could well be the calm water species referred to by Day, 1967, i.e. those species which utilise the estuary when the salinities are approaching those of seawater, in the same way as they would utilise a protected marine embayment.

T. bostocki was the only stenohaline-freshwater species recorded during the survey. This species was taken from freshwater in the upper reaches of the estuary during the July 1974 flood.

All the estuarine and inland species recorded must be able to cope with a wide range of salinities and temperatures. *L. olorum* has been shown to be a more efficient osmoregulator than almost any other fish recorded in the literature (Mutton, 1973). It was able to tolerate rapid dilution of its surrounding medium, but it would not tolerate rapidly increasing salt concentrations. In this respect it is well adapted to living in inland waters which are subjected to rapid dilution after periods of heavy rainfall. Because *Atherinosoma sp.* was collected from the same regions as *L. olorum* (Mutton, 1973), it is likely that this species is also a strong osmoregulator. No physiological data is available on the salinity and temperature tolerance of the other three estuarine and inland species.

* *Atherinosoma rockinghamensis* and *Atherinosoma edelensis* have both been recorded from the Blackwood River estuary. Because these two species were so difficult to tell apart, they were grouped into the one genus *Atherinosoma spp.* in this study. Mutton, (1973) has indicated that he has recorded one *Atherinosoma* species from inland waters. However he has been unable to name the species. It is probable that he has either one or the other of the above two species. It is possible but unlikely that he has collected both, and been unable to tell them apart. The above two fish are the only *Atherinosoma* species recorded from south Western Australia.

Although there is little available data on the thirteen other more abundant species, it is likely that of these species the *Mugilidae* and *S. schomburgkii* are best able to cope osmotically with the extremely low winter salinities in the estuary. *Mugil cephalus* can tolerate salinities from zero to 75 °/oo, (Thomson, 1966), and fry can tolerate a change in salinity from seawater to freshwater (Thomson, 1966). *S. schomburgkii* has been recorded from salinities as high as 54 °/oo (Lenanton, in prep.). It is likely therefore, that they would be able to cope osmotically with very low salinities. The range of salinities recorded in the Blackwood River estuary over the year was <1 - 39.6 °/oo.

The more marine fish respond in a number of ways to salinity change of their external environment (Green, 1968).

A response observed in a *S. punctata* population is of interest.

In Wilson Inlet, further east along the south coast of Western Australia, 1+ and 2+ yr old fish trapped in the Inlet during the winter months by the closure of the estuary mouth to the ocean responded to a long exposure (≃ 6 months) at low salinities (≃ 10 °/oo) by reducing their surface permeability by secreting a thick layer of mucous over their bodies. In an open estuary, however, this situation would probably not have happened, because the fish would have been able to move into the ocean to avoid the low salinity. In this respect it should be noted that 1+ yr old and older *S. punctata* were rarely taken from the Blackwood River estuary.

Although the intention of this section is not to discuss at length the mechanisms of osmoregulation in estuarine teleosts, it is of interest to note that Kowarsky (1973) established that the plotosid *C. macrocephalus* in its efforts to cope with salinities between 3 and 35 °/oo may utilise two extra-branchial pathways of sodium exchange with the environment; the urinary tract and the dendritic organ located near the anus.

The winter freshwater influx had varying effects on the distribution of fish throughout the estuary.

Some minor flooding in May 1974, lowered salinities a little (Figure 2) resulting in the stenohaline-marine group of animals leaving the estuary.

The major flood for the year (July 1974), forced the euryhaline I group of species down the estuary into the ocean, and members of the euryhaline II group towards the mouth of the system, notably Swan Lakes and the Deadwater (Figure 23). This region of the estuary was the only area not to become entirely fresh (Figure 2), and as such it provided an "overwintering habitat" for species which may normally have gone to sea, e.g. *A. georgianus*.

The distribution of the euryhaline III group of species throughout the estuary was virtually unchanged over the year, with the exception of July, when the species tended to be distributed more towards the mouth in response to the powerful freshwater influx.

During the months following the major July flood, progressively higher salinities and temperatures were gradually re-established throughout the estuary (Figure 2). In response to this trend, euryhaline II group of fish gradually became distributed farther upstream, and the euryhaline I and stenohaline-marine groups became established once again in the lower estuary. These latter two groups were virtually never recorded farther upstream than the lagoonal area.

Seasonal salinity and temperature fluctuations in Swan Lakes were more extreme than those in the Deadwater (Tables 2(b) and (c)). This is reflected by consistently fewer species being recorded from Swan Lakes.

The data from the July 1975 survey showed that up until that date the winter flush was not as strong as the July flood of the previous winter. Higher salinities and temperatures, particularly in the lower estuary maintained populations of less euryhaline fish and crustaceans which were not recorded from the estuary in the July 1974 sampling trip (Appendix 4).

(ii) Temperature

Temperature is also an important factor affecting the abundance and distribution of fish between estuaries and within a given estuary (Derickson and Price, 1973; Blaber, 1973; and Targett and McCleave, 1974). For a fish to be able to live successfully within an estuary, it must have the ability to cope with extreme fluctuations in temperature, both diurnally and seasonally.

As a general rule, the estuarine and inland species tend to be more eurythermal, while the basically marine species are usually stenothermal (Nikolsky, 1969). Therefore the extreme fluctuations in estuarine water temperatures of the Blackwood River estuary (Tables 2(a) and (b)) may prevent some of the more marine fish from living in this estuary. The range of temperatures recorded in the Blackwood River estuary over the year was 9.5 - 28.9^{o}C.

There appears to be a relationship between osmoregulation and temperature in some fishes which could affect their distribution and abundance in estuaries. The thermal resistance of some fish is increased if the osmotic stress is lowered or removed (Fry, 1957). The sodium efflux rate in *L. olorum* is increased with increasing temperature (Mutton, 1973). In some fishes, respiration and osmoregulation are more difficult in waters of reduced salinity, and these processes are a function of temperature (McHugh, 1967).

(iii) Oxygen

Dissolved oxygen is another factor which might influence the abundance and distribution of estuarine fish. In the estuarine environment generally, levels between 5 and 8 mg/l are considered most satisfactory for growth and survival. Levels between 3 and 5 mg/l are not lethal but may have effects such as reducing swimming speeds and changing blood serum constituents (Perkins, 1974). Levels below 3 mg/l i.e. 2 mg/l may ultimately result in death (Doudoroff, 1957).

The range of dissolved oxygen recorded from the Blackwood River estuary during the year was 3.24 to >10 mg/l. However levels were mostly between 6 and 8 mg/l which was perfectly adequate for all fish of the estuary. Only one instance of very low dissolved oxygen was detected. This was during July at hydrological station 2 in the Deadwater, the bottom dissolved O_2 fell to 3.24 mg/l as a result of surface low salinity water flowing over and trapping for some months a small pocket of higher salinity water on the bottom in one of the deeper sections of the Deadwater.

However diurnal fluctuation in dissolved oxygen particularly in the summer on shallow banks covered with seagrass and macrophytic algae may cause fish in these areas some physiological stress. In January and March 1975 dissolved oxygen levels greater than 10 mg/l were recorded during the daytime at some stations in the Deadwater and Swan Lakes. Presumably during the evening, when the plants were respiring, the dissolved oxygen levels would fall considerably. This was the author's experience in a similar situation in one other south coast estuary (Walpole Inlet) where over 24 hours during February 1973 the dissolved oxygen levels fluctuated between 2.1 mg/l during the very early morning to 8.3 mg/l during late afternoon. Meagher (1971) also reported a similar phenomonen in the Leschenault estuary during the summer months.

(iv) Other factors

There are many other factors which have been shown to influence the fish behaviour and distribution. They include bottom sediment type, vegetation, current velocity (Derickson and Price, 1973), suspended solids and particulate matter in the water column (Doudoroff, 1957; Sherk 1972; Perkins, 1974; Hoss Coston and Schaaf, 1974; Lenanton, 1974b,), ph. and various pollutants (Doudoroff, 1957; Perkins, 1974).

D Spawning and early stages

From length frequency data and gonad data, it has been determined that of the fifteen more abundant species, only the Mugilid species and *Sillago punctata* were winter spawners. The majority of the remainder spawned during spring and early summer, while one species, *A. georgianus*, spawned during autumn (Table 15). *M. butcheri* spawned entirely within the estuary. The few records of this species from the ocean in Western Australia, would appear to be the result of fish having been washed out of estuaries under conditions of extreme flooding.

S. schomburgkii and *A. forsteri* have both been recorded from the estuary with gonads in an advanced stage of development and it is possible that these species could have spawned within the estuary. However it is likely that they also spawn outside the estuary, perhaps in protected marine embayments. With the exception of the Atherinid and Gobiid species, the remainder of the more abundant species, are all thought to spawn exclusively in the ocean.

Data from plankton tows (Table 8) tended to add support to the above conclusions.

Juvenile Atherinids and Gobiids dominated the catches of the 1 mm mesh plankton net, particularly in the lower estuary during July. The freshwater flush may have concentrated the juveniles in this area of the estuary. Apart from the occasional record of Mugilid species and pelagic fish eggs, the only other notable capture from this net was a number of juvenile *H. vittatus* taken at the 3 metre halocline at Stations 13 and 82 during November. These fish appeared to be feeding on zooplankton (copepods) which were also concentrated at the halocline.

The catches from the 0.2 mm net, particularly from deeper tows, revealed considerable numbers of larval Gobiids and Atherinids over the spring and early summer months. The only other organism which was reasonably abundant was a species of fish, tentatively identified as a Sillaginid. In view of the fact that *S. schomburgkii* was recorded from the estuary with gonads in an advanced stage of development, it seems likely that the larvae were those of *S. schomburgkii*.

A number of pelagic eggs were recorded in December, again mostly from the deeper tows. The majority of these eggs were quite large (≃ 1.0 mm diameter). The only eggs which could be tentatively identified from using the only key available for the identification of Australian and New Zealand pelagic fish eggs (Robertson, 1974) were oval eggs, thought to be those of *E. australis fraseri*.

Assuming the plankton tows provided representative samples of the larval fish present in the estuary, then it is likely that recruitment of most young fish into the estuary is achieved mainly by the 0+ yr old fish actively swimming into the estuary rather than them being passively transported in as eggs or larvae.

Significant proportions of the dominant species i.e. members of the families *Sillaginidae*, *Mugilidae*, and *Sparidae* were represented in the catches as 0+ year old fish (Table 6). One notable exception was the sparid *M. butcheri*, of which 0+ year old individuals occurred mainly in the protective riverine margins, but were not accessible to the seine or vulnerable to the set net sampling gear.

The greatest abundance of juveniles was recorded from the shallow, seagrass-covered (*Ruppia maritima*) banks of the Deadwater (Table 13). The fact that such a large proportion of the total number of species caught were represented as 0+ year old fish (Tables 6 and 7) emphasises the role played by the estuary as a nursery area.

This has been shown to be the case in many other estuaries throughout the world (Day, 1967; McHugh, 1967; Derickson and Price, 1973; McErlean, O'Conner, Mihursky and Gibson, 1973; Wallace, 1973). It has been established that juveniles of a number of species, particularly the essentially marine species *Sillago punctata* and *Rhabdosargus sarba* are present in the estuary all year, while the adults are rarely taken within the estuary. Therefore, physiologically these juveniles are able to tolerate this extreme physical environment (particularly the low winter salinities), and can probably do so better than the adults. This ability of the juveniles may be a mechanism which could generate a higher rate of survival of the young of these species by protecting them from potential predation by fish which are less able to cope with these hydrological extremes. There is some evidence in the literature to show that juveniles are better able to cope with extremes in salinity than adults. Blaber (1974a) showed that juveniles of the South African *Rhabdosargus holubi* are particularly strong osmoregulators, and were much more abundant in estuaries than adults. Although the osmoregulatory ability of the adults was not tested, it was established they needed to remain in the ocean to satisfy their food requirement (Blaber, 1974(b)). Holliday and Blaxter (1961), found that the herring *Clupea harengus* could tolerate salinities between 6 and 40-45 $^{o}/oo$. They also found there were more kidney glomeruli per unit surface area of the 0+ yr old fish than of the adults, and suggested this may have had the function of helping to increase the water excretion rate of the 0+ yr old herring, when they were present in water of low salinity in the estuarine environment.

The available data also supports the theory that the threat from predators is low in winter. Of the 56 fish species recorded from the Blackwood River estuary, only *C. georgianus*, *P. jenynsii*, *P. saltator*, *S. antarctica* and *Platycephaulus* sp. pose a threat to juveniles as potential predators, because over 50% of the food found in their stomachs was fish (Wallace, 1975a). However none of these species was very abundant in the estuary during the period when salinities were low.

E Crustaceans

On the basis of their recorded distribution throughout the estuary, none of the commercial crustaceans appeared to be as well adapted to change as the most euryhaline fishes e.g. Mugilidae taken during the survey. They all appeared to be forced out of the estuary by the major winter floods of July (Table 10). The eastern Australian estuarine prawn *Metapenaeus bennettae* (formerly *M. mastersii*) is an efficient osmoregulator and a hardy euryhaline animal (Dall, 1964). Therefore it is likely that its western counterpart *M. dalli* exhibits a similar osmoregulatory ability. However, whether or not *M. dalli* is able to cope with the extremely low winter salinities, other factors such as low water temperatures and strong current velocities during the flood may have forced this species out of the estuary.

P. pelagicus is an osmoregulator below seawater salinity (35 $^{o}/oo$). At salinity of 9 $^{o}/oo$, it maintained its internal osmotic concentration equivalent to 18 $^{o}/oo$. It can tolerate salinities between 11 and 53 $^{o}/oo$ for sustained periods (Meagher, 1971). However physiologically it would be unable to cope with a winter flush of the severity of the one experienced in the Blackwood River estuary during 1974. There appeared to be no published material reporting the physiological tolerance of *O. australiensis* to physical environmental conditions such as those experienced in the Blackwood River estuary.

The possibility does exist that crustaceans may have been present in the estuary during July, even though they were not recorded. The low winter water temperatures and salinities may have caused these animals to "hibernate" over the winter months by burying in the bottom sediments. Under these conditions, rates of metabolism and respiration would be expected to be very low. Although the water column was fresh the interstitial water can have salinities of ≈ 5 $^{o}/oo$ (Hodgkin, pers. comm.) which may be enough to enable these animals to survive.

VI SUMMARY

In summary, the more euryhaline species were dominant in the estuary throughout the year. The less euryhaline species were most abundant during the summer months when salinities were approaching those of sea water. Only *M. butcheri* and members of the *Gobiidae* and *Atherinidae* families were believed to have spent their entire life cycle within the estuarine system. None of the remaining species utilised the estuary as a permanent habitat, but rather as a protective feeding habitat, and in the case of *S. schomburgkii* and *A. forsteri*, possibly as a spawning habitat. Most of these species were largely represented in the area as juveniles, therefore the estuary was primarily a juvenile protective feeding habitat. However adults of a number of species utilised the area in a similar way. Recruitment of juveniles into the estuary was mainly by means of 0+ yr old fish actively swimming into the area.

Superior physiological tolerance of the extreme estuarine environment by juveniles is suggested as a mechanism which may contribute toward their survival. This ability may protect juvenile fish from potential predation from other fish, however they remain extremely susceptible to the destructive activities of man.

Most of the species recorded from the Blackwood River estuary have been recorded from other south coast estuaries (Lenanton, 1974). Therefore it is likely that there are oceanic stocks of many of the species that have been recorded from our estuaries. Evidence has been presented in this paper to show that the estuary is utilised by these species principally as a nursery area. However what is not known is whether there are additional nursery habitats for these species outside the estuary i.e. marine embayments and other protected areas, and if so, the nature and extent of these areas.

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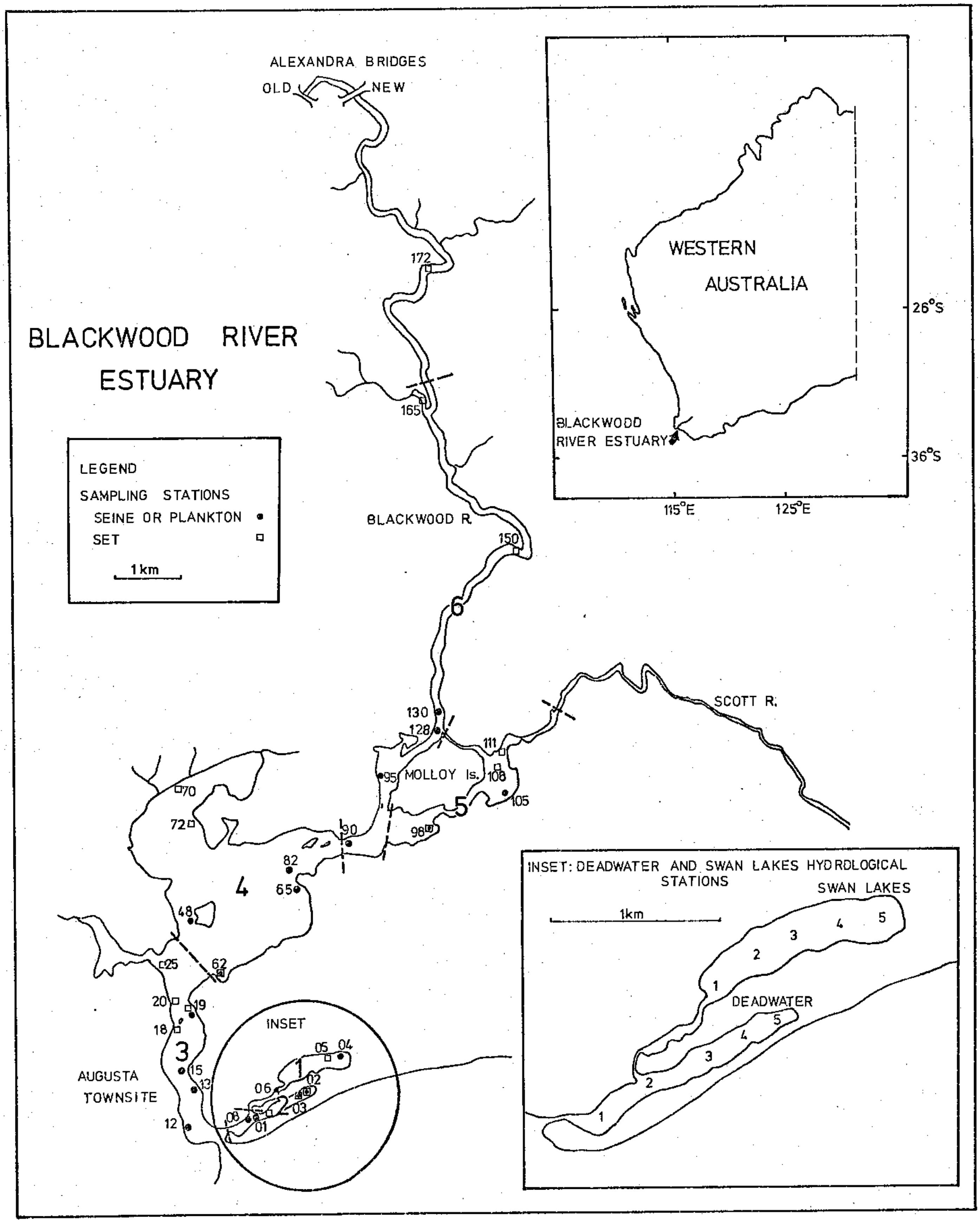


Figure 1 The location of all sampling stations throughout the Blackwood River estuary.

TABLE 1 DETAILS OF THE SAMPLING STATION PARAMETERS IN EACH OF THE FIVE SAMPLING AREAS OF THE BLACKWOOD RIVER ESTUARY.

Sampling Areas		Area (ha) of shallow banks (<2m mean ~~low water level~~)	Sampling Stations		Est. dist. upstream (km)	Depth * range (m)	Dominant Vegetation
			Seine	Set			
Swan Lakes	(1)	40	04		2.8	0.3 - 1.0	*Ruppia* sp.
			06 †	05 s	2.4	0.8 - 1.5	*Ruppia* sp.
Deadwater	(2)	27		01 s	1.0	1.5 - 2.0	*Ruppia* sp.
			02	02 s	2.0	0.4 - 1.6	*Ruppia* sp.
			03	03 s	1.4	0.3 - 2.5	*Ruppia* sp.
Channel	(3)	125	13		0.8	0.5 - 1.1	*Zostera* sp. *Rhizoclonium* sp.
				18 s	2.2	0.5 - 1.0	Very little vegetation
			19	19 s	2.2	0.5 - 0.8	*Ruppia* sp.
				25 s	3.0	1.0 - 4.0	*Ruppia* sp.
Lagoon	(4)	481	48		4.0	0.4 - 1.0	*Ruppia* sp.
			62	62 s	3.8	0.5 - 1.0	*Ruppia* sp.
			65		5.4	0.6 - 1.4	Very little vegetation
				70 s	6.0	0.6 - 1.0	Very little vegetation
				72 s	5.4	0.3 - 1.0	Very little vegetation
Basins	(5)	54	98		8.2	0.5 - 0.6	Very little vegetation
			105		9.8	0.4 - 1.3	*Lamprothamnium* sp.
				108 s	9.4	0.5 - 1.5	*Lamprothamnium* sp.
				111 s	10.0	0.3 - 1.0	Very little vegetation
River	(6)	16	95		8.2	0.5 - 1.3	*Potamogeton* sp.
				150 s	13.4	1.2 - 1.8	*Potamogeton* sp.
				165 s	16.6	0.8 - 3.0	*Potamogeton* sp.

* A combination of astronomic and barometric factors controlled water level within the estuary.
† Included as a regular sampling site only during March 1974.

TABLE 2 (a) HYDROLOGICAL RECORDS FROM SEINE NET SAMPLING STATIONS OF THE BLACKWOOD RIVER ESTUARY, FROM MARCH 1974 TO MARCH 1975. (WHERE SECCHI READING IS THE SAME AS THE DEPTH, THE DEPTH OF EXTINCTION OF THE DISC WAS NOT REACHED).

Sampling Station		† March			† May			July					September				
		Temp (°C)	Sal (°/oo)	Depth (m)	Temp (°C)	Sal °/oo	Depth (m)	Temp (°C)	Sal °/oo	Oxygen (mg/1)	Secchi (m)	Depth (m)	Temp (°C)	Sal °/oo	Oxygen (mg/1)	Secchi (m)	Depth (m)
04	Surface	*17	*36		31.8	31.3	0.4	12.0	3.5	7.21	-	0.9	16.3	17.1	6.77	0.4	0.4
	Bottom	-	-		-	-		12.5	*3.5	6.99			16.3	17.1	6.77		
02	Surface	17.4	36.8	1.0	18.0	30.0	0.4	12.0	3.1	7.08	-	0.9	18.4	22.6	7.30	0.5	0.5
	Bottom				-	-		12.0	*3.1	7.80			18.4	22.6	7.18		
03	Surface	+			+			12.0	1.6	5.81	0.3	2.4	*16.7	*14.4	*7.04	*1.9	*2.0
	Bottom							12.0	6.7	6.99			*17.7	*30.2	*8.57		
13	Surface	22.6	34.4	0.8	21.0	28.9	0.7	11.2	<1 (0.5)	7.27	-	1.0	15.4	4.6	7.09	0.5	0.5
	Bottom	-	-		-	-		10.0	<1 (0.5)	7.78			15.4	4.6	7.09		
19	Surface	20.5	35.4	0.8	+			9.5	<1 (0.5)	8.80	0.2	0.6	17.8	7.7	-	0.5	0.5
	Bottom	-	-	-				9.5	<1 (0.5)	8.64			17.8	7.7	-		
48	Surface	*23	*33	-	16.5	20.3	0.4	11.0	1.4	6.39	0.1	0.9	17.7	10.5	7.12	0.4	0.4
	Bottom	-	-		-	-		11.0	1.4	6.54			17.7	10.5	7.12		
62	Surface	23.0	33.4	-	16.0	23.5	1.0	+					17.6	5.6	-	0.7	0.7
	Bottom	-	-	-	-	-							17.6	5.6	-		
65	Surface	*22.0	30.8	-	*16.0	*23	-	+					16.1	1.4	8.27	0.9	1.4
	Bottom	-	-		-	-							15.5	1.7	7.28		
98	Surface	22.0	28.5	-	16.5	8.4	0.6	10.0	<1 (0.5)	6.56	0.3	1.2	*15.0	* 0.5	*6.98	-	-
	Bottom	-	-		-	-		10.0	<1 (0.5)	6.10			*15.0	* 0.5	*6.34		
105	Surface	21.0	25.8	-	14.0	9.9	0.5	11.5	<1 (0.5)	7.74	0.25	1.2	15.3	0.5	6.94	0.8	0.8
	Bottom	-	-		14.0	9.5		11.0	<1 (0.5)	7.46			15.3	0.5	6.94		
95	Surface	25.5	26.3	-	13.0	9.3	1.0	10.5	<1 (0.5)	7.54	0.1	1.2	15.1	1.3	7.35	1.0	1.0
	Bottom	-	-		-	-		11.0	<1 (0.5)	7.31			15.2	1.4	7.20		

* Estimated values

† Oxygen and Secchi depth were not recorded during March and May, 1974.

\+ A seine net sample was not taken.

\- No data recorded.

TABLE 2 (a) cont. HYDROLOGICAL RECORDS FROM SEINE NET SAMPLING STATIONS OF THE BLACKWOOD RIVER ESTUARY, FROM MARCH 1974 TO MARCH 1975. (WHERE SECCHI READING IS THE SAME AS THE DEPTH, THE DEPTH OF EXTINCTION OF THE DISC WAS NOT REACHED).

Sampling Station		November					January					March				
		Temp. (°C)	Sal. °/oo	Oxygen (mg/1)	Secchi (m)	Depth (m)	Temp. (°C)	Sal. °/oo	Oxygen (mg/1)	Secchi (m)	Depth (m)	Temp. (°C)	Sal. °/oo	Oxygen (mg/1)	Secchi (m)	Depth (m)
04	Surface	23.0	30.3	7.35	0.4	0.4	25.6	39.6	8.69	0.3	0.3	22.6	36.2	8.15	0.5	0.5
	Bottom	23.0	30.3	7.35			25.6	39.6	8.69			22.6	36.2	8.15		
02	Surface	21.8	30.2	6.76	0.5	0.5	20.5	36.0	5.69	1.6	1.6	19.3	35.3	7.70	1.1	1.1
	Bottom	21.8	30.2	6.76			20.2	36.3	5.50			18.9	35.3	8.21		
03	Surface	19.3	30.7	8.41	0.5	0.5	22.0	36.4	7.50	0.8	0.8	21.1	35.4	7.87	0.3	0.3
	Bottom	19.3	30.7	8.41			21.3	36.2	6.55			21.1	35.4	7.87		
13	Surface	18.0	35.4	6.77	0.5	0.5	23.8	35.6	6.08	0.5	0.5	22.2	35.6	5.84	0.6	0.6
	Bottom	18.0	35.4	6.77			23.8	35.6	6.08			22.2	35.6	5.84		
19	Surface	22.5	12.7	7.25	0.5	0.5	23.0	30.6	7.13	0.5	0.5	19.7	32.5	6.19	0.8	0.8
	Bottom	22.5	12.7	7.25			23.0	30.6	7.13			19.9	32.8	6.16		
48	Surface	23.2	21.6	6.49	0.4	0.4	23.0	29.2	5.69	0.5	0.5	20.4	32.5	5.89	0.5	0.5
	Bottom	23.2	21.6	6.49			23.0	29.2	5.69			20.4	32.5	5.89		
62	Surface	20.0	34.0	6.55	0.5	0.5	21.1	29.6	4.79	0.5	0.5	19.8	33.1	5.06	0.8	0.8
	Bottom	20.0	34.0	6.55			21.1	29.6	4.79			19.7	33.1	5.18		
65	Surface	18.1	6.0	6.81	1.0	1.0	26.8	27.0	5.98	0.7	0.7	23.0	30.4	6.61	0.6	0.6
	Bottom	18.1	6.8	6.80			26.7	27.0	5.99			23.0	30.4	6.71		
98	Surface	21.2	3.7	7.32	0.4	0.5	25.3	26.6	8.39	0.6	0.6	21.2	27.9	7.77	0.6	0.6
	Bottom	21.2	3.7	7.32			25.3	26.6	8.39			21.0	27.8	7.91		
105	Surface	24.5	1.2	7.99	0.4	0.4	28.9	23.1	6.84	0.5	0.5	17.6	24.5	4.99	0.8	0.8
	Bottom	24.5	1.2	7.99			28.9	23.1	6.84			17.6	24.5	4.99		
95	Surface	20.6	3.1	6.80	0.3	0.5	26.1	20.2	5.18	0.5	0.5	19.3	23.6	5.19	0.8	0.8
	Bottom	20.6	3.1	6.80			26.1	20.2	5.18			19.3	23.6	5.19		

TABLE 2 (b) HYDROLOGY STATION DATA RECORDED FROM SWAN LAKES BETWEEN MARCH 1974 AND MARCH 1975 DURING THE BLACKWOOD RIVER ESTUARY STUDY.

