NOTES ON THE BIOLOGY OF THREE SPECIES OF THE GENUS RHABDOSARGUS FOWLER, WITH SPECIAL REFERENCE TO THE "WHITE STUMPNOSE", R.GLOBICEPS (CUVIER).

Thesis presented for the degree of
Master of Science.

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I95I.

CONTENT:

I. INTRODUCTION.

The Zoology Department of the U.C.T. has been making an ecological survey of South African estuaries. The plant and animal life of many estuaries has been studied in relation to physico-chemical conditions, and bottom fauna has been dealt with in great detail. Not much is known about the fish populations that occupy these estuaries. It was therefore decided that some information about typical estuarine fish might be of use.

For the first four months nettings were made at two estuaries near Cape Town (Milnerton and Hermanus Lagoons) and the stomachs and gonads of all the species of fish caught were examined. This gave a general idea of the feeding habits of the species present, and it was realised that more useful results would be obtained if after this the general biology of one or two typically estuarine fish was investigated in more detail.

The genus Rhabdosargus Fowler was chosen. All three members of this genus, R.globiceps (Cuvier), R.tricuspidens Smith, and R.sarba (Forskal) occur in South African estuaries, and are very suitable for study for various reasons;

a) In almost all estuaries from Walvis Bay to Natal at least one species of the genus is found, and often in large numbers.

b) In the estuaries studied the major portion of the fish fauna is made up of marine species that are tolerant of estuarine conditions. All the species of Rhabdosargus fall under this category.

c) Two of the species (R.globiceps and R.tricuspidens) are found in estuaries within easy reach of Cape Town, and samples of all the species could be obtained from the estuaries that were being visited by the Zoology Department.

Rhabdosargus globiceps (Cuvier), the "white stumpnose", ranges from Walvis Bay to Durban (Barnard I927), being abundant on the West and South Coasts, and occurring in lesser numbers up the East Coast. Juveniles commonly enter estuaries, but fish over about I50 mm. seem to prefer the sea. The "white stumpnose" is of considerable economic importance as a food fish. Shore netters take great hauls of them on occasion at Langebaan (Biden I930), Blaauwberg, Hout Bay, Fishoek, and Muizenberg. Line boats make fairly regular catches in False Bay throughout the year, especially from May to October in shallow water at night. Trawlers net them on the Agulhas Bank down to 40 fathoms, and they are also an important angling fish on the West and South Coasts. The largest record is 500 mm., about IO lbs. (Smith I949).

Rhabdosargus tricuspidens Smith, the "silvie", is also restricted to South African coasts, being found from the Cape Peninsula to Zululand. Although of fair importance as an angling fish, it does not occur in such large numbers as R.globiceps, and is not of economic importance. The "silvie" is often abundant in estuaries, both juveniles and adults being present. It grows to 350 mm. (about 4 lbs.) (Smith, 1949).

Rhabdosargus sarba (Forskal), the "yellow-fin bream", is the only member of the genus without such a restricted range, being found over the whole Indo-Pacific region, and coming down our East Coast as far as Knysna. It grows up to at least 450 mm. (about 7-8 lbs.), and is an important angling fish on the Natal coasts. It is not of economic importance in South Africa. No Japanese, Chinese, or Indian notes are available on R.sarba, but in Australia this species (called the "tarwhine" or "silver bream") is present in fair numbers, is caught by anglers, but is not of economic significance.(Munro 1949). Both adults and juveniles commonly enter estuaries.

Legend to Figure I.

<u>Rhabdosargus globiceps</u> (Cuvier).

Actual size .....I60 mm.

These three species each seem to be dominant at different regions along the coast, overlapping generously with the species alongside. <u>R.globiceps</u> is the only member of the genus on the West Coast, and is also found on the South Coast overlapping with <u>R.tricuspidens</u>. From Knysna to about Durban <u>R.tricuspidens</u> is the commonest of the three species, and north of this <u>R.sarba</u> is present in greater numbers.

The differences between the three species are small. Differences in coloration and barring, teeth, and the presence or absence of scales on the preopercle flange are mentioned by authors (Barnard I925, Smith I945), as well as some slight differences in body shape. As the teeth of the three species have never been figured before it is of interest to show them here, (see Fig.2).

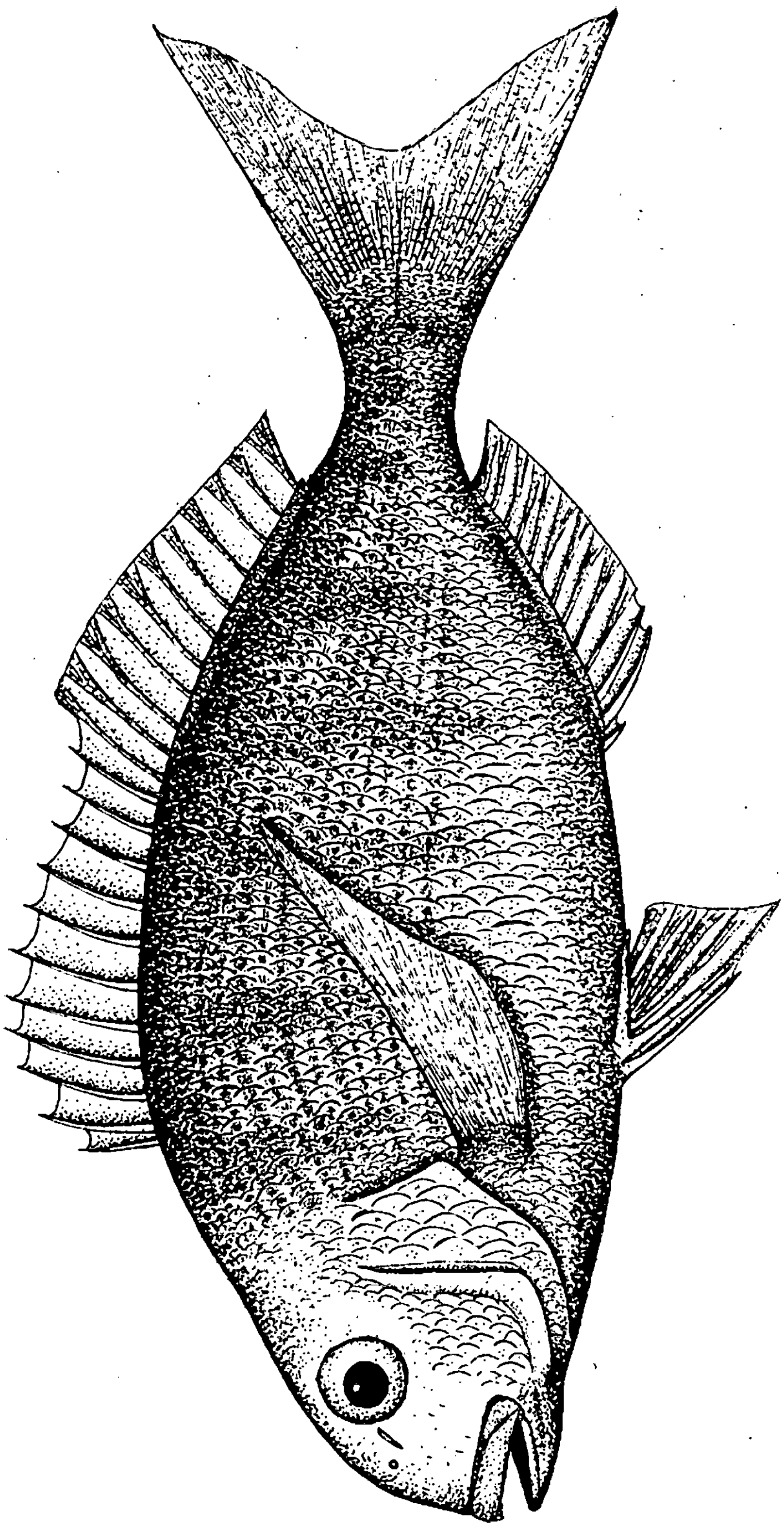


Figure 2.

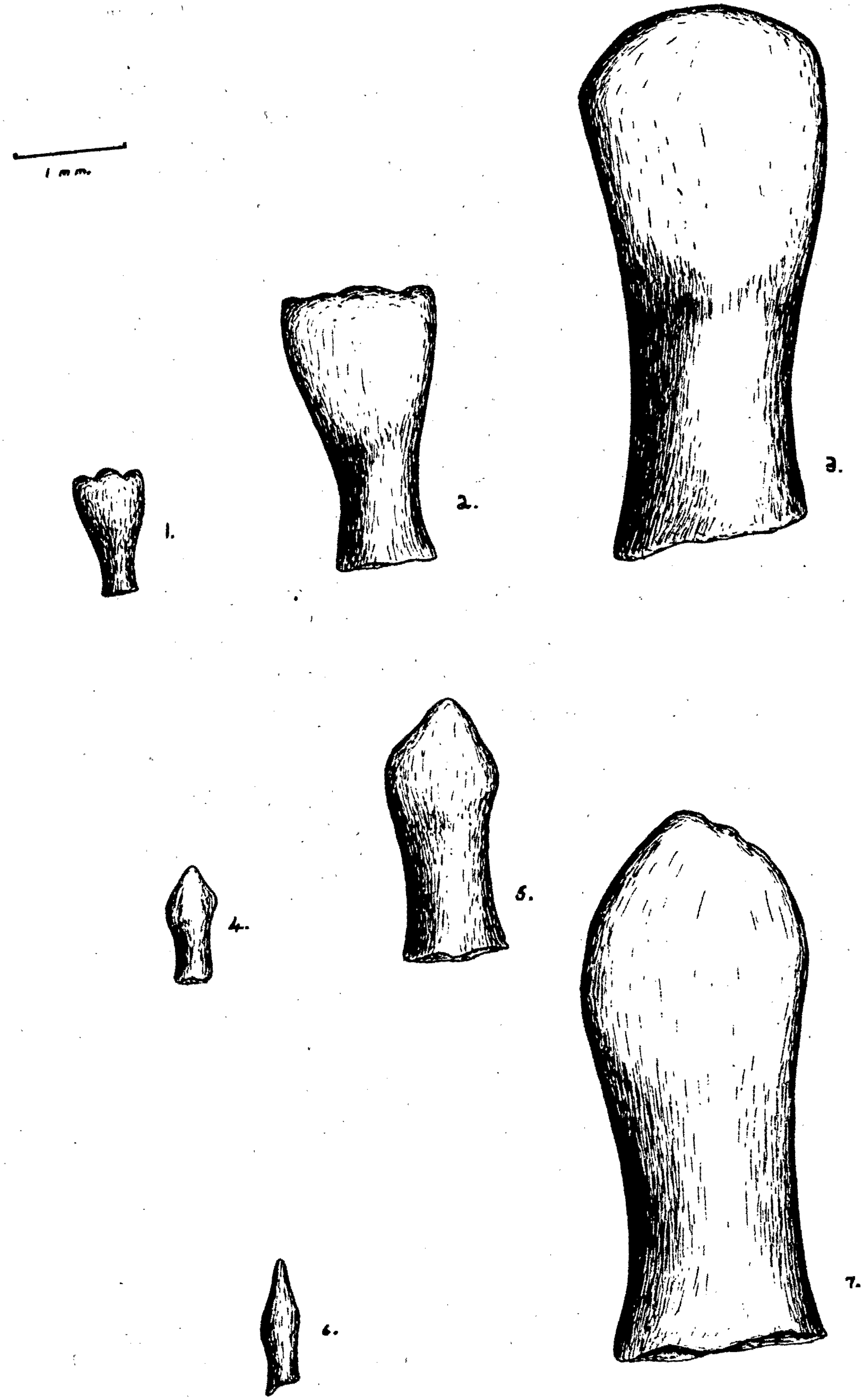
Upper middle incisors of different sized fish of the three species of *Rhabdosargus*.

I. *R. tricuspidens* 35 mm.
2. *R. tricuspidens* I30 mm.
3. *R. tricuspidens* I93 mm.

4. *R. sarba* 5I mm.
5. *R. sarba* 94 mm.

6. *R. globiceps* 35 mm.
7. *R. globiceps* I70 mm.

x 20 approx.


1 mm.
1.
2.
3.
4.
5.
6.
7.

R.tricuspidens is unbarred, the preopercle flange has a few hidden scales, and a golden stripe can usually be seen running along the side of the body just below the lateral line. Juveniles have tricuspid teeth, as can be seen in Fig.2 (I), the sketch of a front upper incisor of a 35 mm. fish. When the fish have reached a size of about I30 mm. the cusps have become much worn, and usually chipped. Fish larger than this show little or no sign of cusps, and a rather broad, spatula-like tooth results.

R.sarba has no, or at most very faint, cross barring, the preopercle flange is naked, and a yellow mark at the base of the pelvic fins running back for about an inch is found in larger fish. The teeth in juveniles (Fig.2 (4)) have a fairly distinct triangular head, but become more peg-like when worn down in the adult,(Fig.2 (5).)

R.globiceps has about seven strong crossbars, and the preopercle flange is naked as in R.sarba. Juveniles have very sharp pointed incisors, but these become worn to pegs very much like those of R.sarba in adults. The adults of these two species could probably not be told apart by the shape of the teeth. For the juveniles of all three species the teeth are the best characters for identification.

Little former work on any of the species of Rhabdosargus has been done. Biden (I930) in his popular book " The Sea-Angling Fishes of the Cape" has devoted a chapter to the "white stumpnose", giving notes on angling, economic importance, and a few records of gonad condition and food organisms found in stomachs by anglers. Gilchrist (1904) in a paper on the development of some South African fishes describes successful fertilisation experiments carried out on this species, and gives details of the subsequent developmental stages observed.

Munro (1945) has described some postlarval stages of R.sarba from Australia, and in a personal communication has stated that no work on the biology of this species has been done in Australia, India, China, or Japan.

Many interesting problems were then in need of study:

a) Feeding. What are the foods of these species inside and outside estuaries ? Is there a change in food with size ? Do seasonal changes in food occur ?

b) Breeding. When do these fish reach maturity ? Do they spawn inside or outside estuaries ? When are the spawning seasons ?

c) What is the rate of growth of these species ? Why are large fish never found in estuaries? Is the rate of growth the same inside and outside the estuaries ?

d) How do salinity and temperature changes in the estuaries effect the distribution of the fish ?

e) As these are typical estuarine fish can information obtained about them be used to understand the habits of other members of the estuarine fish fauna.

Hermanus and Milnerton Lagoons, from which most of the R.globiceps and some of the R.tricuspidens were obtained are in one respect not typical estuaries. Each year the mouth is dug open after the winter rains, and closes again in summer, probably from wave action. Although many estuaries along the coasts are open and closed periodically, this does not happen with such regularity. An estuary may remain closed for three years before exceptional winter rains open it.

In the following account R.globiceps, which could be easily and regularly obtained, is dealt with in detail, and notes on R.sarba and R.tricuspidens are given.

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2. METHODS.

a) Obtaining Samples.

For the general description of the feeding habits of estuarine fish two nettings were made at Milnerton and Hermanus Lagoons in April and May 1950 respectively, and records obtained by Ecological Survey excursions have also been used.

Rhabdosargus globiceps were obtained from regular nettings at Hermanus and Milnerton Lagoons during I950 and I95I. From January to July I95I monthly samples of fish were bought from Kalk Bay line boats, but in May and June the line boats left for the snoeking season at Hout Bay. Fish were also obtained from trawling off Cape Infanta, from an Ecological Survey excursion to the Breede River estuary, and from angling, (See Table I.)

Table I.

Place and Date.	Caught by.	No.Fish Measured	No.Fish. Opened.	Size Range.
Hermanus Lagoon, May'50-July'5I.	L.seine	I,I66	37I	52-I54mm.
Hermanus Lagoon, Jan.,Feb.,March, April,I95I.	Drag net.	I2	I2	27-I05mm.
Milnerton Lagoon, April'50-June'5I.	S.seine	63I	238	28-98mm.
Breede R.Estuary, July I95I.	All nets	44	44	35-I24mm.
Kalk Bay, Jan.,-July'5I.	Hand Lines	4I	4I	I28-300mm.
Cape Infanta, July'50,July'5I.	Trawl at 30 fathoms	5	5	I28-260mm.
Millers Point, May I95I.	Angling	6	6	200-320mm.
Buffels R.Mouth, July I95I.	Angling	-	6	300-350mm. approx.

For description of nets see below.

Rhabdosargus tricuspidens was obtained in small numbers from the following places: Hermanus Lagoon (62 fish), Milnerton Lagoon (3 fish),(from regular nettings during I950 and I95I,)and from a number of surveys by the Zoology Department to the following estuaries, St.Lucia (January'5I), Richards Bay (January'5I), Durban Bay (July'50 and July'5I), Bushmans River (September'50), Knysna (January'5I), Great Brak River (May'50), Breede River (July'5I). The total number of records of fish is 275.

R.sarba was obtained from Ecological Survey trips to the following estuaries; St.Lucia (January'5I), Richards Bay (January'5I), Durban Bay(July'50 and January'5I). The total number of records is I75.

Nettings at Hermanus and Milnerton Lagoons were made with three nets, the Large Seine, the Small Seine, and the drag net. All of these nets are more or less selective, none giving a true random sample of a fish population.

i) The Large Seine.

