THE BIOLOGY OF THE ATHERINIDS CAUGHT IN THE SWAN-AVON RIVER SYSTEM

by

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DECLARATION

I declare that the information contained in this thesis is the result of my own research unless otherwise cited.

November 1, 1979.

ABSTRACT

The ecology and taxonomy of the atherinids caught in the Swan-Avon River system was studied using data collected from monthly samples at ten main and some subsidiary sites. The study demonstrated that five species of atherinids from the three genera Allanetta, Atherinosoma and Pranesus utilise the estuary in different ways. One of the Atherinosoma species found in the estuary is currently unrecognised although it may previously have been described as Atherinosoma rockinghamensis (Whitley). The other species found in the river system are Atherinosoma elongata (Klunzinger), Atherinosoma presbyteroides (Richardson), Allanetta mugiloides (McCulloch) and Pranesus ogilbyi (Whitley). All the atherinid species spawned during the summer and in three Atherinosoma species and in Allanetta mugiloides the spawning period was protracted. The life cycle of these four species occupied one year. By contrast, in Pranesus ogilbyi the life cycle was either two or three years, with spawning occurring in the final two years of life. Although all of the species were opportunistic carnivores which fed in general on small invertebrates this study indicated that interspecific competition was reduced by a certain degree of selective feeding and by a tendency for slightly different distribution patterns. Pranesus ogilbyi, Allanetta mugiloides and Atherinosoma presbyteroides were marine species, while Atherinosoma elongata was estuarine and Atherinosoma rockinghamensis was largely restricted to fresh water. The feeding and breeding habits and pelagic nature as well as their large numbers in every part of the river system, mean that atherinids must be a very important component of the fauna of the estuary.

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TABLE OF CONTENTS

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LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

1. INTRODUCTION

1.1. Atherinids

Atherinids are found in the fresh and marine waters of every continent between latitude 50°N and 50°S (Ivantsoff, 1977). Many of the 150 species are euryhaline and found in a wide range of salinities (Massman, 1954; Carpelan, 1955; Smith, 1965; Hedgpeth, 1967; Lee, 1969; Hubbs, Sharp and Schneider, 1971; Chessman and Williams, 1974; Johnson, 1975). Atherinids show a preference for calm, shallow water where they school in large numbers and feed opportunistically on the zooplankton and benthic crustacea found throughout the water column (Al-Hussaini, 1947; Bayliff, 1950; Smith, 1965; Davis and Louder, 1969; Wallace, 1976; Ivantsoff, 1977). Since atherinids are a first order carnivore, which makes up a large proportion of the biomass in the aquatic environments of many parts of the world, they are clearly of considerable ecological significance (Bayliff, 1950; Hiatt and Strasburg, 1960; Smith, 1965; Gunter, 1967; deSylva, 1975).

Despite their large numbers in many areas the biology of only a small number of species have been studied (Hubbs, 1921 ; Bayliff, 1950; Mense, 1967; Davis and Louder, 1969; Zimmerman, 1970). The lack of information on their biology can be attributed to two main factors. The first is that, although they are used for food fish in some parts of American and the Indian Ocean and for bait in some Australian states (Bayliff, 1950; Smith, 1965; Ivantsoff, 1977) they are generally of little commercial value. The second factor is the difficulty associated with the identification of most atherinid species as all the 41 genera of the atherinid family are morphologically very similar.

All atherinids are small and as adults are generally less than 120 mm in length, they are elongate and have a sub cylindrical body shape. They are usually covered in cycloid scales and have a silvery lateral stripe. The head is short and slightly flattened, bears large lateral eyes and a small mouth. All atherinids have two dorsal fins, the first midway along the trunk and an anal fin that is situated some distance posterior to the cloaca. The structure of the fins is similar in all atherinids (Smith, 1965) (Plate 1).

Many of the Australian species described initially in the latter part of the last century are still the subject of taxonomic revisions and none have been exposed to extensive ecological investigation.

1.2. The Atherinids of the Swan-Avon River System.

Considerable confusion has surrounded the taxonomy of the two *Atherinosoma* species recognised by Ivantsoff (1977) as being present in the Swan-Avon system. Castelnau described two species of atherinid from the Swan-River in 1873 and 1876 giving them the names *Atherinichthys edelensis* and *Atherinichthys obscurus* (Castelnau, 1873; Castelnau, 1876). In 1879 Klunzinger described a species from King George's Sound at Albany in South Western Australia which he called *Atherina elongata*. Whitley (1955) recognised three species of *Atherinosoma* from Western Australia. The first was *Atherinosoma edelensis* which he synonymised with *Atherinichthys obscurus* (Castelnau) and *Atherinichthys edelensis* (Castelnau) and redescribed. The second species Whitley recognised was *Atherinosoma* (*Taeniomembras*) *elongata* which he regarded as synonymous with *Atherina elongata* Klunzinger and also redescribed. Whitley's third species was

Atherinosoma rockinghamensis which Whitley (1943) described.

Ivantsoff (1977) examined Whitley's specimens and reclassified them as belonging to two Atherinosoma species. The first was Atherinosoma elongata Klunzinger which he regarded as synonymous with Atherina elongata, Atherinosoma edelensis (Whitley) and Atherinosoma rockinghamensis (Whitley) The second species was Atherinosoma presbyteroides which was described by Richardson in 1843 from Tasmanian specimens. Ivantsoff (1977) synonymised Atherinichthys edelensis (Castelnau), Atherinichthys obscurus (Castelnau) and Atherinosoma(Taeniomembras) elongata (Whitley) with Atherinosoma presbyteroides Richardson. Both A. elongata and A. presbyteroides were both recorded from the Swan-Avon estuary (Ivantsoff, 1977; Chubb et al; in press).

Whitley (1938) identified two species of Pranesus in the Swan, Pranesus ogilbyi Whitley and Pranesus endrachtensis Quoy and Gaimard, however Ivantsoff (1977) considered that the latter specimen was also P. ogilbyi. The fourth atherinid species that was known to be in the Swan-Avon estuary (Ivantsoff, 1977) was originally described by De Vis in 1885 from Northern Queensland and named Atherinichthys punctata. In 1913 McCulloch renamed the species Atherina mugiloides as punctata was preoccupied. In 1943 Whitley placed the species into a new genus, Allanetta. The genus was later redescribed and a further thirteen species added (Smith, 1965) before Taylor in 1964 pointed out that specimens collected from Arnhem land agreed with De Vis' original description but not with subsequent descriptions of the genus. Ivantsoff (1977) agreed with Taylor's conclusion and concluded that the genus, Allanetta should be regarded as monotypic.

Ivantsoff (1977) also recorded this species from the Swan River although Allanetta mugiloides was not recorded in the checklist for this river system by Chubb et al. (in press) because at the time of study these authors were not able to distinguish it from Atherinosoma spp.

Pranesus ogilbyi is the largest atherinid found in the Swan-Avon system. The adult of this species are deep bodied and the live fish have an irridescent blue colouration on the ventral surface (Ivantsoff, 1977) (Plate 1). A study of this species in Smith's lake, N.S.W. suggested that they bred twice a year (Ivantsoff, 1977). However, Chubb's work in the Swan estuary showed that a single, normally distributed year class of P. ogilbyi used the estuary all year, with growth continuing throughout the year, although slowing down during winter.

Feeding studies on P. ogilbyi have shown that this species usually feeds opportunistically near to the surface, although they are capable of feeding from the bottom (Thompson, 1959; Ivantsoff, 1977). While their diet consisted mainly of amphipods and copepods, flying insects, isopods, crab and barnacle larvae, polychaetes and gastropods were also ingested.

P. ogilbyi is distributed along the west and east coasts of Australia, but is not found along the southern or northern coast lines (Ivantsoff, 1977).

Atherinosoma elongata is a smaller more elongate fish than P. ogilbyi. The living representatives of this species are usually grey-green on the dorsal surface and silvery on the abdomen, but colouration is extremely variable and may include a red or salmon pink colouration of variable intensity along the lateral line (Ivantsoff, 1977) (Plate 2).

Although very little work has been performed on the ecology of this species, its range has been described as stretching from Geraldton in Western Australia southwards around the southern coast to Nelson in Victoria. It has also been recorded from small landlocked lakes, estuaries and lagoons (Ivantsoff, 1977). The latter worker also identified specimens of this species from Beverley (Avon River), Northam (Avon River), Darling Scarp (Helena River), Perth (Swan River) and also from landlocked lakes near Rockingham just to the south of the Swan-Avon River.

Atherinosoma presbyteroides is slightly more slender and smaller than A. elongata (Ivantsoff, 1977). Its external appearance is very similar to A. elongata and A. microstoma, the other Australian species of Atherinosoma (Plate 3). Ivantsoff (1977) states that "live specimens (of A. presbyteroides) may or may not be distinguishable from the other two species of Atherinosoma". The latter worker also records that work done on this species by A. Robertson in the Westernport Bay area showed that it was a mid-water benthic feeder (sic), which ingests amphipods, copepods and polychaetes. It is also said to breed between November and January. In Jervis Bay it has also been recorded as running ripe in August. (Ivantsoff, 1977).

A. presbyteroides ranges from the Abrolhos Islands in Western Australia southwards around the continent to Jervis Bay in New South Wales. In the Swan-Avon River, it has been recorded from Fremantle and the Canning River and elsewhere in Western Australia it has been recorded from Prince's Royal

Harbour, Busselton, Leschenault Estuary, Palm Beach, Point Peron and the Abrolhos Islands (Ivantsoff, 1977). Like other species of atherinids, A. presbyteroides is usually found in calm sheltered pools close to shore. Patten (pers. comm.) says that unlike A. elongata, which has been collected from freshwater, A. presbyteroides seems to be restricted to salt water. He also noted it is sometimes possible to catch both species in the one seine. In other personal communications he has emphasised however that very little is known of their ecology in Western Australia.

Allanetta mugiloides like the Atherinosoma spp. is a small atherinid although not as slender as A. presbyteroides. It is also paler in body coloration than either of the Atherinosoma species. A. mugiloides has a dusky yellow dorsal surface and a silvery abdomen and preopercle, as with both Atherinosoma species the lateral band is often tinged with pink in live specimens (Ivantsoff, 1977) (Plate 4).

A. mugiloides extends from the Swan River, north around the continent to Lindeman Island in Northern Queensland (Ivantsoff,1977). No ecological studies have been published on this species.

1.3. Notes on the Swan-Avon Estuary.

The Swan-Avon River system has two main tributaries, the Canning and Helena Rivers. The Avon flows from above the Darling Scarp down to the coastal plain and into the main part of the upper estuary in the Guildford area, approximately 45km above the point where the Swan-Avon discharges into the Indian Ocean. The Helena River enters the Swan-Avon in this region near to the head of the estuary while the Canning enters Melville Water, 15 km above the river mouth. Hodgkin (1974)

regarded the Swan as having a tidal river region between Guildford and Heirisson Island, a basin region from Perth Water to Point Walter at the bottom end of Melville Water and a deep narrow inlet channel from Blackwall Reach to Fremantle Harbour (Fig. 1). More recently Chalmers, Hodgkin and Kendrick (1976) have redefined the zones in the Swan-Avon estuary on the basis of the benthic fauna. They consider the lower estuary to comprise the channel region of Blackwall Reach to Fremantle Harbour while the middle estuary consists of Mosman and Freshwater Bay, Melville and Perth Waters and bottom end of the Canning River. The main part of the upper estuary lies above Heirison Island and below Middle Swan, with the stretch of the Canning River between Salter Point and Riverton also being considered a part of the upper estuary.

The hydrology of the Swan has been documented by Spencer (1956), Hodgkin (1979) and Jack (1977). One of the important features of the hydrology of the Swan is its consistently high salinities for long periods. For example the middle estuary remains at near full strength sea water (35‰) for the entire summer, and in a relatively dry winter is not reduced to a great extent for many winter months. In summer even the reduced flow of the tidal river is saline as the water flowing down the scarp in the Avon River may be as high as 5-8 ‰. The salinity regime in the estuary during the long, dry, hot summers can be dramatically changed during periods of extreme flushing. This usually occurs after heavy winter rains when the influx of fresh water run off may be flushed into the system within several days. The flushing has a variable effect on the estuary,

in exceptional periods of flooding the entire estuary may become composed of freshwater. During a moderate flush however, only the upper estuary is completely freshened and only a sheet of fresh water is pushed across the surface of the middle estuary. This leaves the deep channels of the lower and middle estuary saline, creating a halocline. A halocline may also be created in the upper estuary during periods of slight run off but is less stable and lasts for a shorter time than in the lower and middle estuary where it may be present throughout winter.

The hydrological conditions within the estuary vary greatly from year to year depending on the number, strength and timing of the flushes. The flushes are in turn governed by the amount and intensity of the winter rainfall, although normally one or two moderate flushes occur at some stage during the months between May and October. Flushes at times other than winter are unusual but have been recorded (Middleton, 1955).

The extremely high salinities are restored to the estuary slowly during the spring as run off ceases and the halocline is broken down by the mixing action of wind, tide and evaporation. The fresh water is slowly replaced with saline water by the action of the tides produced by lunar movements and barometric changes.

To survive within this estuarine system an organism must be able to tolerate the stable, high salinities and temperatures of summer. They must also be able to escape or withstand the extreme physiological demands of the variable, sudden and powerful flushes of freshwater during the winter months.

1.4. Aims of the study

The aim of this study was to clarify the taxonomy of the smaller species of atherinids found in the Swan-Avon estuary

and to gain knowledge about the ecology of all the atherinids caught within the estuary. One particular aspect of the ecology of the atherinids that this study aimed to examine is the problem of whether or not these similar species compete inter-specifically as they are known to occur sympatrically. This information can add to our knowledge of the atherinid family as well as aid our understanding of the Swan-Avon River system ecology.

FIGURE 1.

A map of the Swan-Avon estuary showing the ten sampling sites.

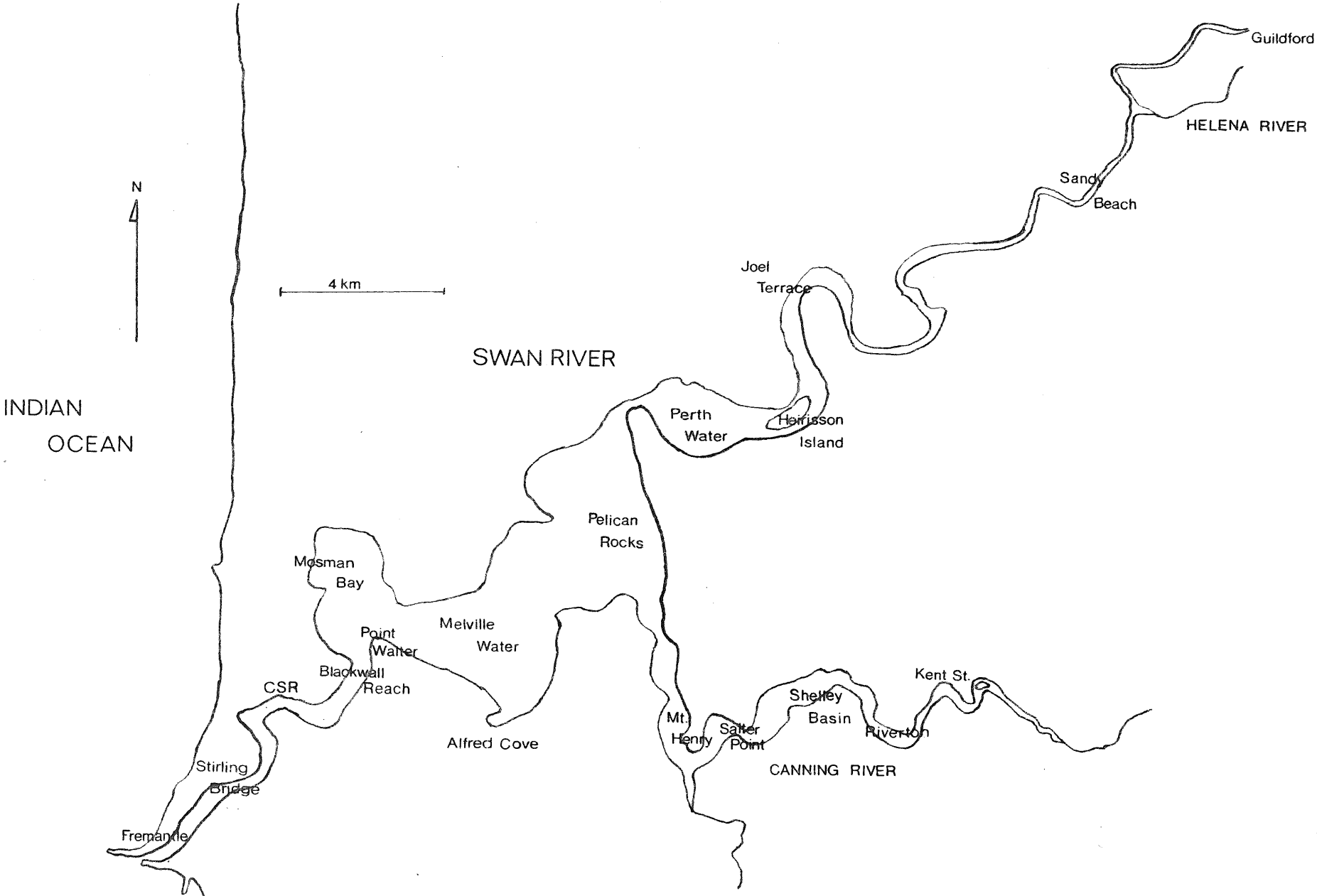

Guildford
HELENA RIVER
Sandy
Beach
N
4 km
Joel
Terrace
SWAN RIVER
INDIAN
OCEAN
Perth
Water
Herisson
Island
Pelican
Rocks
Mosman
Bay
Melville
Water
Point
Walter
Blackwall
Reach
CSR
Kent St.
Shelley
Basin
Mt.
Henry
Salter
Point
Riverton
Alfred Cove
CANNING RIVER
Stirling
Bridge
Fremantle

PLATE 1

Juvenile *Pranesus ogilbyi* (x 1.5)

PLATE 2

Atherinosoma elongata (x 2.5)

PLATE 3

Atherinosoma presbyteroides (x 2.5).

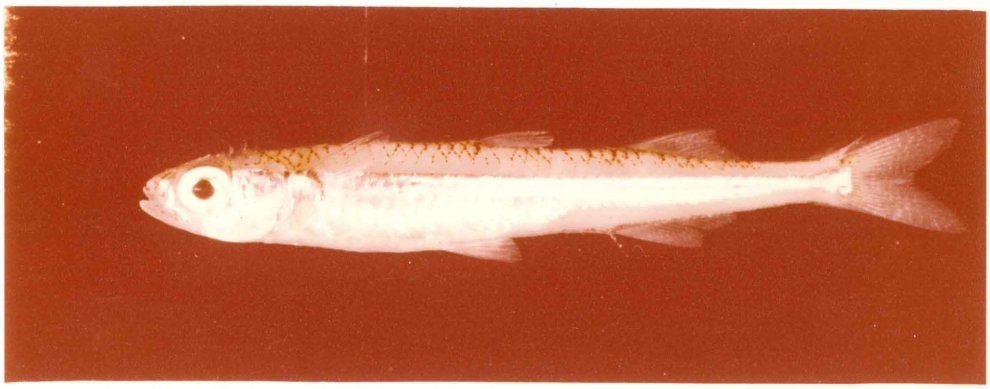


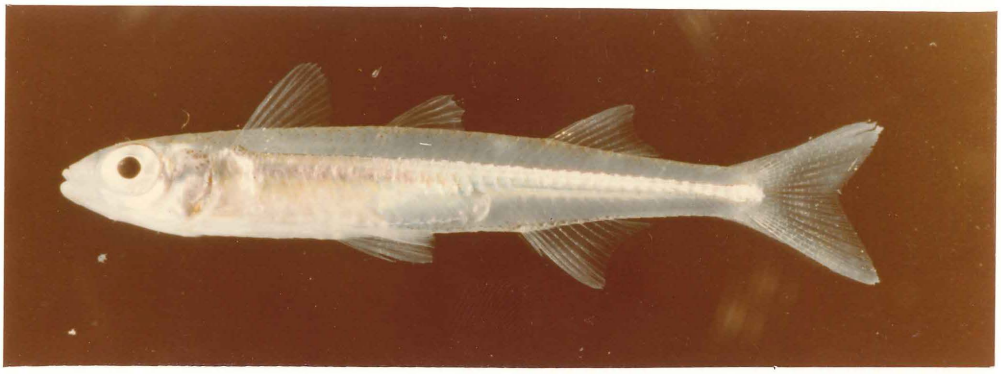
PLATE 4

Allanetta mugiloides (X 2.5)

PLATE 5

Allanetta mugiloides schooling in aquarium

(x1 approx.)



2. MATERIALS AND METHODS

2.1. Field Sampling

Ten sites were sampled throughout the estuary at least once a month (Fig. 1). Two of the sites, Stirling Bridge and Colonial Sugar Refineries (C.S.R.), were situated in the lower Estuary, while three others, Alfred Cove, Mt Henry and Perth Water, were located in the Middle Estuary. The sites in the Upper Estuary were Joel Terrace, Sandy Beach, and Guildford in the Swan, and Shelley Basin and Kent Street in the Canning River. Since most of the sites faced towards the east, they lay in the lee of the prevailing south-westerly winds. Such a position is important in sampling for atherinids which prefer quiet waters (Ivantsoff, 1977). All the collections were made in the morning or early afternoon and each individual site was sampled at approximately the same time of day each month. A few additional samples were taken during the study, both within the estuary and from other areas, to provide data which would aid comparisons between the distribution of the various species. Recordings of salinity and temperature were taken during the course of each sampling trip using a conductivity meter and a mercury thermometer. Notes were also made of cloud cover, the direction and strength of the wind, water condition and the amount and type of weed.

Fish were sampled with a beach seine 2.0m in depth and 133m long. The two wings of the net were 65m long and consisted of 2.5cm mesh. The pocket, joining the wings was 3m wide and comprised of .95 cm mesh. This net was laid from a small dinghy in a semi circle around the site.

Atherinids and all other fish caught in the seine were removed from the net, placed in bags and taken to the laboratory

in an icebox. The current study was part of a larger programme which was investigating the entire ichthyofauna of the Swan-Avon estuary. In addition to beach seining, the programme utilised otter trawling and meshing to provide samples from the channel areas. However, no atherinids were caught using these methods during the year covered by this study.

2.2. Laboratory work

Upon reaching the laboratory, the fish were identified and a record made of the number and the total weight of each species caught at each site. The total length of each fish of each species was measured to the nearest 1mm. However, in those cases when the number from a single site exceeded 100 fish, a random sub-sample of 100 fish were measured. The atherinids were then preserved in 10% formalin for gut and gonad studies. The length measurements of the fish were used to construct length-frequency histograms for each month and for each species, thereby allowing age groups and growth rates to be determined.

Approximately 30 atherinids, representative of each age group in each sample were selected for the work on guts and gonads. Before dissection, each animal was remeasured and weighed to the nearest 1mm and 1mg. The work of Parker (1963), Stobo (1972) and Cadwallader (1974) showed that length changes after preserving fish in 10% formalin are in the region of 1%.

Gonads were removed and weighed from all preserved fish selected for dissection. The Gonadosomic Index (G.S.I.) was calculated by expressing the weight of the gonads as a percentage of the total body weight.

The guts of ten fish from each sample were removed for analysis of their contents. Gut contents were examined between

March and October with the months March and April, May and June, July and August, September and October being considered as representative of estuarine Summer, Autumn, Winter and Spring respectively. The Points method, as outlined by Hynes (1950) was used in this study. This method involves the total gut content being assigned a value between zero and ten according to its fullness. The constituents of the gut contents are then assigned appropriate values according to their volume. Since atherinids do not have a proper stomach, the contents of the entire alimentary tract were examined. The points method was selected as most appropriate for this study because of the difficulties in obtaining accurate quantitative measurements on the extremely small guts and their contents. The results of this section are considered to be relatively accurate indications of the diet of the fish, despite the bias against soft, easily digested materials. These results were not considered to be seriously biased as all items of the diet had digestion resistant integuments with the exception of polychaetes. However the bias against polychaetes is not considered serious as their digestion resistant chaetae always made them detectable.

A few counts of egg number and measurements of diameter were performed. The eggs were teased from gonads into a petri dish and counted and measured with a dissecting microscope with micrometer eye piece.

The taxonomic characters of the Atherinosoma species examined in this study included meristic counts and morphometric measurements. Meristic counts were most easily obtained using fresh or frozen fish, while all morphometric measurements were made on preserved specimens. The measurements made in this study have been taken from the work of Ivantsoff (1977).(Fig. 2).

The proportions calculated were :

- Head length
- Pectoral fin length
- Maximum body depth
- Minimum body depth
- Distance from the snout to the origin of second dorsal fin
- Distance from the snout to the origin of the first dorsal fin
- Distance from the snout to the origin of the anal fin
- Distance from the snout to the tip of ventral fins
- Distance from the snout to the origin of the ventral fins

all expressed as a proportion of the standard length. The following :

- Eye diameter
- Distance from the posterior margin of the orbit to the hindmost edge of the operculum

were calculated as proportions of the head length.

- The distance from the snout to the anterior edge of the orbit
- Distance from the snout to the distal end of the junction between the premaxilla and maxilla

were expressed as a proportion of the eye diameter.

- The length of the longest gill raker was calculated as a proportion of the pupil diameter.
- The length of the second dorsal fin was expressed as a proportion of the anal fin length.

The meristic counts were :-

- Midlateral scale number
- Transverse scale number
- Predorsal scale number
- Interdorsal scale number
- First dorsal fin count

- Second dorsal fin count
- Anal fin count
- Pectoral fin count
- Gillraker count
- Vertebral count.

The morphometric measurements and meristic counts were chosen as being most diagnostic of the Atherinosoma species, on the basis of Ivantsoff (1977). All counts and measurements were performed using the methods described by Ivantsoff (1977). The sample size for each of the counts and measurements was usually 50. The measurements were made with Vernier calipers to the nearest 0.1mm. All tests for significance were carried out using separate variance T-Tests.

FIGURE 2.

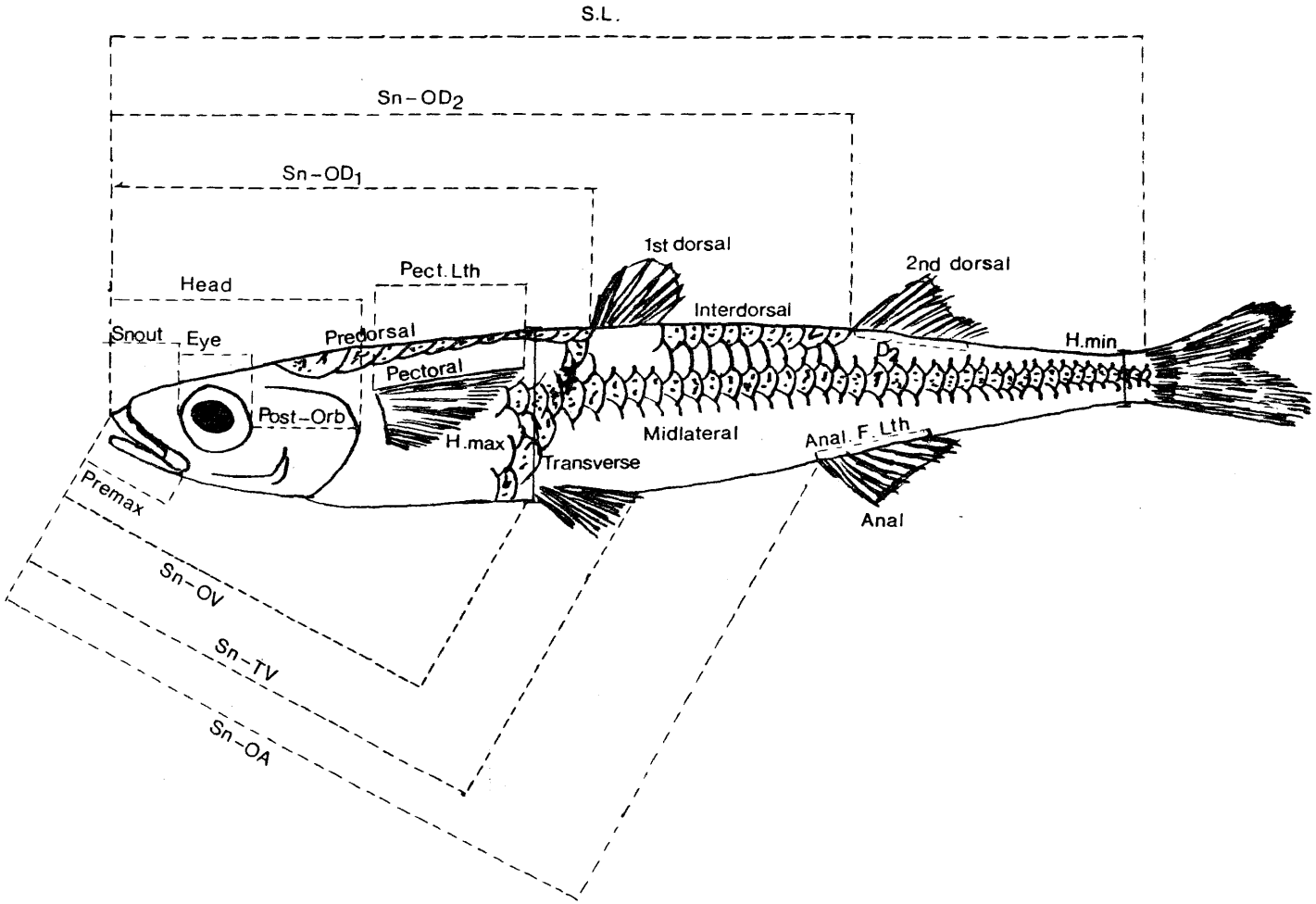
A Diagram of the taxonomic characters measured.

Meristics

Midlateral	-	Number of scales between dorsal origin of pectoral fin and hypural joint.
Transverse	-	Number of scales from the origin of first dorsal to the row where the ventrals are inserted.
Predorsal	-	All scales in the midline from the head to the origin of the first dorsal.
Interdorsal	-	All scales in the midline between the first and second dorsal fins.
1st dorsal	-	Number of spines and rays in the first dorsal fin.
2nd dorsal	-	Number of spines and rays in the second dorsal fin.
Anal	-	Number of spines and rays in the anal fin.
Pectoral	-	Number of rays in the pectoral fin.

Morphometrics

Head	-	Distance from tip of snout to posterior edge of operculum, expressed in Standard Lengths (S.L.).
Pec. Lth.	-	Length of Pectoral fin in S.L.
H. max.	-	Maximum body depth in S.L.
H. min.	-	Minimum body depth in S.L.
$Sn\text{-}OD_1$	-	Distance from the snout to the origin of the first dorsal fin in S.L.
$Sn\text{-}OD_2$	-	Distance from the snout to the origin of the second dorsal fin in S.L.
Sn-OV	-	Distance from the snout to the origin of the ventral fins in S.L.
Sn-TV	-	Distance from the snout to the tip of the ventral fins in S.L.
Sn-OA	-	Distance from the snout to the origin of the anal fin in S.L.
Eye	-	Diameter of orbit in head.
Post. Orb.	-	Distance from posterior margin of the orbit to the posterior edge of the operculum in Head.
Snout	-	Distance from the tip of the snout to the anterior edge of the orbit in Eye.
Premax.	-	Distance from snout to the distal end of junction between premaxilla and maxilla.
D_2	-	Length of the base of the second dorsal fin in the Anal fin length.


S.L.
Sn-OD2
Sn-OD1
Head
Pect. Lth
1st dorsal
2nd dorsal
Snout
Eye
Predorsal
Interdorsal
H.min
Pectoral
Post-Orb
H.max
Midlateral
Anal. F. Lth
Transverse
Premax
Anal
Sn-OV
Sn-TV
Sn-OA

3. RESULTS

3.1. Taxonomy

As mentioned in the introduction at the beginning of this study, four species of atherinid were thought to be present in the Swan-Avon estuary. Two of these, Pranesus ogilbyi and Allanetta mugiloides, can be easily recognised. For this reason, this study has concentrated on Atherinosoma species, which are much more difficult to identify.

The values for four of the meristic counts obtained for each of the species in this study differ from those given by Ivantsoff (1977). These differences were consistent and, in three of the four characters, can be easily explained on the basis of differences in counting techniques. The counts of the number of spines and rays in the second dorsal and anal fins are constantly one spine greater than those of Ivantsoff. This is almost certainly due to the incorporation in the counts given in this study of the very small spine which precedes the other larger spines. This was probably not done by Ivantsoff as the spine mentioned is less than one quarter the size of the succeeding spines and is virtually impossible to separate from the larger second spine in preserved fish. Thus, the difference in results is probably due to the use of fresh fish in this study and of preserved fish in Ivantsoff's investigation. A similar explanation probably accounts for the fact that the interdorsal scale counts in this study are consistently one lower than those of Ivantsoff (1977). In the latter study, it is stated that this count includes "all the scales from the posterior edge of the last spine of the first dorsal fin in the midline to the origin of the second dorsal fin". However, in fresh specimens with intact

fins, it is clear that what in preserved fish appears, because of the shape and pigmentation to be the first scale in the midline, is in fact two scales on either side of the midline, separated by the membrane of the first dorsal fin. The transverse scale count was consistently one scale greater than in the study of Ivantsoff (1977), although no explanation can be made for this difference it would seem that this also reflects a difference in technique. Because of these obvious differences in technique, these counts have not been used for comparison with the results of Ivantsoff (1977). No vertebral counts were obtained by this study due to unforeseen difficulties with the x-ray procedure and the poor quality x-rays that resulted.