Station		*March				May				July				September			
		Temp. (°C)	Sal. (°/oo)	Oxygen (mg/1)	Depth (m)	Temp. (°C)	Sal. (°/oo)	Oxygen (mg/1)	Depth (m)	Temp. (°C)	Sal. (°/oo)	Oxygen (mg/1)	Depth (m)	Temp. (°C)	Sal. (°/oo)	Oxygen (mg/1)	Depth (m)
1	Surface	17.5	36.7	†	0.3	15.0	31.79	†	0.9	13.5	2.32	7.01	2.0	15.72	14.46	7.30	0.8
	Bottom					15.25	31.99			11.75	2.95	7.27		15.72	14.46	7.43	
2	Surface					14.0	31.16		0.9	13.0	2.31	6.81	2.3	16.40	15.98	7.04	0.8
	Bottom					14.5	31.10			11.5	2.80	7.31		16.00	17.28	7.06	
3	Surface					13.0	29.39		0.9	13.0	2.56	7.08	2.0	16.16	16.99	7.04	0.8
	Bottom					13.0	29.39			12.0	2.65	7.53		16.12	17.07	7.05	
4	Surface					13.0	29.42		1.1	13.5	2.89	7.28	2.0	16.00	16.88	7.07	0.9
	Bottom					13.0	29.26			12.0	2.84	7.81		16.00	16.96	7.07	
5	Surface					13.5	29.48		0.7	13.75	2.75	7.52	1.7	15.40	17.24	6.64	0.5
	Bottom					13.5	29.46			11.0	2.79	8.06		15.40	17.24	6.64	

Station		November				January				March			
		Temp. (°C)	Sal. (°/oo)	Oxygen (mg/1)	Depth (m)	Temp. (°C)	Sal. (°/oo)	Oxygen (mg/1)	Depth (m)	Temp. (°C)	Sal. (°/oo)	Oxygen (mg/1)	Depth (m)
1	Surface	22.30	30.10	7.87	0.5	23.34	38.12	>10.00	0.7	21.36	35.53	10.16	0.6
	Bottom	22.30	30.10	7.87		23.38	38.02	>10.00		20.50	35.76	10.31	
2	Surface	22.93	31.14	9.84	0.5	23.76	37.92	>10.00	0.5	21.63	35.72	>10.52	0.5
	Bottom	22.93	31.14	9.84		23.76	37.92	>10.00		21.63	35.72	>10.52	
3	Surface	23.00	30.34	7.76	0.8	24.62	39.18	6.40	0.5	20.95	36.00	7.88	0.8
	Bottom	22.96	30.30	7.88		24.62	39.18	6.40		20.57	36.00	8.04	
4	Surface	23.32	29.33	7.12	1.2	23.15	38.63	6.27	1.3	21.18	36.08	7.73	1.6
	Bottom	23.36	29.38	7.12		22.40	38.65	6.26		20.38	35.90	7.75	
5	Surface	23.16	29.74	7.24	0.6	25.38	39.00	7.00	0.3	21.40	36.00	7.18	0.5
	Bottom	23.16	29.74	6.40		25.38	39.00	7.00		21.40	36.00	7.18	

† Data not recorded until July

* Water was too shallow to allow measurements to be taken

TABLE 2 (c) HYDROLOGY STATION DATA RECORDED FROM DEADWATER BETWEEN MARCH 1974 AND MARCH 1975 DURING THE BLACKWOOD RIVER ESTUARY STUDY.

Station		March				May				July				September			
		Temp. (°C)	Sal. (°/oo)	Oxygen (mg/1)	Depth (m)	Temp. (°C)	Sal. (°/oo)	Oxygen (mg/1)	Depth (m)	Temp. (°C)	Sal. (°/oo)	Oxygen (mg/1)	Depth (m)	Temp. (°C)	Sal. (°/oo)	Oxygen (mg/1)	Depth (m)
1	Surface	18.2	35.9	†	1.2	17.0	35.77	†	2.4	11.0	1.65	7.80	2.0	17.23	15.08	-	2.5
	Bottom	18.2	35.9			17.0	35.66			11.5	17.83	5.53		17.00	32.13	-	
2	Surface	17.6	36.5		1.8	13.0	31.37		2.7	11.0	1.83	7.72	2.3	17.10	14.82	7.47	3.1
	Bottom	17.6	36.5			16.0	34.96			12.0	10.01	3.24		17.71	32.84	9.86	
3	Surface	17.6	36.45		1.8	13.75	31.52		2.1	11.75	1.81	8.03	2.0	16.92	14.42	7.38	2.0
	Bottom	17.8	36.4			13.5	31.42			12.0	19.87	7.33		17.78	30.04	9.14	
4	Surface	17.5	36.5		1.8	14.0	31.39		1.6	12.0	1.97	7.98	2.0	16.52	14.20	7.07	1.1
	Bottom	17.6	36.45			13.5	31.53			12.0	19.83	7.33		17.02	24.04	7.10	
5	Surface	17.4	36.8		1.2	14.25	31.31		1.9	11.5	2.12	7.99	1.7	16.28	14.28	6.84	1.2
	Bottom	17.5	36.7			14.25	31.65			12.0	2.56	7.82		17.50	29.10	6.54	

Station		November				January				March			
		Temp. (°C)	Sal. (°/oo)	Oxygen (mg/1)	Depth (m)	Temp. (°C)	Sal. (°/oo)	Oxygen (mg/1)	Depth (m)	Temp. (°C)	Sal. (°/oo)	Oxygen (mg/1)	Depth (m)
1	Surface	21.66	30.60	6.44	2.5	20.90	35.16	4.97	2.0	19.13	35.33	5.30	2.0
	Bottom	20.48	35.42	6.99		19.45	36.13	9.98		18.30	35.30	5.22	
2	Surface	21.90	27.94	6.81	3.2	21.23	35.52	5.09	3.5	19.10	35.46	6.13	3.5
	Bottom	19.74	35.48	6.76		19.46	36.34	5.14		17.68	35.52	6.58	
3	Surface	21.86	28.82	6.79	2.0	20.76	36.12	5.98	1.5	19.48	35.60	6.02	1.9
	Bottom	21.84	33.14	7.20		20.83	36.16	6.08		19.40	35.58	6.14	
4	Surface	21.80	29.74	6.88	1.5	20.63	36.17	5.46	1.8	19.24	35.22	8.38	1.7
	Bottom	21.74	32.20	6.82		20.00	36.19	5.14		18.94	35.26	8.42	
5	Surface	21.68	30.12	7.20	0.8	20.98	36.50	7.22	0.8	20.82	35.06	9.10	1.3
	Bottom	21.78	30.08	7.19		20.90	36.56	7.23		19.54	35.06	>10.97	

† Data not recorded until July

\- No data recorded

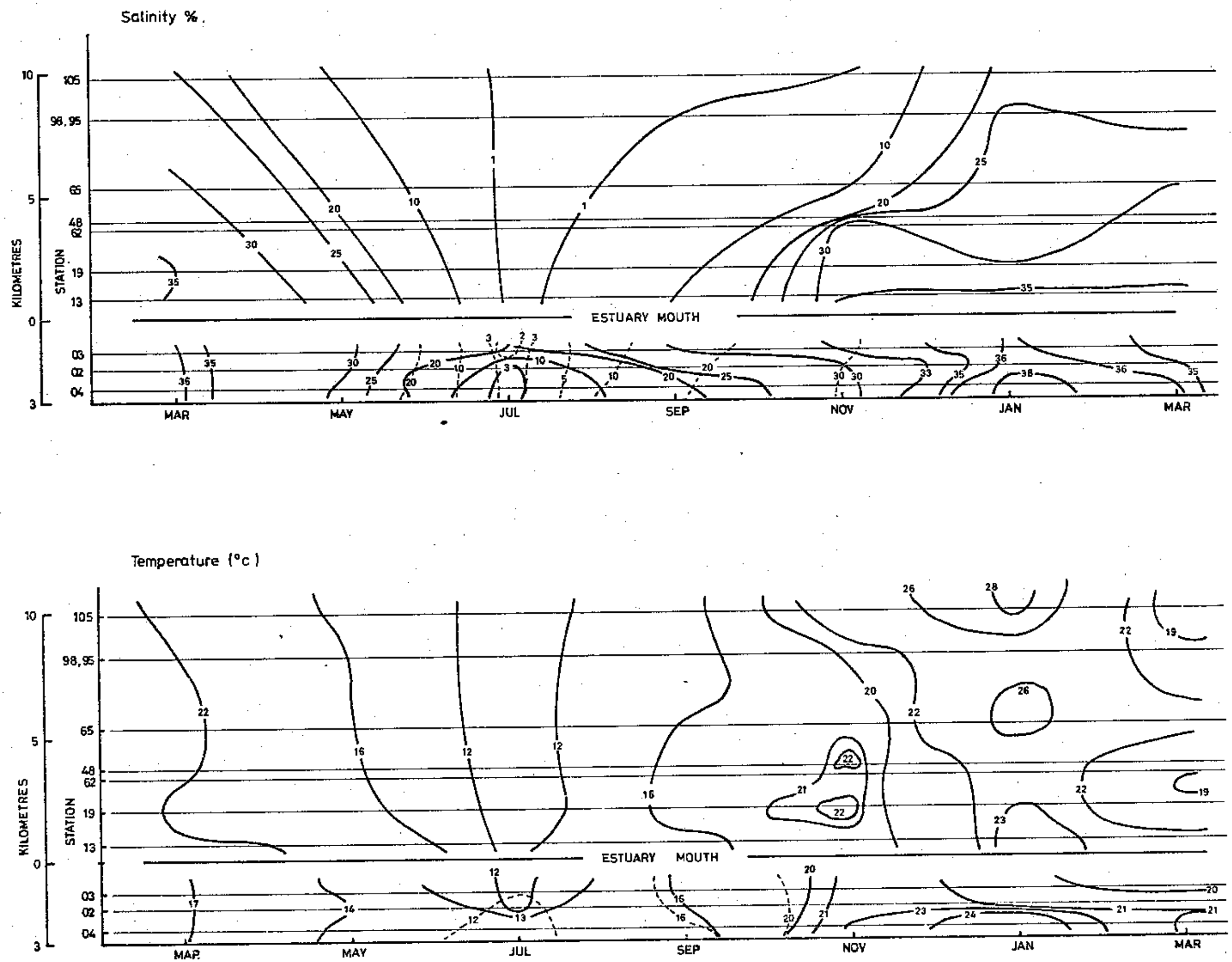


Figure 2 Isohaline and isotherm diagrams constructed from salinity and temperature data collected from the Blackwood River estuary over the period March 1974 to March 1975. Where surface and bottom readings differed, bottom readings are represented by a broken line.

TABLE 3. A CHECKLIST OF FISH AND COMMERCIAL CRUSTACEA COLLECTED FROM THE BLACKWOOD RIVER ESTUARY, OVER THE PERIOD MARCH 1974 TO MARCH 1975.

FAMILY	SCIENTIFIC NAME	COMMON NAME
Mugilidae	*Mugil cephalus*	Sea mullet
	Aldrichetta forsteri	Yelloweye mullet
Sillaginidae	*Sillago schomburgkii*	Western yellow fin whiting
	Sillago punctata	King George whiting
	Sillago bassensis	School whiting
Plotosidae	*Cnidoglanis macrocephalus*	Cobbler
	Tandanus bostocki	Freshwater catfish
Arripidae	*Arripis georgianus*	Australian herring
	Arripis trutta esper	Australian salmon
Exocoetidae	*Hyporamphus melanochir*	Southern sea garfish
Sparidae	*Mylio butcheri*	Black bream
	Chrysophrys unicolor	Snapper
	Rhabdosargus sarba	Silver bream (Tarwhine)
Carangidae	*Caranx georgianus*	Trevally
	Trachurus mccullochi	Yellowtail
Pleuronectidae	*Ammotretis rostratus*	Long snouted flounder
Bothidae	*Pseudorhombus jenynsii*	Small toothed flounder
Pomatomidae	*Pomatomus saltator*	Tailor
Engraulidae	*Engraulis australis fraseri*	Anchovy
Dussumieriidae	*Spratelloides robustus*	Blue sprat
Clupeidae	*Hyperlophus vittatus*	Sandy sprat
Theraponidae	*Helotes sexlineatus*	Striped perch
Enoplosidae	*Enoplosus armatus*	Old wife
Balistidae	*Navodon freycineti*	Six spined leather jacket
	Scobinichthys granulatus	Rough leather jacket
	Acanthaloteres guntheri	Toothbrush leather jacket
Kuhliidae	*Edelia vittata*	Westralian pigmy perch

TABLE 3. (cont) A CHECKLIST OF FISH AND COMMERCIAL CRUSTACEA COLLECTED FROM THE BLACKWOOD RIVER ESTUARY, OVER THE PERIOD MARCH 1974 TO MARCH 1975.

FAMILY	SCIENTIFIC NAME	COMMON NAME
Gobiidae	*Favonigobius lateralis*	Long finned goby
	Favonigobius tamerensis	South west goby
	Arenigobius bifrenatus	Bridled goby
	Lizagobius olorum	Blue spot goby
Atherinidae	*Atherinisoma rockinghemensis*	Rockingham hardyhead
	Atherinisoma edelensis	Swan river hardyhead
Odacidae	*Haletta semifasciata*	Blue rock whiting
Tetraodontidae	*Sphoeroides pleurogramma*	Banded toadfish
	Contusus richei	Prickly toadfish
Labridae	*Pseudolabrus parilus*	Brown spotted parrot fish
	Achoerodus gouldii	Blue groper
Diodontidae	*Aptopomycterus nicthemerus*	Globe fish
Syngnathidae	*Syngnathus* sp.	Pipe fish
Poeciliidae	*Gambusia affinis*	Mosquito fish
Sciaenidae	*Sciaena antarctica*	Mulloway
Elopidae	*Elops australis*	Giant herring
Kyphosidae	*Kyphosus cornelii*	Buffalo bream
Pempheridae	*Shuetta woodwardi*	Woodward's pemferet
Pataecidae	*Aetapcus vincenti*	Smooth prow fish
Syngnathidae	*Hippocampus angustus*	Seahorse
Platycephalidae	*Platycephalus* sp.	Flathead
Clinidae	*Cristiceps australis*	Crested weed fish
Ophichthidae	*Ophisurus serpens*	Serpent eel
Cheilodactylidae	*Psilocranium nigricans*	Dusky morwong
	Goniistius gibbosus	Magpie morwong
Scorpaenidae	*Gymnapistes marmoratus*	Devilfish
Triglidae	*Chelidonichthys kumu*	Red gurnard
ELASMOBRANCHI		
Dasyatidae	*Dasyatis brevicaudata*	Stingray
Rhinobatidae	*Trygonorhina fasciata*	Fiddler ray

TABLE 3. (cont) A CHECKLIST OF FISH AND COMMERCIAL CRUSTACEA COLLECTED FROM THE BLACKWOOD RIVER ESTUARY, OVER THE PERIOD MARCH 1974 TO MARCH 1975.

FAMILY	SCIENTIFIC NAME	COMMON NAME
CRUSTACEA		
Portunidae	*Portunus pelagicus*	Blue manna crab
	Ovalipes australiensis	Sand crab
Penaeidae	*Metapenaeus dalli*	Greasy back prawn

TABLE 4 (a) TOTAL NUMBER AND PERCENTAGE OF TOTAL OF COMMERCIAL FISH TAKEN BY REGULAR SEINE AND SET NET SAMPLING IN THE BLACKWOOD RIVER ESTUARY FROM MARCH 1974 TO MARCH 1975.

Scientific Name	March Number Seine	March Number Set	March Total	March % of Tot.	May Number Seine	May Number Set	May Total	May % of Tot.	July Number Seine	July Number Set	July Total	July % of Tot.	September Number Seine	September Number Set	September Total	September % of Tot.
M. cephalus	80	33	113	2.0	10	140	150	8.7	7	162	169	4.3	45	205	250	6.8
A. fosteri	633	122	755	13.3	127	94	221	12.8	126	450	576	14.7	115	175	290	7.9
S. schomburgkii	2 028	9	2 037	35.9	12	11	23	1.3	1 416	128	1 544	39.4	46	27	73	2.0
S. punctata	124		124	2.2	57		57	3.3	569		569	14.5	78		78	2.1
S. bassensis																
C. macrocephalus	4	7	11	0.2	4		4	0.2					1	4	5	0.1
A. georgianus	21	60	81	1.4	1	32	33	1.9		22	22	0.6	5	217	222	6.0
A. trutta esper.		2	2	<0.1		1	1	0.1	2	1	3	0.1		3	3	0.1
E. melanochir	353		353	6.2	305		305	17.7					1		1	<0.1
M. butcheri	375	55	430	7.6	120	38	158	9.2	46	293	339	8.7	106	202	308	8.4
C. unicolor		1	1	<0.1	2	2	4	0.2								
R. sarba	276	57	333	5.9	35	6	41	2.4	63	9	72	1.8	428	126	554	15.0
C. georgianus	37	4	41	0.7		1	1	0.1						2	2	<0.1
T. mccullochi		1	1	<0.1												
A. rostratus	3		3	<0.1	1	3	4	0.2		2	2	<0.1	1	5	6	0.2
P. jenynsii	17		17	0.3	8	2	10	0.6								
P. saltator	67	23	90	1.6	1	41	42	2.4		1	1	<0.1	1	38	39	1.1
E. australis fraseri					1	1	2	0.1	1		1	<0.1		2	2	<0.1
S. robustus	1		1	<0.1	60		60	3.5								
H. vittatus					17		17	1.0								
A. gouldii																
S. antarctica														1	1	<0.1
Platycephalus sp.																

Scientific Name	November Number Seine	November Number Set	November Total	November % of Tot.	January Number Seine	January Number Set	January Total	January % of Tot.	March Number Seine	March Number Set	March Total	March % of Tot.
M. cephalus	451	40	491	10.5	50	131	181	5.5	42	32	74	1.6
A. fosteri	600	64	664	14.2	739	127	866	26.2	233	167	400	8.5
S. schomburgkii	540	13	553	11.9	204	11	215	6.5	94	27	121	2.6
S. punctata	48		48	1.0	85		85	2.6	945		945	20.2
S. bassensis	1		1	<0.1								
C. macrocephalus	2	9	11	0.2	1	6	7	0.2	1	9	10	0.2
A. georgianus	2	132	134	2.9		66	66	2.0	7	517	524	11.2
A. trutta esper.												
E. melanochir									80		80	1.7
M. butcheri	16	127	143	3.1	10	72	82	2.5	68	69	137	2.9
C. unicolor												
R. sarba	651	71	722	15.5	88	73	161	4.9	665	126	791	16.9
C. georgianus	84		84	1.8	3	2	5	0.2	131	3	134	2.9
T. mccullochi												
A. rostratus	3	2	5	0.1	1	7	8	0.2	1	2	3	0.1
P. jenynsii	1		1	<0.1	2	1	3	0.1	7		7	0.2
P. saltator	19	71	90	1.9	1	28	29	0.9	2	26	28	0.6
E. australis fraseri										1	1	<0.1
S. robustus												
H. vittatus									46		46	1.0
A. gouldii					3		3	0.1				
S. antarctica						5	5	0.2				
Platycephalus sp.		3	3	0.1		4	4	0.1	1	5	6	0.1

TABLE 4 (b) TOTAL NUMBER AND PERCENTAGE OF TOTAL OF NON-COMMERCIAL FISH TAKEN BY REGULAR SEINE AND SET NET SAMPLING IN THE BLACKWOOD RIVER ESTUARY FROM MARCH 1974 TO MARCH 1975.

Scientific Name	March				May				July				September				November				January				March			
	Seine	Number Set	Total	% of Tot.	Seine	Number Set	Total	% of Tot.	Seine	Number Set	Total	% of Tot.	Seine	Number Set	Total	% of Tot.	Seine	Number Set	Total	% of Tot.	Seine	Number Set	Total	% of Tot.	Seine	Number Set	Total	% of Tot.
T. bostocki										1	1	<0.1																
H. eerlineatus	555	25	580	10.2	2	7	9	0.5	5	1	6	0.2	2	2	4	0.1	95	15	110	2.4	36	17	53	1.6	390	37	427	9.1
E. armatus	3		3	<0.1	8		8	0.5													3		3	0.1	1		1	<0.1
K. freycineti)																												
S. granulatus)	5		5	0.1	51		51	3.0	1		1	<0.1									1		1	<0.1	3		3	0.1
A. guntheri)																												
F. lateralis)									56		56	1.4	499		499	13.6	287		287	6.2	285		285	8.6	75		75	1.6
F. tamerensis)	118		118	2.1	174		174	10.1	359		359	9.2	764		764	20.8	285		285	6.1	295		295	8.9	51		51	1.1
L. olorum)									13		13	0.3	256		256	7.0	81		81	1.7	36		36	1.1	2		2	<0.1
A. bifrenatus	10		10	0.2	1		1	0.1	2		2	<0.1	4		4	0.1	94		94	2.0	20		20	0.6	9		9	0.2
A. rockinghamensis)	222		222	3.9	270		270	15.6	146		146	3.7	238		238	6.5	776		776	16.6	870		870	26.4	717		717	15.3
A. adelensis)																												
E. semifasciata	3		3	<0.1																	1		1	<0.1	9		9	0.2
S. pleurogramma	330		330	5.8	72		72	4.2	1	1	2	<0.1	81		81	2.2	63	1	64	1.4	7		7	0.2	52		52	1.1
C. richei	4		4	0.1	5		5	0.3	32		32	0.8					11		11	0.2	4		4	0.1	14		14	0.3
P. parilus					2		2	0.1																	3		3	0.1
A. niethemerus					1		1	0.1																				
Syngnathus sp.																					2		2	0.1				
E. australis														1	1	<0.1												
K. cornelii																						1	1	<0.1				
S. woodwardi																						1	1	<0.1				
H. angustus																		1	1	<0.1								
O. serpens										1	1	<0.1																
P. nigricans																									1	1	2	<0.1
G. gibbosus																										2	2	<0.1
G. marmoratus																									1		1	<0.1
C. kumu																										1	1	<0.1
Dasyatidae (1 sp)	2	1	3	<0.1																		1	1	<0.1	2		2	<0.1
TOTAL	5271	400	5671		1347	379	1726		2845	1072	3917		2671	1010	3681		4110	550	4660		2747	553	3300		3653	1032	4685	

TABLE 5 (a) TOTAL WEIGHT AND PERCENTAGE OF TOTAL OF COMMERCIAL FISH TAKEN BY REGULAR SEINE AND SET NET SAMPLING IN THE BLACKWOOD RIVER ESTUARY FROM MARCH 1974 TO MARCH 1975.

Scientific Name	March Weight (gm) Seine	March Weight (gm) Set	March Weight (gm) Total	March % of Total	May Weight (gm) Seine	May Weight (gm) Set	May Weight (gm) Total	May % of Total	July Weight (gm) Seine	July Weight (gm) Set	July Weight (gm) Total	July % of Total
M. cephalus	3 850	4 590	8 440	1.9	130	27 345	27 475	25.4		45 760	45 760	9.5
A. forsteri	52 610	25 350	77 960	17.3	13 507	11 700	25 207	23.3	12 330	87 980	100 310	20.7
S. schomburgkii	121 150	1 540	122 690	27.2	1 933	2 183	4 116	3.6	231 860	16 000	247 860	51.2
S. punctata	2 510		2 510	0.6	714		714	0.7	19 310		19 310	4.0
S. bassensis												
C. macrocephalus	20	3 910	3 930	0.9	83		83	0.1				
A. georgianus	7 690	9 230	16 920	3.8	60	4 750	4 810	4.4		3 550	3 550	0.7
A. trutta esper.		520	520	0.1		210	210	0.2		260	260	<0.1
E. melanochir	11 100		11 100	2.5	7 871		7 871	7.3				
M. butcheri	64 450	10 930	75 380	16.7	22 422	4 067	26 489	24.4	11 800	51 360	63 160	13.0
C. unicolor		30	30	<0.1	73	449	522	0.5				
R. sarba	19 210	8 670	28 080	6.2	26	464	490	0.4	570	950	1 520	0.3
C. georgianus	3 080	700	3 780	0.8		90	90	0.1				
T. mcculochi		50	50	<0.1								
A. rostratus	5		5	<0.1	715	50	765	0.7		170	170	<0.1
P. jenynsii	165		165	<0.1	89	56	145	0.1				
P. saltator	2 100	4 620	6 720	1.5	2	4 120	4 122	3.8		70	70	<0.1
E. australis fraseri					3	4	7	<0.1	4		4	<0.1
S. robustus	1		1	<0.1	147		147	0.1				
H. vittatus					34		34	<0.1				
A. gouldii												
S. antarctica												
Platycephalus sp.												

Scientific Name	September Weight (gm) Seine	September Weight (gm) Set	September Weight (gm) Total	September % of Total	November Weight (gm) Seine	November Weight (gm) Set	November Weight (gm) Total	November % of Total	January Weight (gm) Seine	January Weight (gm) Set	January Weight (gm) Total	January % of Total	March Weight (gm) Seine	March Weight (gm) Set	March Weight (gm) Total	March % of Total
M. cephalus	4 460	64 220	68 680	25.4	1 840	11 920	13 760	4.7	300	48 710	49 010	27.0	420	11 350	11 770	3.8
A. forsteri	6 100	43 360	49 460	18.3	39 600	16 930	56 530	19.2	14 500	31 640	46 140	25.4	4 050	36 260	40 310	13.2
S. schomburgkii	4 890	5 140	10 030	3.7	49 450	1 960	51 410	17.4	5 380	8 660	14 040	7.7	12 920	4 100	17 020	5.6
S. punctata	1 230		1 230	0.5	1 830		1 830	0.6	280		280	0.2	8 970		8 970	2.9
S. bassensis					40		40	<0.1								
C. macrocephalus	10	2 240	2 250	0.8	210	6 180	6 390	2.2	1 050	5 280	6 330	3.5	3	2 680	2 683	0.9
A. georgianus	470	36 710	37 180	13.8	440	22 460	22 900	7.8		11 480	11 480	6.3	1 280	85 930	87 210	28.5
A. trutta esper.		780	780	0.3												
E. melanochir	60		60	<0.1									2 130		2 130	0.7
M. butcheri	23 090	34 940	58 030	21.5	2 500	24 710	27 210	9.2	2 680	13 520	16 200	8.9	14 480	18 090	32 570	10.6
C. unicolor														80	80	<0.1
R. sarba	3 100	14 910	18 010	6.7	53 940	10 850	64 790	22.0	4 970	6 370	11 340	6.2	3 140	16 530	19 670	6.4
C. georgianus		160	160	0.1	10 710		10 710	3.6	70	350	420	0.2	7 350	200	7 550	2.5
T. mcculochi																
A. rostratus	20	350	370	0.1	250	130	380	0.1	10	710	720	0.4	150	200	350	0.1
P. jenynsii					60		60	<0.1	350	80	430	0.2	660		660	0.2
P. saltator	230	5 570	5 800	2.2	4 580	15 500	20 080	6.8	300	5 030	5 330	2.9	2	4 060	4 062	1.3
E. australis fraseri		8	8	<0.1										6	6	<0.1
S. robustus																
H. vittatus													96		96	<0.1
A. gouldii									28		28	<0.1				
S. antarctica		11 900	11 900	4.4		600	600	0.2		570	570	0.3		2 160	2 160	0.7
Platycephalus sp.						2 120	2 120	0.7		1 000	1 000	0.6	2 300	1 300	12 600	1.2

TABLE 5 (b) TOTAL WEIGHT AND PERCENTAGE OF TOTAL OF NON-COMMERCIAL FISH TAKEN BY REGULAR SEINE AND SET NET SAMPLING IN THE BLACKWOOD RIVER ESTUARY FROM MARCH 1974 TO MARCH 1975.

Scientific Name	March				May				July				September			
	Weight (gm)			% of	Weight (gm)			% of	Weight (gm)			% of	Weight (gm)			% of
	Seine	Set	Total	Tot.	Seine	Set	Total	Tot.	Seine	Set	Total	Tot.	Seine	Set	Total	Tot.
T. bostocki										270	270	0.1				
E. sexlineatus	51 390	3590	54980	12.2	130	835	965	0.9	14	100	114	<0.1	100	280	380	0.1
E. armatus	6		6	<0.1	24		24	<0.1								
N. freycinati)																
S. granulatus)	5		5	<0.1	556		556	0.5	83		83	<0.1				
A. guntheri)																
F. lateralis)									69		69	<0.1	703		703	0.3
F. tamerensis)	180		180	<0.1	320		320	0.3	561		561	0.1	1660		1660	0.6
L. olorum)									9		9	<0.1	144		144	<0.1
A. bifrenatus	80		80	<0.1	12		12	<0.1	2		2	<0.1	63		63	<0.1
A. rockinghamensis)	297		297	0.1	571		571	0.5	297		297	0.1	435		435	0.2
A. edelensis)																
H. semifasciata	60		60	<0.1												
S. pleurogramma	11 485		11485	2.6	2229		2229	2.1	24	65	89	<0.1	2190		2190	0.8
C. richei	180		180	<0.1	374		374	0.4	474		474	-0.1				
P. parilus					20		20	<0.1								
A. niothemerus					19		19	<0.1								
Syngnathus sp.																
E. australis														580	580	0.2
K. cornelii																
S. woodwardi																
H. angustus																
O. serpens										†						
P. nigricans																
G. gibbosus																
G. marmoratus																
C. kumu																
Dasyatidae (1 sp)	*16 000	*9000	*25000	5.6												
TOTAL	367 624	82930	450554		52064	56323	108387		277407	206535	483942		48955	221148	270103	

Scientific Name	November				January				March			
	Weight (gm)			% of	Weight (gm)			% of	Weight (gm)			% of
	Seine	Set	Total	Tot.	Seine	Set	Total	Tot.	Seine	Set	Total	Tot.
T. bostocki												
E. sexlineatus	9530	1780	11310	3.8	3720	2160	5880	3.2	37570	3540	41110	13.4
E. armatus					6		6	<0.1	2		2	<0.1
N. freycinati)												
S. granulatus)					1		1	<0.1	11		11	<0.1
A. guntheri)												
F. lateralis)	357		357	0.1	367		367	0.2	149		149	<0.1
F. tamerensis)	603		603	0.2	265		265	0.2	101		101	<0.1
L. olorum)	61		61	<0.1	22		22	<0.1	2		2	0.1
A. bifrenatus	1070		1070	0.4	119		119	0.1	104		104	<0.1
A. rockinghamensis)	883		883	0.3	1110		1110	0.6	2170		2170	0.7
A. edelensis)												
H. semifasciata					5		5	<0.1	170		170	0.1
S. pleurogramma	1750	100	1850	0.6	180		180	0.1	1720		1720	0.6
C. richei	269		269	0.1	50		50	<0.1	396		396	0.1
P. parilus									30		30	<0.1
A. niothemerus												
Syngnathus sp.					1		1	<0.1				
E. australis												
K. cornelii						280	280	0.2				
S. woodwardi					70		70	<0.1				
H. angustus		†										
O. serpens												
P. nigricans									6600	100	8700	2.8
G. gibbosus										160	160	<0.1
G. marmoratus									2		2	<0.1
C. kumu										180	180	0.1
Dasyatidae (1 sp)						*10000	*10000	5.5	10130		10130	3.3
TOTAL	179973	115240	295213		35834	145840	181674		119108	186926	306034	

* estimate of unweighed rays

† weight not recorded

TABLE 6 RELATIVE ABUNDANCE (MEAN CATCH {NO.} PER HAUL), TYPE, AND PERCENTAGE OF 0^+ YEAR OLD FISH OF EACH OF THE MORE ABUNDANT SPECIES TAKEN DURING THE REGULAR SAMPLING PROGRAMME IN THE BLACKWOOD RIVER ESTUARY BETWEEN MARCH 1974 AND MARCH 1975.