This is a seine of English design which is weighted to sink when pulled, so that it covers the bottom, and does not float as do the seines of commercial fishermen used for shore and estuary netting in this country. It is I52 ft. in length, has a purse of I9 ft., being 5 ft. deep in the wings and 7 ft. deep at the purse. The mesh of the wings is I½ inch bar, and that of the purse ¾ inch bar. To either end of the

Figure 3.

Packing the Large Seine.

Figure 4.

Throwing the purse.

net are attached to ropes of 250 ft.

The net is most efficiently worked with four persons. It is first packed on a boat, (see Fig.3). One of the ropes is held ashore and the boat is rowed out at right angles to the shore. When the net is reached the boat is rowed in a U shaped curve while the net is laid. The purse will lie in the middle of this U, and must be cast clear to prevent it lying over and fouling the net,(see Fig.4). The boat is then rowed ashore while the second rope is payed out, and the two ropes are pulled till the net reaches the shore. The head and foot ropes of the net are then pulled separately . In Fig.5 the net has just been reached, and as soon as the end of the net is clear of the water the head and foot ropes will be pulled sepatately.

The Large Seine was used at Hermanus Lagoon. Its sampling error effects a) species of fish that swim upward when distrubed, b) fish fast and wary enough to swim round the net, and c) fish small enough to slip through the mesh. Liza ramada and Mugil cephalus must often escape by swimming over the net. Hypacanthus amia and Pomatomus saltator being typically fast pelagic fish should often be able to swim over or round the net. Fish between 60-80 mm. must start slipping through the mesh. For Rhabdosargus sp. it is an excellent net, for they are bottom feeders, and not (if one may judge by their shape) extremely fast swimmers .

Figure 5.

Landing the Large Seine.

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ii) The Small Seine.

This is a much smaller net than the above, being 40 ft. in length, 4 ft. deep at the wings, and 6½ ft. deep at the bunt. Unlike the large seine it has no long purse, but has a slight belly of about 6 ft. The mesh is ½ inch bar. The Small Seine is pulled by two persons without ropes, and is therefore limited to water that is shallow enough for wading, (about 4½ ft.)

Figure 6.

The Small Seine.

The Small Seine was used at Milnerton Lagoon, as the Large Seine dug into the soft muddy bottom. The Small Seine has considerable netting error. Larger fish have often been seen to swim out of the net due to the slow pulling, and smaller fish, probably of about 30 mm. and below are able to slip through the mesh.

iii) The Drag Net.

This is a small triangular net pulled by two persons. Short ropes (IO ft.) are attached to each end of the mouth, which is 6 ft. 9 inches wide. The depth at the mouth is I5 inches, and the length of the net I0 ft. The net has retaining flaps half way down its length, helping to keep in fish already caught. The mesh is ½ inch bar. The upper side of the mouth is corked, and the lower attached to a length of chain. The net is simply a trawl (originally intended to be kept open with a beam) that has been put to a different use. It is ideal for dragging through Zostera and Ruppia beds, for the chain prevents the net rolling up, which occurs with the small seine for instance. The people working the net pull slightly apart to keep the mouth open.

This net was used at Hermanus Lagoon first in January I95I, and for the following three months. After this the water became too high for wading over the Zostera beds, a nd it was found to catch no Rhabdosargus over the sandy shallows. The net is very selective. Large fish tend to escape for those pulling the net walk fairly near the region to be netted before the net gets there. The upper limit of catching was usually about 60 mm., and the lower 30 mm. It is a useful net when used in conjunction with the Large Seine, but there is probably still a netting gap between these nets.

In conclusion we can say that netting was probably efficient at Hermanus Lagoon above about 70 mm. for Rhabdosargus, but not below this, and at Milnerton between about 40 mm. and I00 mm.

b) Preserving Fish.

In opening fish brought back from Ecological Survey field trips it was found that the contents of the body cavity were often so decayed as to be impossible to study, whereas others that had perhaps been kept for a year or more were in excellent condition. An experiment was made to find an efficient method of preventing decay, and if possible of preventing the digestive juices from working long after the fishes were netted.

Different methods of preservation were tested on some *Gobius nudiceps*, kept in an aquarium. The fish were starved for some time, and then fed on quantities of mosquito larvae. Some fish were preserved immediately in different strengths of formalin and alcohol, with or without the abdominal cavity being opened. Others were left for 24 hrs. before preserving, being placed in a cool place after being killed. It was found that I) immediate preserving, 2) strong formalin, and 3) opening the abdominal cavity helped prevent excessive decay.

In sampling at Hermanus and Milnerton Lagoons fish were preserved a few hours after catching, being thrown into strong formalin (about20%) after an incision had been made in the wall of the abdominal cavity.

c) Working Through Samples.

P.T.O.

c) <u>Working Through Samples.</u>

At the monthly nettings the numbers of the different species caught, and their maximum and minimum sizes were recorded, and if possible the fish were returned alive to the water. The measurement of length was made to the base of the caudal peduncle.

All *Rhabdosargus* were kept and preserved in the manner described (page I5). In the laboratory the lengths and weights of all the fish were taken, and a random sample of 30 fish opened.

The different food organisms, and the number of each organism present, were noted. Gonads were weighed, and the gonad described, if male as "milky" or "not milky", and if female the colour of the ovary, and the diameter of the ova recorded. Parasites in the gut were also recorded.

Four or more fish of different sizes from each sample were selected, and the supra-occipital crest, one otolith, and a number of scales removed and kept dry in paper packets.

Scales were taken from beneath the pectoral fin, as these scales are large, and being in a protected place are seldom regenerated. They were examined using the method of Lea (I9I9) and Graham (I929), taken from Blackburn (I949). The scales were left for six or more hours in 2% sodium peroxide, and then put into a 2% solution of sodium sulphite for a few minutes, rubbed with the fingers to remove any adhering skin, and then pressed on to a slide with some blotting paper. The scale remains attached to the slide for some minutes, and can be projected on a screen in a dark room and observed. Large scales do hot adhere to a single slide and were placed between a pair of slides.

The supra-occipital crests were examined dry under a dissecting microscope with side lighting against a dark background.

Otoliths were removed by cutting down through the skull on one side of the midline in small fish. Larger fish were more difficult to deal with, and a diagonal cut from the posterior end of the operculum of one side of the fish to the eye of the opposite side was easier. Some otoliths showed rings when examined under water with side lighting against a dark background, but others had to be ground. This was done with powdered glass as an abrasive against a ground glass plate. It was then examined under water as before, or with just the ground face moistened.

d) <u>Sources of Error.</u>

In all experiments where a sample is taken as representative of a whole population there is a certain amount of error in the results purely due to chance. This is greater the smaller the sample. In sampling a fish population of unknown size it is very difficult to know how much this sampling error is affecting the results.

Error in Length-Frequency Graphs. From the uniformity of the length-frequency graphs for *R.globiceps* at Hermanus Lagoon over a length of about 80 mm. it would seem that the samples are not greatly affected by numerical error. Below this size the graphs are not representative, and possibly modes of fish below about 60 mm. may be completely missing. At Milnerton probably only the January, February and March samples are representative.

Error in Assessing Monthly Changes in Feeding. The accuracy of 30 fish as a sample at Hermanus and Milnerton Lagoons is difficult to assess. Small fluctuations in the monthly percentage occurrence of food items may be due to chance, and not reflect an actual change in the feeding of the population. Only the more definite changes in the percentages can be considered as indicative of an actual change of diet in the population.

The occurrence of an Acanthocephalan parasite (see page 76) is of interest in connection with sampling error. One to about five of these parasites are found firmly attached to the rectum of about 20% of *R.globiceps* at Hermanus. The following are the percentages of fish that contained these parasites in the monthly samples:-

November 1950	December	January	February	March 1951	April	May.
20%	16%	46%	16%	40%	34%	14%

If it is assumed that at least during the period in which the vlei was closed to the sea (February to May) the percentage of fish that contained these parasites did not fluctuate violently, some interesting conclusions follow. This does not seem to be an unreasonable assumption, for the adult attached parasite is non-motile, and if fish were being infected through a crustacean food organism one would expect the increase in the percentage of parasitised fish to be fairly even. There was probably no loss of parasitised fish through deaths, as fish containing parasites seemed to be in excellent condition. If through some other cause the number of parasitised fish was being reduced (for instance through death of parasites) one would again expect this to be a fairly consistent change. The monthly percentages show violent fluctuations, however. If our assumption that the total percentage of parasitised fish in the vlei is fairly constant is correct, these fluctuations must be due to sampling error.

This can be utilised in studying the monthly percentage of a food item. If a certain food item is present over a period of months in exactly 20% of fish, and monthly samples of the population were taken, we could expect fluctuations similar to those in the number of parasites, and these would not be showing changes in the feeding of the population.

It must be realised then that only very marked changes in monthly percentages of food organisms can be considered as changes in feeding.

e) <u>Marking Experiment.</u>

An attempt was made to estimate the population of *Rhabdosargus globiceps* in Hermanus Lagoon, using the Peterson Method (Scott 1949). By this method a certain number of marked individuals are released into the population, and the population then sampled at a later date. The number of fish is estimated by multiplying the number of released individuals by the ratio of marked to unmarked fish in the later sampling.

As opercular or other tags would have had to be imported a simple but adequate method of marking was devised. Short pieces (5 mm.) of fine silver wire were numbered with various combinations of fine cross cuts. One end of the wire was marked by flattening it, and a scratch one tenth of the way along the wire from this end represented one digit, two tenths along represented two digits, and so on to nine tenths. Tens were two scratches close together, and hundreds three scratches close together. This method would become cumbersome if large numbers of fish were to be marked, for no number with more than one of the same numeral can be represented. For the two hundred fish that were marked, however, it was easily workable.

The marking was made in the beginning of March, 1951, and three normal monthly samples were made after this before the mouth of the lagoon opened in June. No marked fish were recoverd. The marking was also advertised in the local Hermanus newspaper, notices placed at various points, and both commercial fishermen and anglers contacted with the help of Mr. Ion Williams, well known in the town. No reports of marked fish being caught were received.

It is possible that marked fish were handicapped by the tags, which were secured at the base of the spiny dorsal, and so were unable to escape predators, or that marked fish had a heavy mortality. This does not seem likely however, for the tags seemed to offer little resistance to the fishes movements, and the small incision at the base of the fin would harm the fish no more than the method of tagging with wire through the body widely used in America.

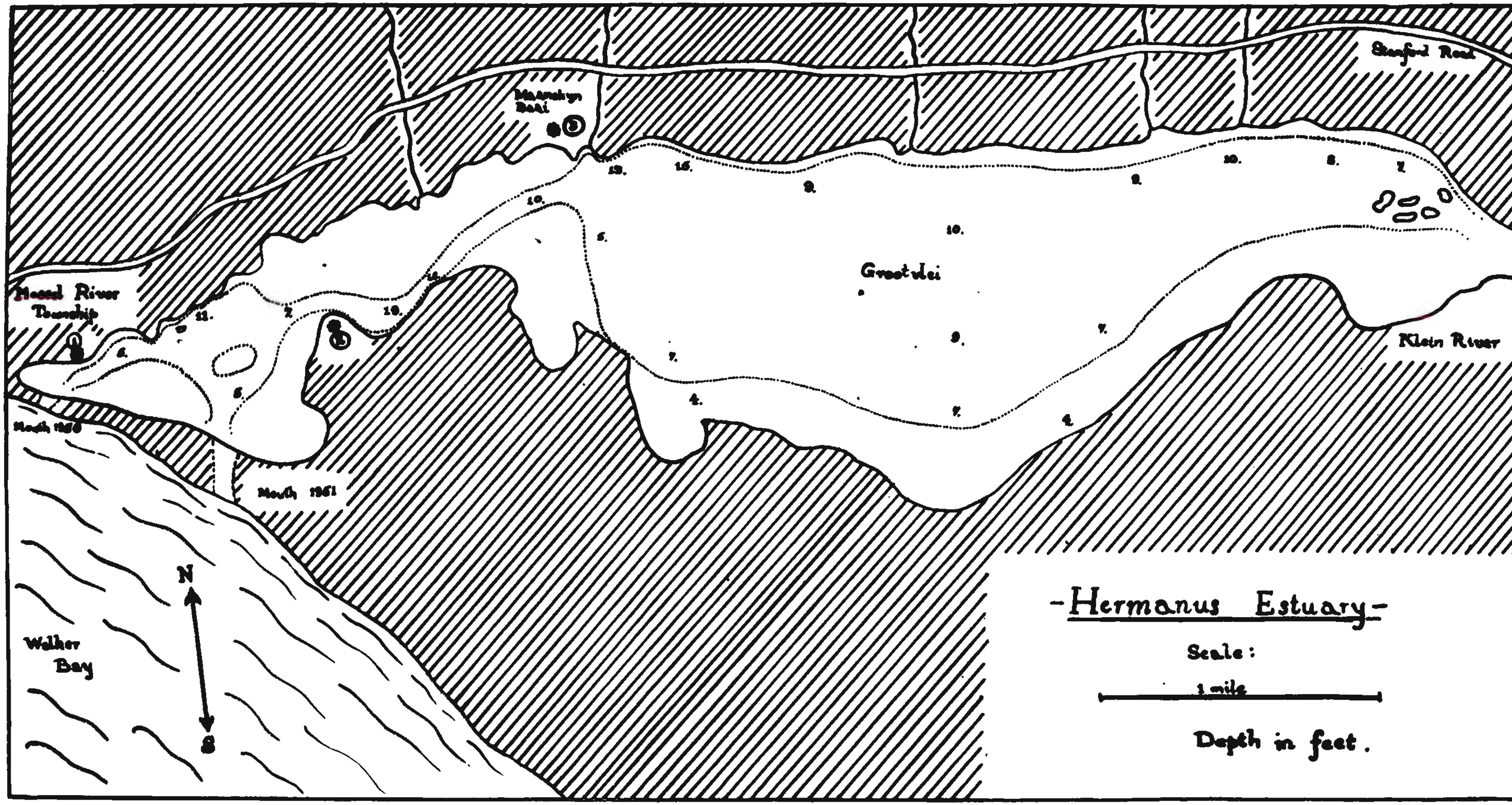
478 fish were taken from the vlei before it opened without obtaining one marked fish. If one fish had been recovered the estimated population would be about 100,000. As no fish were caught the estimated population is higher than this. Where so few (in this case no) fish are recovered such an estimate does not have much value, however. Many more than two hundred fish would apparently have to be marked to get a useful estimate.

f) <u>Nomenclature.</u>

Fish nomenclature throughout is from Smith (1949).

Figure 7.

Hermanus Estuary


Stanford Road
Mossel River Township
Mouth 1961
Grootvlei
Klein River
Walker Bay
N
S
-Hermanus Estuary-
Scale:
1 mile
Depth in feet.

3. HERMANUS LAGOON.

a) Description.

A detailed description of this lagoon and its bottom fauna has been made by Scott, Harrison, and Macnae (in press) so only a short description will be given here.

This estuary lies in the curve of Walker Bay, about 80 miles to the east of Cape Town. It is formed by the Klein River, and a few small streams coming from the mountains on its western edge. It forms a lake about six miles long and at most half a mile wide, with an average depth of about 8 ft. in summer, and a few feet greater in winter when the lagoon is full of flood water. Depths up to 19 ft. have been recorded from the channel, (see Fig.7).

When in the summer months little water is entering the vlei a sand bank is built up at the mouth (probably mainly by wave action) and the vlei becomes land locked. The levels usually drop slightly during the summer as water is evaporated, and then starts filling with the winter rains. When the increase in extent of the lake interferes with farming operations the mouth is cut open. At first a narrow man-made channel, the mouth soon becomes wide as the mass of water pours out, and the lagoon becomes tidal for most of its length. The mouth then gradually closes, taking usually about five months. There are thus fairly regular periods every year during which the mouth is open and shut. During I950 and I95I when this study was taking place the state of the mouth was as follows:-

	Mouth Shut	Mouth Open
I950;	February - September	October - January('5I)
I95I;	February - June	July onward.

Both the flora and the fauna of the lagoon are rich. Beds of Zostera marina, Ruppia maritima, and filamentous algae shelter and feed abundant life. Animals such as the small gasteropod Assiminea sp., the pelecypod Modiola capensis, the amphipods Corophium triaenonyx and Melita zeylanica, and Chironomid insect larvae are abundant in areas of the weed beds. Callianassa kraussi is found in muddy sand in the shallows and along the edges of the lagoon, and in the firmer sand of the mouth Solen capensis forms rich beds.

The lagoon has therefore the main elements to support a very rich fish fauna; both plant and animal foods in abundance, and cover from enemies.

Two stations were chosen for regular netting at Hermanus Lagoon,(see Fig.7). The region at the mouth, lying between asterisk (I) and asterisk (2) in Figure 7, was the first station, and Maanskyn Baai (asterisk (3)) was the second. The first therefore lay in the channel, and the second at the edge of the open vlei. A station higher up the lagoon would have been useful, but these two stations were just near enough to allow for a boat to be taken from one to the other and both to be netted thoroughly in one day.

b) Fish Fauna Present in the Lagoon.

