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THE BIOLOGY OF THE SAND SHARK RHINOBATOS ANNULATUS, IN  
ALGOA BAY WITH NOTES ON OTHER ELASMOBRANCHS

by

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## ABSTRACT

The biology of the lesser sand shark, Rhinobatos annulatus, was studied off sandy beaches in Algoa Bay over a period of two years. Tagging studies, due to low numbers tagged, did not reveal major movements. However, comparison of numbers of sand sharks caught off the beach and deep water during summer and winter months suggested that migration occurred during these seasons with the animals being inshore in summer.

Annual rings on the vertebral centra were used to determine age. Both sexes can reach a maximum age of seven years. Conventional growth curves could not be fitted and empirical curves were used to illustrate growth. The reproductive cycle was investigated and indicated that both sexes matured after three years of age. The breeding season was during late summer when the shallow water was utilized as a nursery area. The sand shark is an aplacental viviparous species with a gestation period of 10 months. Breeding occurred every year and fecundity increased with total body length to a maximum litter size of 10 young.

The most important prey items taken inshore were the mysid Gastrosaccus psammodytes, the prawn Macropetasma africanum, the crab Ovalipes punctatus and the sand mussels Donax spp. Differential predation by different length classes of sand shark resulted from a dynamic zonation of

these different size classes in the surf zone. Smallest individuals fed closest inshore.

Seasonal variation recorded in the hepatosomatic index was primarily due to the accumulation of hepatic lipids. This variation showed significant correlations with the breeding cycle in adult sand sharks. The contribution of liver lipids to the formation of egg yolk was estimated and found to be secondary to lipid reserves for maintenance. Liver colour varied depended on the amount of liver lipids. Ancillary observations were made of other elasmobranchs in the surf zone.

## UITTREKSEL

Die biologie van die kleiner sandkruiper, Rhinobatos annulatus is bestudeer langs die sandstrande van Algoabaai oor 'n tydperk van twee jaar. As gevolg van lae getalle gemerkte individue is geen grootskaalse bewegings met merkstudies waargeneem nie. 'n Vergelyking van die getalle sandkruipers gevang vanaf die sandstrande en diepsee gedurende somer- en wintermaande, dui aan dat migrasie gedurende hierdie maande plaasgevind het. Gedurende die somer was hulle in die vlak water.

Jaarringe op die werwelsentra was gebruik om ouderdom te bepaal en beide geslagte kan 'n maksimum ouderdom van sewe jaar bereik. Gebruiklike groeikurwes kon nie gepas word nie en empiriese kurwes is gebruik om groei aan te toon. 'n Studie van die voortplantingssiklus het aangetoon dat beide geslagte na drie jaar geslagsryp was. Die teelseisoen was gedurende die laatsomer wanneer die vlakwater as teelgebied gebruik word. Die sandkruiper is aplasentaal lewendbarend met 'n draagtydperk van 10 maande. Voortplanting geskied elke jaar en vrugbaarheid het toegeneem met totale liggaamslengte tot 'n maksimum werpsel van 10 kleintjies.

Die belangrikste prooi was die buidelkrewel, Gastrosaccus psammodytes, die garnaal, Macropetasma africanum, die swemkrap Ovalipes punctatus en sand mossels

Donax spp.      Differentiële predasie deur verskillende lengtegroottes sandkruipers het meegebring dat verskillende klasgroottes 'n dinamiese sonering in die brandersone getoon het. Die kleinste individuë het naaste aan die kuslyn gevoed.

Die seisoenale veranderinge waargeneem in die hepatosomatiese indeks was hoofsaaklik te wyte aan die stoor van lewervette. 'n Korrelasie is gevind in volwasse sandkruipers wanneer hierdie veranderinge vergelyk is met die voortplantingssiklus. 'n Poging is aangewend om die bydrae van lewervette tot die vorming van eiergeel te kwantifiseer en daar is gevind dat die bydrae sekondêr is tot lewervette aangewend as reserwes vir onderhoud. Lewerkleur het verander met die hoeveelheid lewervette aanwesig. Bykomende waarnemings van ander kraakbeenvisse in die brandersone is gemaak.



## CHAPTER 1

## GENERAL INTRODUCTION

Although elasmobranchs have a worldwide distribution, occurring from the polar regions to the tropics and from coastal zones to a depth of at least 3000m, only one species, Squalus acanthias, has been studied intensively by several authors e.g. Holland (1957); Holden (1966); Ketchen (1972, 1975); Jones and Geen (1977). Holden (1974) found this not surprising considering the fact that elasmobranchs are difficult to catch and keep alive in aquaria and many species are dangerous, for example the great white shark Charcharodon carcharias. The absence of a shark fishery industry in the majority of countries which have fishery research facilities, like South Africa, has resulted in a meagre knowledge of elasmobranchs. The majority of research done on elasmobranchs in South Africa was done on large and potentially dangerous sharks. Research on these animals was motivated by a high incidence of shark attacks and later included smaller and harmless species (Bass et al, 1973, 1975a, b, c, d, 1976). The approach of this work, however, has been to regard taxonomy as a tool for the identification of species so that their biology can be investigated with a minimum of confusion (Bass et al, 1973). Thus the taxonomy of elasmobranchs in South Africa is well known but biological and ecological studies have been sadly neglected. Bass et al (op cit) only recorded short biological notes on the species studied. The batoid fishes of the east coast

of South Africa have been studied in a similar approach by Wallace (1967a; b, c). Studies on batoids here and elsewhere in the world are few and scattered and cover a variety of subjects, e.g. ion and water metabolism (Bok, 1973), age determinations (Steven, 1936; Ishyama, 1951; Daiber, 1960; Holden and Vince, 1973; Du Buit, 1977), reproductive aspects (Samuel, 1943; Holden, 1975; Sieben, 1979). No literature on seasonal biological studies on batoids were available for this study.

Sand sharks (Fig. 1.1) are found in the region between the Cape and Zanzibar and are very common off sandy beaches in the Eastern Cape (Smith, 1965). Wallace (1967a) questions the occurrence of Rhinobatos annulatus as far north as Zanzibar and the matter is hitherto unresolved. There is a single genus in the family Rhinobatidae and four endemic species occur off the east coast of Southern Africa (Wallace, 1967a). In the present study only one species, R. annulatus, was found in Algoa Bay.

The body of R. annulatus is broad and dorso-ventrally flattened for a sedentary habit as much time is spent half buried in the sandy substrate. The colour varies from a light sandy tone to a dark brown and variation in the spots on the upper surface depends on the turbidity of the water and the colour of the sand (Wallace, 1967a). Although the flesh of the sand shark is very palatable, little interest is shown in the species either by sport anglers or commercial vessels. In southern Brazil, however, Rhinobatos percellens

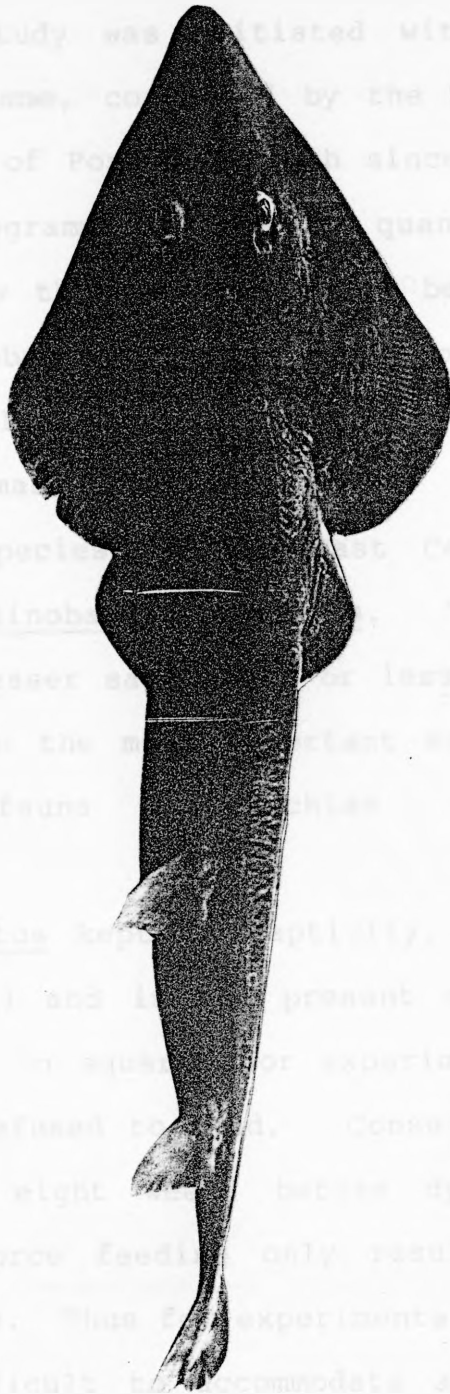


FIG. 1.1 Rhinobatus annulatus, mature female,  
870mm in total length.

is caught in large numbers during the summer months for human consumption (Gianuca, pers. comm.).

This study was initiated within the Sandy Beach Research Programme, conducted by the Zoology Department at the University of Port Elizabeth since 1978. The overall aim of this programme has been to quantify the structure of and energy flow through open sandy beaches in the Eastern Cape. Elasmobranchs form a major part of the surf zone community in Algoa Bay (Rossouw, 1979) and dominate surf zone fish biomass (Lasiak, 1982). The most abundant elasmobranch species in the East Cape surf zone is the sand shark, Rhinobatos annulatus. This species is also known as the lesser sand shark or lesser guitar fish. This species is also the most important marine predator on the beach macrofauna (McLachlan et al, 1981).

R. annulatus kept in captivity, generally refuses to eat (Bok, 1973) and in the present study all attempts to keep specimens in aquaria for experimental purposes failed because they refused to feed. Consequently animals lasted about six to eight weeks before dying in an emaciated condition. Force feeding only resulted in regurgitation soon afterwards. Thus for experimental purposes sand sharks were very difficult to accommodate and laboratory studies were abandoned. Investigations were thus initiated on the biology of R. annulatus and the aims of this study were framed as follows:

1. To describe the biology of R. annulatus, including reproduction, feeding, age and growth.
2. To investigate the distribution, seasonality and migrations of the sand shark in Algoa Bay.
3. To define the rôle of R. annulatus in the beach/surf zone food chains.

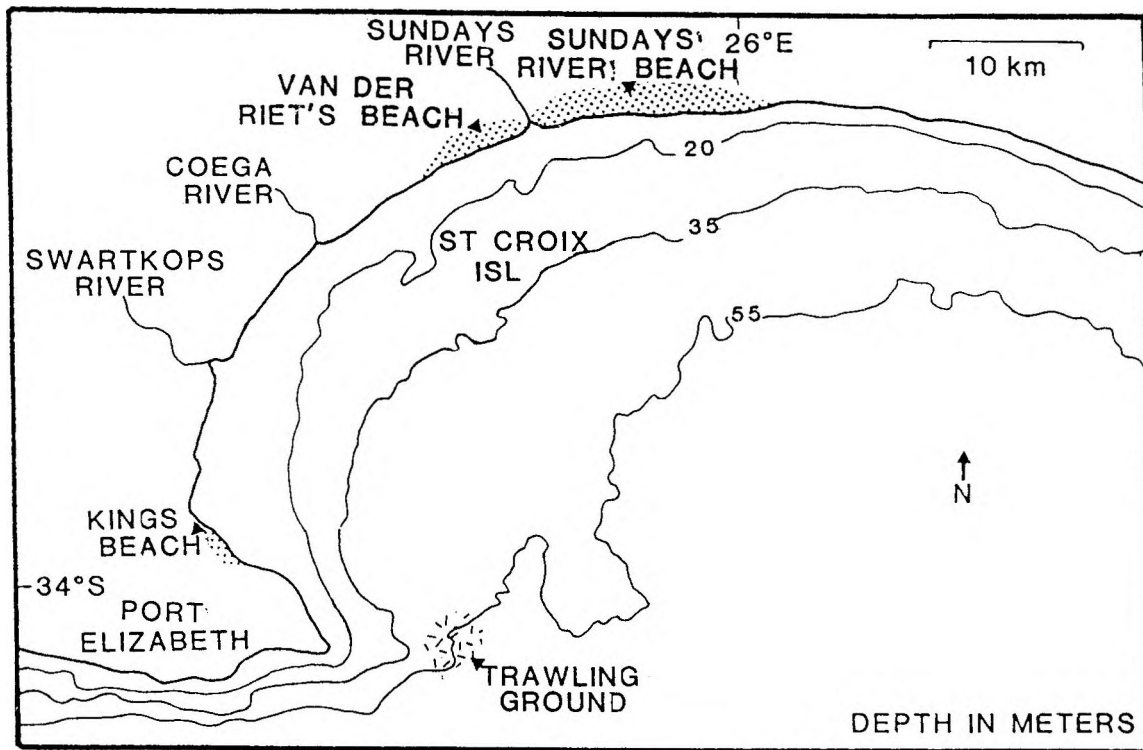
## CHAPTER 2

### THE STUDY AREA

#### 2.1 PHYSICAL FEATURES

Algoa Bay, situated on the south-east coast of Southern Africa, is a logarithmic spiral bay (Bremner, pers. comm.) characterized by long exposed sandy beaches stretching for 80km of the total 90km extent of coastline (Fig. 2.1). Two major rivers, the Swartkops and Sundays Rivers, have estuaries opening into the bay. St. George's beach and van der Riet's beach are exposed beaches backed by small dune systems while Sundays River beach is very exposed and isolated with very large dunes.

The Agulhas Current flows southward along the Eastern Cape Coast adhering to the coastline as far as East London. From here the depth contours are followed as the current diverges from the coast. Maximum velocity of the current is found where the continental shelf gives way to the slope (Harris, 1978). Direct effects of the current are therefore not normally experienced in Algoa Bay. A study of surface current circulation in Algoa Bay has been initiated by the Zoology Department at the University of Port Elizabeth. Detailed results are not yet available but it would appear, from preliminary observations, that there is a predominately cyclonic circulation in Algoa Bay, with the flow parallel to the coast. This direction of flow may be reversed during



DEPTH IN METERS

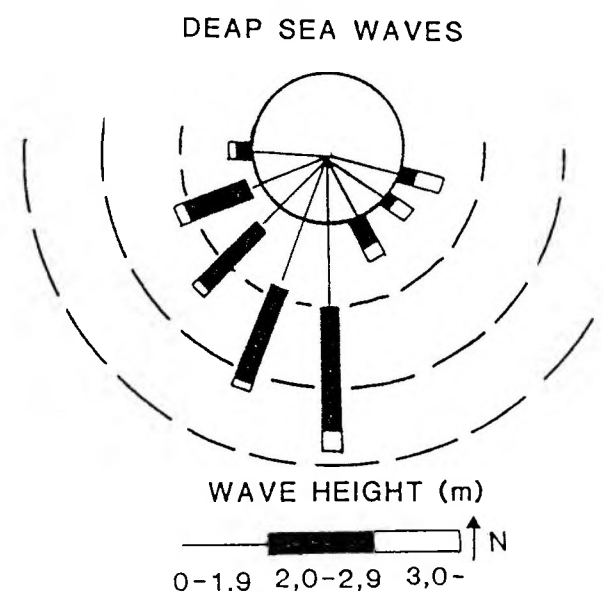
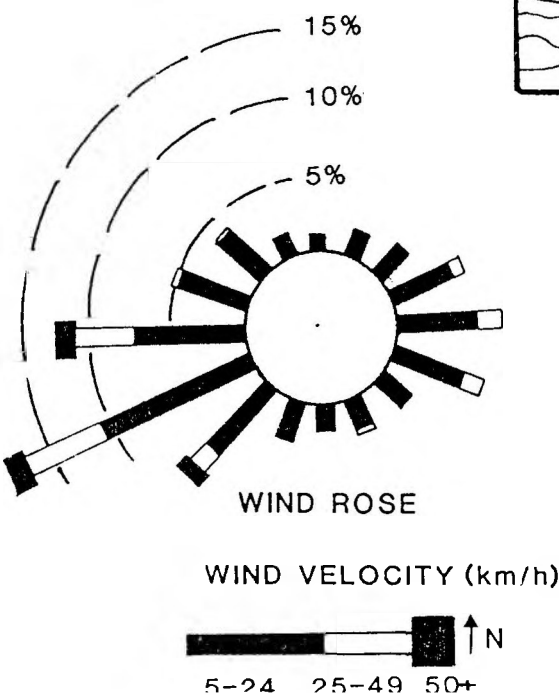


FIG. 2.1 The study area including wind rose (Port Elizabeth Airport) and wave rose (St Croix Island) from Beckley and McLachlan (1979).

# MEAN SEA SURFACE TEMPERATURE

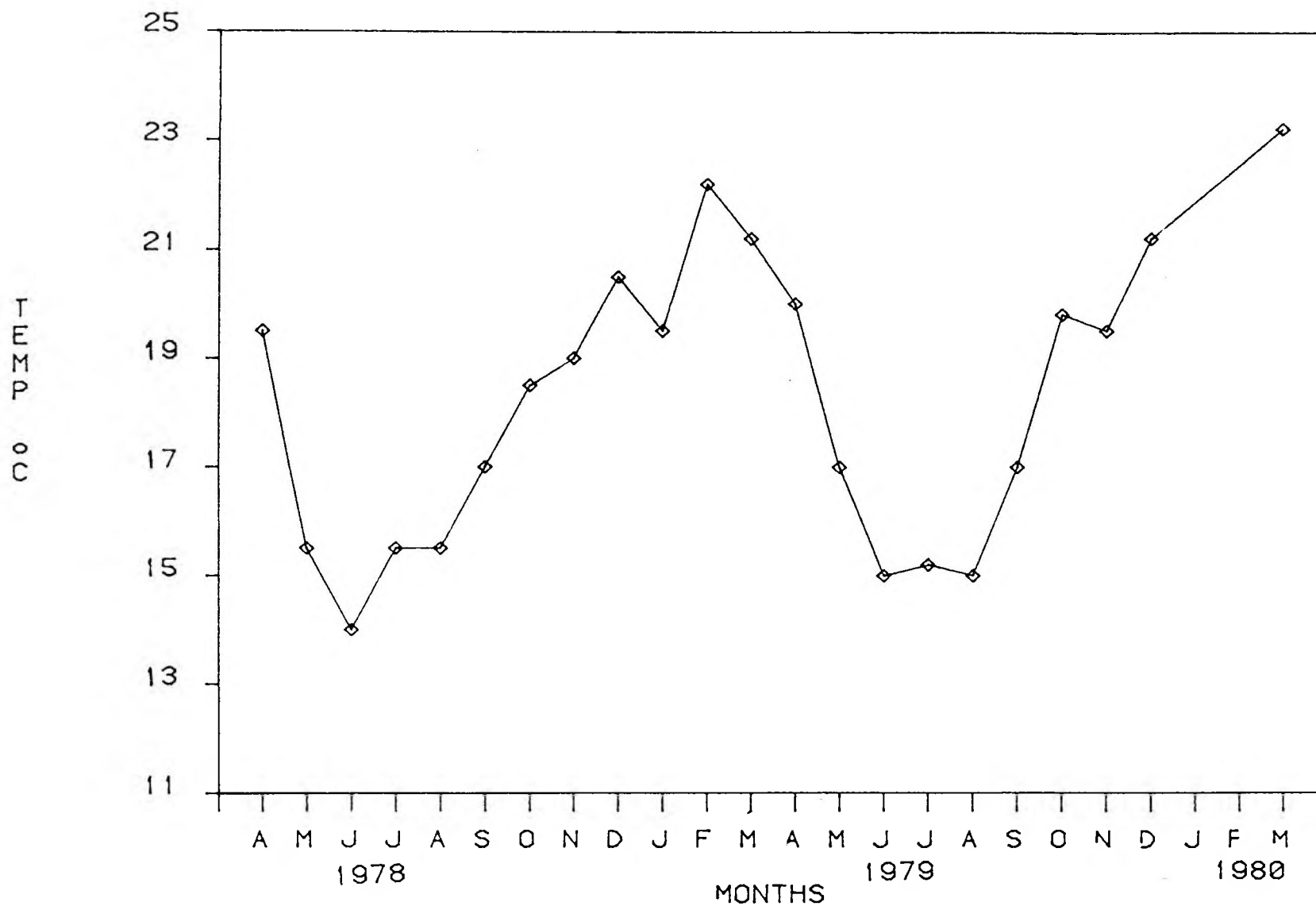


FIG. 2.2 The mean sea surface temperature at sampling areas as recorded on actual days of sampling.



TABLE 2.1 Macrofauna biomass values (ash-free dry mass in g) per 1m transect from ELWS to HW at St. Georges beach.