Species	Relative abundance		Type	Percentage 0+ yr. old fish					
	Seine	Set		Seine			Set		
				Number			Number		
				0^+	Total	% 0^+	0^+	Total	% 0^+
A. forsteri	29.06	16.62	Euryhaline III	1178	2573	45.8	2	1199	0.2
Δ*M. cephalus*	2.78	11.15	Euryhaline III	599	685	87.4	0	743	0
S. schomburgkii	40.83	3.75	Euryhaline III	189	4340	4.4	0	226	0
**S. punctata*	19.82	0	Euryhaline III	1323	1906	69.4	0	0	0
R. sarba	22.0	7.94	Euryhaline III	1510	2215	68.2	1	459	0.2
†*M. butcheri*	7.04	8.20	Euryhaline III	0	741	0	0	856	0
**H. melanochir*	12.06	0	Euryhaline I	255	739	34.05	0	0	0
Δ*A. georgianus*	0.40	7.55	Euryhaline II	6	36	16.7	0	1046	0
C. georgianus	3.29	0.24	Euryhaline II	168	255	65.8	5	12	41.6
Δ*P. saltator*	0.59	2.77	Euryhaline II	43	91	47.2	0	228	0
H. sexlineatus	12.39	0.71	Euryhaline III	10	1085	0.9	0	104	0
**S. pleurogramma*	7.21	0.008	Euryhaline II	0	606	0	0	2	0
ϕ**F. lateralis*	22.09	0	Euryhaline III	-	1193x	-	0	0	0
ϕ**F. tamarensis*	20.08	0	Euryhaline III	-	1412x	-	0	0	0
ϕ**Atherinosoma spp.*	31.13	0	Euryhaline III	-	3229	-	0	0	0
ϕ**A. bifrenatus*	3.92	0	Euryhaline III	-	140x	-	0	0	0
ϕ**L. olorum*	4.68	0	Euryhaline III	-	388x	-	0	0	0

Δ Large specimens poorly represented in seine catches
* Rarely taken in Set nets
† 0+ year old fish present only outside the study area
ϕ 0+ year old fish unable to be identified
x Excluding those fish taken in March and May, 1974.

TABLE 7 RELATIVE ABUNDANCE (MEAN CATCH {NO.} PER HAUL), TYPE, AND PERCENTAGE OF 0^+ YEAR OLD FISH OF EACH OF THE LESS ABUNDANT SPECIES TAKEN DURING THE REGULAR SAMPLING PROGRAMME IN THE BLACKWOOD RIVER ESTUARY, BETWEEN MARCH 1974 AND MARCH 1975.

Species	Relative abundance		Type †	Percentage 0^+ year old fish					
				Seine			Set		
				Number			Number		
	Seine	Set		0^+	Total	% 0^+	0^+	Total	% 0^+
A. trutta esper.	0.02	0.18	Euryhaline II	2	2	100.0	7	4	57.1
C. macrocephalus	0.13	0.32	Euryhaline II	8	13	61.5	0	35	0
A. rostratus	0.13	0.25	Euryhaline II	8	12	66.6	16	19	84.2
P. jenynsii	0.51	0.01	Euryhaline II	32	35	91.4	3	3	100.0
Platycephalus sp.	0.01	0.09	Stenohaline-marine	0	1	0	0	12	0
S. antarctica	*	0.12	Stenohaline-marine	0	0	0	12	13	92.3
C. unicolor	0.02	0.015	Euryhaline I	2	2	100.0	2	4	50.0
T. mcculochi	*	0.03	Stenohaline-marine	0	0	0	1	1	100.0
H. vittalus	0.75	*	Euryhaline I	0	63	0	0	0	0
S. robustus	0.51	*	Euryhaline I	0	61	0	0	0	0
E. australis fraseri	0.01	0.03	Euryhaline II	0	2	0	0	4	0
E. australis	*	0.007	Stenohaline-marine	0	0	0	0	1	0
S. bassensis	0.002	*	Stenohaline-marine	0	1	0	0	0	0
C. kumu	*	0.007	Stenohaline-marine	1	1	100.0	0	0	0
P. nigricans	0.01	0.001	Stenohaline-marine	1	1	100.0	0	1	0
G. vizonarius	*	0.03	Stenohaline-marine	0	0	0	1	1	100.0
A. gouldii	0.01	*	Stenohaline-marine	3	3	100.0	0	0	0
P. parilus	0.02	*	Euryhaline I	5	5	100.0	0	0	0
T. bostocki	*	0.004	Stenohaline-freshwater	0	0	0	0	1	0
C. richei	0.47	*	Euryhaline II	27	70	38.0	0	0	0
E. armatus	0.14	*	Euryhaline I	15	15	100.0	0	0	0
A. nicthemerus	0.003	*	Euryhaline II	1	1	100.0	0	0	0
H. semifasciata	0.03	*	Stenohaline-marine	13	13	100.0	0	0	0
H. angustus	*	0.05	Stenohaline-marine	0	0	0	0	1	0
O. serpens	*	0.007	Stenohaline-marine	0	0	0	0	1	0
K. corneli	*	0.02	Stenohaline-marine	0	0	0	0	1	0
S. woodwardi	*	0.007	Stenohaline-marine	0	0	0	0	1	0
G. mamoratus	0.01	*	Stenohaline-marine	1	1	100.0	0	0	0
Balistidae	0.76	*	Euryhaline I & II	-	61	-	0	0	-
Dasyatidae	0.05	0.04	Stenohaline-marine	3	3	100.0	2	2	100.0
Syngnathus sp.	0.04	*	Stenohaline-marine	-	2	-	0	0	-

* No fish caught

† In many cases this judgement was made on a very limited amount of data.

Figures 3 - 22. Length frequency distribution of fishes taken from the Blackwood River estuary over the period March 1974 to July 1975.