In the species identified as Atherinosoma elongata, the longest gill raker was shorter than the diameter of the pupil in all of the 42 fish measured. The mean number of gill rakers on the first lower gill arch was 13.2, with values ranging from 12 to 15 and the premaxilla never extended posteriorly to the extent where it reached a point equivalent to a line drawn vertically through the anterior margin of the orbit. The mean midlateral scale count for 38 fish was 39.3, with a range of 35 to 41, and the swim bladder ended bluntly behind the cloaca. On these characteristics this species agreed with the description of A. elongata given in Ivantsoff (1977) (Fig. 3). Other counts and measurements obtained in this study agreed closely with those given by the latter worker (Fig. 4). Two separate samples of this species sent to J. Patten, a co-worker of Ivantsoff were both identified by him as A. elongata.

The gill rakers of the species identified as Atherinosoma presbyteroides during this study were the same length or longer

than the diameter of the pupil in 48 of the 51 fish measured. The mean number of gill rakers in the first lower gill arch was 17.0, with a range of 16 to 19, and the premaxilla always stretched posteriorly beyond a line drawn vertically through the anterior margin of the orbit. The midlateral scale count on 51 fish gave a mean of 42.7, with a range of 41 to 47. The posterior end of the swim bladder tapered slightly backwards and upwards. On these characteristics this species agreed with the description of A. presbyteroides given in Ivantsoff's (1977) key. In all the counts and measurements performed on characteristics not mentioned specifically in the key, close agreement was found between the counts obtained in this study and those given by Ivantsoff (1977).

The gill rakers of a third species were marginally shorter than the pupil in 96 of the 100 fish measured and the mean number of gill rakers on the lower gill arch was 15.6, with a range of 14 to 17 for the 53 fish examined. The premaxilla reached posteriorly to a point where it was equivalent to a line drawn vertically through the anterior margin of the orbit. The midlateral scale count for 53 fish was 39.8 with a range of 36 to 45. Unlike the other two species the swim bladder was transparent in fresh specimens and the posterior end formed an arc between the cloaca and the back bone (Plate 6-8). This species varied significantly ($P<0.01$) in midlateral scale count, transverse scale count, predorsal scale count, interdorsal scale count, gill raker count, maximum body depth, snout to the origin of ventral fin, premaxilla length and length of the gillrakers between the fish that were caught in the Swan and those caught in the Canning River. The differences in the other

16 characteristicswere not significant. Because of these differences all the counts and measurements have been performed on approximately equal numbers of each type and have been shown separately and as pooled samples (Fig. 4).

On the basis of the key characters this species could not be classified as one of the three Atherinosoma species recognised by Ivantsoff (1977). Both of the types of this species were significantly different in midlateral scale count, gill raker number, length of the gill rakers, transverse scale count, first dorsal fin count, second dorsal fin count, anal fin count, pectoral fin count, minimum body depth, snout to the second dorsal fin, and snout to the origin of the anal fin to A. presbyteroides ($P < 0.01$).

The Swan River type of the unidentified species also differed significantly with this species in predorsal scale count, head length, snout to the origin of the first dorsal fin, eye diameter and snout length. While the Canning River type also differed significantly in interdorsal scale count, pectoral length, maximum body depth and premaxilla length from A. presbyteroides. Despite these clear differences J. Patten twice identified specimens of these species as A. presbyteroides. This was probably because, when compared with A. elongata, which was the other group of specimens sent, this species has longer and more numerous gill rakers and a longer pre-maxilla which are the separating characters for A. presbyteroides.

Both types of this species differ significantly from A. elongata in gill raker length and number, interdorsal scale count, pectoral fin count, snout to the origin of the ventral fin distance, eye diameter, post-orbital distance and snout

length. While the Swan River type also differs in transverse scale number, predorsal scale number, second dorsal fin count, anal fin count, pectoral fin length and distance from the snout to the origin of the first dorsal fin. Although the Canning River type differs in midlateral scale count, head length, maximum body depth, distance from the snout to the second dorsal fin and the distance from the snout to the tip of the ventral fin from A. elongata. In general appearance and biology, the unidentified species is clearly different to both of the recognised species of Atherinosoma found in the Swan-Avon estuary. In general appearance this species was more slender than the others and always possessed deep orange and red colours in fresh specimens. Its biology also clearly separates it from A. elongata and A. presbyteroides and this will be dealt with elsewhere in this study. This species is clearly not A. microstoma which is the third species of Atherinosoma recognised by Ivantsoff (1977) as this worker's key shows. Although this unidentified species does not key out to the Atherinosoma species recognised by Ivantsoff (1977), it fits his description of the genus and so must be a member of this genus. For the purpose of this study it will be referred to as the "unidentified species".

FIGURE 3.

The key to the species of the genus Atherinosoma.

From Ivantsoff (1977)

KEY TO SPECIES OF THE GENUS *ATHERINOSOMA*

1 a. Gill rakers short, less than diameter of pupil, 12-16 on first lower gill arch; premaxilla usually not reaching vertical through anterior margin of orbit; midlateral scales 36-41; posterior end of swim bladder ending bluntly 2

1 b. Gill rakers usually as long as diameter of pupil, 15-20 on first lower gill arch; premaxilla always reaching vertical through anterior margin of orbit; midlateral scales 40-47; posterior end of swim bladder tapering backwards and upwards but never extending far into haemal arches ..... *A. presbyteroides*

2 a. Three scales above and three scales below midlateral band at first dorsal origin; body depth 4.6-7.9 in SL but usually closer to 5 ; dentition variable, but with teeth frequently appearing in oval patches on tongue ..... *A. microstoma*

2 b. Two to three scales above and two to three scales below midlateral band, always 2 scales above and below midlateral band in western populations; body depth 5.1-8.6 in SL, usually about 6 or more; dentition variable, but no distinct patches of teeth on tongue. Vomerine teeth often well developed. ..... *A. elongata*

FIGURE 4.1.

The number of midlateral scales, the length of the premaxilla, the number of gillrakers on the lower half of the first gill arch and the length of the longest gillraker recorded for *Atherinosoma* spp. both in this study and in that of Ivantsoff (1977). In this and figures 4.1 - 4.6. horizontal lines represent the mean, the shaded bars indicate ± two standard errors, unshaded bars indicate ± one standard deviation and vertical lines indicate the range. The data from the measurements made in this study is contained in the appendix.

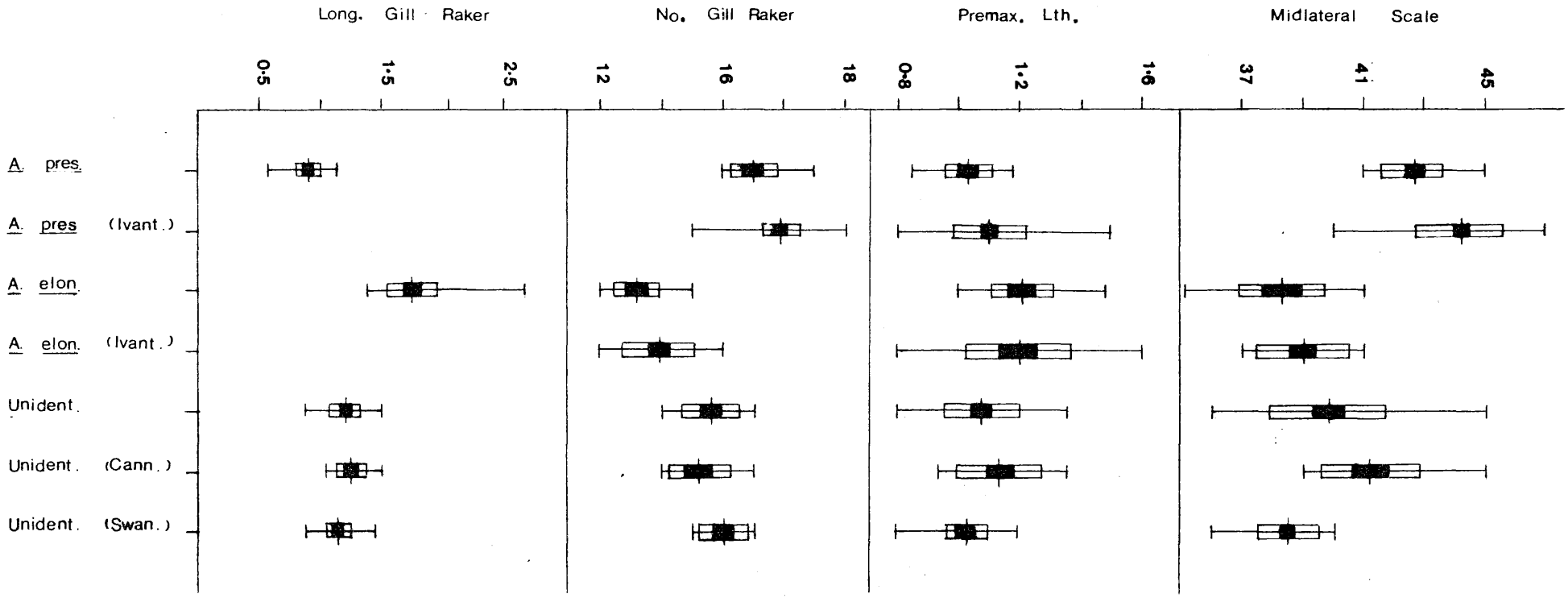

Long. Gill Raker
No. Gill Raker
Premax. Lth.
Midlateral Scale
0·5
1·5
2·5
12
16
18
0·8
1·2
1·6
37
41
45
A. pres.
A. pres (Ivant.)
A. elon.
A. elon. (Ivant.)
Unident.
Unident. (Cann.)
Unident. (Swan.)

FIGURE 4.2.

The numbers of, spines and rays in the anal fin, transverse scales, spines and rays in the second dorsal fin and interdorsal scales recorded for *Atherinosoma* spp. both in this study and in that of Ivantsoff (1977).

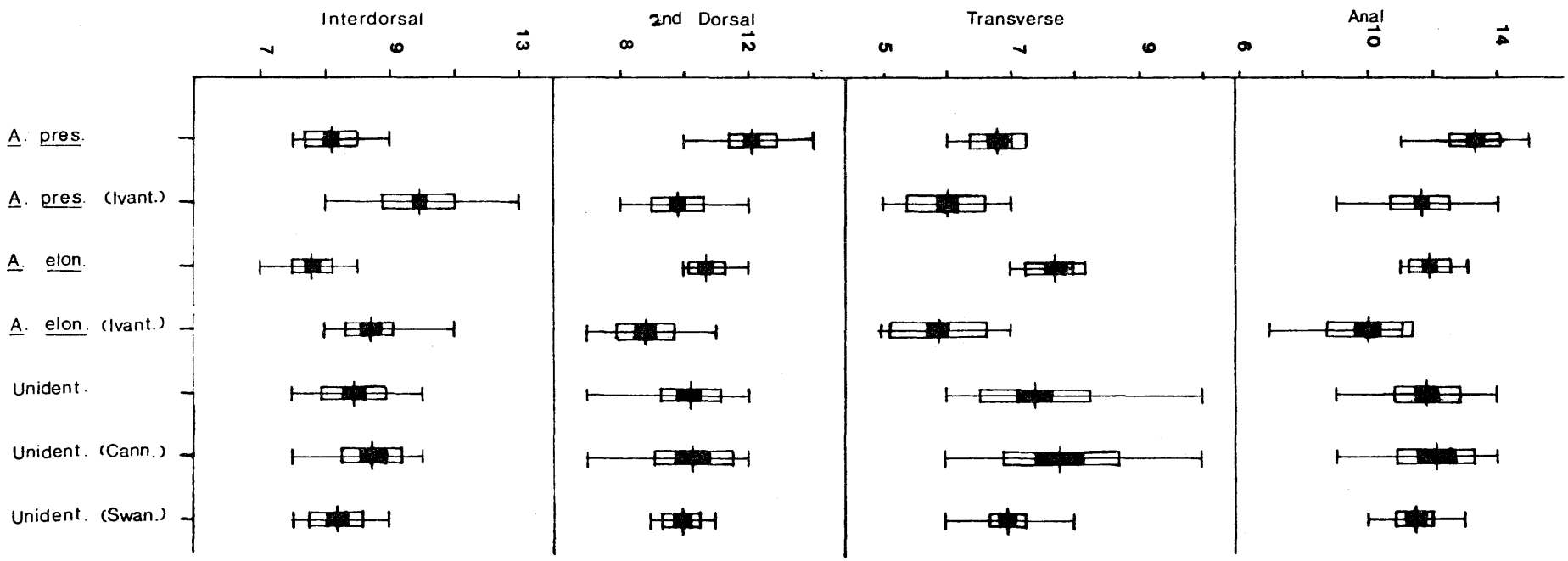

Interdorsal
7
9
13
2nd Dorsal
8
12
Transverse
5
7
9
Anal
6
10
14
A. pres.
A. pres. (Ivant.)
A. elon.
A. elon. (Ivant.)
Unident.
Unident. (Cann.)
Unident. (Swan.)

FIGURE 4.3.

The numbers of predorsal scales and pectoral fin rays, and the distances from the snout to the first dorsal fin and from the snout to origin of the ventral fins, recorded for *Atherinosoma* spp. both in this study and in that of Ivantsoff (1977).

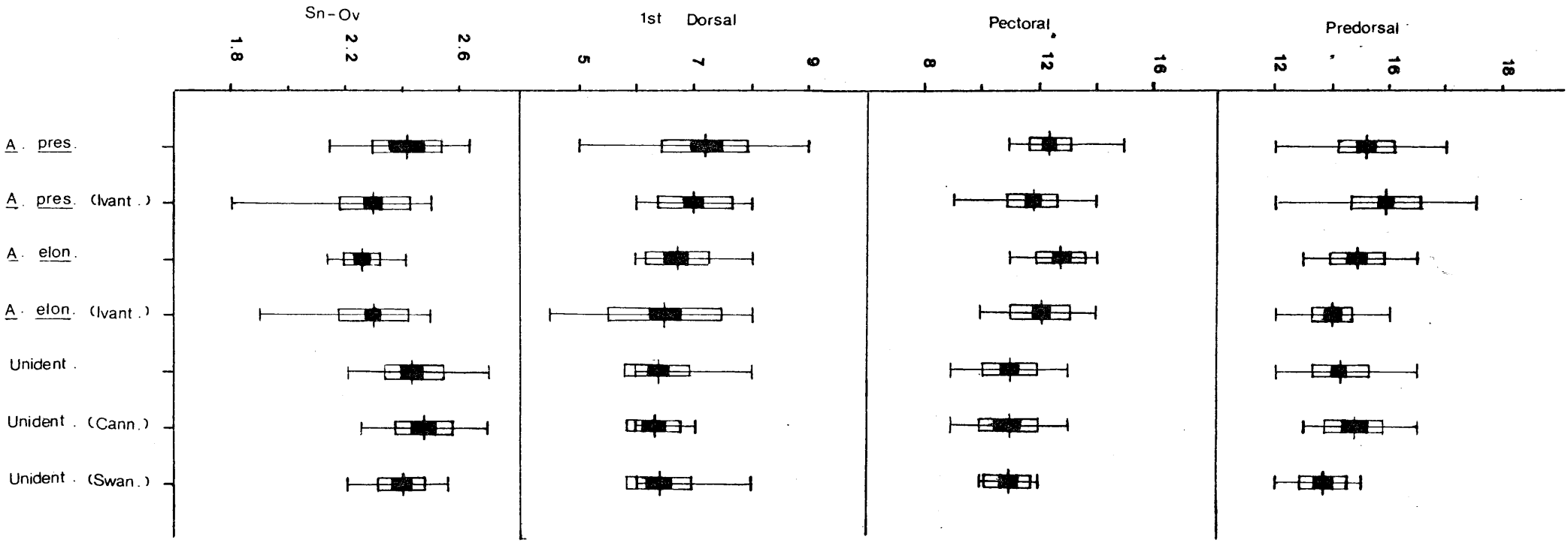

Sn-Ov
1.8
2.2
2.6
1st Dorsal
5
7
9
Pectoral
8
12
16
Predorsal
12
16
18
A. pres.
A. pres. (Ivant.)
A. elon.
A. elon. (Ivant.)
Unident.
Unident. (Cann.)
Unident. (Swan.)

FIGURE 4.4.

The distances from the snout to the tip of the ventral fins, and from the snout to the origin of the anal fin, the diameter of the eye and the distance from the posterior edge of the orbit to the edge of the operculum, recorded for *Atherinosoma* spp. both in this study and in that of Ivantsoff (1977).

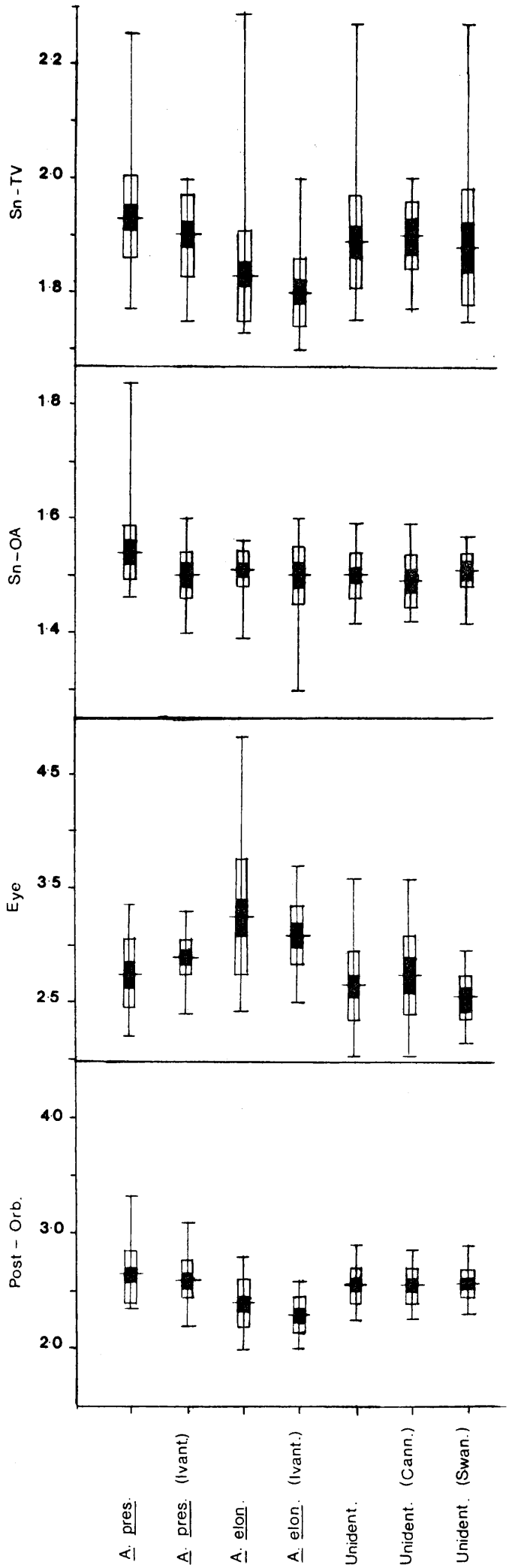

Sn-TV
2·2
2·0
1·8
Sn-OA
1·8
1·6
1·4
Eye
4·5
3·5
2·5
Post - Orb.
4·0
3·0
2·0
A. pres.
A. pres. (Ivant)
A. elon.
A. elon. (Ivant.)
Unident.
Unident. (Cann.)
Unident. (Swan.)

FIGURE 4.5.

The minimum body depth, distances from the snout to the origin of the first dorsal fin, and the snout to the origin of the second dorsal fin and the length of the second dorsal fin recorded for Atherinosoma spp. both in this study and that of Ivantsoff (1977).

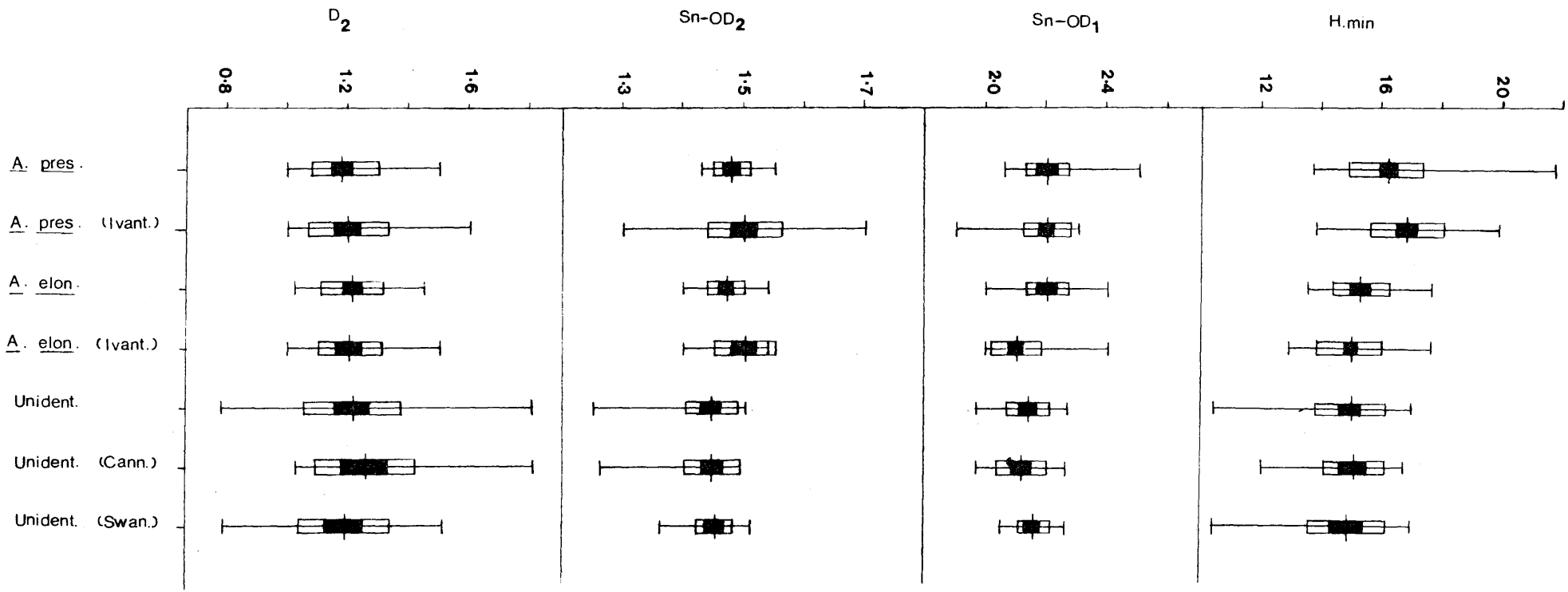

D2
Sn-OD2
Sn-OD1
H.min
0·8
1·2
1·6
1·3
1·5
1·7
2·0
2·4
12
16
20
A. pres.
A. pres. (Ivant.)
A. elon.
A. elon. (Ivant.)
Unident.
Unident. (Cann.)
Unident. (Swan.)

FIGURE 4.6.

The length of the snout, head and pectoral fin and the maximum body depth recorded for *Atherinosoma* spp. both in this study and in that of Ivantsoff (1977).

Snout
2·5
1·5
0·5
Head
5·0
4·0
3·0
Pec. Lth.
9·0
7·0
5·0
H.max
9·0
7·0
5·0
A. pres.
A. pres. (Ivant.)
A. elon.
A. elon. (Ivant.)
Unident.
Unident. (Cann.)
Unident. (Swan.)

PLATE 6.

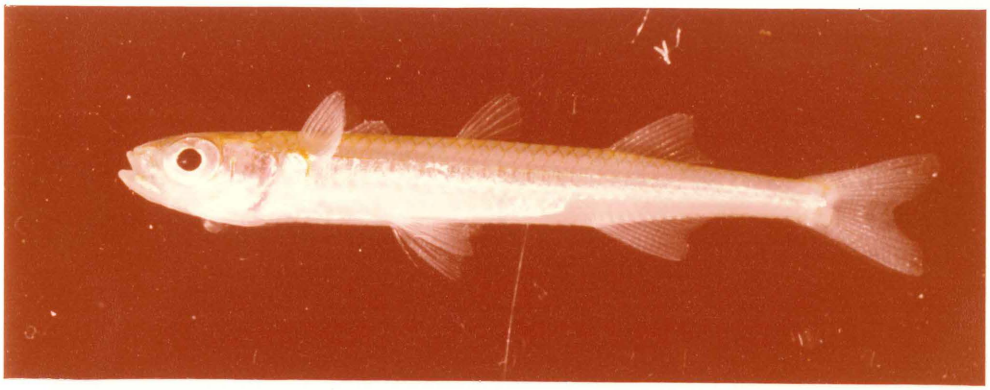
Unidentified species (x 2.5)

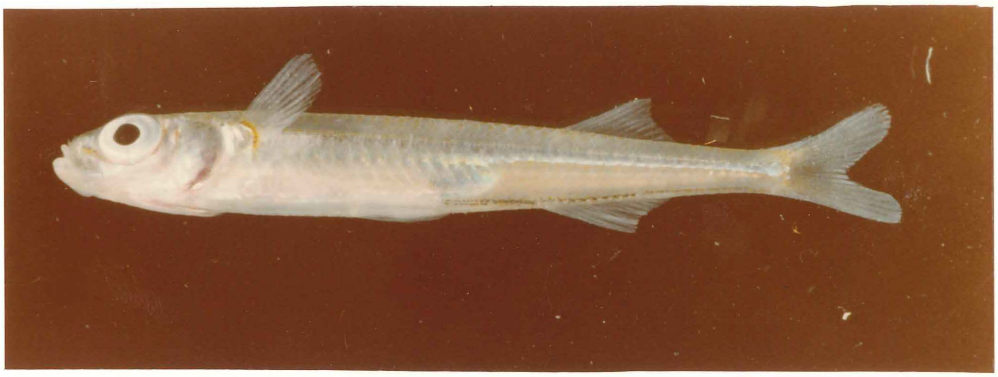
PLATE 7.

Unidentified species (x 4.0) showing swimbladder forming arc between cloaca and backbone

PLATE 8.

Unidentified species schooling in an aquarium





3.2. Unidentified atherinid

LIFE CYCLE

Estimates of growth from the length-frequency histograms for this species are complicated to some extent by the fact that the mean length of the males was significantly less than the females throughout the year ($P<0.01$) (Table 1). This feature produced a degree of bimodality in the length-frequency histograms. Despite the differences between sexes, the appearance of significant numbers of the size class corresponding to very young animals was clearly detectable in November (Fig. 5). Smaller numbers of this juvenile size class were also present in the histograms for the preceding two months.

From the growth curve (Fig. 6), based on the mode of a curve fitted by eye to the length-frequency data, increases in length can be seen to be relatively rapid between November and April, with the mean increasing from approximately 25 to 45 mm. The rate of length increase slows during the colder months until August when growth resumes. The maximum modal length of just under 60 mm was reached in the period between December to February, approximately 15 months after the first appearance of a significant number of very young fish. Few fish, estimated as being more than one year old, were caught after April.

The seasonal pattern exhibited by the G.S.I. (Fig. 7) indicates that breeding generally occurs between August and January. The histogram showing the relative frequency within the sample of different G.S.I. values (Fig. 8) shows that the period when maximum G.S.I's are present is September and

October. The histogram also shows that the first spent gonads were observed in November. From these data, it thus seems reasonable to assume that the majority of the population spawns during October and November. This view is consistent with the length-frequency data. However, since it was not until February that all the gonads were spent and small numbers of juveniles were detected in September the breeding period is almost certainly protracted.

The mean number of eggs in the 27 gonads examined was 15.7, with a range from 11-50. The mean diameter of 162 eggs was 0.92 mm. Although these counts were based on the number of the largest eggs in each gonad, a distinct but smaller size class of eggs was also present. All eggs were observed to have filaments attached to their surface.

In all the samples, the number of females was greater than the males. This is believed to be the result of two sources of bias.The first is an inability to identify with certainty the sex of the smallest fish, even during the breeding season some of the adult fish were still only 30-40mm in total length. Since males are smaller than females, most of this latter group of fish would probably have belonged to the former sex. The second source of bias is related to a selection by the net for larger fish. Small atherinids were able to push through the mesh of the pocket, and escape. However, as the larger females were less able to escape, the samples were more likely to consist of females than males.

Distribution

This species was caught mainly in the upper estuary, with relatively few being taken from below Guildford in the Swan-Avon (Fig. 9). Catches of up to 1000 were also recorded from Mt. Henry in the Canning, with smaller numbers being caught above this site at Shelley Basin and Kent Street. The trend observed in the Canning River, with the highest numbers present lower in the river, was opposite to the trend observed in the Swan-Avon. The reason for this reversal was probably due to the presence of large numbers of Perth herring (Nematalosa vlaminghi) at the upstream sites which tended to distend the net and allow atherinids to escape through the mesh. The numbers of atherinids caught at these sites and at Guildford are inversely related to the number of Perth herring caught.

The distribution of this species of atherinid in the Canning and Swan were effectively isolated with few animals being caught between Guildford and the point where the Canning enters Melville Water. Opportunistic sampling confirmed that this species was an upper estuarine to freshwater species as it was collected in 8‰ in the Avon River as it passed through Walyunga National Park and also in less than 3‰ in the Moore River, 75 km further north.

Feeding

During the summer months of March and April, flying insects, copepods and diatoms made up 81% of the stomach contents (Fig. 10). The fish caught at Guildford contained only diatoms (88%) and copepods, while fish from Joel Terrace and Mt. Henry ate a wider range of food items, including

polychaetes, atherinid eggs, amphipods and algae.

During May and June, copepods were the predominant food item found in the stomachs examined (41%). However, polychaetes were also important (26%), with flying insects, diatoms and unidentified material making up the remainder (Fig. 11). Fish captured throughout the range of sites showed similar diversity of diet during the autumn.

The stomach contents in July and August were similar to those of the preceding months, with copepods making up 31% of the diet. Flying insects were of more importance than in the preceding month making up 30% of the diet. Polychaetes, algae detritus and non-planktonic crustacea made up the remainder (Fig. 12). As in the autumn, the composition of the diet during the winter period was equally diverse throughout this range of the species.

During September and October, flying insects, zooplankton and polychaetes were eaten uniformly throughout the range made up 35%, 28% and 26% of the diet respectively (Fig. 13). During the spring period, crab zoea, as well as copepods, were important components of the zooplankton ingested.

TABLE 1.

Separate variance T-Test for length of unidentified species

males against females

MONTH	SEX	N	MEAN	S.D.	S.E.	t	D.F.	PROB.
November	M	29	44.9	4.55	0.84			
	F	44	55.7	7.03	1.06	7.98	71	<0.001
December	M	7	46.6	3.87	1.46			
	F	22	56.8	3.01	0.64	6.39	8	<0.001
January	M	8	46.2	2.49	0.88			
	F	12	52.8	4.39	1.27	4.21	18	0.001
February	M	3	52.0	1.00	0.58			
	F	11	58.2	2.71	0.82	6.17	10	<0.001
April	M	17	43.1	5.28	1.29			
	F	56	53.2	6.57	0.88	6.53	32	<0.001
May	M	62	43.0	4.60	0.58			
	F	100	47.9	5.51	0.55	5.98	146	<0.001
June	M	17	42.4	6.92	1.68			
	F	51	49.7	6.49	0.91	3.86	26	0.001
July	M	10	46.5	4.04	1.28			
	F	61	50.6	4.35	0.56	2.96	13	0.01

FIGURE 5.

Length-frequency histograms for the unidentified species from all sites.