Table II. is a list of species of fish netted in the estuary at Hermanus during the monthly samplings in 1950 and 1951. At least 20 of the 25 species found there were marine fish tolerant of estuarine conditions. Of the other five species *Gilchristella aestuarius*, *Atherina breviceps*, and *Psammogobius knysnaensis* seem to be found chiefly in estuaries, and *R. tricuspidens* and *Syngnathus acus* are possibly more estuarine than littoral in habit.

The fish in Table II. have been arranged very roughly into three groups, "abundant", "common", and "rare". A more accurate picture of relative abundance is not given by the sampling because:-

i) Smaller species get through the mesh of the Large Seine.

ii) The Large Seine catches bottom fish and tends to lose those fish that swim near the surface of the water.

iii) Fish going to the deeper water of the channels where the net could not reach would escape capture.

An unnexpected omission from this list is *Mugil cephalus*, a mullet common in estuaries both east and west of Hermanus. It is possible that this fish was present in

Table II.

FAMILY. Species and Author.	Size Range.	A.	C.	R.
RHINOBATIDAE.				
Rhinobatos annulatus Muller and Henle.	740 mm.			x
STOLEPHORIDAE.				
Gilchristella aestuarius (Gilchrist and Thompson).	38-50 mm.		x	
TACHYSURIDAE.				
Tachysurus feliceps (Valenciennes).	60-250 mm.		x	
SOLEIDAE.				
Heteromycteris capensis Kaup.	20-70 mm.		x	
Solea bleekeri Boulenger.	90-110 mm.		x	
SYNGNATHIDAE.				
Syngnathus acus Linnaeus.	61-155 mm.		x	
CARANGIDAE.				
Hypacanthus amia (Linnaeus).	225-530 mm.		x	
POMATOMIDAE.				
Pomatomus saltator (Linnaeus).	205-300 mm.		x	
SCIAENIDAE.				
Atractoscion aequidens (Cuvier).	220 mm.			x
POMADASYIDAE.				
Pomadasys olivaceum Day.	95-156 mm.			x
SPARIDAE.				
Rhabdosargus globiceps (Cuvier).	27-158 mm.	x		
Rhabdosargus tricuspidens Smith.	112-260 mm.		x	
Diplodus sargus Linnaeus.	70-105 mm.			x
Diplodus trifasciatus (Rafinesque).	70-100 mm.			x
Lithognathus lithognathus (Cuvier).	90-330 mm.	x		
Lithognathus mormyrus (Linnaeus)	75-170 mm.			x
Sarpa salpa (Linnaeus).	105-120 mm.		x	
Spondyliosoma emarginatum (Cuvier).	85 mm.			x

P.T.O.

Table II. (continued).

FAMILY. Species and Author.	Size Range.	A.	C.	R.
MUGILIDAE.				
Liza ramada (Risso).	?50-260 mm.	x		
ATHERINIDAE.				
Atherina breviceps Cuvier.	15-60 mm.		x	
GOBIIDAE.				
Psammogobius knysnaensis Smith.	27-50 mm.		x	
Gobius nudiceps Cuvier.	50-115 mm.		x	
CLINIDAE.				
Clinus superciliosus (Linnaeus).	62-110 mm.		x	
TRIGLIDAE.				
Trigla capensis Cuvier.	140-200 mm.			x
LAGOCEPHALIDAE.				
Amblyrhynchotes honkenii (Bloch).	120-145 mm.		x	

Fish netted in Hermanus Lagoon
during 1950 and 1951.
A..........abundant.
C..........common.
R..........rare.

---

the vlei and was not netted, for it is known for its habit of swimming, and sometimes jumping over nets. Perhaps as at Milnerton Lagoon it is present mainly in the upper regions of the estuary.

c) Distribution.

Seasonal movement to and from the estuary. Along the coastline many fish are known to have seasonal migrations, being more abundant, or only present, at certain times of the year. In an estuary, where there are big differences between summer and winter conditions, a change in fauna could be expected. At Hermanus, however, the lagoon is only open to the sea usually in spring and the first half of summer, and fish in the vlei when the mouth closes are forced to remain during the winter, when the estuary has low salinity, low temperatures, and often high turbidity.

In 1951 the mouth was opened earlier than usual, and the lagoon was connected to the sea in midwinter. The lagoon was muddy, and cold water was pouring out from exceptionally heavy rains. Scott, Harrison, and Macnae(op.cit.) have found that temperatures may go down to 12^{o} C. and salinities to 20 parts per thousand or less at times like this. In the june and July samples only the following species were netted;

Lithognathus lithognathus
Liza ramada
Solea bleekeri
Tachysurus feliceps

P.T.O.

Syngnathus acus
Clinus superciliosus
Gobius nudiceps
Psammogobius knysnaensis
Gilchristella aestuarius.

The most striking difference was that R.globiceps was entirely absent from the lagoon. It seems very unlikely that this species had migrated up the lagoon, for conditions there were, if anything, more severe. Probably they had migrated out to sea. The previous year the mouth was closed in midwinter, and the nettings contained R.globiceps in usual amounts. The fish seem then able to stand these winter conditions, but would migrate to escape them if the lagoon was connected to the sea. This may also apply to other species of fish that were found in the estuary, but which were rarely netted, so that no marked change in the nettings could be seen.

Some migration of large fish away from the lagoon and small fish to the lagoon must exist, at least with species such as R.globiceps and L.lithognathus where only immature fish are found within the estuary. This was shown for R.globiceps from length-frequency distribution before and after the mouth opened in 1950, (see page 40).

Difference in fish fauna between the Mouth and Maanskyn Baai. Little difference in fauna between Maanskyn Baai and the Mouth was found. Heteromycteris capensis seemed to be restricted to the mouth region, however. This may be due to

a) higher salinity at the mouth than Maanskyn Baai, for Scott, Harrison, and Macnae have shown that almost at all times a salinity gradient is present in the lagoon, b) the nature of the bottom, which is sandy at the mouth, but more muddy and weed-covered at Maanskyn, or c) that distribution of some food organisms may keep it at the mouth.

Daily movement of Tachysurus feliceps. It is well known among fishermen at Hermanus Lagoon that more "barbel" are caught in night than day netting. Gill nets laid in the lagoon during the day catch usually Liza ramada, Lithognathus lithognathus, and R.globiceps, but those laid during the night catch these species and also a great number of Tachysurus feliceps, hated by netters because of their poisonous spines. In netting at night at Maanskyn Baai in February 1951 the predominant fish was T.feliceps, although in exactly the same place a few hours before in daylight not one of this species was caught. During the day the fish are probably in deeper water where they were not reached by the sampling, but at night move into shallower water perhaps to feed.

d) General Note on Feeding.

As in any biotope plants form the basic food in the vlei. Few fish feed directly on vegetable matter, perhaps the only complete herbivore being the "mullet" Liza ramada, whose diet consists of diatoms and unicellular algae, which it crushes with an exceptionally muscular stomach filled with sand grains.

Rhabdosargus globiceps, R.tricuspidens, Sarpa salpa, and probably also Diplodus sargus and D.trifasciatus are omnivorous, cropping plants such as Zostera marina, Ruppia maritima, and filamentous algae (mainly Enteromorpha sp.), and also feeding on the small crustaceans, polychaetes, and small molluscs in the weed beds and on the bottom.

Lithognathus lithognathus, the "white steenbras", although taking vegetable matter occasionally, is mainly a carnivore, feeding on animals sheltering in the weeds, and also using its prognathous snout to suck or blow Callianassa kraussi and Solen capensis out of the sand.

The small "sole" Heteromycteris capensis and the "goby" Psammogobius knysnaensis are common on the sandy shallows near the mouth of the vlei. P.knysnaensis was found to contain ostracods, amphipods, and sphaeromid isopods, and the few Heteromycteris capensis examined had eaten ostracods and foramenifera protozoans. Solea bleekeri, the larger "sole" present in the lagoon, and not restricted to the mouth region, had a more varied diet, containing isopods, amphipods, Assiminea sp., and Modiola capensis.

Typical of the weed beds are Syngnathus acus, Clinus superciliosus, and Gobius nudiceps, the former sucking up amphipods and copepods with its ludicrously long snout, and the two latter having a varied diet of amphipods, sphaeromid isopods, Assiminea sp., and sometimes crabs and small fish.

The "whitebaits", Athorina breviceps and Gilchristella aestuarius, which are small, almost transparent fish, swim in shoals and feed on planktonic copepods and amphipods.

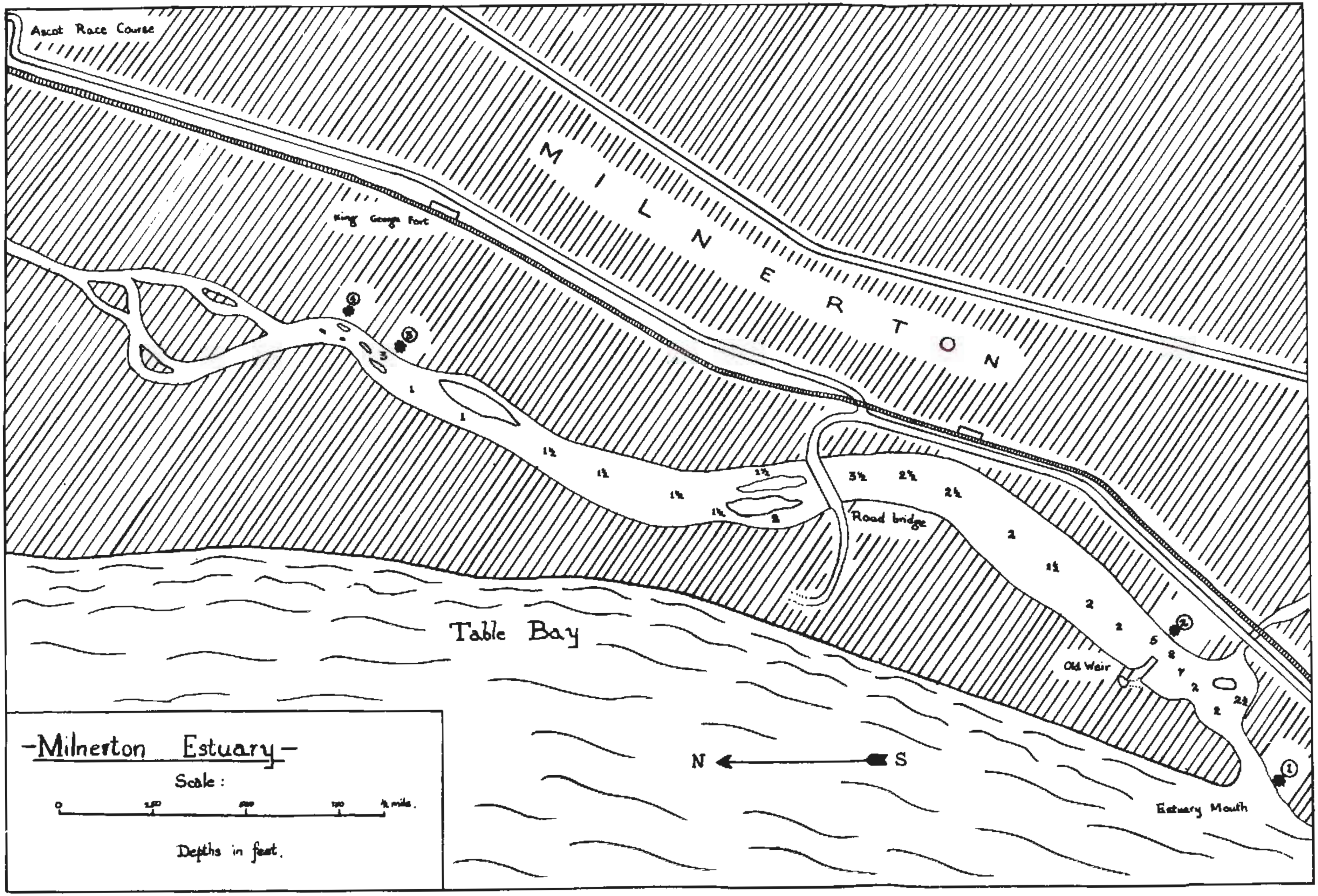
Two large fish predators were present in the vlei, the "leerfish" or "garrick", Hypacanthus amia, and the "elf" or "shad", Pomatomus saltator. They were only occasionally caught, but being exceptionally fast fish, and probably swimming near the surface, they may be present in greater numbers than is shown by Large Seine nettings.

Three species of cormorant, the "white breasted comorant" (Phalacrocorax neglectus), the "trek duiker" (Phalacrocorax capensis), and the "reed duiker" (Phalacrocorax africanus), were present on the vlei, as well as the "darter" (Anhinga rufa). These birds are all notorious fish catchers, but predation due to them cannot be very heavy, for a usual count during a days netting was only I2 - I5 birds.

It must be emphasized that the above note is based on the examination of very few fish. Much more work would have to be done to get a good general picture of the food relation of the whole lagoon fauna.

Figure 8.

Milnerton Estuary


Ascot Race Course
MILNERTON
King George Fort
Road bridge
Old Weir
Table Bay
N
S
Estuary Mouth
-Milnerton Estuary-
Scale :
0
½ mile.
Depths in feet.

4. MILNERTON LAGOON.

a) Description.

A detailed study of the estuary at Milnerton and the chemical and physical conditions that prevail there has been made by Millard and Scott (to be published shortly), so only a brief description will be given here.

Milnerton Lagoon lies in the curve of Table Bay, about five or six miles from Cape Town. The Diep River which forms it flows first into a fresh water vlei, which in winter harbours a large fauna of insect larvae, crustaceans and fresh water snails, and which dries up in summer. This vlei connects to the estuary proper by a shallow winding channel. The estuary is I½ miles long from the mouth to King George Fort, which is the limit of tidal influence, except at spring tides. This lower region, which is here called Milnerton Lagoon to separate it from the fresh water Rietvlei, is at most 300 yards across and shallow. The deepest part is 8 - IO ft. near the mouth, and King George Fort is about 3 ft. (see Fig.8).

The same periodic opening and closing of the mouth that was found at Hermanus Lagoon is found here. During the time that fish samples were taken from Milnerton the state of the mouth was as follows:-

P.T.O.

	Mouth Closed	Mouth Open
1950;	February - July	August - December
1951;	January - March	April - August.

Milnerton Lagoon is not as rich in plant life as Hermanus vlei. Ruppia maritima is is found in a few places but Zostera is absent. No quantitative sampling has been done at either estuary so it is difficult to compare the abundance of food organisms. Much more silt seems to flow into Milnerton estuary, however, and except for an area of muddy sand near the mouth the bottom of the lagoon is deep soft mud, a type of bottom which does not usually support an abundant macrofauna according to Percival (1929, from Day 1951). Near the mouth of Milnerton Lagoon there is an area richly colonised by Callianassa kraussi, and Chironomid larvae, isopods, and amphipods seem to abound.

Two stations were netted in the lagoon. The region called the "mouth" lies between asterisk (1) and asterisk (2) in Fig.8, and "King George Fort" between asterisk (3) and asterisk (4). Three samples were also taken from the Road Bridge.

The Large Seine was tried at Milnerton Lagoon, but because of the soft bottom the net could not be used, merely digging into the mud when it was pulled. The small seine was therefore used for sampling.

b) Fish Fauna Present in the Lagoon.

Table III. lists the species of fish netted in Milnerton Lagoon during 1950 and 1951.

Table III.

FAMILY. Species and Author.	Size Range.	A.	C.	R.
STOLEPHORIDAE.				
Gilchristella aestuarius (Gilchrist and Thompson).	30-60 mm.		x	
SOLEIDAE.				
Heteromycteris capensis Kaup.	45-60 mm.			x
POMATOMIDAE.				
Pomatomus saltator (Linnaeus).	70-145 mm.			x
SPARIDAE.				
Rhabdosargus globiceps (Cuvier).	28-115 mm.		x	
Rhabdosargus tricuspidens Smith.	63-87 mm.			x
Lithognathus lithognathus (Cuvier).	25-160 mm.	x		
MUGILIDAE.				
Mugil cephalus Linnaeus.	70-200 mm.	x		
Liza ramada (Risso).	?25-263 mm.	x		
ATHERINIDAE.				
Atherina breviceps Cuvier.	19-60 mm.		x	
GOBIIDAE.				
Psammogobius knysnaensis Smith.	22-55 mm.		x	
Gobius nudiceps Cuvier.	42-113 mm.		x	

Fish netted in Milnerton Lagoon during 1950 and 1951.
A.......abundant.
C.......common.
R.......rare.

The three species, _Atherina breviceps_, _Gilchristella aestuarius_, and _Psammogobius knysnaensis_ that have been considered as being the "estuarine element" in the fauna at Hermanus Lagoon are all common at Milnerton. _R.tricuspidens_, which was thought perhaps to favour estuaries more than the shore, is found very occasionally, being at the extreme end of its range. The "marine element" accounts for the remaining seven species, and includes the three species that are most abundant in the lagoon, _Liza ramada_, _Lithognathus lithognathus_, and _Mugil cephalus_.

In considering relative abundance it must be mentioned that larger and faster fish such as _Pomatomus saltator_ might be escaping the net, and be present in greater numbers than shown, and that any fish inhabiting water deeper than wading depth would not be netted.