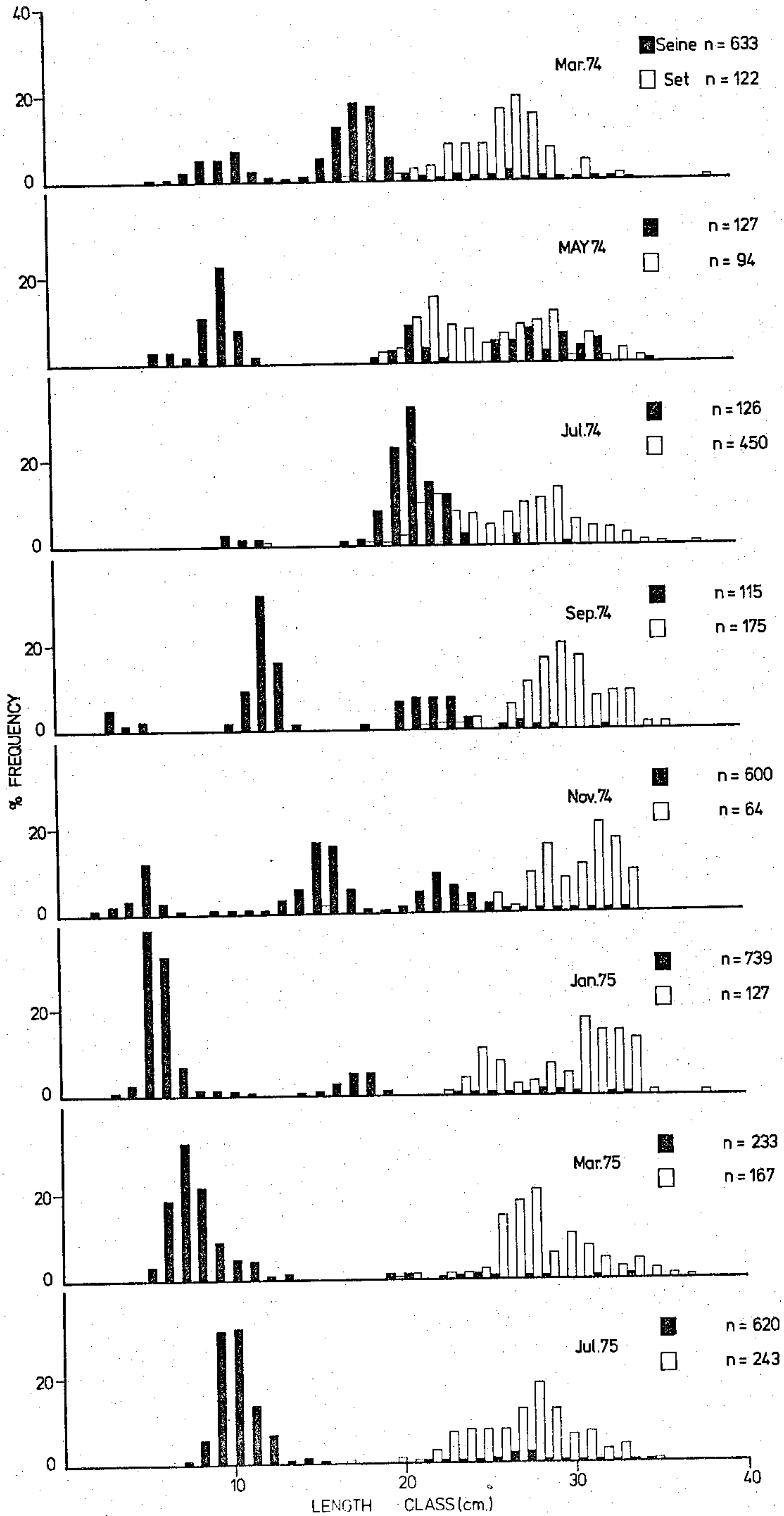


Fig. 3 *Aldrichetta forsteri*

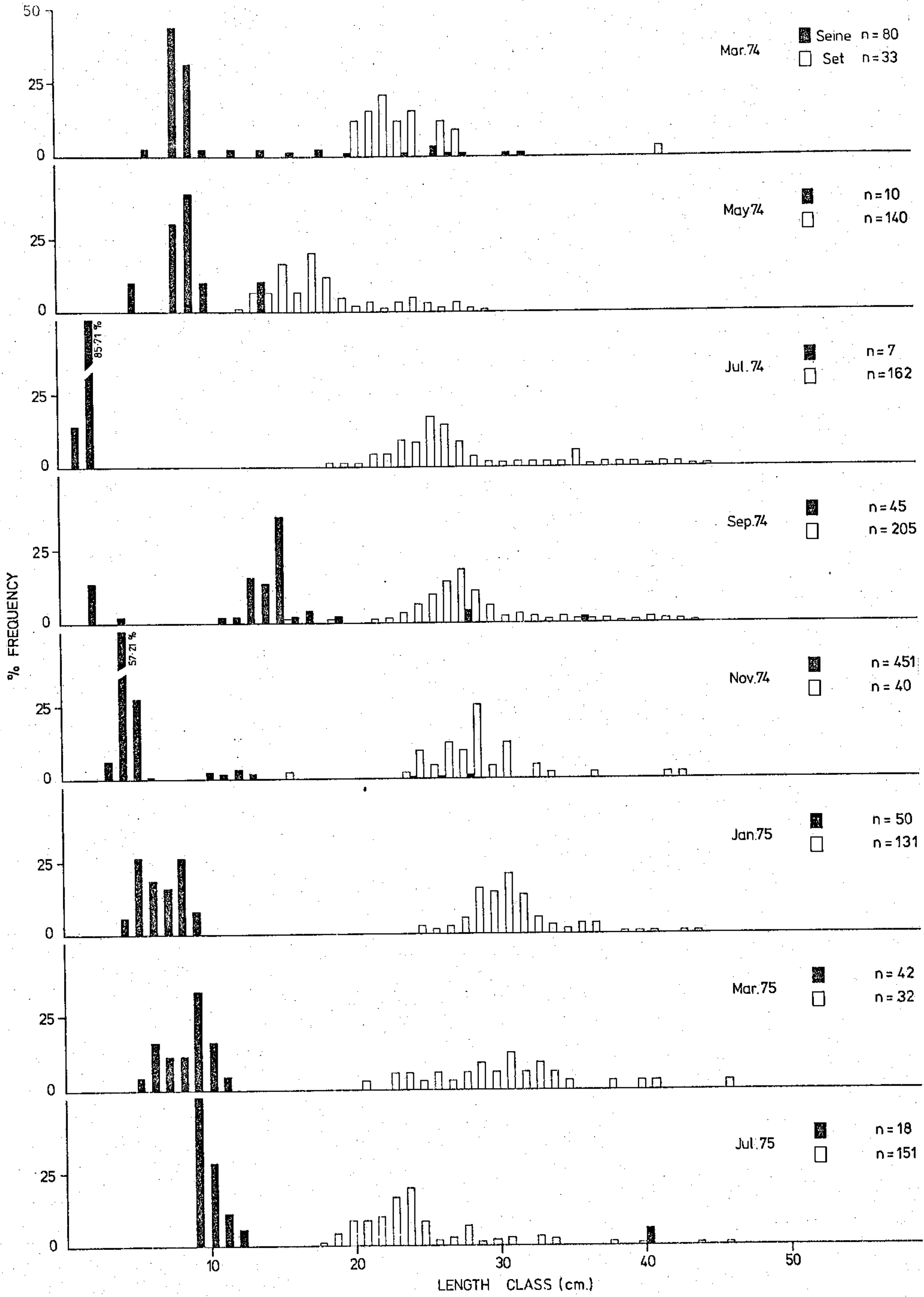


Fig. 4 *Mugil cephalus*

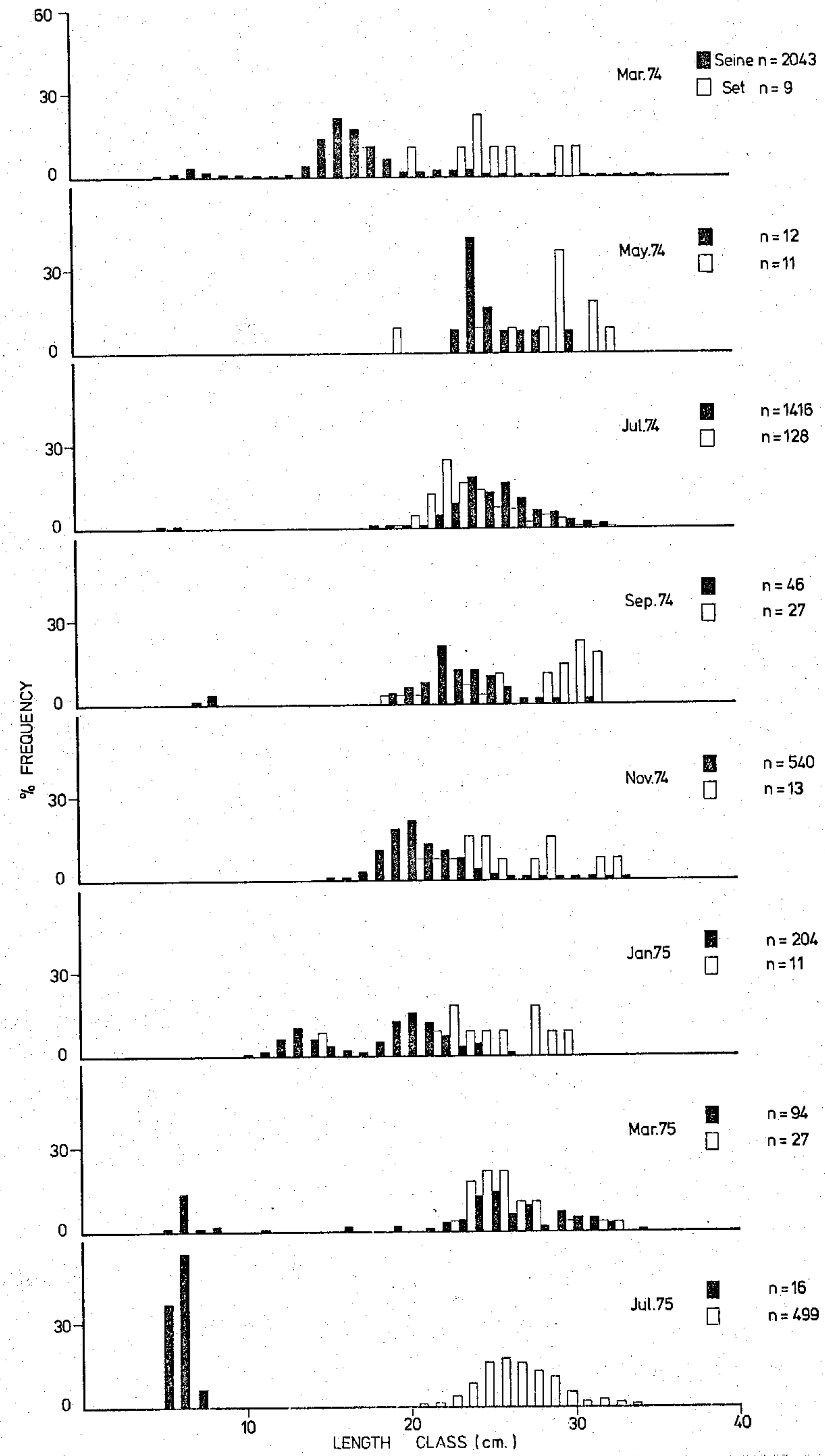


Fig. 5 Sillago schomburgkii

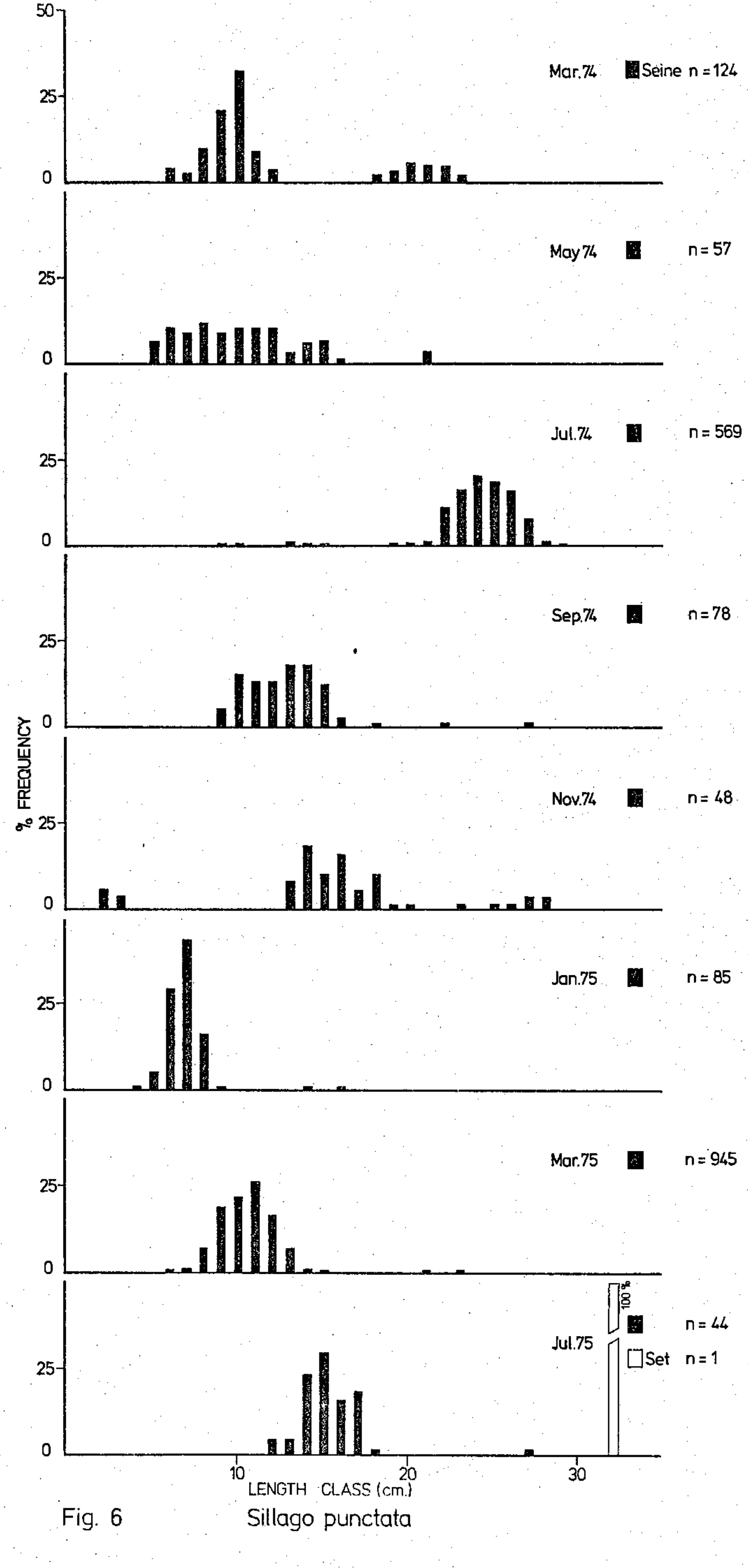


Fig. 6 *Sillago punctata*

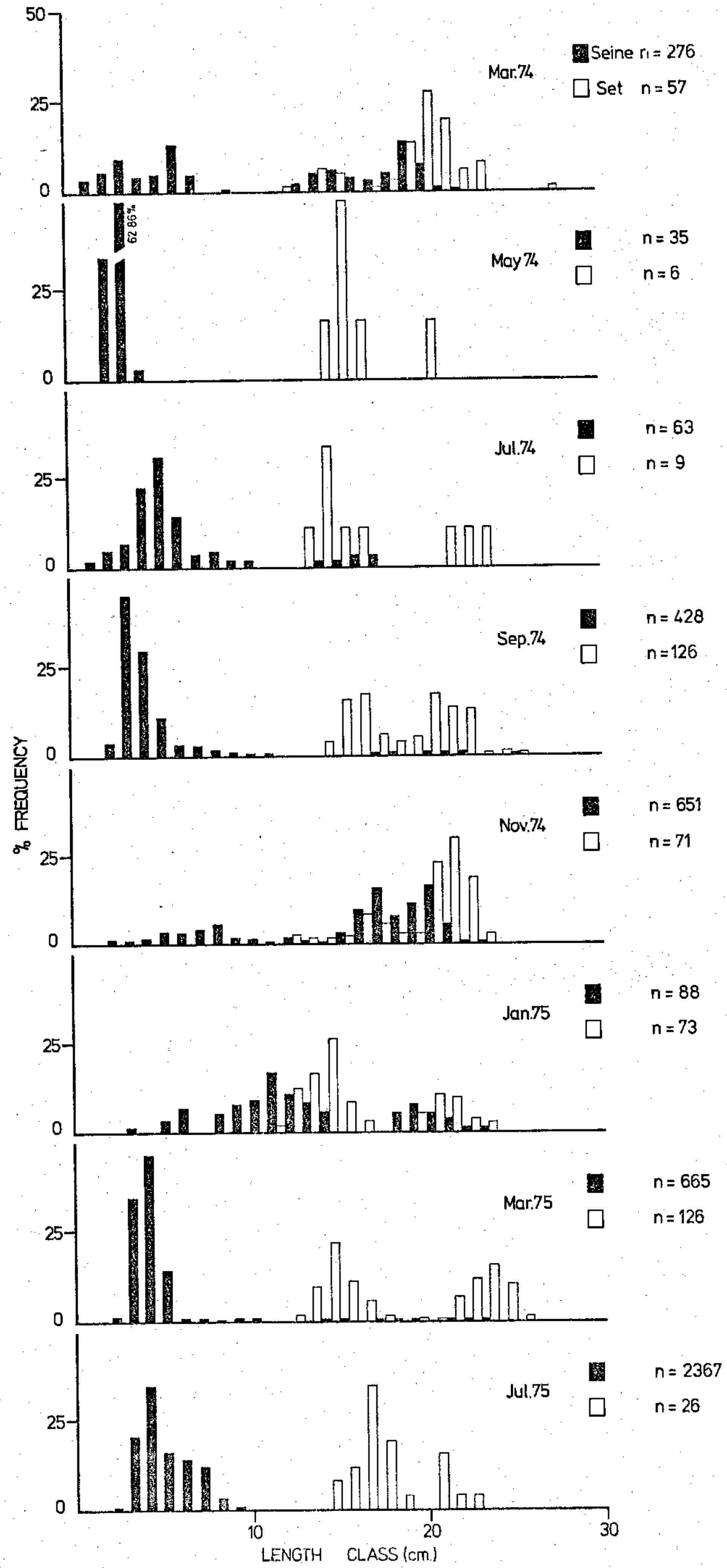


Fig. 7 *Rhabdosargus sarba*

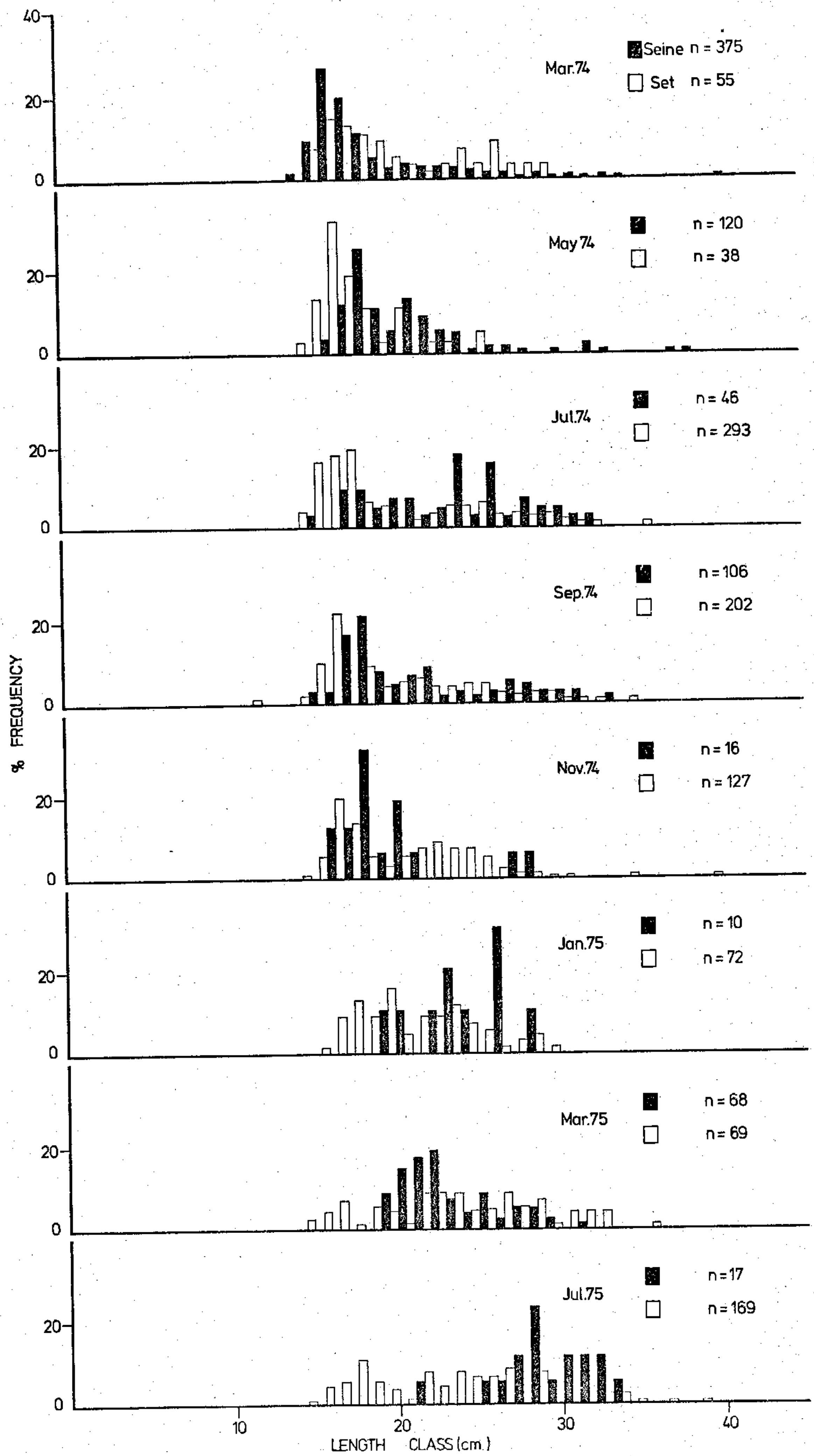


Fig. 8 *Mylio butcheri*

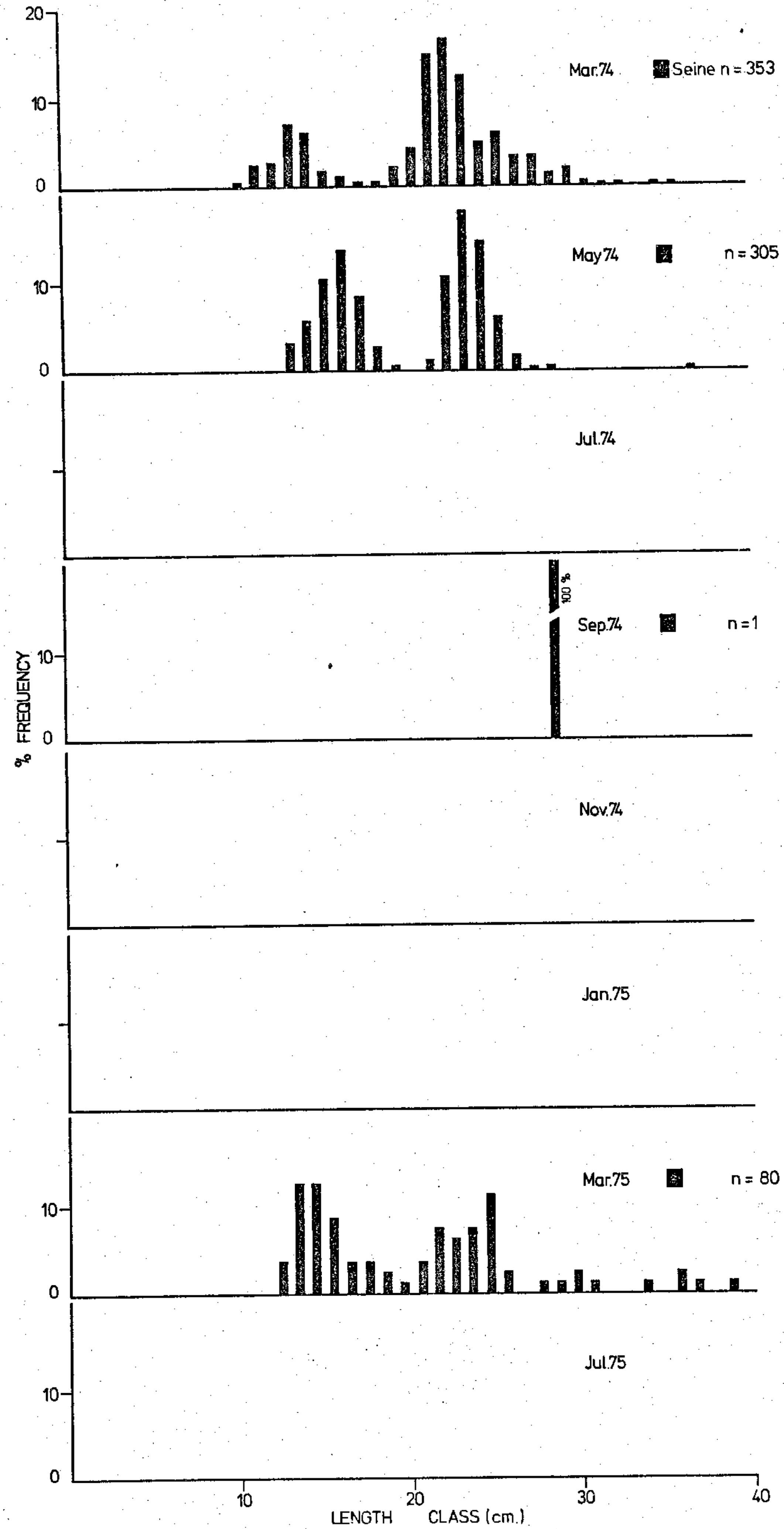


Fig. 9 *Hyporhamphus melanochir*

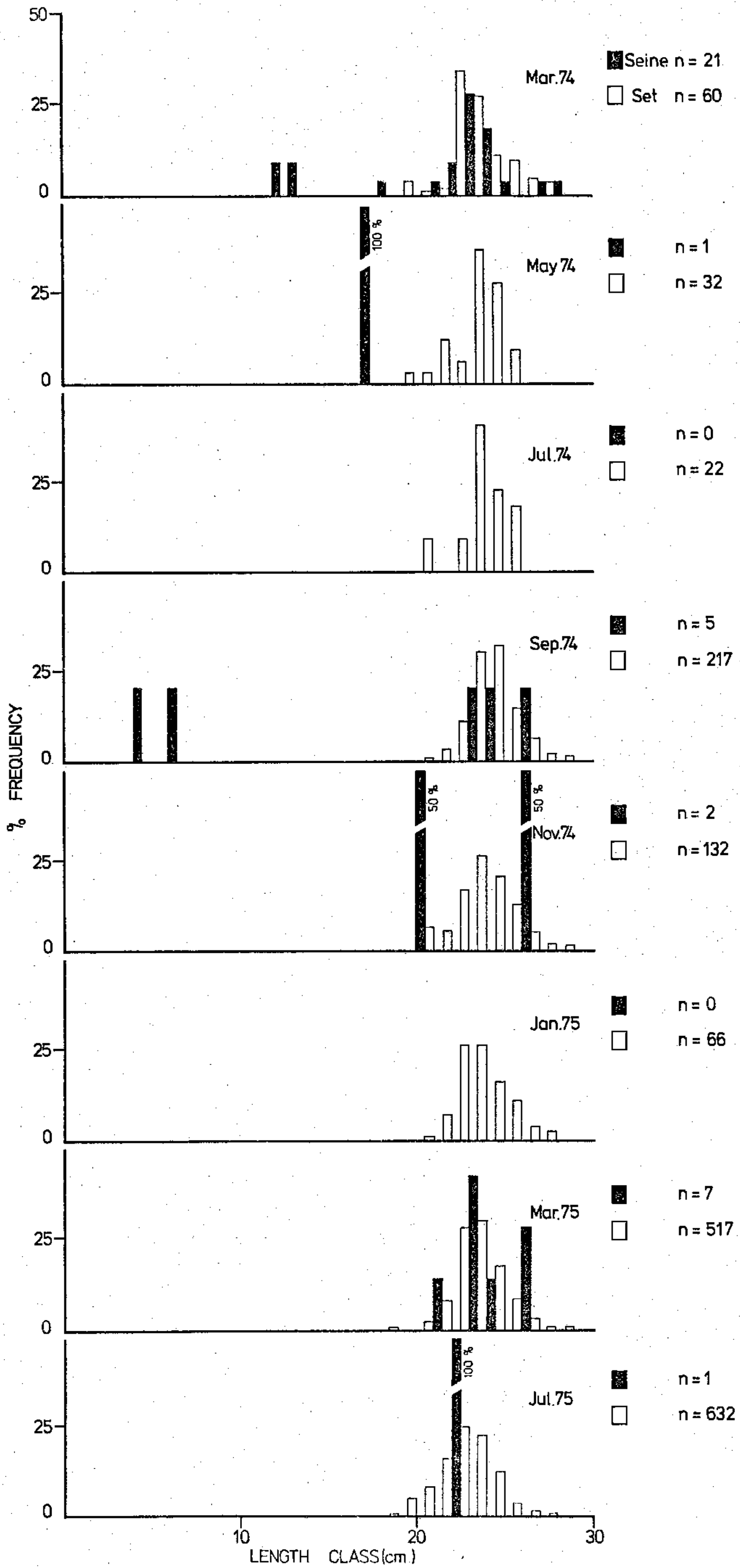


Fig. 10 *Arripis georgianus*

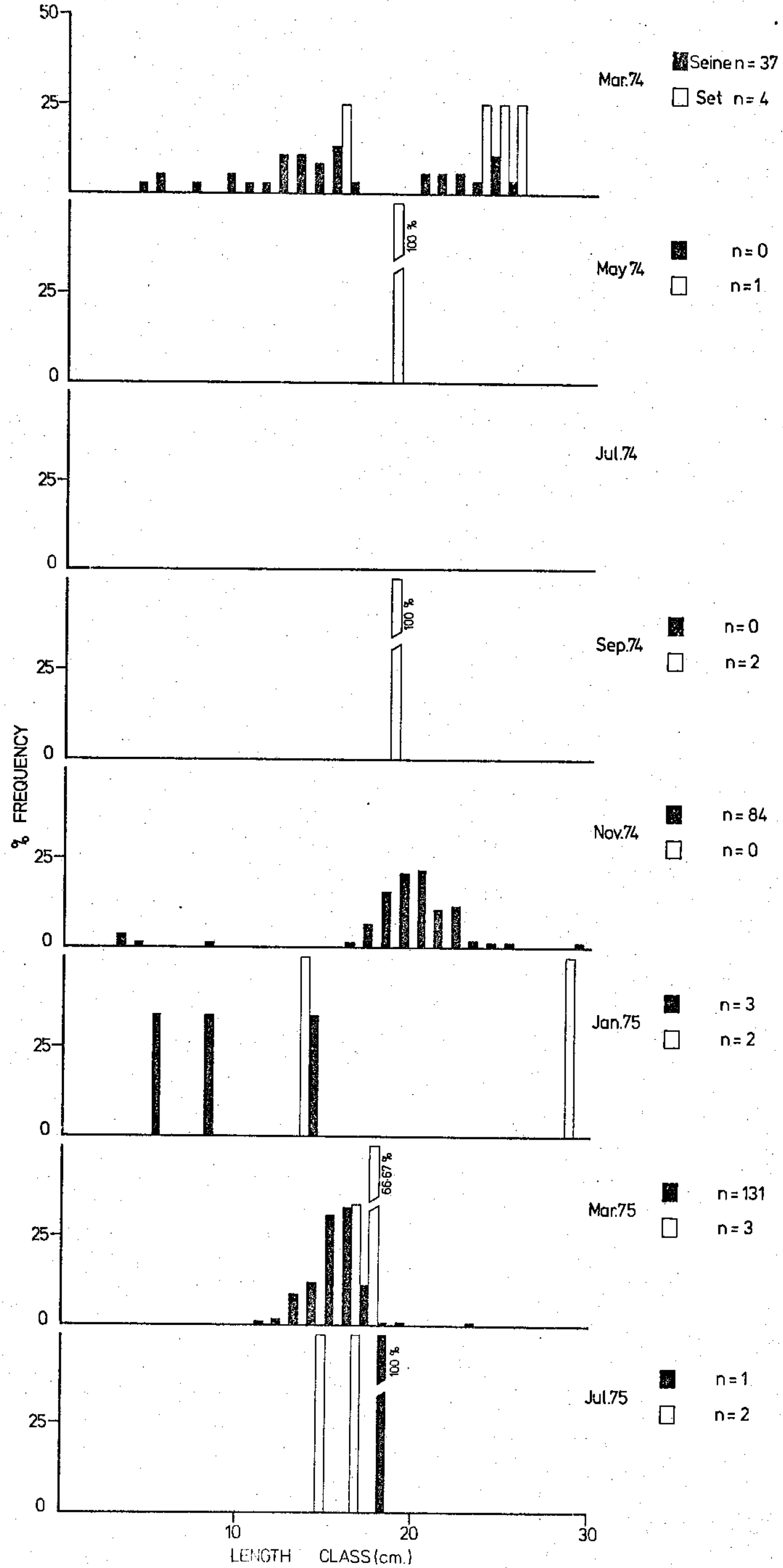


Fig. 11 *Caranx georgianus*

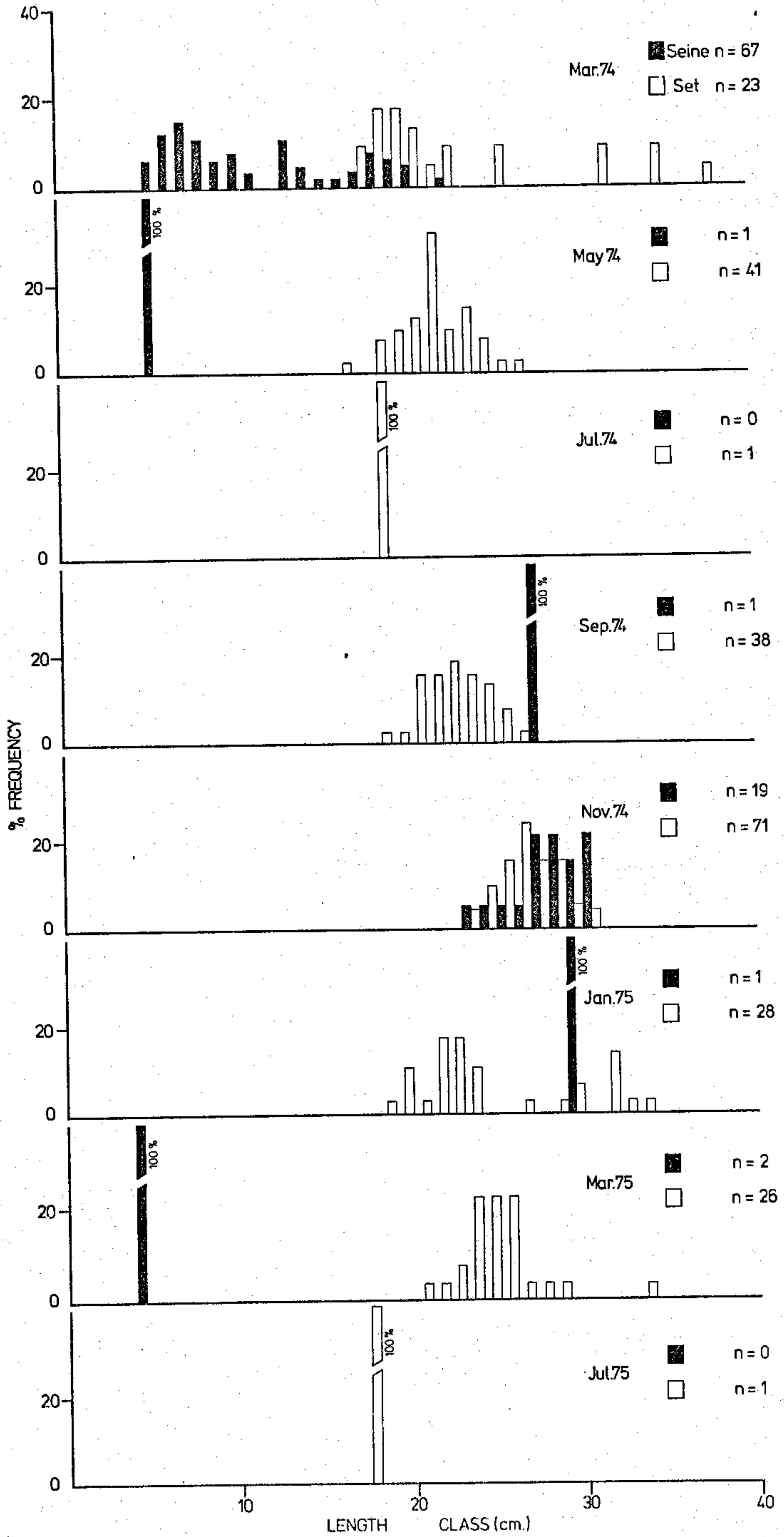


Fig. 12 *Pomatomus saltator*

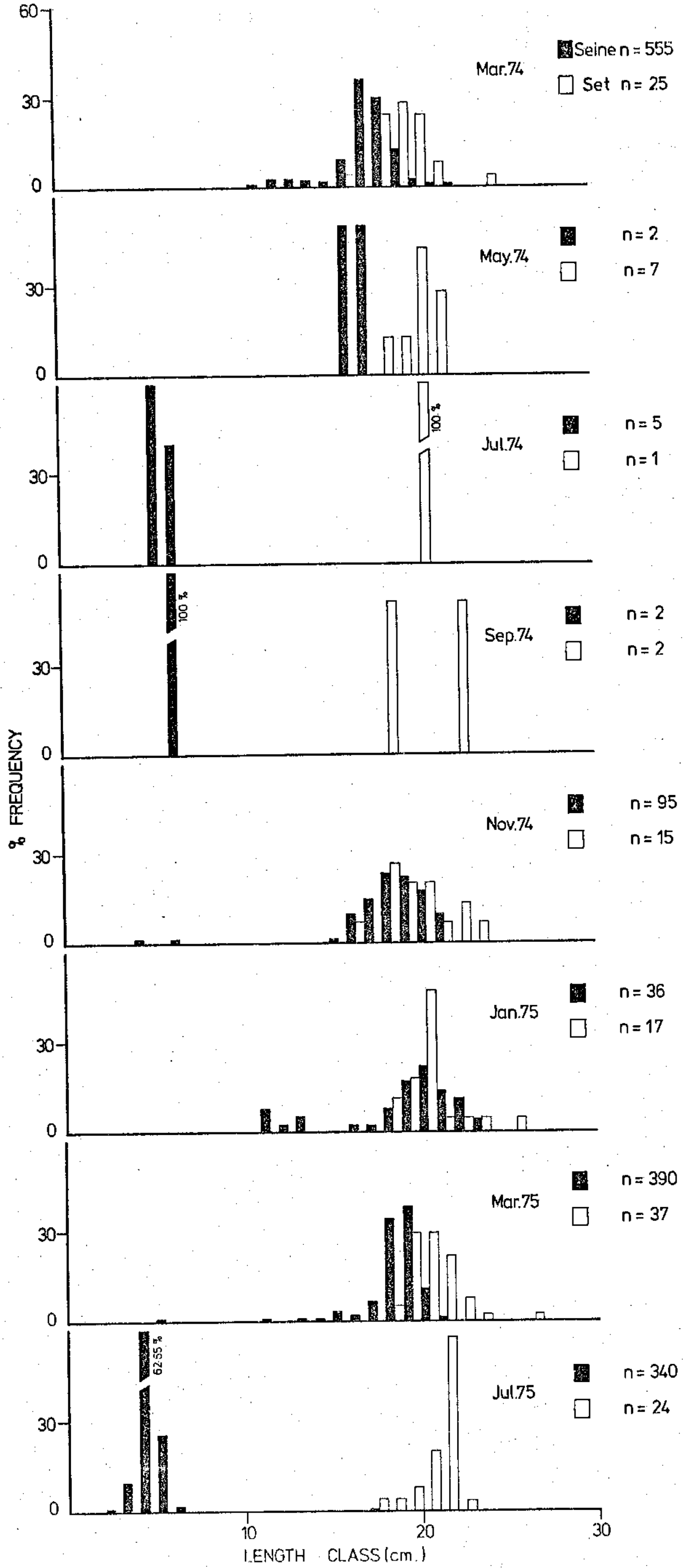


Fig. 13 Helotes sexlineatus

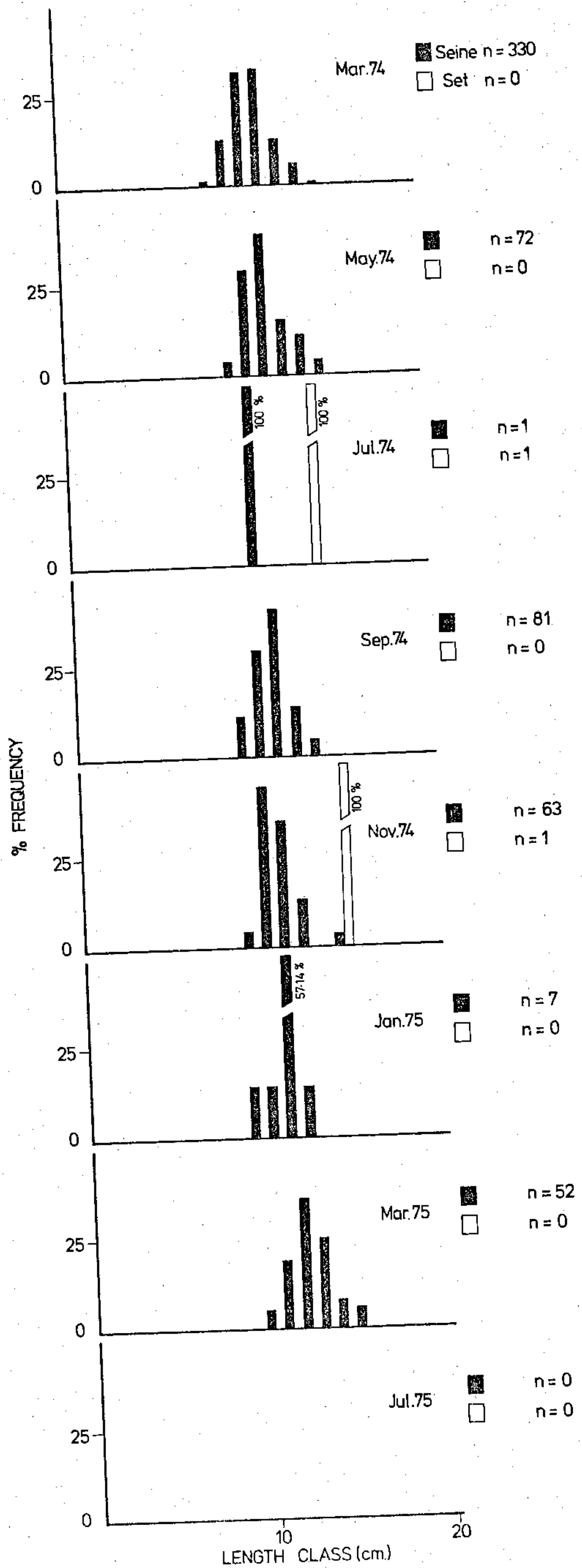


Fig. 14 Sphoeroides pleurogramma

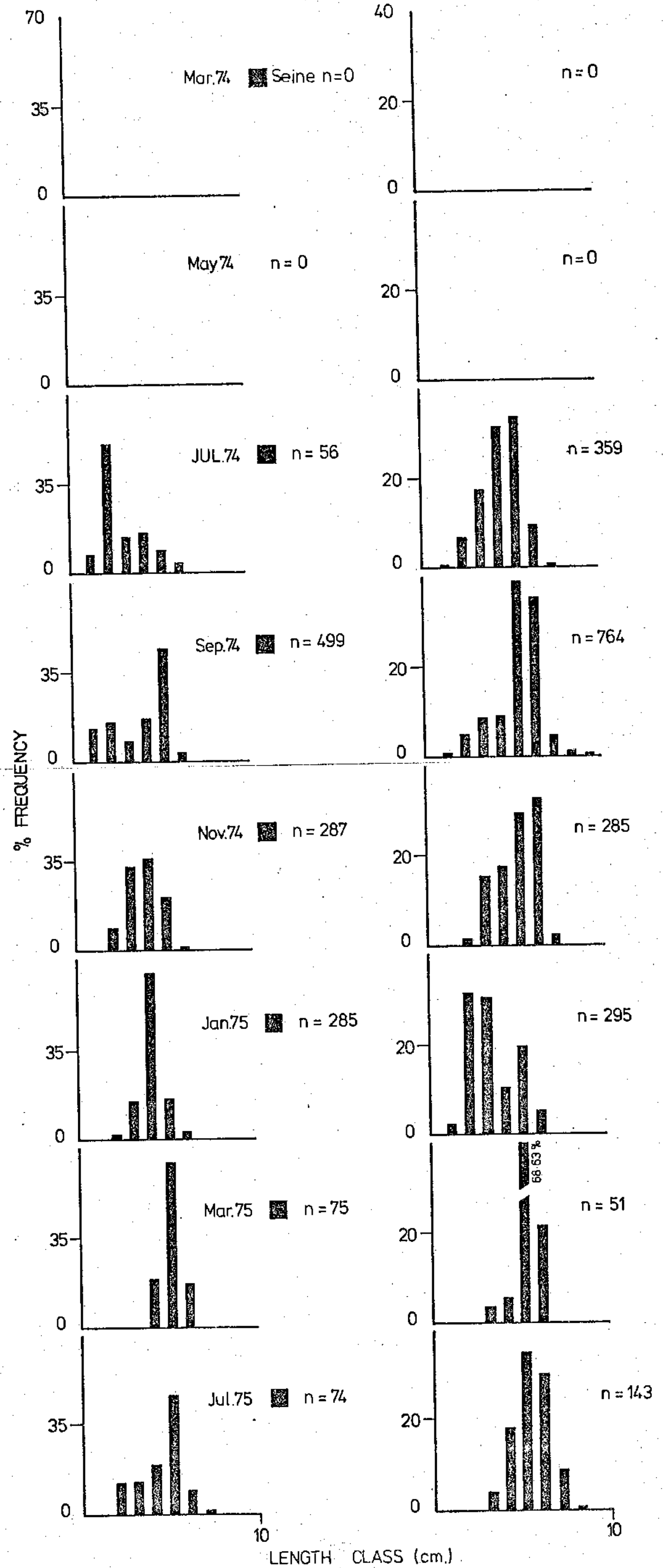


Fig. 15 Favonigobius lateralis Favonigobius tamarensis

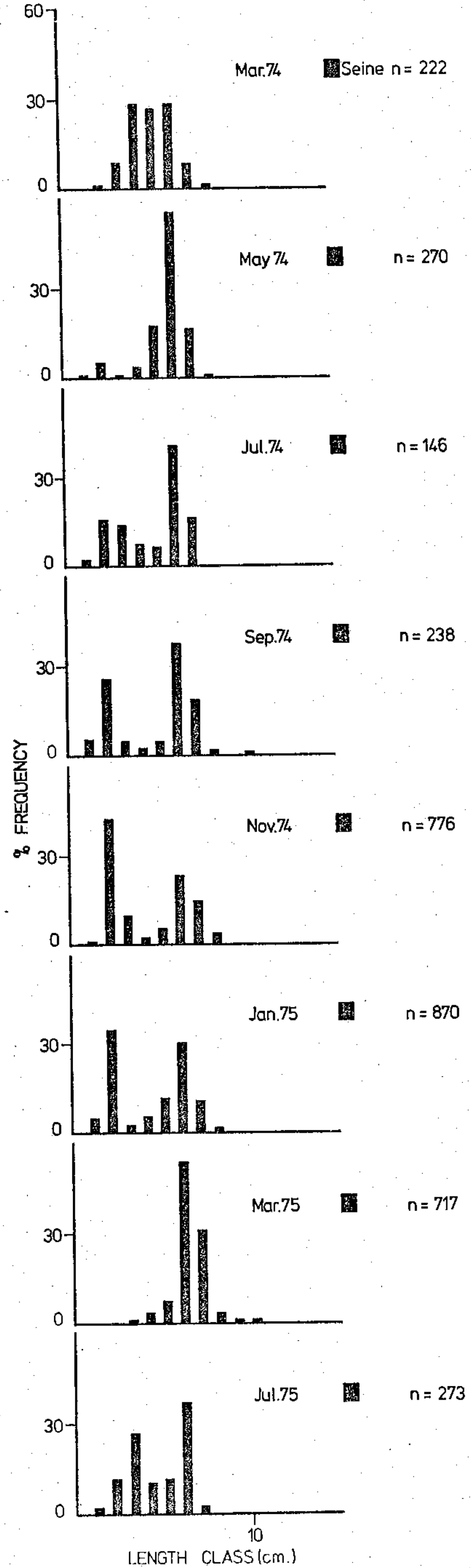


Fig. 16 Atherinisoma spp.