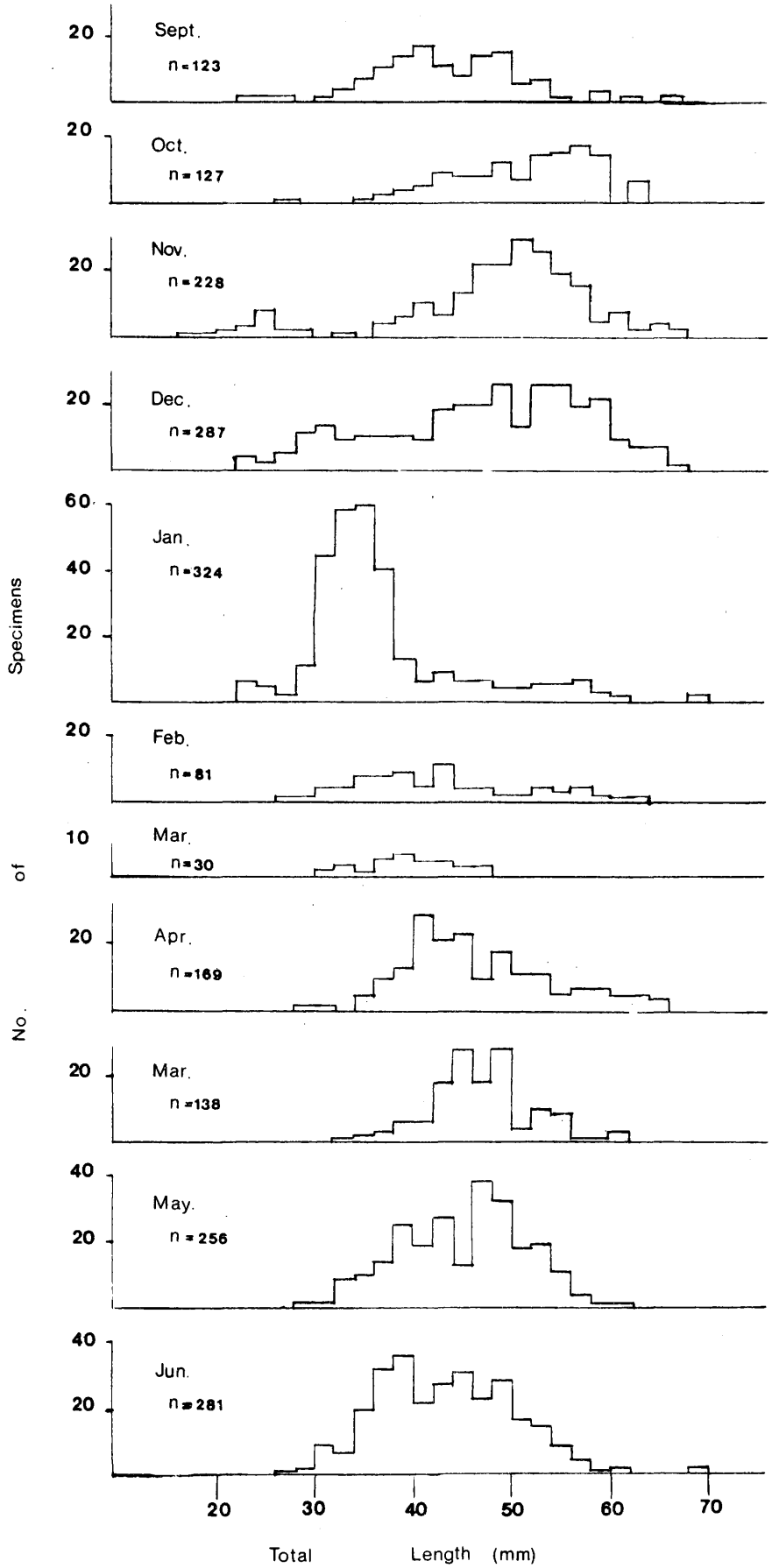

Sept.
n=123
Oct.
n=127
Nov.
n=228
Dec.
n=287
Jan.
n=324
Feb.
n=81
Mar.
n=30
Apr.
n=169
Mar.
n=138
May.
n=256
Jun.
n=281
No. of Specimens
20
30
40
50
60
70
Total Length (mm)

FIGURE 5 (Contd)

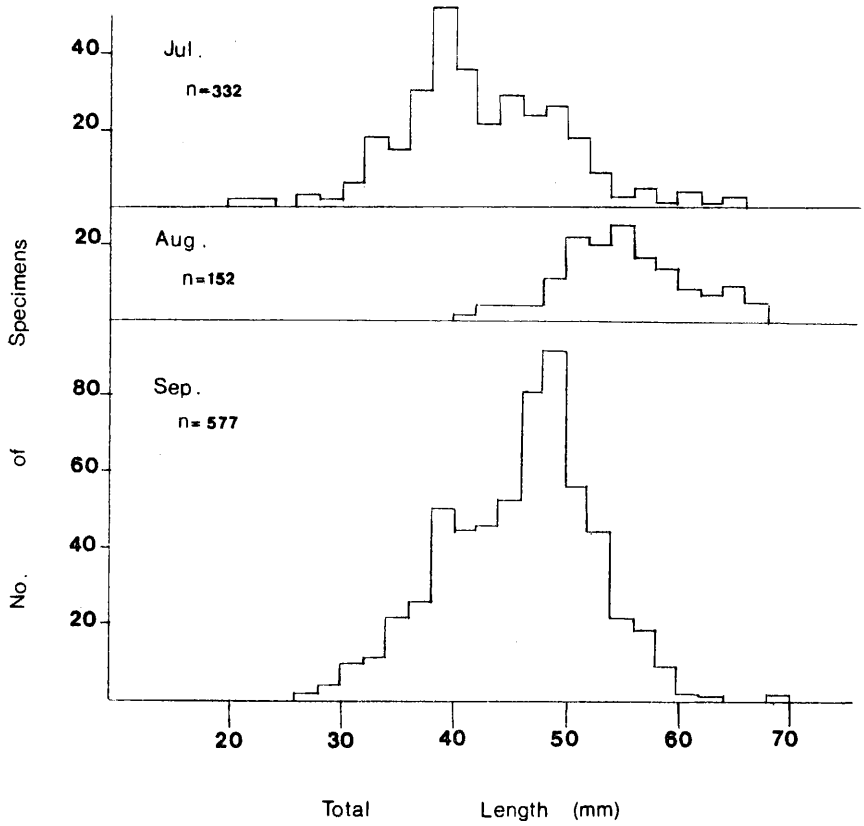

Jul.
n=332
Aug.
n=152
Sep.
n= 577
No. of Specimens
40
20
20
80
60
40
20
20
30
40
50
60
70
Total Length (mm)

FIGURE 6.

Growth curve for the unidentified species.

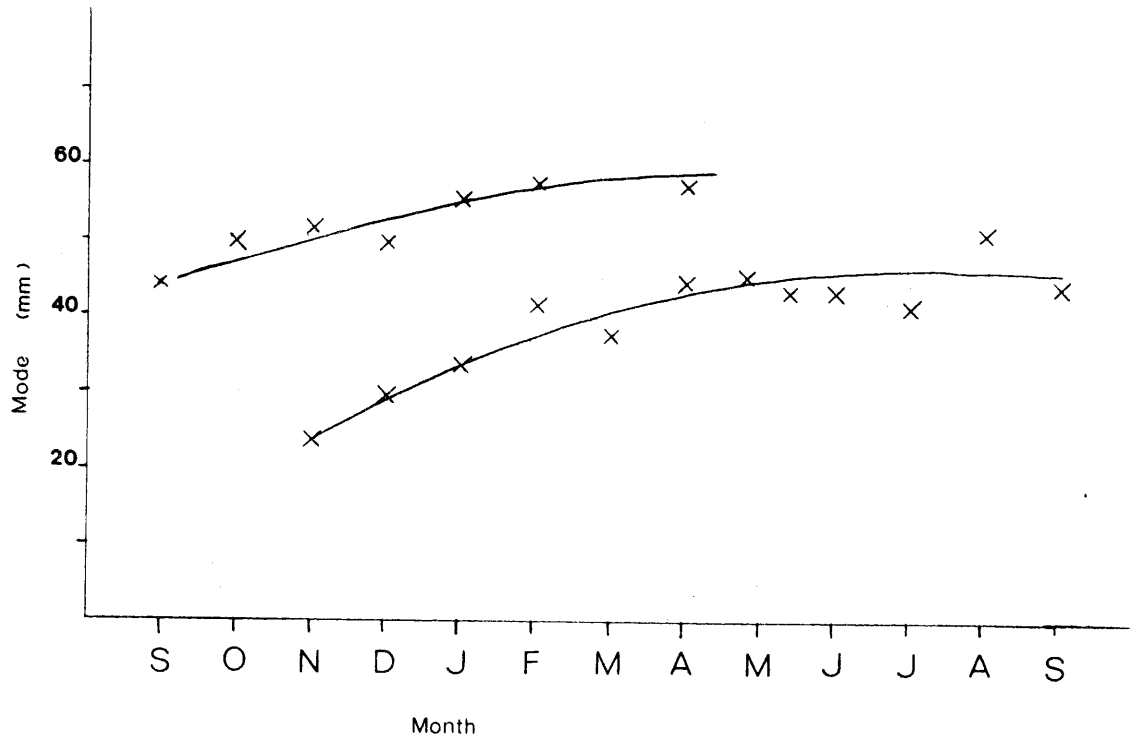

60
40
20
Mode (mm)
S
O
N
D
J
F
M
A
M
J
J
A
S
Month

FIGURE 7.

The G.S.I. of the unidentified species for each month, with ± 95% confidence intervals indicated by the vertical lines. Unbroken line indicates females and the broken line indicates males.

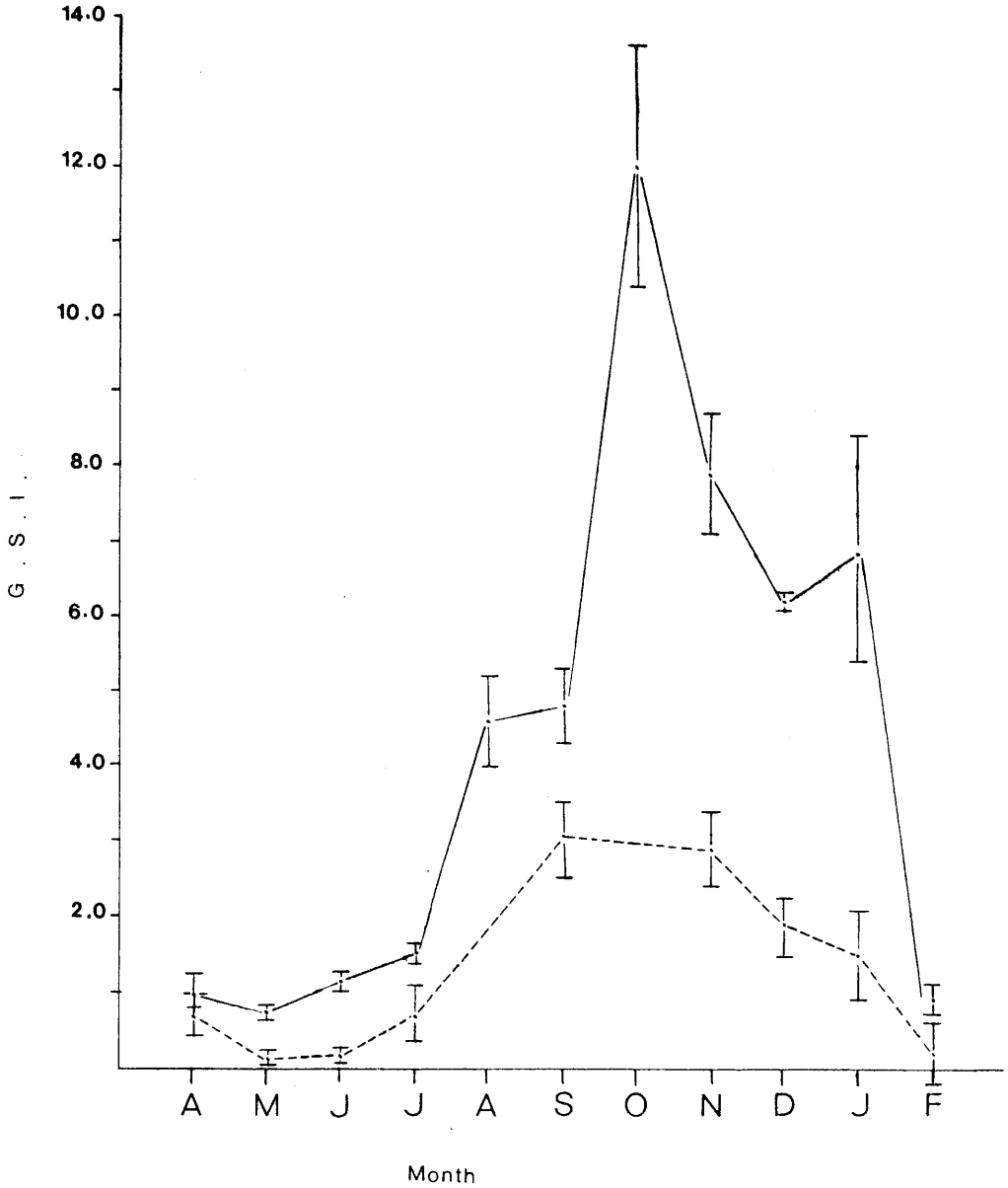

14.0
12.0
10.0
8.0
6.0
4.0
2.0
G . S . I .
A
M
J
J
A
S
O
N
D
J
F
Month

FIGURE 8.

Frequency histograms for the G.S.I's of the females of the unidentified species

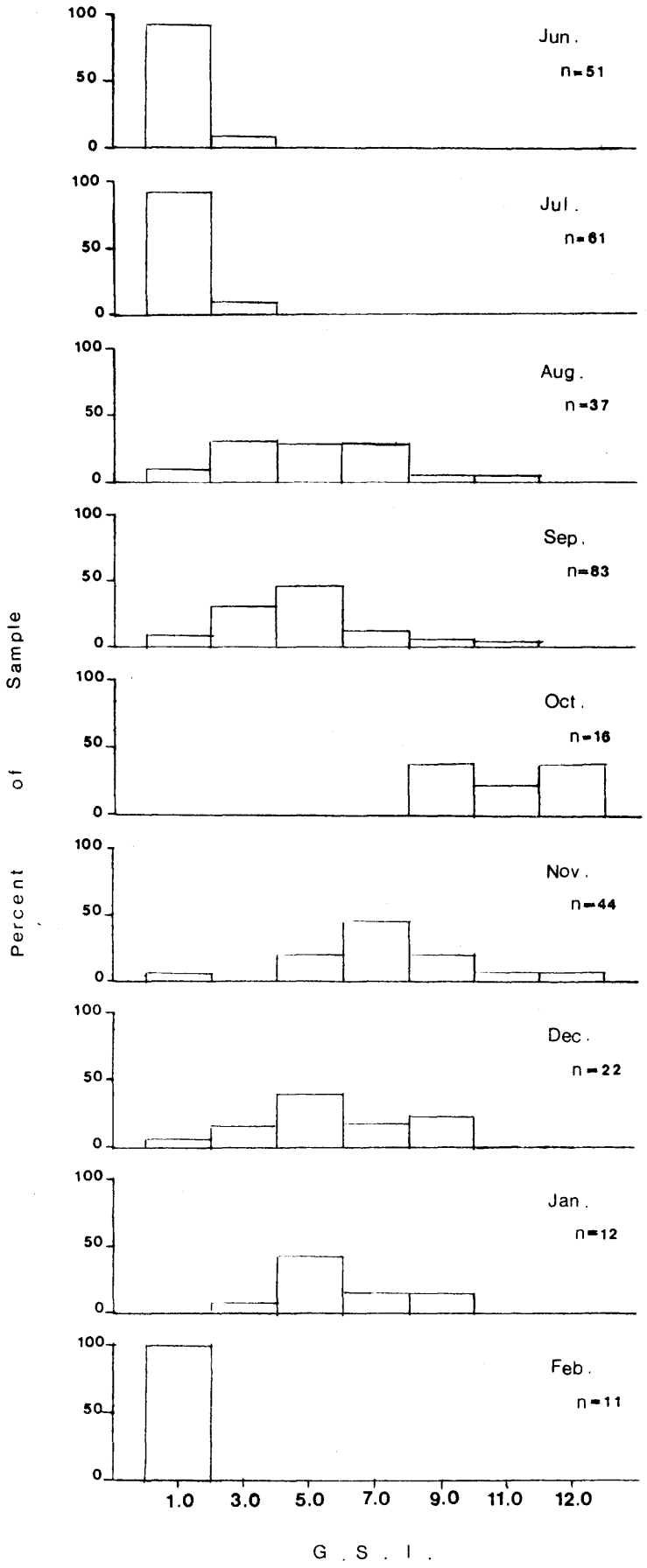

Percent of Sample
100
50
0
Jun.
n=51
Jul.
n=61
Aug.
n=37
Sep.
n=83
Oct.
n=16
Nov.
n=44
Dec.
n=22
Jan.
n=12
Feb.
n=11
1.0
3.0
5.0
7.0
9.0
11.0
12.0
G.S.I.

FIGURE 9.

Numbers of the unidentified species caught in each sample at Kent Street, Mt. Henry, Guildford, Sandy Beach and Joel Terrace, together with data on salinity (broken line) and temperature (unbroken line).

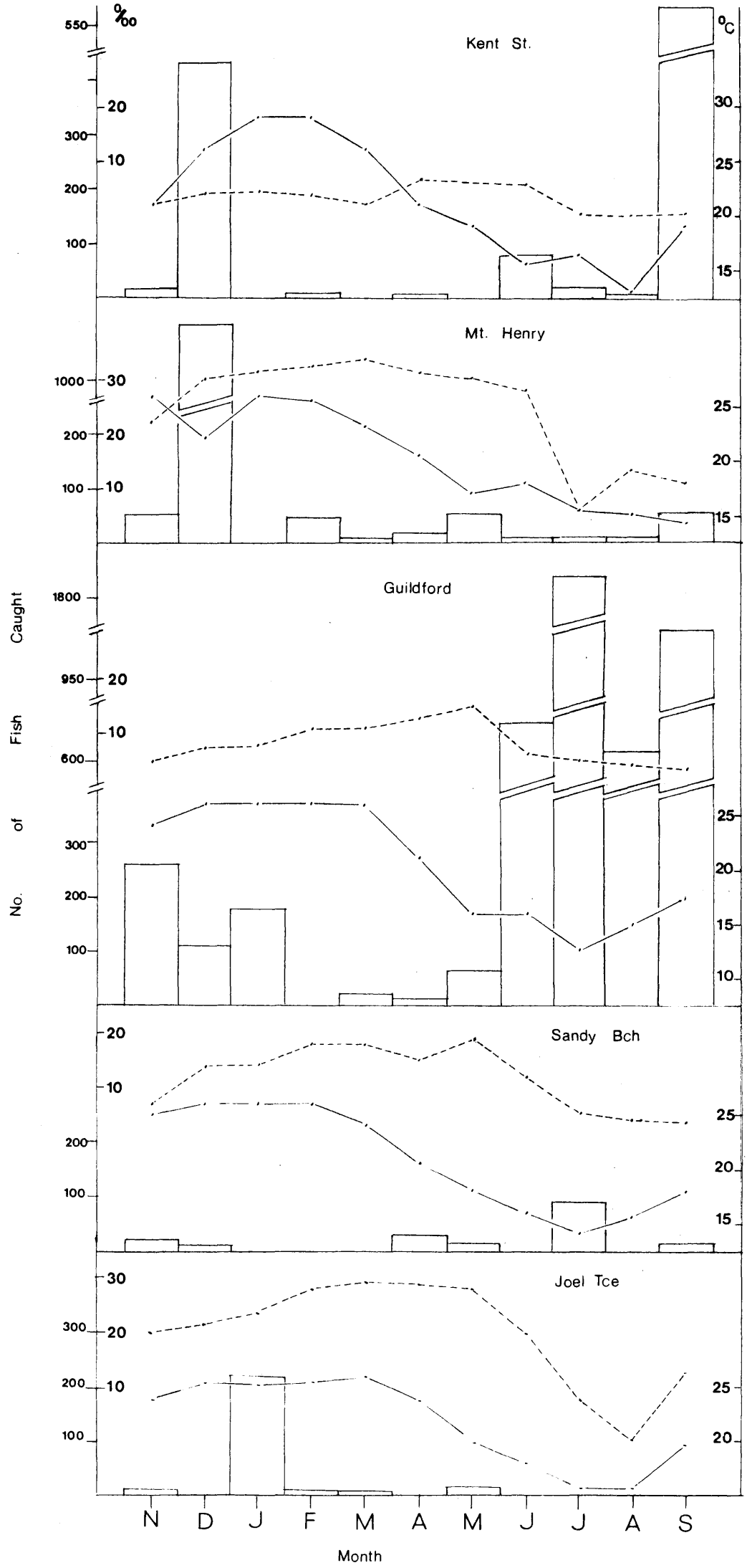
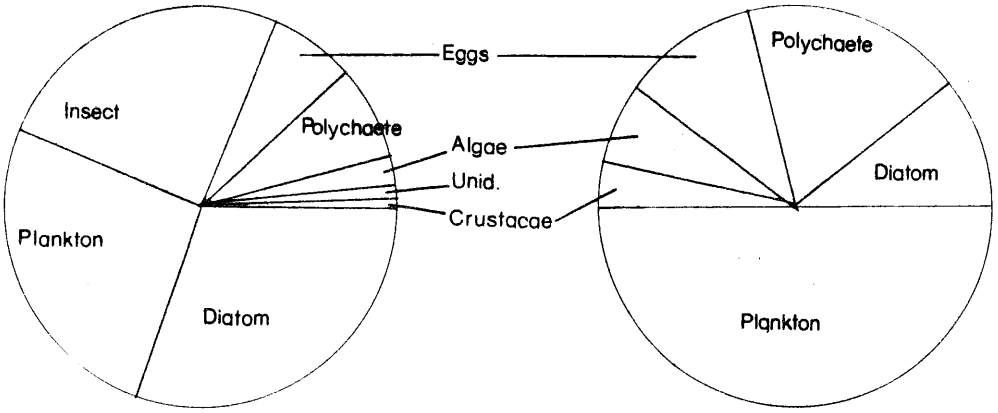

Kent St.
Mt. Henry
Guildford
Sandy Bch
Joel Tce
‰
°C
No. of Fish Caught
N D J F M A M J J A S
Month

FIGURE 10

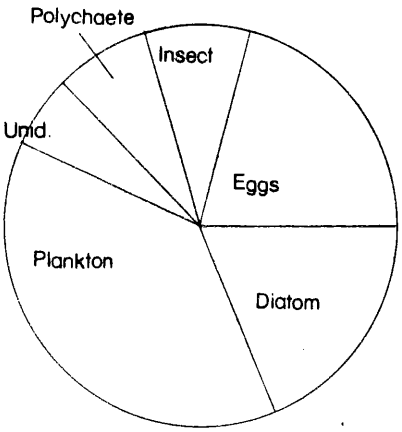
Composition of the stomach contents of the unidentified species at Mt Henry, Joel Terrace, Sandy Beach and Guildford during March and April.



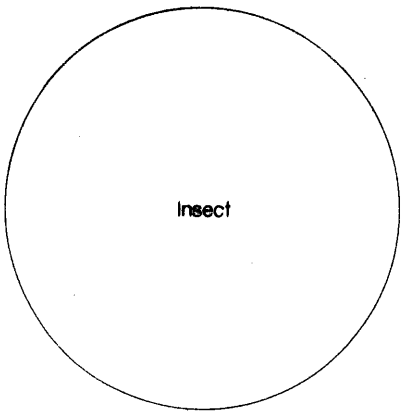
All Sites
n = 42

Mt. Henry
n = 13

Joel Tce. n = 8



Sandy Bch.
n = 10



Guildford
n = 11

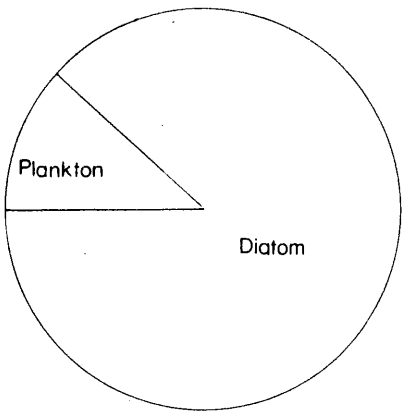
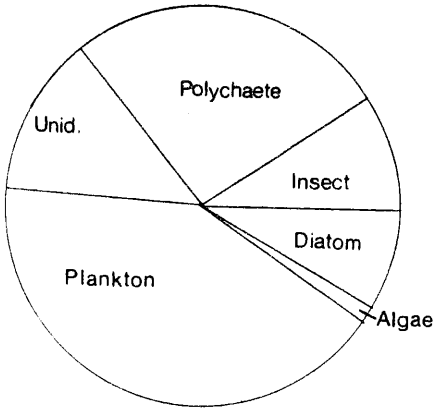
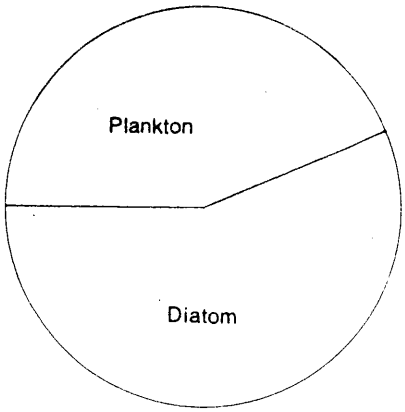


FIGURE 11

Composition of the stomach contents of the unidentified species at Mt. Henry, Kent Street, Joel Terrace, Sandy Beach and Guildford during May and June.

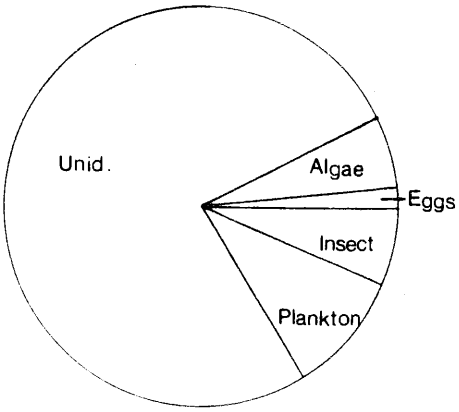


All Sites
n = 70

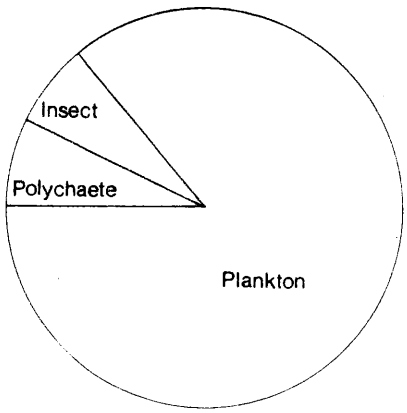


Mt. Henry
n = 10

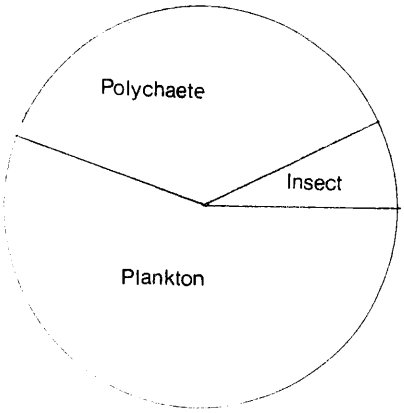
Kent St.
n = 10



Joel Tce.
n = 10



Sandy Bch.
n = 10



Guildford
n = 70

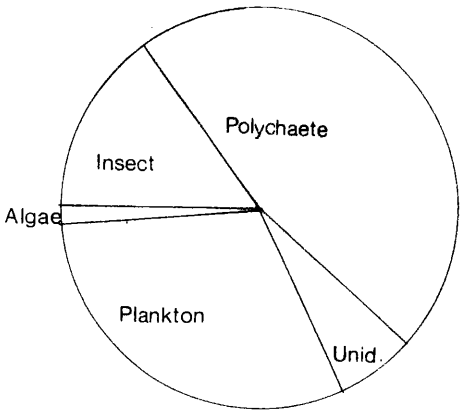
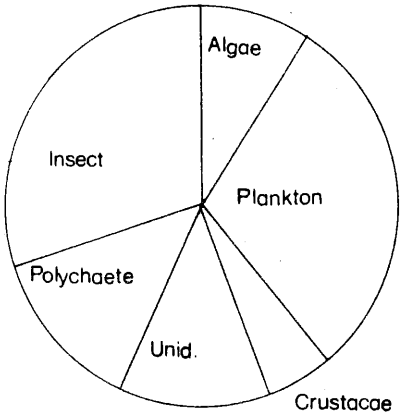
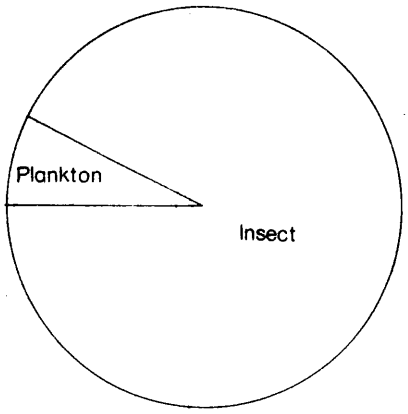


FIGURE 12

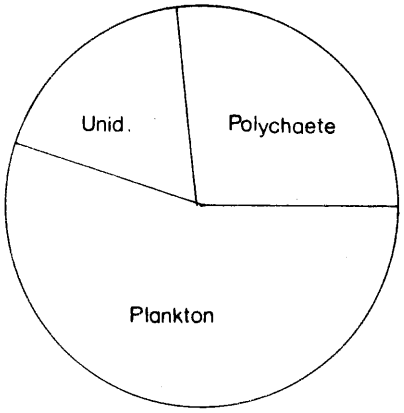
Composition of the stomach contents of the unidentified species at Mt Henry, Shelley Basin, Kent Street, Sandy Beach, and Guildford during July and August.



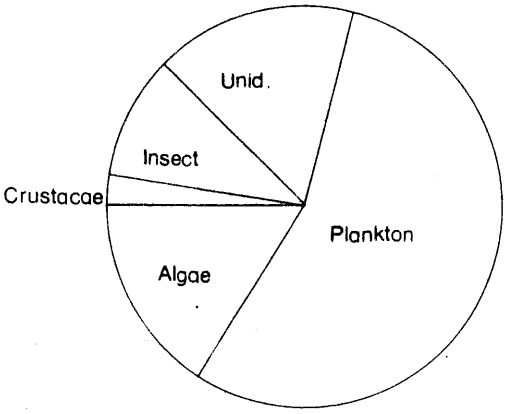
All Sites
n = 53



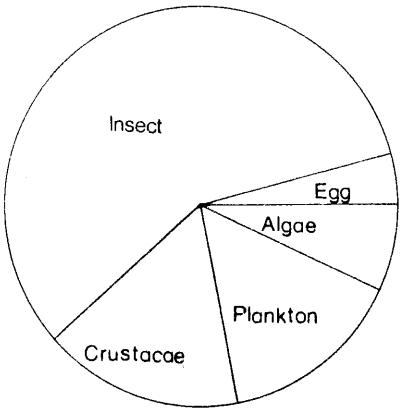
Mt. Henry
n = 7



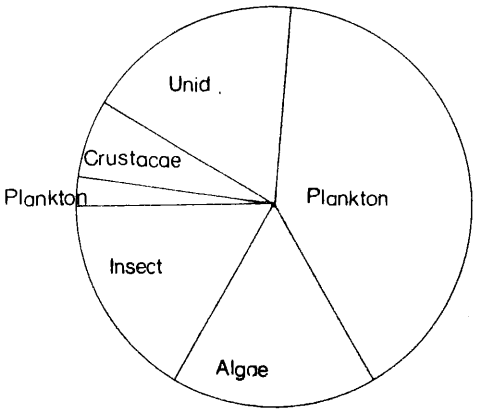
Shelley
n = 10



Kent St.
n = 16



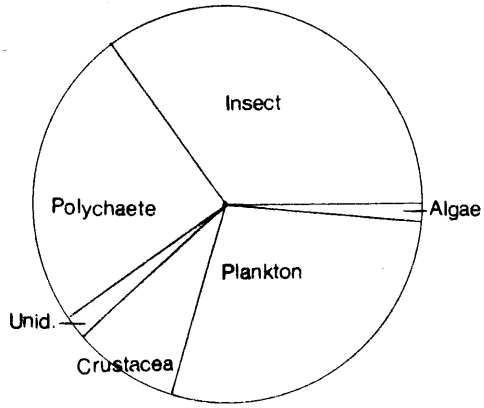
Sandy Bch.
n = 10



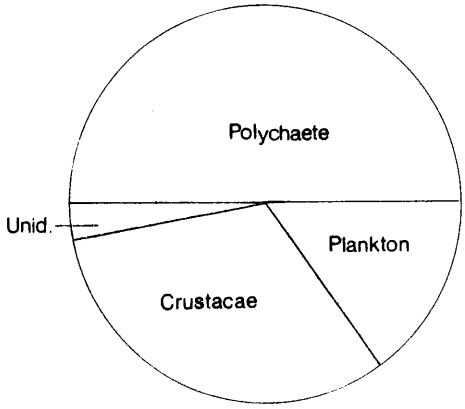
Guildford
n = 10

FIGURE 13.

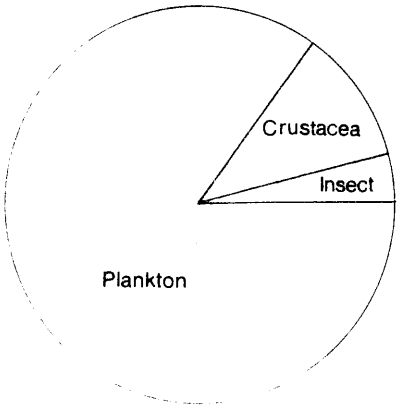
Composition of the stomach contents of the unidentified species from Mt. Henry, Shelley Basin, Kent Street and Guildford during September and October.