A noticeable feature of the fish fauna at Milnerton Lagoon was that the majority of _R.globiceps_, _L.lithognathus_, _Liza ramada_, and _Mugil cephalus_ were extremely small in size. _R.globiceps_ usually averaged about 60 mm., a size rarely netted at Hermanus. Hundreds of _Mugil cephalus_, _Liza ramada_, and _Lithognathus lithognathus_ averaging about 100 mm. or less were caught. Average lengths for the latter two species at Hermanus are more usually about 200 mm.

This may in part be due to netting, but it is safe to say that in general the average size of _R.globiceps_, _Lithognathus lithognathus_, and _Liza ramada_ is much smaller at

Milnerton than Hermanus.

c) Distribution and Migrations.

Movement to and from the estuary. No seasonal migrations were shown by the nettings. Some movement of large fish away from, and smaller fish to the estuary must take place, however, for no mature or large fish of R.globiceps, Pomatomus saltator, and Lithognathus lithognathus were found.

Difference in fish fauna between the mouth and King George Fort. Most of the species netted seemed to be equally common at King George Fort and the mouth, but three species had a more uneven distribution. Heteromycteris capensis was restricted to the sandy region near the mouth of the lagoon. R.globiceps was common at the mouth, present at the Road Bridge, but never found at King George Fort. The mullet Mugil cephalus was abundant at King George Fort, but seldom caught at the mouth. (Discussed on page).

d) Note on Feeding.

The general picture is very similar to that at Hermanus Lagoon. Attached diatoms are eaten by the two mullets Mugil cephalus and Liza ramada, and Enteromorpha sp. and other filamentous algae are included in the diet of R.globiceps and to a lesser extent Lithognathus lithognathus.

Detritus feeding crustacea, such as Exosphaeroma hylecoetes and the amphipod Melita zeylanica, and Chironomid larvae form important foods for the carnivorous fish present.

Atherina breviceps and Gilchristella aestuarius, as well as the smaller R.globiceps and L.lithognathus, feed to a large extent on planktonic copepods and amphipods.

The fish predators present are Pomatomus saltator and two cormorants, the "trek duiker" (Phalacrocorax capensis) and the "white breasted cormorant" (P.neglectus).

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5. NOTES ON THE BIOLOGY OF RHABDOSARGUS GLOBICEPS.

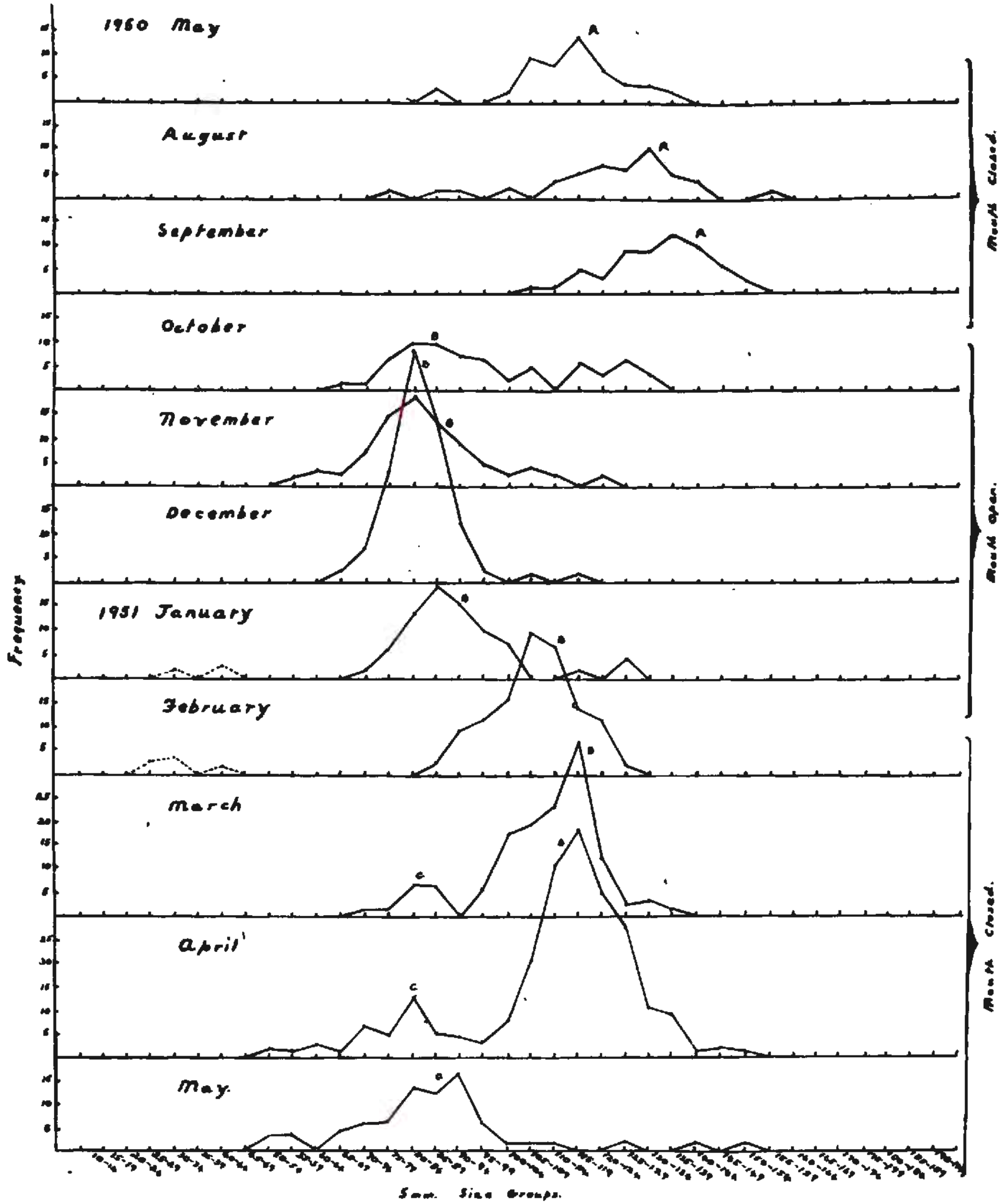
a) Length-Frequency Distribution in Hermanus Lagoon.

Length-frequency distribution curves were made for all the R.globiceps netted in Hermanus Lagoon, (see Fig.9). The Large Seine seems to start catching fish in quantity at a length of about 60 mm., and although fish smaller than this were present in the vlei (shown by the Drag Net catches of January and February 1951), they were not caught by the Large Seine. A 60 mm. fish can easily be pushed through the mesh of the wings of the net, so it is feasible that fish of about this size and below must be mostly lost. Movement of modes, caused in all probability by normal growth (see below) only occurs at about 80 mm., so probably only modes above this size are significant. From the regularity of the modes of

Figure 9.

Length-frequency distribution of *Rhabdosargus globiceps* netted in Hermanus Lagoon from May 1950 to May 1951.

Large Seine......unbroken line.
Drag Net..........dotted line.


1950 May
August
September
October
November
December
1951 January
February
March
April
May
Frequency
5mm. Size Groups.
Mouth Closed.
Mouth Open.
Mouth Closed.

most monthly samples they seem to be representing the normal distribution of a particular size group (or in some months more than one size group), which may be fish of the same years spawning, or perhaps just a small group that were spawned together.

It will be seen that some modes are far larger than others. This probably does not signify that more or less fish were present, for in netting it is found that six hauls may sometimes be made without catching one R.globiceps, and then 200 may be taken in one haul. The fish seem to shoal, so the chance netting of a shoal may greatly increase or decrease the height of a mode.

Two important changes in the monthly samples can be seen from Fig.9, i. modes tend to move to the right in successive months, and ii. modes appear and disappear.

i. Movement of modes. The gradual movement of the majority of modes to the right in successive months represents a slight increase in length of most or all of the fish in the new mode. It is improbable that a new population is being sampled, and this movement must just represent normal growth of the members of the population. From the distance that the modes move we can get a rough estimate of the average growth of the size group being sampled. In the modes of the May, August, and September samples a movement of about 5 mm. per month is seen. This gives an idea of the growth of fish of about 110 mm.-140 mm. in length over winter and early spring. The movement of mode (B) from January to April 1951 would give roughly 10 mm. growth per month, but this movement is erratic, and can only be taken as a slight indication of the rate of growth.

During October, November, and December the main mode shows no movement. It is unlikely that growth should cease in spring and summer, and this lack of movement seems to be caused either by netting error, or migration.

Netting error could cause a stationary peak if the population being sampled was at the extreme end of the netting range, and the majority of the fish were escaping through the mesh. Roux (1947), working on Cape stockfish netted in otter trawls has found a peak which is due to no particular size group of fish, but to the mesh of the net. He calls this a "mesh-selection peak". The peaks in October, November, and December may be of this sort. Movement of the January peak would then mean that the population had grown enough to fall within the netting range.

Migration out of the vlei might effect the peaks. The lack of movement can be correlated to the state of the mouth. During the months that there was no movement the mouth was a wide channel, and in January, when there was slight movement of the peak the mouth was almost closed, for when it was observed at low tide it was only about 6 inches deep, and slightly deeper when washed by waves from the surf. In February the mouth had been closed for nearly a month, and the mode (B) shows considerable movement. Continued migration out of the vlei by the larger fish would keep the modes stationary, and they would only reflect the normal growth of the fish when the mouth was closed and prevented such a migration.

Of the two possibilities that of "mesh-selection" seems the most feasible, for the modes are definitely near (if not at) the end of the netting range of the large seine. At Milnerton, however, lack of mode movement can again be seen to coincide with the open state of the mouth,(see p.) I do not believe that a definite conclusion can be reached with the evidence available.

ii. <u>Appearance and disappearance of modes</u>. The mouth of the Lagoon was opened in October, and the sample taken some time after the opening shows a different frequency distribution from former months. Mode (A) of May, August, and September seems to have almost disappeared, and a new size group, which has been labelled mode (B) has appeared. From this it seems that the larger fish of about I30 - I50 mm. have migrated out of the vlei, and a smaller population has entered, of an average size of about 80 mm., or less if netting error is effecting the mode. All those fish that had been trapped in the vlei during the time it was closed and have reached a size of about I30 mm. seem to have a preference for the sea, perhaps related to their state of maturity. A migration like this occurring every time the mouth opened would explain the absence of large R.globiceps in the lagoon.

A new mode seems to be appearing in the sample of March 195I. It seems probable that this mode represents a size group that is just reaching the netting range of the Large Seine, and which before has been missed in the nettings. Perhaps the few fish of the mode (X) in January and February netted in the Drag Net may belong to this size group.

The mode (B) is not represented in the catch of May 195I except by a few fish. The vlei at this time had been filled with water from exceptionally heavy rains, and must have had a very much lowered salinity. The water was dark coloured from dissolved organic matter brought down by the rivers. It has been suggested that water of higher salinity might have sunk to the deeper parts of the lagoon, and the fish of mode (B) might have moved to these deeper parts and been out of range of the netting. The fact that the smaller fish of mode (C) did not move although the larger fish did is in accordance with the difference in preference of the larger and smaller size groups when the mouth opened in October.

The mouth of the lagoon was opened in early June, and the June and July samples contain no R.globiceps at all. The fish seemed to have migrated from the lagoon because of the conditions prevailing then; low salinity (about 20 parts per thousand), low temperature (about 20° C.) and high turbidity.

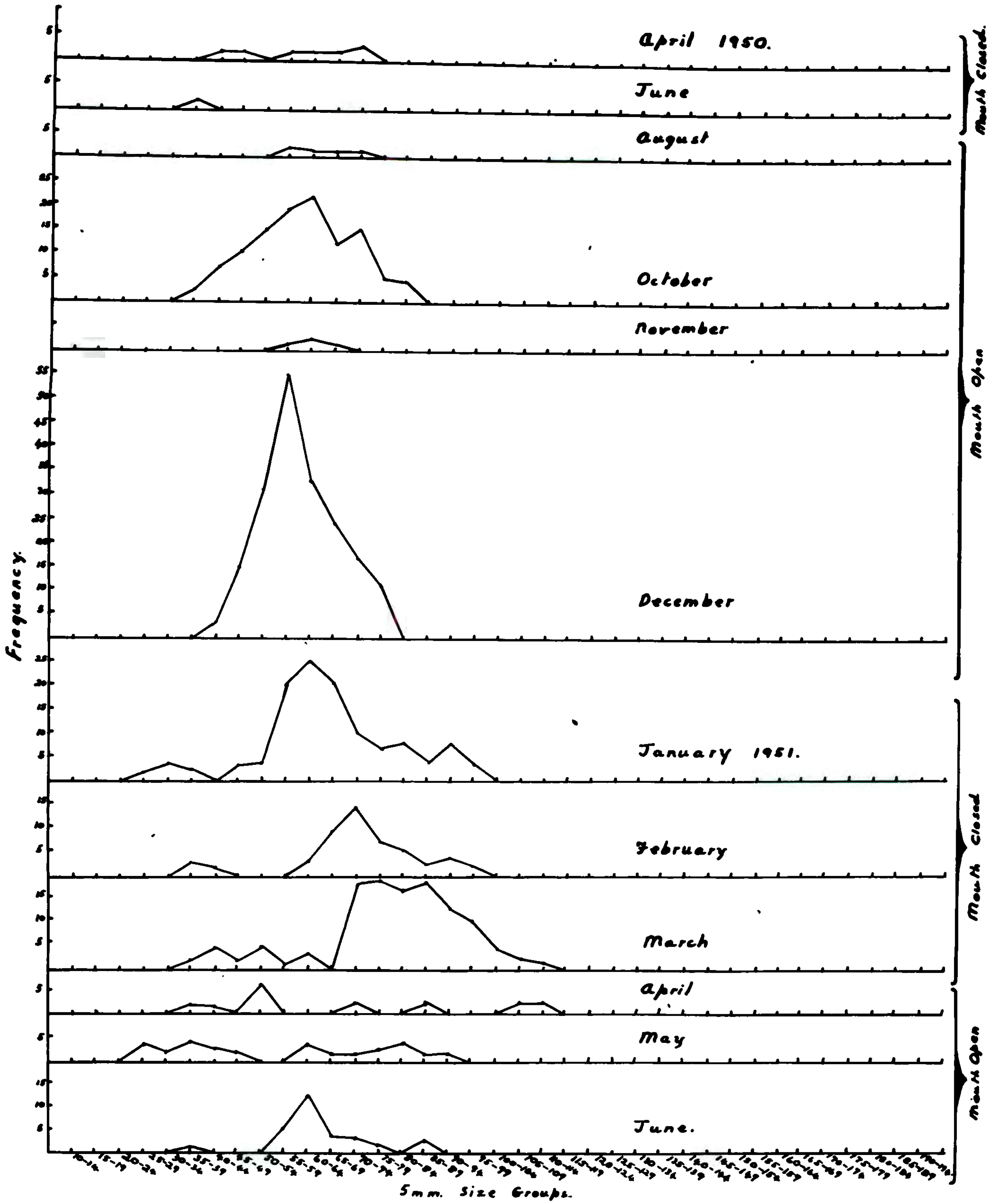
b) Length-Frequency Distribution in Milnerton Lagoon.

Catches of R.globiceps were much more variable at Milnerton Lagoon than at Hermanus, so the length-frequency graphs are not so complete. (See Fig.IO).

i. Movement of modes. Between the October and the December samples there is again no mode movement seen. It is difficult to say whether this is due to netting error, or some other cause, as at Hermanus. The mode is approaching the lower limit of the netting range of the Small Seine, for few fish of any sort below 40 mm. are caught with this net. As at Hermanus, however, the lack of movement is found when the mouth is open, and as soon as it closes mode movement is again seen. It is therefore possible that as the population grows the larger fish are continually leaving the vlei (and perhaps small ones entering it), and keeping the mode constant. If this is so, outward migration is taking place at a smaller size than at Hermanus (about 60-70 mm. as opposed to the I30-I50 mm. at Hermanus). The first three samples (April, June, August I950), and the last three samples (April, May, June I95I), were so small that no clear peaks are shown in the graphs, and little can be drawn from them.

Figure IO.

Length-frequency distribution of Rhabdosargus globiceps netted in Milnerton Lagoon from April 1950 to June 1951. All nettings made with the Small Seine.


April 1950.
June
August
October
November
December
January 1951.
February
March
April
May
June.
Mouth Closed
Mouth Open
Mouth Closed
Mouth Open
Frequency.
5mm. Size Groups.

Movement of ~~mode (A)~~ is seen when the mouth is closed, (January to March 1951). This seems again to be due to normal growth, which is in the neighbourhood of 5 mm. per month.

ii. <u>Appearance and disappearance of modes.</u> The first two samples were netted in April and June 1950, and almost no <u>R.globiceps</u> were caught. It was concluded that few of this species were present in the lagoon, apparently not many having been trapped in when the mouth closed in February 1950.

The mouth of the lagoon was opened in August, and remained open until December. The four nettings made during this period show great fluctuation in the numbers of <u>R.globiceps</u> caught. The number of fish present depended on the state of the tide, for in the two months during which many fish were netted (October and December) the tide was high at the netting, and in the two months when few fish were taken (August and November) the tide was low. It seemed as if the appearance and disappearance of mode (A) was due to migration of the fish in and out of the mouth with the tides.

After the lagoon closed in January, the numbers of fish netted were fairly constant, but when the mouth was opened again in April the numbers of fish again dropped, migration out of the vlei presumably having taken place.