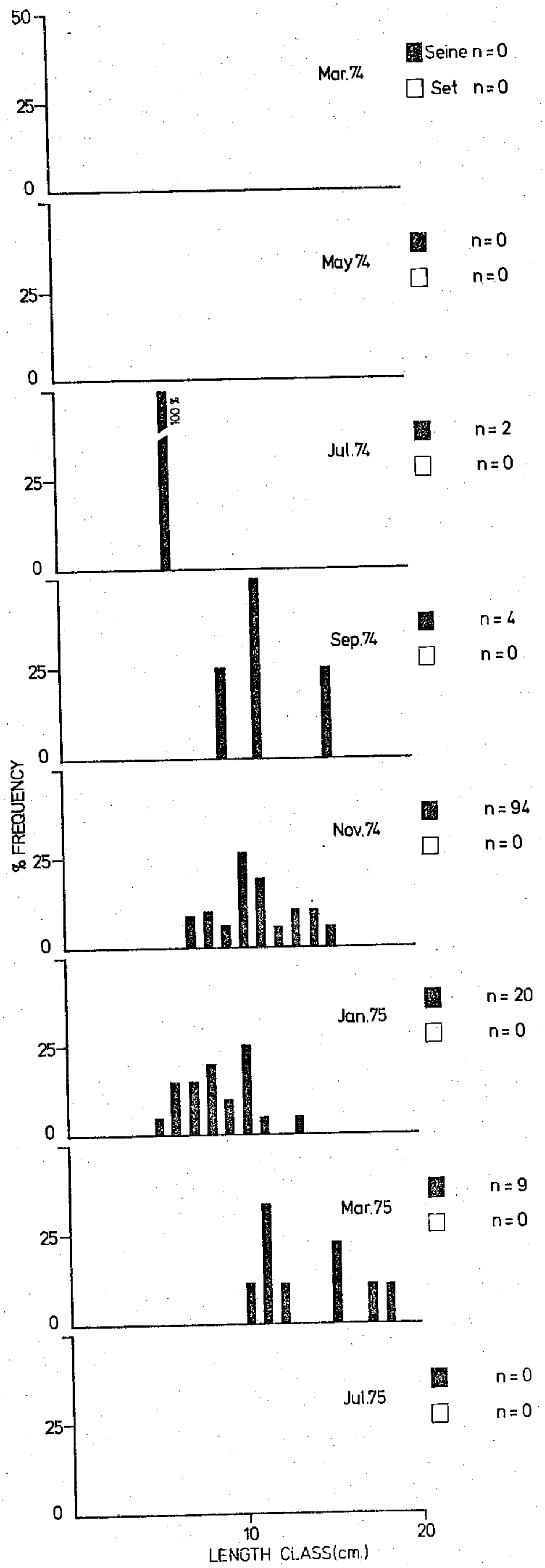


Fig. 17 Arenigobius bifrenatus

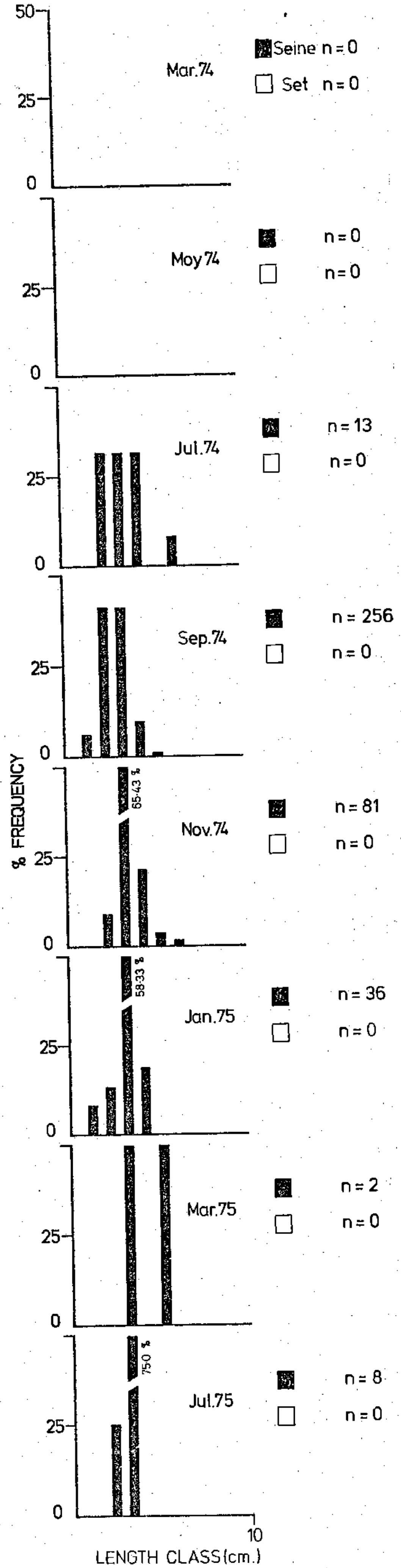


Fig. 18 Lizagobius olorum

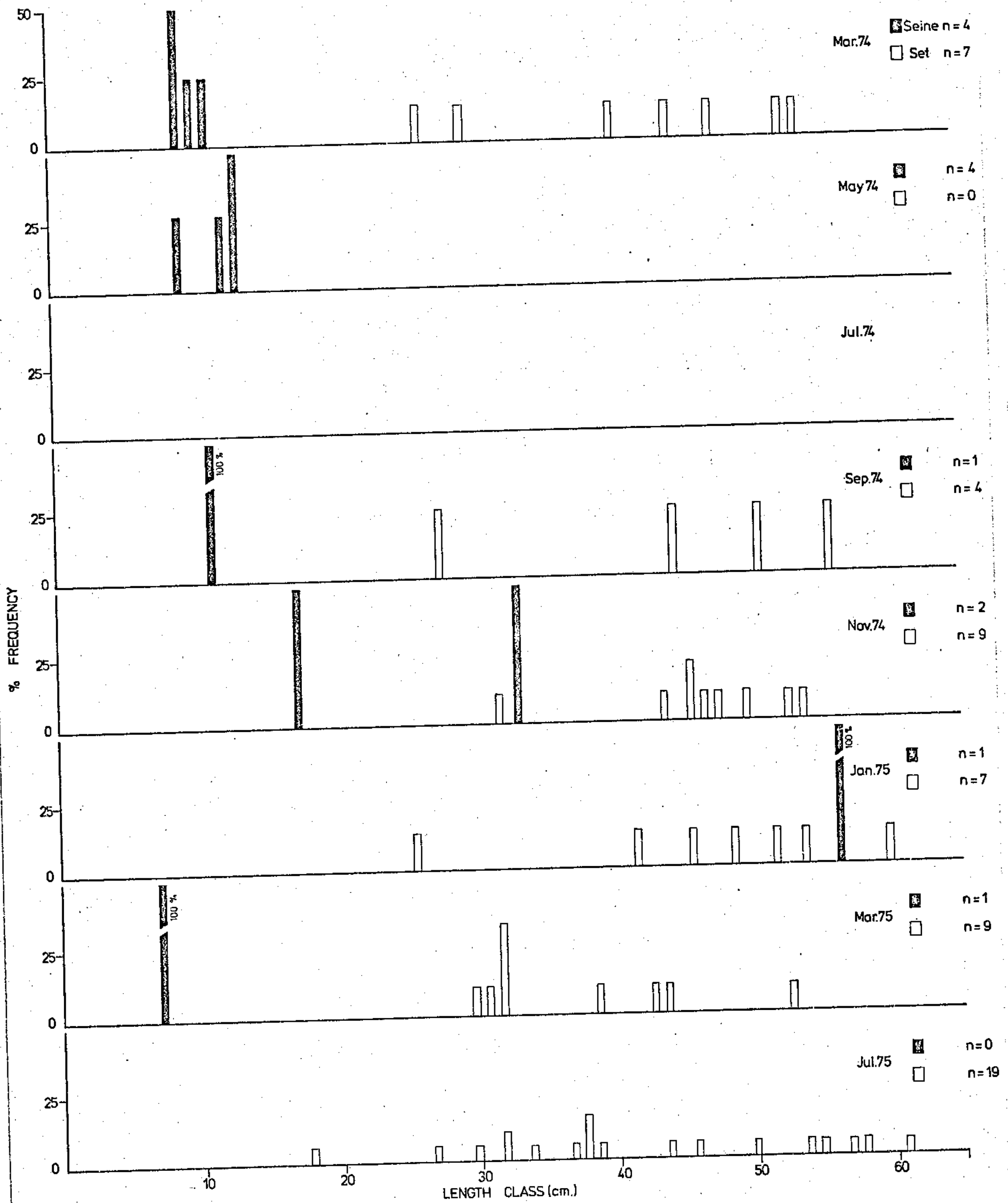


Fig. 19 *Cnidoglanis macrocephalus*

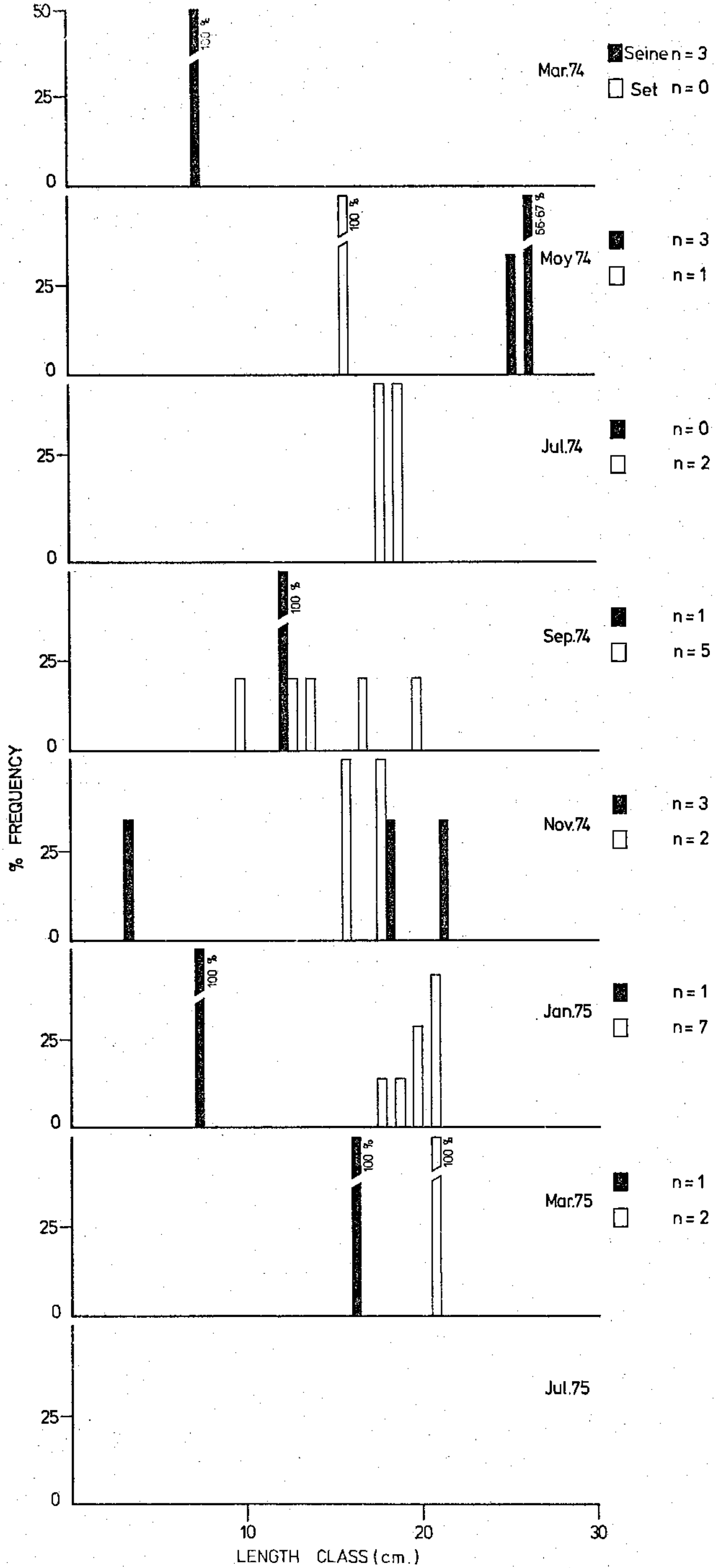


Fig. 20 *Ammotretis rostratus*

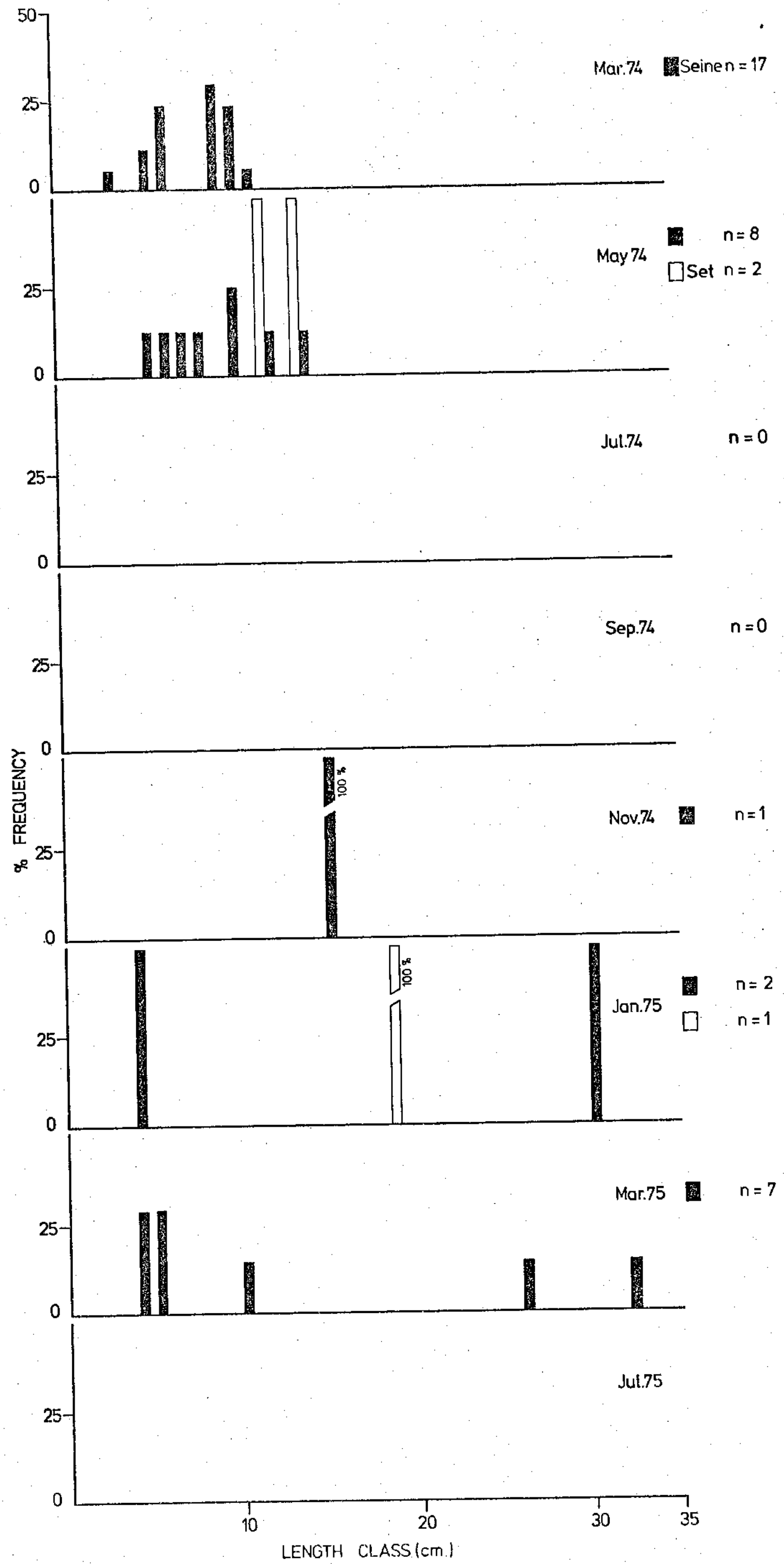


Fig. 21 *Pseudorhombus jenynsii*

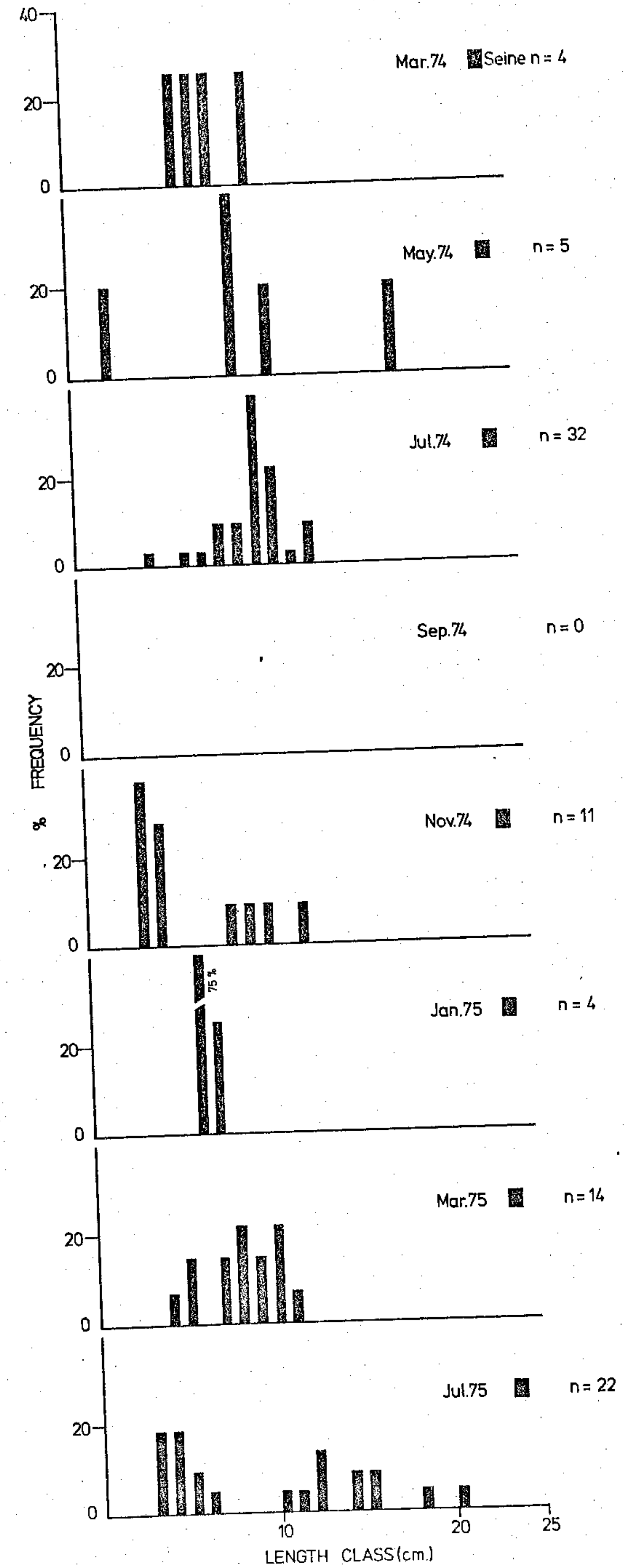


Fig. 22 *Contusus richei*

TABLE 8. SUMMARY OF PLANKTON DATA COLLECTED FROM THE BLACKWOOD RIVER ESTUARY BETWEEN JULY 1974 AND MARCH 1975.

Date	Area	Temp. (°C)	Sal. (°/oo)	Depth (m)	Pelagic Eggs: no oil droplets	Pelagic Eggs: one or two oil droplets	Pelagic Eggs: > two oil droplets	Larvae: Atherinidae	Larvae: Gobiidae	Larvae: Sillaginidae	Larvae: Tetradontidae	Larvae: Sygnathidae	Larvae: Other	Juveniles: Atherinidae	Juveniles: *F. lateralis*	Juveniles: *F. tamarensis*	Juveniles: *L. olorum*	Juveniles: *R. sarba*	Juveniles: *A. forsteri*	Juveniles: *M. cephalus*	Juveniles: *H. vittatus*	Juveniles: *G. mamoratus*	Juveniles: *R.* lobster Phyllosoma
JULY																							
1 mm net:																							
12. 7.74	02	13.0		Surface										61	19								
16. 7.74	04			Surface										194	1								
15. 7.74	13			Surface				1						36	1	3	24	3					
14. 7.74	19	10.8		Surface				2						77	12		24	2					
24. 7.74	65			Surface										1			1						
24. 7.74	95			Surface										2									
24. 7.74	105			Surface										1									
24. 7.74	128			Surface												1							
				Total				3						372	33	4	49	5					
SEPTEMBER																							
1 mm net:																							
25. 9.74	19			Surface					no	organisms				taken									
25. 9.74	25			Surface					no	organisms				taken									
20. 9.74	65			Surface					no	organisms				taken									
24. 9.74	95			Surface										4					2				
28. 9.74	98			Surface													1						
24. 9.74	165			Surface										6									
				Total										10			1		2				
0.2 mm net:																							
25. 9.74 *	03			2		5			1														
24. 9.74 †	25			2					7														
				Total		5			8														
OCTOBER																							
1 mm net:																							
25.10.74	03	18.5	20.5	Surface										1					3				1
25.10.74	03	18.5	20.2	2		1																	
25.10.74	12	17.7	35.0	Surface		5																	
25.10.74	48	18.7	5.5	1					no organisms					taken									
				Total		6								1					3				1

* Time of tow 0730 hrs.
† Time of tow 1600 hrs.

TABLE 8 (continued)

Date	Area	Temp. (°C)	Sal. (°/oo)	Depth (m)	Pelagic Eggs: no oil droplets	Pelagic Eggs: one or two oil droplets	Pelagic Eggs: > two oil droplets	Larvae: Atherinidae	Larvae: Gobiidae	Larvae: Sillaginidae	Larvae: Tetradontidae	Larvae: Sygnathidae	Larvae: Other	Juveniles: Atherinidae	Juveniles: *F. lateralis*	Juveniles: *F. tamarensis*	Juveniles: *L. olorum*	Juveniles: *R. sarba*	Juveniles: *A. forsteri*	Juveniles: *M. cephalus*	Juveniles: *H. vittatus*	Juveniles: *G. mamoratus*	Juveniles: R. lobster Phyllosoma
0.2 mm net:																							
26.10.74	03	18.5	20.5	Surface									3										
25.10.74	03	18.5	20.5	2					59	8													
25.10.74	48	18.7	5.5	1					8														
				Total					67	8			3										
NOVEMBER																							
1 mm net:																							
26.11.74	03	20.1	24.2	Surface					no organisms taken														
26.11.74	03	20.9	30.2	2					no organisms taken														
26.11.74	13	18.0	35.4	Surface		2					1												
29.11.74	13	19.0	33.9	Surface		2																	
25.11.74 *	13	17.5	34.0	3		17	1			2											9		
28.11.74	48			Surface					no organisms taken														
23.11.74	62			Surface					no organisms taken														
28.11.74	62			Surface					no organisms taken														
19.11.74	65			Surface					no organisms taken														
25.11.74 *	82	21.8	6.5	3																	15		
23.11.74	95			Surface					no organisms taken														
23.11.74	98			Surface					1														
29.11.74	105	22.8	6.1	Surface		2	1																
25.11.74	150	20.2	1.7	Surface					no organisms taken														
				Total		23	2		1	2	1										24		
DECEMBER																							
0.2 mm net:																							
15.12.74	13			Surface		38		2	27	1													
15.12.74	13			2	1	78		3	213			1	2										
15.12.74	90			Surface				1	7	2													
15.12.74	90			2				4	37	35						1							
15.12.74	130			Surface					6														
15.12.74	130			1	4†	1		2	25	22													
15.12.74	130			2					40	5													
				Total	5	117		12	355	65		1	2			1							

* Tows of 5 minutes duration
† Oval eggs, possibly *E. australis fraseri.*

TABLE 8 (continued)

Date	Area	Temp. (°C)	Sal. (°/oo)	Depth (m)	Pelagic Eggs: no oil droplets	Pelagic Eggs: one or two oil droplets	Pelagic Eggs: > two oil droplets	Larvae: Atherinidae	Larvae: Gobiidae	Larvae: Sillaginidae	Larvae: Tetradontidae	Larvae: Sygnathidae	Larvae: Other	Juveniles: Atherinidae	Juveniles: *F. lateralis*	Juveniles: *F. tamarensis*	Juveniles: *L. olorum*	Juveniles: *R. sarba*	Juveniles: *A. forsteri*	Juveniles: *M. cephalus*	Juveniles: *H. vittatus*	Juveniles: *G. mamoratus*	Juveniles: R. lobster Phyllosoma
JANUARY																							
1 mm net:																							
22. 1.75	02			Surface				no		organisms		taken											
22. 1.75	03			Surface			1																
22. 1.75	03			2				no		organisms		taken											
22. 1.75	12			Surface				no		organisms		taken											
22. 1.75	13			Surface				no		organisms		taken											
22. 1.75	19			Surface				no		organisms		taken											
22. 1.75	48			Surface				no		organisms		taken											
22. 1.75	62			Surface				no		organisms		taken											
22. 1.75	62			2				no		organisms		taken											
23. 1.75	65			Surface				no		organisms		taken											
23. 1.75	65			2		1																	
23. 1.75	95			Surface				1															
23. 1.75	98			Surface				no		organisms		taken											
23. 1.75	105			Surface				no		organisms		taken											
				Total		1	1	1															
MARCH																							
1 mm net:																							
23. 3.75	02			Surface				no		organisms		taken											
23. 3.75	02			2				8						4	5							1	
23. 3.75	04			Surface																			
23. 3.75	13			Surface									2										
23. 3.75	19			Surface				no		organisms		taken											
23. 3.75	48			Surface						1													
23. 3.75	62			Surface						1			2										
23. 3.75	62			2									1										
23. 3.75	65			Surface	1																		
23. 3.75	65			2				no		organisms		taken											
11. 3.75	95			Surface				no		organisms		taken											
23. 3.75	98			Surface				no		organisms		taken											
23. 3.75	105			Surface				no		organisms		taken											
23. 3.75	150			Surface				no		organisms		taken											
				Total	1			8		2			5	4	5							1	

TABLE. 9 DETAILS OF TRAWLING OPERATIONS IN THE BLACKWOOD RIVER ESTUARY DURING 1974

Month	Sample Stn.	Depth (m)	Shot	Speed (knots)	* Catch
September	off 13	5 - 6	1	variable 1 - 3	1 flounder (*P. jenynsii*)
	off 13	5 - 6	1	1 - 3	dead seagrass and algae
	01 - 03	2 - 3	1	1 - 3	dead seagrass and algae
	01 - 03	2 - 3	1	1 - 3	4 prawns (*M. dalli*)
November	off 13	5 - 6	1	1 - 3	6 sand crabs (*O. australiensis*)
	off 13	5 - 6	1	1 - 3	dead seagrass and algae
	off 13	5 - 6	1	1 - 3	dead seagrass and algae
	08	2 - 3	1	1 - 3	dead seagrass and algae.

* For details of carapace length and weight see Table 10.

TABLE 10 - A SUMMARY OF CRUSTACEAN DATA COLLECTED DURING THE BLACKWOOD RIVER ESTUARY STUDY.

Date	Fishing Method	Sample Stn.	Species: *Portunus pelagicus* Carapace Length (cm)	*Portunus pelagicus* Weight (gm)	*Ovalipes australiensis* Carapace Length (cm)	*Ovalipes australiensis* Weight (gm)	*Metapenaeus dalli* Carapace Length (cm)	*Metapenaeus dalli* Weight (gm)	Temp. (°C)	Sal. (°/oo)
29. 3.74	Set	72	8.0, 15.6	34.0, 365.0						
31. 3.74	Set	70	8.4	50.0	4.9, 3.9	29.3	*		20.5	35.4
1. 4.74	Seine	19					*		22.0	28.5
2. 4.74	Seine	98								
22. 5.74	Set	108	8.0, 8.0	59.2	8.3	39.3				
23. 5.74	Set	72								
23. 5.74	Set	70	7.8, 8.9	75.0			† 1.0	0.9	4.6	15.4
23. 9.74	Trawl	01, 03					0.9, 1.0, 0.9, 0.9	2.9		
25. 9.74	Seine	13								
27.11.74	Seine	19					1.2, 1.2, 1.6, 1.3, 1.3, 1.2, 1.1, 1.1, 1.2, 1.2, 1.1, 1.2, 1.3, 1.3, 1.2, 1.2, 1.2.	30.6	12.7	22.5
28.11.74	Seine	62					1.2, 1.0, 1.2, 1.2, 1.0, 1.1, 1.3, 1.1, 1.3, 1.3, 1.3, 1.1, 1.1.	18.4	33.9	19.9
29.11.74	Trawl (5 min.)	off 13			3.4, 4.2, 4.5, 5.2, 5.1, 5.6	146.4				
15. 1.75	Set	25			4.0	10.0				
13. 3.75	Set	25			2 x 5.0, 3 x 6.0, 3 x 7.0, 1 x 8.0	485. 0	5 .3	19 .0	35.3	19.3
15. 3.75	Seine	02								
21. 3.75	Set	05	18.0	675. 0						

* Animals caught were not counted, measured or weighed.

† Only one out of 4 animals caught was measured and weighed.

TABLE 11 TOTAL NUMBER OF FISH SAMPLED AT THE SET NET SAMPLING STATIONS IN THE CHANNEL AREA DURING THE BLACKWOOD RIVER ESTUARY SURVEY.

Station	18	19	25
Stn Depth (m)	0.5 - 1.0	0.5 - 0.8	1.0 - 4.0
July	18	-	6
September	11	31	3
November	30	41	3
January	32	29	5
March	197	109	22
Total	288	210	39

TABLE 12 THE CATCH COMPOSITION OF ONE DAY AND ONE NIGHT SEINE HAUL*AT STATION 98 IN THE BLACKWOOD RIVER ESTUARY DURING MARCH 1974.

Species	Catch (no.) Day	Night
M. butcheri	0	15
R. sarba	80	49
M. cephalus	4	0
A. forsteri	1	221
S. schomburgkii	1 425	202
A. georgianus	0	2
P. saltator	25	4
P. jensynii	2	0
H. sexlineatus	0	35
S. pleurogramma	3	2

* Both hauls were made during the same 24 hours.

TABLE 13 THE PERCENTAGE OF 0+ YR OLD FISH CAUGHT AT STATION 02, COMPARED WITH 0+ YR OLD FISH CAUGHT AT ALL OTHER STATIONS IN THE ESTUARY DURING THE BLACKWOOD RIVER ESTUARY STUDY.

Species	% of 0+ yr old fish from stn 02	
	In total stn 02 catch	Off the total 0+ yr old catch of all stns *
S. punctata	98	32
R. sarba	99	31
A. forsteri	41	14
M. cephalus	98	71

* There were 9 seine set sampling stations

TABLE 14 - THE NUMBER OF SPECIES RECORDED FROM EACH SAMPLING AREA EACH MONTH DURING THE BLACKWOOD RIVER ESTUARY STUDY.

Sampling Areas	March	May	July	September	November	January	March
River	5	4	2	3	2	7	4
Basins	13	13	7	7	12	12	13
Lagoon	23	21	7	16	21	20	18
Channel	17	19	11	18	20	21	27
Deadwater	15	15	17	20	17	19	22
Swan Lakes	8	4	11	10	13	11	14

TABLE 15 - A SUMMARY OF THE AVAILABLE NATURAL HISTORY DATA RELATED TO THE SPAWNING OF THE MORE ABUNDANT FISH OF THE BLACKWOOD RIVER ESTUARY.

Species	Estimated spawning times	Evidence of spawning within the estuary	Recorded as larvae	Initial record of 0+ yr old
A. forsteri	August	*		September
M. cephalus	June			July
S. schomburgkii	December	*	*	March (July)
S. punctata	June		* ‡	November
R. sarba	October			March (July)
M. butcheri	December	*		†
H. melanochir	December			March
A. georgianus	May			September
U. georgianus	September			November
P. saltator	December			March
H. sexlineatus	March			July
S. pleurogramma	February			March
Δ *F. lateralis*)				
Δ *F. tamarensis*)	September	*	*	September
Δ *L. olorum*)	to			
Δ *A. bifrenatus*)	March			
Δ *Atherinosoma* spp.	September	*	*	May

† one specimen only.

‡ 0+ yr old fish never taken in the reasearch area.

Δ Small 0+ yr old fish may escape through 3/8" mesh of the seine bunt. Record possibly as a result of a second spawning shown in parentheses.

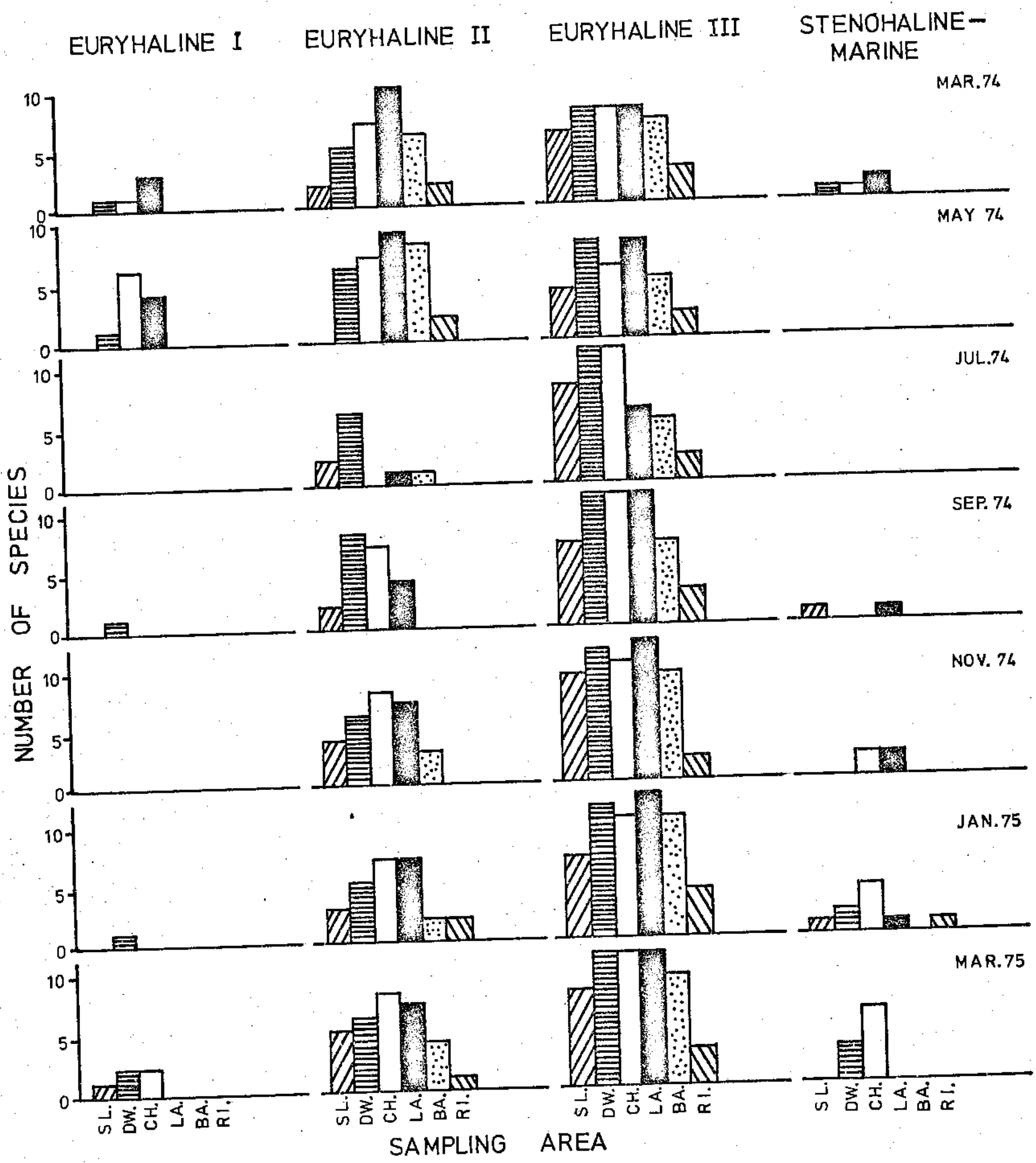


Figure 23 - The distribution of fish species of types euryhaline I to III and stenohaline marine throughout the Blackwood River estuary sampling areas Swan lakes (SL.), deadwater (DW), channel (CH), lagoon (LA), basins (BA) and river (RI) every second month from March 1974 to March 1975.