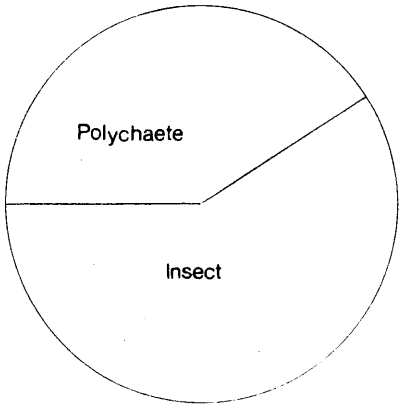
All Sites
n = **57**



Mt. Henry
n = **10**

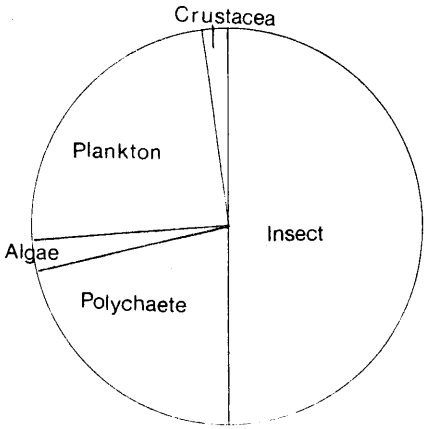


Shelley
n = **10**



Kent St.
n = **10**

Guildford n = **27**



3.3. A. mugiloides

Life cycle

All the fish caught in September, October and November were longer than 38mm (Fig. 14). In December, however, small fish of approximately 20mm length were caught for the first time. The growth curve plotted from the mode of a normal curve fitted by eye to the length data (Fig. 15), showed that this small class of fish grew from the length of 20mm in December to 40 mm in April. Little growth took place in the colder months following April. Growth resumed in October and the maximum modal length of 60mm was reached between January and March. The numbers of the larger fish decreased rapidly after February and significant numbers of this group were not caught after May. This indicates that the life cycle of this species occupies no more than 16 months and is probably of 12 months duration.

The size range of the smallest group of fish in January, February and March was almost twice that of the range observed in the larger fish. The range in size of the group of small fish decreased in the months after March from 40 to 20 mm approximately, which corresponded to the range observed in the adults. The distribution of each size class remained normal at most times of the year, although the distribution of lengths of the smallest fish was slightly skewed during January and March. This feature was not evident, however, during any other month.

The G.S.I. of A. mugiloides (Fig.16) reached peak values between October and February. The frequency histogram of the G.S.I's of the female fish (Fig. 17) shows that the G.S.I. increased rapidly from October until December. This histogram also indicates

that no spent gonads were detected in the population until February, three months after the first of the juvenile fish were caught. No G.S.I's over 6.0 were present in March, whereas in the previous months the majority of G.S.I's exceeded this value. It is thus reasonable to conclude that the spawning period is protracted and that it begins in November and ends in February. The gonads of the smallest fish were very small until February.

The mean number of eggs in the 15 gonads examined was 67 with a range of 30 to 86. Although two size groups of eggs were present in the gonads, only the largest group were counted. The presence of two distinct size classes of eggs was also observed in the unidentified species. It seems possible that the smaller size class of egg matures and are spawned after the larger eggs have been spawned. The spawning of at least two groups of eggs could explain the protracted nature of the breeding period in these two species. The mean egg diameter of 90 of the larger eggs in A. mugiloides was 0.88 mm. The eggs all had filaments attached to their surface, which was also observed in the unidentified species and suggests that the eggs are demersal. This has been observed by a number of other workers (Hildebrand, 1922; Hildebrand and Schroeder, 1927; Bayliff, 1950; Davis and Louder, 1969; Llewellyn, 1971; Hubbs, 1976).

No significant differences in length were observed between the sexes ($P > 0.05$). The ratio of males to females caught never departed significantly from 1:1.

Distribution

Within the Swan-Avon estuary, A. mugiloides is most abundant in the upper region of the middle estuary (Fig. 18).

From September until April, the number of this species caught at Perth Water and Mt Henry rose. Between December and March, large numbers were also caught at Joel Terrace and Shelley Basin. Only two fish were recorded from the regular sampling sites above the latter two sites.

As the salinity in the estuary declined during the winter, the number of A. mugiloides caught at Joel Terrace and Shelley Basin decreased. For example, at Joel Terrace the numbers declined from 290 in February to five in May and to zero in the following months. After April and May, the numbers caught at Perth Water and Mt Henry decreased, although some A. mugiloides were caught at these sites at all times of the year. There was no evidence from the regular sampling that the drop in numbers at these sites was caused by movement to other areas. The large drop in numbers at Perth Water during the summer and between October and January was probably due to the large numbers of N. vlaminghi caught at this site during these months. A. mugiloides was not caught consistently at sites lower in the estuary than Perth Water and Mt Henry, although small numbers were caught at Stirling Bridge and C.S.R. between September and November. The numbers caught at Alfred Cove rose rapidly after November, until January when over 1000 were caught. Few fish were caught after February.

This distribution indicates recruitment from a marine population as the salinity of the middle estuary rises. The small numbers caught at Stirling Bridge and C.S.R. and the build-up of numbers at Alfred Cove during this period suggests that fish from the marine environment move through the lower estuary and into the middle estuary during September, October and November.

Feeding

Copepods made up 20% of the diet of A. mugiloides during March and April (Fig.19), with flying insects, polychaetes and amphipods making up 18, 14, and 16% respectively. The flying insects and copepods were most common in the diet of the fish caught at Perth Water and Mt. Henry, while polychaetes and amphipods were most common at Joel Terrace and Alfred Cove.

During May and June copepods (51%) and diatoms (46%) were eaten almost exclusively by the fish at Joel Terrace and Mt Henry. The fish caught at Perth Water had also eaten small amounts of amphipods and flying insects (Fig. 20).

During July and August, 63% of the diet consisted of copepods with the other major item in the diet being flying insects (15%). The remainder of the diet was made up of fish eggs, detritus, algae and diatoms. Fish were only caught from Perth Water and Mt Henry during this period and little difference in diet existed between sites (Fig. 21).

Copepods made up 75% of the diet during September and October (Fig. 22), with flying insects and amphipods being the other major items eaten. The fish from higher in the estuary ate a higher proportion of flying insects, whereas the fish from Alfred Cove, C.S.R. and Stirling Bridge ate a greater proportion of copepods.

FIGURE 14.

Length-frequency histograms for *A. mugiloides* from all sites.

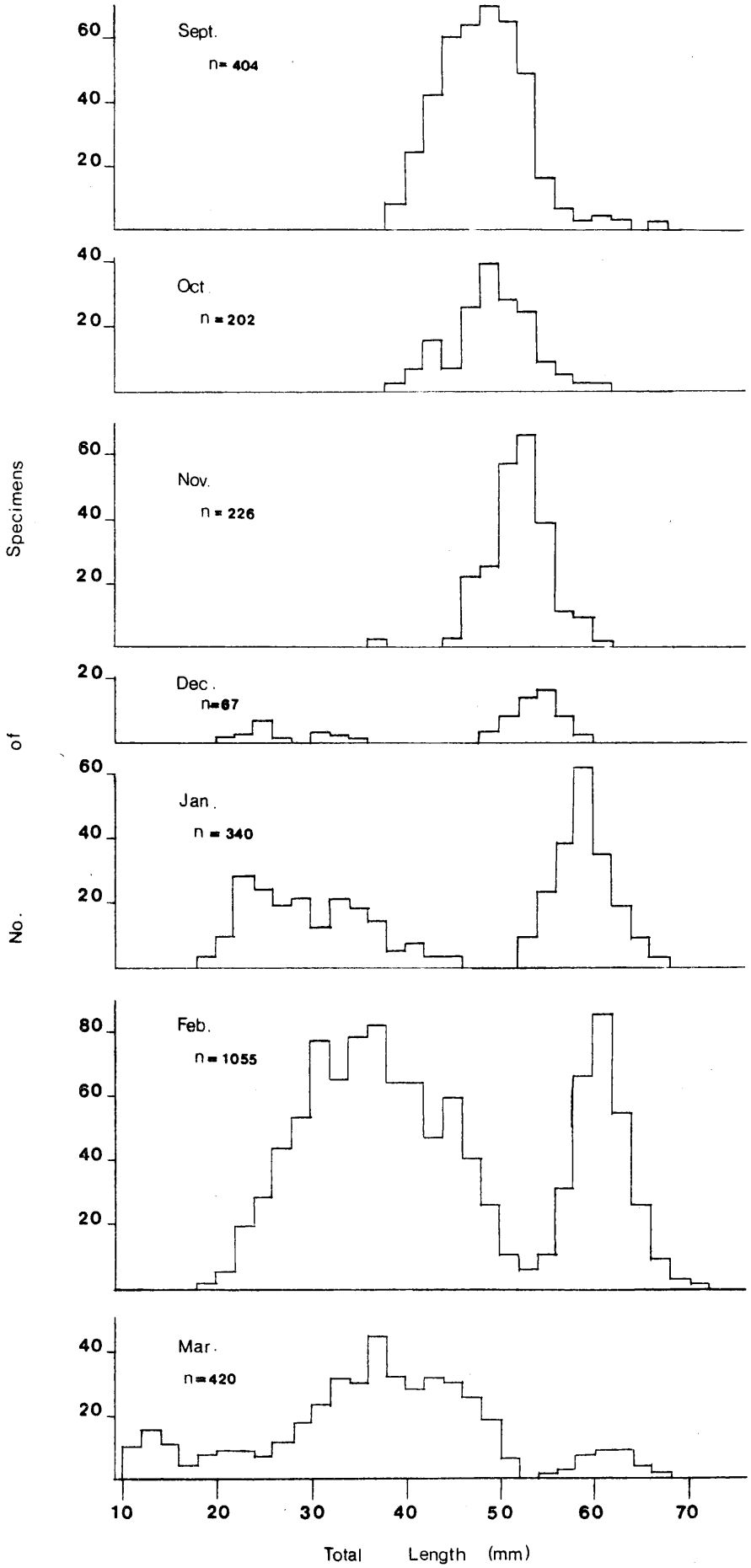

Sept.
n= 404
Oct.
n = 202
Nov.
n = 226
Dec.
n=67
Jan.
n = 340
Feb.
n = 1055
Mar.
n=420
No. of Specimens
Total Length (mm)
10
20
30
40
50
60
70

FIGURE 14 (Contd)

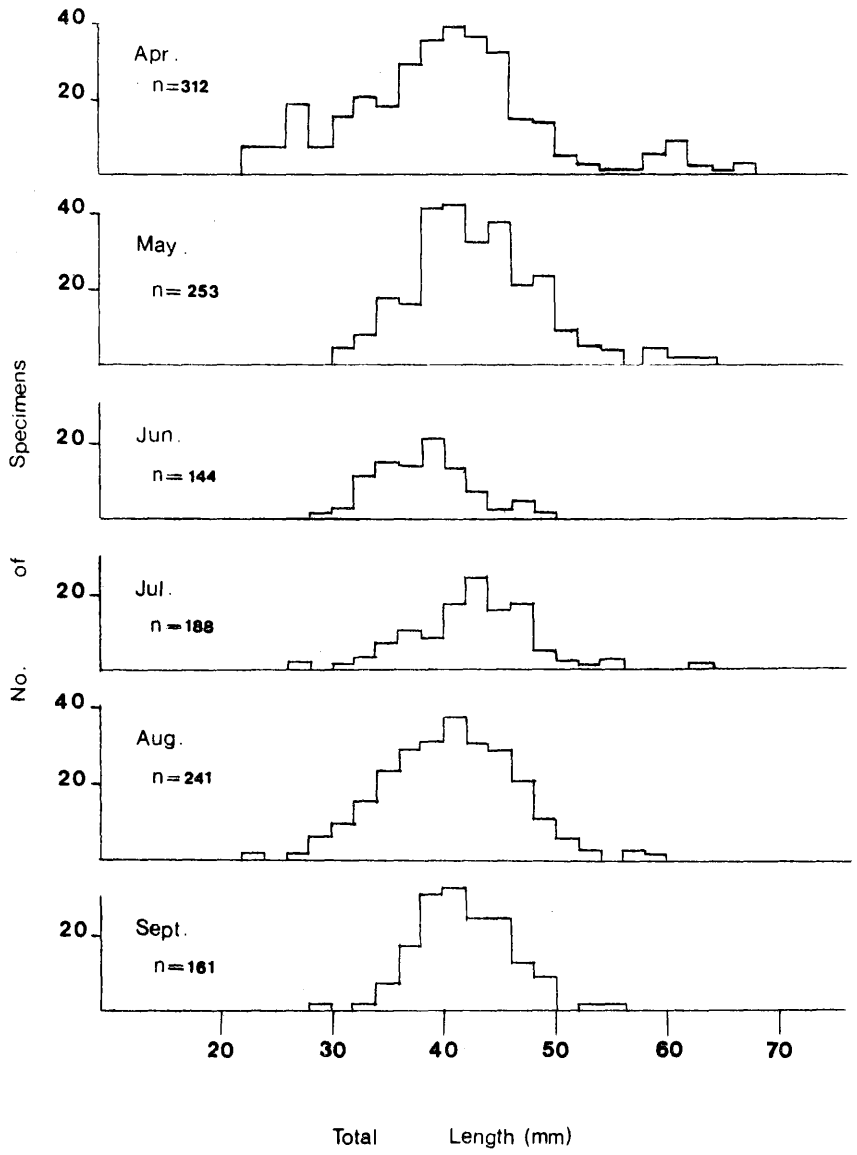

40
20
Apr.
n=312
40
20
May.
n=253
20
Jun.
n=144
20
Jul.
n=188
40
20
Aug.
n=241
20
Sept.
n=161
No. of Specimens
20
30
40
50
60
70
Total Length (mm)

FIGURE 15.

Growth curve for *A. mugiloides* .

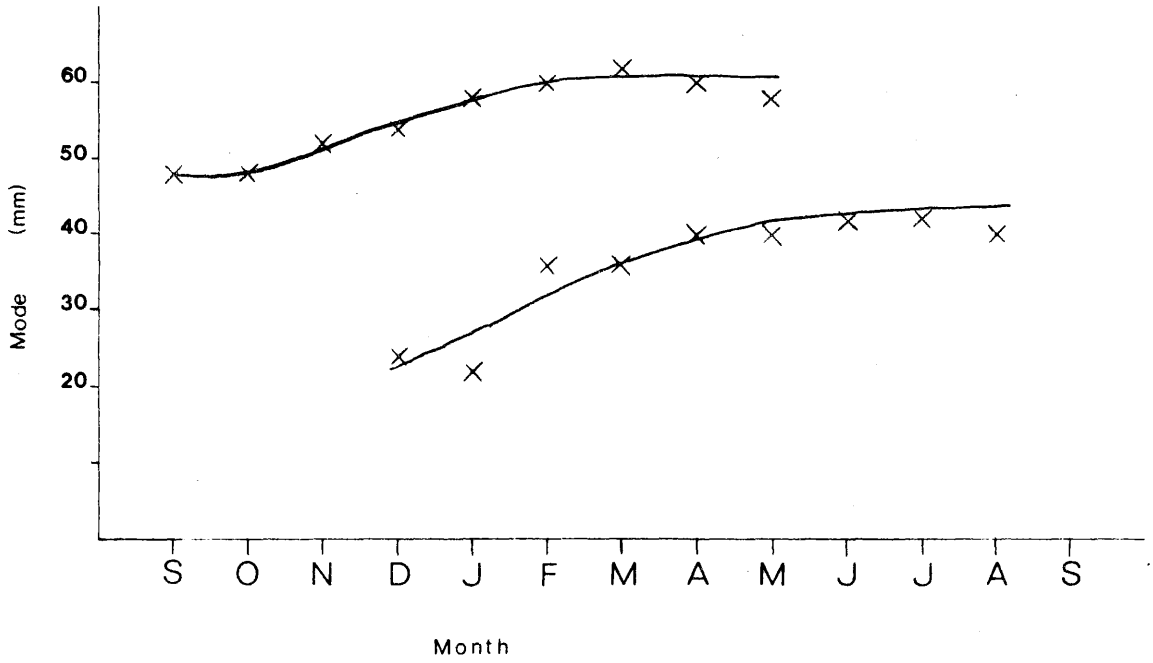

60
50
40
30
20
Mode (mm)
S
O
N
D
J
F
M
A
M
J
J
A
S
Month

FIGURE 16.

The G.S.I. of *A. mugiloides* for each month, ± 95% confidence intervals indicated by vertical lines. Unbroken line indicates females and the males are indicated by the broken line.

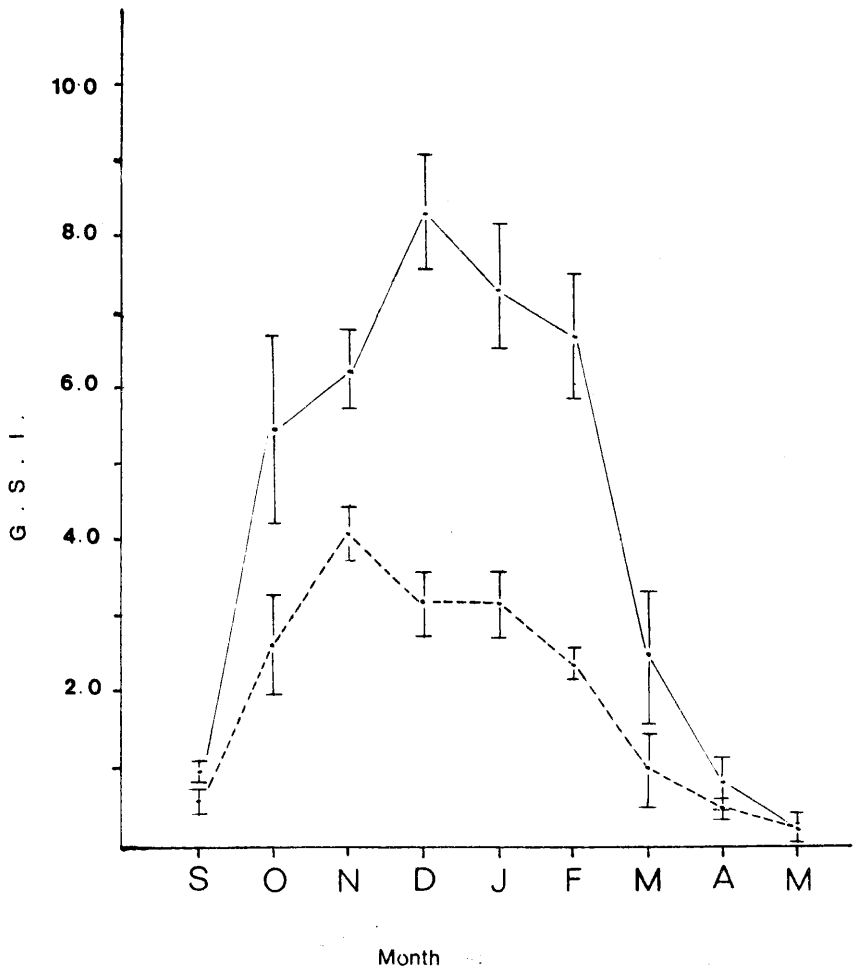

10·0
8.0
6.0
4.0
2.0
G . S . I .
S
O
N
D
J
F
M
A
M
Month

FIGURE 17

Frequency histograms for the G.S.I's of the female *A. mugiloides*.

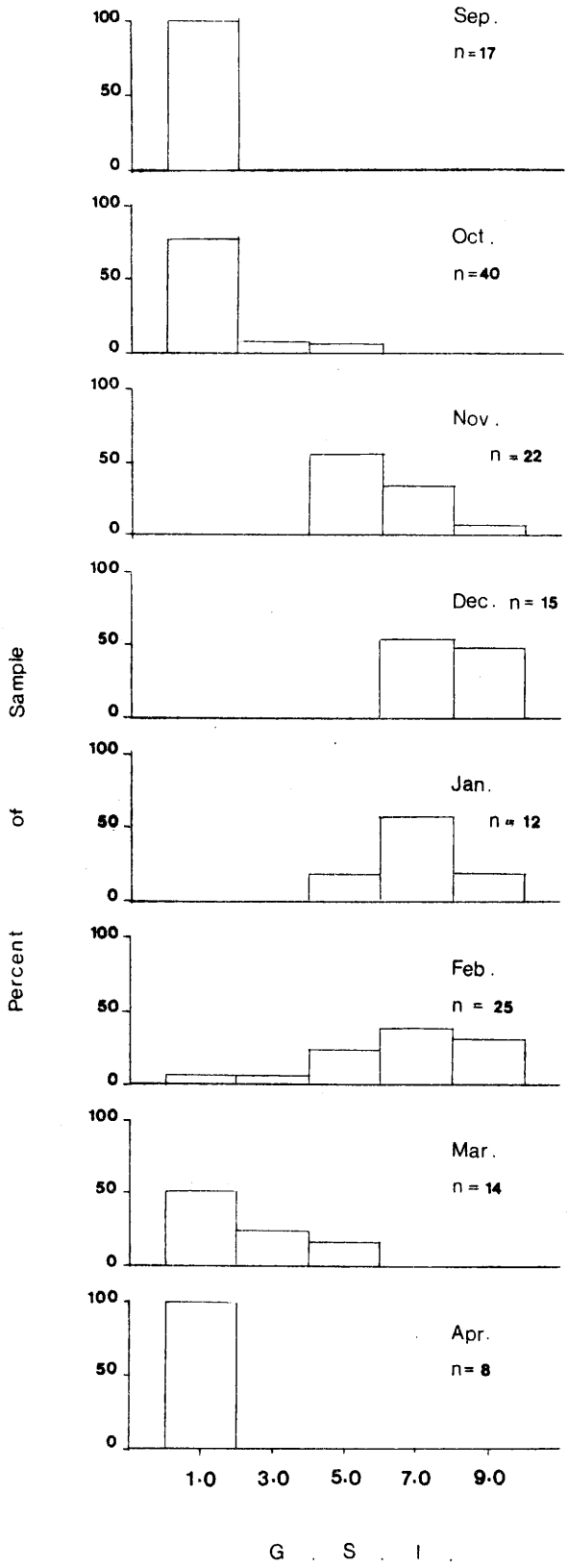

Percent of Sample
Sep.
n=17
Oct.
n=40
Nov.
n = 22
Dec. n= 15
Jan.
n = 12
Feb.
n = 25
Mar.
n = 14
Apr.
n= 8
100
50
0
1·0
3·0
5·0
7·0
9·0
G . S . I .

FIGURE 18.

Numbers of *A. mugiloides* caught in each sample at Joel Terrace, Perth Water, Alfred Cove, C.S.R., Stirling Bridge, Shelley Basin and Kent Street together with data on salinity (broken line) and temperature (unbroken line).

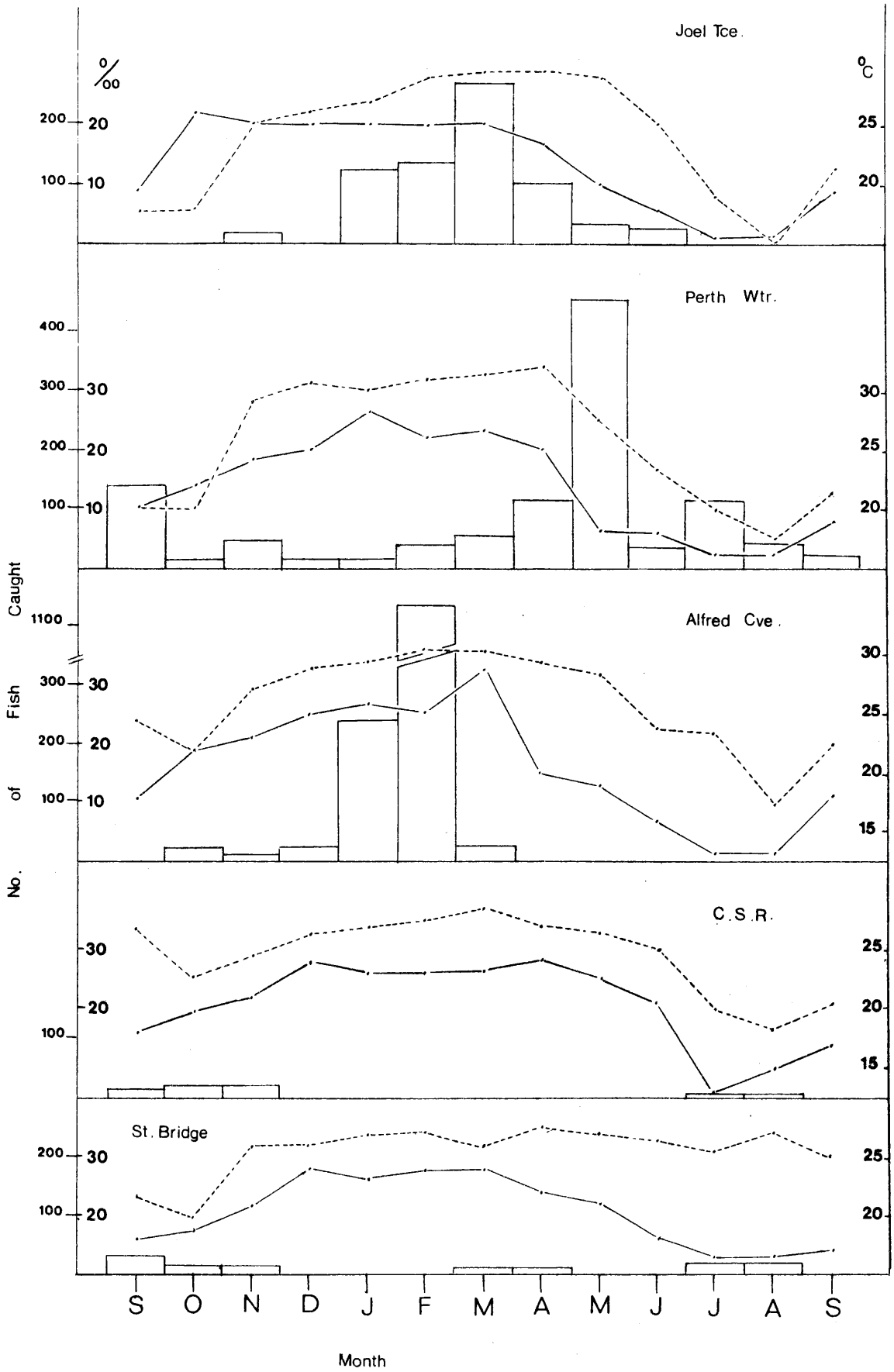

Joel Tce.
‰
°C
200
20
100
10
25
20
Perth Wtr.
400
300
30
200
20
100
10
30
25
20
Alfred Cve.
1100
300
30
200
20
100
10
30
25
20
15
C.S.R.
30
20
100
25
20
15
St. Bridge
200
30
100
20
25
20
No. of Fish Caught
S O N D J F M A M J J A S
Month

FIGURE 18 (Contd)

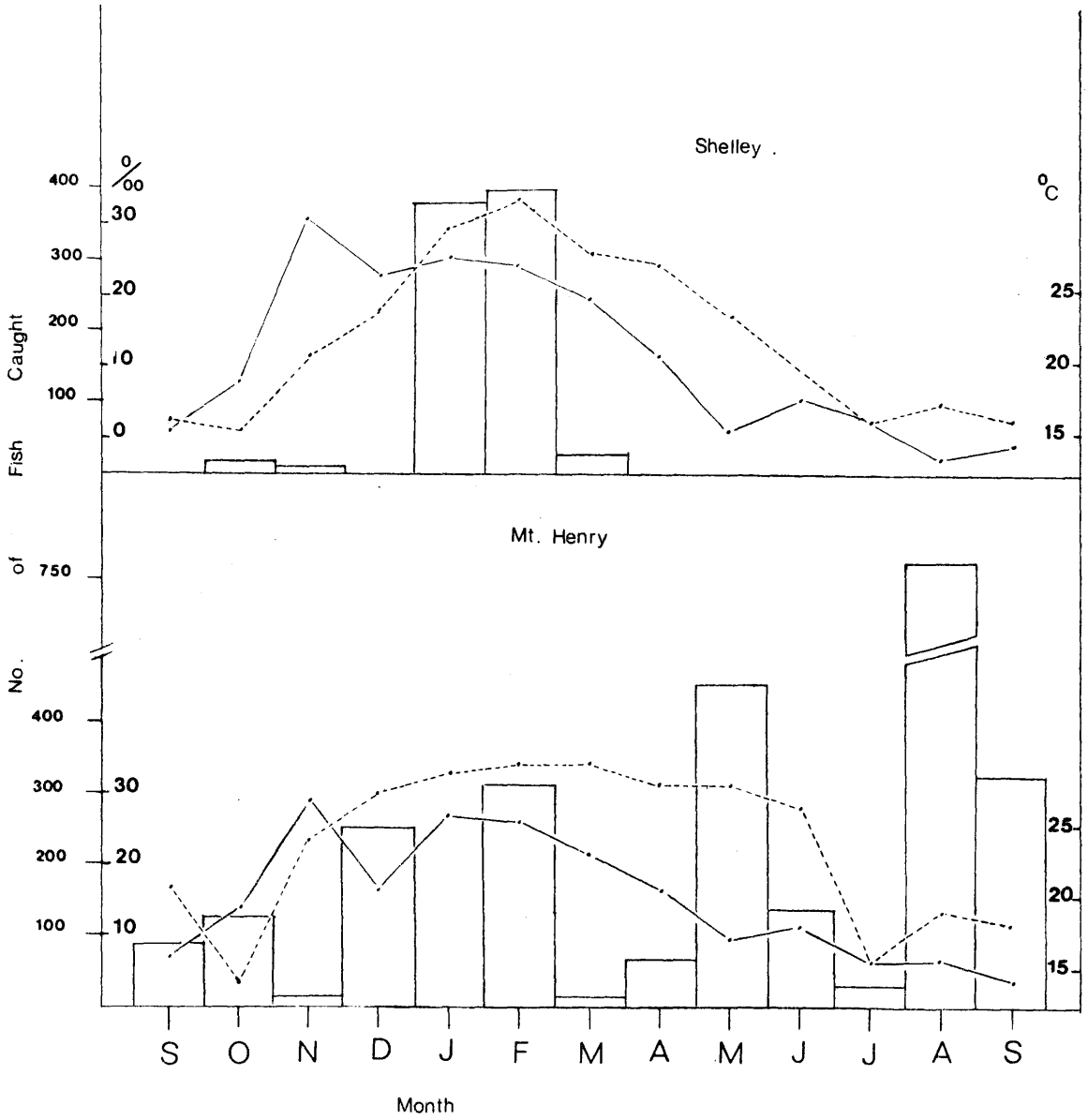
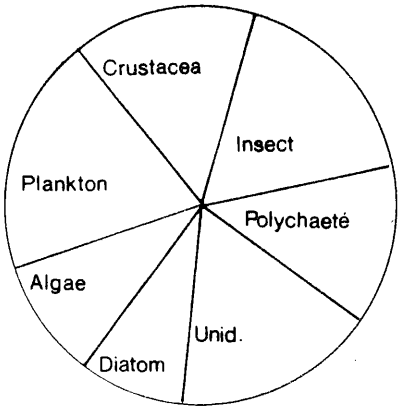
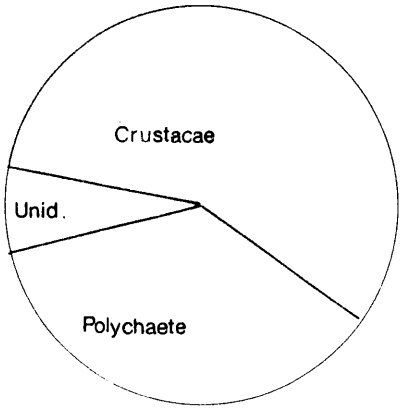

Shelley .
Mt. Henry
No. of Fish Caught
0/00
°C
400
300
200
100
30
20
10
0
25
20
15
750
S O N D J F M A M J J A S
Month

FIGURE 19.

Composition of the stomach contents of *A. mugiloides* at Alfred Cove, Perth Water, Joel Terrace and Mt. Henry during March and April.