During these last three nettings the correlation between the state of the tide and the numbers of R.globiceps caught was not clear, but some evidence for tidal migration was also obtained. A netting was made in June 1951 when muddy water was pouring out of the estuary after high tide, much of the turbid water having run in from rain inland, and no R.globiceps were caught. Three days later at low tide and in less turbid water a netting was again made. No R.globiceps were netted until a seine was made in a pool behind the old weir (see Fig.8) which was isolated from the rest of the estuary, but had been connected at high tide. Here a number were caught, so although no fish were found in the estuary itself at low tide, they had been trapped a few hours before at high tide, again pointing to tidal migration.

c) Age Groups and Rate of Growth.

Many authors have found that bands or rings are present on the scales, otoliths, and supra-occipital crests of some fish species, usually due to different transparencies of the material laid down during growth. These are almost invariably annual in nature. In the study of R.globiceps it was attempted to fidn whether any such regular marks were present on scales, otoliths, and supra-occipital crests.

About 200 scales were examined from fish of different sizes from Hermanus and Milnerton Lagoons, and line caught fish. Scales often showed faint rings, but different scales from the same fish often showed different numbers of rings. Fish of the same size also showed different numbers of rings. Scales dyed with Alizarine dye (after Menon 1950) showed no improvement. The length of the scales from the nucleus to the posterior edge, and the length of each ring from the nucleus was at first measured, so that if annual rings were present the relation of scale length to fish length could be obtained, and the lengths of a fish at different ages calculated from the rings on its scales. Many American Authors have used this method with much success to obtain the growth rates of fish at different ages,(Ricker 1945, Hile 1942, Carlander 1949, and others). It was concluded, however, that no clear annual rings were present on the scales of R.globiceps examined.

Supra-occipital crests gave similar negative results. Those of fish larger than about 80 mm. have spaces in the bone, which obscures any bands that might be present. In fish smaller than this, and sometimes at the anterior edge of larger crests, banding is present. The bands were not clear, however, and an estimation of the number of transparent and opaque bands present was to a large extent guesswork. The specimens used had been preserved in formalin, however, and it is possible that if unpreserved fish are used the zonation would be more distinct.

The otoliths usually showed clear concentric opaque and transparent banding. The otoliths of 55 R.globiceps from Hermanus Lagoon and Kalk Bay line boats were examined. The otoliths of all fish had opaque centres. The Hermanus fish usually had clear rings, but the Kalk Bay fish, which were larger, had the rings crowded toward the periphery and the transparent bands usually very narrow.

In previous work done on age reading by otoliths some authors (for instance Roux I947 on the Cape stockfish) have just assumed the annual nature of the rings. In all those cases where the validity of this has been tested (Menon I950 on the poor cod, Hickling I933 on the hake, Jones and Hynes I950 on the stickleback, among others) it has been found to hold. The commonest method of testing is to ascertain from periodic samples the seasons at which each type of band is laid down.

Hickling (from Jones and Hynes I950) has found that in the hake the light and dark bands are due to "alternating layers of thick and thin organic lamellae embedded between radially arranged inorganic crystalline material". Why this change in the thickness of the lamellae occurs is not known. The majority of workers have found that the transparent ring is formed in winter, and the opaque band in summer, but this does not seem to be an invariable rule and may vary with the species of fish studied (Jones and Hynes I950).

1. Time of formation of opaque and transparent zones, in R.globiceps otoliths. This seemed to vary between sea and estuarine fish.

Fish of mode (A) (see Fig.9) at Hermanus in September had a wide transparent zone at the periphery of their otoliths. The remnant of mode (A) present in the lagoon in October after the mouth had opened showed the same thing.

Fish of mode (B) that entered the lagoon as soon as the mouth opened had a small opaque band at the periphery of the otolith. In October there were therefore two size groups in the vlei, the larger having a transparent zone at the edge of the otoliths, and the smaller an opaque zone. This is probably due to the difference in conditions between the estuary and the sea.

Fish of mode (B) had the opaque edge to the otoliths during October, November, and December, but in January a transparent ring had started forming. The transparent ring was then present at the periphery of the otoliths of this size group until the last R.globiceps were caught in May.

The (C) mode which appeared in March, April, and May in the nettings contained fish also with the transparent band forming.

It is interesting to note that the beginning of the transparent zone in the otoliths of (B) group fish coincides with a) the partial closing of the mouth, and b) the movement of mode (B).

Table IV.

Month.	Ring at the periphery of each size group.		
	Mode (A)	Mode (B)	Mode (C).
September 1950	Transparent		
October	Transparent	Opaque	
November	Transparent	Opaque	
December		Opaque	
January 1951		Transparent	
February		Transparent	
March		Transparent	Transparent
April		Transparent	Transparent
May.		Transparent	Transparent

Nature of the zone present at the periphery of the otoliths of R.globiceps from Hermanus Lagoon.

It was hoped that some confirmation of this seasonal ringing might be obtained from the otoliths of the Kalk Bay fish. The crowding of the bands, and the fact that the transparent band is so narrow made it very difficult to see which band was at the edge. The thinning of the otolith at its edge also tends to obscure any opaque band at the periphery that may be just forming. If larger samples were worked so that more of the occasional distinctly banded otoliths could be obtained the seasons during which each band is laid down could probably be discovered. From the results obtained here no conclusions can be reached, however. It will be assumed that the ringing is annual, and in the following work the transparent ring is always counted. As in most other fish, this is probably the winter band.

ii. Age groups. Table V. shows the number of otolith rings found in fish of different sizes. The reading of rings on otoliths is liable to error from one or two sources. The first transparent band is often unclear. It may be a clear band, but sometimes may not be present right round the otolith. The spawning season of *R.globiceps* is probably in early summer, when presumably the large opaque centre of the otolith is laid down, and perhaps the effect of the first winter on the fish is different from those of the following years. The transparency at the edge of the otolith due to thinning may obscure a small opaque ring, or be considered as an extra transparent ring. Many otoliths are very clear, however. Another source of error is that the lagoon fish, due to differnt conditions from sea fish, and perhaps also due to the opening and closing of the mouth, may show false rings, or lack of normal rings. Table V probably gives a good indication of the year groups,however.

Correlation between year groups and the modes (see Fig.9) of length-frequency distribution in Hermanus Lagoon

Table V.

Length in mm.	I ring.	2 rings.	3 rings.	4 rings.
60	x			
70				
80	x			
90	x	x		
I00		x		
II0	x	x		
I20		x		
I30		x		
I40		x		
I50		x		
I60				
I70				
I80		X		
I90		X	X	
200		X	X	
2I0			X	X
220			X	
230				
240			X	
250			X	X
260				X
270				
280				X
290			X	X
300			X	
3I0				
320				X
No. of fish exam:	I7	2I	I0	7

The number of transparent rings in the otoliths of R.globiceps of different sizes from Hermanus Lagoon (x) and Kalk Bay (X).

---

was found. Mode (A) had two transparent rings. The fish of mode (B) that entered the vlei in October had only one transparent ring, and another started to form in January. Fish of mode (C) had one transparent ring. Otoliths of the small mode (X) were not examined.

iii. Rate of growth. From Table V. the sea fish seem to have reached about 260 mm. in their 4th year. This would give a growth of roughly 70 mm. per year. From the movement of modes in Hermanus and Milnerton Lagoons growth was found to be between 5 and IO mm. at the former, and 5 mm. at Milnerton per month. The fish of mode (A) in Hermanus lagoon in September I950, and those of mode (B) that entered in October seem to be different year groups, and the distances between the peaks is 55 mm., and if mode (A) had grown another five mm. from September to October the distance is 60 mm. Presuming the groups of fish were each spawned in the same time of year this would represent one years growth. The growth rates are then 70 mm., 60 - I20 mm., 60 mm., and 60 mm. calculated by different methods. They seem to agree well. From Table V. it also looks as though the increase in length is faster in smaller than in larger fish, which is the case in most fish. The only growth rate that has been calculated in Cape waters is that of the stockfish (*Merluccius capensis*) a member of the Gadidae. Roux (I947) found it to be from about 90 - II0 mm.

iv. Conclusion. Fish of two years and under are found in Hermanus Lagoon. Fish older than this seem to prefer the sea. When the mouth of the lagoon opened in October I950 a large number of one year fish entered the vlei. Mode (X) and mode (C) show that smaller fish were also present in the lagoon, although because of the mesh of the large seine they were not regularly netted. The ages of the fish of these modes is not easy to determine. When fish of mode (C) are seen in the March netting the otoliths have an opaque centre, and a transparent band around this. Spawning of R.globiceps is probably in early spring (see page 75), and it is possible that these are fish from the spawning of 1950 and are only 7-8 months old. The few fish of mode (X) may be small fish of the same mode selected by the Drag Net.

d) Feeding.

i. Introduction. Four main problems were tackled:

What types of food are taken by the species, and what is the relative importance of these food items to the population as a whole ?

Is there change of food with growth ?

Are there seasonal changes of food ?

What is the difference in feeding inside and outside of the estuary.

In the investigation the organisms of the entire gut were identified as far as possible, and the numbers of each food organism present in the gut counted. By opening the whole gut organisms with hard indigestible parts, such as the shells of molluscs, are found in both stomach and intestine, but more digestible forms of food may be disintergrated and unrecognisable in the intestine. In a comparison of these organisms there would be a biass in favour of the harder foods. The method has one decided advantage, however. A great number of fish had empty stomachs, but investigation of the intestine gave a good idea of what they had been eating. In large samples, therefore, enough stomachs containing food would be found to give a more or less accurate picture of the relative importance of the different items. In small samples, such as 7, I, 5, and 4, fish (as were netted in Milnerton Lagoon in April, June, August, and November I950 respectively) an investigation of the whole gut undoubtably gives a better idea of the feeding. After the main food organisms in the two lagoons became known it was not usually difficult to identify organisms in the intestine. Very soft animals, such as amphipods and polychaetes were usually so far digested in the intestine as to render identification to genus and species impossible, but they were quite recognisable as "amphipods" and "polychaetes". In the stomach and the anterior portion of the intestine soft animals were often almost undigested, and could be easily identified.

The size of the food organisms varies so considerably that a comparison of the different food items by number has no value.

To obtain the relative importance of the different food items, both for the total number of fish studied, and from month to month, the occurrence method was used. In this method the number of fish in which a food item occurs is listed as a percentage of the total number of fish that were studied. This method is not entirely free from error, for an organism which occurs often, but always in very small numbers would be listed as more important than an organism that was found slightly less frequently but in much greater numbers in each fish. Where the numbers of each individual food item are also counted any extreme case such as described can be detected. A combination of counting and percentage occurrence must give an accurate picture of the relative importace of food organisms.

To find variation of diet with season two methods were tried: a) From the counting of the number of individuals of each food species, the average number of each food organism per fish for each sample was calculated; b) The percentage occurrence of each food item for each sample was also found. The two methods were found to give very similar results. Fig.II shows the quantities of Chironomid larvae present in the monthly samples of R.globiceps at Hermanus Lagoon.

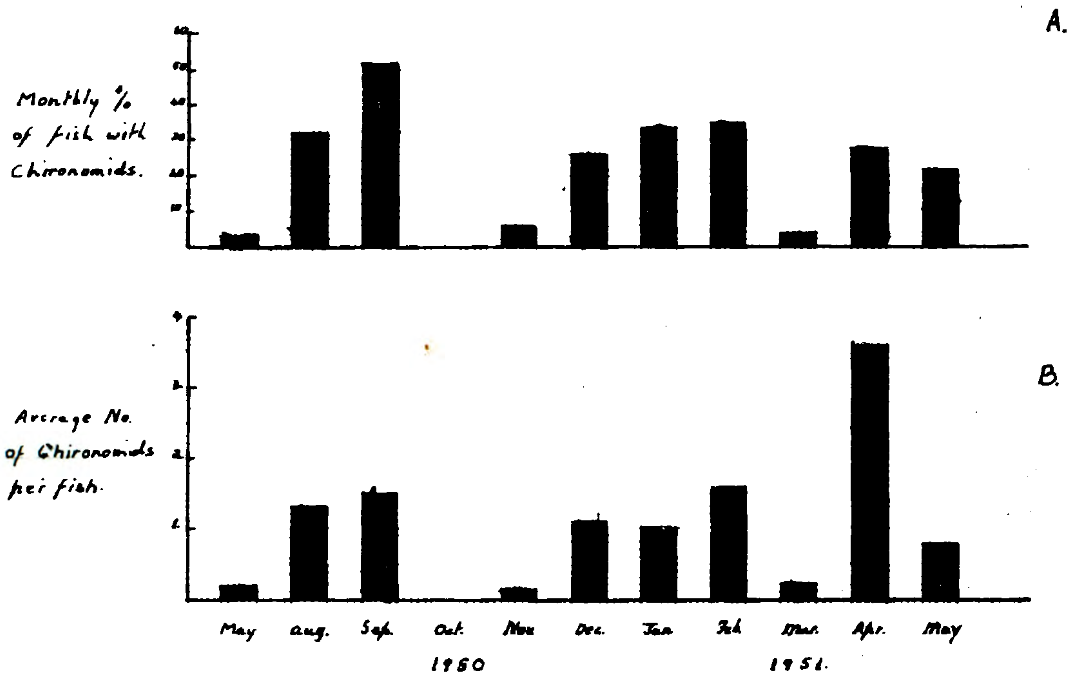
The results are so similar by each method it seems that assessment purely by the occurrence method gives as good an idea of the importance of a food organism in different

Figure II.

Comparison of two methods of fish food assessment.

A. The percentage of fish containing Chironomid larvae in each sample of *R.globiceps* from Hermanus Lagoon has been calculated.

B. The total number of Chironomid larvae in each sample of fish has been counted, and the average number of chironomids per fish calculated.


A.
Monthly %
of fish with
Chironomids.
B.
Average No.
of Chironomids
per fish.
May
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
1950
1951.

months as by laboriously counting the number of food items in each gut. Hynes (1950) has discussed in detail the methods of assessing fish foods and has found that if the sample is adequate "any of the commonly accepted methods of assessing the composition of the diet of fish from gut contents will give substantially the same result". The simplest and fastest of the "commonly accepted methods" is occurrence.

If the percentage occurrence of parasites is any guide (see page 18) the greatest error lies in the using of 30 fish as a sample. Comparisons of food from month to month would be more accurate if the sample were increased. With a larger sample it might be possible to deal with the feeding of say small, medium, and large fish separately, for at Hermanus and Milnerton the comparison of some monthly samples loses its value when different size groups of fish were present in different months. With the size of sample used general tendancies of the diet will be shown, however.

ii. Feeding of R.globiceps at Hermanus Lagoon.

Table VI. lists all the food organisms found in *R.globiceps* at Hermanus. A wide variety of both hard and soft foods were found. As well as small animals, algae, blades of *Zostera* and *Ruppia*, and seeds were eaten.

In Table VII. the 20 most important food organisms are given, the number of times they were found in stomachs being expressed as a percentage of the total number of fish

Table VI.

Food Organisms.	Where Found. Hermanus Lagoon	Where Found. Milnerton Lagoon.
PROTOZOA.		
Foramenifera.	x	x
POLYCHAETA.		
Spionid ?*Prionospia* larva.	x	-
Spionid.	-	x
Lumbriconereis sp.	x	-
Glycera sp.	x	-
Pectinaria sp.	x	-
HIRUDINEA.		
Small leech (sent for identification)	-	x
MOLLUSCA.		
Haminoea alfredensis.	x	-
Modiola capensis Krauss.	x	-
Solen capensis.	x	-
Mytilus crenatus.	-	x
Mytilus meridionalis.	-	x
Assiminea sp.	x	-
INSECTA.		
Chironomid larvae.	x	x
Syrphid larvae.	x	x
Syrphid pupae.	x	x
CRUSTACEA.		
Ostracods.	x	x
Copepods.	x	x
Cirripede.	-	x
Melita zeylanica Stebbing.	x	x
Parorchestia rectipalma Barnard.	x	-
Corophium triaenonyx Stebbing.	x	-
Talorchestia quadrispinosa Barnard.	-	x
Exosphaeroma hylecoetes Barnard.	x	x
Excirolana natalensis (Vanhoffen).	-	x
Eurydice longicornis (Studer).	-	x
Tanais philetaerus Stebbing.	x	-
Callianassa kraussi Stebbing.	x	x
Hymenosoma orbiculare Desm.	x	x
Megalopa larva.	-	x

P.T.O.

Table VI. (continued).

Food Organisms.	Where Found. Hermanus Lagoon.	Milnerton Lagoon.
PISCES.		
Psammogobius knysnaensis Smith.	x	-
Fish scales.	x	x
ALGAE.		
Filamentous Algae.(Being ident.)	x	x
Enteromorpha sp.	x	x
?Ulva sp.(being identified).	x	x
ANGIOSPERMAE.		
Grass seeds.	x	x
Potamogetonaceae seed.	x	x
Ruppia maritima Linnaeus.	x	x
Zostera marina	x	-
Sand and Detritus.	x	x

Comparitive list of food organisms found in R.globiceps at Hermanus and Milnerton estuaries.

Table VII.