Appendix 1. An annotated checklist of all species of fish collected during the Blackwood River estuary study.

More abundant species: A summary of the seasonal relative abundance and distribution throughout the estuary of these species is presented in Figure 1 located at the end of this section.

Aldrichetta forsteri (Cuvier and Valenciennes), 1836 - Yelloweye mullet. Fish taken: seine 2 573, set 1 199, comprising 1 180 fish 0+ year old (≤ 14 cm) and 2 592 fish 1+ and older; size range 3-39 cm; gonads observed as gravid with some spent in Sep.; salinity range < 1-39.6°/oo; temperature range 9.5 - 28.9°C; O_2 range 4.79 - 8.69 mg/l.

Mugil cephalus Linnaeus, 1758 - Sea mullet. Fish taken: seine 685, set 743; comprising 599 fish 0+ year old (≤ 12 cm) and 829 fish 1+ and older; size range 2-56 cm; gonads observed as recently spent in Jul.; salinity range < 1-39.6°/oo; temperature range 12.0 - 28.9°C; O_2 range 4.79 - 8.56 mg/l.

Sillago schomburgkii Peters, 1865 - Western sand whiting. Fish taken: seine 4 340; set 226, comprising 189 fish 0+ year old (≤ 10 cm) and 4 377 fish 1+ and older; size range 6-36 cm; gonads observed as gravid in Nov. with some spent in Jan.; larvae suspected as being those of this species first recorded late Oct. 74, most abundant Dec. 74; salinity range < 1 - 39.6°/oo; temperature range 9.5 - 28.9°C; O_2 range 4.99 - 8.69 mg/l.

Sillago punctata Cuvier and Valenciennes, 1829 - King George whiting. 1 906 fish taken by seine, comprising 1 323 fish 0+ year old (≤ 20 cm) and 583 fish 1+ and older; size range 3 - 30 cm; all fish taken were sexually immature; salinity range < 1 - 36.8°/oo; temperature range 9.5 - 28.9°C; O_2 range 4.79 - 8.64 mg/l.

Rhabdosargus sarba (Forskal), 1775 - Tarwhine. Fish taken; seine 2 215, set 459, comprising 1 511 fish 0+ year old (≤ 12 cm) and 1 163 fish 1+ and older; size range 2 - 28 cm; both gravid and spent gonads observed in Nov.; salinity range < 1 - 39.6°/oo; temperature range 9.5 - 28.9°C; O_2 range 5.50 - 8.69 mg/l.

Mylio butcheri Munro, 1949 - Black bream. Fish taken: seine 741, set 856, comprising 0 fish 0+ year old (≤ 10 cm) and 1 597 fish 1+ and older; size range 12-41 cm, preliminary observations suggest gonads commence ripening late Sep. Initial records of spent gonads made in Jan.; salinity range < 1 - 36.8°/oo; temperature range 9.5 - 25.5°C; O_2 range 5.18 - 8.64 mg/l.

Hyporhamphus melanochir (Valenciennes), 1846 - Southern sea garfish. 739 fish taken by seine, comprising 255 fish 0+ year old (≤ 18 cm) and 484 fish 1+ and older; size range 11 - 39 cm; no data available relating to spawning time; salinity range 22.6 - 35.6 ^{o}/oo; temperature range 16.0 - 23.0 ^oC; 0_2 range 5.84 - 7.18 mg/l.

Arripis georgianus (Cuvier and Valenciennes), 1831 - Australian herring. Fish taken: seine 36, set 1 046, comprising 6 fish 0+ year old (≤ 18 cm) and 1 076 fish 1+ and older; size range 5 - 29 cm; gonads observed as either maturing virgin or recovering spent in Jul., (this species known to spawn in May, however, estuarine populations may spawn at a different time); salinity range 12.7 - 36.8 ^{o}/oo; temperature range 16.0 - 23.0 ^oC; 0_2 range 7.18 - 8.57 mg/l.

Caranx georgianus Cuvier, 1833 - Trevally. Fish taken: seine 255, set 12, comprising 173 fish 0+ year old (≤ 18 cm) and 94 fish 1+ and older; size range 4 - 30 cm; gonads observed as either maturing virgin or recovering spent, and spent in Jan.; salinity range 6.7 - 36.8 ^{o}/oo; temperature range 17.4 - 23.0 ^oC; 0_2 range 5.50 - 8.41 mg/l.

Pomatomus saltator (Linnaeus), 1758 - Tailor. Fish taken: seine 91; set 228, comprising 43 fish 0+ year old (≤ 12 cm) and 276 fish 1+ and older; size range 5 - 40 cm; gonads observed as gravid in Nov.; salinity range 9.3 - 36.8 ^{o}/oo; temperature range 13.0 - 23.0 ^oC; 0_2 range 5.50 - 8.57 mg/l.

Helotes sexlineatus (Quoy and Gaimard), 1825 - Striped perch. Fish taken: seine 1 085, set 104, comprising 10 fish 0+ year old (≤ 10 cm) and 1 179 fish 1+ and older; size range 5 - 27 cm; no data available relating to spawning time; salinity range < 1 - 36.8 ^{o}/oo; temperature range 10.0 - 23.0 ^oC; 0_2 range 5.50 - 8.41 mg/l.

Sphoeroides pleurogramma* (Regan), 1903 - Banded toadfish. Fish taken: seine 606, set 2, only one juvenile fish taken (see appendix 3); size range 9 - 15 cm; newly hatched fish observed in Deadwater in Mar. '75; salinity range 4.6 - 36.8 ^{o}/oo; temperature range 12.0 - 23.8 ^oC; 0_2 range 5.18 - 8.21 mg/l.

Favonigobius lateralis (MacLeay), 1881 - Long finned goby. 1 202 fish taken by seine between Jul. '74 and Mar. '75. Prior to Jul. '74 precise identification of this species was not established; the 0+ year old group of this species was not identified; size range 2 - 7 cm; Gobiidae eggs and larvae were collected during the period Sep. to Dec. '74. (incl.); salinity range < 1 - 39.6 ^{o}/oo; temperature range 9.5 - 26.7 ^oC; 0_2 range 4.79 - 8.69 mg/l.

* Shipp and Yerger, (1969)

Favonigobius tamarensis (Johnston), 1883 - South west goby. 1 754 fish taken by seine between Jul. '74 and Mar. '75. Prior to Jul. '74 precise identification of this species was not established; the 0+ year old group of this species was not identified; size range 2 - 10 cm; Gobiidae eggs and larvae were collected during the period Sept. to Dec. '74 (incl.); salinity range < 1 - 36.3 ^{o}/oo; temperature range 9.5 - 26.0^{o}C; 0_2 range 4.79 - 8.64 mg/l.

Atherinisoma spp. - Hardyhead. 3 239 fish taken by seine. Two very similar species, *A. rockinghamensis* and *A. edelensis*, were identified from the estuary. Great difficulty was experienced differentiating between them. For the purpose of the study therefore, they were grouped together as one genus. The large majority of hardyheads taken are thought to be *A. rockinghamensis;* the 0+ group of these species was not identified; size range 1 - 11 cm; fish observed in spawning condition in Sep. '74; larvae recorded in Jul. '74, Dec., Jan. '75 and Mar.; salinity range < 1 - 39.6^{o}/oo; temperature range 10.0 - 28.9^{o}C; 0_2 range 4.79 - 8.69 mg/l.

Arenigobius bifrenatus (Kner), 1865 - Bridled goby. 140 fish taken by seine, comprising 9 fish estimated to be 0+ year old and 131 fish 1+ and older; size range 5 - 19 cm; no spawning data available; salinity range < 1 - 35.6 ^{o}/oo; temperature range 9.5 - 23.0^{o}C; 0_2 range 4.79 - 8.64 mg/l.

Lizagobius olorum (Sauvage), 1880 - Blue spot goby. 388 fish taken by seine between Jul. '74 and Mar. '75; prior to Jul. '74 precise identification of this species was not established; the 0+ year old group of this species was not identified; size range 2 - 7 cm; Gobiidae eggs and larvae were collected during the period Sep. to Dec. '74 (incl.); salinity range < 1 - 36.3^{o}/oo; temperature range 9.5 - 26.7^{o}C; 0_2 range 5.18 - 8.64 mg/l.

<u>Less abundant species:</u> A summary of the seasonal occurrence and distribution throughout the estuary of each species is included in the normal text.

Sillago bassensis Cuvier and Valenciennes, 1829 - School whiting. One adult speciment taken by seine at stn 62, Nov. '74; length 16 cm; salinity 33.9 ^{o}/oo; temperature 19.9 ^{o}C; O_2 6.55 mg/l.

Cnidoglanis macrocephalus (Cuvier and Valenciennes), 1840 - Cobbler. Fish taken: seine 13, set 35, comprising 8 fish 0+ year old (< 20 cm) and 40 fish 1+ and older; size range 8 - 60 cm; no spawning data available, seasonal occurrence at stns, Mar. '74: 06, 62, 02s, 62s, 108s, 150s; May: 13; Sept: 13, 01s, 05s, 18s, 70s; Nov: 03, 13, 05s, 25s, 70s; Jan. '75: 95, 01s, 02s, 72s; Mar: 13, 02s, 03s, 19s, 70s, 108s; salinity range 4.5 - 35.6 ^{o}/oo; temperature range 15.3 - 25.4 ^{o}C; O_2 range 5.18 - 8.41 mg/l.

Arripis trutta esper Whitley, 1949-50 - Australian salmon. Fish taken: seine 2, set 7, comprising 6 fish 0+ year old (< 25 cm) and 3 fish 1+ and older; size range 5 - 30 cm; all fish taken were sexually immature. Seasonal occurrence at stns, Mar. '74: 70s, 72s; May: 72s Jul.: 04, 02s; Sept: 02s, 19s, 70s; salinity 3.5 ^{o}/oo; temperature 12.5 ^{o}C; O_2 6.99 mg/l.

Chrysophrys unicolor Quoy and Gaimard, 1824 - Snapper. Fish taken: seine 2, set 4, comprising 4 fish 0+ year old (< 14 cm) and 2 fish 1+ and older; size range 10 - 24 cm; all fish taken were sexually immature; seasonal occureence at stns, Mar. '74: 01s; May: 13, 65, 01s; Mar. '75: 05s; salinity 28.9 ^{o}/oo; temperature 21 ^{o}C.

Trachurus mccullochi Nichols, 1920 - Yellowtail. One specimen (estimated to be 0+ year old) taken by set at stn 70s, Apr. '74; length 16 cm.

Ammotretis rostratus Gunther, 1862 - Long snouted flounder. Fish taken: seine 12, set 19, comprising 24 fish 0+ year old (< 20 cm) and 7 fish 1+ and older; size range 4 - 27 cm; no spawning data available; seasonal occurrence at stns Mar. '74: 19, 65, 105; May: 02, 13, 65, 70s; Jul.: 62s; Sept: 02, 01s, 02s, 18s, 70s, Nov: 19, 62, 98, 25s; Jan. '75: 65, 01s, 05s, 19s, 25s, 70s; Mar: 19, 19s; 25s; salinity range 3.6 - 35.4 ^{o}/oo; temperature range 16.0 - 26.7 ^{o}C; O_2 range 5.99 - 7.32 mg/l.

Pseudorhombus jenynsii (Bleeker), 1855 - Small toothed flounder. Fish taken: seine 35, set 3, comprising 35 fish 0+ year old (< 20 cm) and 3 fish 1+ and older; size range 4 - 33 cm; no spawning data available; seasonal occurrence at stns, Mar. '74: 19, 65, 98, 105; May: 13, 48, 62, 65, 02s, 111s; Nov: 19; Jan. '75: 62, 25s; Mar: 13, 48, 62; salinity range 12.7 - 35.6 ^{o}/oo; temperature range 16.0 - 22.5^{o}C: 0_2 range 4.79 - 7.25 mg/l.

Engraulis australis fraseri Gunther, 1868 - Southern anchovy. Fish taken: seine 2, set 4; estimated that all fish 1+ year old and older; size range 7 - 10 cm; no spawning data available; seasonal occurrence at stns: Mar. '74: 95, 165s; Jul.: 03; Sept.: 01s, 25s; Mar. '75: 62s; salinity range 6.7 - 9.3 ^{o}/oo; temperature range 12.0 - 13.0^{o}C; 0_2 (Jul.) 6.99 mg/l.

Spratelloides robustus Ogilby, 1897 - Blue sprat. 61 fish taken by seine; estimated that all fish 1+ year old and older; size range 5 - 9 cm; no spawning data available; seasonal occurrence at stns Mar. '74: 62; May: 13; salinity range 28.9 - 33.4 ^{o}/oo; temperature range 21.0 - 23.0^{o}C; no 0_2 data available.

Hyperlophus vittatus (Castelnau), 1875 - Sandy sprat. 63 fish taken by seine; estimated that all fish 1+ year old and older; size range 5 - 9 cm; larvae present in plankton tows during Nov. '74; seasonal occurrence at stns, Mar. '74: 13, 48, 65; Mar. '75: 19; salinity range 20.3 - 32.7 ^{o}/oo; temperature range 16.0 - 21.0^{o}C; 0_2 (Mar. '75) 6.16 mg/l.

Enoplosus armatus (White), 1790 - Old wife. 15 fish taken by seine; all fish estimated to be 0+ year old; size range 3 - 8 cm; no spawning data available; seasonal occurrence at stns, Mar. '74: 62; May: 13, 62; Jan. '75: 03; Mar.: 03; salinity range 23.5 - 36.2 ^{o}/oo; temperature range 16.0 - 23.0^{o}C; 0_2 range 6.55 - 7.87 mg/l.

Balistidae - Leatherjackets. 61 fish taken by seine. Three species, *Scobinichthys granulatus* (White), 1790 - Rough leatherjacket, *Acanthaluteres guntheri* (MacLeay), 1881 - Toothbrush leatherjacket and *Navodon freycineti* nov. sp. - Six-spined leatherjacket, were identified from the estuary; size range 2 - 18 cm; no spawning data available. Only a small number of the leatherjackets taken were identified to species level. The seasonal occurrence at stns of all fish taken was *N. freycineti* May '74: 65; Jul.: 02; Mar. '75: 02. *S. granulatus* Mar. '75: 62. *A. guntheri* Mar. '75: 105. Unidentified leatherjackets: Mar. '74: 62; May: 13, 62, 65, 95: Jan. '75: 13; salinity range 9.3 - 35.6 ^{o}/oo; temperature range 13.0 - 23.8^{o}C; 0_2 range 4.99 - 8.21 mg/l.

Haletta semifasciata (Cuvier and Valenciennes), 1840 - Blue rock whiting. 13 fish taken by seine; size range 9 - 15 cm; no data available relating to spawning time; if spawning occurs in spring, the 3 largest fish taken (15 cm) were probably 1+ year old, however, if spawning occurs in autumn all fish taken were probably 0+ year old; seasonal occurrence at stns, Mar. '74: 02; Jan. '75: 02; Mar.: 02; salinity range 35.3 - 36.8 $^o/oo$; temperature range 17.4 - 20.2°C; 0_2 range 5.50 - 8.21 mg/l.

Contusus richei (Freminville), 1873 - Prickly toadfish. 70 fish taken by seine, comprising 27 fish 0+ year old (< 12 cm) and 43 fish 1+ and older; size range 3 - 19 cm; no spawning data available; seasonal occurrence at stns, Mar. '74: 13, 62, 73; May: 02, 04, 13, 65: Jul.: 02,04; Nov: 02, 03, 13, 19, 62, 65; Jan '75: 13, 62; Mar.: 04, 19, 98, salinity range 3.1 - 36.1 $^o/oo$; temperature range 12.0 - 23.8°C; 0_2 range 4.79 - 8.41 mg/l.

Pseudolabrus parilus (Richardson), 1850 - Brown spotted parrot fish. 5 fish taken by seine; all fish estimated to be 0+ year old; size range 7 - 10 cm; no spawning data available; seasonal occurrence at stns, May '74: 13; Mar. '75: 02; salinity range 28.9 - 36.5 $^o/oo$; temperature range 17.6 - 21.0°C; 0_2 (Mar. '75) 8.21 mg/l.

Achoerodus gouldii (Richardson), 1843 - Blue groper. 3 fish taken by seine at stn 03, Jan. '75; 7, 8 and 9 cm length; all 0+ year old; salinity 36.2 $^o/oo$; temperature 21.3°C, 0_2 6.55 mg/l.

Atopomycterus nicthemerus (Cuvier), 1818 - Globe fish. 1 specimen estimated to be 0+ year old taken by seine at stn 95, May '74; length 6 cm; salinity 9.3 $^o/oo$; temperature 13.0°C.

Syngnathus sp. - Pipe fish. 2 specimens (estimated to be 0+ year old) taken by seine at stn 13, Jan. '75; length (both specimens) 9 cm; salinity 35.6 $^o/oo$; temperature 23.8°C; 0_2 6.08 mg/l.

Gambusia affinis (Baird and Girard), 1853 - Mosquito fish. Some specimens taken at stn 98 with a hand dip net during Jul. '74.

Sciaena antarctica Castelnau, 1872 - Mulloway. 13 fish taken by set, comprising 12 fish estimated to be 0+ year old and 1 fish 1+ or older; size range 21 - 39 cm and one specimen 112 cm; gonads of large ♀ (22 kg.) taken by angler in Nov. at estuary mouth were spent; seasonal occurrence at stns, Sept. '74; 70s; Nov: 72s; Jan. '75: 05s, 150s; Mar.: 02s, 25s.

Elops australis Regan, 1909 - Giant herring. 1 specimen (> 1+ yr old) taken by set at stn 05s, Sept. '74; length 47 cm.

Kyphosus cornelii (Whitley), 1944. - Buffalo bream. 1 adult specimen taken by set at stn 62s, Jan. '75; length 31 cm.

Schuetta woodwardi Waite, 1905 - Woodward's pemferet. 1 adult specimen taken by set at stn 18s, Jan. '75; length 16 cm.

Aetapcus vincenti (Steindachner), 1883 - Smooth prow fish. 1 specimen found on shore of the estuary in Nov. '74.

Hippocampus angustus Gunther, 1870 - Seahorse. 1 specimen taken by set at stn 19s, Nov. '74.

Platycephalus sp. - Flathead. Fish taken: seine 1, set 12, all fish estimated to be 1+ year old and older; size range 25 - 72 cm; no spawning data available; seasonal occurrence at stns, Nov. '74: 18s, 19s; Jan. '75: 18s; Mar: 13, 18s, 19s; salinity 35.6 $^o/oo$; temperature 22.1°C; O_2 5.84 mg/l.

Cristiceps australis Cuvier and Valenciennes, 1836 - Crested weedfish. 1 specimen taken by seine at stn 02, Mar. '75; length 16 cm; salinity 35.3 $^o/oo$; temperature 18.9°C; O_2 8.21 mg/l.

Ophisurus serpens (Linnaeus), 1758 - Serpent eel. 1 adult specimen taken by set at stn 05s, Jul. '74.

Psilocranium nigricans (Richardson), 1850 - Dusky Morwong. 1 adult specimen taken by seine at stn 13, Mar. '75; length 101 cm; 1 specimen (estimated to be 0+ yr old) taken by set at stn 02s, Mar. '75; length 20 cm; salinity 35.6 $^o/oo$; temperature 22.1°C; O_2 5.84 mg/l.

Goniistius gibbosus (Richardson), 1841 - Magpie morwong. 2 specimens (estimated to be 0+ yr old) taken by set at stns 25s, Mar. '75; and 62s, Mar. '75; length both 20 cm.

Gymnapistes marmoratus (Cuvier and Valenciennes), 1829 - Devilfish. 1 specimen (estimated to be 0+ yr old) taken by seine at stn 13, Mar. '75; length 46 cm; salinity 35.6 $^o/oo$; temperature 22.1°C; O_2 5.84 mg/l.

Chelidonichthys kumu (Lesson and Garnot) 1826 - Red gurnard. 1 specimen (estimated to be 0+ yr old) taken by set at stn 25s, Mar. '75; length 20 cm.

Tandanus bostocki Whitley, 1944 - Freshwater catfish. 1 adult specimen taken by set at stn 108s, Jul. '74; length 30 cm.

Edelia vittata Castelnau, 1873 - Westralian pigmy perch. 1 specimen taken by diving in channel north of Molloy Island, Mar. '75.

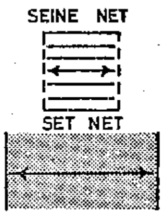
ELASMOBRANCHI

Dasyatis brevicaudata (Hutton), 1875 - Smooth stingray. Fish taken: seine 4, set 2, all estimated to be greater than 0+ year old. Only 2 of the specimens taken were retained and measured. These were taken by seine at stn 19, Mar. '75; lengths 69 cm and 97 cm. Specimens were also taken by seine at stn 19, Apr. '74; by set at stn 70s, Apr. '74 and stn 25s, Jan. '75; salinity range 32.7 - 35.4 $^{o}/oo$; temperature range 19.8 - 20.5^{o}C; O_2 (Mar. '75) 6.16 mg/l.

Trygonorhina fasciata Muller and Henle, 1841 - Fiddler ray. 1 specimen taken by seine at stn 01, Mar. '75; length 46 cm.

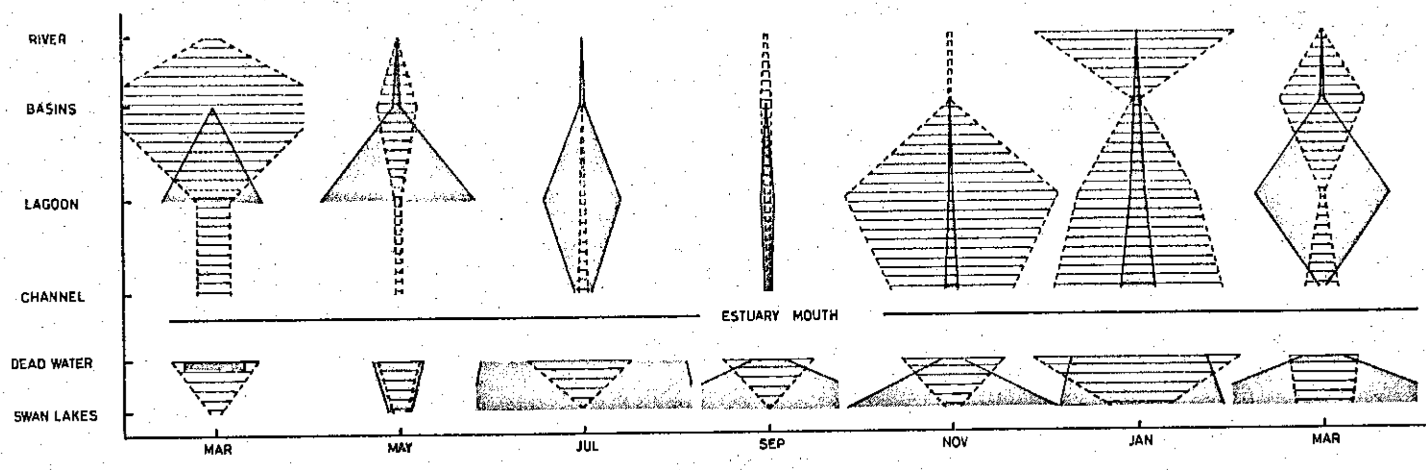
Figure 1 A summary of the seasonal relative abundance and distribution throughout the estuary of each of the more abundant species taken during the Blackwood River estuary study.

SCALE

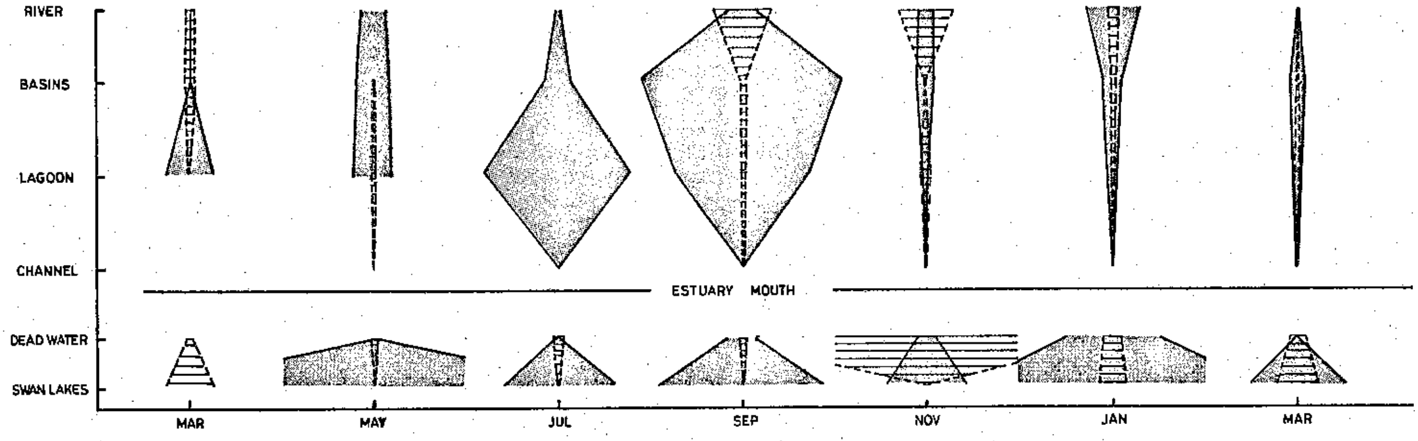


proportional to a relative abundance of 20 fish per haul.