Species	Summer biomass	Winter biomass	Mean	%
<u>Donax serra</u>	74,73	102,76	88,75	81,96
<u>D. sordidus</u>	13,31	5,55	9,43	8,71
<u>Bullia rhodostoma</u>	2,40	9,50	5,95	5,50
<u>Gastrosaccus psammodytes</u>	0,00	1,67	0,84	0,78
Isopoda	1,42	1,31	1,37	1,27
Polychaetes	3,90	0,00	1,95	1,80

from McLachlan, 1977b

certain times of the year (Baird, pers. comm.).

Exposed sandy beaches are usually characterized by turbulent surf zones where much wave energy is expended in water and sediment transport (McLachlan, 1980). The amount of wave action is dependent on the relative position of the beach to the approaching swell, in combination with the prevailing wind conditions. Beckley and McLachlan (1979) constructed a wave rose which indicated that deep sea waves reaching the shallow area near Cape Recife are refracted into Algoa Bay (Fig. 2.1). Thus St. George's beach and Van der Riet's beach are relatively sheltered from heavy wave action while Sundays River beach, to the eastern corner, is more exposed and is characterized by heavy wave action.

Strong south-westerly winds blow throughout the year and south-easterly winds which are more pronounced during the summer, have an important influence on the currents in Algoa Bay (Fig. 2.1) (Beckley, 1977).

Fig. 2.2 shows the mean sea surface temperatures as recorded on actual sampling days at the three sampling sites: St. George's beach, Van der Riet's beach and Sundays River beach. A regular seasonal fluctuation is shown and although these temperatures were higher than the annual temperatures recorded at Humewood Beach (range between 11-26°C (Beckley, 1977)), the same seasonal variations are shown. Maximum surface temperatures were recorded during

February-March and minimum temperatures during June-July.

The trawling ground used for offshore sampling in this study was situated at 34°05'S and 25°45'E in the mouth of Algoa Bay between the 55m and 95m depth contours (Fig. 2.1). The maximum depth recorded on the sampling ground was approximately 80m. Echo soundings and the absence of fauna associated with a rocky substrate in the otter trawl nets indicated that the trawling ground had a soft bottom consisting predominantly of a sandy substrate.

## 2.2 BIOLOGICAL FEATURES

The microfauna, meiofauna and macro-fauna categories of the sandy beach benthos have received considerable attention in the Eastern Cape (McLachlan 1977a, b, c; McLachlan and Furstenberg, 1977; McLachlan, Erasmus and Furstenberg, 1977; McLachlan and Hanekom, 1979; Dye, 1979; McLachlan 1980a, b; McLachlan et al, 1981; Wooldridge, 1981). The composition, distribution and biomass of the micro- and meiofauna of Algoa Bay has been described by Dye (1979) and McLachlan (1977 a, b, c); McLachlan and Furstenberg (1977); McLachlan, Erasmus and Furstenberg (1977).

On Eastern Cape beaches, the supralittoral macrofauna communities are virtually absent, probably due to the absence of drift line algae and exposure to relatively high temperatures. Only occasional juvenile specimens of the ghost crab, Ocypode ryderi are observed. Few of these crabs survived more than a year (McLachlan, 1980a).

The midlittoral zone extending from MTL to HWN, is dominated by the white sand mussel, Donax serra. Low numbers of isopods (Pontogeloides latipes and Eurydice longicornis) were also observed to be present in this zone. The lower zone, below MTL, is occupied by the plough-shell (Bullia rhodostoma), the sand mussels (Donax serra and D. sordidus) and the beach mysid (Gastrosaccus psammodytes) (McLachlan, 1980b).

Biomass values for the species occupying the three zones at St. Georges strand is given in Table 2.1. The bulk of the intertidal macrofauna biomass on Eastern Cape beaches is made up of filter feeders (98%) and the rest by scavengers (McLachlan, 1980c).

The species occupying the lower zone undergo tidal migrations which vary in extent but are all upshore on the incoming tide and downshore on the outgoing tide during day and night (McLachlan, Wooldridge and Van der Horst, 1979). Other species occurring in the intertidal zone included polychaetes, nemerteans and the mole crab, Emerita austroafricana (McLachlan, 1977b).

In the sublittoral zone, the three-spotted swimming crab, Ovalipes punctatus, preys on molluscs from the intertidal and shallow subtidal (Du Preez, 1981).

The zonation and distribution of the beach mysid, Gastrosaccus psammodytes, in the intertidal and surf zone, has been described by Wooldridge, (1981). Of four species of mysids recorded in the zooplankton, Mesopodopsis slabberi is dominant followed by G. psammodytes (Wooldridge, pers. comm.). The penaeid, Macropetasma africanum, occurs in greatest numbers close to the area where approaching waves first break (Cockcroft, pers. comm).

These beaches thus support a moderately rich macrofauna dominated by molluscs and crustaceans which are concentrated between the low and mid tide levels. All species do, however, undergo tidal migrations.

## CHAPTER 3

## SAMPLING METHODS

## 3.1 INTRODUCTION

Sampling of elasmobranchs poses a problem in that it usually involves expensive fishing gear e.g. large nets or long lines. Gear of this type is used commercially and needs many hands or mechanical means for operation. Fisheries were the most common sampling outlets for most research done in the past on elasmobranchs. A considerable amount of information relevant to the exploitation of an elasmobranch species can be obtained in this way (Holden, 1974). Not all species are exploited and those that are, are well documented in the literature to date e.g. Squalus acanthias. For seasonal studies a constant supply of samples (at least monthly) is necessary over a period of at least two years.

In the present study three methods were used to obtain sand sharks during the sampling period. Animals were captured from the beach by organized angling parties and by beach seine netting while offshore trawling yielded animals from deeper waters.

## 3.2 ANGLING

Two local angling clubs (Greenbushes and St. Croix) were approached to participate in a research programme which involved the capturing of elasmobranchs by hook and reel in

the surf zones off sandy beaches in Algoa Bay. The two parties, which consisted on average of 15 anglers each, fished at monthly intervals for an average of four hours per outing from April 1978 to March 1980 (see Appendix I). The choice of angling spots within the sampling areas was left to the anglers. During unfavourable weather conditions when heavy wave action and pounding breakers were encountered, this often resulted in the anglers moving up and down the coast within the sampling area. Angling usually commenced at 06h00.

Pink prawn, Callinassa kraussi, was considered the most favourable bait for R. annualtus, although other baits were also used, including pilchard (Sardinops ocellata), white sand mussel (Donax serra) and squid (Loligo reynaudi). Although the selection of bait and fishing gear was aimed at catching sand sharks, the capturing of bony fish as well was inevitable.

### 3.3 BEACH SEINE NETTING

Specimens were obtained from monthly fish seining between September 1978 and October 1980. This was carried out by Lasiak (1982) who was studying the surf zone fish community at Kings Beach (see Fig. 2.1). Two nets, a coarse net (60m long, 2m deep, with stretched mesh size of 4cm) and a fine seine net (30m long, 2m deep, with stretched mesh size of 1,7cm) were used for sampling. This sampling method supplemented the smaller size classes of sand sharks which were not captured by the anglers due to selective

fishing for the larger size classes.

#### 3.4 TRAWLING

During the study period seven cruises were undertaken by a commercial trawler in Algoa Bay (see Appendix II). Bottom trawling was done by means of otter trawl. The footrope was 38m long, the headrope 27m long and the stretched mesh size 85mm. The selection of the trawling ground was determined by the knowledge of the local trawlermen of the nature of the bottom and the presence of elasmobranchs.

The duration, position and depth in fathoms was noted for each drag. For the purpose of this study only the numbers and stomach contents of sand sharks were collected. All specimens of elasmobranchs captured were identified and additional biological data will serve as a basis for future research on elasmobranchs in Algoa Bay.

Specimens of R. annulatus were tagged on board and released.

#### 3.5 COLLECTION OF DATA AND MATERIALS

All specimens were identified according to Smith (1965), whereafter wet mass, sex, total length, disc width and first dorsal length were recorded. Two clasper lengths, inner and outer, were taken for males. Length measurements were taken to the nearest 1mm (see Chapter 4 for methods of measurement). Gonads were dissected out, weighed to the



nearest 0,1g and fixed in Bouin's fluid for histological sections. Macroscopic observations and egg-numbers were recorded for the ovaries. Embryos in utero were counted and preserved in 10% formalin. Livers for both sexes were dissected out, weighed to the nearest 0,1g, colour noted and frozen for subsequent analysis. Vertebral sections were collected for age determination studies (Chapter 6). A piece of the vertebral column, extending from the first dorsal fin posteriorly was removed and frozen.

Stomach contents were removed and preserved in 10% formalin for stomach contents analysis. Physical data collected on angling days, were sea surface temperature, wind conditions and general sea conditions.

## CHAPTER 4

## MORPHOMETRIC RELATIONSHIPS

## 4.1 INTRODUCTION

Morphometric relationships of external characters have been used extensively by taxonomists to separate closely related species (Hubbs and Ishyama, 1968, Teshima and Koga, 1973). Thus important taxonomic criteria are established. Once these relationships have been acquired and statistically described and quantified a means is also provided whereby measurements may be interconverted. If the relationship between two measurements is known and any one measurement is not available it can be calculated from the relationship equation. This has been used in this study when certain measurements were not available for individual specimens. Further, sexual dimorphism and changes with growth can be evaluated from morphometric relationships.

## 4.2 MATERIALS AND METHODS

Females used ranged in total length from 270-1098mm and males from 235-1010mm. The number of specimens used for computation of different interrelationships is shown in Table 4.1

The methods of measurement used in this study were similar to those used by Wallace (1967a) and are illustrated in Fig. 4.1. The following measurements were taken:

- A. Disc width - greatest distance between outermost tips of pectoral fins.
- B. Disc length - greatest distance from snout tip to posterior margin of pectoral fins.
- C. First dorsal length - the distance from snout tip to the origin of the first dorsal fin.
- D. Total length - the horizontal distance from the tip of the snout to the most posterior point on the caudal fin.
- E. Inner clasper length - from the tip of the clasper to its inner origin below cloaca.
- F. Outer clasper length - from the tip of the clasper to its outer origin at the pelvic fin.

Regressions were obtained between total length and the rest of the measurements taken, as well as between inner and outer clasper lengths.

For comparison of data obtained in this study with that of Wallace (1967a) each measurement was converted into a percentage of the specimen's total length.

#### 4.3 RESULTS AND DISCUSSION

Table 4.1 shows the results of regressions obtained between different length parameters for R. annulatus. The relationships between total length vs disc width and first dorsal length showed simple isometric growth. This is illustrated in Figs. 4.2 and 4.3 in the relationship between total length and disc width for different sexes. When sexes were combined the relationships between total length and

TABLE 4.1 Summary of regressions of length parameters of R. annulatus.

Parameter	Sex	Type of Regression	a	b	r	n	p
Total length vs Disc width	♀	linear	1,90	0,34	0,992	158	p<0,001
"	♂	linear	14,63	0,31	0,989	242	
"	♀+♂	linear	9,23	0,32	0,939	404	"
Total length vs Disc length	♀	power	0,24	1,07	0,951	159	"
"	♂	power	0,48	0,96	0,949	245	"
"	♂+♂	linear	3,50	0,40	0,900	404	"
Total length vs First dorsal length	♀	linear	-23,97	0,61	0,850	154	"
"	♂	linear	32,52	0,52	0,834	240	"
"	♀+♂	linear	25,67	0,54	0,827	394	"
Total length vs Outer clasper length	A	power	0,33	0,76	0,539	182	"
"	J	power	0,01	2,62	0,743	46	"
"	A+J	log	721	127	0,901	228	"
Total length vs Inner clasper length	A	power	0,24	0,91	0,903	183	"
"	J	power	0,01	1,90	0,739	45	"
"	A+J	log	720	124	0,914	228	"
Inner clasper length vs Outer clasper length	A	power	1,63	0,76	0,549	182	"
"	J	power	0,10	1,37	0,981	46	"
"	A+J	power	0,23	1,17	0,923	228	"
Total length vs mass	♀	power	1,08x10 <sup>-6</sup>	3,18	0,991	137	"
"	♂	power	2,42x10 <sup>-6</sup>	3,04	0,993	202	"
"	♀+♂	power	1,08x10 <sup>-6</sup>	3,17	0,990	339	"

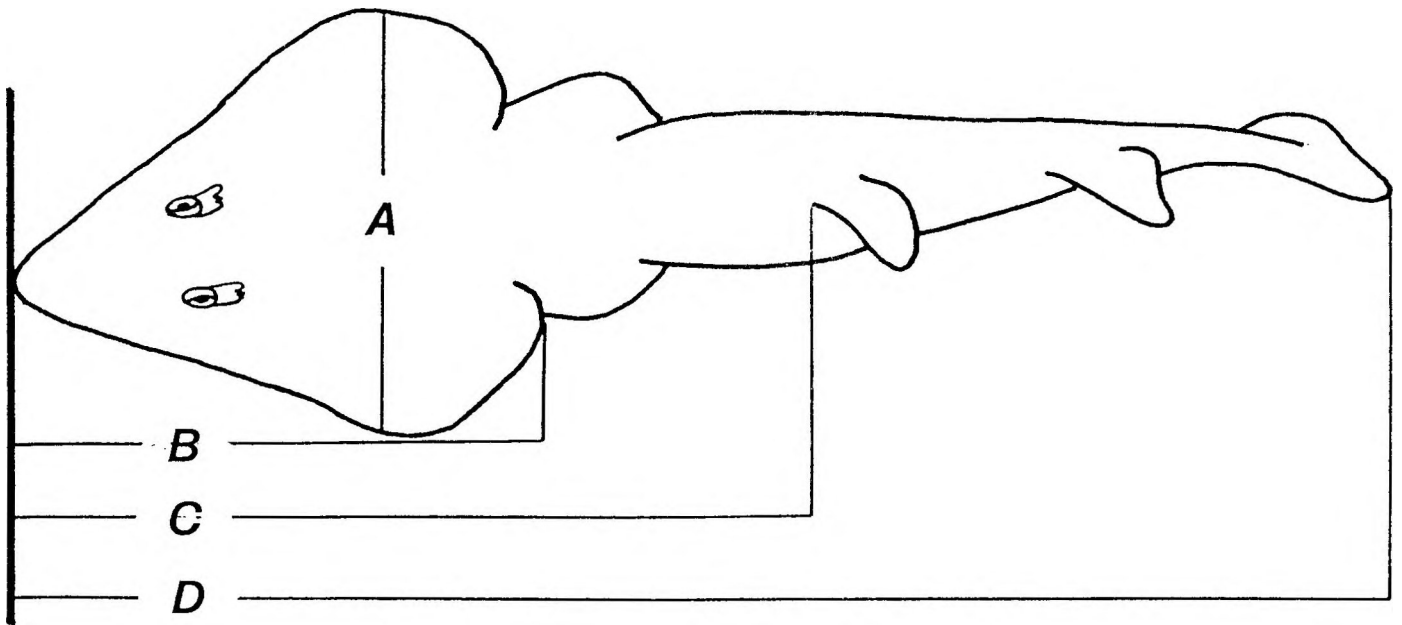
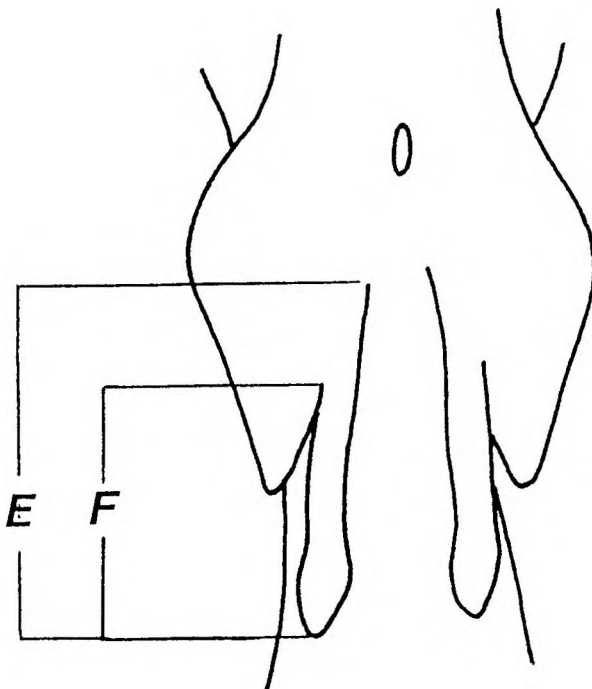


FIG. 4.1 Outline of *R. annulatus* to illustrate the methods of measurement.

- A. Disc width
- B. Disc length
- C. First dorsal length
- D. Total length
- E. Inner clasper length
- F. Outer clasper length



DISC WIDTH IN MM

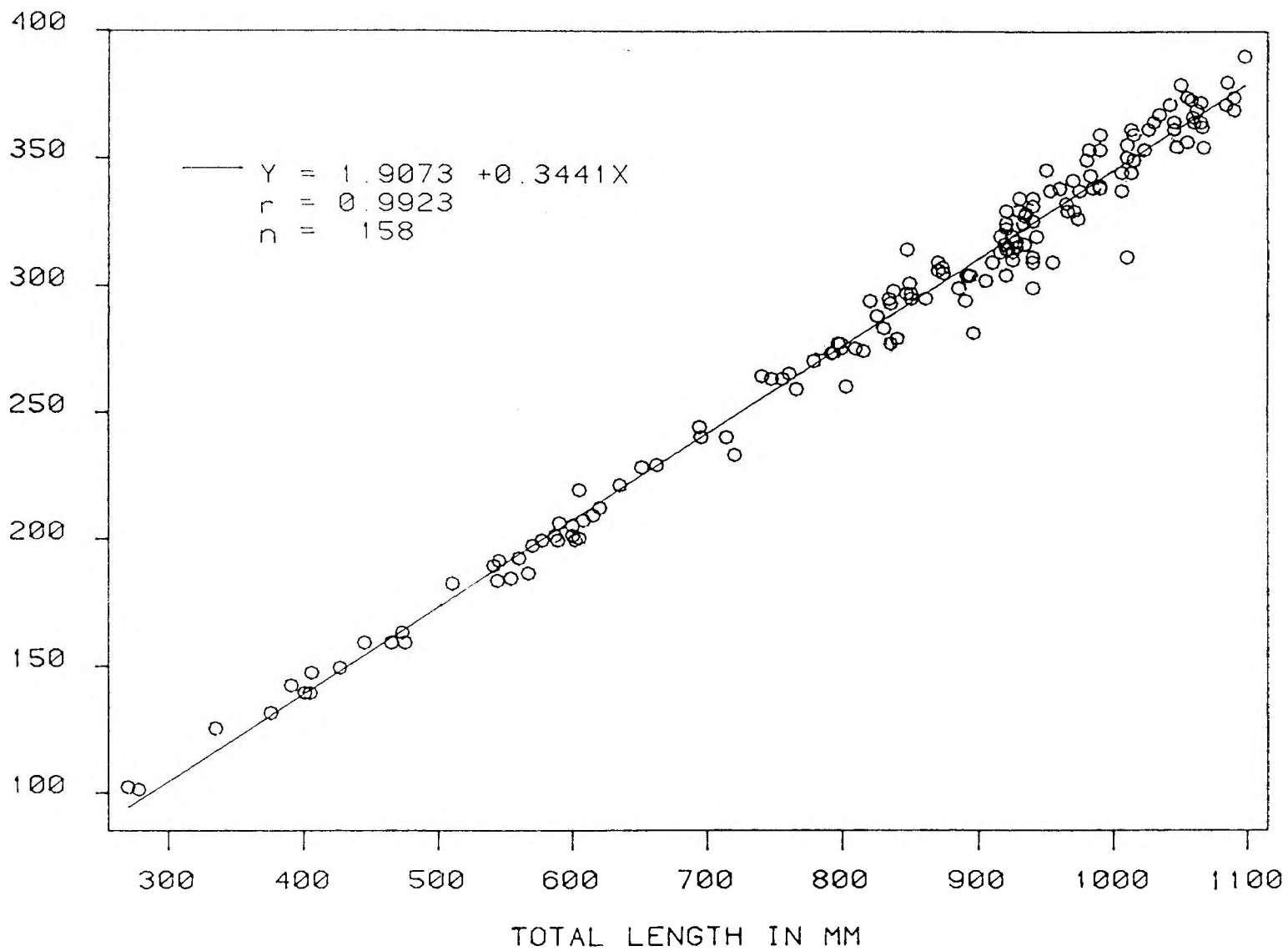


FIG. 4.2 The relationship between total length and disc width in R. annulatus (females).