Filamentous Algae (chiefly Enteromorpha sp.)	70.0%
Chironomid larvae	2I.2%
Assiminea sp.	20.6%
Amphipods	20.I%
Polychaete worms	I7.5%
Sphaeromid Isopods	I6.6%
Modiola capensis	I4.7%
Zostera marina and Ruppia maritima	I4.4%
Solen capensis siphons	5.6%
Potamogetonales seeds	5.0%
Grass seeds	4.4%
Ostracods	3.I%
Hymenosoma orbiculare	2.8%
Hamînoea alfredensis	2.8%
Foramenifera	2.5%
Copepods	I.6%
Mysids	I.0%
Syrphid larvae	0.6%
Callianassa kraussi	0.6%
?Ulva sp.	0.6%
Unidentified crustacean remains	2.5%
Unidentified bivalve remains	4.7%

The 20 most important food items found in R.globiceps at Hermanus Lagoon.
The number of times each item was found is expressed as a percentage of the total number of fish investigated.

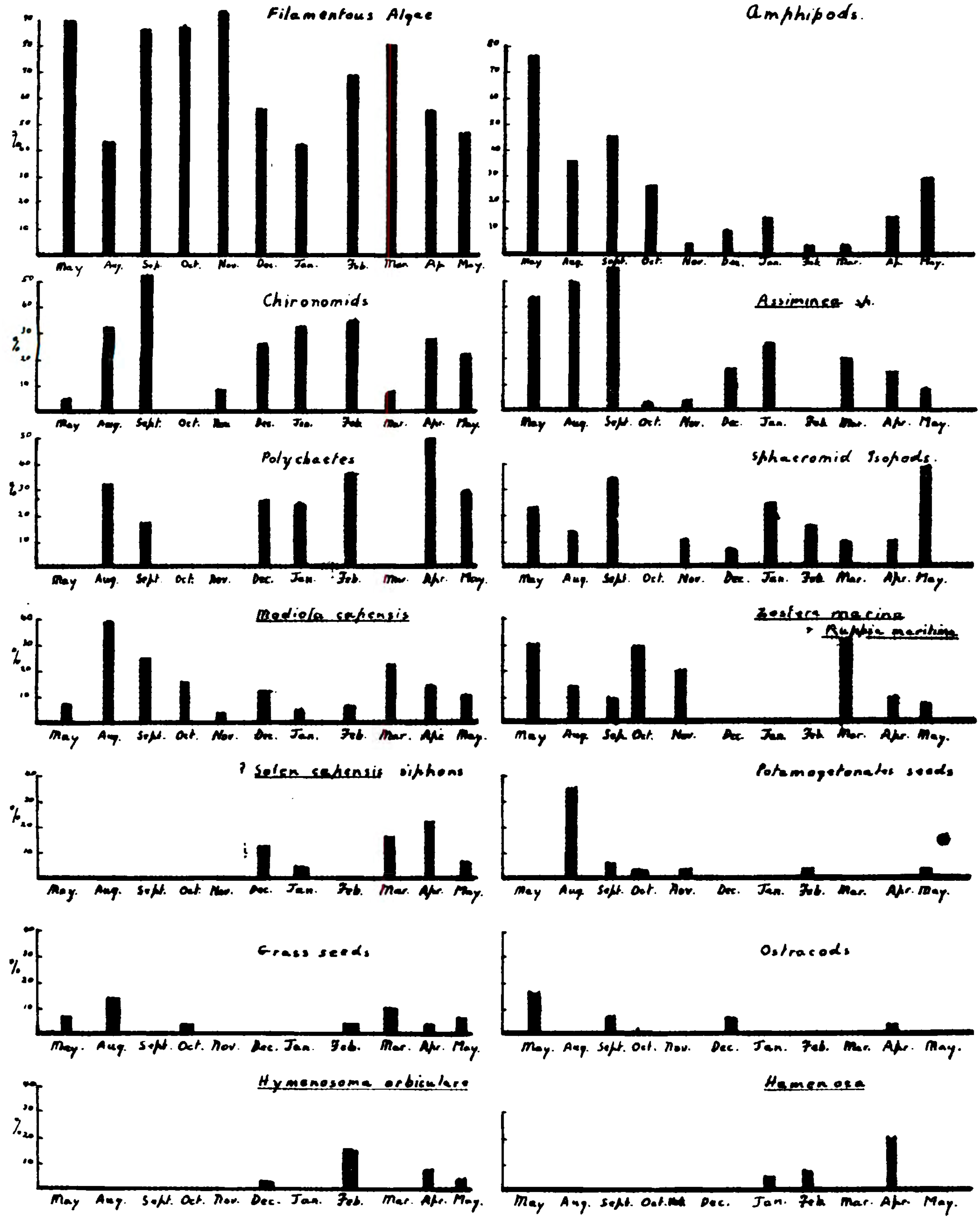
Table VIII.

	Size Groups.(inmm.)				
	20-39.	40-69.	70-99.	I00-I29.	I30-I59.
Copepods.......	83%		2%	I%	
Amphipods......	83%	38%	23%	25%	34%
Ostracods......	I7%	8%	3%	3%	5%
Fil. Algae.....	I7%	46%	70%	74%	67%
Sphaeromids....	I7%	23%	I5%	I6%	20%
Chironomids....		38%	22%	I6%	26%
Lumbriconereis.		3I%	8%	4%	2%
Zostera and *Ruppia*...		8%	I3%	I6%	I8%
Glycera sp.....			I%	I%	
Haminoea.......			I%	4%	
Solen siphons..			6%	6%	
Modiola........			5%	I6%	48%
Assiminea......			7%	29%	56%
Grass seeds....			I%	5%	I3%
Potamogetonales seeds...			I%	7%	I0%
Hymenosoma.....			I%	6%	5%
Callianassa....				I%	2%
No. of Fish.	6	I3	I40	I40	6I

Change of food organisms with size of *R.globiceps* from Hermanus Lagoon. The number of times an organism is found in each size group is represented as a percentage of the total number of fish in that group.

Figure I2.

Percentage occurrence of the most important food organisms of R.globiceps in II samples netted in Hermanus Lagoon from May I950 to May I95I.



Filamentous Algae
%
May Aug. Sep. Oct. Nov. Dec. Jan. Feb. Mar. Ap. May.
Amphipods.
May Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Ap. May.
Chironomids
%
May Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May
Assiminea sp.
May Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May.
Polychaetes
%
May Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May.
Sphaeromid Isopods.
May Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May.
Modiola capensis
%
May Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May.
Zostera marina
+ Ruppia maritima
May Aug. Sep. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May.
? Solen capensis siphons
%
May. Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May.
Potamogetonales seeds
May Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May.
Grass seeds
%
May. Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May.
Ostracods
May. Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May.
Hymenosoma orbiculare
%
May Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May.
Hamenosa
May Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May.

examined. From the number of times that filamentous algae (usually *Enteromorpha sp.*) occur in the fish it would seem that they are the most important food item. Whether the fish derive as much nutriment from vegetable as from animal foods is not known, however. It was first thought that the algae might be eaten for animals sheltering in them. This is not the case, however, for many fish of a sample may have the stomach and intestine packed with algae although no animal remains are present. It has been suggested that algae may only be eaten when no animal food is available. If a preference for animal food over algae exists it cannot be strong enough to make the fish search far, for often in the same sample some fish may be packed with animal organisms, showing that these are present, while others contain only algae. In some months, noticeably October and November 1950, filamentous algae formed by far the bulk of the food, and it must be concluded that algae form one of the most important, if not the most important, foods of estuarine *R.globiceps*.

The remainder of the important food organisms are animals that shelter in the weed beds, such as *Melita zeylanica*, *Corophium triaenonyx*, *Exosphaeroma hylecoetes*, and *Assiminea sp.* (found to be the commonest animals in weeds by Scott, Harrison and Macnae), and bottom animals such as *Modiola capensis*. Cropped pieces of *Ruppia maritima* and *Zostera marina* are often found. Seeds of a grass, and some member of the family Potamogetonaceae, perhaps Ruppia or Zostera, were occasionally present, sometimes in a germinating state. No whole specimens of Solen capensis were ever found, although this animal is abundant in places near the mouth. The fish were apparently not able to dig the whole animal out of the sand, but nipped off the ends of the siphons.

In general the commonest organisms in the diet seemed to be the commonest organisms in the habitat that were available to the fish, as has been found by Stephen (I930) and other authors to be a general rule. Sometimes fish in a sample showed individual preferences, for one fish might have fed only on grass seeds, another only on Chironomid larvae, another only on Assiminea sp. and another only on Enteromorpha.

Some change of food organisms with increasing size of fish is found,(see Table VIII). The smallest fish found (just over 20 mm.) seem to have a diet that consists of planktonic copepods and amphipods chiefly, but also of sphaeromids, ostracods and algae. It is known that the larval fish are first pelagic (Gilchrist I904) and then later become bottom feeders. Here it looks as though the young fish are still partial plankton feeders.

As the fish grow more animals become available to them, and the larger fish have a more varied diet. Large polychaetes such as *Lumbriconereis sp.*, and chironomid larvae are eaten by fish of 40 mm. and upwards. The first hard foods (the gastropod *Assiminea sp.* and the bivalve *Modiola capensis*) are taken by fish over 70 mm. Above this size also large animals such as *Haminoea alfredensis* and *Hymenosoma orbiculare* were included in the diet, and the first pieces of *Solen* siphons are found. In the large fish of 100 mm. and over *Callianassa kraussi* was eaten, and hard molluscs became increasingly important.

Three fairly distinct stages seem to be shown. The very small fish (20 - 40 mm.) feed mainly on planktonic animals, although some bottom forms are taken. Medium sized fish, up to 100 mm. feed on a wide range of small animals, but only a very small proportion of these have hard shells. Above 100 mm. hard molluscs become very important in the diet. Throughout all three stages filamentous algae and amphipods are important foods.

Little change of food with season was found, (see Fig.12), among the common food organisms. When the mouth of the lagoon opened in October some difference was seen, but a smaller population is being dealt with in October than September, for the smaller one year fish have almost replaced the two year group. Size may be effecting the comparison. The young fish entering the lagoon feed mainly on filamentous algae, *Zostera* and *Ruppia*, *Modiola capensis* and *Corophium* triaenonyx. The quantities of Assiminea sp., the isopod Exosphaeroma hylecoetes, polychaetes, and Chironomid larvae show a sudden reduction from the September sample, however. Scott, Harrison, and Macnae found almost no change in the fauna when the mouth was opened, and although no quantitative samples were taken there seemed to be little difference in the abundance of the common animals. The change in food is then probably not due to a change in the food organisms present. Size may be effecting the change in feeding, but most of the food organisms which show a reduction in occurrence when the smaller size group enters are animals which are taken by very small fish (see Table VIII.), and although there is no size increase in the population from October to December, the four food species mentioned are found in increasing abundance again. The small size group of fish that entered the lagoon in October seem then first to feed on vegetable matter, Modiola capensis, and the amphipod Corophium triaenonyx, although other food organisms are available. Gradually other food species are taken. This "lag" may be due to feeding habits before the fish entered the estuary. If they were used to feeding on other types of food outside the estuary new feeding habits would have to be learnt before the unusual estuarine foods were taken. Lebour (1918), Scott (1922, from Hartley 1940), and others have shown that some fish do learn definite feeding habits, and it is reasonable to suppose that it must take some time to change these. Amphipods and bivalves are important foods of R.globiceps outside the estuary (see page 69½), and these, with vegetable food, were eaten as soon as the fish entered.

Most of the food organisms show an increased occurrence in summer, and then a slight reduction in April and May. The May sample consists of a new size group of fish (mode (C) in Fig.9), but the reduction in April may be accounted for by the lower temperature of the vlei. The drop in temperature from March to May in 1948 was found by Scott, Harrison, and Macnae to be from 27° C. to 17° C. Such a drop in temperature must have a marked effect on the activity of any poikilothermic animal,(a 10° drop in temperature reducing the speed of a chemical reaction to half by Van't Hoff's Law), and a corresponding reduction in the quantity of food taken would be expected.

iii. Feeding of R.globiceps at Milnerton Lagoon.

Table VI. lists the food organisms found in R.globiceps at Milnerton. They are essentially similar to those from Hermanus fish. Filamentous algae (usually Enteromorpha) were again the most frequent food organism. The average size of the population is much smaller than that in Hermanus Lagoon so smaller organisms, such as ostracods and copepods are given much greater prominance in the percentage

Table IX.

Filamentous Algae (Chiefly *Enteromorpha* sp.)	75.2%
Chironomid larvae	46.2%
Copepods	I7.7%
Syrphid larvae	I2.6%
Ostracods	I2.2%
Isopods	8.0%
Polychaete worms	6.3%
?*Ulva sp.*	4.6%
Leeches	2.9%
Amphipods	2.5%
Mytilus meridionalis	2.5%
Ruppia maritima and ?grass blades	2.5%
Syrphid pupae	2.5%
Callianassa kraussi	0.8%
Potamogetonales seeds	0.8%
Sphaeromid isopods	0.8%
Unidentified crustacean remains	I7.0%
Unidentified bivalve remains	0.4%

The I6 most important food items found in *R.globiceps* at Milnerton Lagoon.
The number of times each item was found is expressed as a percentage of the total number of fish investigated.

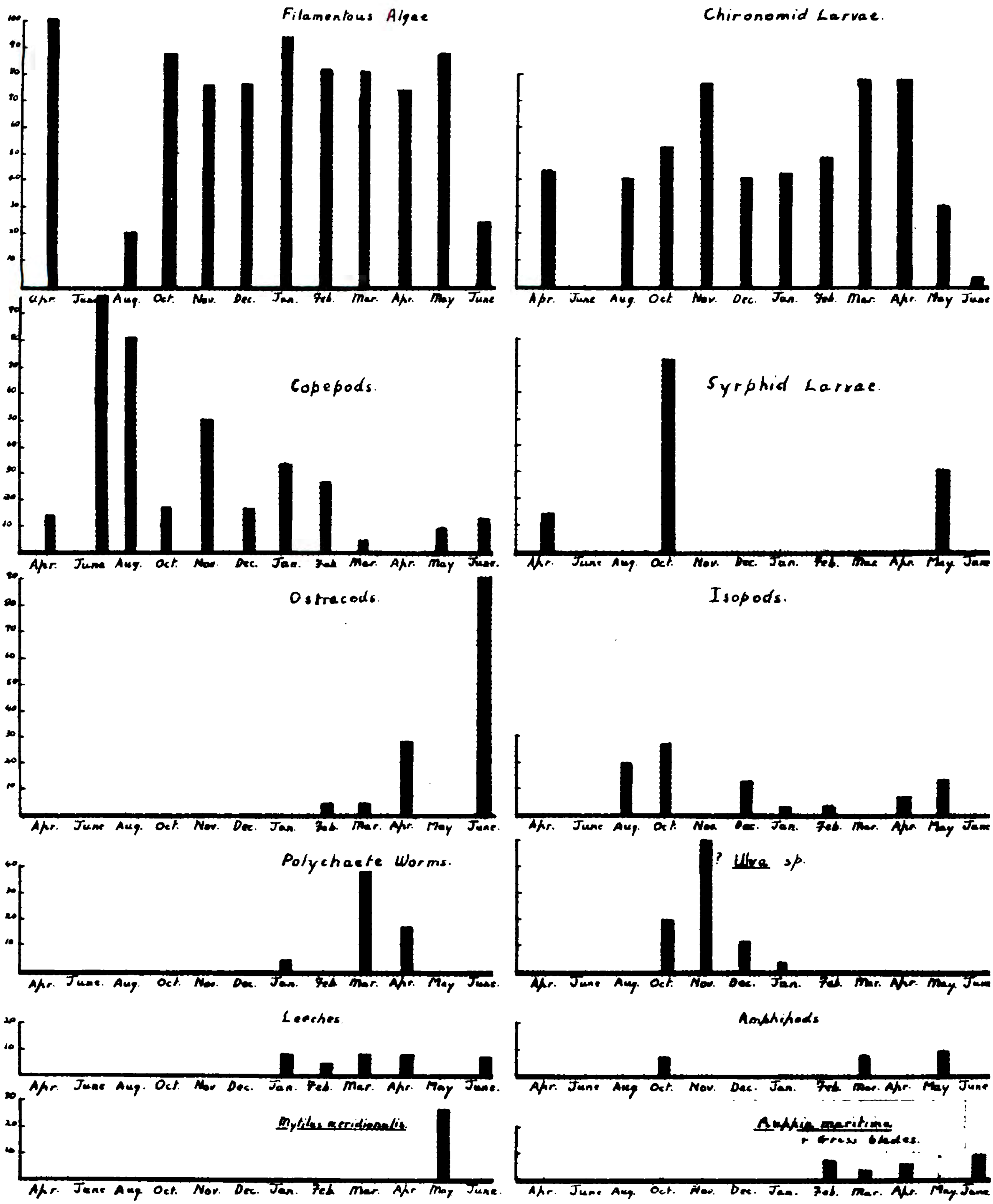
Table X.