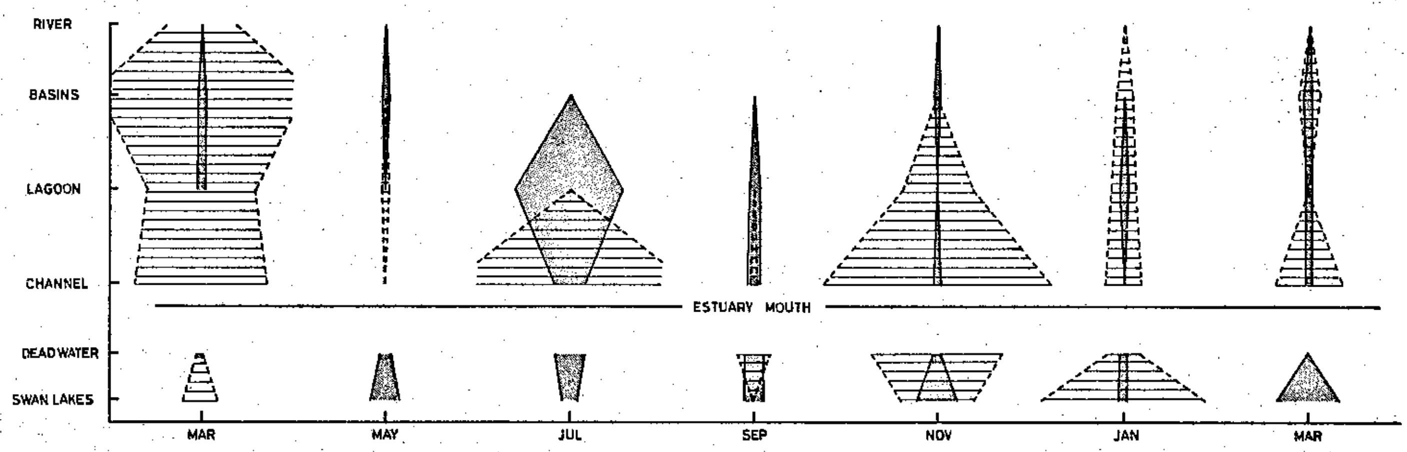
Aldrichetta forsteri



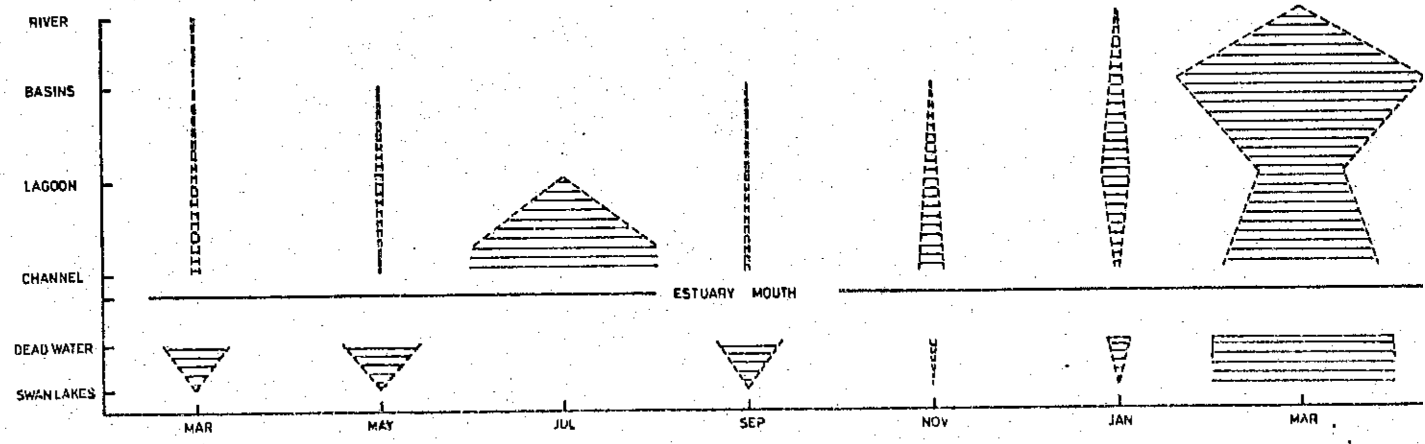
Mugil cephalus



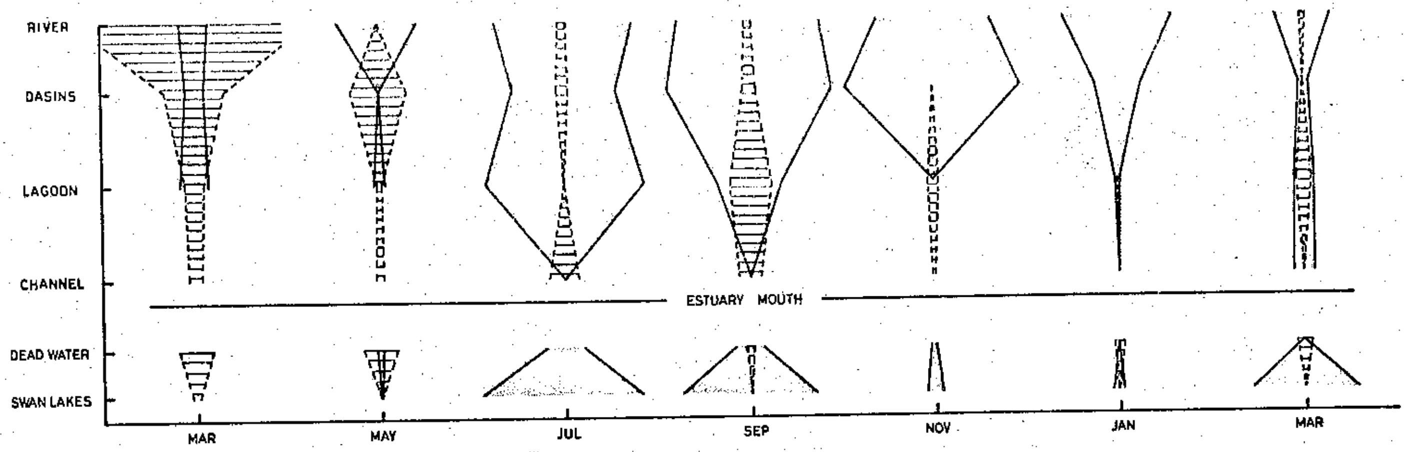
Sillago schomburgkii



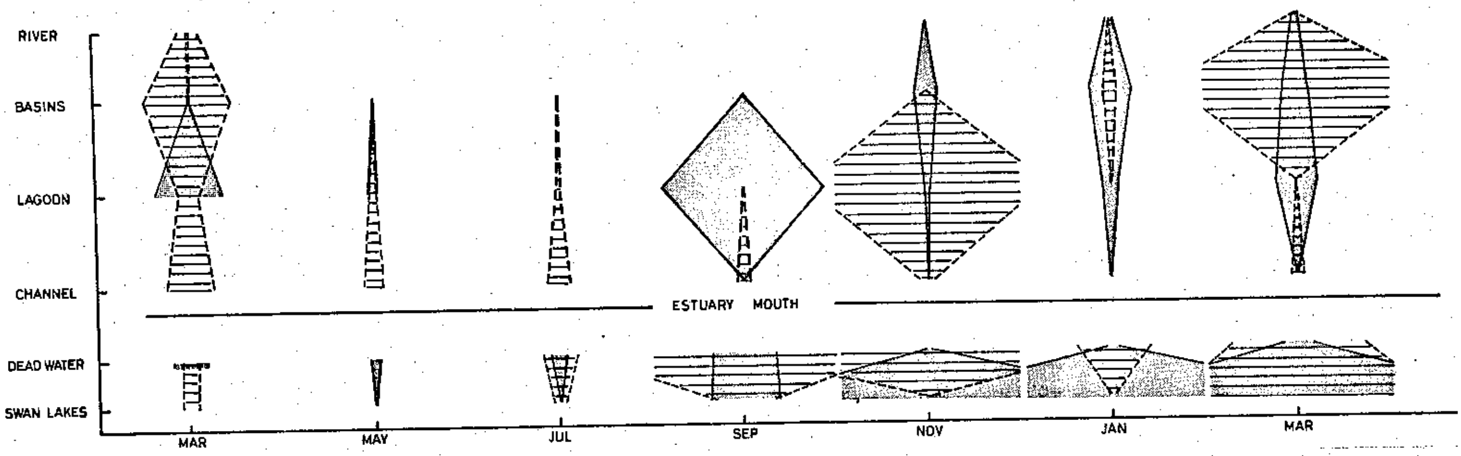
Sillago puntata



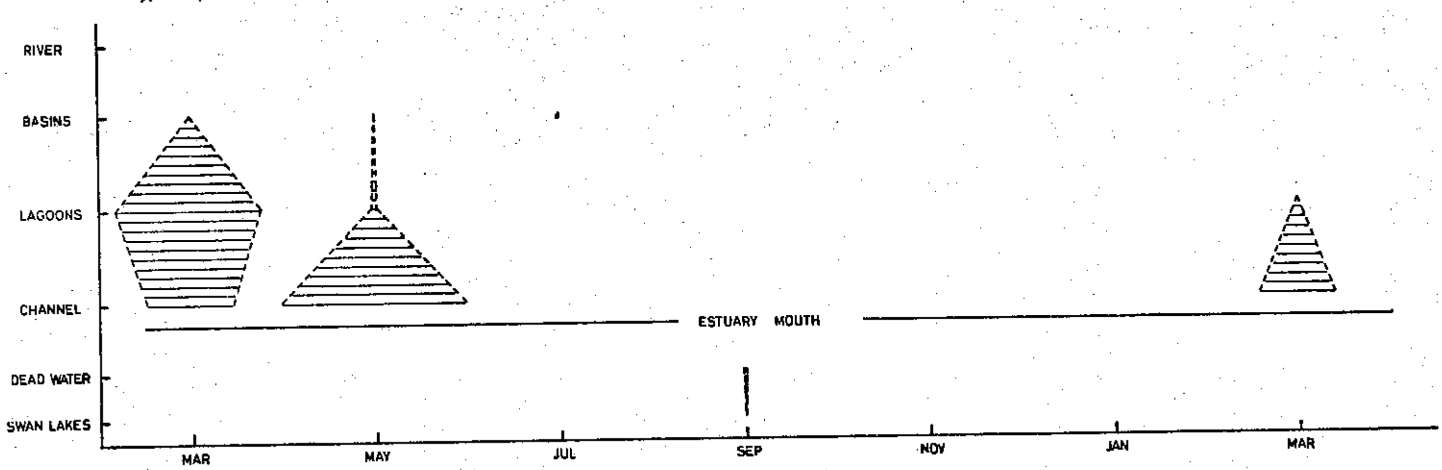
Mylio butcheri



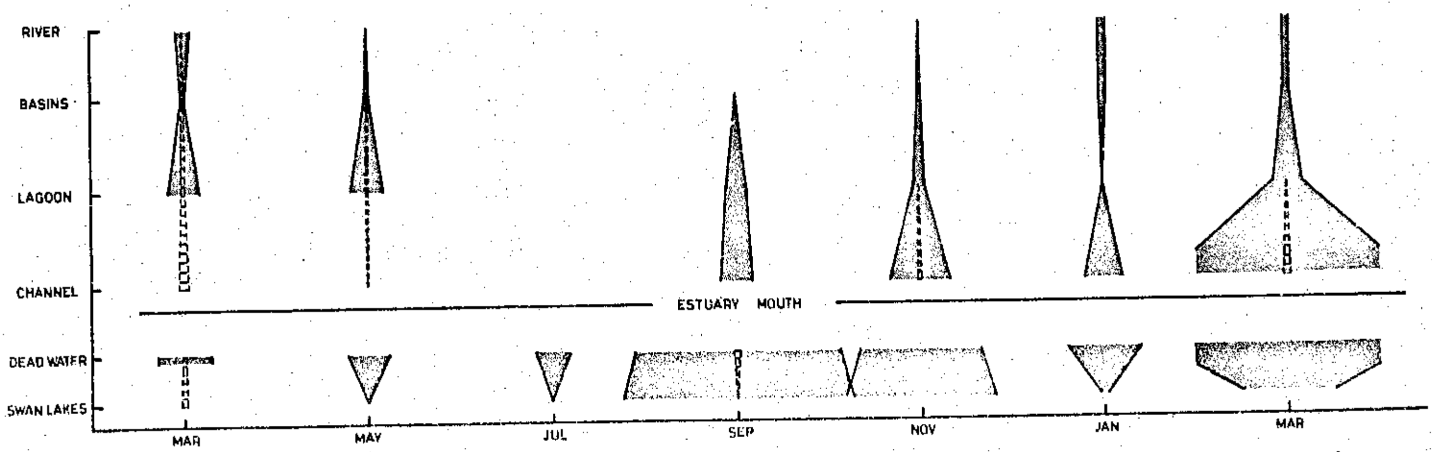
Rhabdosargus sarba



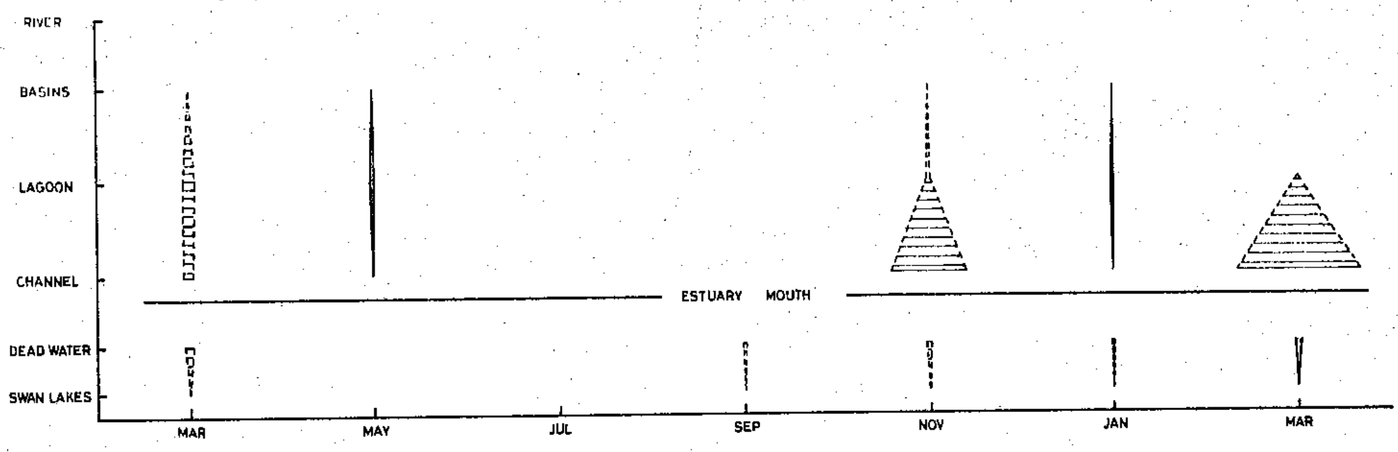
Hyporamphus melanochir



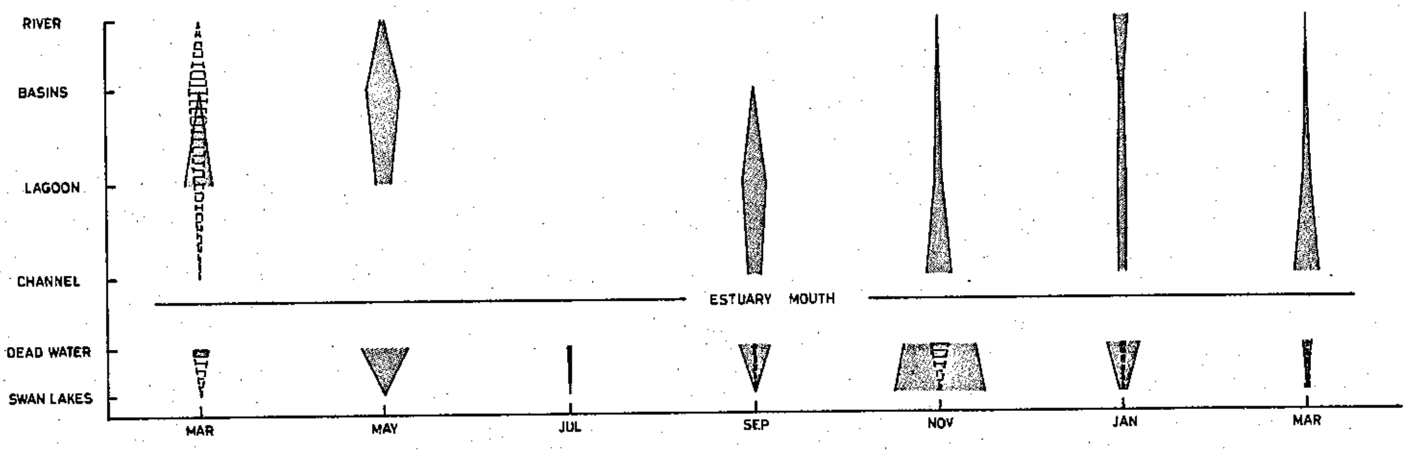
Arripis georgianus



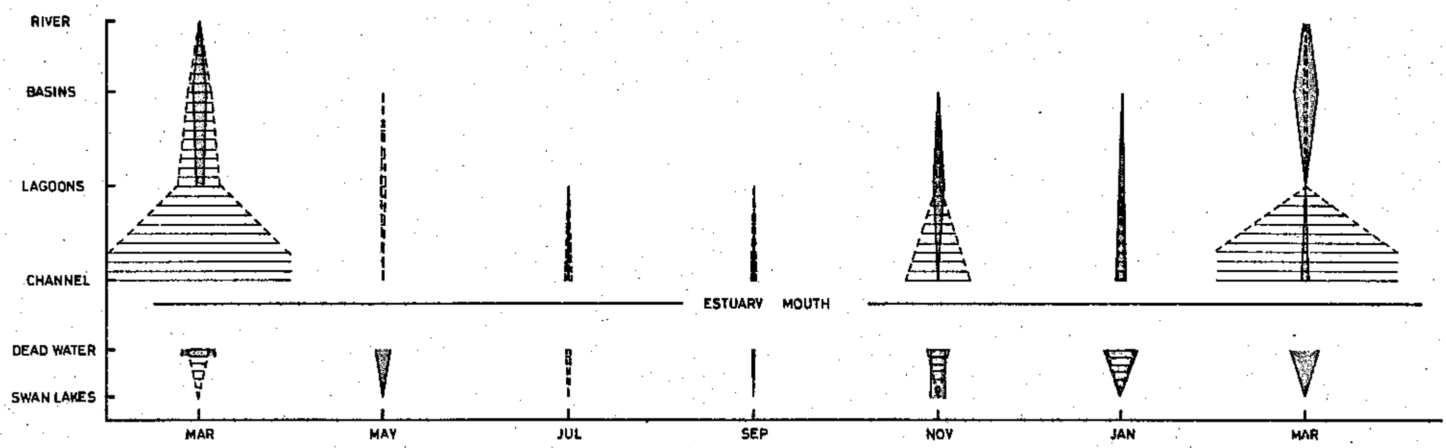
Caranx georgianus



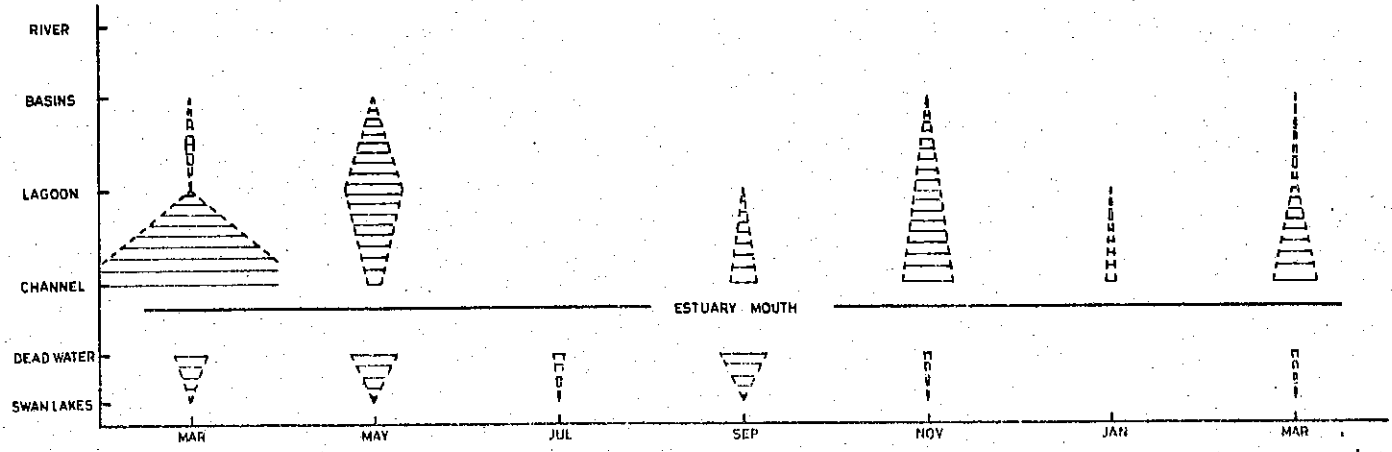
Pomatomus saltator



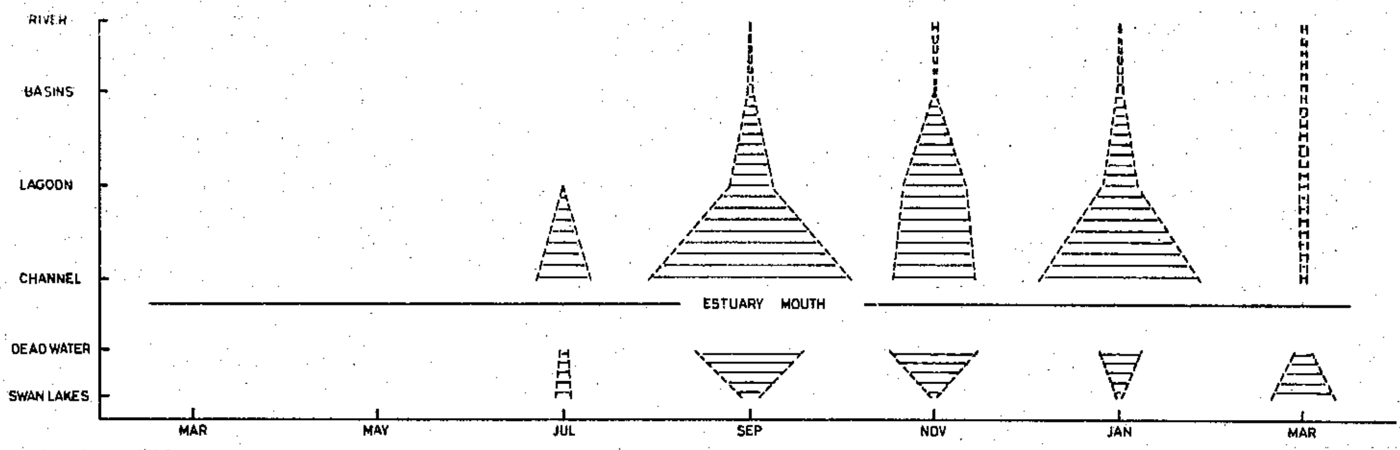
Helotes sexlineatus



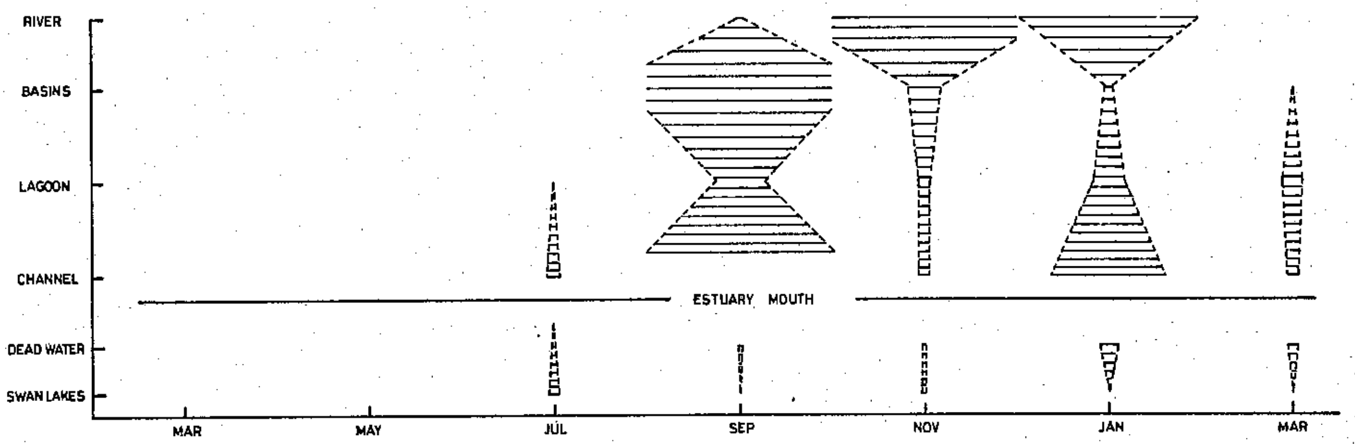
Sphoeroides pleurogramma



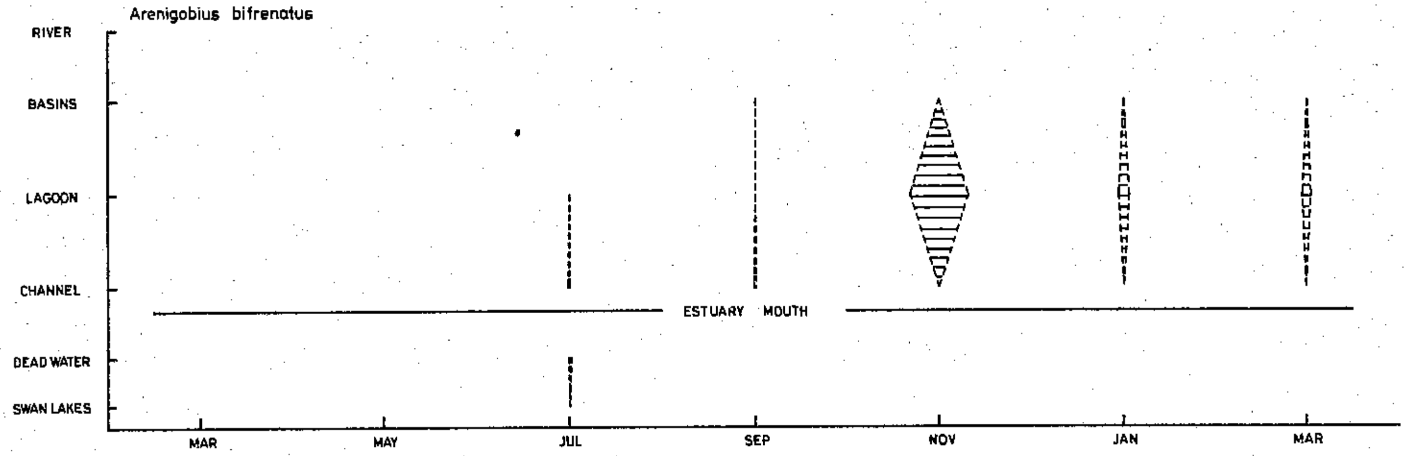
Favonigobius lateralis



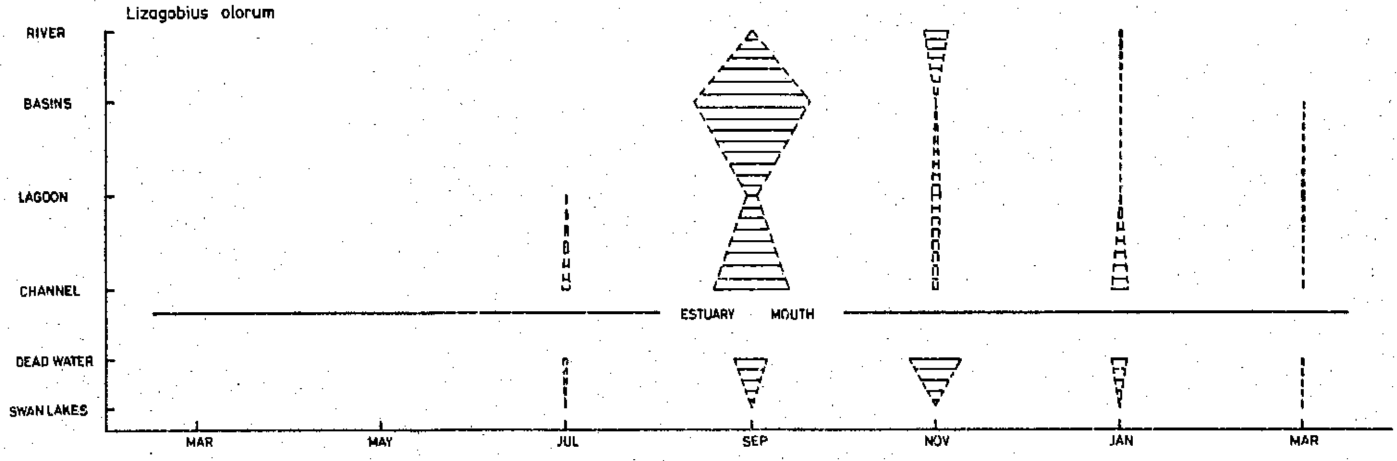
Favonigobius tamarensis

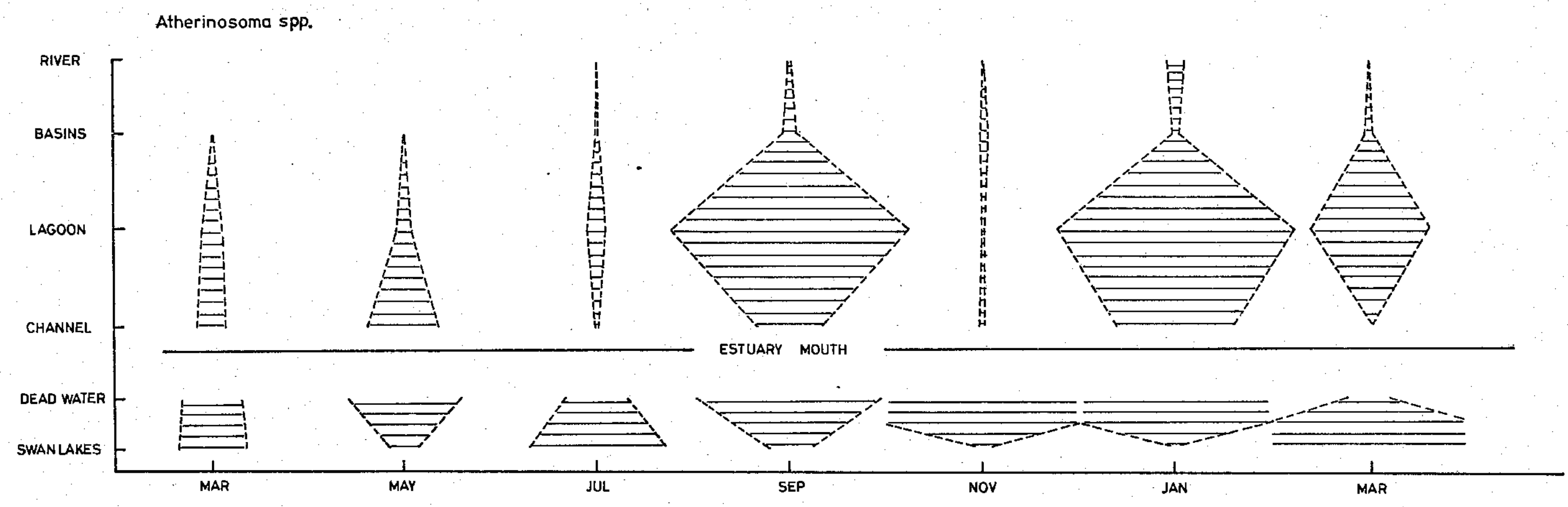


Arenigobius bifrenatus



Lizagobius olorum





Atherinosoma spp.
RIVER
BASINS
LAGOON
CHANNEL
ESTUARY MOUTH
DEAD WATER
SWAN LAKES
MAR
MAY
JUL
SEP
NOV
JAN
MAR

Appendix 2. A summary of data collected in the non-routine sampling programme.

Seine Net * Hauls	1			2			3			4			5		
Species	No.	Size Range (cm)	Modal Size (cm)	No.	Size Range (cm)	Modal Size (cm)	No.	Size Range (cm)	Modal Size (cm)	No.	Size Range (cm)	Modal Size (cm)	No.	Size Range (cm)	Modal Size (cm)
A. forsteri							16	17-34	26	217	6-29	25	127	19-31	21
S. schomburgkii	1	-	26	14	19-25	20	28	19-32	24	88	21-34	30	6	24-28	26
S. punctata	4	19-21	-				1	-	21				2	14-22	-
M. butcheri				1	-	20	4	23-31	-	15	23-38	29	3	13-15	-
R. sarba				3	14-22	-	17	14-24	17	47	14-25	17,22	16	16-24	17,22
A. georgianus							2	-	22(both)	1	-	23	1	-	28
A. trutta esper										1	-	21			
A. rostratus										1	-	21			
P. jenynsii										1	-	27	1	-	29
C. georgianus													11	13-17	17
C. macrocephalus	1	-	54												
H. sexlineatus													3	19-21	-
S. pleurogramma	1	-	11	1	-	12							2	11-12	-
C. richei	1	-	11										1	-	8
Syngnathus sp.	3	7-11	-												
P. parilus	1	-	4												
H. semifasciata				1	-	15									
T. fasciata										1	-	46			
A. bifrenatus										5	12-16	-			
Atherinosoma spp.										1	-	5			
Date		28.3.74			28.3.74			11.3.75			11.3.75			12.3.75	
Station		08			01			08			01			15	

* Net specifications - 146 m long, 100 meshes deep, wings 2.5 cm mesh, pocket 2.5 cm mesh.