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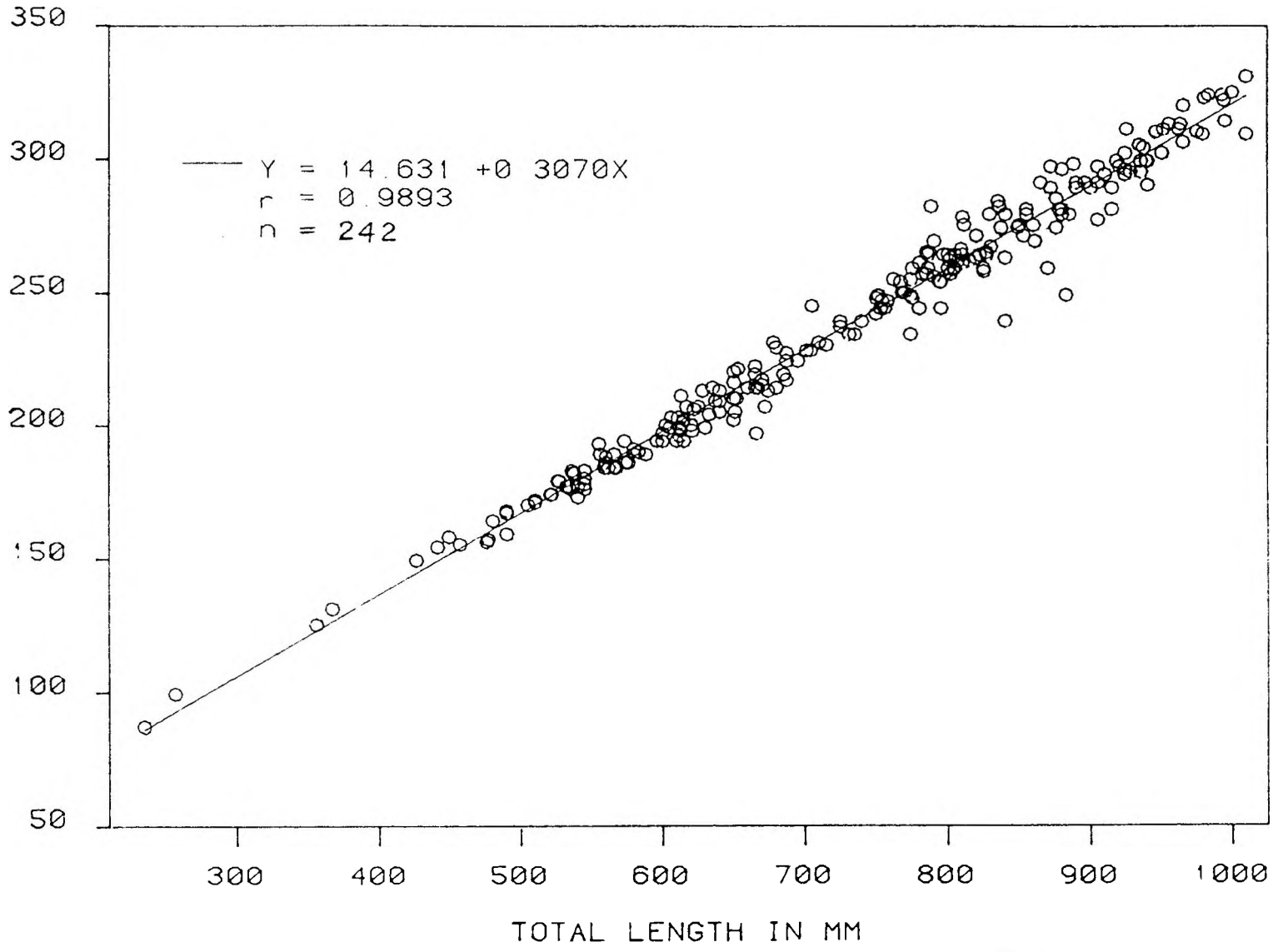


FIG. 4.3 The relationship between total length and disc width in R. annulatus (males).

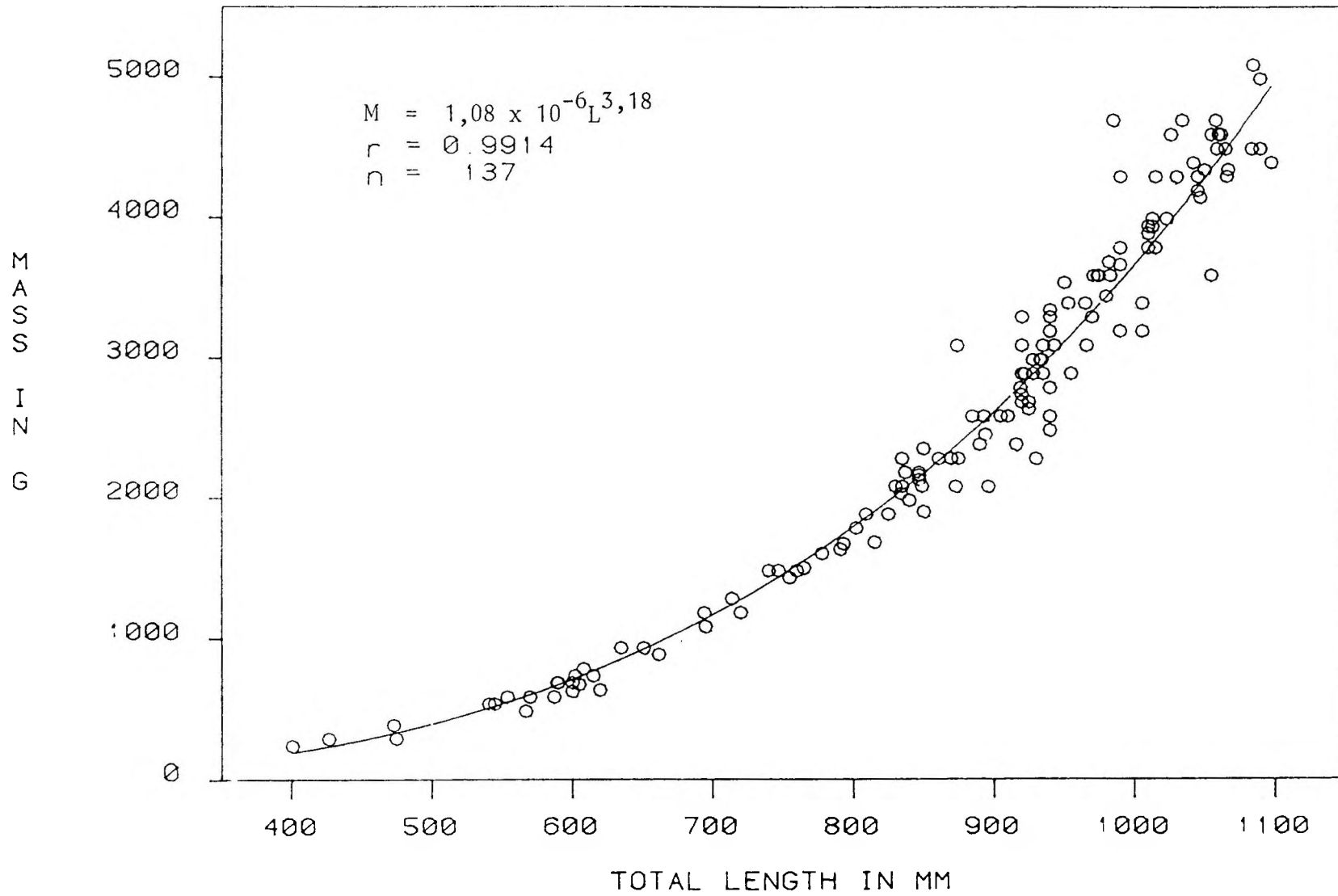


FIG. 4.4 The relationship between total length and mass in R. annulatus (females).



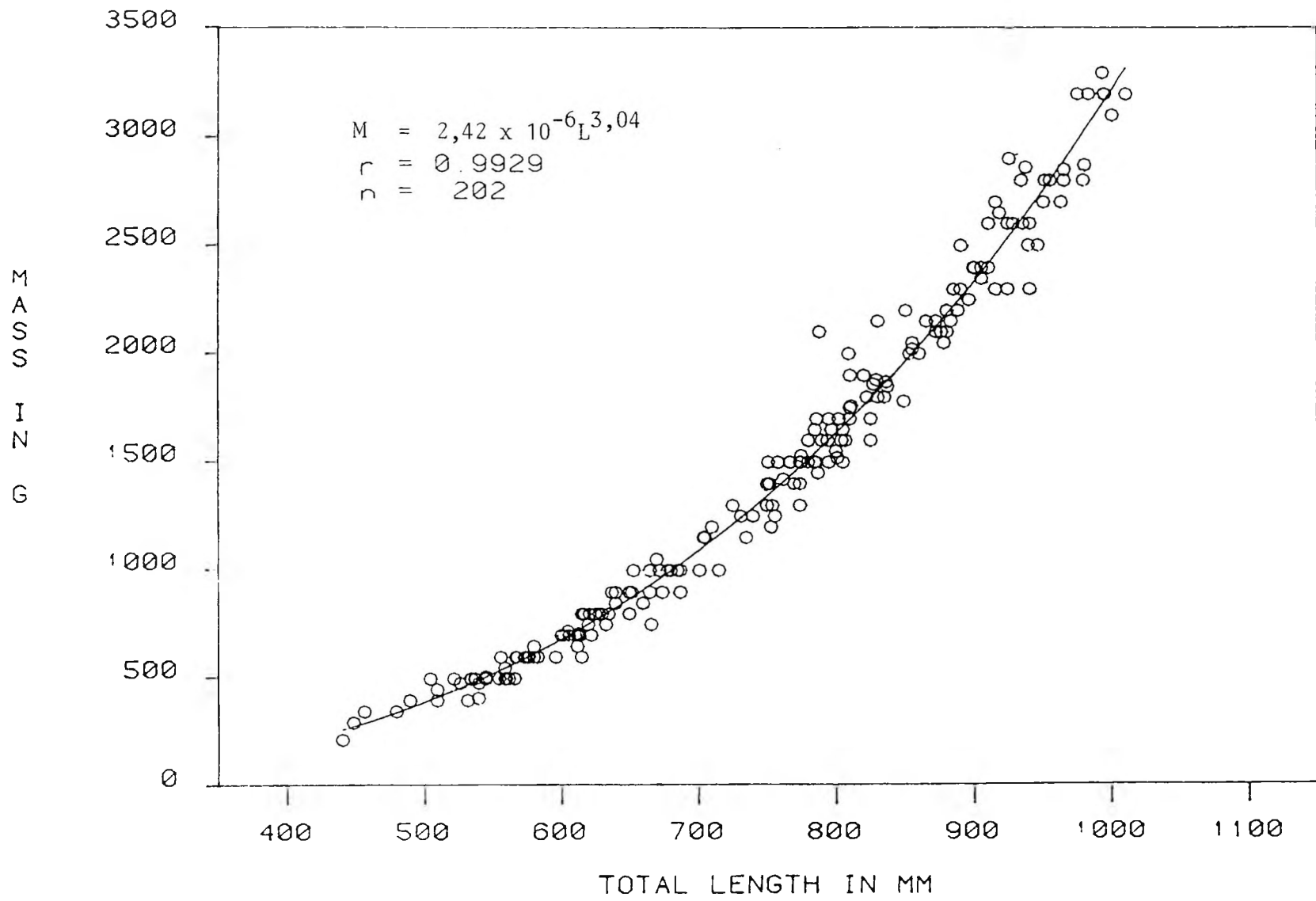


FIG. 4.5 The relationship between total length and mass in R. annulatus (males).

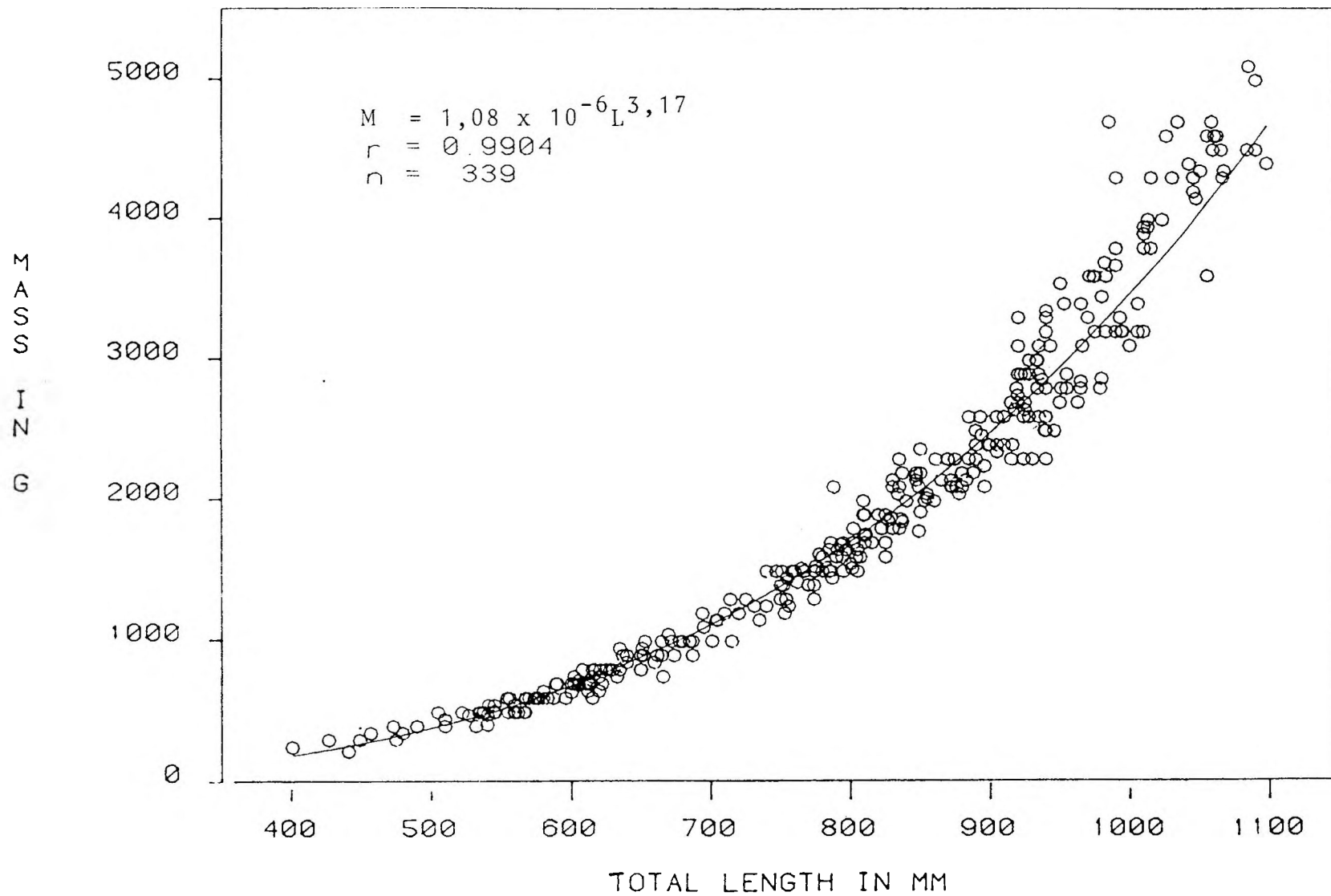


FIG. 4.6 The relationship between total length and mass in R. annulatus (males and females).

disc length also showed isometric growth. All the other parameters, however, showed allometric growth (Table 4.1).

The length and mass measurements made each month were pooled and separated for the sexes. Using the expression  $M = aL^b$  (where  $M$  = mass and  $L$  = total length) the length mass relationship is illustrated in Figs. 4.4, 4.5 and 4.6 for different sexes and sexes combined. Allometric growth was shown by both sexes. Capapé (1980) showed that the relationship between size and weight indicated a higher ponderal growth in young rays than in adults. R. annulatus conformed to the latter statement. A significant difference ( $p < 0,01$ ) was found between the mass and total lengths of males and females. This sexual dimorphism in length and mass existed in R. annulatus with females bigger than males at the same age.

In Table 4.2 the results obtained in the present study are compared with Wallace's (1967a) results. Although he stated that R. annulatus from the cooler waters of the Cape appears to grow to a larger size the specimens obtained in this study did not show any morphometric differences from the specimens obtained by him.

When adults and juveniles were combined, clasper growth showed a logarithmic relationship. This was due to differences in pre- and post maturity growth (see chapter 7). Teshima (1981) described similar growth patterns for the claspers of Japan se dogfishes.

TABLE 4.2 Morphometric analysis of R. annulatus.

Measurements are expressed as a percent of total length.

Measurements	Mean %			Wallace*
	Females n = 159	Males n=245	Sexes combined n = 404	
Total length	100,0	100,0	100,0	100,0
Disc length	41,7	39,9	40,3	39,0
Disc width	34,6	33,3	33,5	33,9
Snout to first dorsal	59,0	58,3	57,5	59,2
Inner clasper length	-	13,3	-	-
Outer clasper length	-	7,3	-	-

\* Wallace, 1967a.

n = Number of specimens

## CHAPTER 5

## SEASONAL ABUNDANCE AND MIGRATION

## 5.1 INTRODUCTION

As far as known, no previous tagging of elasmobranchs took place in South African seas prior to 1964 when the Oceanographic Research Institute began a program of shark tagging in Durban. The majority of these included the larger, predatory and potentially dangerous species (Davies and Joubert, 1967). Only one batoid species, Rhyncobatus djeddensis, was included in this tagging program. No literature was available on other batoids tagged in South Africa or elsewhere. This study appears to be the first attempt to elucidate movements of R. annulatus by means of tagging.

Although the sand shark is the most abundant elasmobranch in the surf zone (Rossouw, 1979), very little is known about its movements. Smith (1965) states that R. annulatus moves into shallow waters and estuaries during the summer to give birth. Local anglers observed that there is an increase in abundance of sand sharks during the summer months and a decrease during the winter months. This was interpreted as resulting from an on-shore/off-shore migration. Consequently a tagging programme was started in June 1978. In addition catch per unit effort (C.P.U.E.) information was employed to elucidate the seasonal movements of R. annulatus.

## 5.2 TAGGING

Tag-evaluation experiments on elasmobranchs by Davies and Joubert (1967) showed that the Petersen discs, nylon-barbed dart tags and several other type dart tags all caused irritation, necrosis of the tagged area and shedding within varying periods of up to four months. Due to this evidence it was decided not to use tags that required prepunched holes in the present study but rather a small spaghetti type tag that could be applied directly by means of a hollow needle.

### 5.2.1 MATERIALS AND METHODS

A Banok 103-L tagging gun was used to apply the Floyd FD-67c spaghetti type tags. The tag was applied to the base of the leading edge of the first dorsal fin, after recording the sex, total length and disc width. The tagging programme was publicised in the local press and all the angling clubs in the Eastern Cape were notified. Sand sharks obtained from otter-trawling in Algoa Bay were first examined to obtain only healthy, undamaged specimens before tagging commenced. Large numbers of sand sharks were killed on the trawler when the net was hoisted aboard, due to the compressing effect on the fish concentrated in the cod end. Of the survivors, 197 were tagged and released. A further 118 which were caught by anglers off St. Georges beach and Kings Beach, were tagged after careful removal of the hook.

### 5.2.2 RESULTS AND DISCUSSION

By November 1982, nine tags had been recovered, an overall recapture rate of 2.6%. Davies and Joubert (1967), tagging elasmobranchs off the Natal coast, South Africa, tagged 17 specimens of the guitar fish, Rhynchobatus djeddensis of which two were recaptured. The return rate of blue sharks tagged by Stevens (1976) was 1.5% (30 recaptured from 2024 marked fish). Details of tag recoveries are given in Table 5.1.

All the recoveries were from the same locality where tagging was done therefore no on-off-shore movements could be derived from specimens tagged. This could be attributed to low numbers tagged over a short period and only continuation of the tagging programme could result in definition of migration patterns, if they exist. On-shore recoveries, however, revealed short along-shore movements and the greatest distance covered between tagging and recapture was 3km from the original site of tagging. Davies and Joubert (1967) have tagged and recaptured R. djeddensis in the same season and therefore could not indicate on/off-shore movement but a distance of 2,5km southwards was recorded for one recaptured specimen.