	Size Groups (in mm.)			
	20-39.	40-69.	70-99.	100-129.
Copepods........	33%	26%	8%	
Syrphid larvae..	13%	13%	12%	
Ostracods.......	7%	21%	3%	
Fil. Algae......	67%	69%	88%	70%
Polychaetes.....	7%	1%	13%	10%
Chironomids.....	20%	38%	56%	70%
Mysids..........		4%		
Amphipods.......		2%	3%	
Leeches.........		5%	2%	
?*Ulva* sp..........		7%	6%	
Ruppia and grass blades		1%	6%	
Sphaeromids.....		1%	1%	
M.meridionalis..		1%	4%	
Isopods other .. than sphaer.		7%	11%	10%
Hymenosoma......			1%	
Potam. seeds....			1%	10%
Fish remains....				10%
Callianassa.....				20%
No. of Fish:	15	122	90	10.

Change of food organisms with size in *R.globiceps* from Milnerton Lagoon. The number of times an organism is found in each size group is represented as a percentage of the total number of fish in that group.

Figure I3.

Percentage occurrence of the most important food organisms of R.globiceps in I2 samples netted in Milnerton Lagoon from April I950 to June I95I. The samples of April, June, August, and November I950 are too small to give significant percentages, (7, I, 5, and 4 fish respectively).


Filamentous Algae
Chironomid Larvae
Copepods
Syrphid Larvae
Ostracods
Isopods
Polychaete Worms
? Ulva sp.
Leeches
Amphipods
Mytilus meridionalis
Ruppia maritima
+ Grass blades
Apr. June Aug. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June

occurrence given in Table IX, and there is almost a total lack of bivalves and gasteropods. Filamentous algae, Chironomid larvae, and copepods were the most important foods being found consistently throughout the period of study. The majority of the other foods were spasmodically important.

Change of food with increased size of fish was found as at Hermanus,(see Table X). The smaller fish fed mainly on filamentous algae, copepods and insect larvae, again partly planktonic and partly attached foods. Insect larvae, (mainly Chironomids), and filamentous lagae remained important foods in the larger fish, but many more items were added to the diet. Isopods such as Eurydice longicornis, and the juveniles of the mussel Mytilus meridionalis were eaten above 40 mm., and over 70 mm. Hymenosoma orbiculare and the Potamogetonaceae seed were found. As at Hermanus only fish over 100 mm. took Callianassa kraussi.

Little can be deduced from the monthly comparisons of each food organism,(see Fig.13). Apart from filamentous algae, chironomids and isopods, and copepods, which are fairly regular elements of the fishes' diet, the fish seem to feed on anything that occurs in abundance at any time. In May 1951, when the mouth was open, a fall of the spat of Mytilus meridionalis seems to have occurred and the fish have eaten a great deal of it, although it was not found before or after this month. Syrphid larvae also seem to have been abundant in only a few months of the year, and in these months they are found in many of the fish in the samples. Ostracods, which were only found in stomachs from February to June 1951, were in 90% of stomachs in the June sample. Temporary increases in the populations of any food species seem to be utilised by the fish, again pointing to the fact that the fish will in general feed on the most abundant available organisms.

iv. Feeding of R.globiceps at Breede River Estuary.

A sample of 44 R.globiceps was obtained from the Breede River Estuary in July 1951, netted by the same nets used at Hermanus and Milnerton Lagoons (page 9.). This sample showed that feeding was very similar to that at Hermanus Lagoon. The fish ranged from 30-124 mm., and the most important food organisms were:-

Bivalves (Oval bivalve with radiating brown stripes, being identified).
Enteromorpha sp.

?Ulva sp.

Sphaeromid Isopods (incl. Exosphaeroma sp.)

Zostera marina.

Leander pacificus, polychaetes, amphipods, copepods, and fish scales and vertebrae were also found.

v. Feeding of *R.globiceps* from Sea Samples.

58 specimens of *R.globiceps* were obtained from the sea. Unlike the estuarine fish, where the percentage of fish with nothing in the intestinal tract was negligible, I9 out of 58 fish had both stomach and intestine empty, or contained only bait.

The only record of the feeding of marine *R.globiceps* is that of Biden (I930), who mentions that *Mytilus perna* and *Mytilus meridionalis*, and polychaete worms are important foods.

Table XI. lists the food organisms found in the fish from different places. Amphipods were by far the commonest food, being found in abundance in Kalk Bay and West Coast fish. Bivalves were also important. Six fish caught by Mr.Reed when angling at Miller's Point were packed with *Mytilus perna*, and many fish caught by other anglers at the same time also contained these mussels. Small white bivalve fragments were also found in Kalk Bay fish, and a small brown bivalve was present in a sample of three fish from Cape Infanta. Crab remains were found in a few stomachs, and the other organisms listed in Table XI. were present in one or two fish.

No change of food with size, or with season could be obtained from the data.

In conclusion it can be stated that:-

a) Amphipods and bivalves are important foods, b) ostracods, isopods, crabs, echinoids, barnacles, and fish are also taken, and c)vegetable remains are seldom found. The fish are bottom feeders, as all the organisms found, including the amphipods and the fish, live on the bottom. The strong incisors and molars must be used to break barnacles and bivalves from the rocks and crush them.

vi. Conclusions on Feeding Habits.

The estuaries studied act as "nurseries" to R.globiceps up to about I50 mm. In the estuaries the fish are both vegetable and animal feeders. Filamentous algae such as Enteromorpha sp. are an extremely important food, and Zostera marina and Ruppia maritima are also cropped. The fish prey on the majority of small weed and bottom dwelling crustaceans, polychaetes, molluscs and insect larvae.

The smallest fish found (20-40 mm.) are partially planktonic feeders, but also eat algae and small weed dwelling animals. With increase of size of mouth, strength of incisors and molars, and speed of movement, more animals become available to the fish and up to about I00 mm. they feed on a wide variety of small animals, but not to any great extent on hard shelled molluscs. Planktonic animals are not eaten much at this stage, and the fish have become bottom feeders. In fish over I00 mm. hard shelled gastero-pods and bivalves become important foods, and large animals

Table XI.

Place and Date.	Size.	Foods.	No.Fish.
Kalk Bay Line Boats. Summer and Autumn I95I.	I28 mm. -300 mm.	Amphipods Barnacle shells. Bivalve remains. Sand. Ostracods. Crab remains. Chorisochismus dentex.	4I.
Cape Infanta. Trawled 36 fath. July I950.	260 mm.	Crab remains. Bivalves. Polychaete worms.	3.
Cape Infanta. Trawled 35 fath. July I95I.	I28 mm. -203 mm.	Crushed Echinoid. Amphipods. Crab leg.	2.
Miller's Point. Cape Peninsula. Angling by Mr. Reed, May I95I.		Mytilus perna.	6.
Buffels River Mouth. West Coast. Angling by Mr.Guy Currie,July '5I.	300 mm. -350 mm.	Amphipods, including Hyale saldanha Chilton. Paridotea sp. Blue compound Ascidian. Ulva like thallus Orange sponge.	6.
			58.

Food organisms found in *R.globiceps* from samples from the shore to 36 fathoms.

such as the crab Hymenosoma orbiculare and the "prawn" Callianassa kraussi are also eaten.

Fish in the estuaries seem to take the most abundant available organism as a general rule.

No major food cycles exist in the estuaries, but less food may be eaten in the colder months.

R.globiceps of 180 mm. - 360 mm. from sea samples show a difference in feeding from estuarine fish. The fish are carnivorous bottom feeders eating no vegetable matter. Amphipods were found to be the commonest food, which seems a strange diet for a fish with such powerful teeth. Bivalves were also much eaten, as well as a number of bottom living animals such as crabs, barnacles, and echinoids.

e) Spawning and Sexual Maturity of R.globiceps.

R.globiceps lays floating eggs that give rise to a pelagic larva,(Gilchrist 1904). Spawning probably takes place close inshore, for fertilised eggs have been pumped into the old St.James aquarium through the water inlet, (Biden 1930). Not much is known about the spawning season, but Gilchrist (op.cit.) states that an abundance of ripe males and females can be obtained from trawlers in November and December, and he performed successful fertilisation experiments with the eggs and sperm of these fish. Biden (op.cit) mentions that very enlarged yellow ovaries can be found throughout the year in fish caught by Kalk Bay line boats.

In December 1950 it was decided not to restrict the records of R.globiceps to estuarine fish, and from this date until August 1951 the gonads of fish bought from Kalk Bay line boats were examined. Although gonads that were very yellow and had rounded eggs were found in December January and February, the only fish that had fully ripe eggs (large, round, and perfectly transparent with a central oil globule) were taken in August. The eggs were very similar to the description of Gilchrist (1904), but measured about 1.05 mm. across. Gilchrist measured 50 eggs from one female, and found them to be 0.85 mm. - 0.88 mm. Whether the egg diameter may vary with different fish or the ripe female in August had abnormally large eggs is impossible to determine without more data.

Eggs seem to go through three stages during their development. They are at first transparent, closely packed, and of different shapes, dependent on how they are pressed by neighbouring eggs; later they become granular, yellow, and more rounded; finally the egg ready for shedding has again become transparent and is very rounded and soft, with one clear oil globule in the centre.

The gonad weights and the diameters of the ova were recorded from R.globiceps from Hermanus and Milnerton estuaries and Kalk Bay. Table XII. gives the average egg diameters for 20 mm. size groups.

Table XII.

Size Groups.	Average Egg Diameter.
60-79	0.04
80-99	0.04
I00-II9	0.06
I20-I39	0.08
I40-I59	0.09
I60-I79	-
I80-I99	0.08
200-2I9	0.07
220-239	0.6
240-259	0.68
260-279	0.6
280-299	0.I
300-3I9	-
320-339	0.5

Average diameter of ova of R.globiceps from Hermanus and Milnerton Estuaries and sea fish from Kalk Bay, for different size groups.
All measurements in mm.

Fish below 60 mm. had gonads that were fine threads. At about 220 mm. the average egg diameter increases by nine times. All the estuarine fish were found to have gonads of small size, the females having a maximum egg diameter of 0.I2 mm. They were all immature.

Fish of up to I80 mm. had ovaries that weighed at most I.7 gms., but 200 mm. fish had gonads up to 8.0 gms. At 240 mm. some fish had tremendously enlarged gonads, one female of this size having an ovary of 4I gms. The condition of maturity and ripeness in males is difficult to determine, but the first male to be described as "faintly milky" was 275 mm.

It can be seen then that both egg diameters and ovary weights show a sudden increase at about 200 mm.

The ratio of males to females is difficult to determine among the juvenile fish in the estuaries, for there is little difference to be seen between females with very undeveloped gonads and immature males. There are definitely more females than males, however. The ratio from the Kalk Bay samples was approximately 2:I females to males. Biden (I930) mentions that ratios of I0:I and 20:I females to males are common in large shoals of R.globiceps

Conclusion:

R.globiceps seem to mature at a size of just over 200 mm., when they are at the end of their second or beginning of their third year.

The only completely ripe fish are known from August, November and December, so the breeding season probably is in spring and early summer. The fact that enlarged and yellow ovaries are found at other times of year may point to a longer and less definite breeding period. A spring breeding season would fit in well with the (A) and (B) size groups in Hermanus vlei (Fig.9). If mode (A) fish had been spawned in the spring of 1947 they would have reached about 140 mm. in roughly two years. This would give a growth rate of about 70 mm. per year, which is very similar to the estimated growth rates (page 51). They would be expected to show two winter rings on the otoliths. Two transparent rings are found on the otoliths of mode (A) fish. If mode (B) fish had been spawned in the spring of 1948 they would have reached about 80 mm. in one year. A slightly faster growth rate could be expected in smaller fish. They would be expected to show one winter ring on their otoliths. One transparent ring is found.

The fish do not breed in estuaries, but probably spawn fairly near the shore. The eggs are pelagic, and give rise to a pelagic larva.

f) Parasitism in *R.globiceps*.

A Trematode and some small Nematode parasites were found in the gut of *R.globiceps* from both Hermanus and Milnerton Lagoons, an Acanthocephalan parasite was found in Hermanus Lagoon fish only, and no parasites were found in sea fish.

3% and 2% of Hermanus and Milnerton fish respectively were parasitised by small nematodes. The fish were never heavily parasitised, usually only one or two nematodes being present, and fish containing them seemed to be in excellent condition.

The trematode found was a small parasite of about 3 mm. long, found in the intestine. It was first seen at Hermanus and Milnerton only after the mouths had been opened after the winter rains of 1950. The new populations entering the vleis after they were connected to the sea were parasitised, although the populations which had been present did not seem to have been. It is interesting to note that at both lagoons the percentage infection was at first high (35% at Hermanus, 40% at Milnerton), but rapidly decreased in both lagoons over a period of about three months, and after this was found only occasionally.

The acanthocephalan parasite, with a body of about 5 mm. and a proboscis of about 2 mm., was attached to the rectum just inside the anus. Usually only two or three fish were present, but up to 12 were found. About 20% of Hermanus fish were parasitised.

None of the parasites found were ever present in very large numbers, and in no cases were the parasitised fish in poor condition.

6. NOTES ON RHABDOSARGUS TRICUSPIDENS.

R.tricuspidens is the commonest species of the genus in estuaries from approximately Knysna to Durban, being replaced by R.globiceps and R.sarba westward and northward respectively. 62 fish were studied from Hermanus Lagoon (netted in small numbers from May 1950 to March 1951), and 76 fish from Durban Bay (taken during two visits to Durban in July 1950 and January 1951). Smaller samples were obtained from different estuaries along the coast (page 9). The whole alimentary canal was studied in fish from Hermanus, but in all other samples only the stomach was opened.

a) Feeding.

At Hermanus Lagoon the feeding of R.tricuspidens was very similar to that of R.globiceps. Table XIII. lists the food organisms found in R.tricuspidens at Hermanus in order of relative abundance. Filamentous algae were the commonest food, and neatly bitten off pieces of Zostera marina were often found. The most important animal foods were the gasteropod Assiminea sp. and the bivalve Modiola capensis. Only large fish were netted in the lagoon at Hermanus (112-260 mm.), and if their diet is compared to that of the larger R.globiceps (Fig. VIII.) it is found to be strikingly similar.

Table XIII.

Filamentous Algae (mainly Enteromorpha sp.)	82%
Assiminea sp.	55%
Zostera marina	50%
Modiola capensis	26%
Amphipods (Corophium triaenonyx and Melita zeylanica)	18%
Sphaeromid Isopods	11%
Hymenosoma orbiculare	3%
Grass seeds	3%
Syrphid larvae	2%
Chironomid larvae	2%
Mysid	2%
Unidentified crustacean remains	2%
Unidentified bivalve remains	8%

Organisms found in R. tricuspidens from Hermanus Lagoon. The percentage occurrence of each food item is given.

No change of diet with season was seen at Hermanus Lagoon, and as only large fish were netted change of food organisms with size could not be observed.

The feeding of R. tricuspidens in Durban Bay was also essentially the same. Enteromorpha sp. and other filamentous algae form the commonest food, and gasteropods (Assiminea sp. and Nassarius kraussiana), bivalves (Loripes sp., and Modiola capensis), crabs (Hymenosoma orbiculare), and the burrowing Upogebia sp. and Callianassa kraussi were also important.

The percentage occurrence of the different types of food organisms from all the fish recorded is given in

Table XIV.

Filamentous Algae	20%
Zostera marina	16%
Hard shelled bivalves	14%
Hard shelled gasteropods	8%
Crabs	8%
Callianassa kraussi	5%
Copepods	5%
Upogebia sp.	3%
Amphipods	2%
Ulva sp.	2%
Solen capensis (usually siphons only)	2%
Polychaete worms	2%
?Leander pacificus	1%
Insect larvae	1%
Unidentified crustacean remains	2%
Fish with empty stomachs	29%

Percentage occurrence of food organisms found in 213 R.tricuspidens from seven estuaries between Breede River Mouth and Lake St.Lucia. Only organisms in the stomachs have been considered.

Table XIV, (excluding Hermanus fish), the low percentages being due to the fact that only the stomachs of the fish were opened.

In all the estuaries from which samples have been obtained feeding seems to be much the same. Algae and usually Zostera are the most important vegetable foods, bivalves and gasteropods are the most important animal foods, and crabs and other crustaceans are also preyed on. In the different estuaries the species which comprise the diet may be different, however. At Hermanus, for instance,

Table XV.

	Size Groups (in mm.)					
	20-39	40-69	70-99	I00-I49	I50-I99	200-249.
Copepods....	4I%	5%				
Fil. Algae..	45%	57%	I7%	23%	57%	56%
Amphipods...	9%	5%	2%	3%	6%	37%
Ulva sp.....	5%	I0%	3%			
Zostera.....		5%	22%	20%	43%	50%
Insect larv.			2%	I%	4%	
Polychaets..			2%	2%	2%	
Sphaeromids.			2%	6%	I2%	
Callianassa.			I%	6%	4%	6%
Crabs.......			8%	7%	8%	I9%
Gastropods..			8%	2I%	45%	I2%
Bivalves....			8%	I6%	37%	50%
Upogebia....				5%		2%
No. Fish:	22	2I	64	I03	49	I6.

Change of food organisms with size in *R.tricuspidens*. The number of times an organism is found in each size group is expressed as a percentage of the total number of fish in that group.

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b) Spawning and Sexual Maturity of R.tricuspidens.

The only reference to the spawning of R.tricuspidens is made by Smith (1949), who states that it breeds in estuaries. This is based on the fact that very small fish are found in estuaries (Smith, personal communication), and it seems possible that these fish might enter the estuaries when still extremely small, perhaps still as pelagic larvae.