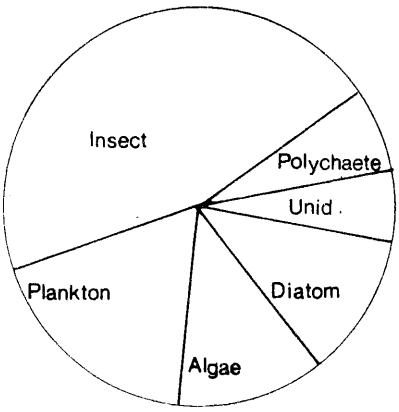


All Sites
n= 58

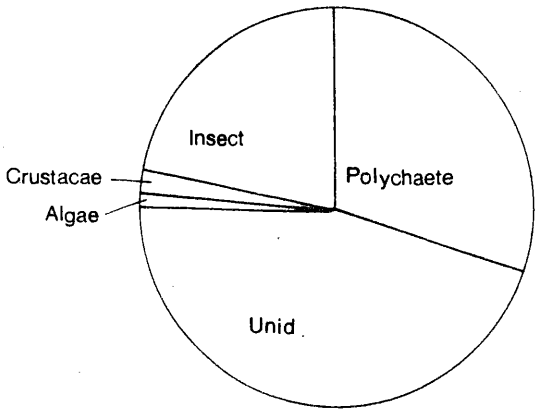


Alfred Cve.
n= 10

Perth Wtr. n=20



Joel Tce. n = 10



Mt Henry n=18

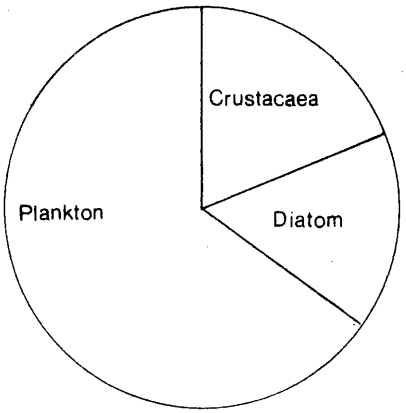
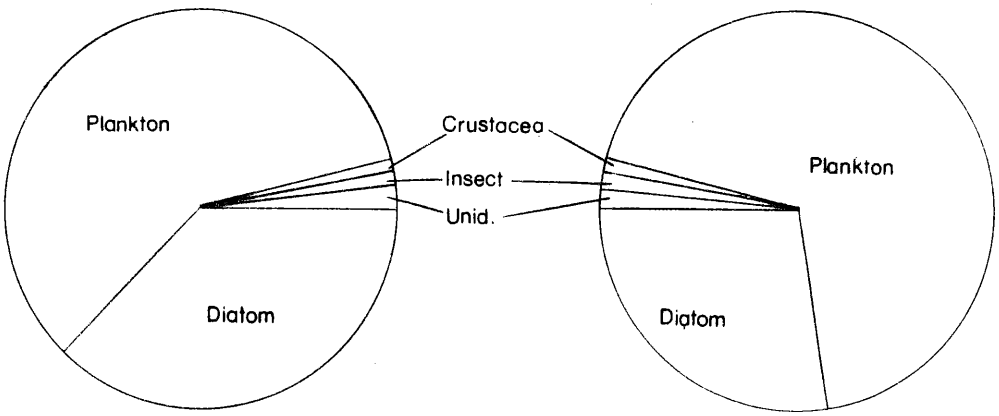


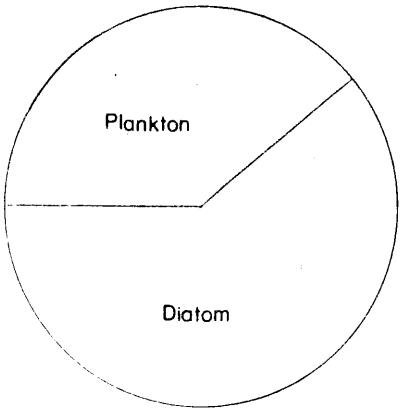
FIGURE 20.

Composition of the stomach contents of *A. mugiloides* at Perth Water, Joel Terrace and Mt. Henry during May and June.

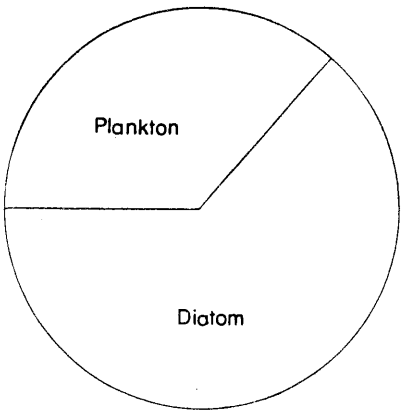


All Sites
n = 50

Perth Wtr.
n = 20



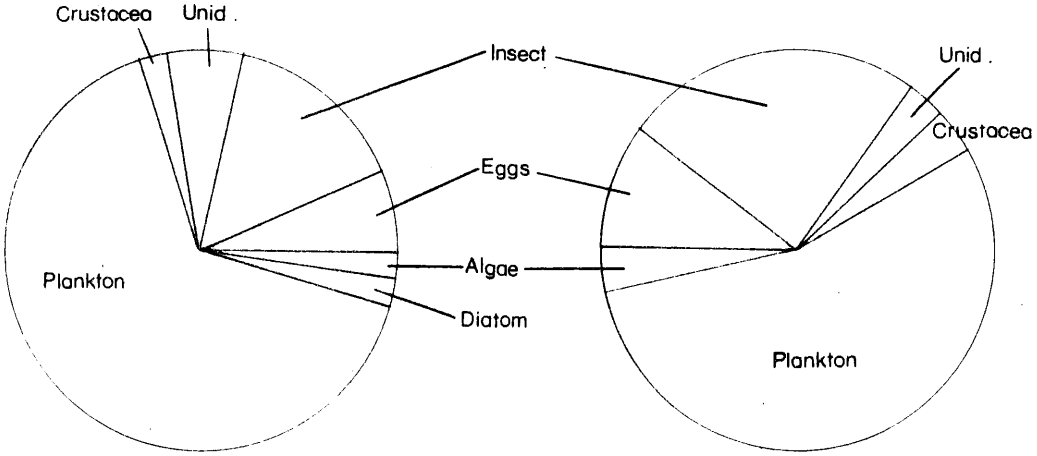
Joel Tce.
n = 10



Mt. Henry
n = 20

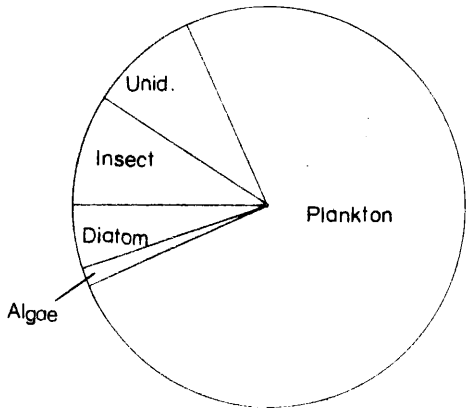
FIGURE 21.

Composition of the stomach contents of *A. mugiloides* at Perth Water and Mt. Henry during July and August.



All Sites
n=50

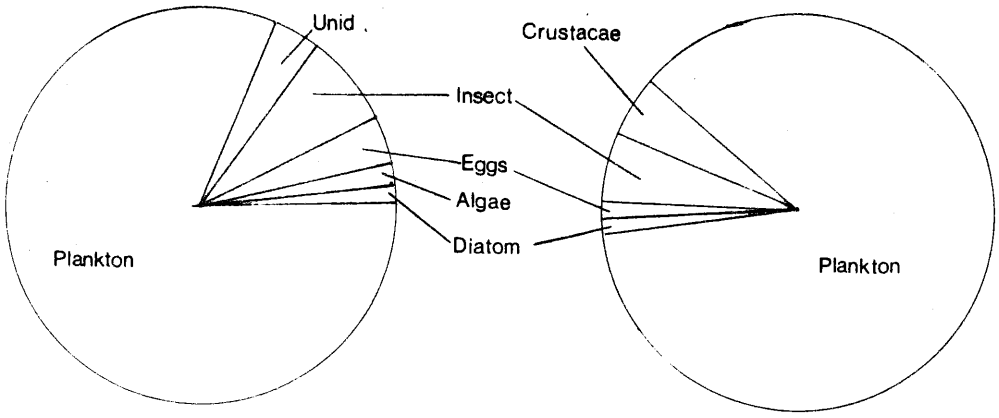
Perth Wtr.
n=30



Mt . Henry
n=20

FIGURE 22

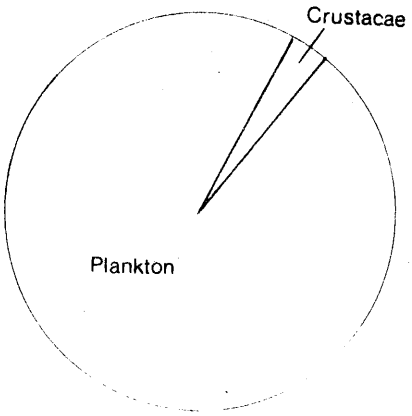
Composition of the stomach contents of *A. mugiloides* at Stirling Bridge, C.S.R., Alfred Cove, Perth Water and Mt. Henry during September and October.



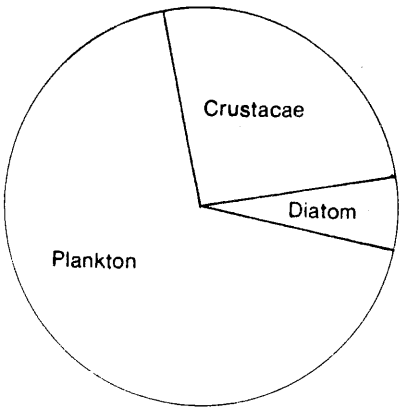
All Sites

St . Bridge

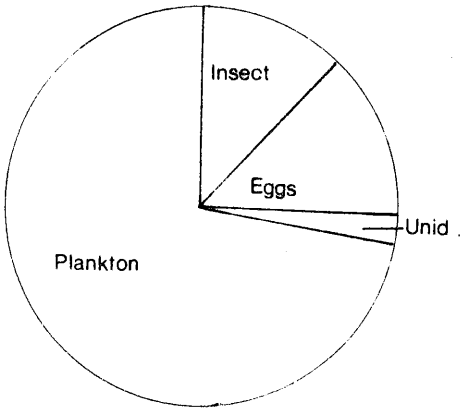
Alfred Cve .



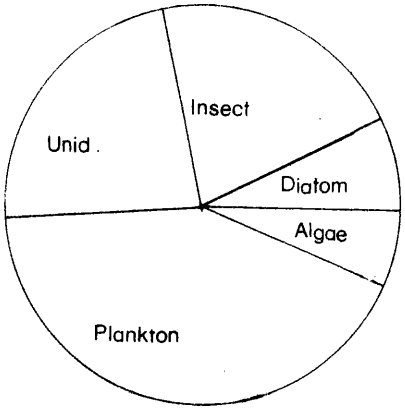
C.S.R.



Perth Wtr.



Mt . Henry



3.4. *P. ogilbyi*

Life cycle

P. ogilbyi was only studied during the period between February and September. There was evidence for the presence of at least two and possibly three year classes in the length-frequency data for March, April, August and September (Fig.23). The largest size class, which when caught was always distinct, increased in length from 118 mm in March to 125 mm in September. The two proposed smaller size classes were not always distinct, and in May, June and July, they formed a "single" skewed group. The smallest length class, with a modal length of 48 mm in February, increased in length to approximately 70 mm by September. The second size group increased from approximately 75 mm in March to 100 mm in September (Fig.24).

The G.S.I. for this species shows that the gonads declined in size rapidly between January and March and remained small between March and August. The G.S.I. values for September were slightly higher than in the preceding months, indicating that the gonads were beginning to develop. The G.S.I. graphs, which were obtained for the largest size class of fish (Fig.25), suggest that this size group spawned between October and December of 1978, before this study began and would probably spawn again during the summer months following the conclusion of this study. The gonads of the fish 90-110 mm in length in September were just beginning to mature and become distinguishable as either testis or ovary. However, the gonads of the fish in the smallest class were undetectable with a dissecting microscope in September.

No significant differences were observed between the length of males and that of the females during any period of the year ($P>0.05$), while the ratio of males to females never varied significantly from 1:1 in any samples.

Distribution

During the summer, P. ogilbyi was most common in the upper region of the middle estuary, being caught in large numbers at Perth Water and Mt Henry. It was also caught at Joel Terrace during April. However, when the salinity of the middle estuary fell below the summer levels, few of this species were caught from the latter sites. During the months between May and October, large numbers of P. ogilbyi were caught from the sites in the lower estuary, namely C.S.R. and Stirling Bridge. This suggests that P. ogilbyi uses the estuary as an extension of its marine habitat and is restricted in its distribution within the estuary by the availability of these conditions (Fig. 26).

Feeding

During March and April P. ogilbyi ate polychaetes (65%) and flying insects (26%) almost exclusively although fish eggs, copepods and amphipods were ingested. At Stirling Bridge, polychaetes were the only item found in the diet of this species, while at C.S.R. amphipods and fish eggs made up 3% of the diet. At Mt Henry, polychaetes were not eaten

but flying insects 79%, copepods 18%, amphipods 2% and fish eggs 1% made up the diet (Fig. 27).

During May and June 25% of the diet was non-planktonic crustacea, mainly Apseudes sp. and marine amphipods, 16% of the diet was polychaetes and 42% of the diet was copepods. The copepods were eaten throughout the estuary. The non-planktonic crustacea were eaten mainly by the fish in the lower estuary and polychaetes, flying insects and diatoms were eaten predominantly in the middle estuary (Fig. 28).

In July and August non-planktonic crustacea, mainly Caprella sp. and Apseudes sp. made up 60% of the diet, polychaetes made up 26% and copepods made up 9%. Polychaetes were again eaten most commonly in the middle estuary while copepods and other crustacea were more important in the diet of the fish from the lower estuary (Fig. 29).

In September, fish were only caught from C.S.R. and Stirling Bridge, Carophium minor, Apseudes sp. and Caprella sp. made up 59% of the diet, polychaetes eaten at both sites made up 15% and copepods eaten only at C.S.R. made up 15% of the diet. Flying insects eaten at both sites constituted 8% of the diet (Fig. 30).

FIGURE 23.

Length-frequency histograms for *P. ogilbyi* from all sites.

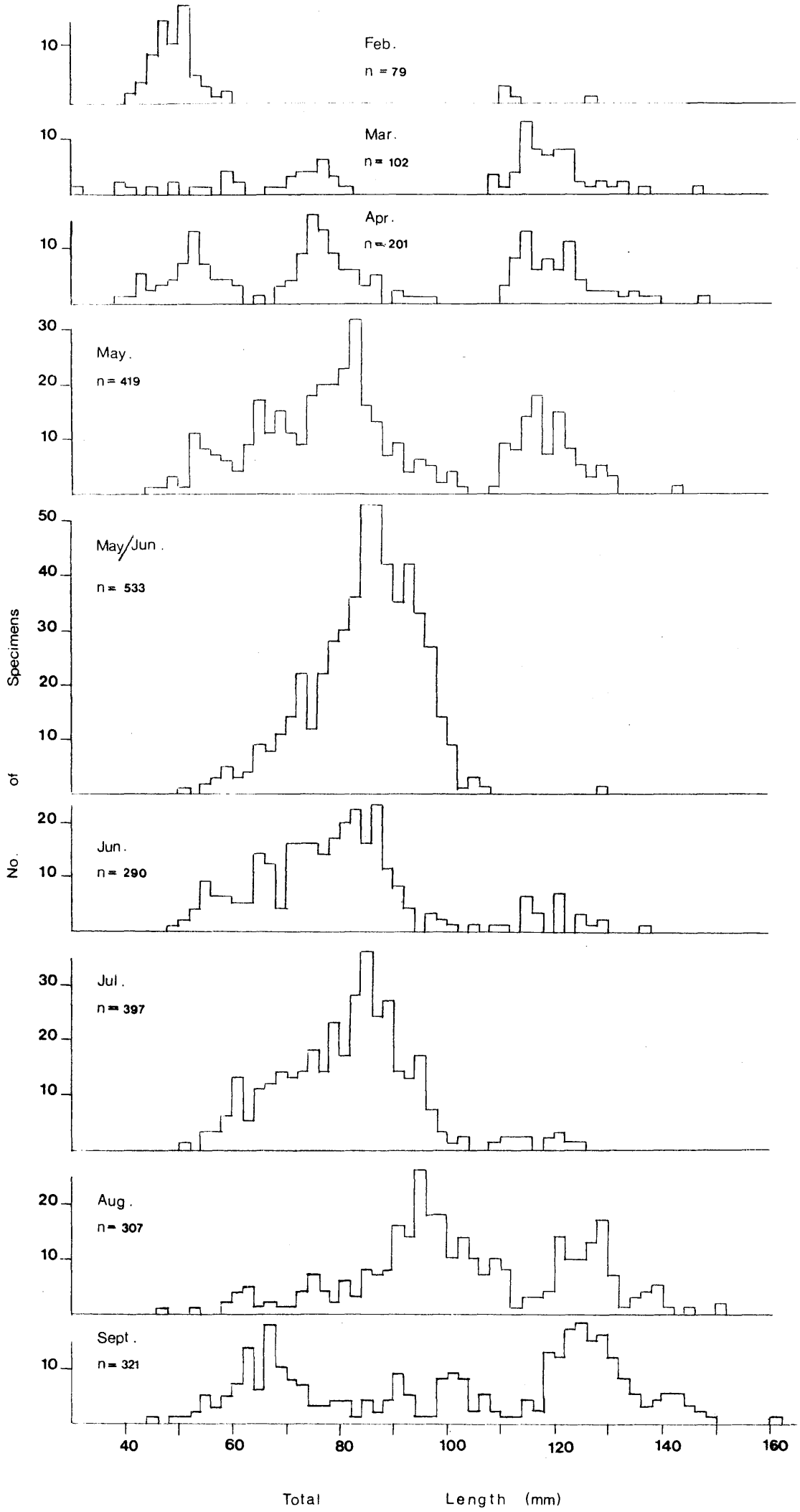

Feb.
n = 79
Mar.
n = 102
Apr.
n = 201
May.
n = 419
May/Jun.
n = 533
Jun.
n = 290
Jul.
n = 397
Aug.
n = 307
Sept.
n = 321
No. of Specimens
Total Length (mm)
40
60
80
100
120
140
160

FIGURE 24.

Growth curve for *P. ogilbyi*.

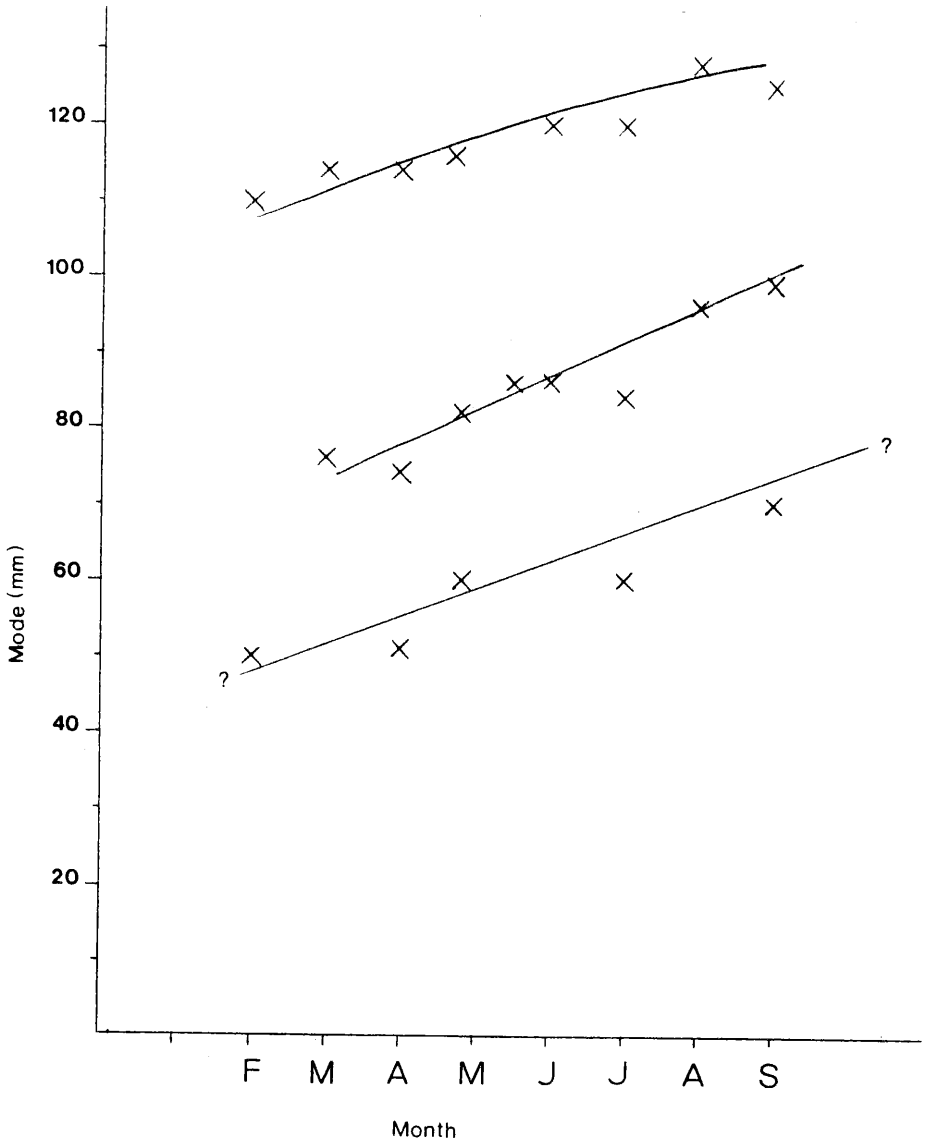

120
100
80
60
40
20
Mode (mm)
?
?
F
M
A
M
J
J
A
S
Month

FIGURE 25.

The G.S.I. of *P. ogilbyi* for each month, with 95% confidence intervals indicated by the vertical lines. Unbroken line indicate females and the broken line indicates males.

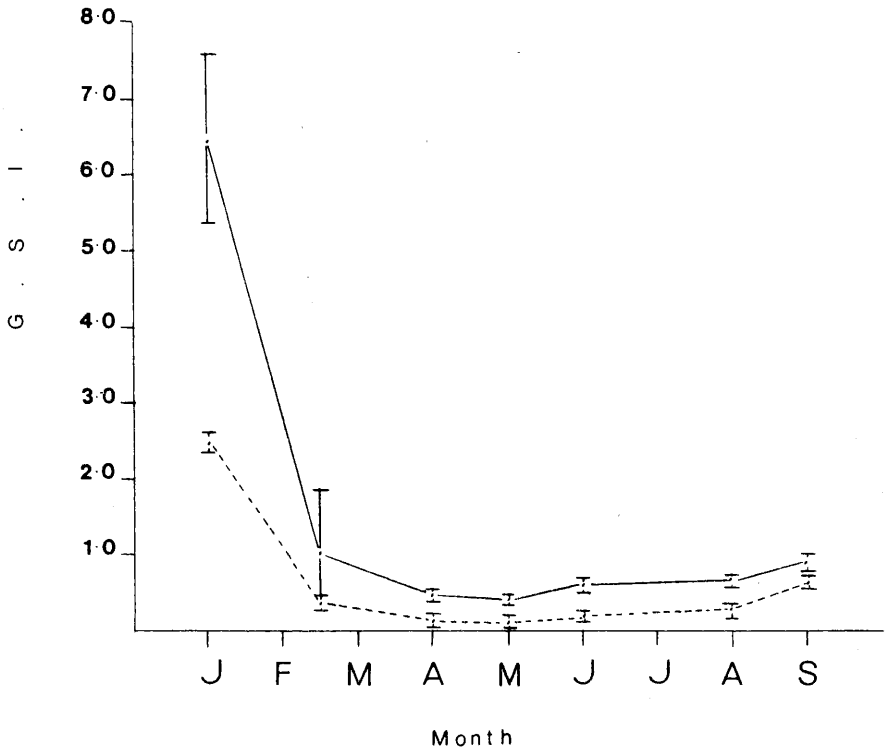

8·0
7·0
6·0
5·0
4·0
3·0
2·0
1·0
G . S . I .
J
F
M
A
M
J
J
A
S
Month

FIGURE 26.

Numbers of *P. ogilbyi* caught in each sample at Joel Terrace, Mt. Henry, Perth Water, C.S.R. and Stirling Bridge, together with data on salinity (broken line) and temperature (unbroken line).

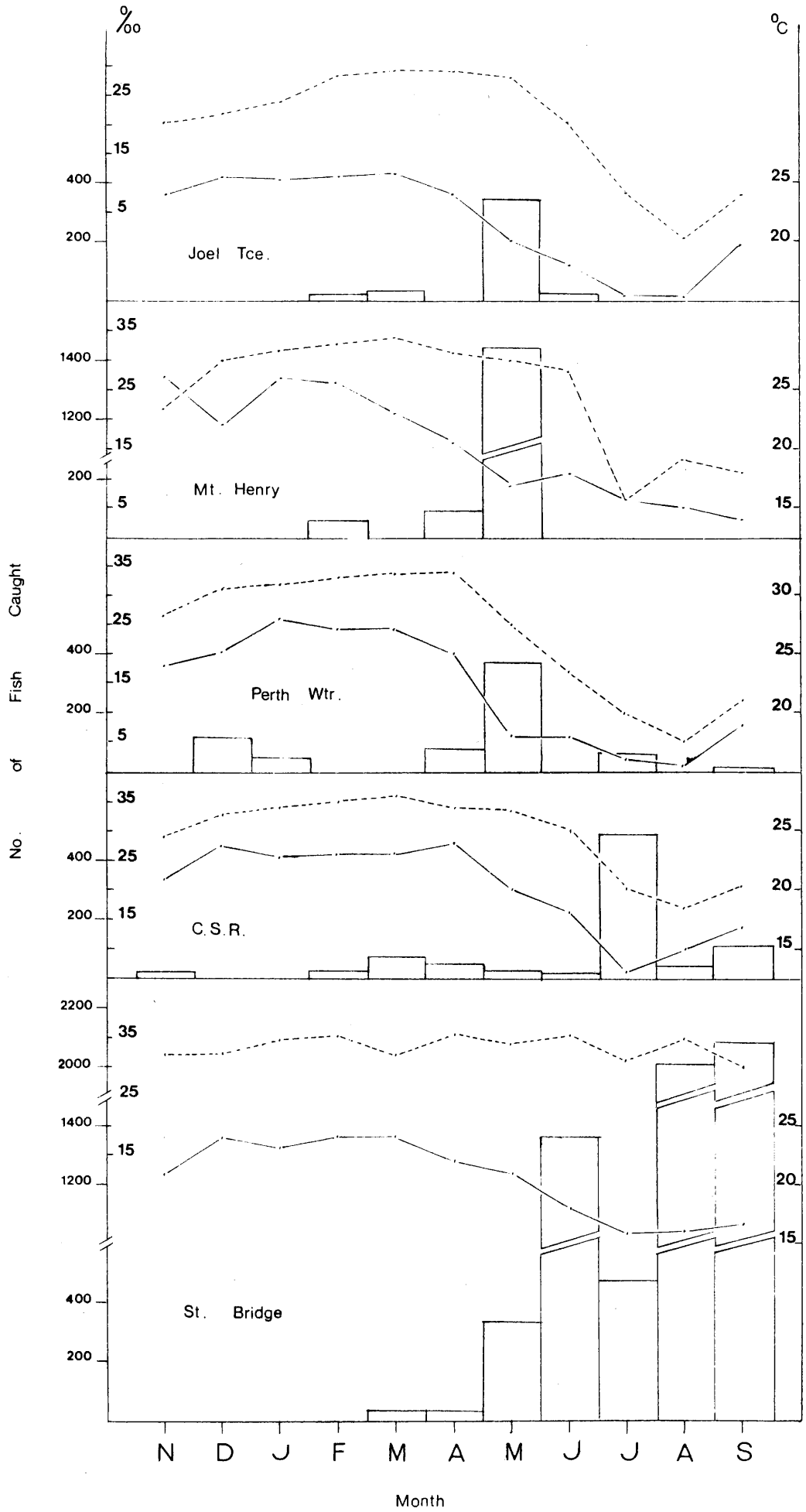
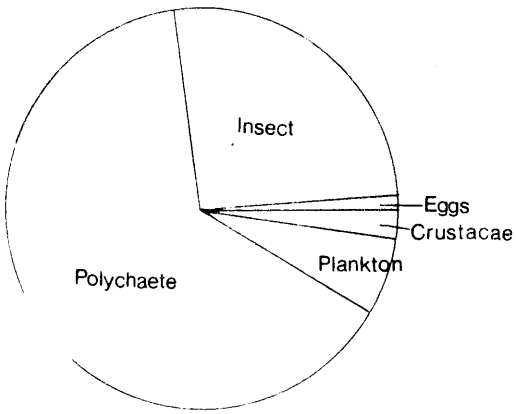
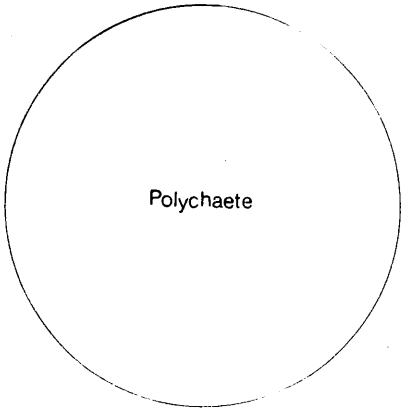

‰
°C
Joel Tce.
Mt. Henry
Perth Wtr.
C.S.R.
St. Bridge
No. of Fish Caught
N D J F M A M J J A S
Month

FIGURE 27.

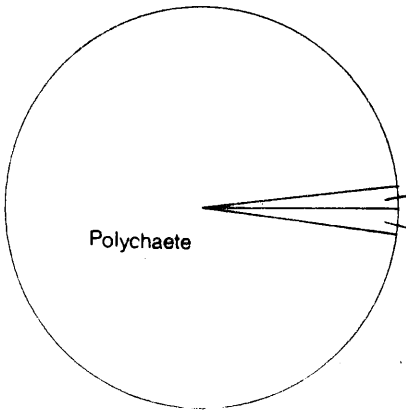
Composition of the stomach contents of *P. ogilbyi* at Stirling Bridge, C.S.R. and Mt. Henry during March and April.

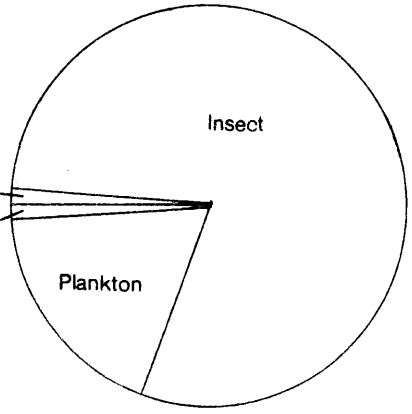


All Sites
n = 30



St. Bridge
n = 10





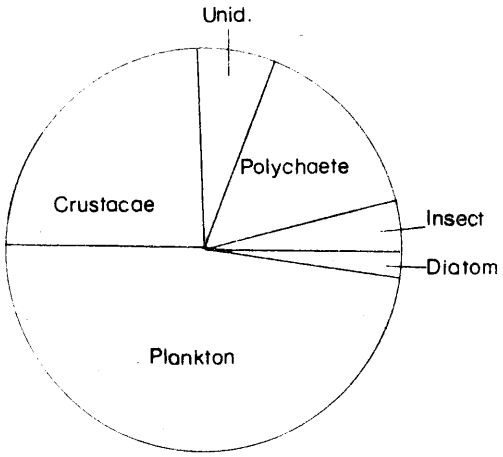
Eggs
Crustacea

C.S.R.
n = 10

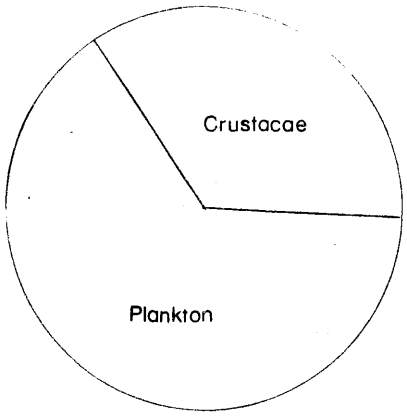
Mt. Henry
n = 10

FIGURE 28.

Composition of the stomach contents of *P. ogilbyi* at Stirling Bridge, C.S.R., Perth Water, Joel Terrace and Mt. Henry during May and June.