Tags returned after longer than 200 days had early stages of red and green algal growths on them obscuring the lettering. No serious tagging wounds occurred and fish that had tags for over 400 days showed no signs of abrasion,

TABLE 5.1 Tag recoveries of R. annulatus

Sex	Total length (mm)	Date tagged (t <sub>1</sub> )	Locality	Total length (mm) 12	Recovery data			Locality	Remarks
					Date t <sub>2</sub>	l <sub>2</sub> -l <sub>1</sub> (mm)	t <sub>2</sub> -t <sub>1</sub> (days)		
♂	625	24/ 6/78	St. Georges Beach	634	11/ 2/79	9	323	St. Georges Beach	
♂	870	26/6/78	Trawling ground	884	4/ 9/79	14	435	Trawling ground	Released
♀	790	26/ 6/78	Trawling ground	796	24/10/78	6	120	Trawling ground	
♀	670	26/ 6/78	Trawling ground	730	4/ 9/79	60	435	Trawling ground	
♀	870	26/ 6/78	Trawling ground	875	24/10/78	5	120	Trawling ground	
♀	370	19/12/78	Kings Beach	373	14/ 5/79	3	146	Kings Beach	
♂	450	15/ 1/79	Kings Beach	460	8/ 8/79	10	205	Kings Beach	Released
♂	336	15/ 1/79	Kings Beach	336	19/ 3/79	0	63	Kings Beach	
♂	425	27/ 6/79	Kings Beach	433	21/ 2/80	8	239	Kings Beach	Released



necrosis or swelling of the skin.

No information on tagging mortality or shedding of tags is available in this study. However, 10 tagged sand sharks that survived for longer than three months in an aquarium in the laboratory, showed no signs of rejection of the tags.

### 5.3 CATCH PER UNIT EFFORT

Due to low numbers of sand sharks tagged, low numbers of recapture and the methods employed to obtain sand sharks in this study, assessment of population size was not possible. However, catch per unit effort (C.P.U.E.) refers to the amount of fish caught per specific amount of work and provides an index of abundance. The C.P.U.E. can be expressed in terms of numbers or mass of fish caught per unit of work done. In this study the C.P.U.E. was expressed as number or mass of sand sharks caught per man per hour for anglers catches and number or mass of sand sharks trawled per drag per hour. Comparison of these indices were used to determine the abundance of sand sharks inshore and offshore at any one month.

#### 5.3.1 MATERIALS AND METHODS

The C.P.U.E. was calculated for anglers catches each month when catches were made off sandy beaches.

Offshore, the same otter trawl gear was used and a consistent trawling speed maintained during all cruises when sampling was done offshore.

### 5.3.2 RESULTS AND DISCUSSION

Fig. 5.1 shows the C.P.U.E. of anglers catches expressed as the number of sand sharks caught per man hour over a period of 24 months. Although the hook and reel method of capturing fish tends to be selective, Fig. 5.1 does reveal some trends. Catches were higher during the months November to March (summer months) followed by a decrease in numbers from March to August. Catches during the winter months of 1978 and 1979 were dominated by juveniles. This is revealed by the sex composition of the catch in Fig. 5.2. The prevalence of juveniles is also reflected in Fig. 5.3 where the C.P.U.E. (inshore) is expressed as mass caught per man hour.

Catches off the beach were negatively influenced on days when heavy plunging waves occurred. Sand sharks seem to avoid the surf zone during storm surf and move further out to an area behind the breakers and these conditions coincided with sampling days in November 1979 and during the summer months in 1980 causing low sampling numbers.

Although heavy seas complicated sampling, the C.P.U.E. decreased during the winter months and increased during the summer months for adult sand sharks caught by hook and reel off sandy beaches (Fig. 5.1 and Fig. 5.3).

The C.P.U.E. of sand sharks captured by trawling expressed as number or mass per trawl per hour reveals a decrease in catches during the summer months and conversely

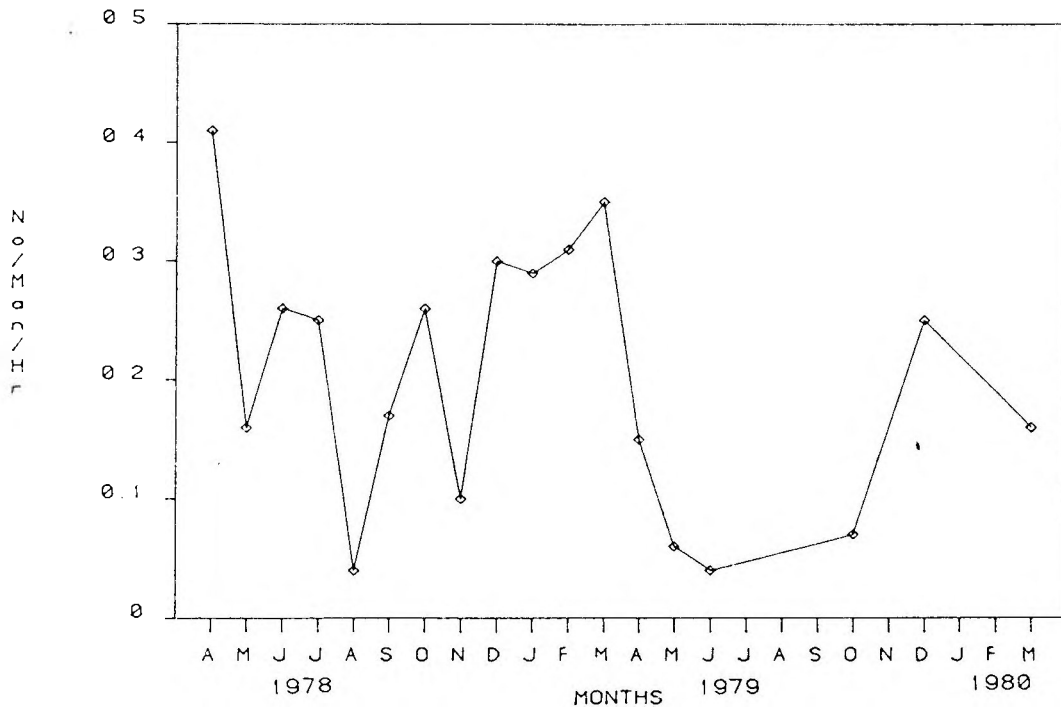


FIG. 5.1 Catch per unit effort expressed as number of sand sharks per man hour caught by hook and reel.

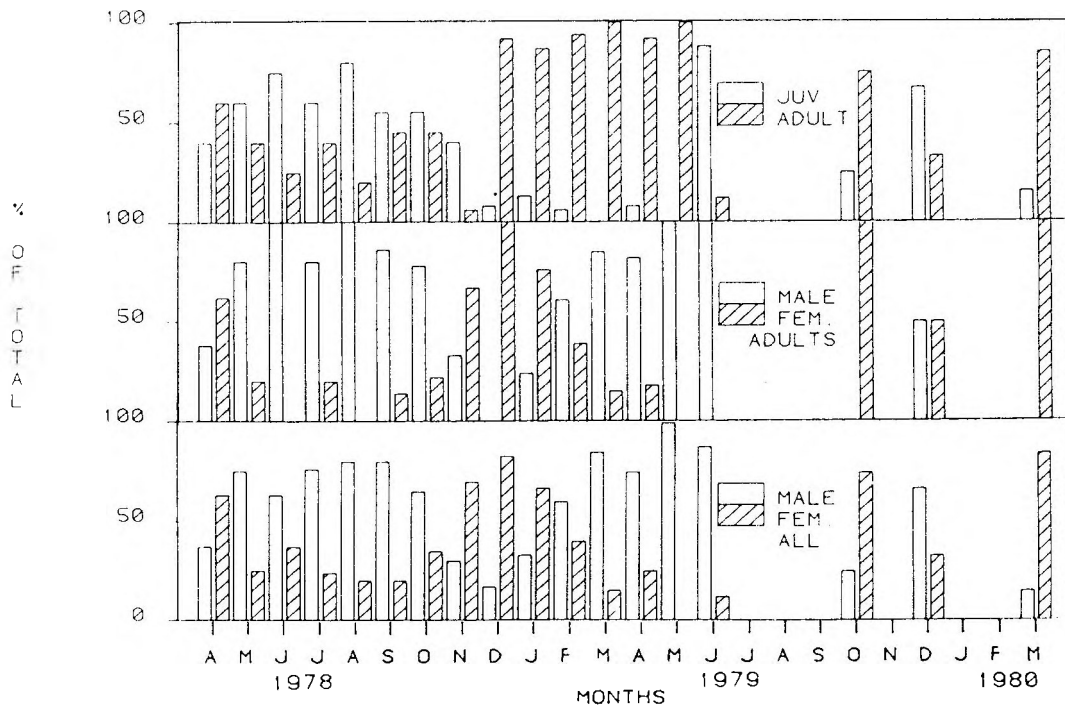


FIG. 5.2 Sex composition of *R. annulatus* caught by hook

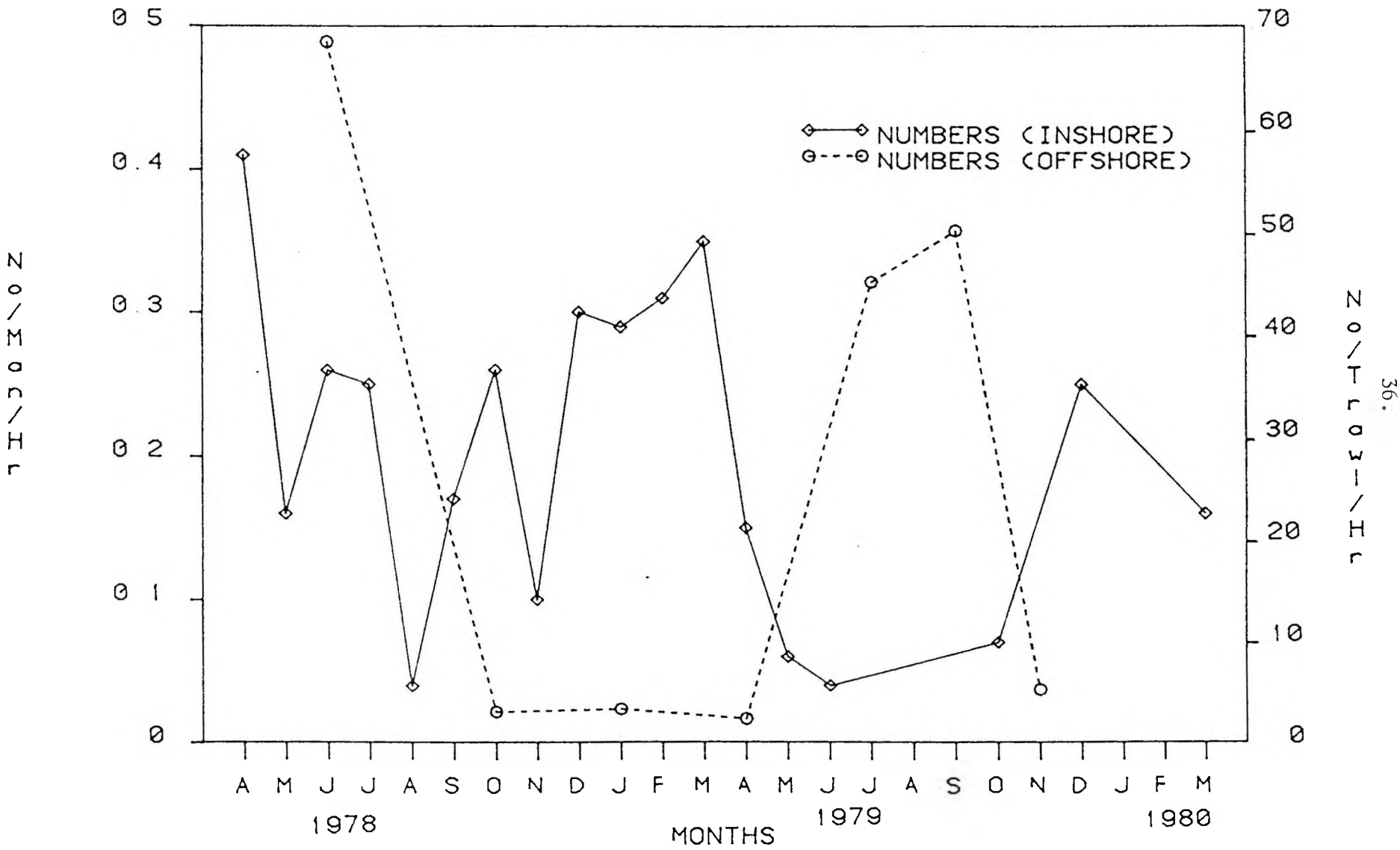


FIG. 5.3 Catch per unit effort of *R. annulatus* expressed as numbers caught per man hour (inshore) and numbers trawled per hour (offshore).

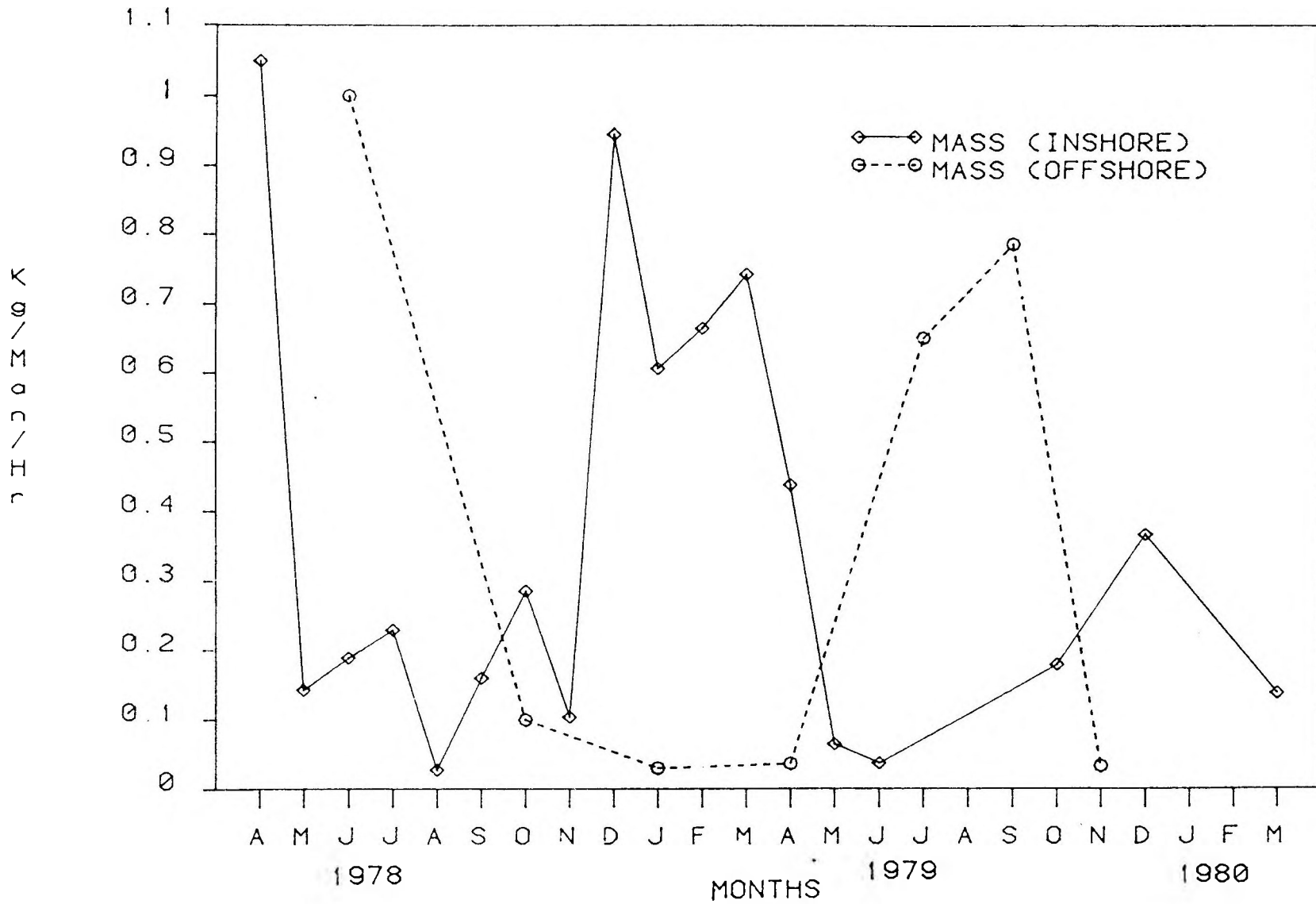


FIG. 5.4 Catch per unit effort of *R. annulatus* expressed as mass caught per man hour (inshore) and mass trawled per hour (offshore).

an increase during the winter months. All specimens captured during trawling operations were adults.

Thus for adult sand sharks at least, the 'disappearance' during the winter months and 'appearance' early in summer (as observed by local anglers) is confirmed by the C.P.U.E.

#### 5.4 MIGRATION

The tagging programme could not confirm any major movements of R. annulatus as no sharks tagged offshore were caught in the surf or vice versa. However, the C.P.U.E. calculations based on anglers catches and trawling off-shore suggest some seasonal movements.

The presence of juveniles throughout the year in the surf zone (confirmed by beach seine netting) and exceeding the adults in numbers during the winter months suggests that sand sharks only become migratory when sexual maturity has been reached. The initial predominance of females in early summer (November), and the late arrival of males, indicates that female sand sharks utilize the surf zone as nursery areas. Dominance of the males from March to June indicates that parturition and mating takes place with females starting to migrate after been fertilized (see Chapter 7). Only oviducal eggs were observed in females captured offshore during winter. Thus migration in R. annulatus should be correlated with reproductive patterns (see Fig. 7.21).

Migration probably does exist in the case of adult R. annulatus but to establish the exact winter grounds further tagging and recoveries are necessary. Gianuca (pers. comm.) studying the ecology of sandy beaches in southern Brazil noticed similar movements by Rhinobatus percellens. These batoids, known to the local population as "viola", appear in large numbers in the surf zone from October-November and disappear again towards the end of April-May. Inspection of the reproductive state of the adult females revealed large and full-term embryos suggesting that the "viola" utilizes the surf zone as nursery areas during the summer months. During these months the fish is extensively exploited for human consumption.

## CHAPTER 6

GROWTH AND AGE OF RHINOBATOS ANNULATUS6.1 INTRODUCTION

The estimation of yield per recruit from a fishery depends on a knowledge of the growth rate, among other factors (Holden, 1974). Generalization of data in the form of growth curves or models assist the description of growth patterns, thereby making comparisons with other species, or the same species at different times and places, more feasible (Ricker, 1971). The structures most commonly used to determine the age of fishes are bones, otoliths and scales as evidence of seasonal changes in deposition of hard tissue is usually depicted in these structures. However, since these structures are not present in elasmobranchs, age determinations have been attempted in other ways.

A multitude of methods have been used for ageing sharks, skates and rays. These included the utilization of tagging data (Steven, 1936; Holland, 1957); size frequency analysis (Olsen, 1954); and markings on the spines of Squalus acanthias (Holden and Meadows, 1962) and the elephant fish, Callorhynchus milii (Sullivan, 1977). Calcified vertebral rings have been described for Carcharhinus leucas by Haskell (1949), Raja fusca by Ishiyama (1951), Raja eglanteria by Daiber (1960), Squalus



acanthias by Ketchen (1975), Prionace glauca by Stevens (1975), Raja batis and Raja naevus by Du Buit (1977) and Mustelus manazo by Tanaka and Mizue (1979). Holden and Vince (1973) described an experiment in which individuals of Raja clavata were tagged and injected with tetracycline. By relating the opaque and hyaline zones to the deposition of tetracycline, it was proved that one of each type of zone was laid down annually. Jones and Green (1977) estimated the ages of Squalus acanthias by an X-ray spectrometric technique which involved measuring variations in the element composition within vertebrae. The cyclic changes in calcium appeared to be annual and the authors suggested that age may be estimated by counting the cycles.

Tanaka and Mizue (1979) observed the monthly marginal growth of the vertebrae over a period of 12 months and concluded that the rings of the Japanese dogfish, Mustelus manazo were annual. Stevens (1975) demonstrated the annual nature of the rings in Prionace glauca by correlation with length-frequency and tagging data. However, most of the authors that studied rings in elasmobranchs, failed to comment on the annual nature of the rings (Haskell, 1949; Ishiyama, 1951; Daiber, 1960). At present studies on age and growth of elasmobranchs are few compared with studies of teleost fishes. No studies of this type have been conducted in South-African waters. The aim of this study was to assess vertebral annuli as a method for age-determination for the lesser sand shark, R. annulatus, and if feasible, to construct a growth curve.

## 6.2 MATERIALS AND METHODS

Vertebrae were obtained from sand sharks caught off sandy beaches in Algoa Bay and trawled offshore in depths ranging from 40 to 80 meters. The vertebrae were collected from May 1978 to March 1980 at monthly intervals (Table 6.1). Each specimen was sexed, weighed and the total length, first dorsal length and disc width were measured (see Chapter 3). From each sand shark a block of eight or ten vertebrae which extended posteriorly from below the leading edge of the first dorsal fin was removed. From preliminary observations these proved to represent the largest vertebrae in the vertebral column. Excess muscle tissue was removed and the samples stored frozen. The vertebrae were not preserved in formalin due to the decalcifying action of formic acid (La Marca, 1966).