No R.tricuspidens from any estuary have been found in a completely ripe state. At Hermanus six females netted in May 1950 had swollen and yellow ovaries, and rounded opaque eggs. No ripe males were found at the same time. A statement based on this one record concerning the breeding season would have no value, however.

Females seem to mature at about 200 mm. Fish below this size had ovaries with a maximum weight of 0.87 gms., and egg diameters of up to 0.22 mm. At 210 mm. fish were found with yellow enlarged ovaries (4.8 gm.) and eggs were opaque and had diameters of 0.45 mm. The gonad weights and the egg diameters show a sudden increase, and although the fish were not ripe they were approaching it.

No ripe males were found.

c) Parasitism in R.tricuspidens.

Hermanus R.tricuspidens were found to be parasitised with the same Acanthocephalan parasite attached to the rectum as was found in R.globiceps. These parasites, about one to five usually being present in a fish, were found in 15% of Hermanus R.tricuspidens.

Small nematodes were found in one fish from the Bushman's River Mouth, and in one fish from Hermanus.

Gut parasites are therefore extremely few in number, and no fish seemed to be in bad condition through parasitism.

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7. NOTES ON RHABDOSARGUS SARBA.

One winter and one summer sample of R.sarba (89 and 69 fish respectively) were obtained from Durban Bay, and a small number from Lake St.Lucia and Richard's Bay. In food investigation only the stomach was opened.

a) Feeding.

Table XVI. gives the relative importance of the foods found in all Durban fish. Bivalves (Loripes sp., Modiola capensis, and an unidentified triangular speckled bivalve) were the commonest food organisms present in the stomachs. Gasteropods (Assiminea sp., Natica sp., and Nassarius kraussiana), and the crab Hymenosoma orbiculare were also commonly found, and a small percentage of stomachs contained crustaceans such as Penaeid prawns and isopods, polychaetes and chewed Balanus amphitrite. The fish were almost entirely

Table XVI.

Bivalves (*Loripes sp.*, *Modiola capensis*, triangular speckled)	28%
Gasteropods (*Assiminea sp.*, *Natica sp.*, *Nassarius kraussiana*)	14%
Crabs (*Hymenosoma orbiculare*)	14%
Prawns (*Penaeus japonicus*)	3%
Copepods	3%
Filamentous Algae (including *Enteromorpha sp.*)	3%
Balanus amphitrite	1%
Polychaete worms	1%
Zostera marina	1%
Ulva sp.	1%
Callianassa kraussi	1%
Mysid	1%
Isopod	1%
Fish with empty stomachs	26%

The percentage occurrence of food organisms of 158 *R.sarba* from Durban Bay. Only the organisms in stomachs have been considered.

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carnivorous, vegetable matter being found in very few stomachs. Filamentous algae, which were of such importance in *R.globiceps* and *R.tricuspidens*, were only present in 3% of *R.sarba*.

No differences in feeding between the winter and summer samples from Durban were seen.

As in the other two species there is a change in food organisms with growth, (Table XVII), although the records are too few to give a very accurate picture. The smallest fish contained amphipods and copepods. Crabs and

Table XVII.

	Size Groups (in mm.)					
	20-39	40-69	70-99	100-149	150-199	200-249.
Amphipods...	67%					
Copepods....	67%		8%	3%		
Crabs.......		100%	8%	11%	14%	7%
Prawns......		25%		4%	3%	
Zostera.....			8%	1%	10%	7%
Gastropods..			17%	14%	7%	14%
Bivalves....			8%	27%	28%	29%
Fil. Alg....				5%		
Polychaetes.				2%		
Barnacles...				1%		
Callianassa.					3%	
No. Fish:	6	4	12	104	29	14.

Change of food organisms with size in *R.sarba* netted from Durban Bay, St.Lucia, and Richard's Bay. The number of times an organism is found in each size group is expressed as a percentage of the total number of fish in that group.

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prawns were first eaten at about 50 mm., and gastropods and bivalves were taken by fish over 70 mm. Crabs, gastropods, and bivalves remained important foods of all sizes of fish above this. Only fish over 100 mm. seemed capable of crushing barnacles.

R.sarba seems then to be almost entirely a carnivore, the small fish below 40 mm. feeding on amphipods and copepods, and fish above this size taking various crustaceans and molluscs. Bivalves, gastropods, and crabs form the predominant foods.

b) Spawning and Sexual maturity of R.sarba.

No ripe fish have been netted in any of the estuaries. The ovaries and testes seem to be undeveloped and thin until about 200 mm. At 216 mm. a male was found with thickened and slightly milky testes, and also one at 230 mm., and at 240 mm. a female was described as having an ovary "slightly thickened and diffused with blood vessels". It looks therefore as though the fish mature at about 200 mm.

In Australia there seem to be conflicting opinions as to the breeding season of R.sarba. Munro (1945) thinks that the fish breed over an extended winter season, but mentions Roughley in "The Fishes of Australia and their Technology" to state that they spawn in early summer. The estuarine fish netted in Natal do not elucidate the problem.

c) Parasitism in R.Sarba.

A trematode parasite which looks identical to that found in Hermanus and Milnerton Lagoon R.globiceps was present in the intestine of four Durban R.sarba. No other parasites of any type were found.

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8. COMPARISON OF THE THREE SPECIES OF RHABDOSARGUS.

R.tricuspidens and R.sarba seem to be restricted to shallow coastal water and estuaries, and are not recorded from trawlers. They do not seem to occur in vast shoals. Both adults and juveniles are found in estuaries.

R.globiceps, however, is found in abundance right down to 40 fathoms, often being present in huge shoals around the Cape. As is typical for many marine animals, the cold rich waters of the West Coast seem able to support larger numbers than the sub-tropical East Coast. Only the juveniles were found in estuaries, larger fish migrating out before they were mature. What causes this preference for the sea in larger fish is difficult to determine. Lack of suitable food does not seem to be the answer, for hard shelled molluscs which are an important part of the diet of larger fish are present in estuaries such as Hermanus Lagoon and the Breede River Mouth. If food were the cause of migration it does not seem likely that all the larger fish would suddenly leave, as they did in Hermanus in

October I950. It looks as though some salinity, temperature, or perhaps even pressure preference is changing with the growth of the fish. There is no evidence of a sudden change in the state of the gonads just before the fish leave the estuary, but while the fish were growing inside the estuary the average gonad weight, and the average egg diameter in females, were steadily increasing. The migration may be connected to change in state of gonads. The fish are not nearly ripe by the time they leave the estuaries, however, the gonads of males being still threadlike, and those of femalse being under I gm. in weight.

Fish of all three species are partially planktonic feeders in the young stages, and from the smallest fish netted, about 25 mm., to about 40 mm. feed mainly on copepods, amphipods, and (excepting the carnivorous R.sarba) filamentous algae.

Fish above 40 mm. become entirely bottom feeders, but differences in feeding are seen between the three species.

R.tricuspidens, with the most chisel-like incisors, takes vegetable and animal foods both as a juvenila and an adult in estuaries.

R.globiceps, with more pointed incisors, feeds on animal and vegetable foods as a juvenile in the estuaries, but takes less Zostera than R.tricuspidens, which may be related to the incisors of the latter facilitating the biting-off of Zostera blades. Adult R.globiceps out at sea have an almost carnivorous diet.

R.sarba, also with rather pointed incisors, is mainly carnivorous both as a juvenile and as an adult, in the estuaries.

There seems then to be some relation between teeth and feeding. The two species with pointed incisors feed more on animals than does R.tricuspidens with its chisel-like incisors. Teeth do not fully explain the differences in diet, however. Small R.globiceps in estuaries feed to quite a large extent on filamentous algae. R.sarba of the same size, and with very similar teeth, do not, even though they must come across algae during their feeding. As there is no other structural difference that could make filamentous algae not "available" to R.sarba it looks as though its avoidance of such food is due to some innate behaviour pattern.

Where R.tricuspidens and R.globiceps occur together in South Coast estuaries they feed on the same species of animal and vegetable food. Similarly in those Natal estuaries in which both R.tricuspidens and R.sarba are found the same species of bivalves and gasteropods are important in the diet of both fish. There must be some competition for food organisms between these pairs of species.

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9. CONCLUSIONS AND GENERAL DISCUSSION.

The composition of the fish fauna. In a review of estuarine conditions Day (I95I) has stated that an estuarine fauna is mainly derived from the sea, with a few fresh-water forms at its upper reaches, and that the number of species that is restricted to estuaries is very small. This has also been shown specifically for estuarine fish faunas by Hardenberg (I93I), Hartley (I940), and Irvine (I947). This was found to be true for the fish faunas of Milnerton and Hermanus estuaries.

In the regions of the two estuaries that were studied the fresh-water component is absent. Scott, Harrison, and Macnae (in press) found one small fresh-water Silurid in the upper reaches of Hermanus estuary, however.

Only Psammogobius knysnaensis seems to be entirely restricted to estuaries (Smith I949). Gilchristella aestuarius is also mainly estuarine, but is known to exist occasionally in completely fresh water (Barnard I947).

All the other species present in both lagoons can be considered as marine species tolerant of estuarine conditions. It is difficult to say which of these are resident in the estuaries throughout their lives, and which migrate to and from the estuaries. Possibly only Clinus superciliosus, Gobius nudiceps, and Syngnathus acus are marine species that reside their whole lives in estuaries, for they all seem to breed there. By far the majority of the larger fish are marine migrants. Typical of this category are Rhabdosargus globiceps, Lithognathus lithognathus, Hypacanthus amia, Pomatomus saltator, and Liza ramada.

Irvine (1947) in studying the fish faunas of Gold Coast estuaries and temporary lagoons found that the young of some species were present although the adults were not. Similarly at Hermanus and Milnerton only the young of Lithognathus lithognathus, R.globiceps, and Pomatomus saltator were found. It seems as if the young are more tolerant of estuarine conditions.

Physical and Chemical conditions, and their affect on fish distribution.

Salinity: Most of the fish in the estuaries seem to be extremely euryhaline. At Milnerton salinities were taken by Millard and Scott (in process of publication) at the same time that nettings were made. Table XVIII. shows the highest and lowest salinities at which the different

Table XVIII.

Species.	Lowest Salinity.	Highest Salinity.
Mugil cephalus	I.8	5I.
Liza ramada	I.8	55.
Lithognathus lithognathus	I.8	55.
Psammogobius knysnaensis	I.8	5I.
Rhabdosargus globiceps	I7.2	55.
Gilchristella eastuarius	F.W.(Barn.'47)	5I.
Heteromycteris capensis	I7.2	44.
Atherina breviceps	I7.2	45.
Gobius nudiceps	I7.2	55.
Pomatomus saltator	35.	5I.

The highest and lowest salinities in parts per thousand at which the different species of fish were netted at Milnerton Lagoon. Salinities from Millard and Scott,(in process of publication).

species of fish were netted at Milnerton. It must be emphasized that this does not represent the range which each fish is capable of withstanding, and that because so few salinities are embodied in the table a comparison of the salinity ranges between species is not of much value. The table shows, however, that some species are capable of standing great variation of salinity. Bassindale (1943, cited by Day 1951) stresses that many animals can withstand great salinity changes if these are made slowly, but that the rate of change of salinity is important. No indication of what rate of change of salinity the species of fish can stand is given by the data, and the high salinities in Table XVIII. were reached slowly as the lagoon was evaporating while the mouth was closed.

Temperature: The temperature variation over the year at Hermanus is thought to be about from 12° C. to 28° C. At Milnerton the variation in temperature at the mouth during the time of study was 10° C. to 20° C., and at King George Fort 12° C. to 27° C. As not much variation occurs in the fish fauna over the year the fish must be able to stand these temperature changes.

Turbidity: The turbidity of Hermanus Lagoon is seldom high. At Milnerton, however, the water is usually very turbid at King George Fort, a Secchi Disc often being invisible at a few inches. The mouth may also be fairly turbid, but turbidity is always higher at the upper than the lower end of the estuary.

Distribution: Both at Hermanus and Milnerton estuaries some species show differences in occurrence between the upper and the lower stations. At Milnerton R.globiceps was common at the mouth, present at the Road Bridge, and never found at King George Fort. Mugil cephalus was rare at the mouth, but abundant at King George Fort. Both at Hermanus and Milnerton Heteromycteris capensis was restricted to the sandy areas near the mouths. It was first thought that the distribution was related to salinity differences between the upper and lower stations in each estuary. At Hermanus a constant salinity gradient has been found to exist, but the gradient at Milnerton is variable. When the mouth closes, and little water flows into the estuary the salinity rises and King George Fort becomes more saline than the region near the mouth, e.g. King George Fort 58.6, and mouth 49.56 parts per thousand. When the mouth is open the salinity in the whole estuary falls, King George Fort salinity going down as far as I.83, and the mouth varying from I8.0 to 35.0 parts per thousand, but always being lower than King George Fort, (figures from Millard and Scott, in process of publication). The salinity gradient is at times higher at the mouth, and at others higher at King George Fort, but no change in distribution of the fish is found to occur with the change in the salinity gradient.

Other factors that might effect distribution are

a) the state of the bottom, b) the turbidity of the water, or c) the distribution of food organisms. The temperatures, specially when the mouth is closed, differ only slightly between the upper and lower stations at Milnerton, and probably less at Hermanus where the water is deeper.

In the case of Heteromycteris capensis the restricting factor is probably the state of the bottom, for it is found only on the clean sand around the mouth at both estuaries, and not on the muddier bottom of the upper stations. At Milnerton it was not netted even a IOO yards away from the mouth on a muddy bottom.

The causes of the distribution of R.globiceps and Mugil cephalus are more difficult to determine. Distribution of food organisms does not offer a satisfactory explanation in either case. R.globiceps is found at the Road Bridge but not at King George Fort, but the fauna varies little if at all between the two places. Mugil cephalus is mainly found in the upper estuary although Liza ramada, feeding on the same diatoms, is present throughout the estuary.

Turbidity might be an important factor in the case of R.globiceps, but probably more data would have to be obtained before a satisfactory explanation for the distribution of these two species could be obtained.

Probably not one factor but a combination of factors is effecting distribution of these species.

Spawning in estuaries. In spite of the prevalent opinion of South African anglers and commercial fishermen few fish seem to breed in estuaries. Developing eggs were found in the brood pouches of male "pipe fish", Syngnathus acus, and in the uteri of the viviparous Clinus superciliosus. One Psammogobius knysnaensis was described as having an ovary that was "ripe running" at Milnerton when the mouth was closed, and ripe Gobius nudiceps have also been found in the Breede River Mouth. No ripe Gilchristella aestuarius were among the few opened, but they probably also breed in estuaries.

The only large fish seen with enlarged ovaries were Liza ramada and R.tricuspidens. Neither of them were completely ripe and it is possible that they migrate out of estuaries to breed. Liza ramada is known to migrate out of estuaries in quite considerable numbers at times.

The majority of large fish, such as Lithognathus lithognathus, Rhabdosargus globiceps, Pomatomus saltator, and Hypacanthus amia, were never found with developed ovaries or testes. What has been found for R.globiceps, i.e. that they migrate out of the estuaries before they are mature, may well apply to these fish.

Bionomics. In both Milnerton and Hermanus estuaries the food chains seem to be very similar. Green food matter is taken by some animals (some of the common fishes, and probably also Assiminea sp. Bursatella leachii, and Haminoea alfredensis), but detritus derived from the beds of Ruppia, Zostera (at Hermanus), and algae support a large invertebrate population on which the majority of fish feed. MacGinitie and MacGinitie (1949), and Day (1951), both stress the importance of detritus as a basic food in estuaries.

Some of the common fishes are wholly or partially herbivorous, such as the mullets Mugil cephalus and Liza ramada which graze on attached diatoms. R.globiceps and R.tricuspidens which crop Zostera, Ruppia, and Enteromorpha, and to some extent Lithognathus lithognathus which sometimes takes filamentous algae.

The small carnivorous fishes such as Clinus superciliosus, Psammogobius knysnaensis, and Gobius nudiceps, and the omnivorous R.globiceps, R.tricuspidens, and Lithognathus lithognathus feed to a large extent on detritus eating animals such as amphipods (mainly Melita zeylanica), sphaeromid isopods (Exosphaeroma hylecoetes), the bivalves Modiola capensis and Solen capensis(at Hermanus), the "prawn" Callianassa kraussi, and Chironomid larvae.

Hypacanthus amia and Pomatomus saltator prey on the fish population at Hermanus, and only the latter at Milnerton. In both estuaries cormorants also take their toll of small fish.

Farmers from the surrounding districts do much netting in Hermanus Lagoon, using very large seines, and catch shoals of R.globiceps, Lithognathus lithognathus, and Liza ramada. They must also help to reduce the fish population.

The main sources of error in the work done seem to lie in sampling methods. If this work was continued many more fish would be caught, using as many nets as possible in each estuary, to improve the length-frequency distribution data.

The counting of food organisms which took so much time would be discontinued, and only the occurrence of food organisms be noted. The sample of 30 fish for opening would be increased, say to 50 fish.

Stress would be laid on marine fish, and if possible length frequency distribution data obtained from Kalk Bay or trawler catches.

No work on scales or supra-occipital crests would be attempted, but age reading by otoliths would be concentrated on, to obtain more accurate information on age groups and rate of growth.

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