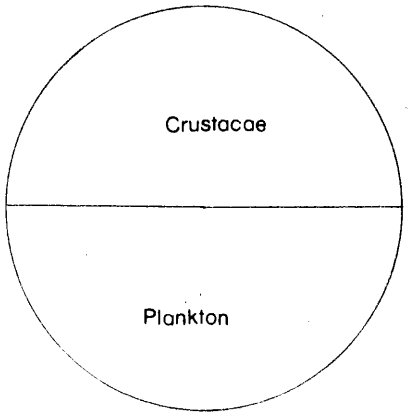


All Sites
n=55

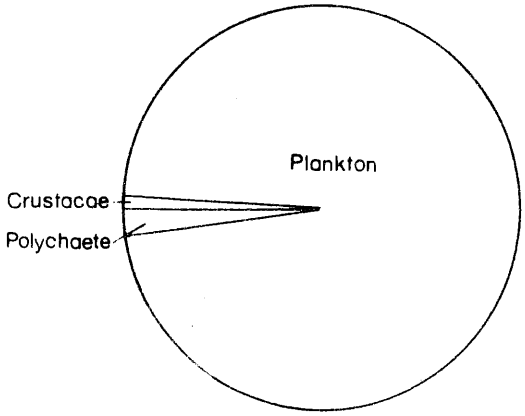


St. Bridge
n=15

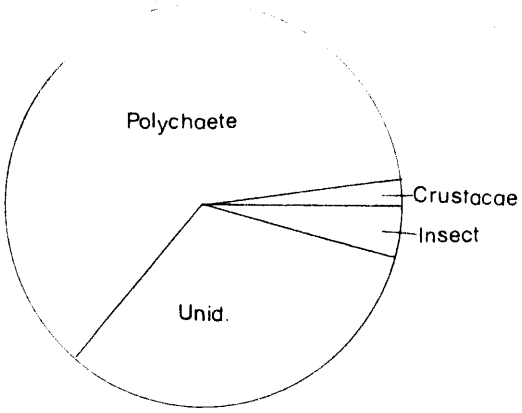
C.S.R.
n=10



Perth Wtr.
n=10



Joel Tce.
n=10



Mt. Henry
n=10

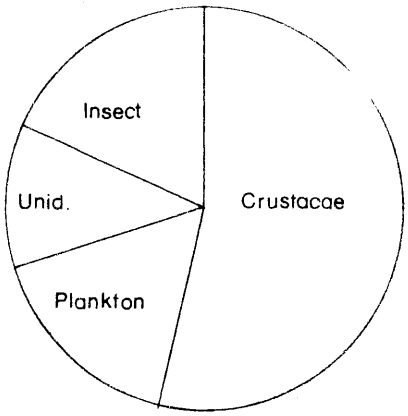
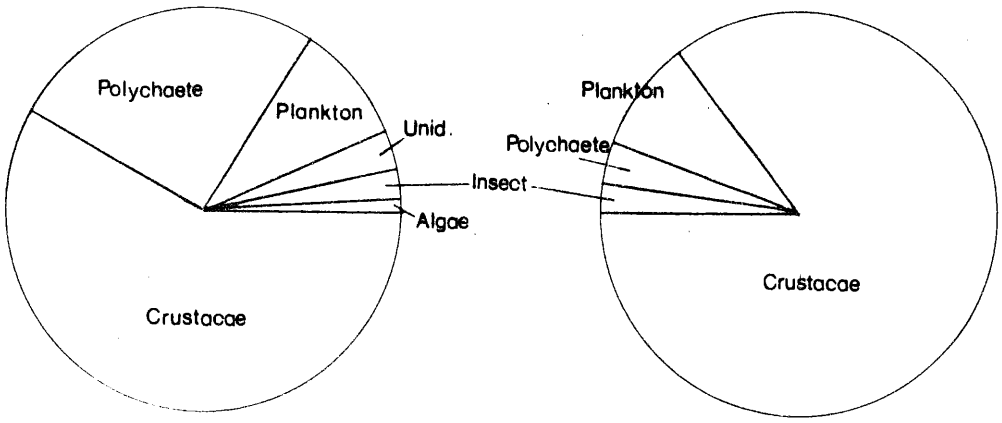


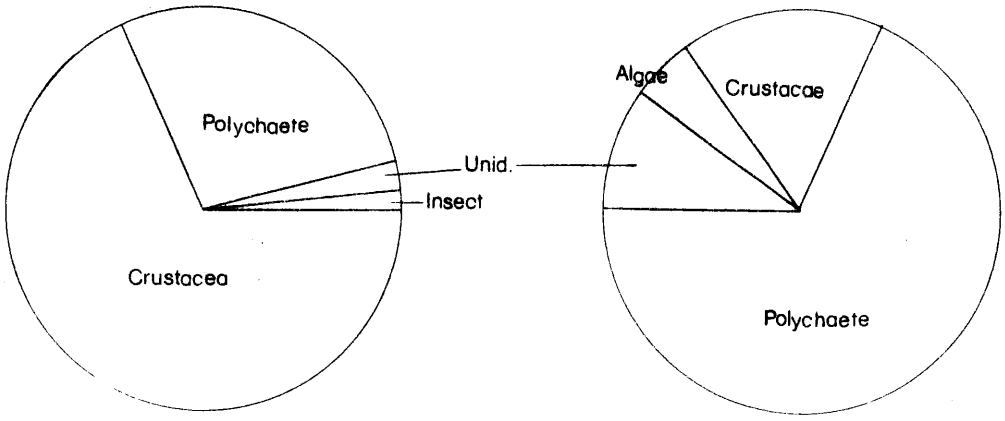
FIGURE 29.

Composition of the stomach contents of *P. ogilbyi* at Stirling Bridge, C.S.R. and Perth Water during July and August.



All Sites
n=50

St. Bridge
n= 20

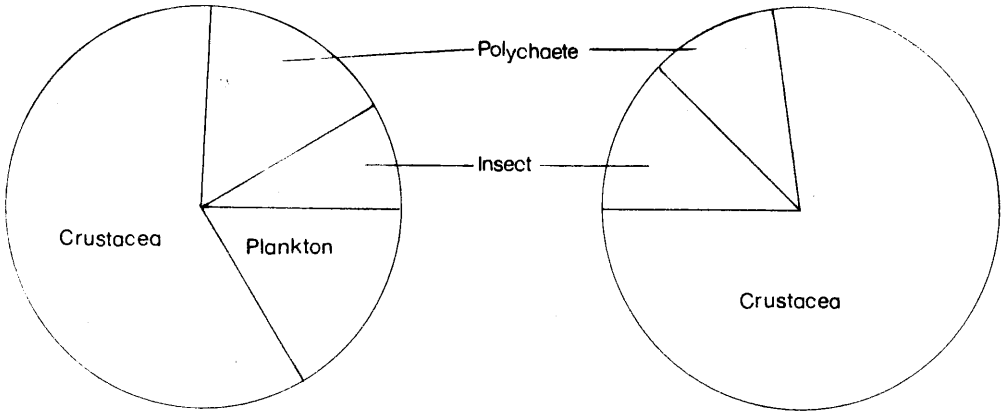


C.S.R.
n=20

Perth Wtr.
n=10

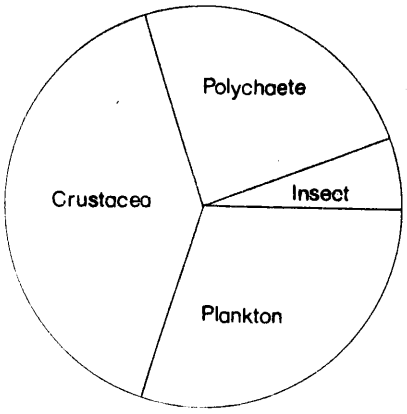
FIGURE 30.

Composition of the stomach contents of *P. ogilbyi* at Stirling Bridge and C.S.R. during September.



All Sites
n = 20

St . Bridge
n = 10



C.S.R.
n = 10

3.5. A. presbyteroides

LIFE CYCLE

Since this species was not caught during December, February or March, the length-frequency histograms (Fig. 31) and the growth curve (Fig. 32) do not provide a complete sequence for analysing seasonal trends. The largest size group of fish had a modal length of 65-70 mm during September, October and November of 1978 and were not caught in the following year.

Significant numbers of small fish (20-25 mm) were caught on three completely different occasions, November, April and June. The initial pattern of growth of the small fish caught in November cannot be followed because of the small numbers of this species caught during the ensuing months. However, the size group with a mode of 55 mm in the April length-frequency histogram are probably the result of the growth of this November group. The April and June histograms also show the continued presence of very small fish (25 mm). The largest group of fish during July, August and September showed little growth. However, the small fish during this period continued to grow so that by September a separate group of small fish was not apparent. Instead a single skewed size group was observed.

The G.S.I. for A. presbyteroides showed that a peak was reached in September, October and November and that the G.S.I. dropped rapidly after November. The G.S.I. also indicates that the younger year class of fish had very high G.S.I. values during April and May (Fig. 33). The frequency histogram for the G.S.I's of the females indicates that these high values during April and May are due to a small proportion of this young

class having extremely well developed gonads (Fig. 34). It appears probable that a small proportion of the population breeds during this period as the G.S.I's of these fish are as high as those of the fish during the September to November breeding period. The length of these fish with well developed gonads indicate that they are only five to six months old and not a remnant of the adults from the previous year. The histogram for the G.S.I's also indicates that the major proportion of the population breeds between September and November.

The mean number of the largest size group of eggs in 16 gonads was 59.1, with a range of 27 to 87. The mean diameter of 96 of these large eggs was 1.5 mm. As has been observed for A. mugiloides and the unidentified species a distinct smaller size class of eggs were also present suggesting the possibility that these may develop and be spawned after the largest size class of eggs has been spawned. All eggs had filaments attached to their surface, this has also been observed in A. mugiloides, and the unidentified species and suggests that they are demersal.

In most of the months, significant differences in length existed between males and females ($P<0.01$) (Table 2). However this was not as great as the differences observed between the two sexes of the unidentified species.

Distribution

A. presbyteroides was caught only in the lower estuary. The largest samples were taken at Stirling Bridge between April and November. Although the June catch at this site was low, this could be attributed to net failure due to snagging which permitted large numbers of atherinids to escape. Small catches were made at this site between December and March, which was the summer period when the salinity and temperatures were highest. It is

possible that this distribution pattern could also be associated with the calmness of the ocean outside the river mouth, with the fish moving to the calmer waters of the estuary during the winter months. The pattern of catches was similar at C.S.R., with the lowest numbers being caught over the summer period. A. presbyteroides was also caught at Alfred Cove in April and June (Fig. 35).

From the distribution it is clear that A. presbyteroides prefers the marine environment and uses the estuary as an extension of this environment.

Feeding

During March and April, copepods were 60% of the diet of A. presbyteroides, non-planktonic crustacea, mainly Corophium minor, Caprella sp. and Apseudes sp. made up 31% of the diet, polychaetes, diatoms and algae were also eaten. Non-planktonic crustacea were more prevalent in the diet of the fish caught at Stirling Bridge, while copepods were more important in the diet of the fish caught at C.S.R. (Fig. 36).

During May and June copepods made up 70% of the diet and non-planktonic crustacea, Caprella sp. and Apseudes sp, made up a further 27%. The diet was similar between Stirling Bridge and C.S.R. during these months (Fig. 37).

During July and August, copepods were 64% of the diet and other crustacea, mainly Caprella sp. made up 35% of the diet, fish eggs were the only other item eaten. The diet, as in the previous two months was similar between the two sites (Fig. 38).

In September and October non-planktonic crustacea, mainly Corophium minor was the most important part of the diet, making up 79% of the diet, copepods made up a further 11% and fish eggs, flying insects, and algae were also eaten (Fig. 39).

TABLE 2.

Separate variance T-Test for length of *A. presbyteroides* males against females.

MONTH	SEX	N	MEAN	S.D.	S.E.	t	D.F.	PROB.
October	M	9	57.8	3.35	1.12			
	F	14	65.9	2.73	0.73	6.12	15	<0.001
November	M	22	58.9	4.59	0.98			
	F	38	71.2	4.66	0.76	9.93	45	<0.001
January	M	13	61.6	4.52	1.25			
	F	18	66.4	3.33	0.78	3.23	21	0.004
April	M	13	53.8	5.80	1.61			
	F	22	54.8	2.79	0.59	0.57	15	0.579
May	M	81	59.0	6.92	0.77			
	F	63	63.0	7.07	0.89	3.40	132	0.001
July	M	25	59.7	5.88	1.18			
	F	35	64.4	6.14	1.04	2.99	53	0.004
August	M	6	64.2	5.04	6.06			
	F	24	71.6	7.17	1.46	2.96	11	0.013
September	M	22	63.8	4.42	0.94			
	F	38	66.2	5.34	0.87	1.90	51	0.062

FIGURE 31.

Length-frequency histograms for *A. presbyteroides* from all sites.

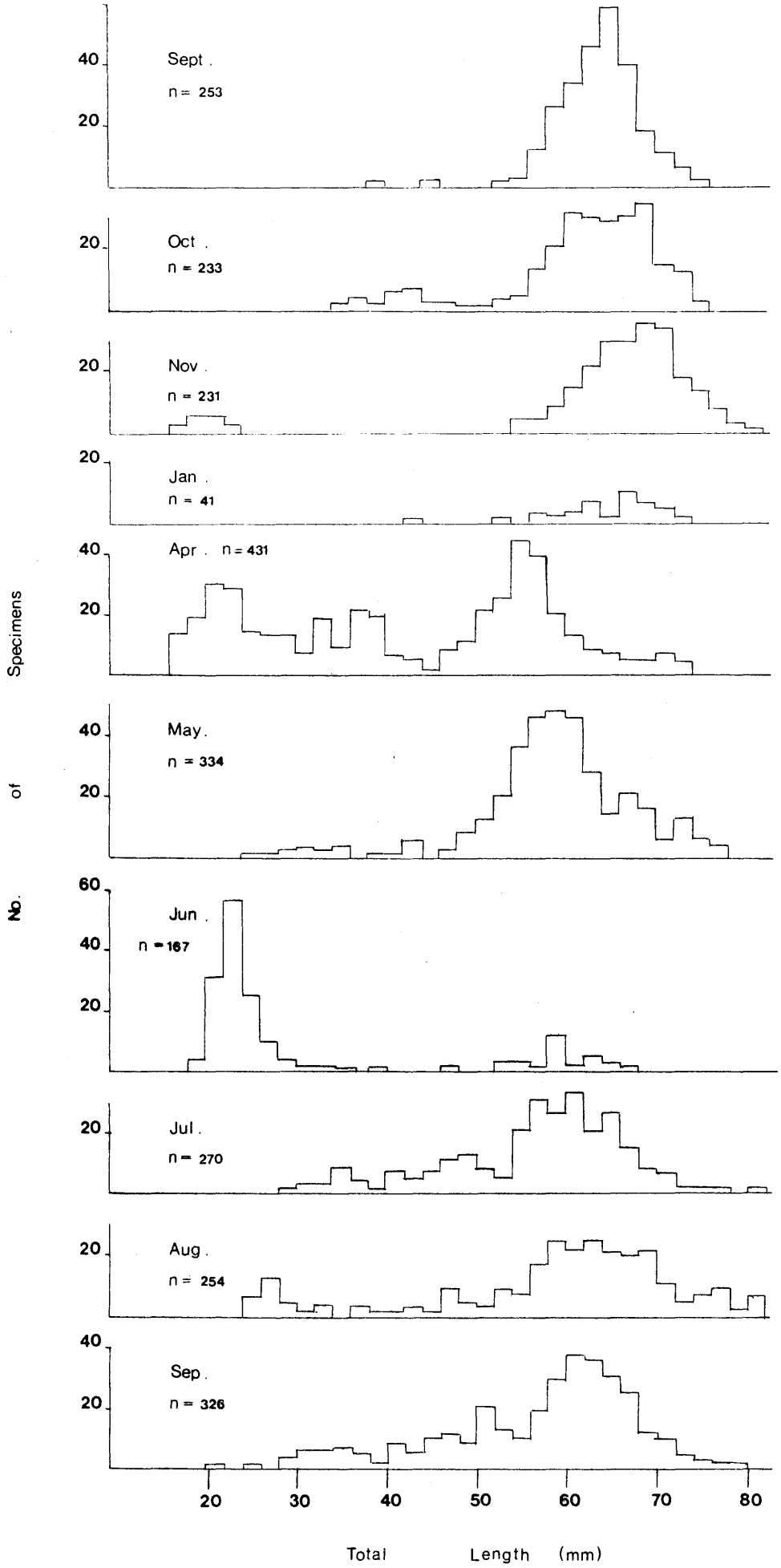

Sept.
n = 253
Oct.
n = 233
Nov.
n = 231
Jan.
n = 41
Apr. n = 431
May.
n = 334
Jun.
n = 167
Jul.
n = 270
Aug.
n = 254
Sep.
n = 326
No. of Specimens
Total Length (mm)
20
30
40
50
60
70
80

FIGURE 32.

Growth curve for *A. presbyteroides* .

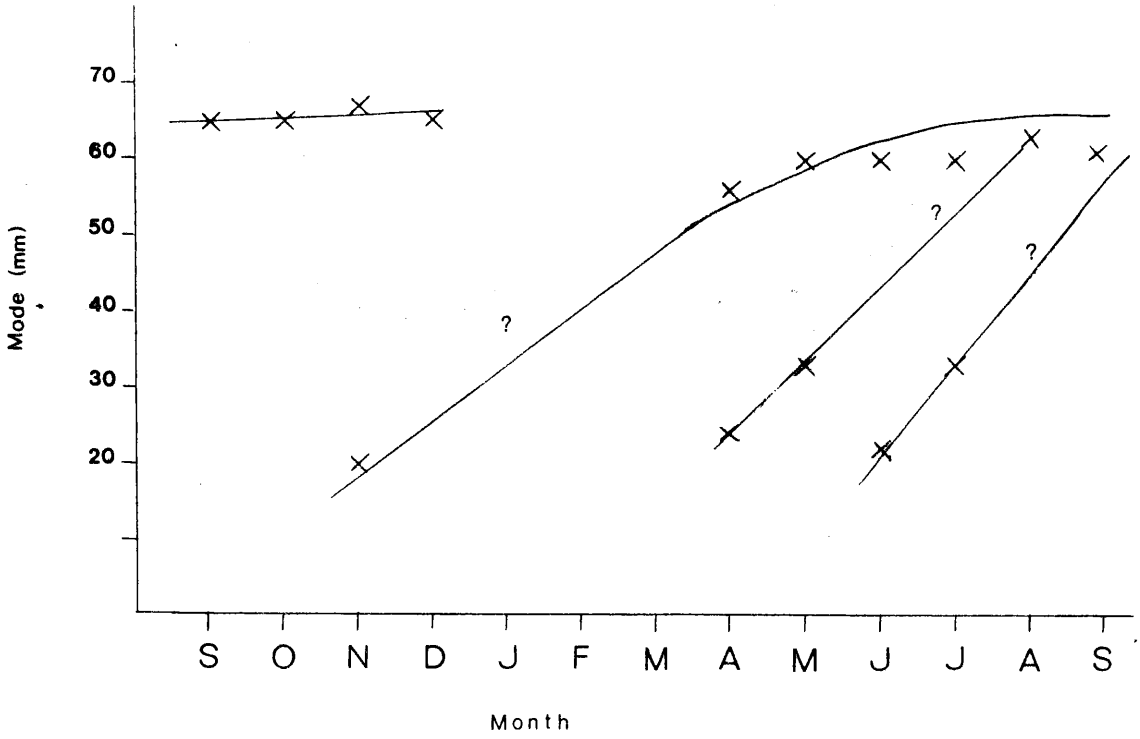

70
60
50
40
30
20
Mode (mm)
?
?
?
S
O
N
D
J
F
M
A
M
J
J
A
S
Month

FIGURE 33.

The G.S.I. of *A. presbyteroides* for each month, with ± 95% confidence intervals indicated by the vertical lines. Unbroken line indicates females and the broken line indicates males.

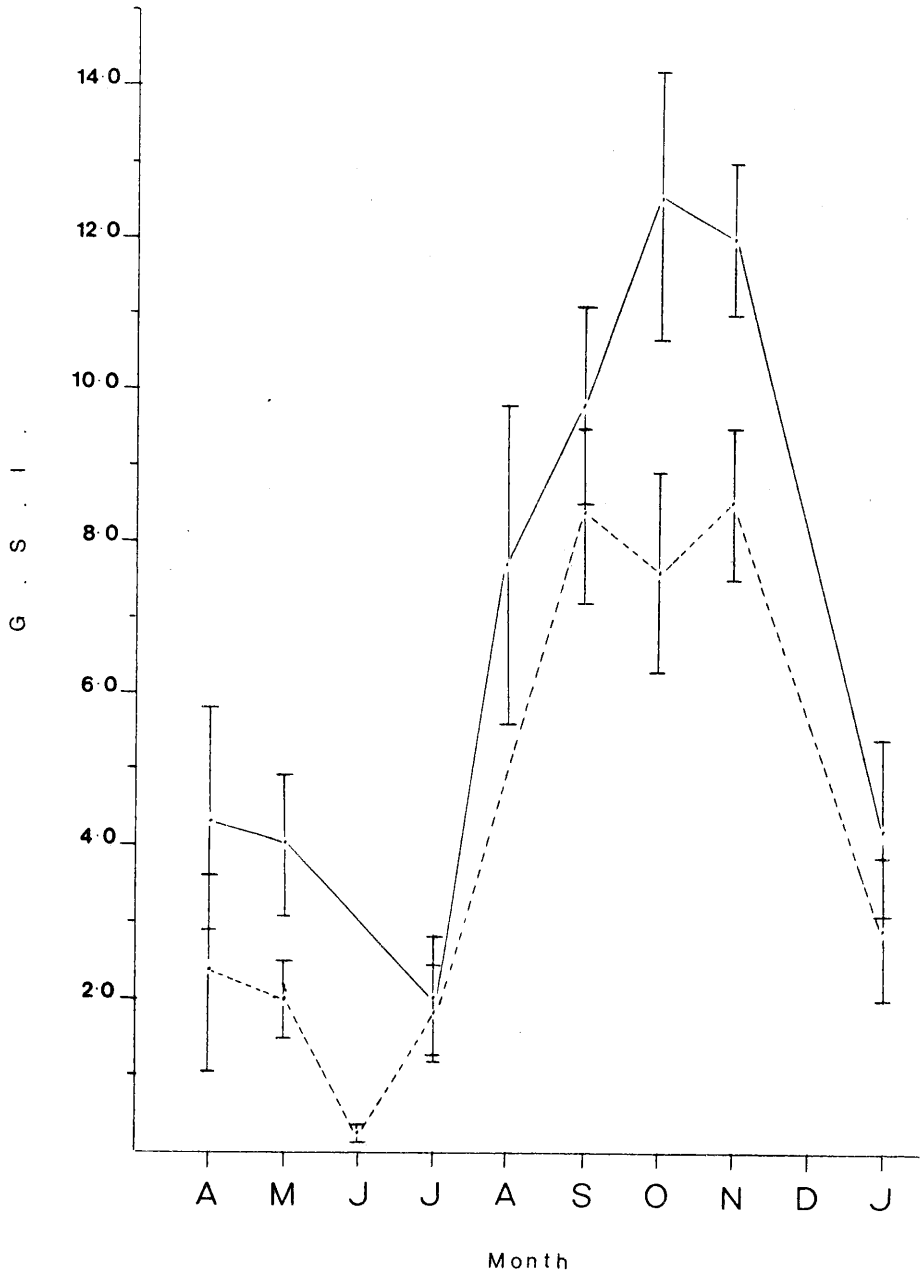

14·0
12·0
10·0
8·0
6·0
4·0
2·0
G . S . I .
A
M
J
J
A
S
O
N
D
J
Month

FIGURE 34.

Frequency histograms for the G.S.I's of the female *A. presbyteroides*.

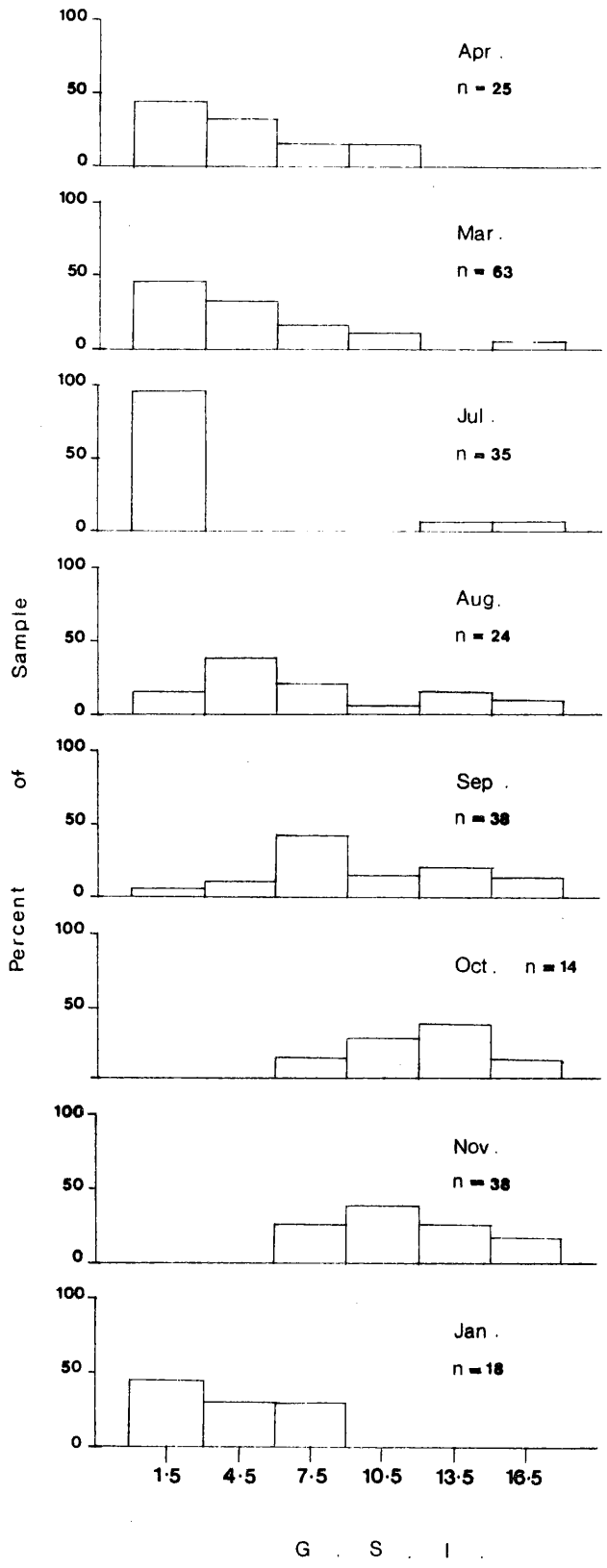

Percent of Sample
100
50
0
Apr.
n = 25
Mar.
n = 63
Jul.
n = 35
Aug.
n = 24
Sep.
n = 38
Oct.
n = 14
Nov.
n = 38
Jan.
n = 18
1·5
4·5
7·5
10·5
13·5
16·5
G . S . I .

FIGURE 35.

Numbers of *A. presbyteroides* caught in each sample at Stirling Bridge, C.S.R. and Alfred Cove together with data on salinity (broken line) and temperature (unbroken line).

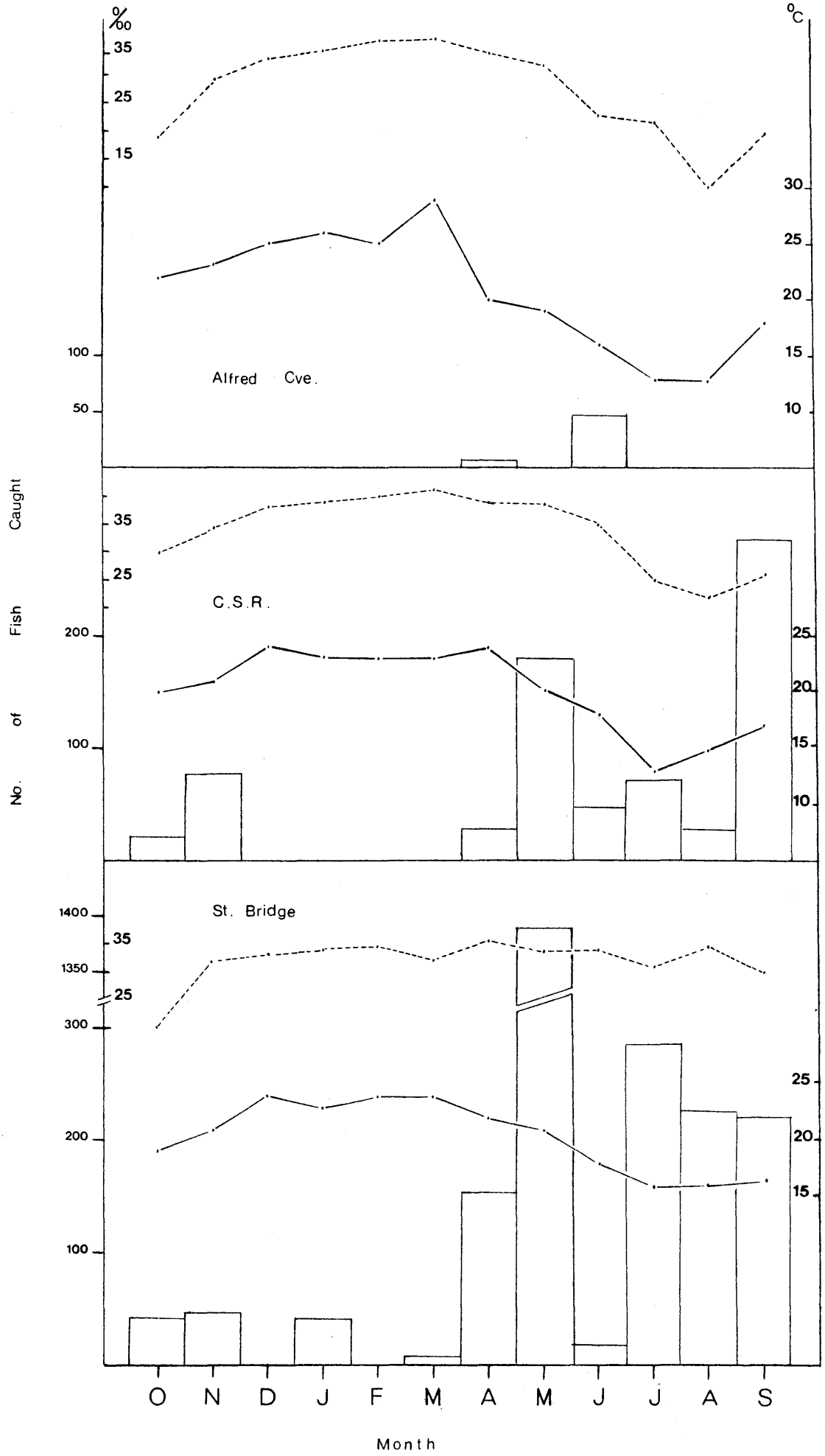
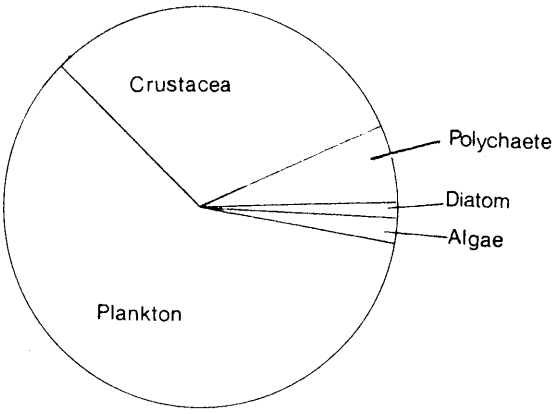
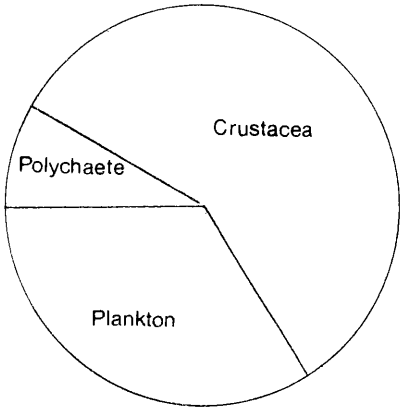

%oo
°C
35
25
15
30
25
20
15
10
100
50
Alfred Cve.
No. of Fish Caught
35
25
200
100
C.S.R.
25
20
15
10
1400
1350
300
200
100
St. Bridge
35
25
25
20
15
O N D J F M A M J J A S
Month

FIGURE 36.

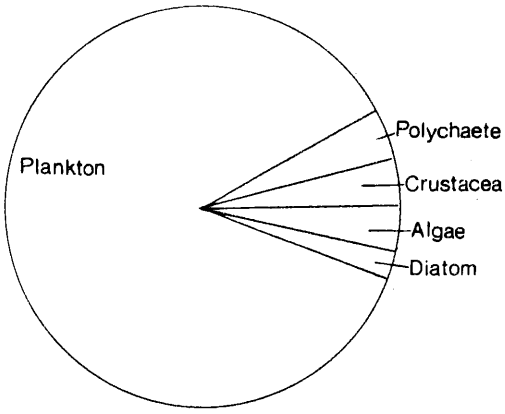
Composition of the stomach contents of *A. presbyteroides* at Stirling Bridge and C.S.R. during March and April.



All Sites
n=40



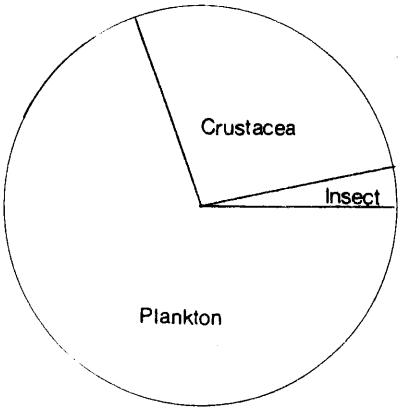
St. Bridge
n=20



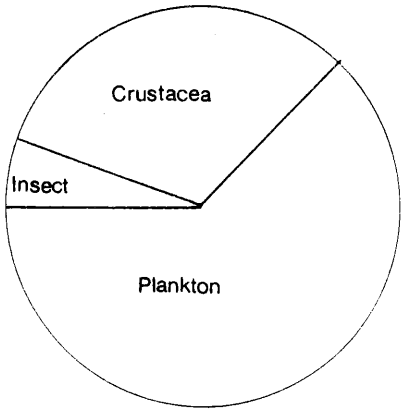
C.S.R.
n=20

FIGURE 37.

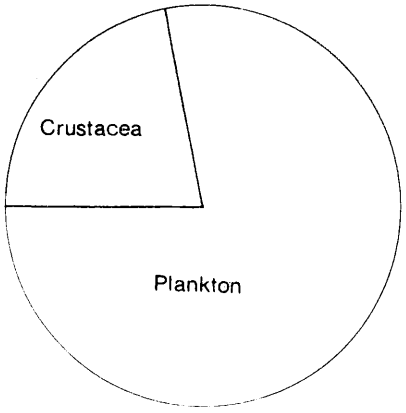
Composition of the stomach contents of *A. presbyteroides* at Stirling Bridge and C.S.R during May and June.