For processing, the vertebrae were defrosted by placing them in hot water kept boiling for three to five minutes. After further excess muscle tissue and cartilage were removed, the vertebrae were washed in tap water and placed in the sun to dry for eight hours. In a dry state they could be stored indefinitely until such time that reading of the rings were undertaken. After drying, individual vertebrae were separated by carefully breaking them apart. Extreme care was taken to remove the connective tissue and notochordal remnants covering the anterior and posterior concave surfaces of the vertebrae. This was done with the

TABLE 6.1 Monthly number of specimens used to obtain annuli.

MONTH		MALE	FEMALE	TOTAL
MAY	1978	8	2	10
JUNE		10	5	15
JULY		0	0	10
AUG		3	1	4
SEPT		8	1	9
OCT		0	0	0
NOV		2	3	5
DEC		2	3	5
JAN	1979	8	9	17
FEB		18	14	32
MAR		18	3	21
APR		10	10	20
MAY		3	0	3
JUNE		8	1	9
JULY		0	0	0
AUG		5	3	8
SEPT		4	0	4
OCT		0	3	3
NOV		0	2	2
DEC		2	1	3
JAN	1980	0	0	0
FEB		10	10	20
MAR		<u>2</u>	<u>5</u>	<u>7</u>
		<u>121</u>	<u>76</u>	<u>197</u>

aid of fine forceps under a stereo microscope. The largest vertebra was then selected for measurements of centrum length and centrum diameter and processed with one or two others of the same block which served as controls. Centrum diameter was taken as an average value of two readings taken from opposite angles on each face. Vernier calipers were used to obtain centrum length and centrum diameter to 0,01mm for the vertebrae.

A small paintbrush was used to apply a 6% silver nitrate solution on both concave surfaces. Illumination by ultra-violet light enhanced the drying process considerably. Two to three minutes was sufficient time to stain the hyaline zones brown to black. The rings were then counted under a stereo microscope using reflected light. A combination of one dark zone and one light zone was taken to represent one ring. Each reading was compared with the controls of each block. The zone formed prior to the peripheral zone was also noted for each vertebra. Individual stained vertebrae and controls were then stored in plastic bags and reread after six months. Only those cases where reading after six months coincided with the initial reading were retained for age-determination. Those that did not coincide were discarded. Ten advanced embryo vertebrae centra were also investigated to determine the presence or absence of rings before birth.

### 6.3 RESULTS AND DISCUSSION

#### 6.3.1 Vertebral centrum and rings

Various techniques have been used to increase the clarity of the rings on the vertebral centra of elasmobranchs. The techniques described by Haskell (1949), Ishiyama (1951), La Marca (1966), Culling (1972), Stevens (1975) and Du Buit (1977) were all investigated in search of a procedure that is effective and requires a short preparation time. The technique finally adopted was based on the method used by Stevens (1975) to stain calcified rings on whole vertebrae of Prionace glauca. This silver nitrate method makes use of a substitute reaction in which a calcium salt in the vertebrae, usually a carbonate, phosphate or chloride, is replaced with silver. This staining method gave clear results and was quick and simple to use.

A stained centrum is shown in Fig. 6.1. The rings appeared as alternative concentric light and dark zones surrounding a central canal marking the position of the primitive notochord. Viewed under reflected light the dark rings represent the hyaline zones and the light rings the opaque zones. The rings of 90% of the vertebrae collected for the study could eventually be counted and they spanned the whole size range. Sexes were kept separate when the counting was done. In neither male nor female specimens were more than seven rings encountered. It is therefore

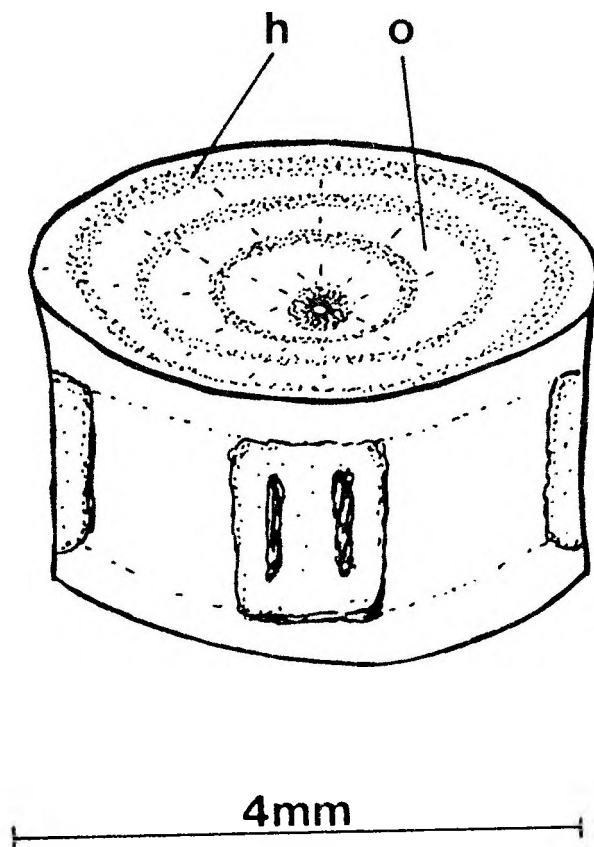


Fig. 6.1 Diagrammatic illustration of a stained centrum of *R. annulatus* showing opaque (o) and hyaline (h) rings.

suggested that this is the maximum number of rings formed during the lifetime of R. annulatus. A female which measured 109cm in total length and had a mass of 5kg, had the greatest length recorded in this study and showed only seven rings on the vertebral centrum. Furthermore, the mass was only 90g less than the maximum recorded mass for R. annulatus captured in the Eastern Cape (Official Eastern Province Records at 1st November 1978). Fig. 6.2 indicates the relationship between the number of vertebral rings and total body length in R. annulatus for males and females combined. Fig. 6.3 and Fig. 6.4 show the sexes separated.

There was no significant difference ( $p < 0,001$ ) whether the anterior or posterior face on a vertebra was used to measure centrum diameter or to count the rings. Although centrum radius has been measured in previous investigations of this nature (Ishiyama, 1951; Stevens, 1975; Tanaka and Mizue, 1979), it was decided to use centrum diameter for the present study because greater accuracy could be obtained measuring the diameter of the individual vertebrae as both faces gave similar results. Figs. 6.5, 6.6, and 6.7 show the relationship between vertebral length and centrum diameter.

VERTEBRAL RINGS VS LENGTH  
MALES AND FEMALES

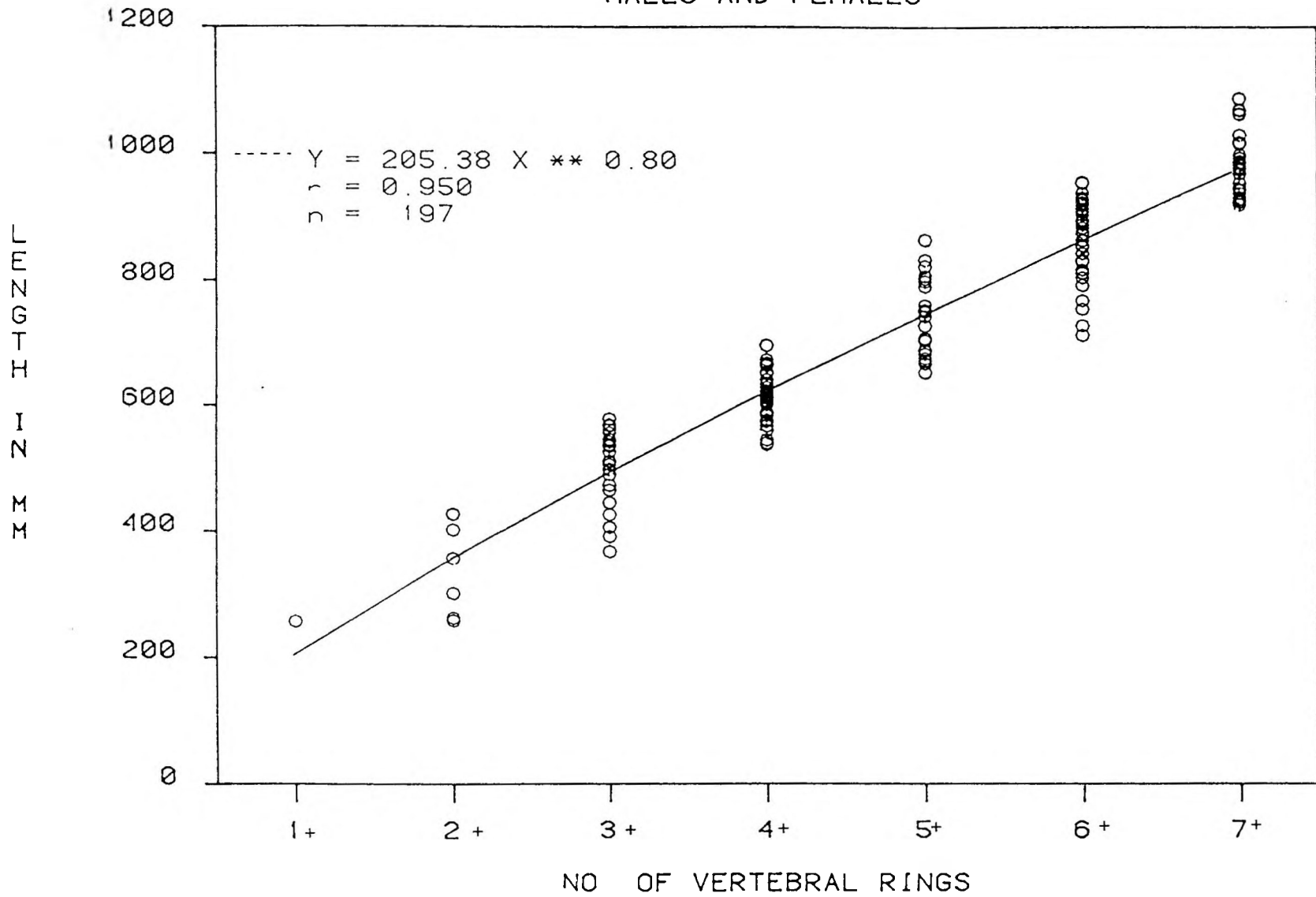


FIG. 6.2 The relationship between the number of vertebral rings and total body length in R. annulatus.



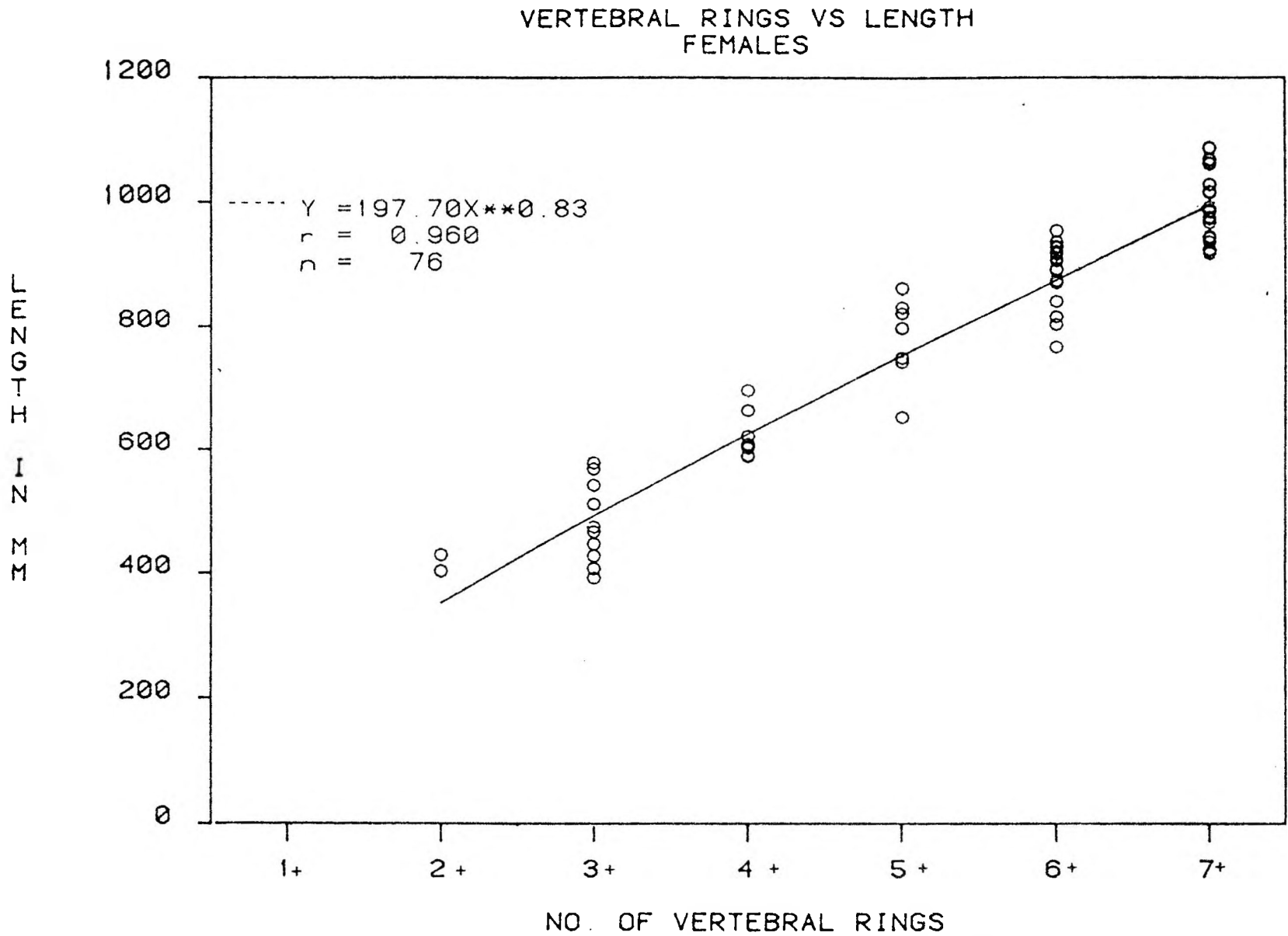


FIG. 6.3 The relationship between the number of vertebral rings and total body length in female R. annulatus.

VERTEBRAL RINGS VS LENGTH  
MALES

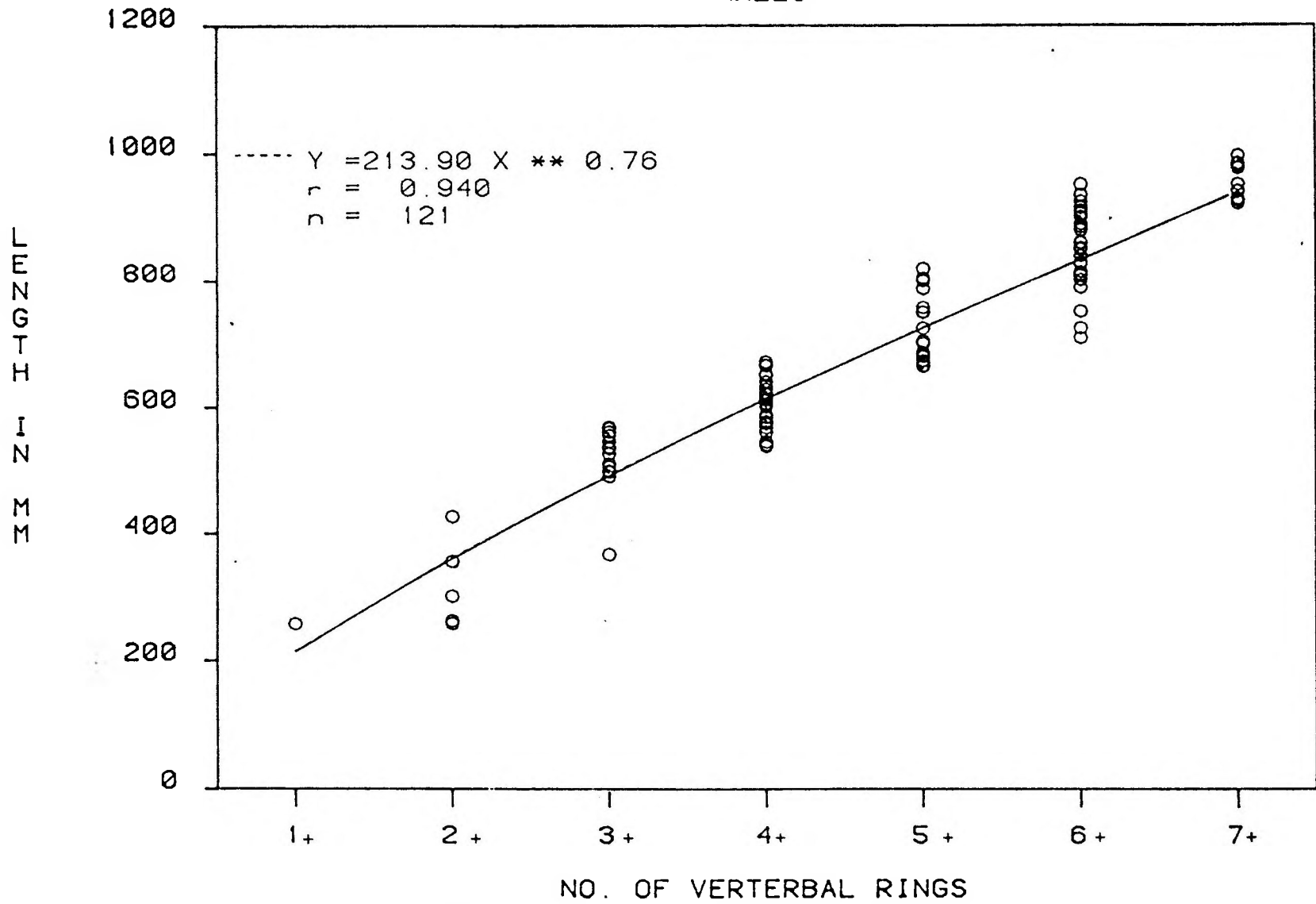


FIG. 6.4 The relationship between the number of vertebral rings and total body length in male R. annulatus.

VERTEBRAL DIAMETER VS VERTEBRAL LENGTH  
FEMALES

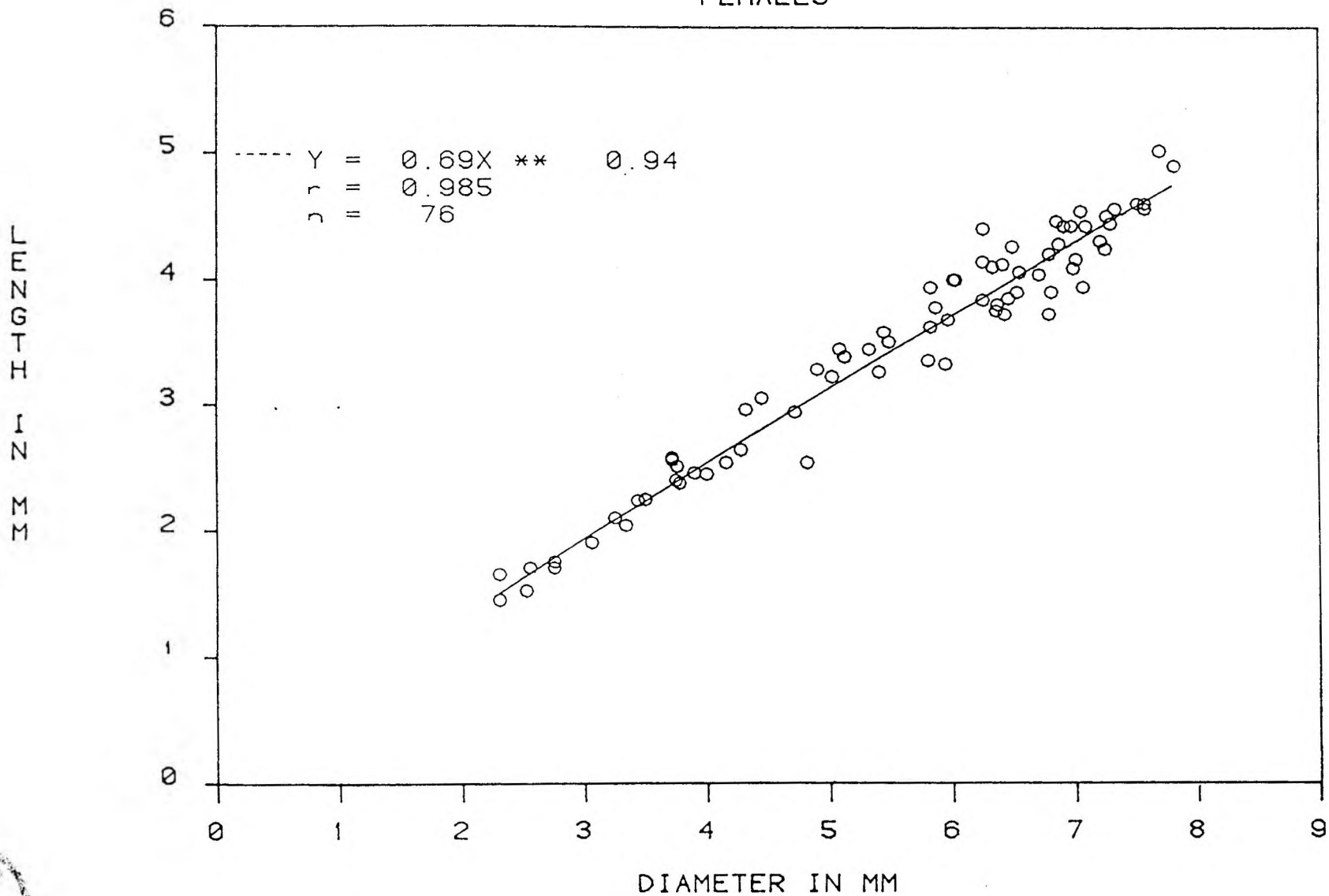


FIG. 6.5 The relationship between vertebral length and centrum diameter in female R. annulatus.