Appendix 2 (cont.)

Set Nets *	1,2,3.			4.			3,4.		
Species	No.	Size Range (cm)	Modal Size (cm)	No.	Size Range (cm)	Modal Size (cm)	No.	Size Range (cm)	Modal Size (cm)
M. cephalus				5	23-28	25			
A. forsteri				3	27-32	-			
S. schomburgkii				2	25-26	-			
M. butcheri				5	18-21	19	1	-	28
R. sarba	1	-	20	5	16-23	16			
A. georgianus	2	-	22 (both)	1	-	23			
A. rostratus	1	-	19						
C. georgianus	1	-	27						
S. antarctica	4	34-30	-				4	22-27	24
Platycephalus sp.	1	-	29						
H. sexlineatus	1	-	19	2	23-25	-			
Date		22.3.75			18.3.75			12.3.75	
Station		20s			98s			172s	

* Net specifications

	Length (m)	Mesh (cm)
1.	19	5.08
2.	93	8.25
3.	27	10.16
4.	91	5.71

Appendix 3 Seine net efficiency experiment.

Objective. Determination of the efficiency of the seine netting technique used in the regular sampling programme.

Methods. At one of the regular sampling stations the area of shallow bank usually swept by one seine net haul was fenced off with a length of very small mesh (0.95 cm) net, trapping all the fish which were located within the swept area. Five consecutive seine net hauls were then made inside this enclosed area. The number and size distribution of each species of fish taken in each seine haul was recorded.

Assuming that

(i) Fish did not immigrate into or emmigrate from the enclosed area,

(ii) The catchability of each species of fish remained constant over the period of the experiment,

the efficiency of the netting technique can be calculated for each species of fish caught, by first plotting the catch per unit of effort (catch/haul) against the cumulative catch. This should give a straight line whose slope (catchability) is negative, and whose intercept on the x axis is an estimate of the original population size of fish trapped in the enclosed area (Ricker, 1963). Then, by dividing the estimated original population size into the number caught in the first haul, an estimate of the efficiency of the seine netting technique at that particular location is obtained, for each species of fish caught by the seine. This procedure can be repeated at each of the regular sampling stations.

Results and Discussion

This experiment was able to be conducted at only one of the regular sampling stations. Station 02 was chosen as this was the area where the technique was suspected of being most inefficient, due principally to the ability of small fish to avoid the net by sheltering in the dense beds of *Ruppia maritima* which grows on the shallow banks.

The results of the experiment are presented in Table 1. The cummulative catch and catch/haul for each species caught is presented in Table 2.

It is obvious (Table 2), that there is a decreasing trend in C/E each haul only for the larger individuals of two species present e.g. *M. butcheri* and *S. schomburgkii*. For most of the smaller individuals of each species the C/E increased after the first 2 or 3 hauls, then began to decrease. This latter trend in the C/E was almost certainly reflecting the ability of the smaller fish, particularly the gobies, to avoid the net, until the weed cover had been destroyed. Assumption (ii) above does not hold therefore, and the efficiency of the net cannot be quantified using the above technique.

Reference

Ricker, W.E. (1963) - Handbook of computations for biological statistics of fish populations. *Fish. Res. Bd. Canada Bull. 119*. p. 146-147.

Table 1. Results of the repetitive seining experiment at Station 02, Blackwood River estuary, March, 1975.

Haul	1*			2			3			4			5		
Species	Size range (cm)	Modal size (cm)	No.	Size range (cm)	Modal size (cm)	No.	Size range (cm)	Modal size (cm)	No.	Size range (cm)	Modal size (cm)	No.	Size range (cm)	Modal size (cm)	No.
M. cephalus	8–11	10	6	9–12	11	10	5–15	11	6	7–12	10	5			
A. forsteri	6–34	8	22	6–11	8	117	8–9	8	10	7–9	–	5	–	11	1
S. schomburgkii	–	31	1												
S. punctata	8–14	10	185	8–13	10	71	9–13	9,11	14	8–17	10	34	9–12	10	7
M. butcheri	22–32	–	13	–	22	2									
R. sarba	3–23	4	28	2–6	4	28	3–5	4	28	2–5	4	127	2–5	4	44
S. pleurogramma	12–13	13	3				–	2	1						
H. semifasciata	12–15	14	9	6–10	–	3	–	15	2	–	14	1			
P. parilus	8–10	–	3				–	5	1						
F. lateralis	5–6	6	5	–	6	13	4–7	6	13	3–7	6	11	–	6	4
F. tamarensis	6–7	6	11	4–8	7	25	4–8	7	42	2–8	7	44	4–7	6	14
L. olorum	–	6	1	4–5	5	16	3–6	5	35	3–6	5	44	3–6	5	45
A. bifrenatus										–	9	1	–	8	1
Atherinosoma spp.	5–9	5	22	3–12	5	66	4–8	5	66	2–11	3,6	116	2–9	5	60
N. freycineti	–	8	1				–	9	1				–	15	1
S. granulatus				–	5	1	5–6	–	2	–	6	1	–	5	1
A. guntheri				–	6	1				3–5	–	2			
C. australis							–	13	1						
Total number			310			353			222			391			178

* This haul was regarded as the regular sample from Station 02 during March 1975.

Table 2 - The catch (no's) cummulative catch, effort (hauls) and catch per unit effort for each species taken in the seine net efficiency experiment in the Blackwood River estuary during March 1975.

Species	Catch (no.	ΣCatch (no.)	Effort (hauls)	Catch/Effort (C/E)
R. sarba	28	0	1	28
	28	56	1	28
	28	84	1	28
	127	211	1	127
	44	255	1	44
S. punctata	185	0	1	185
	71	256	1	71
	14	270	1	14
	34	304	1	34
	7	311	1	7
M. butcheri	13	0	1	13
	2	15	1	2
	0	15	1	0
A. forsteri	22	0	1	22
	117	139	1	117
	10	149	1	10
	5	154	1	5
	1	155	1	1
M. cephalus	6	0	1	6
	10	16	1	10
	6	22	1	6
	5	27	1	5
	0	27	1	0
S. pleurogramma	3	0	1	3
	0	3	1	0
	1	4	1	1
	0	4	1	0
Atherinosoma spp.	22	0	1	22
	66	88	1	66
	66	154	1	66
	116	270	1	116
	60	176	1	60
H. semifasciata	4	0	1	9
	0	9	1	0
	2	11	1	2
	1	12	1	1
	0	12	1	0

Table 2 (continued)

Species	Catch (no.)	ΣCatch (no.)	Effort (hauls)	Catch/Effort (C/E)
P. parilus	3	0	1	3
	3	6	1	3
	1	7	1	1
	0	7	1	0
Balastidae	1	0	1	1
A. freycineti	2	3	1	2
S. granulatus	3	6	1	3
A. guntheri	3	9	1	3
	2	11	1	2
F. lateralis	5	0	1	5
	13	18	1	13
	13	31	1	13
	11	42	1	11
	4	46	1	4
F. tamerensis	11	0	1	11
	25	36	1	25
	42	78	1	42
	44	122	1	44
	14	136	1	14
L. olorum	1	0	1	1
	16	17	1	16
	35	42	1	35
	44	86	1	44
	45	131	1	45
S. schomburgkii	1	0	1	1
	0	1	1	0
A. bifrenatus	0	0	1	0
	0	0	1	0
	0	0	1	0
	1	0	1	1
	1	2	1	1
C. australis	0	0	1	0
	0	0	1	0
	1	0	1	1
	0	1	1	0

Appendix 4 - Results of the July 1974 sampling trip.

Introduction: The idea of this extra sampling trip was conceived well after reporting of the one year programme was well advanced. Therefore this additional information could not be included in the main text of the report.

Objectives: To extend the regular sampling procedure adopted in the initial one year survey, to include one further trip in July 1975 to enable comparisons to be made between the fish and crustacean populations present in the estuary during two consecutive winters.

Methods: Except for the discontinuation of plankton sampling, and some changes to the trawl net design, sampling methods were the same as those reported in the main text of the paper. The trawl net was redesigned by "setting back" the bottom panel of the net to obtain a cover of headrope netting (or "overhang") above the foot rope to prevent the upward escapement of fish. Also the cod-end mesh size was changed from 5 to 2.5 cm to reduce the chance of escapement of small fish. It is suspected that these design improvements contributed towards the good catches obtained in this months short trawling programme (Table 4, Results).

Results: Hydrological records from the seine net sampling stations and the hydrology stations of the Swan Lakes and Deadwater are presented in Tables 1 and 2 respectively. The number and weight of all species of commercial and non-commercial fish taken by regular seine and set net sampling during this trip are presented in Table 3. A summary of results of the trawling programme are given in Table 4.

The index of relative abundance of each of the more and less abundant species taken from each sampling area by seine and set net, and the totals for the month are presented in Table 5.

The salinity type, and the percentage of 0+ year old fish of each of the more and less abundant species taken is presented in Table 6.

For the sake of continuity, length frequency data was able to be added to data collected during the initial year's survey, presented in Figures 3 to 22 of the main text.

Discussion:

Generally speaking, during July, salinities and temperatures, particularly in the lower estuary were higher in 1975 than 1974. Of particular interest were the bottom salinities and temperatures of the Deadwater and Channel areas. During 1974, the Deadwater bottom salinities were significantly higher than those in any other area of the estuary. However during 1975, both Deadwater and Channel salinities were in excess of 20 °/oo. Deadwater bottom salinities were between 30 and 34 °/oo, and the temperatures and salinities recorded offshore from Channel sampling stations 13 and 25 were 35 °/oo and 17 °C; and 22.3 °/oo and 15.3 °C respectively.

Although as a result of poor tidal exchange with the ocean, the dissolved oxygen levels were low in the Deadwater, they were obviously sufficiently high to support the less euryhaline species *C. georgianus* and *C. macrocephalus* which were not reported from that area during July 1974. Also, *A. georgianus*, which was present in 1974, was much more abundant in 1975 (Table 5). *S. antarctica* recorded from the deeper higher salinity channel waters at station 25 during July 1975 was also not recorded during July 1974.

The absence of the freshwater species *T. bostocki* from the upper reaches of the estuary also emphasises the fact that the flood conditions were not as extreme during July 1975. The total number of species taken from each of the sampling areas in 1974 and 1975 (Table 7) reflects the increased penetration of species upstream in 1975, which included a number of the less euryhaline species recorded from the system (Figure 1).

Additional records of species from known salinities supported the initial classifications of species as salinity types (Tables 6 and 7, main text). Of particular interest were the further records of numbers of the *Arripidae* from waters of low salinity and temperature. *A. georgianus* was recorded from salinity of 4.6 °/oo and temperature of 12 °C, and 0+ yr old *A. trutta esper* from salinities of 3.9 and 4.6 °/oo, and temperatures of 12 °C. Records of *H. vittatus* and

S. antarctica from salinities of 3.9 ‰ and 22.3 ‰ were also worthy of note. The previous lowest salinity these species were recorded from were 20.3 ‰ and 35 ‰ respectively.

All the more abundant species recorded during July 1975 were euryhaline, and the most abundant of these such as the Mugilidae, Sillaginidae, Sparidae, Atherinidae and Gobiidae were the most euryhaline (Tables 5 and 6). Some interesting points arose from comparisons of the data from the two winters. The different hydrological regime of July 1975 was reflected in abundance data for some species. *M. butcheri* was less abundant in 1975, perhaps due to the fact that the more moderate winter floods prior to July 1975 had not concentrated populations from the whole system in the lower estuary, as was suspected to have been the case in 1974 (Appendix 1). There is also further evidence (Table 5) to suggest that there may be two distinct concentrations of *M. butcheri* in the Blackwood River estuarine system, one in the Swan Lakes-Deadwater and one in the estuary proper.

The increased abundance of *H. sexlineatus* in the channel, and *A. georgianus* in the Deadwater in July 1975 is most likely in response to the higher salinities and temperatures in the lower estuary during that month.

School size had a marked effect on the magnitude of the indices of abundance of some species. The very high indices of abundance of *S. schomburgkii* and *S. punctata* in 1974 and *R. sarba* in 1975 from the channel area resulted from very large schools of each species being caught at station 13.

The 1975 catches of Mugilidae, Sillaginidae, *R. sarba* and *A. trutta esper* were dominated by juveniles (Table 6). These results were similar to trends apparent in the data of the previous year's survey (Tables 6 and 7, main text), and further emphasizes the importance of the estuary as a nursery area for the young.

The species composition of the trawl catches reflected the high bottom salinities of the channel area. Relatively large catches of young *P. pelagicus* and *C. macrocephalus* also emphasise the importance of the estuary as a nursery area. *P. pelagicus* were young from the previous summers spawning in the adjacent ocean embayment (Flinders Bay). They entered the estuary actively during late summer or autumn.

Conclusions:

1. The higher salinity and temperatures particularly in the lower estuary during July 1975, maintained populations of less euryhaline fish and crustaceans which were absent from the estuary in the previous more severe July of 1974.

2. The large proportion of 0+ yr old fish and crustaceans represented in the catches of a number of species emphasises the importance of the Blackwood River estuary as a nursery area for juvenile fish and crustaceans.

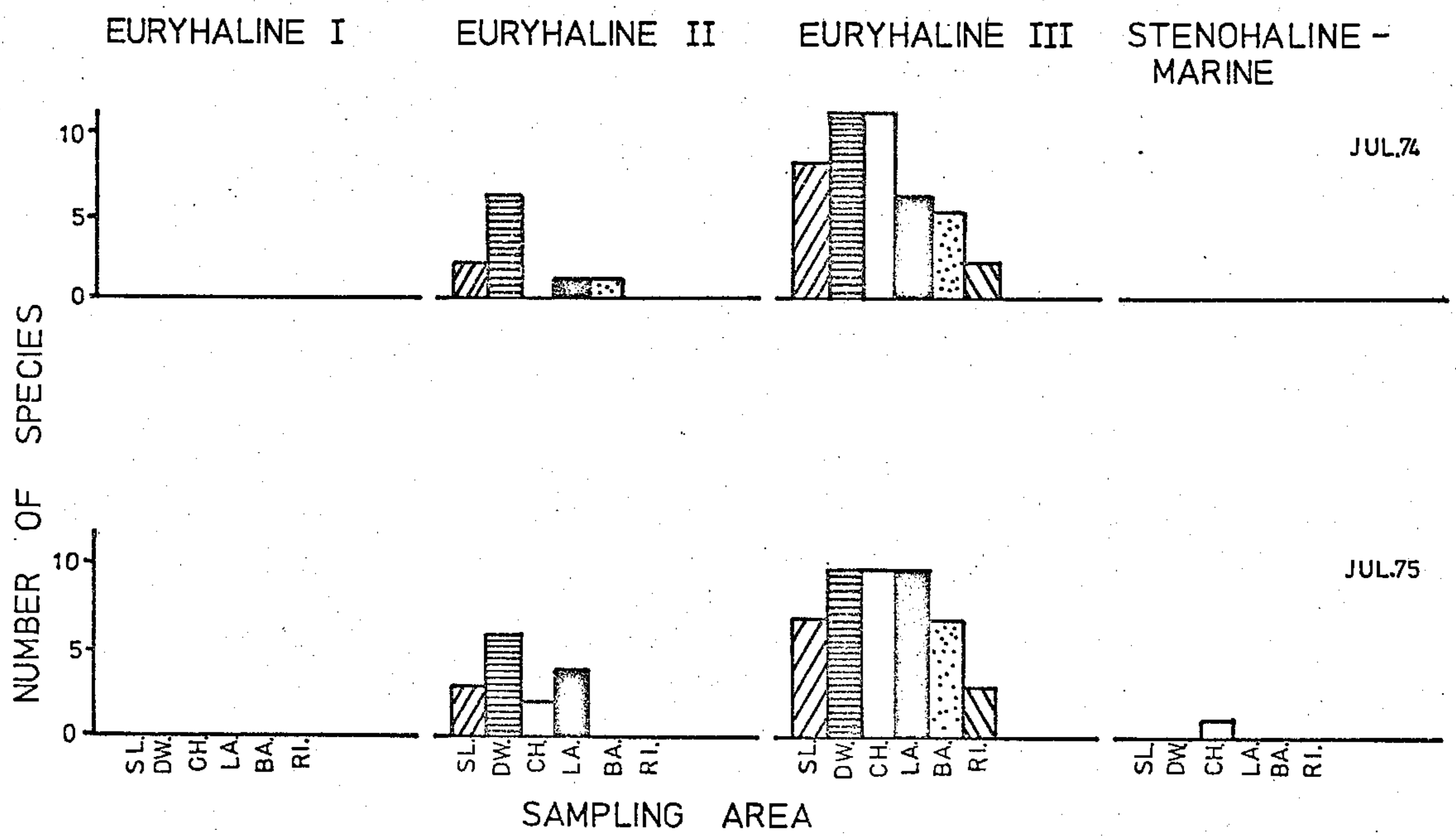


Figure 1 The distribution of fish species of types euryhaline I to II and stenohaline-marine throughout the Blackwood River estuary sampling areas Swan Lakes (S.L.), Deadwater (DW), Channel (CH), Lagoon (LA), Basins (BA) and River (RI), during July 1974 and July 1975.

TABLE 1 HYDROLOGICAL RECORDS FROM SEINE NET SAMPLING STATIONS OF THE BLACKWOOD RIVER ESTUARY DURING JULY 1975.

Sampling Station		Temp. (°C)	Sal. (°/oo)	Oxygen (mg/l)	Secchi † (m)	Depth (m)
04	Surface	11.4	7.5	6.2	0.6	0.6
	Bottom	11.4	7.5	6.3		
02	Surface	12.7	3.8	7.4	0.5	0.5
	Bottom	12.7	3.9	7.4		
03	Surface	12.6	4.6	7.0	0.3	0.3
	Bottom	12.6	4.6	7.0		
13	Surface	13.9	2.1	7.2	1.0	1.0
	Bottom	13.9	2.1	7.2		
19	Surface	14.0	1.2	6.8	0.9	1.0
	Bottom	14.2	1.2	6.9		
48	Surface	14.3	1.2	7.2	0.9	1.0
	Bottom	14.2	1.2	7.2		
62	Surface	13.7	1.2	7.1	0.9	1.3
	Bottom	13.5	1.2	7.1		
65	Surface	12.8	1.1	6.1	1.0	1.8
	Bottom	12.7	1.1	6.4		
98	Surface	13.7	0.3	6.8	0.7	0.8
	Bottom	13.9	0.3	6.7		
105	Surface	13.7	0.2	6.5	0.7	1.0
	Bottom	13.7	0.2	6.5		
95*	Surface	12.0	< 1	6.6	0.7	1.5
	Bottom	12.0	< 1	6.6		

* Estimated values only for this station.

† Where secchi reading is the same as the depth, the depth of extinction of the disc was not reached.

TABLE 2 HYDROLOGICAL STATION DATA FROM SWAN LAKES AND THE DEADWATER COLLECTED IN JULY 1975, DURING THE BLACKWOOD RIVER ESTUARY STUDY.

Swan Lakes

		Temp. (°C)	Sal. (°/oo)	Oxygen (mg/l)	Secchi * (m)	Depth (m)
1	Surface	14.62	7.62	7.12	-	0.8
	Bottom	14.62	8.16	6.84		
2	Surface	14.34	6.80	6.78	1.0	1.0
	Bottom	14.34	6.80	6.78		
3	Surface	14.20	6.98	6.79	1.0	1.0
	Bottom	14.12	6.96	6.80		
4	Surface	14.48	7.18	6.75	1.6	1.6
	Bottom	14.24	7.14	6.78		
5	Surface	14.80	7.18	6.57	0.9	0.9
	Bottom	14.64	7.18	6.45		

Deadwater

		Temp. (°C)	Sal. (°/oo)	Oxygen (mg/l)	Secchi (m)	Depth (m)
1	Surface	14.92	9.12	7.17	2.2	2.7
	Bottom	17.02	33.70	5.67		
2	Surface	14.78	6.98	7.11	1.8	3.6
	Bottom	17.04	33.30	3.94		
3	Surface	14.76	6.98	7.25	1.8	2.0
	Bottom	16.74	32.56	4.67		
4	Surface	14.88	6.98	7.23	1.6	2.0
	Bottom	16.46	31.32	3.31		
5	Surface	14.86	6.62	7.78	1.2	1.2
	Bottom	14.50	13.60	7.11		

* Where secchi reading is the same as the depth, the depth of extinction of the disc was not reached.

TABLE 3 TOTAL NUMBER AND WEIGHT AND PERCENTAGES OF TOTAL OF COMMERCIAL AND NON-COMMERICAL FISH TAKEN BY REGULAR SEINE AND SET NET SAMPLING IN THE BLACKWOOD RIVER ESTUARY DURING JULY, 1975. THE JULY 1974 DATA IS LISTED FOR THE PURPOSE OF COMPARISON.

Species	Number					Weight				
	Seine	Set	Total	% of Total 1975	% of Total 1974	Seine	Set	Total	% of Total 1975	% of Total 1974
Commercial										
M. cephalus	18	151	169	3.0	4.3	900	26970	27870	7.7	9.5
A. forsteri	620	243	863	15.0	14.7	23050	44370	67420	18.7	20.7
S. schomburgkii	16	499	515	9.0	39.4	40	81340	81380	22.6	51.2
S. punctata	44	1	45	0.8	14.5	1150	230	1380	0.4	4.0
C. macrocephalus	0	19	19	0.3	0	0	9760	9760	2.7	0
A. georgianus	1	632	633	11.0	0.6	140	90440	90580	25.2	0.7
A. trutta esper.	16	2	18	0.3	0.1	30	530	560	0.2	<0.1
M. butcheri	17	169	186	3.2	8.7	9350	51740	61090	17.0	13.0
R. sarba	2367	26	2393	41.7	1.8	9900	2610	12510	3.5	0.3
C. georgianus	1	2	3	<0.1	0	130	130	260	<0.1	0
P. saltator	0	1	1	<0.1	<0.1	0	50	50	<0.1	<0.1
E. australis fraseri	0	6	6	0.1	<0.1	0	50	50	<0.1	<0.1
S. antarctica	0	2	2	<0.1	0	0	1230	1230	0.3	0
H. vittatus	1	0	1	<0.1	0	1	0	1	<0.1	0
Non-commercial										
H. sexlineatus	340	24	364	6.3	0.2	660	3150	3810	1.1	<0.1
F. lateralis	74	0	74	1.3	1.4	124	0	124	<0.1	<0.1
F. tamarensis	143	0	143	2.5	9.2	317	0	317	0.1	0.1
L. olorum	8	0	8	0.1	0.3	5	0	5	<0.1	<0.1
Atherinosoma spp.	273	0	273	4.8	3.7	378	0	378	0.1	0.1
C. richei	22	0	22	0.4	0.8	1330	0	1330	0.4	0.1
Total	3961	1777	5738			47505	312600	360105		

TABLE 4 A SUMMARY OF THE RESULTS OF THE JULY 1975 TRAWLING PROGRAMME IN THE BLACKWOOD RIVER ESTUARY.

Total length/ Carapace length class (cm)	In the channel offshore from Station 13					In the channel offshore from Station 19			
	Fish				Crustacea	Fish		Crustacea	
	P. jenynsii	*C. macro-cephalus*	*F. tamaren-sis*	*L. olorum*	**P. pelagicus*	*P. jenynsii*	*C. macro-cephalus*	*P. pelagicus*	*M. dalli*
1									2
2					1				
3									
4				1	8				
5			1		37				
6					12				
7			2		5			2	
8			1		7			1	
9					3	1		2	
10		1			1		1	4	
11	1				1			5	
12							4		
13	1						9		
14		1					3		
15							2		
16							3		
17						1	1		
18									
19									
20						1 (26 cm)			
Total number	2	2	4	1	75	3	23	14	2
Total weight (gm)	39	21	14	1	1272	243	340	950	8
Duration of trawl			3 min.				3 min.		

* *P. pelagicus* was also taken, set net Station 01, Length class 7, 9cm, wt 70, 30 gm; Station 05, Length class 7 cm, wt. 40 gm.

TABLE 5 RELATIVE ABUNDANCE (MEAN CATCH {NO.} PER HAUL) OF EACH OF THE MORE AND LESS ABUNDANT SPECIES TAKEN IN EACH SAMPLING AREA OF THE BLACKWOOD RIVER ESTUARY DURING JULY 1975. THE JULY 1974 DATA IS LISTED FOR THE PURPOSE OF COMPARISON.

Sampling Area	Swan Lakes		Deadwater		Channel		Lagoon		Basins		River		Totals			
Species	Seine	Set	Seine	Set	Seine	Set	Seine	Set	Seine	Set	Seine	Set	Seine 1975	Seine 1974	Set 1975	Set 1974
More abundant																
A. forsteri	16.0	129.0	285.5	38.0	15.0	1.0	0.7	11.7	0.5	0	0	0	14.25	4.84	16.07	28.90
M. cephalus	0	38.0	9.0	0	0	0	0	35.7	0	0	1.0	3.0	0.35	0.13	25.22	22.14
S. schomburgkii	1.0	22.0	7.5	98.5	0	57.7	0	35.3	0	0	0	0.5	0.33	119.20	37.33	16.57
S. punctata	0	0	0	0.5	17.5	0	3.0	0	0	0	0	0	4.89	47.86	0.02	0
R. sarba	3.0	0	0	8.5	1178.0	3.0	2.7	0	0	0	0	0	200.09	3.47	0.81	0.10
M. butcheri	1.0	114.0	3.5	0.5	4.0	0	0	1.7	0.5	0	0	24.5	0.89	3.03	7.78	26.26
A. georgianus	0	83.0	0.5	274.5	0	0	0	0	0	0	0	0	0.02	0	14.44	0.26
H. sexlineatus	0	0	0	9.5	170.0	1.3	0	0.3	0	0	0	0	28.60	0.29	0.76	0.08
**F. lateralis*	41.0	0	0.5	0	7.5	0	5.0	0	1.0	0	0	0	6.80	5.34	0	0
**F. tamarensis*	0	0	0.5	0	43.5	0	6.0	0	16.0	0	2.5	0	12.44	1.30	0	0
**Atherinosoma*	32.0	0	69.5	0	34.5	0	10.7	0	0.5	0	0	0	17.02	10.96	0	0
**C. richei*	11.0	0	2.0	0	3.0	0	0.3	0	0	0	0	0	1.36	0.65	0	0
Less abundant																
A. trutta esper	0	0	8.0	1.0	0	0	0	0	0	0	0	0	0.29	0.11	0.04	0.01
C. georgianus	0	0	0	1.5	0	0	0	0	0	0	0	0	0	0	0.05	0
P. saltator	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0.19	0.10
C. macrocephalus	0	1.0	0	8.5	0	0	0	0.3	0	0	0	0	0	0	0.56	0
S. antartica	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0.12	0
(*E. australis fraseri* (	0	0	0	0	0	1.0	0	1.0	0	0	0	0	0	0.02	0.82	0
**H. vittatus*	0	0	0.5	0	0	0	0	0	0	0	0	0	0.02	0	0	0
**L. olorum*	0	0	0	0	0.5	0	0	0	3.5	0	0	0	0.34	0.61	0	0

* Rarely taken in set nets.

TABLE 6 THE TYPE AND PERCENTAGE OF 0+ YR OLD FISH OF EACH OF THE MORE AND LESS ABUNDANT SPECIES TAKEN DURING JULY 1975, BY THE REGULAR SAMPLING PROGRAMME IN THE BLACKWOOD RIVER ESTUARY.

Species	Type	% of 0+ yr old fish					
		Seine			Set		
		0+	Number Total	% 0+	0+	Number Total	% 0+
More abundant							
A. forsteri	Euryhaline III	526	620	84.8	9	243	0
M. cephalus	Euryhaline III	16	18	88.9	0	151	0
S. schomburgkii	Euryhaline III	16	16	100.0	0	499	0
S. punctata	Euryhaline III	43	44	97.7	0	1	0
R. sarba	Euryhaline III	2367	2367	100.0	0	26	0
M. butcheri	Euryhaline III	0	17	0	0	169	0
A. georgianus	Euryhaline II	0	1	0	0	632	0
H. sexlineatus	Euryhaline III	339	340	99.7	0	24	0
F. lateralis	Euryhaline III	-	74	-	0	0	0
F. tamarensis	Euryhaline III	-	143	-	0	0	0
Atherinosoma spp	Euryhaline III	-	273	-	0	0	0
C. richei	Euryhaline II	13	22	59.1	0	0	0
Less Abundant							
A. trutta esper	Euryhaline II	16	16	100.0	0	2	0
C. georgianus	Euryhaline II	0	1	0	2	2	100.0
P. saltator	Euryhaline II	0	0	0	0	1	0
C. macrocephalus	Euryhaline II	0	0	0	1	19	5.3
S. antarctica	*Euryhaline I	0	0	0	0	2	0
E. australis fraseri	Euryhaline II	0	0	0	0	6	0
H. vittatus	*Euryhaline II	0	1	0	0	0	0
L. olorum	Euryhaline III	-	8	-	0	0	0

* The salinity type has been revised on the basis of new data collected.

\- 0+ yr old fish were unable to be identified.

TABLE 7 THE NUMBER OF SPECIES RECORDED FROM EACH SAMPLING AREA IN JULY 74 AND JULY 75 DURING THE BLACKWOOD RIVER ESTUARY STUDY.

Sampling Area	July 74	July 75
River	2	3
Basins	7	7
Lagoon	7	14
Channel	11	13
Deadwater	17	16
Swan Lakes	11	10