All Sites
n = 40



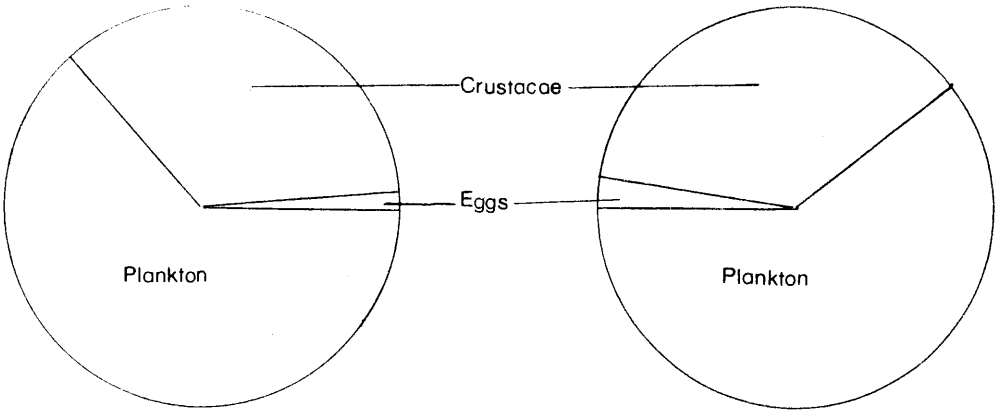
St. Bridge
n = 20



C.S.R.
n = 20

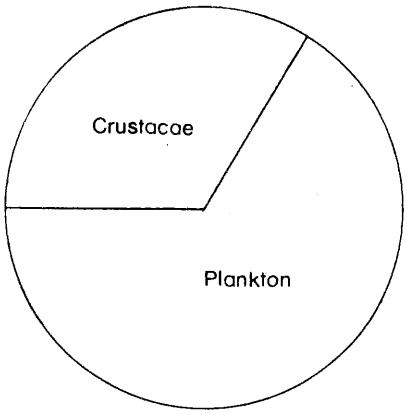
FIGURE 38.

Composition of the stomach contents of *A. presbyteroides* at Stirling Bridge and C.S.R. during July and August.



All Sites
n = 30

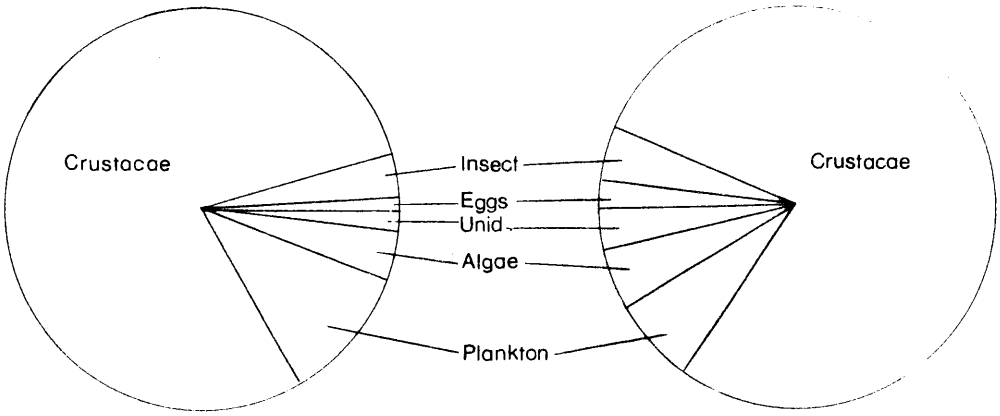
St . Bridge
n = 20



C.S.R.
n = 10

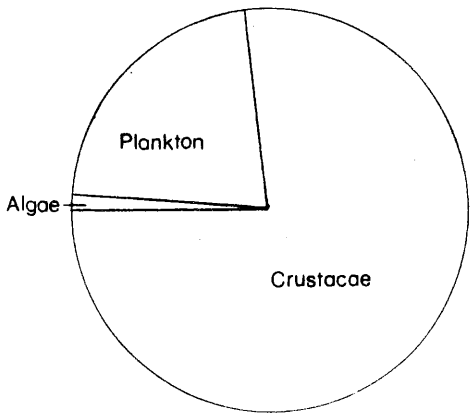
FIGURE 39.

Composition of the stomach contents of *A. presbyteroides* at Stirling Bridge and C.S.R. during September and October.



All Sites
n=35

St. Bridge
n=25



C.S.R.
n=10

3.6. A. elongata

LIFE CYCLE

The smallest group of fish belonging to this species, were first caught in November and December, when their modal length was between 25 and 32 mm. The growth curve shows that this small length class reached a length of 55 mm by May, after which the rate of growth slowed (Fig. 40). Few of the largest class, whose modal length was approximately 65 mm, were caught after December and the sizes of this and the preceding month's catches were considerably reduced from those obtained in October (Fig. 41). The values for the G.S.I. indicated that the largest size class reached maturity during September, October and December (Fig. 42). The G.S.I. subsequently decreased markedly in February. The G.S.I. of the small size group, which was approximately five months old in March, reached a small peak in March and April. However the frequency histogram for the G.S.I's of the females shows that, although the gonads of this group developed rapidly between December and February, the G.S.I. of less than 5% of females had reached a value of over 9.0 by April (Fig. 43). As the mean G.S.I. during the summer breeding peak was over 13.0, it seems unlikely that breeding occurred at this time.

These data suggest that the life cycle of A. elongata is of approximately 12 months duration and that breeding is confined to October, November and December.

Males were significantly smaller than females ($P < 0.01$) during most of the year (Table 3). However, this did not result in the females being more commonly caught than males. The ratio of males to females caught, did not vary significantly from the ratio 1:1 although in isolated catches the number of one sex sometimes

considerably outnumbered the other. The difference in size between the sexes was not as great as that observed in the unidentified species and it is probably because of this that the ratio of the sexes caught did not favour the females as it did in the unidentified species.

Distribution

A. elongata was caught predominantly in the middle estuary and catches of 100 fish were consistently caught at Alfred Cove. The lowest catches at this site were during the highest temperatures between October and February and between July and September when the salinity had been reduced by the flush (Fig. 44). At Mt. Henry, catches of slightly less than 50 were common, with one catch of 241 being obtained in February, when moderately high salinities and temperatures prevailed. Although this species were not caught in large numbers at C.S.R., a sample of 44 was collected in July. Only 25 of this species were taken outside these three sites, of which seven came from Joel Terrace in March and May, six at Perth Water during May and June and 12 at Stirling Bridge during July. This distribution clearly indicates that A. elongata prefers the marine conditions of the middle estuary.

Feeding

During March and April, the diet consisted mainly of crustacea, Corophium minor being the most common species eaten, and polychaetes which made up 30 and 15% of the diet respectively. Copepods, fish eggs, flying insects, diatoms and algae were also eaten. Polychaetes and amphipods were only eaten at Alfred Cove, while the other food items were eaten at both Alfred Cove and Mt. Henry. The fish from Joel Terrace ate only diatoms (Fig. 45).

During May and June 30% of the diet was copepods, 15%

was polychaetes and 13% of the diet was Apseudes sp. and other amphipods. Fish eggs and diatoms made up 10% of the diet each. The fish from Alfred Cove had only eaten polychaetes and amphipods, while the fish from Perth Water had only eaten copepods. The fish from Mt Henry had eaten fish eggs, flying insects, polychaetes, diatoms, algae and copepods (Fig. 46)

During July and August, the diet was only analysed for fish caught at Alfred Cove and 80% of the diet was Corophium minor and other amphipods, 19% of the diet was polychaetes, the only other item eaten was fish eggs (Fig. 47).

During September and October, as in the previous two months, fish were only analysed from Alfred Cove. Apseudes sp. and Corophium minor made up 65% of the diet while 24% of the diet was polychaetes. Fish eggs and flying insects had also been eaten (Fig. 48).

TABLE 3.

Separate variance T-Test for length of *A. elongata*

males against females

MONTH	SEX	N	MEAN	S.D.	S.E.	t	D.F.	PROB.
December	M	7	56.4	2.88	1.09			
	F	17	63.8	9.14	2.21	2.97	21	0.007
December	M	8	37.4	3.34	1.18			
	F	7	39.6	3.26	1.23	1.29	13	0.220
February	M	6	68.0	3.22	1.32			
	F	13	77.1	4.66	1.29	4.92	14	<0.001
February	M	10	49.7	2.91	0.92			
	F	17	53.7	2.59	0.63	3.60	17	0.002
April	M	36	50.7	2.89	0.48			
	F	35	54.0	3.45	0.58	-4.41	66	<0.001
May	M	11	52.3	2.80	0.84			
	F	34	57.7	3.72	0.63	4.68	22	<0.001
June	M	23	54.1	3.88	0.81			
	F	30	62.4	5.12	0.94	6.69	51	<0.001
July	M	9	52.4	3.47	1.16			
	F	11	61.0	5.14	1.55	4.43	17	0.002

FIGURE 40.

Growth curve for *A. elongata*.

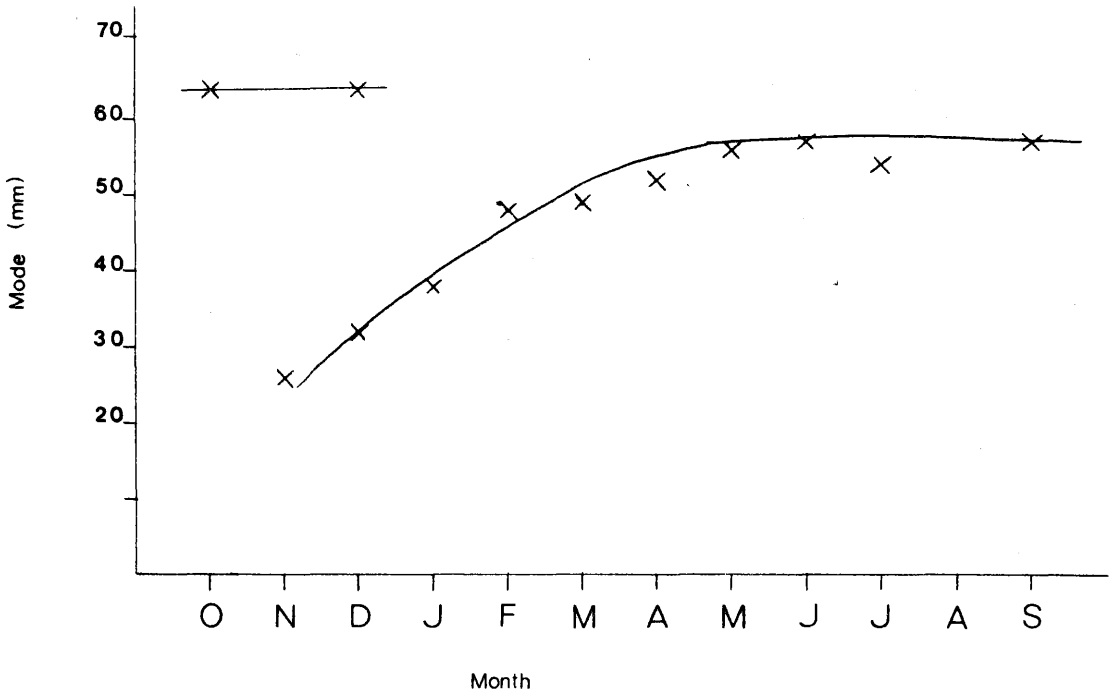

70
60
50
40
30
20
Mode (mm)
O
N
D
J
F
M
A
M
J
J
A
S
Month

FIGURE 41.

Length-frequency histograms for *A. elongata* from all sites.

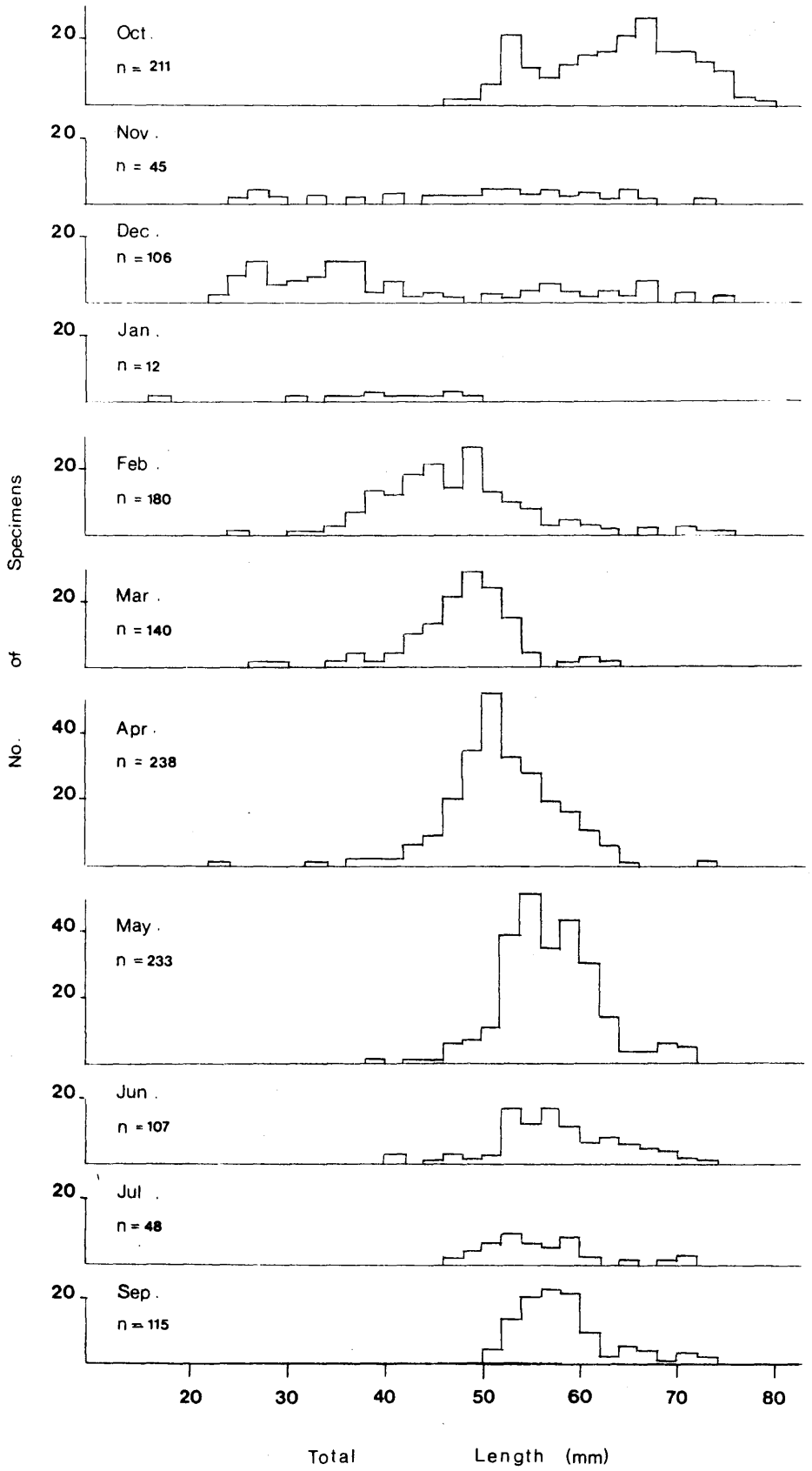

No. of Specimens
Oct.
n = 211
Nov.
n = 45
Dec.
n = 106
Jan.
n = 12
Feb.
n = 180
Mar.
n = 140
Apr.
n = 238
May.
n = 233
Jun.
n = 107
Jul.
n = 48
Sep.
n = 115
20
40
20
30
40
50
60
70
80
Total Length (mm)

FIGURE 42.

The G.S.I. of A. elongata for each month, with ± 95% confidence intervals indicated by the vertical lines. Unbroken line indicates females and the broken line indicates males.

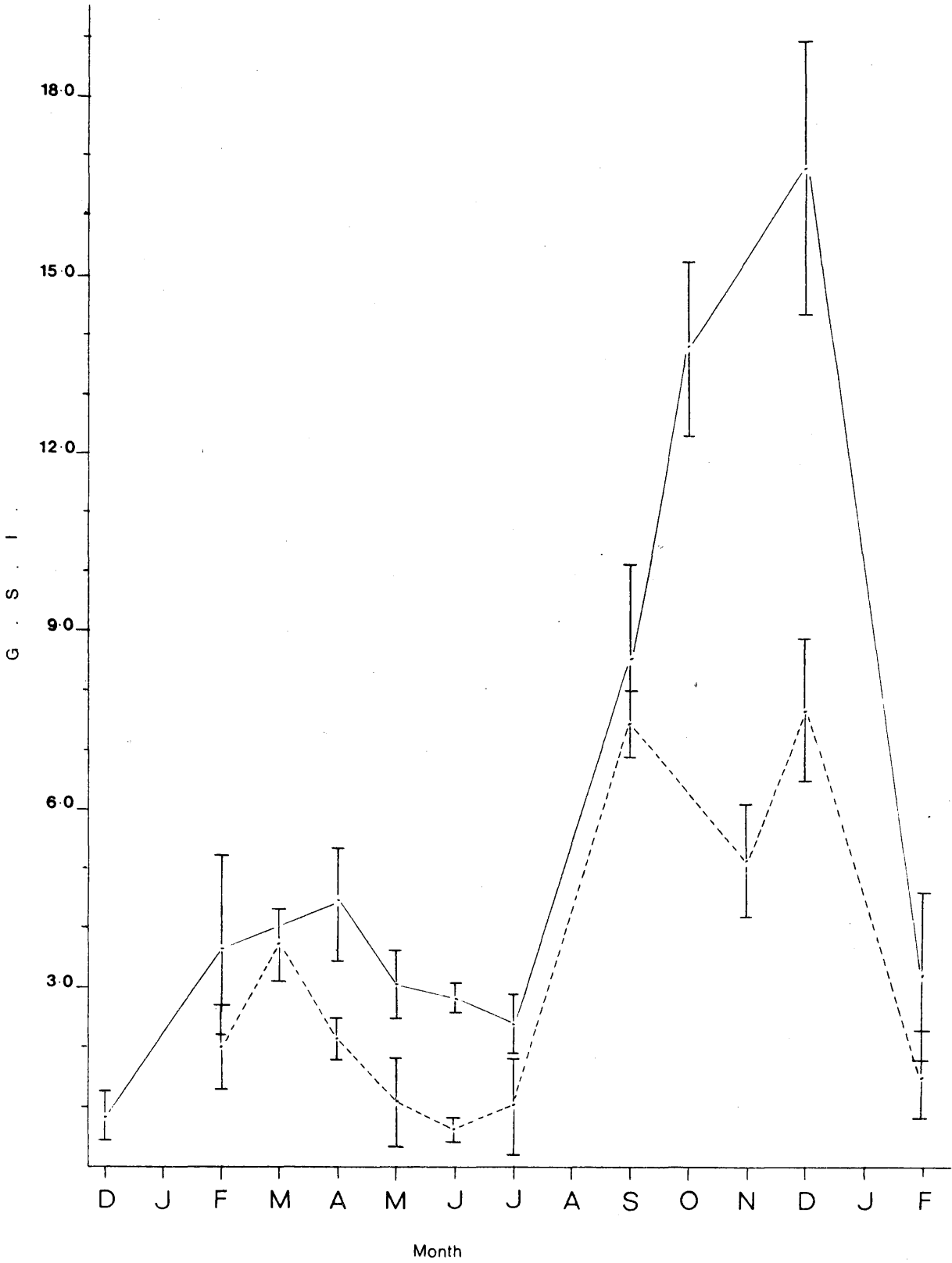

18·0
15·0
12·0
9·0
6·0
3·0
G . S . I .
D
J
F
M
A
M
J
J
A
S
O
N
D
J
F
Month

FIGURE 43.

Frequency histograms for the G.S.I's of the female *A. elongata*

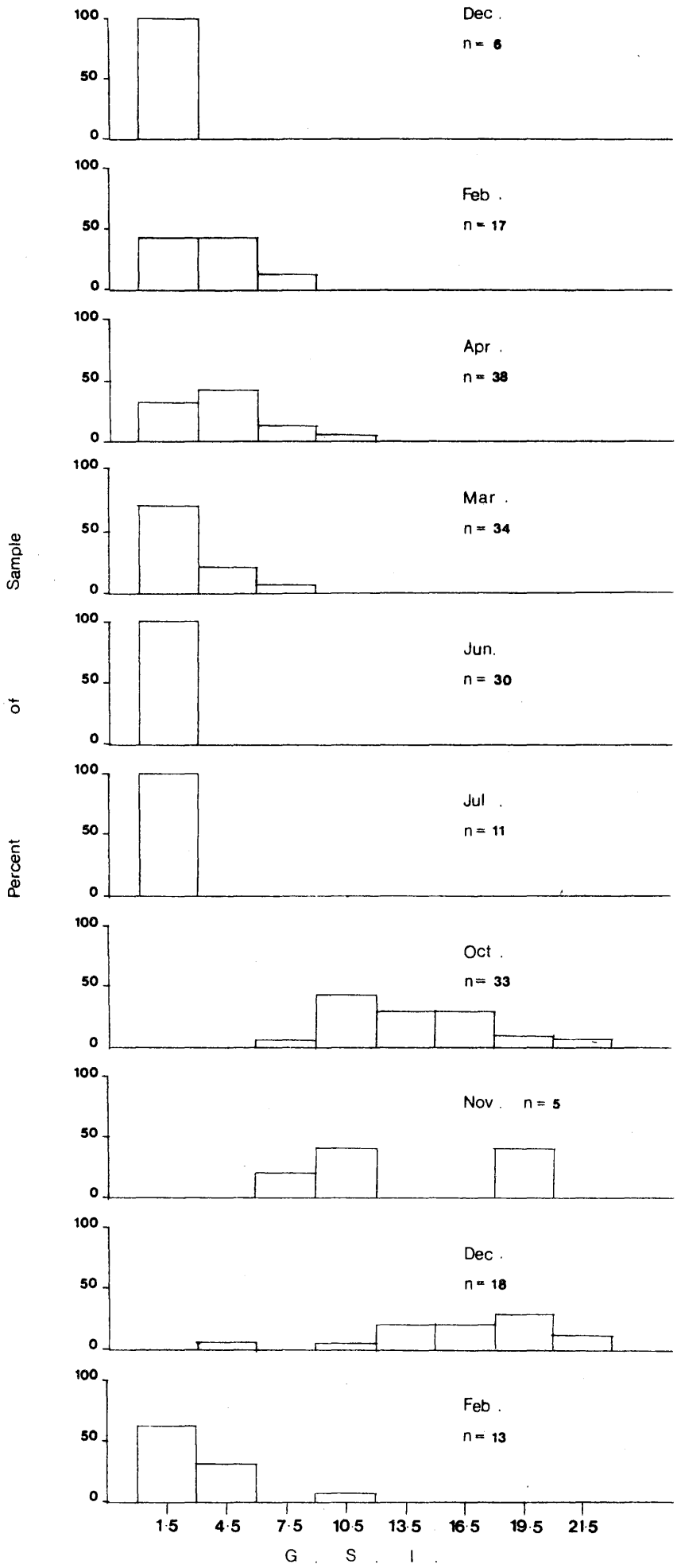

Percent of Sample
100
50
0
Dec .
n = 6
Feb .
n = 17
Apr .
n = 38
Mar .
n = 34
Jun.
n = 30
Jul .
n = 11
Oct .
n = 33
Nov . n = 5
Dec .
n = 18
Feb .
n = 13
1·5
4·5
7·5
10·5
13·5
16·5
19·5
21·5
G . S . I .

FIGURE 44.

Numbers of *A. elongata* caught in each sample of Mt. Henry, Alfred Cove and C.S.R. together with data on salinity (broken line) and temperature (unbroken line).

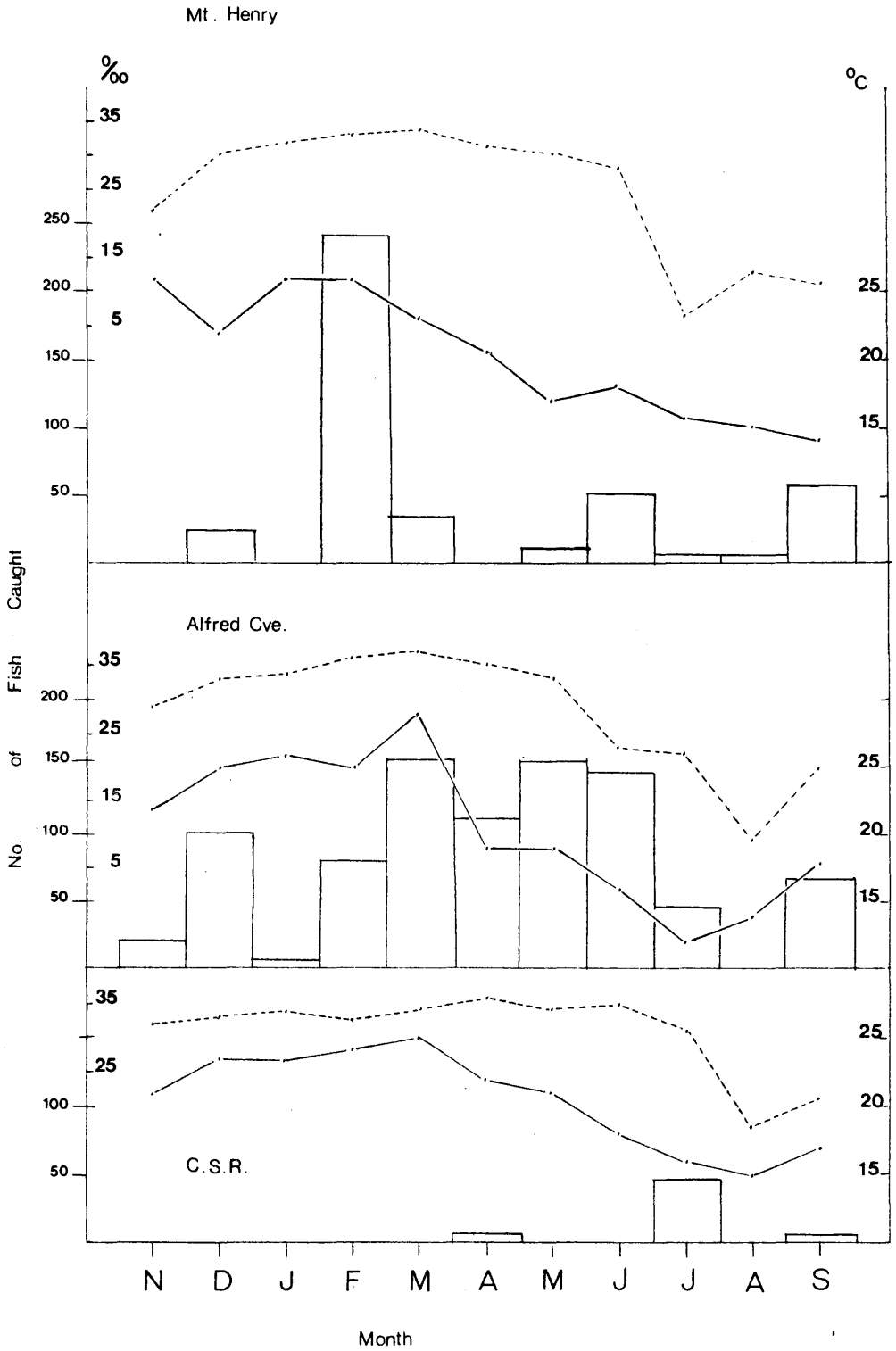
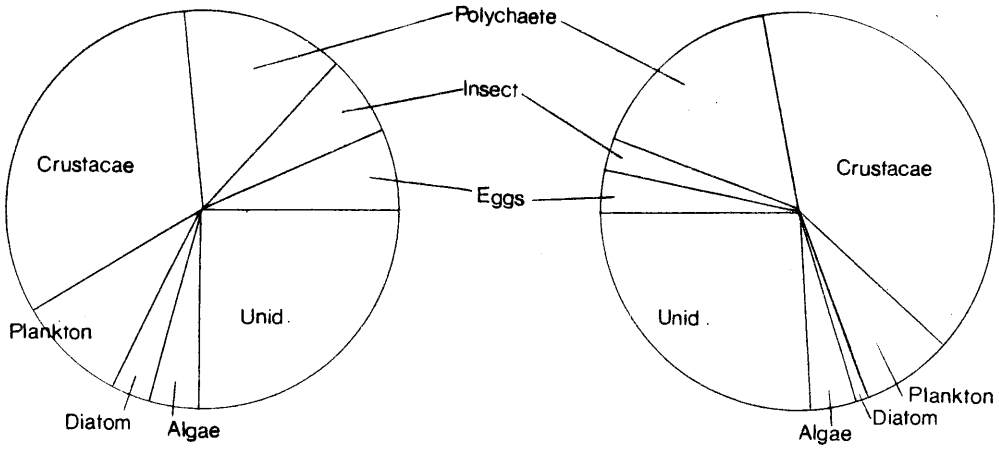

Mt. Henry
‰
°C
35
25
15
5
250
200
150
100
50
25
20
15
Alfred Cve.
35
25
15
5
200
150
100
50
25
20
15
35
25
100
50
C.S.R.
25
20
15
No. of Fish Caught
N
D
J
F
M
A
M
J
J
A
S
Month

FIGURE 45.

Composition of the stomach contents of *A. elongata* at Alfred Cove, Mt Henry and Joel Terrace during March and April.

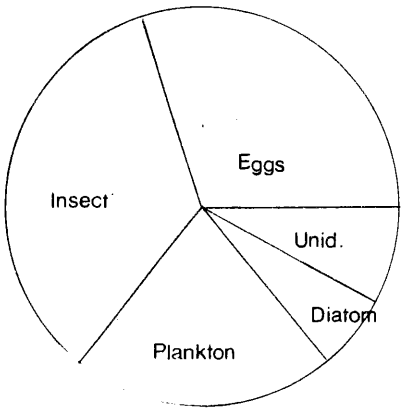


All Sites

n = 73

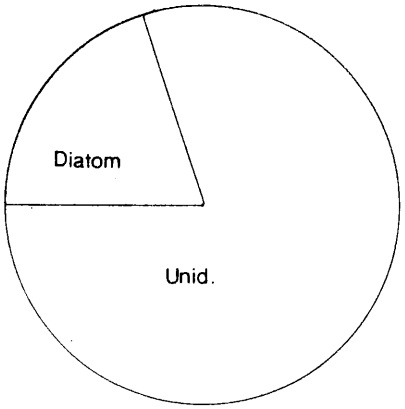
Alfred Cove

n = 58



Mt. Henry

n = 10

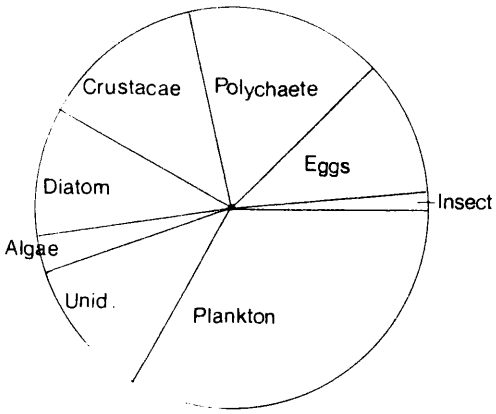


Joel Tce.

n = 5

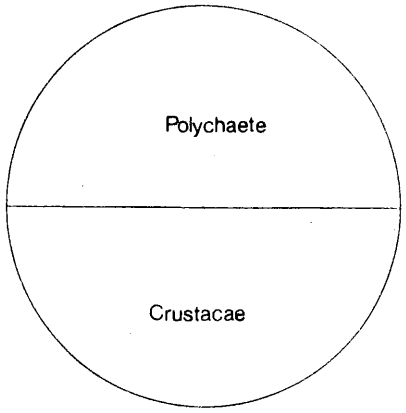
FIGURE 46.

Composition of the stomach contents of *A. elongata* at Alfred Cove, Perth Water and Mt. Henry during May and June.



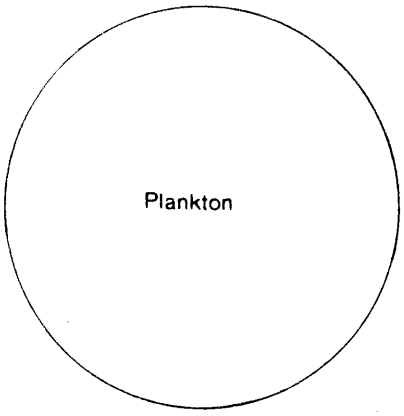
All Sites

n = 38



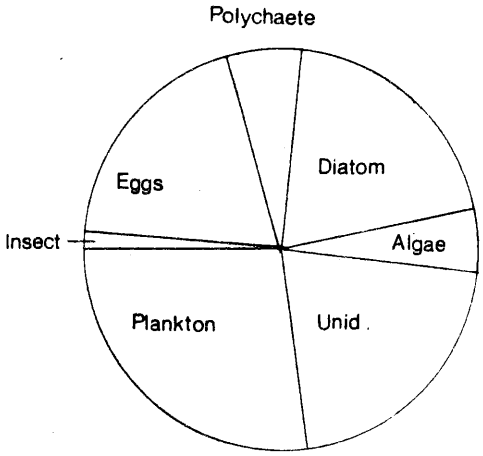
Alfred Cve.

n=10



Perth Wtr.

n = 8



Mt. Henry

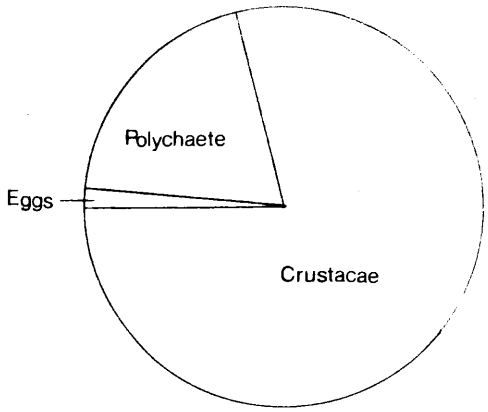
n = 20

FIGURE 47.