VERTEBRAL DIAMETER VS VERTEBRAL LENGTH  
MALES AND FEMALES

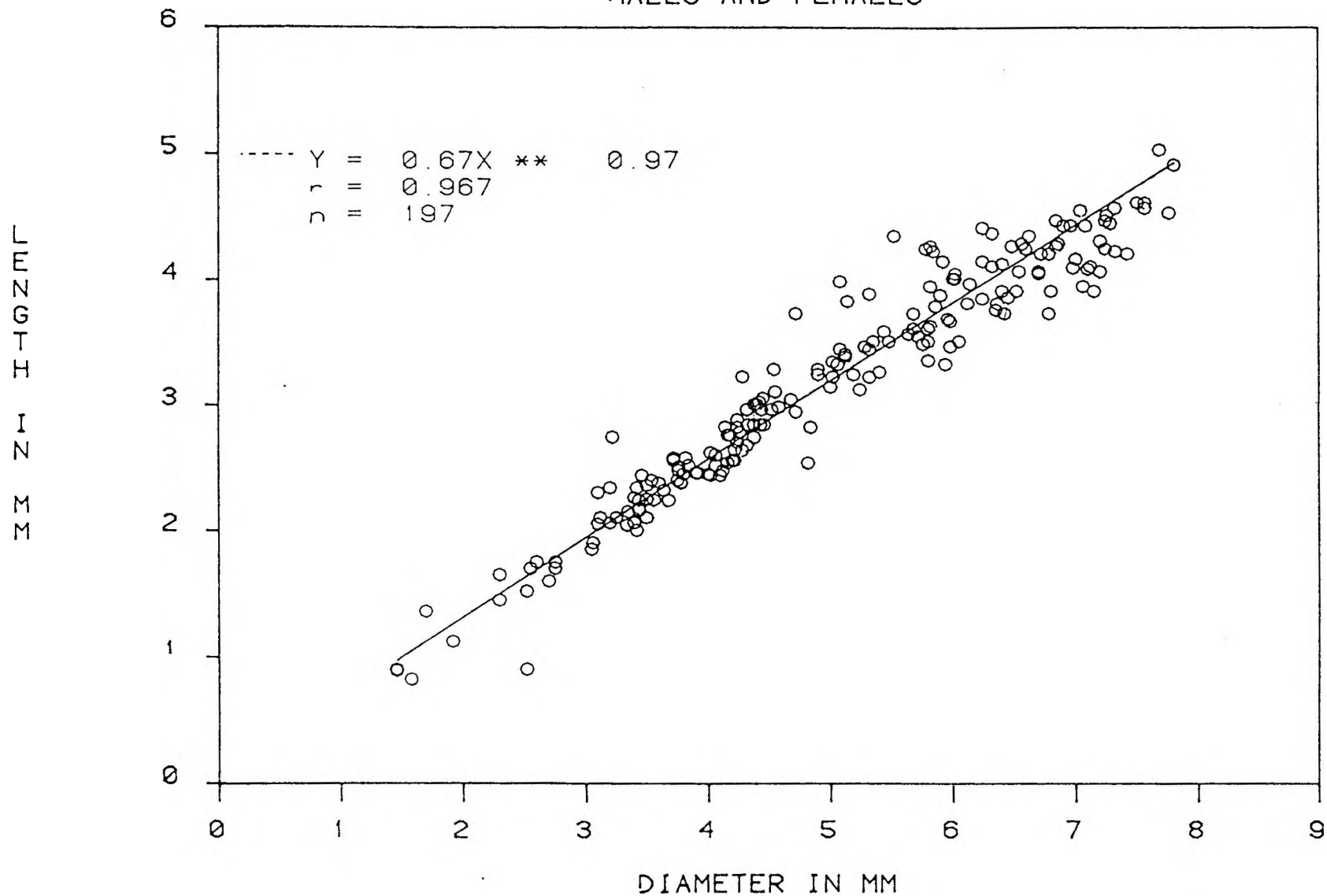


FIG. 6.7 The relationship between vertebral length and centrum diameter in R. annulatus (sexes combined).

### 6.3.2 Number of rings and length at birth

The presence or absence of annuli before birth has important implications when the age of a free swimming animal is to be derived from the number of rings present on the vertebral centrum. Stevens (1975) stated that if the first vertebral ring is laid down at birth then the number of rings minus one indicates the age in years from parturition. If the first ring is formed in utero or after birth, adjustment relative to the time of birth will be required.

The ten embryos used to investigate the latter phenomenon were all obtained in March 1979 and ranged in total length from 206cm to 225cm. The vertebral centra diameter ranged from 0,9mm to 1,42mm with an average of 1,24mm. The vertebral centra of all these embryos had a narrow hyaline zone followed by a wider opaque zone. Conception takes place soon after birth (see Chapter 7) and the formation of the narrow hyaline zone is formed in utero during the late winter months while the wider opaque zone is formed during the last few months before birth. There is no reason why calcification changes cannot occur in the embryo before birth. The first ring in R. annulatus therefore represents a birthmark and succeeding rings are formed after parturition. Similar conclusions were made by Stevens (1975) for the blue shark, Prionace glauca and Tanaka and Mizue (1979) for Mustelus manazo.

The relationship between vertebral diameter and total length is given by a power curve, the equation of the line being:

$$Y = 187 X^{0,85}$$

where Y = total length in mm

X = vertebral diameter in mm

Substitution of the average vertebral diameter obtained for the ten full term embryos investigated gives a total length of 225mm. The smallest free swimming sand shark was caught in June 1978 and measured 235mm total length. The average length at birth for R. annulatus is suggested to be ca 230 mm total length.

### 6.3.3 The annual nature of the rings and the period of ring formation

Complete removal of the connective tissue on the periphery of the vertebral centra was not possible without damage to the centra. Due to the presence of this connective tissue, which stained dark brown, difficulties were encountered observing the marginal zone in R. annulatus. The same problem was encountered by Holden and Vince (1973) for Raja clavata where the connective tissue on the periphery appeared to obscure the marginal zone. The nature of the marginal zone was only apparent after the succeeding

zone had begun to form. To eliminate this problem the nature of the zone preceeding the peripheral zone was taken as the last zone during this study. Knowing that a dark zone is succeeded by a light zone and vice versa, the nature of the last formed ring was noted in all specimens throughout the sampling period.

The time of formation of a zone is not necessarily the time at which it becomes visible at the periphery of the centrum (Holden and Vince, 1973). The obscuring effect of the connective tissue on the edge of the centrum could result in a time lag of several months before the appearance of the peripheral zone. The method followed in the present study eliminated this possible time lag. Fig. 6 represents the variation of the nature of the peripheral zone on the centra of R. annulatus over a period of 21 months. Due to low numbers of vertebrae obtained in certain months, the observations were grouped into three-monthly units. It is apparent that the opaque zone is formed between the months July and April and that April to July marks the time of formation of the hyaline zone (Fig. 6.8). The time of formation of the hyaline zone is a relatively short period (4 months) compared with the time elapsing to form the opaque zone (9 months). This could explain the difference in the width of the zones as observed on the vertebral centra. The time elapsed to form a hyaline zone and an opaque zone, representing one counted ring, was twelve months and is regarded as an age indicator for R. annulatus. The rings counted on the centra are therefore



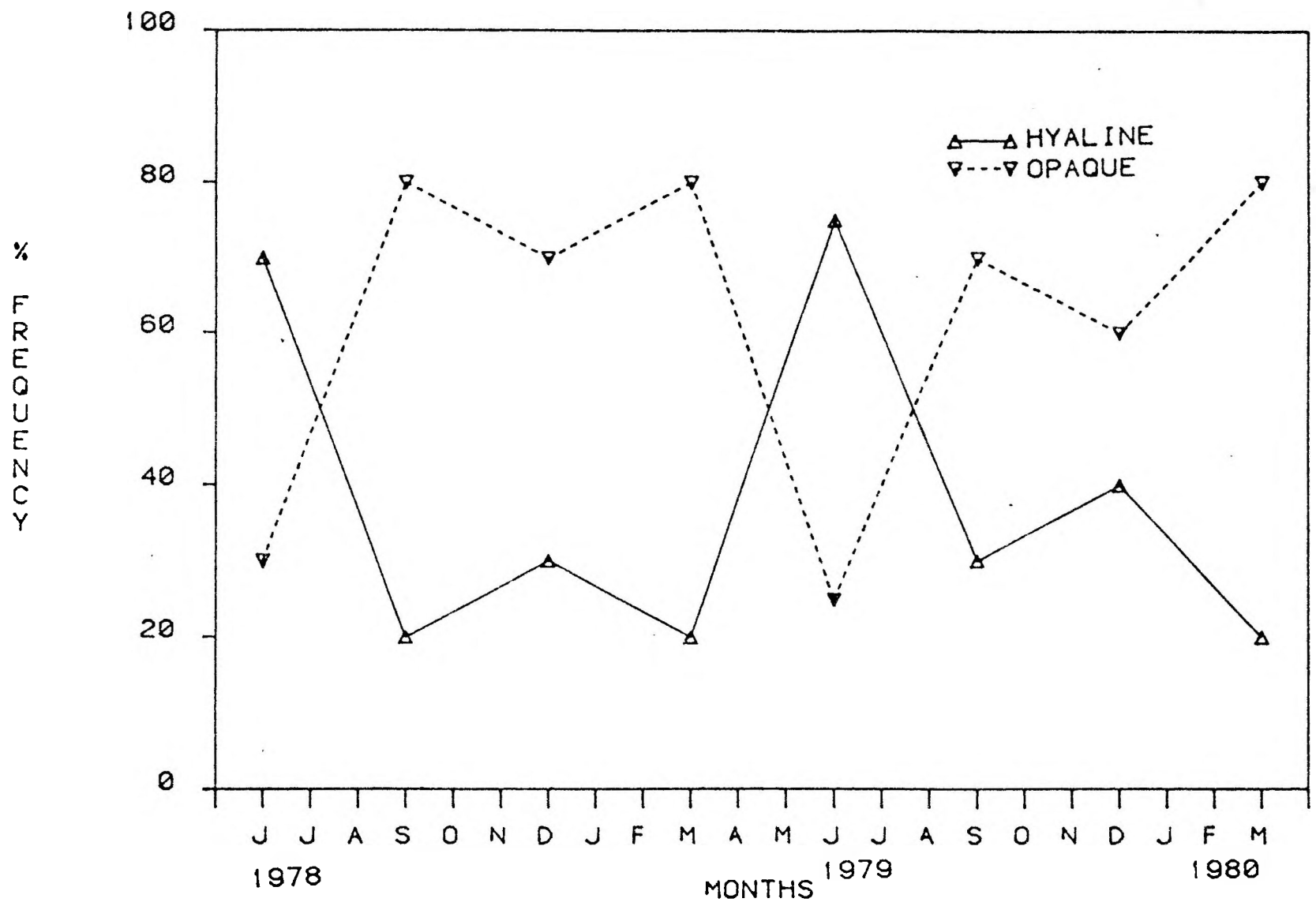


FIG. 6.8 The monthly percentage of vertebrae with hyaline and opaque edges.

accepted to be annual. Observing the nature of the peripheral zones, Tanaka and Mizue (1979) reached the same conclusions studying the age of the Japanese dogfish over a period of twelve months.

The basis for seasonal changes in the vertebral calcification rates are unknown and can only be speculated on. Stevens (1975) stated that for certain elasmobranch species these rings may be related to seasonal changes in temperature. The temperate waters of Algoa Bay show a regular seasonal fluctuation with an annual range of 11°C to 25°C. The lowest mean temperature (15°C) occurs in August (Beckley, 1977).

Ridewood (1921) suggested that calcification may develop purely in response to physiological demands for strengthening of the cartilage but offered no experimental proof.

#### 6.3.4 Age and growth curves

If the rings in R. annulatus are annual, age classes can be ascertained for the species according to the number of vertebral rings observed. The first ring represents a birth-mark and adjustment relative to the time of birth is thus required if the age is to be expressed as age after birth.

Figs. 6.2, 6.3 and 6.4 show the relationship between total length and the number of vertebral rings for the sexes combined and separate. It must be noted that the values for

the number of rings indicated by "+" means that the peripheral ring may consist of an extra hyaline zone and thus have a hyaline, opaque, hyaline arrangement (see Table 6.2). Only on completion of a hyaline zone was a ring considered to be complete. Adjustment relative to the time of birth would therefore mean a vertebra possessing 1 + rings would belong to a shark of the 0 + age group. Only one male, total length 257mm, was observed in this age group.

While there is no evidence that the von Bertalanffy growth model is the best model to describe elasmobranch growth (Francis, 1981), it has been fitted successfully to growth data of Raja clavata, R. brachyura and R. montagui (Holden, 1972), Prionace glauca (Stevens, 1975) and Mustelus manazo (Tanaka and Mizue, 1979). Schoener and Schoener (1978) suggested that the logistic-by-length and logistic-by-weight growth models may fit the observed data better.

Holden (1974) suggested the construction of von Bertalanffy growth curves on the basis of embryonic growth rates to provide fishery managers with a rapid method for estimating elasmobranch growth rates. This method assumes that growth curves for free-living animals can be extrapolated from the growth curves of embryos.

The von Bertalanffy growth equation is usually expressed in the form:

$$L_t = L_{\infty}(1 - e^{-K(t - t_0)}) \quad (1)$$

where  $L_t$  = total length at time  $t$

$L_{\infty}$  = maximum theoretical length

$K$  = growth constant

$t_0$  = theoretical age at zero length

Based on a knowledge of elasmobranch life histories, Holden (1974) modified equation (1) for insertion of the growth parameters:

$$L_t + T = L_{\infty} (1 - e^{-KT}) \quad (2)$$

where  $L_t + T$  = length at birth

$L_{\infty}$  = maximum theoretical length

$K$  = growth constant

$T$  = gestation period

Holden (1974) further suggested that the maximum observed length provides a good estimate of  $L_{\infty}$ . If the length at birth, gestation period and maximum observed length are known, the growth constant ( $K$ ) for embryonic growth can be calculated from equation (2).

The maximum observed length for R. annulatus in Algoa Bay is 109cm, the period of gestation 10 months (see Chapter 7) and the average length at birth 23cm. Thus from (2):

$$23 = 109 (1 - e^{-K})$$

$$23/109 = 1 - \exp(-K)$$

$$0.2110 = 1 - \exp(-K)$$

$$0.7890 = \exp(-K)$$

Taking log both sides  $K = 0.24$

The known values of K for elasmobranchs tend to be of the same order: 0.1 - 0.2 for Selachii and 0.2 - 0.3 for Batoidea (Holden, 1974). The figure of 0.24 fell within the range of growth constants predicted by Holden (1974) (See Table 6.2). Francis (1981) found Holden's growth constant range invalid for Mustelus spp. and suggested that the method for estimating K should only be used when gestation period has been independently determined. Although the gestation period of R. annulatus has been determined in this study (Chapter 7), the growth of embryo's showed a different rate to the growth of post partum animals. Holden (1974) however states that growth in utero might be expected to be faster than in free-living individuals which have to expend energy in capturing food.

Although an acceptable estimate for K could be obtained by Holden's (1974) method, attempts to obtain estimates for  $L_{\infty}$ , using the Walford (1946) graph, or regressing  $\log(L_{\infty} - L_t)$  on t to obtain  $t_0$ , were unsuccessful. Tanaka and Mizue (1979) used Allen's (1966) method to obtain growth parameters without using the Walford graph. This method as well as those proposed by Gullard and Holt (1959) and Riffenburg (1959) were investigated but none could give a successful fit to the von Bertalanffy growth curve.

At present the most reasonable assumption seems to be that the increments of growth towards the maximum age in years do not decrease significantly enough to permit a fit of

the von Bertalanffy growth model for R. annulatus. The relationship between the number of vertebral rings and total body length was therefore adopted as the most suitable and representative indication of growth in R. annulatus (Fig. 6.2 and Fig. 6.3). Table 6.3 shows the observed and calculated total length at age of R. annulatus. Both males and females reach an age of six years and then apparently die. The difference in length for the younger age groups where the length of males exceeds those of the females could be erroneous due to the small sample size. Towards the maximum age groups the females are bigger than the males with a difference in total length of ca 45mm.

The only other growth data available for R. annulatus, is that of van der Elst (1981) who used the Holden (1974) method to obtain his data. For the smaller lengths similar values were obtained as in the present study but towards maximum size and age the difference becomes bigger. The key assumption underlying Holden's (1974) method could be responsible for this, in that the growth curve constructed is an extrapolation of embryonic growth. The growth rates of R. annulatus embryos (see Chapter 7) differ considerably from those of the free-living animals and although an acceptable value can be obtained for the growth constant, the parameters  $L_{\infty}$  and  $t_0$  cannot be obtained for R. annulatus by the conventional methods.



TABLE 6.3 Mean observed and calculated total length at age of  
R. annulatus

Age (yrs)	Observed mean total length (mm)	±SD	N	Calculated total length (mm) (From Fig. 6.4 and Fig. 6.5)
0 + ♀	-	-	-	197.70
♂	257,00	-	1	213.90
1 + ♀	414,00	-	2	351,45
♂	320,60	±70,88	5	362,24
2 + ♀	476,42	±64,55	12	492,06
♂	521,39	±45,48	18	492,98
3 + ♀	617,30	±34,45	10	624,76
♂	614,82	±36,80	38	613,45
4 + ♀	777,86	±70,96	7	751,89
♂	726,61	±52,50	18	726,82
5 + ♀	890,50	±49,74	20	874,73
♂	845,16	±47,61	31	834,84
6 + ♀	993,00	±57,26	25	994,12
♂	953,40	±27,27	10	938,61

±SD = standard deviation

N = number of sharks



## CHAPTER 7

## REPRODUCTION

## 7.1 INTRODUCTION

The reproductive patterns, structure of gonads, ducts and accessory glands of chondrichthyans were reviewed by Matthews (1950); Amoroso (1960); Dodd (1960); Hoar (1969) and Wourms (1977). Relatively little work has been done on the reproduction of viviparous species and the lack of information is explained by the difficulty of collecting adequate material (Tewinkel, 1950). Seasonal breeding cycles have been described for Mustelus canis (Tewinkel, 1950); Squalus acanthias (Hisaw and Albert, 1947; Jensen, 1966 and Ketchen, 1972); Raja clavata (Holden, 1975); Scyliorhinus canicula (Harris, 1952) and Cetorhinus maximus (Matthews, 1950). All of these species occur in the northern hemisphere. The reproductive cycle of Mustelus lenticulalatus (Francis and Mace, 1980) is the only recent description of a viviparous species of the southern hemisphere. No detailed description of reproduction in any South African batoid has been published. Short notes on the reproduction of R. annulatus were reported by Wallace (1967a). He only mentioned total length ranges for gravid males and females, a range for the number of embryos found and the months that embryos were found. No breeding cycles for male or female could be derived from this information.

This study attempted to elucidate the breeding cycles of female and male R. annulatus with descriptions of oogenesis, spermatogenesis and associated reproductive structures. An attempt to estimate fecundity is also made.

## 7.2 MATERIAL AND METHODS

Specimens were collected and measured as described in Chapter 3. External observations included inspection for any signs of mating scars in the pelvic regions, the presence of semen in males when slight pressure was administered on the region of the seminal vesicles (ripe running) and bleeding claspers. Two measurements were taken on the claspers (see Chapter 4).