Composition of the stomach contents of *A. elongata* at Alfred Cove during July and August.

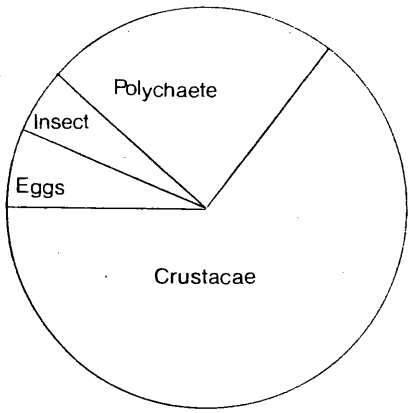
FIGURE 48.

Composition of the stomach contents of *A. elongata* at Alfred Cove during September and October



Alfred Cve.

n = 10



Alfred Cve.

n = 20

4. DISCUSSION

4.1. Feeding

This study showed that throughout the year A. mugiloides fed extensively on zooplankton, although diatoms, flying insects and non-planktonic crustacea were also eaten in significant amounts. The unidentified atherinid species had a more diverse diet, with no single food item making up more than 50% of the diet during any period. Zooplankton, flying insects, diatoms and polychaetes were all important components of the diet.

A. elongata fed mainly on non-planktonic crustacea,although polychaetes, copepods, diatoms, flying insects and fish eggs were all eaten. A. presbyteroides ate copepods mainly with non-plantkonic crustacea also being eaten in large numbers, with polychaetes and flying insects being eaten in smaller amounts. This agrees closely with work of Robertson on this species in Victoria (See Ivantsoff, 1977). P. ogilbyi were found to feed extensively on non-planktonic crustacea and to a lesser extent on polychaetes and copepods. This also agrees with the studies on this species by Patten in N.S.W. (see Ivantsoff, 1977) and with Thompson (1959).

Studies on a number of atherinid species (Bayliff, 1950; Hubbs, 1921 ; Hiatt and Strasburg, 1960; Davis and Louder, 1969 Zimmerman, 1970 ; Wallace, 1976) gave similar results to this study, showing that atherinids feed on a variety of small invertebrates, with copepods, flying insects, non-planktonic crustacea and polychaetes all being common food items. These studies show that minor differences are present between the diets of various species, and that the main differences appear to be associated with the extent to which the differing species feed from the surface or the bottom. They all clearly feed in shallow water and are capable of opportunistically utilising the food

resources of the whole water column. This is illustrated by the fact that each of the five species in this study were found to have eaten food items from each of the seven categories used to classify the food items ingested, namely planktonic crustacea, diatoms, plants other than diatoms, flying insects, polychaetes, fish eggs and non-planktonic crustacea.

Despite the ability to feed opportunistically, this study has also shown that variation in diet between the five species, was due to selection for certain food items and not entirely to variation in distribution. This selection was demonstrated when atherinids of different species were caught at the same time from the same site. In most of these cases the importance of certain items in the diet were shown to vary between species although the same food items were eaten by each species. Because the fish were caught in the same area at the same time this variation in importance of food items was due to selection by the species and not the availability of the food item. When A. presbyteroides and P. ogilbyi were caught in the same samples the former ate larger amounts of copepods than the latter which had ingested polychaetes and non-planktonic crustacea. When A. mugiloides was caught with P. ogilbyi, it showed a preference for copepods and diatoms, while P. ogilbyi chose larger amounts of polychaetes and non-planktonic crustacea.

When A. mugiloides was caught with A. elongata, it selected copepods while the latter species ate larger amounts of fish eggs and flying insects. When caught with the unidentified species, A. mugiloides ate large amounts of copepods, while the unidentified species ingested large amounts of flying insects

and polychaetes.

When the unidentified species was caught with A. elongata, the latter species ate larger amounts of fish eggs than the unidentified species which had eaten larger amounts of flying insects. These results show that, despite the opportunistic feeding behaviour of the atherinids in the Swan-Avon system, P. ogilbyi was likely to choose polychaetes and non-planktonic crustacea. By contrast, A. presbyteroides selected copepods, A. elongata preferred fish eggs and flying insects, while A. mugiloides selected copepods and diatoms and the unidentified species selected flying insects and polychaetes.

In May and June of this study this selection pattern was not observed and copepods were the most important food item in the diet of all five atherinid species. This was probably due to the fact that copepods were extremely abundant within the estuary during this period (Wallace, pers. comm.).

4.2. Life cycle and breeding

The life cycle of the four smaller species of atherinids were all very similar, with the life span being approximately 12 months and the spawning period relatively protracted. Breeding occurred over four months in A. mugiloides, at least three months in A. elongata and A. presbyteroides, and over at least five months in the unidentified species. Other studies on small atherinids (total length of 100mm or less) have all given similar results (Hubbs, 1921; Bayliff, 1950; Mense, 1967; Nelson, 1968; Davis and Louder, 1969; Ivantsoff, 1977).

The prolonged spawning period, the time between the commencement of spawning and the detection of spent gonads in the population and the presence of more than one size class of eggs in the gonads all suggest that the small atherinids spawn serially. This view has also been proposed by a number of American workers, (Hildebrand, 1921; Hildebrand and Shroeder, 1927; Mense, 1967) , although Bayliff (1950) claimed that this was not the case in the species he examined. This latter worker suggested that two different populations of the same species spawned at slightly different times. However this worker also cited work by Gunter (1945) that showed that a similar species did spawn twice in a season.

The work of Robertson, cited by Ivantsoff (1977) demonstrated that in Victoria A. presbyteroides breeds between November and January. Ivantsoff (1977) also states that fish caught in N.S.W. were running ripe in August and concluded that the breeding season differs between the two areas. This view seems unlikely considering the similarity between the breeding season of the fish in this study and those cited. It seems more likely that this is simply a similar situation to that observed in this study with the main breeding occurring between September and December and isolated spawning by young animals occurring around May.

All of the species in which the number of eggs were counted had a low fecundity which is clearly related to the large size of the eggs and the small size of the fish. It is thus possible that serial spawning has developed to increase the fecundity of these species. This would give these species the advantage of having eggs of a large size as well as

producing many eggs over the whole breeding season, which could be important to these species as they are subjected to heavy predation.

No evidence of a protracted spawning period or unseasonal spawning was found in P. ogilbyi. The life cycle of this species was also longer than in the other species although whether it was two or three years in duration was not determined by this study. Chubb (1977) found no evidence for more than one year class of this species within the estuary. However this could be due to misidentification of the smallest fish at some times of the year as well as the use of 5mm size classes instead of 2mm size classes in the construction of the length-frequency histograms. This study showed that spawning occurs during the penultimate and final years of life. It is likely that the fecundity of this species is greater than in the other species, as the eggs were seen to be of a similar size to the other species and the gonads were larger. The larger fecundity and two breeding seasons during the life cycle may have the same effect as serial spawning in increasing the overall fecundity of the species.

4.3. Growth patterns

In all of the atherinid species found within the Swan-Avon estuary, the maximum rate of length increase was during the initial summer of life. In the unidentified species, A. elongata, A. presbyteroides and A. mugiloides, the mode of the main size class of fish did not increase over the winter period. However, in A. mugiloides the range in distribution of the

sizes of the fish in the main class decreased from 40mm to 20mm between March and June, a period when the mode increased by less than 5mm.

In A. presbyteroides the major age class, spawned in November, did not increase in modal length between May and September. However the fish spawned during this period continued to grow, although the larger fish of the same year class had stopped growing. The growth patterns of these two species show that the fish within the same year class grew at different rates. This suggests that a factor other than the winter conditions suggested by Chubb (1977) also has an effect on slowing the growth rate of these species.

In P. ogilbyi, the growth curves are not comprehensive enough to make positive statements. However whether the data is interpreted to show a two or a three year life cycle it is evident that growth is least in the last year of life. If it is assumed that a three year life cycle is indicated, growth is fastest during the first year of life and slows during each successive year of life. In this species this can clearly be associated with increased use of resources for gonadal development rather than continued growth. This would explain why growth is least in the last year of life as spawning occurs twice during that year.

This probably also explains the differing growth rates observed within the single year classes of the smaller atherinid species. It is clear that in these species the mature fish grow more slowly than the immature fish within the same year class. These larger more mature fish would have been spawned

earliest in the protracted breeding season and would also mature sooner than the fish spawned later. On reaching maturity these older fish would stop growing in order to put their resources into gonadal development, while the fish that spawned later would continue to grow rapidly. It seems probable that if serial spawning occurs the oldest fish of the year class would begin spawning early in the protracted spawning period and spawn several times before the younger fish have matured and are ready to spawn. The fish of the year class that mature last probably only spawn once before the end of the breeding season.

Thus the slowing of growth during the winter period is probably related to both the colder conditions and to a less extent the beginning of gonadal development in the larger fish. While the difference in growth rate observed between the largest and smallest fish of the same age group, which caused a decrease in the range of sizes observed through the year, is probably entirely due to the protracted spawning period and the serial spawning with which it is probably associated.

4.4. Distribution and Use of the Estuary

This study showed that the five atherinid species have different distributions in the Swan-Avon estuary. The unidentified species has the most distinct distribution of the five species, being found only in the upper estuary. This species is clearly euryhaline, being caught during this study in salinities ranging from less than 1 to 28 ‰ and being capable of living in aquaria for many months at 35 ‰. Despite its euryhaline ability, this species clearly favoured the freshwater conditions, being caught in the upper estuary

through the year, including during the period of maximum flow. It has thus been concluded that this species is a euryhaline freshwater fish that uses the estuary as an extension of its habitat. Although overlap was detected between the latter species and A. mugiloides, this only occurred at the extreme ends of the distribution of the two species. A. mugiloides was caught in salinities ranging from 5 to 35 ‰ and has been kept in aquaria in salinities between 1 and 35 ‰ (McLaughlin, pers. comm.). Despite the euryhaline nature of this species, it preferred the marine conditions of the middle estuary. This species was also affected by the freshwater flush which reduced the numbers caught during this period. Movement of this species to other more saline areas, or into deeper water was not detected during the flush. Whether this represents mortality in the estuarine population or movement to unsampled areas is difficult to determine. It is possible that this species moved into the Pelican Rocks area in the middle estuary, where no samples were taken. However, it seems unlikely that this area would provide significantly higher salinities than Perth Water and Mt. Henry. As this species was not detected lower in the estuary during this period it seems improbable that this species avoids the fresh water.

The evidence for immigration of small numbers of this species into the estuary each year suggests that the estuarine population is maintained by a marine population. However there is no evidence for a marine population in the ocean in the close proximity to the estuary. Small numbers of this species have been caught in the Peel-Harvey estuary 80 km south of the Swan-Avon. The small numbers caught, despite the extensive

sampling indicates that the population in that estuary is either extremely small, or that these animals also represent immigrants from a marine population. The record of this species in Western Australia, from Point Samson, Port Hedland, Broome and Shark Bay (Ivantsoff, 1977) support the view that this is a marine species. If this is the case, the estuary would be utilised by a comparatively small and isolated population of this species as a habitat in which to spend the whole of its life cycle. It seems likely that in the years of little rainfall, the population in the estuary could easily maintain itself. However, in years of a prolonged flush in which the population could be seriously reduced, the marine population could repopulate or add to the estuarine population.

A. elongata was the only species which was restricted entirely to the estuary and was not recorded outside this habitat. For this reason, it is the only species that could be termed a truly estuarine species (Day, 1951; Day, 1967). This species, as with the other three species, was extremely euryhaline being caught in salinities between 6 and 35‰. It has also been kept in aquaria at salinities as low as 1 ‰ (McLaughlin, pers. comm.). A. elongata has been recorded by Ivantsoff (1977) from high in the Avon and Helena Rivers, Northam and Beverley, and from freshwater lakes from around Rockingham. This is probably due to confusion by this author between A. elongata and the unidentified species which is more likely to occur in those areas. A. elongata only occurs in small numbers, with the former species at the point where the two populations overlap. The overlap of A. elongata with

A. mugiloides and P. ogilbyi is probably more extensive, although some separation seemed to occur with the former species being caught in the lower middle estuary and the latter two in the upper region of the middle estuary. Further sampling in the Pelican Rocks region would show to what extent these species occur sympatrically.

For A. presbyteroides and P. ogilbyi, which have extensive marine populations (Ivantsoff, 1977), the estuary provides an extension of the marine environment. A. presbyteroides only utilised the lower estuary and this was used most extensively during the winter period. This is probably because of the calm conditions found within the estuary at a time when the ocean is particularly rough and the prevailing winds are on-shore. During the summer months smaller numbers of this species were found within the lower estuary and this may indicate a movement back to sea, to utilise the calm conditions prevailing during the summer. The distribution of A. presbyteroides given by Ivantsoff (1977) includes the Canning River but from the information given by this study this seems unlikely. It seems more likely that this is a result of confusion with the identification of the unidentified species. The distribution of A. presbyteroides found by this study was distinct from all the other species except P. ogilbyi. These two species were also observed schooling extensively together in the region of Point Peron, outside the estuary.

Like A. presbyteroides, it is probable that a small part of the marine population of P. ogilbyi use the estuary as an

extension of the marine environment. However, unlike the former species, P. ogilbyi, is able to enter the estuary during summer to the full extent of the marine influence. This allows it to utilise the abundant invertebrate fauna on the large area of shallows in the middle estuary. This species was also able to avoid the freshwater flush by moving back to the lower estuary. The behaviour of these two species contrast with A. mugiloides which is also considered a marine species. Unlike A. presbyteroides, this species is able to utilise the shallow banks of the middle estuary, but unlike P. ogilbyi, A. mugiloides remains in this region through out the year. This is possibly because A. mugiloides, unlike P. ogilbyi is not large enough to rapidly traverse the distance to the lower estuary, before the whole estuary is freshened by the flush. However, since it is more robust than A. presbyteroides it is capable of withstanding the freshwater conditions. A. presbyteroides is probably too small to traverse the distance out of the estuary rapidly and not sufficiently euryhaline to survive the flush and for this reason is restricted to the lower estuary. By contrast, P. ogilbyi is capable of traversing the distance out of the estuary rapidly, enabling it to utilise the middle estuary but avoid the freshwater flush.

4.5. Competition

Within the Swan-Avon estuary the different atherinids appeared to be well adapted to avoiding interspecific competition. The study of their movements and distribution within the estuary showed that, although they occurred sympatrically in some localities, their occurrence together was not as common as originally expected. Most of the species were only caught together at the margins of their distributions. The only

exceptions to this were A. mugiloides and P. ogilbyi and possibly A. elongata in the middle estuary. P. ogilbyi and A. presbyteroides also occurred sympatrically in the lower estuary. It is of interest that the three species of Atherinosoma are the most distinct in distribution which prevents competition at this level. Atherinids which appear euryhaline have been observed to utilise different parts of the same estuary by at least two workers (Bayliff, 1950; Massman, 1954). These differences in distribution would clearly reduce the possibilities of inter-specific competition.

The feeding study showed that despite the fact that the five atherinid species took similar food, differences in the amounts of the same food items eaten produced significant differences in their diets. This, at least partial avoidance of competition, by sympatric species through selective feeding has been found in a number of studies (Idyll, 1941; Hartley, 1948; Carter,Jeffrey and Williamson, 1978; Whitfield and Blaber, 1978). However a similar study by Frost (1950) found no evidence of this phenomenon and also found no evidence for competition occurring. This could possibly be a similar phenomenon to that observed during May and June in this study, when all the species fed heavily on the same food item. This was probably caused by a seasonal abundance which made the food item readily available to all species.

4.6. Importance to the estuary

This study did not attempt to quantify the proportion of the biomass that the five atherinid species constitute within the Swan-Avon estuary. An attempt at this type of study is fraught with difficulty, Lenanton (1977) demonstrated that a single sweep of a seine net similar to that used during this

study caught only approximately 5% of the atherinids originally encompassed. The proportion of the atherinids present that are caught is capable of varying to an extremely large degree, depending on the other fish present, the amount of weed and many other factors. It was for these reasons that no estimates of biomass were attempted.

Despite this reservation it is clear that atherinids are present in the estuary in exceedingly large numbers. Atherinids are very well adapted to a life of heavy predation and have been shown to be an important forage fish or "bait fish" (Bayliff, 1950; Mense, 1967; Davis and Louder, 1969; Llewellyn, 1971; Major, 1976). The atherinidsare definitely the most abundant forage fish in the estuary. This study showed that all of the five species utilised the abundant invertebrate fauna of the shallow banks. Wallace (1977) showed that these large but shallow bank areas are clearly the most productive areas of the estuary and it seems that the atherinids are probably extremely important in making this resource available to the larger carnivores within the estuary.

The atherinids were found in every part of the estuary in every season and the extended breeding periods of these fish caused an extremely wide size range of atherinids to be available for predation. Both of these factors make it likely that atherinids are important to a wide range of estuarine predators. Atherinids are some of the few invertebrate feeding fish in the estuary that are pelagic and this would make them more vulnerable than the camouflaged, sedentary species such as gobies. The pelagic nature of the atherinids would make them vulnerable to predation

by birds as well as to all the piscivorous fish. The larger piscivorous fish may find the banks inaccessible because of their extreme shallowness, but the atherinids which move over the deeper regions would still be accessible to these deeper water species. This suggests that the atherinids in the Swan-Avon estuary play an important role in making the resources of the fertile bank areas available to the piscivorous fauna of the estuary.

4.7. Taxonomy

This study has shown that an atherinid species was present in the Swan-Avon system that was not recorded by Ivantsoff (1977). Ivantsoff only recognised four atherinid species in the system, namely *P. ogilbyi*, *A. mugiloides*, *A. elongata* and *A. presbyteroides*. Although significant differences existed in certain characters between the specimens of the unidentified species from the Canning and Swan-Avon Rivers, the animals from the two areas were very similar in many respects. In appearance and biology no observable differences were detected. Moreover, the differences in the meristic and morphometric measurements were not as great as the differences between the three species of *Atherinosoma* recognised in this study. For these reasons it seems likely that the differences are probably variations within a single species.

The distribution of this species showed that the two concentrations of this species in the Canning and Swan-Avon Rivers are separated by part of the middle and upper estuary. Since there was no evidence that interchange occurred between these areas, it appears reasonable to conclude that there are two isolated populations of this species.

Atherinids have been recognised by many workers as exhibiting considerable intraspecific variability. Johnson (1975) suggested that much of the variation within and between species of the American genus of atherinid, Menidia, was due to salinity and latitudinal gradients. Lee and Williams (1969) showed that significant differences existed between the meristics of two populations of the same atherinid species and suggested these were due to salinity differences between the respective environments. The salinity of the Canning and Swan-Avon Rivers differ, due to the fact that only the Canning River is influenced by fresh water discharge throughout the year. Thus, the differences between the two populations of the unidentified species may be due to salinity differences as well as to genetic variation.

The biology of the unidentified species is clearly different from that of A. presbyteroides. For example A. presbyteroides has not been caught from fresh water and is mainly confined to marine embayments (Patten, pers. comm.;Ivantsoff, 1977), in this study it has been clearly restricted to the highly saline regions of the Swan. The breeding season of the unidentified species, growth patterns and the magnitude of the difference in size between the sexes also distinguish this species from A. presbyteroides and A. elongata.

The identity of this unidentified species is problematical and clearly requires further study. If it has been named before this study, it probably belongs to a group that Ivantsoff (1977) synonymised with A. elongata or A. presbyteroides. Atherinichthys obscurus and Atherinicthys edelensis are two such species that were originally caught and described from the Swan River. Unfortunately, the type descriptions of these two

species do not provide much information (Castelnau, 1873; Castelnau, 1876). Whitley (1943) examined the type specimens in the Paris Museum and synonymised them under the name Craterocephalus edelensis (Whitley). In this paper, Whitley gave the midlateral scale count as 32 and the gill raker count as nine. Later, Whitley (1955) reclassified these species as Atherinosoma edelensis (Whitley) and gave the midlateral scale count as 39-41 and the gill raker count as "about 14". He also described the premaxilla as reaching the anterior margin of the eye. Whitley recorded the type specimen of this species as having been captured at Northam on the Avon River. This description closely agrees with the data collected for the unidentified species, although Whitley's midlateral scale counts and gill raker counts have a smaller range than the values in this study. For example, the midlateral scale count recorded in this study ranged from 36 to 45 and Whitley recorded a range of 39 to 41. The number of predorsal scales and rays in the pectoral fin are very similar, as are most of the other characteristics, which are, however, less diagnostic than the midlateral scale and gill raker counts. The anal fin count and interdorsal scale number compare least favourably. However the distribution of A. edelensis (Whitley) is similar to that of the unidentified species in that both are recorded from the Avon River above the estuary.

Ivantsoff (1977) re-examined Castelnau's original specimens and recorded a gill raker count of 17 and 18, and a midlateral scale count of over 40. Using these characteristics and the length and shape of the premaxilla, this worker classified

them as A. presbyteroides and thus synonymised Atherinichthys edelensis (Castelnau) and Atherinicthys obscurus with the latter species. Atherinosoma edelensis (Whitley) and Craterocephalus edelensis (Whitley) were synonymised by Ivantsoff with A. elongata.

Whitley (1943) described a species Atherinosoma rockinghamensis which he caught in landlocked freshwater lakes around Rockingham. The description for this species was very similar to that given for A. edelensis (Whitley) (Whitley, 1955; Munro, 1958) and Whitley suggested that it could represent part of a cline in the latter species. As in the case of A. edelensis, the description for A. rockinghamensis describes the unidentified species well. Whitley separated the two species on fin ray count, fin position and a slight difference in premaxilla length. Ivantsoff (1977) criticised Whitley's separation into two species because of the variability of the fin rays and fin position. The length of the premaxilla was also criticised because Ivantsoff considered that it might be subjective interpretation, and on examination he found both species to have a small gape. For these reasons he synonymised A. rockinghamensis with A. elongata.

Since the type specimens are held in the National Museum, no conclusive diagnosis of the situation was possible within the time constraints of this study. However, it appears possible that further study might indicate that A. edelensis (Whitley) and A. rockinghamensis (Whitley) are synonymous, but are a fresh water species of atherinid distinct from A. elongata and A. presbyteroides. If this is the case, the unidentified species recognised by this study would have to be named Atherinosoma rockinghamensis Whitley as Atherinosoma edelensis (Whitley) is based on the misidentification of Atherinichthys edelensis

(Castelnau). If A. rockinghamensis and A. edelensis (Whitley) are proved to be synonymous with A. elongata, it seems likely that the unidentified species found by this study is a new species.

4.8. Conclusions

This study has shown that, in the Swan-Avon there are five rather than the four atherinid species listed by Ivantsoff (1977) as occurring in this region of Western Australia. The species not listed by Ivantsoff is clearly a freshwater member of the genus Atherinosoma and further study may indicate that it corresponds to the species that Whitley (1955) described as Atherinosoma rockinghamensis.

This study showed that five species of atherinid utilise the estuary in significantly different ways. The unidentified species is a freshwater species that uses only the upper estuary as an extension of its freshwater habitat. A. elongata is the only truly estuarine species and is found only in the middle estuary. A. mugiloides is a marine species which can apparently remain in the upper region of the middle estuary for the whole of its life cycle. P. ogilbyi is a marine species which utilises the areas of the estuary in which the salinities remain high. A. presbyteroides is a marine species which uses only the lower estuary, the lower estuary appears to be of particular importance during the winter period allowing the rough conditions existing in the ocean at that time to be avoided. The differences in distribution, and a certain extent of selective feeding, reduced the probability of interspecific competition. Despite the differences observed in the diets of the five species, all the atherinids were basically opportunistic predators of small

invertebrates.

This study showed that the four smaller atherinid species had similar life cycles with the major spawning period being protracted and occurring at the end of a one year long life cycle. There was also evidence that in these species, individual fish may spawn more than once in the breeding season. The largest species, P. ogilbyi, spawned in two consecutive years at the end of its life cycle, but whether the life cycle was two or three years in duration could not be determined. All the atherinids spawned in the estuary during the summer.

This study indicated that the atherinids probably have an important ecological role throughout the estuary, making the resources of the shallow banks available to the piscivorous predators within the estuarine ecosystem.

APPENDIX 1

Results of taxonomic measurements made in this study.

TAXONOMIC CHARACTERS FOR UNIDENTIFIED SPECIES.

CHARACTER	TYPE	N	MEAN	RANGE	S.D.	S.E.
Meristics						
Scales						
Midlateral	Swan	27	38.5	36-40	0.98	0.19
	Cann	26	41.2	39-45	1.58	0.31
	All	53	39.8	36-45	1.88	0.26
Transverse	Swan	27	7.0	6-8	0.28	0.05
	Cann	26	7.8	6-10	1.03	0.20
	All	53	7.4	6-10	0.84	0.12
Predorsal	Swan	27	13.7	12-15	0.81	0.19
	Cann	26	14.8	13-17	0.98	0.16
	All	53	14.3	12-17	1.04	0.14
Interdorsal	Swan	27	7.4	6-9	0.80	0.15
	Cann	26	8.5	6-10	0.95	0.19
	All	53	7.9	6-10	1.02	0.14
Fin counts						
1st dorsal	Swan	27	6.4	6-8	0.58	0.11
	Cann	26	6.3	6-7	0.47	0.09
	All	53	6.4	6-8	0.53	0.07
2nd dorsal	Swan	27	10.0	9-11	0.65	0.12
	Cann	26	10.3	7-12	1.15	0.27
	All	53	10.2	7-12	0.93	0.13
Anal	Swan	27	11.4	10-13	0.75	0.14
	Cann	26	12.1	9-14	1.20	0.24
	All	53	11.8	9-14	1.04	0.14
Pectoral	Swan	27	11.0	10-12	0.78	0.10
	Cann	26	11.0	9-13	1.00	0.20
	All	53	11.0	9-13	0.89	0.12

CHARACTER	TYPE	N	MEAN	RANGE	S.D.	S.E.
Other counts						
Gill raker	Swan	27	16.0	15-17	0.78	0.15
	Cann	26	15.2	14-17	0.94	0.18
	All	53	15.6	14-17	0.95	0.13
Morphometrics						
In S.L.						
Head	Swan	25	4.0	3.6-4.3	0.16	0.03
	Cann	24	4.4	4.1-4.8	0.18	0.04
	All	50	4.3	3.6-4.8	0.39	0.06
Pec. Lth.	Swan	25	6.5	5.7-7.7	0.45	0.09
	Cann	24	6.9	5.8-7.8	0.49	0.10
	All	50	6.7	5.7-7.8	0.51	0.07
H. max.	Swan	25	6.8	6.3-7.9	0.38	0.08
	Cann	24	6.3	5.5-6.9	0.35	0.07
	All	50	6.6	5.5-7.9	0.45	0.06
H. min.	Swan	25	14.9	10.4-17.0	1.31	0.26
	Cann	24	15.2	12.0-16.6	1.00	0.20
	All	50	15.0	10.4-17.0	1.16	0.16
$Sn\text{-}OD_1$	Swan	25	2.1	2.0-2.3	0.08	0.02
	Cann	24	2.2	2.0-2.3	0.08	0.02
	All	50	2.2	2.0-2.3	0.16	0.02
$Sn\text{-}OD_2$	Swan	25	1.5	1.4-1.5	0.03	0.01
	Cann	24	1.4	1.2-1.5	0.04	0.01
	All	50	1.4	1.2-1.5	0.04	0.01
Sn-OV	Swan	25	2.4	2.2-2.6	0.08	0.02
	Cann	24	2.5	2.3-2.7	0.10	0.02
	All	50	2.4	2.2-2.7	0.10	0.01

CHARACTER	TYPE	N	MEAN	RANGE	S.D.	S.E.
Sn-TV	Swan	25	1.9	1.7-2.3	0.10	0.02
	Cann	24	1.9	1.8-2.0	0.06	0.01
	All	50	1.9	1.7-2.3	0.08	0.01
Sn-OA	Swan	25	1.5	1.4-1.6	0.03	0.01
	Cann	24	1.5	1.4-1.6	0.04	0.01
	All	50	1.5	1.4-1.6	0.04	0.01
In Head						
Eye	Swan	25	2.6	2.2-3.0	0.20	0.04
	Cann	24	2.8	2.0-3.5	0.34	0.07
	All	50	2.6	2.0-3.5	0.30	0.06
Post. Orb.	Swan	25	2.6	2.3-2.9	0.13	0.03
	Cann	24	2.6	2.2-2.9	0.14	0.03
	All	50	2.6	2.2-2.9	0.15	0.03
In Eye						
Snout	Swan	25	1.8	1.3-2.7	0.30	0.06
	Cann	24	1.6	0.9-3.0	0.69	0.14
	All	50	1.7	0.9-3.0	0.51	0.18
Premax.	Swan	50	1.0	0.8-1.2	0.08	0.02
	Cann	50	1.1	0.9-1.4	0.11	0.01
	All	100	1.1	0.8-1.4	0.15	0.02
In Pupil						
Long. Gil.r.	Swan	50	1.3	0.6-1.5	0.11	0.02
	Cann	50	1.2	1.0-1.5	0.12	0.02
	All	100	1.2	0.6-1.5	0.12	0.02
In Anal						
D_2	Swan	25	1.2	0.8-1.5	0.18	0.03
	Cann	24	1.2	1.0-1.8	0.17	0.03
	All	50	1.2	0.8-1.8	0.16	0.02

TAXONOMIC CHARACTERS FOR *A. PRESBYTEROIDES*

CHARACTER	N	MEAN	RANGE	S.D.	S.E.
Meristics					
Scales					
Midlateral	51	42.7	41-45	1.12	0.16
Transverse	51	6.8	6-7	0.43	0.06
Predorsal	51	15.2	12-18	1.03	0.14
Interdorsal	51	7.2	6-9	0.80	0.11
Fin counts					
1st Dorsal	51	7.2	5-9	0.77	0.11
2nd Dorsal	51	12.1	10-14	0.72	0.10
Anal	51	13.3	11-15	0.80	0.11
Pectoral	51	12.4	11-15	0.75	0.10
Other counts					
Gill Raker	51	17.0	16-19	0.79	0.11
Morphometrics					
In SL					
Head	58	4.5	4.1-5.3	0.27	0.04
Pec. Lth.	58	6.5	5.6-7.6	0.36	0.04
H. max.	58	6.7	5.4-8.0	0.39	0.05
H. min.	58	16.1	13.7-21.7	1.22	0.16
Sn - OD_1	58	2.2	2.1-2.5	0.08	0.01
Sn - OD_2	58	1.5	1.4-1.6	0.03	0.01
Sn - OV	58	2.4	2.2-2.6	0.10	0.01
Sn - TV	58	1.9	1.8-2.3	0.07	0.01
Sn - OA	58	1.5	1.5-1.8	0.05	0.01
In Head					
Eye	58	2.8	2.2-3.4	0.30	0.04
Post. Orb.	58	2.6	2.4-3.3	0.21	0.03

CHARACTER	N	MEAN	RANGE	S.D.	S.E.
In Eye					
Snout	58	1.5	1.0-2.0	0.26	0.04
Premax	40	1.0	0.8-1.2	0.08	0.01
In Pupil					
Long. Gil. r.	40	0.9	0.6-1.1	0.11	0.02
In Anal					
D_2	58	1.2	1.0-1.5	0.11	0.02

TAXONOMIC CHARACTERS FOR *A. ELONGATA*

CHARACTER	N	MEAN	RANGE	S.D.	S.E.
Meristics					
Scales					
Midlateral	38	38.3	35-41	1.43	0.23
Transverse	38	7.7	7-8	0.45	0.07
Predorsal	38	14.9	13-17	0.94	0.15
Interdorsal	38	6.6	5-8	0.64	0.10
Fin counts					
1st dorsal	38	6.7	6-8	0.56	0.09
2nd dorsal	38	10.7	10-12	0.52	0.08
Anal	38	11.9	11-13	0.57	0.09
Pectoral	38	12.8	11-14	0.81	0.13
Other counts					
Gill Raker	38	13.2	12-15	0.72	0.12
Morphometrics					
In SL					
Head	50	4.1	3.7-4.5	0.17	0.02
Pec. Lth.	50	7.1	5.9-8.4	0.54	0.08
H. max.	50	6.6	5.8-7.5	0.39	0.06
H. min.	50	15.3	13.5-17.6	0.85	0.12
$Sn\text{-}OD_1$	50	2.2	2.0-2.4	0.07	0.10
$Sn\text{-}OD_2$	50	1.5	1.4-1.5	0.03	0.01
Sn-OV	50	2.3	2.1-2.4	0.06	0.01
Sn-TV	50	1.8	1.7-2.3	0.08	0.01
Sn-OA	50	1.5	1.4-1.6	0.03	0.01
In Head					
Eye	50	3.2	2.4-4.8	0.51	0.07
Post. Orb.	50	2.4	2.0-2.8	0.19	0.03

CHARACTER	N	MEAN	RANGE	S.D.	S.E.
In Eye					
Snout	50	1.2	0.9-1.9	0.25	0.04
Premax.	40	1.0	1.0-1.5	0.08	0.01
In Pupil					
Long. Gil.r.	40	0.9	1.4-2.7	0.02	0.02
In Anal					
D_2	50	1.2	1.0-1.4	0.10	0.01

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