Internal investigations on all size classes were conducted on the testes, ovaries and embryos. The paired gonads were carefully dissected out from the body cavity and weighed to the nearest 0,1g. Bouin's solution (Humason, 1966) was used as a fixing fluid for the gonads. After at least two weeks representative portions were cut at right angles to the length of the testes and were embedded in paraffin wax (Histosec) and sectioned at a thickness of 7-10  $\mu\text{m}$ . The sections were stained in haematoxylin and counterstained with eosin. Clearmount was used as mounting media.

Due to the large size of the ova with the onset of vitellogenesis (2mm), these ovaries were investigated macroscopically for number and size of large ova.

Embryos, when present, were removed from the uteri, counted, total body length measured and preserved in 10% formalin. The embryo's extruded from left and right uteri were kept separate in containers and sexed where possible. External characters such as branchial filaments were then observed in the laboratory.

The mean monthly gonadosomatic index (G.S.I.) was calculated for both sexes as follows:

$$\text{G.S.I.} = \frac{\text{wet mass of gonad}}{\text{wet mass of fish}} \times 100$$

Breeding cycles for both females and males were assessed. The relationship between total body length and inner clasper length was used to determine the length at maturity in males. This was validated by microscopic examination of histological sections of the testis. Distinct ova in the ovaries and an expanded, loose, flaccid uterus was regarded as signs of maturity in females.

To determine yolk reduction, the attached yolk sac was carefully lowered into a beaker of water filled to the brim. The overflow was caught up in a measured glass cylinder and the displacement was accordingly measured. The yolk-stalks were not included in this measurement.

### 7.3 RESULTS AND DISCUSSION

#### 7.3.1 Mode of reproduction

All recent chondrichthyans employ internal fertilization, produce a small number of heavily yolked eggs and are either oviparous or viviparous (Wourms, 1977). The distinction between ovoviviparity and viviparity was regarded as artificial by Budker (1958) and consequently he subdivided the viviparous chondrichthyans into placental and aplacental viviparous species. The aplacental species have been categorized as: 1) embryos dependent solely on yolk reserves; 2) oophagous; or 3) possessing placental analogues. Viviparity, in varying degrees, is widespread and seems almost characteristic of the elasmobranchs (Wourms, op. cit.). Twelve of the sixteen families of the order Squaliformes and ten of the twelve families of the order Rajiformes are viviparous.

The least specialized of the aplacental viviparous species are those with embryos which depend solely on yolk reserves. R. annulatus falls in this category where the eggs are retained and enclosed in an elongated egg case. The egg case remains intact for a few months, after which the embryos hatch and further embryonic development is completed in utero. After complete absorption and utilization of the yolk, gestation terminates and the young are born alive.

Viviparity seems to have evolved independently, almost on a group-specific or species-specific basis and the reproductive success of viviparous species attests to its advantages. These advantages are protection from predators offered by the maternal environment and the physiological regulation of the environment. This retention of the embryo leads to an increase in the size of full term embryos which is advantageous and an apparent reduction in fecundity does not seem important in this type of reproductive strategy employed in chondrichthyans (Wourms, 1977).

### 7.3.2 The female reproductive system

#### 7.3.2.1 Functional organization

The female reproductive organs in R. annulatus are composed of ovaries, the oviducts, the nidamental glands and uteri (Fig. 7.1).

The ovaries, which are both functional, are formed at the anterior end of the epigonal organs. The epigonal organs are small in immature specimens and although they increase in size with growth, the mature ovaries (consisting of ova in all stages of development) seemed to invade the epigonal organ that served as a matrix for the imbedded ova.

Both ovaries are attached to the dorsal wall of the body cavity by the mesovarium.

The two oviducts unite in a common ostium situated ventrally at the anterior border of the liver. The oviducts lead to the nidamental gland which is reduced and

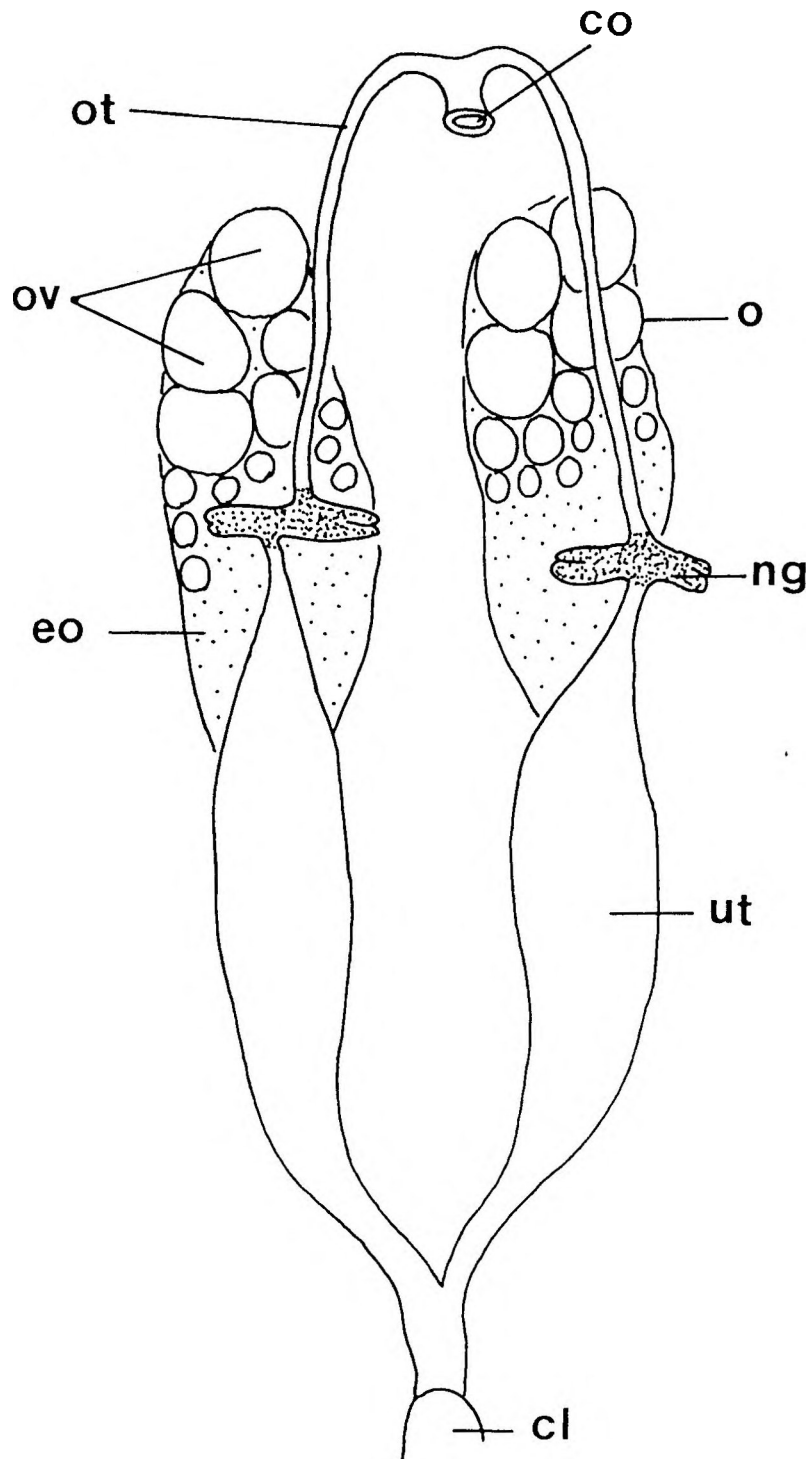


Fig. 7.1 The female reproductive organs in *R. annulatus*  
 cl: cloaca, co: common ostium, eo: epigonal  
 organ, ng: nidamental gland, o: ovary,  
 ov: ova, ot: oviduct, ut: uterus

only serves to secrete the thin membranous egg-case that encloses the ovulated eggs. The thin walled uterus is flaccid in sexually mature animals. No modifications for viviparity in the uteri is evident and therefore an aplacental viviparity type of reproduction is displayed by the sand shark. The posterior ends of the oviducts merge to form a common vagina that opens in the cloaca.

Among the viviparous rays, the right ovary and oviduct undergo varying degrees of reduction or loss. In the blue ray, Dasyatis pastinacus, only the left ovary is functional and although the left oviduct is present it does not receive eggs and therefore do not develop a thick wall (See Chapter 10).

Samuel (1943) studying the corpus luteum in R. granulatus found both ovaries functional and described the species as typical ovoviviparous. No further description of the reproductive organs were given.

#### 7.3.2.2 Oogenesis, eggs, fecundity and embryo growth.

The ovaries are both functional and of equal size at all stages of maturity. Due to difficulties experienced in sectioning mature ovaria containing large eggs (ca. 20-30mm in diameter), only two ovaries were successfully sectioned from those regions where small ova were present. Some idea of oogenesis could, nevertheless, be obtained. The reproductive cells appear in the ovarian epithelium that covers the ovaries and sunk into the epigonal organ that

Fig. 7.2 The ovary containing oocytes at various developmental stages.

Fig. 7.3 Two adjacent follicular epithelia showing two types of cells.

bm; basement membrane, eo: epigonal organ, fe: follicular epithelium, n: nucleus, o: oocyte, oe: ovarian epithelium  
ov: ovulated follicle, tf: theca folliculi, y: yolk,  
zr: zona radiata.



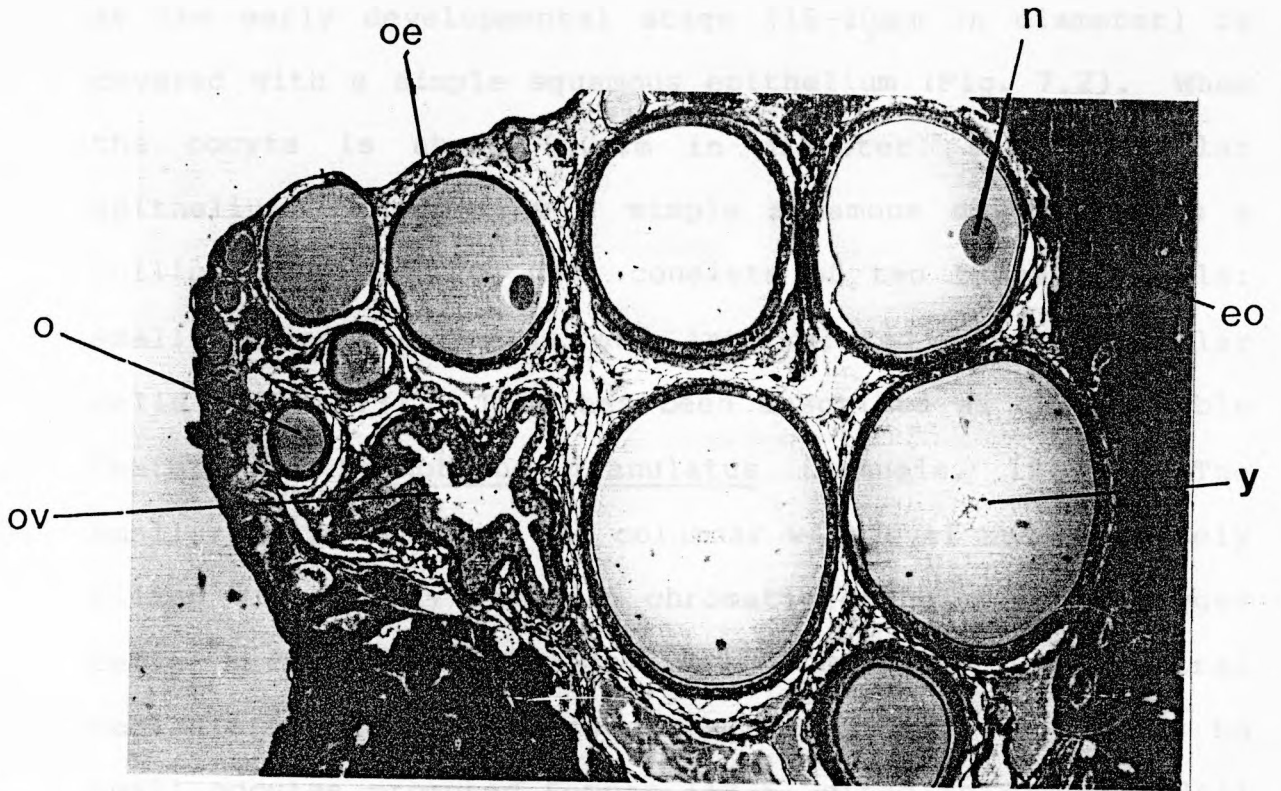


Fig. 7.2

x62



Fig.7.3

x800

forms a matrix for developing ova (Fig. 7.2). The oocyte, at the early developmental stage (15-20 $\mu$ m in diameter) is covered with a simple squamous epithelium (Fig. 7.2). When the oocyte is about 500 $\mu$ m in diameter, the follicular epithelium changed from a simple squamous epithelium to a follicular epithelium that consists of two types of cells: small cylindrical cells and interrelated large vesicular cells (Fig. 7.3). This has been described as a remarkable feature in Rhinobatus granulatus (Samuels, 1943). The smaller cells are long and columnar with oval nuclei densely filled with deeply staining chromatin granules. The bigger cells have clear cytoplasm and a more or less central vesicular nucleus. The resemblance of these large cells to small oocytes prompted Semper (1875, cited in Samuel, 1943) to suggest that these cells were primitive ova destined to become mature ova. Surrounding the follicular epithelium is the theca folliculi that is composed of an outer theca externa and an inner theca interna. Fig. 7.3 shows the zona radiata situated on the inside of the follicular epithelium and the yolk granules filling the ripening ovum.

After ovulation (Fig. 7.2) the follicular epithelium of the follicle becomes thicker and capillaries are scattered between the follicular epithelium and theca folliculi. These capillaries are minute and only the presence of the biconcave bloodcells indicated their existence. Corpora lutea that are formed in the follicles after ovulation have been reported in Rhinobatus granulatus (Samuel, 1943), Squalus acanthias (Hisaw and Albert, 1947), Mustelus canis (Te Winkel, 1972), Mustelus

manazo and M. griseus (Teshima, 1981). The resemblance of the ovulated follicle in R. annulatus to those as described by the above authors suggests that this follicle could be a corpus luteum analogue. Further histochemical and endocrinology studies are however necessary to elucidate the structure and function of these bodies in R. annulatus.

Ovarian eggs turned to a bright yellow as they ripened and reached a maximum diameter of about 30 mm and weighed ca. 20g. Examination of 59 mature females yielded counts of large ovarian eggs ranging from one to seven per ovary. The total count of eggs in the ovaria of 59 mature females were respectively 262 for left and 266 for the right side. This represented a 1:1 ratio of egg production in the left and right ovaries with an average of 4.5 eggs per ovary or nine per individual. Similar counts of the embryos in the left and right uteri of 58 pregnant females gave a total count of 193 for the left uterus and 194 for the right one, again indicating a 1:1 ratio for embryos developing in the left and right uterus. The average number of embryos was 3,5 per uterus or seven per individual sand shark. Statistically there was no tendency for any one side to dominate for either the eggs or the embryos in the individual sand sharks ( $p < 0,001$ ).

It should be noted, however, that averages of the number of offspring are rather meaningless unless there is reasonable assurance that the average size of the parents in samples is close to the average for the female population as a whole

(Ketchen, 1972). The relation of size of parent to number of large ovarian eggs is shown in Fig. 7.4. In R. annulatus the number of large eggs increases with adult length. The same tendency is shown in Fig. 7.5 for the number of embryos in relation to parent total length. This would imply that each consecutive breeding would increase fecundity by an average of two embryos per litter. A comparison of the two figures indicate that ovarian fecundity is higher than uterine fecundity. The maximum number of embryos and large eggs counted were 10 embryos and 12 eggs in a female of 1090mm total length.

No egg-cases devoid of yolk were found during this study and only once were deformed embryos witnessed. A female (928mm total length) captured in November, 1979 carried four embryos, two in each uterus. The two in the left uterus appeared normal and in good condition but the two in the right uterus were severely stunted and the regions from the pelvic fins posteriorly were twisted in a corckscrew fashion (Fig. 7.6). Although they were alive when removed, survival in the field after birth seemed impossible. This is a first record for deformed embryos in R. annulatus.

Reproductive success, thus seems to be high. Table 7.1 gives the number of embryos for different size classes of female R. annulatus. Based on average litter size and life expectancy a female R. annulatus can produce 24 young in an expected four years of successful breeding after the onset of sexual maturity (see Chapter 6). This could not be compared with other batoids because data of this kind could not be

TOTAL LENGTH VS NO. OF LARGE EGGS

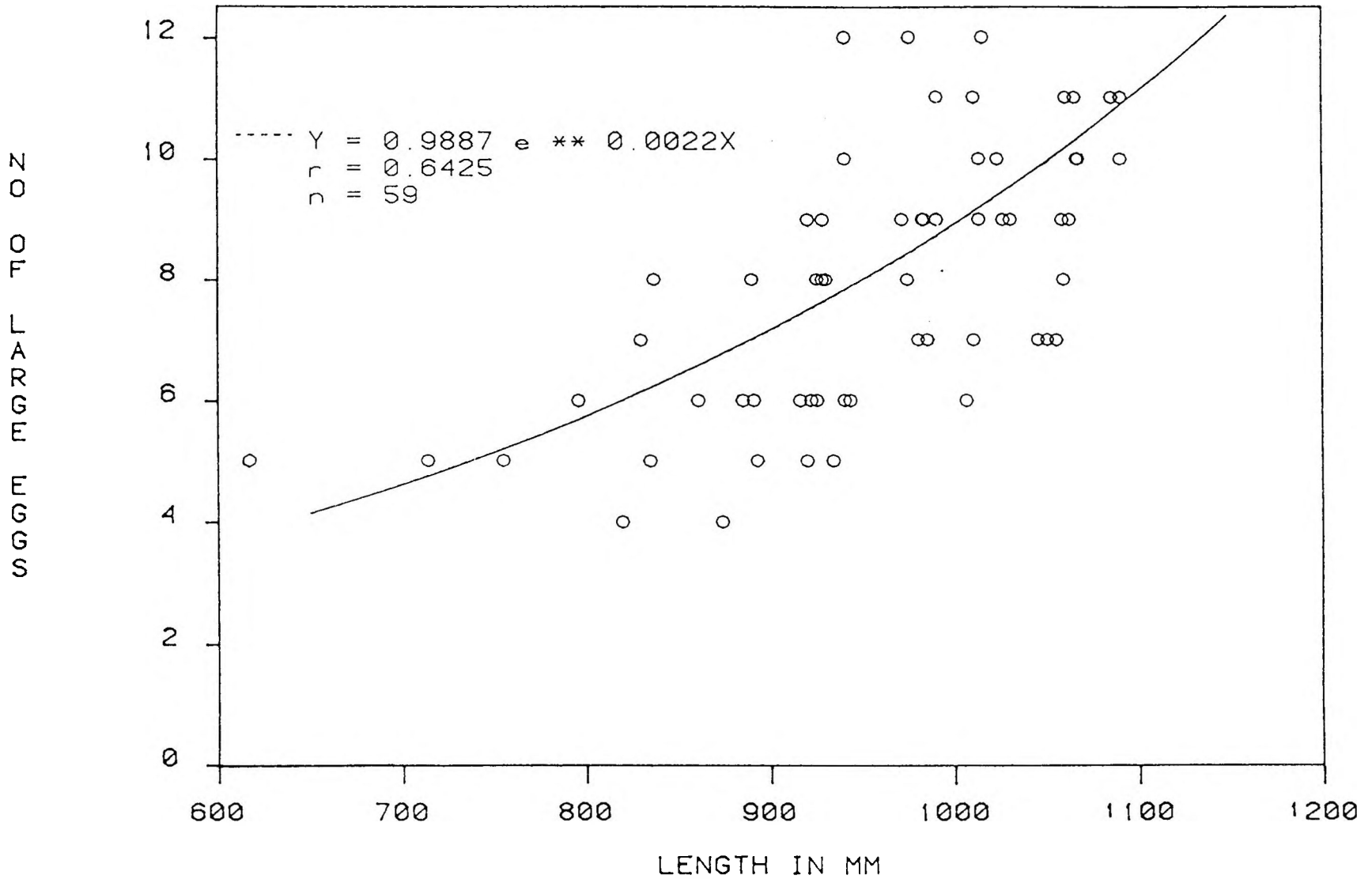


FIG. 7.4 The relationship between total body length and number of large ovarian eggs in R. annulatus.

TOTAL LENGTH VS NO. OF EMBRYOS

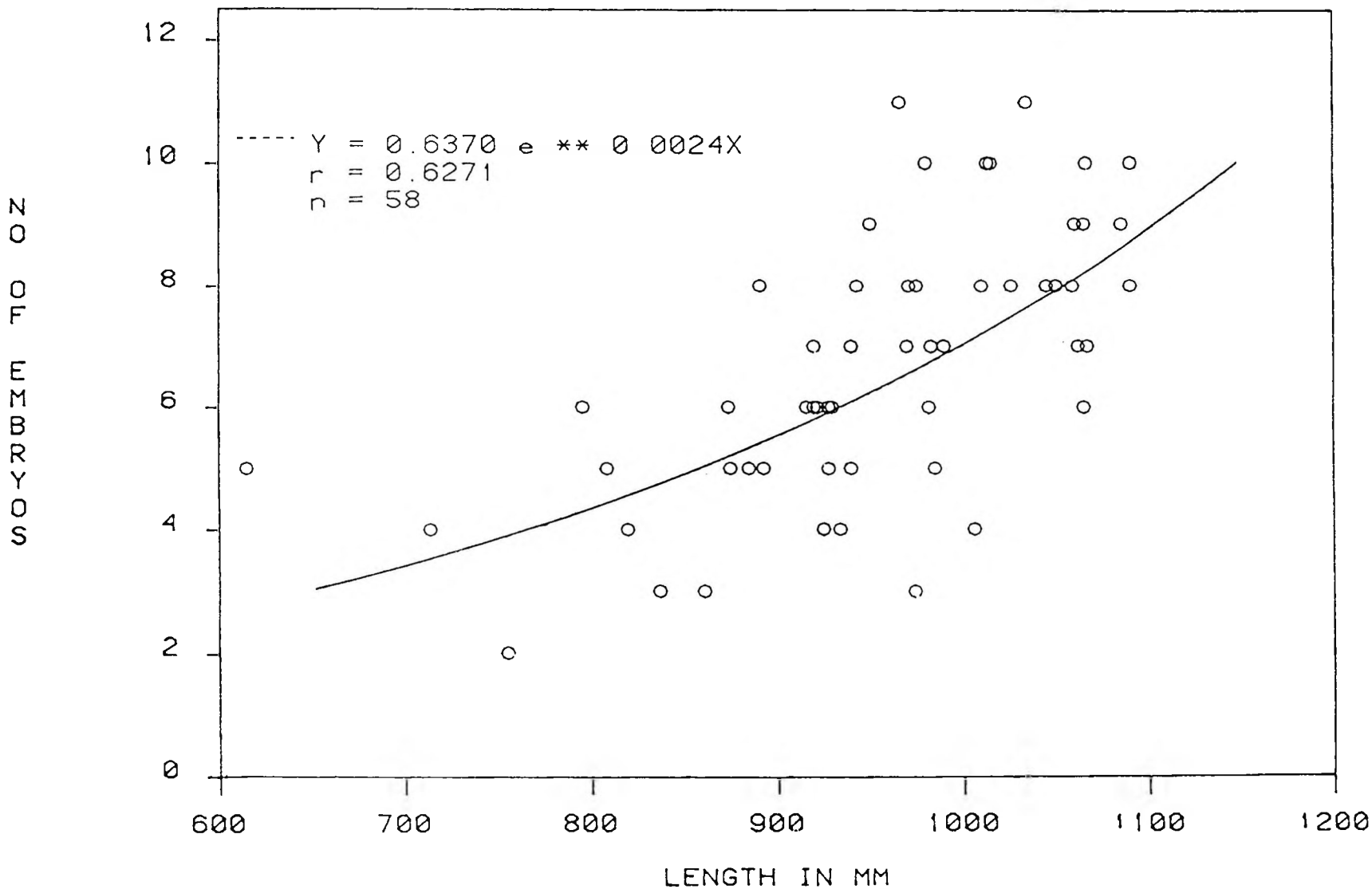


FIG. 7.5 The relationship between adult total length and number of embryos per litter (uterine eggs regarded as embryos) in *R. annulatus*.



Fig. 7.6. Deformed embryos

found in available literature.

Mature eggs descend into the nidamental gland where they are fertilized and pass from there into the oviducts where they are encased in an amber-coloured gelatinous capsule, the so-called candle-stick. TeWinkel (1950) calculated the rate of ovulation in Mustelus canis from records of the embryonic stages present in the uterus. He found that the egg nearest the nidamental gland was always the earliest stage present. In R. annulatus eggs have to be ovulated in rapid succession because only one egg case covers all the eggs ovulated at any one cycle. The eggs were thus all in the same developmental stage and consequently embryos of the same litter did not differ significantly in total length ( $p < 0,01$ ).

Fig. 7.7 illustrates intra-uterine growth of R. annulatus. After the egg-capsules rupture between October and November the embryos are visible and external characters as indicated in Fig. 7.7 may be noted as the length progresses. The embryo seems to be wholly dependent on the external yolk sac for sustenance. The rate of yolk absorption is shown in Fig. 7.8. This regression represents a third degree polynomial where  $y = 3,90 + 0,29x - 160 \times 10^{-3}x^2 + 3.65 \times 10^{-6}x^3$ . The initial increase in volume is probably due to uptake of water from the uterine fluid during the first 10 weeks after the egg capsule has ruptured.

TeWinkel (1968) did separate analysis in recently ovulated eggs, embryos and their corresponding yolk-sacs for



water, organic-matter and ash in Mustelus canis. The composition of the embryo, as it grew, was relatively stable in analyses but the relative proportions of components in the yolk-sacs changed radically with age; the proportion of water and minerals have risen and organic substance has declined. M. canis is a placental viviparous species, but the placenta had not begun to form in the embryos TeWinkel used (only three months of a 10 to 11 month gestation was completed). Despite this the definite increments of water and minerals indicated marked absorption of these components from uterine fluid. Uptake of water by the yolk-sac membrane caused it to be flaccid with watery content. Hisaw and Albert (1947) found a similar increase in water and a decrease in organic matter, suggesting gestation in the spiny dogfish, Squalus acanthias to be ovoviviparous.

Increase in the volume of the yolk-sac during the first 10 weeks in R. annulatus is probably due to the uptake of water from the uterine fluid bathing the developing young. The consequent absorption of the yolk by the growing embryos suggests that the embryo is dependent on the yolk reserves only and receives no supplementary nutrition from the mother.

The average length at birth for R. annulatus was estimated at ca. 230mm total length (Chapter 6). This length corresponds with the length reached when all the yolk will be absorbed (Fig. 7.8).

### 7.3.2.3 Gonadosomatic index (G.S.I.) and the breeding cycle of the female

The monthly gonad index for females is shown in Fig. 7.9. The maximum value was reached in March-April and the minimum value in June-July.

The breeding cycle and other events correlated with the cycle are shown in Fig. 7.20.

The maximum size (ca. 30mm in diameter) ovarian eggs were observed from April to June. During this period the G.S.I. was descending from a maximum that was reached just before April. This suggested oviposition to occur after April. By June the G.S.I. reached a minimum value indicating that the ovaries had reached their lowest weight. Observations also showed them to be devoid of large eggs. Oviposition occurred in June after which the eggs in the oviduct were encased in an egg case to form candle sticks. The oviducal egg stage lasted five months from June till the end of October when the egg capsule ruptured and the embryos were then free living in the uterus. By this time vitellogenesis of the ovarian eggs for the next generation has started. This was indicated by a maximum value of the H.S.I. (see Chapter 8). When the H.S.I. reached the minimum value in June vitellogenesis was accepted to be complete. The embryos in utero reached maximum size (230mm total length) towards the end of March. Parturition took place between March and April. It was noted that full term embryos were all orientated with their

TABLE 7.1 Number of embryos for different size classes of  
female R. annulatus

Size class (total length in mm)	Mean no. of embryos	SD	n	Year of breeding
600 - 800 mm	3,6	1,5	3	1
800 - 900 mm	5	1,5	10	2
900 - 1000 mm	6,8	1,6	22	3
> 1000 mm	<u>8,6</u>	1,2	23	4
TOTAL	24			

SD = Standard deviation

N = number of female specimens

# EMBRYO GROWTH IN UTERO

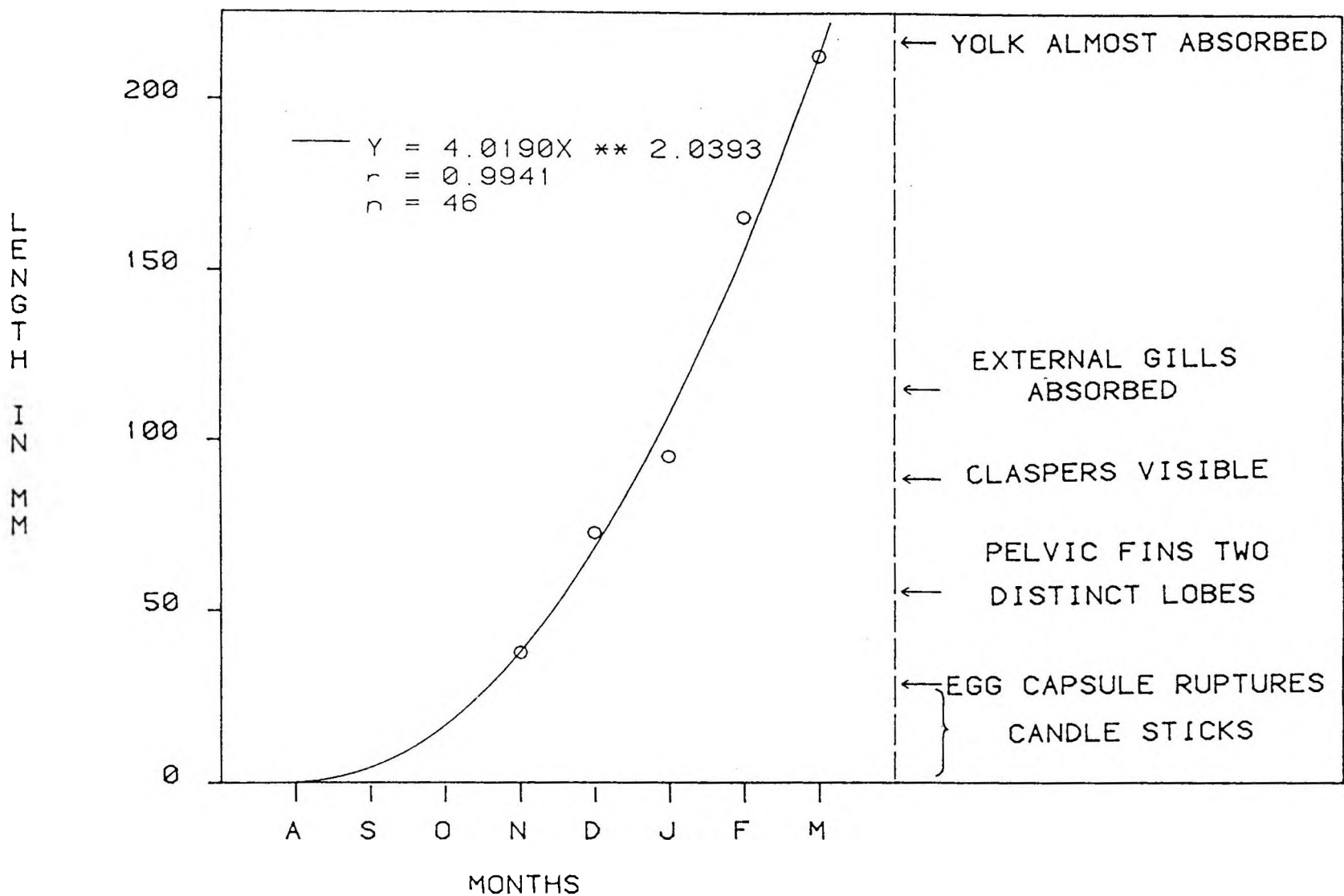


FIG. 7.7 Mean length of embryos in utero at various stages of development.

EMBRYO LENGTH VS YOLK REDUCTION

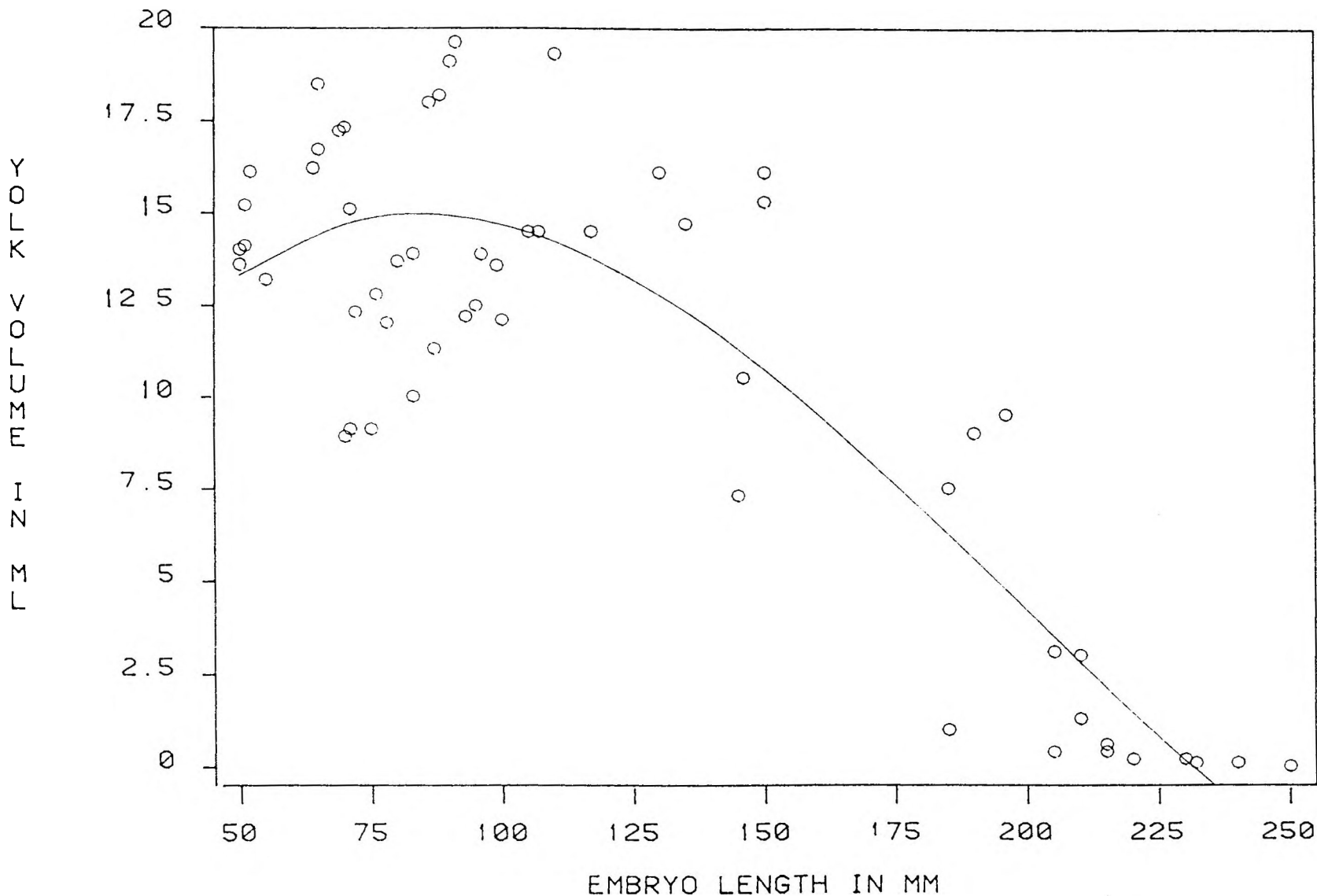


FIG. 7.8 The relationship between embryo length and yolk sac volume in R. annulatus (see text for regression equations).

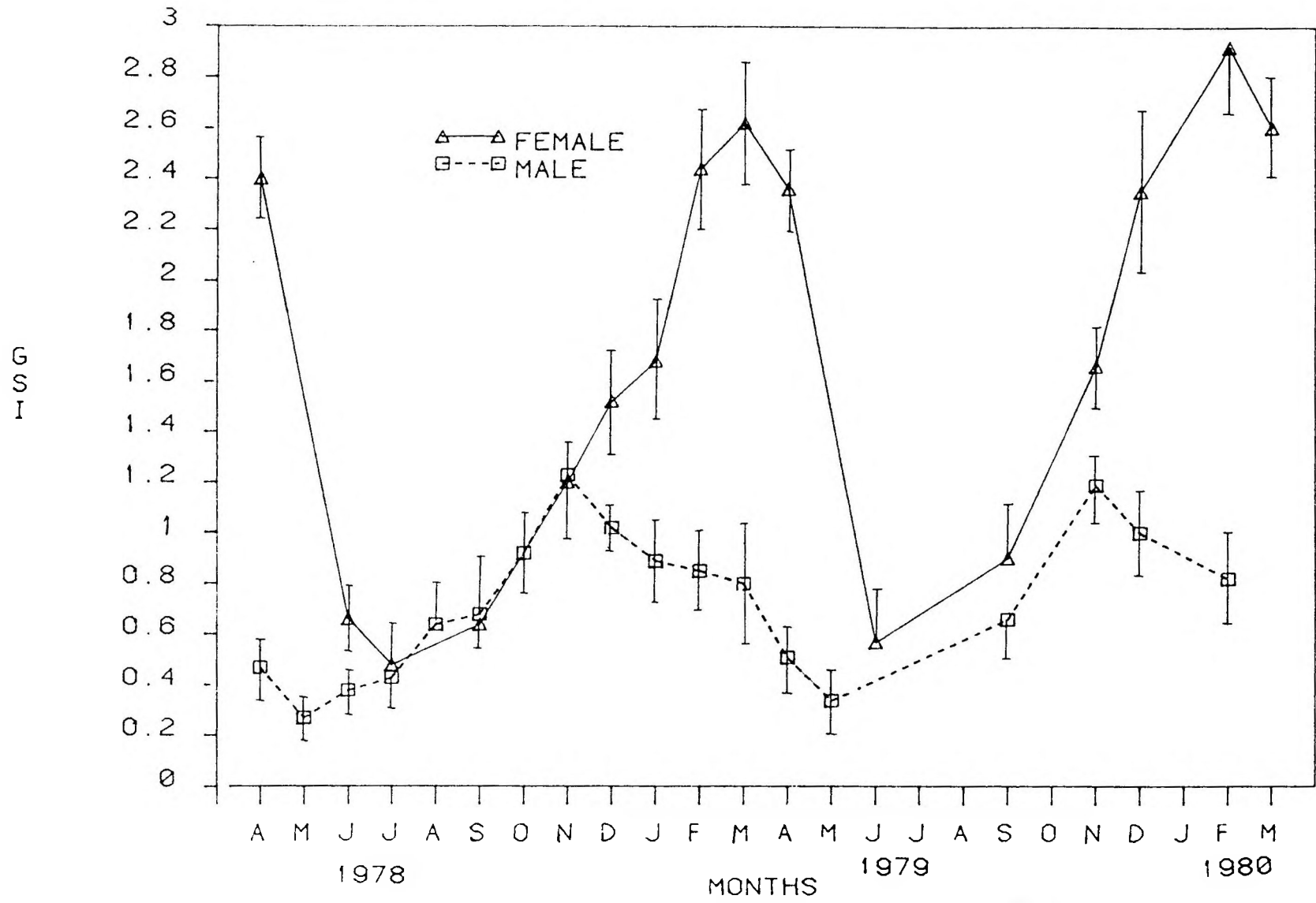


FIG. 7.9 The monthly gonadosomatic index for male and female *R. annulatus*. Mean  $\pm$  standard deviation.

heads towards the cloaca and dark brown remnants of the egg cases were present with them. These are expelled with the embryos during birth. The onset of a new cycle, after fertilization, in April-June, coincided with the onset of migration offshore (see Chapter 5). The gestation period of R. annulatus thus lasted 10 months after oviposition with a resting period of 2 months between parturition and fertilization and the females breed every year.

Thus two overlapping cycles, oviducal and ovarian, occur in the same animal (see Fig. 7.20). Usually, in the selachian, the oocytes develop with the embryonic development and they reach maturity before the embryos are born (Teshima, Mizue and Koga, 1974). This seems to be the case in viviparous batoids too according to the present study.

In the south of Brazil, a related species, Rhinobatos percellens, show a very similar breeding cycle with parturition, oviposition and mating occurring in the same months as in R. annulatus (Gianuca, pers. comm.).

### 7.3.3 Male reproductive system

#### 7.3.3.1 Functional organization

The testes are paired elongated organs of equal size attached to the body wall along either side of the vertebral column by a mesorchium (Fig. 7.10). Combined with the testis and forming the posterior part is the epigonal organ. The testes forming the anterior part is embedded in this organ. Visible on the dorsal surface of the testes are

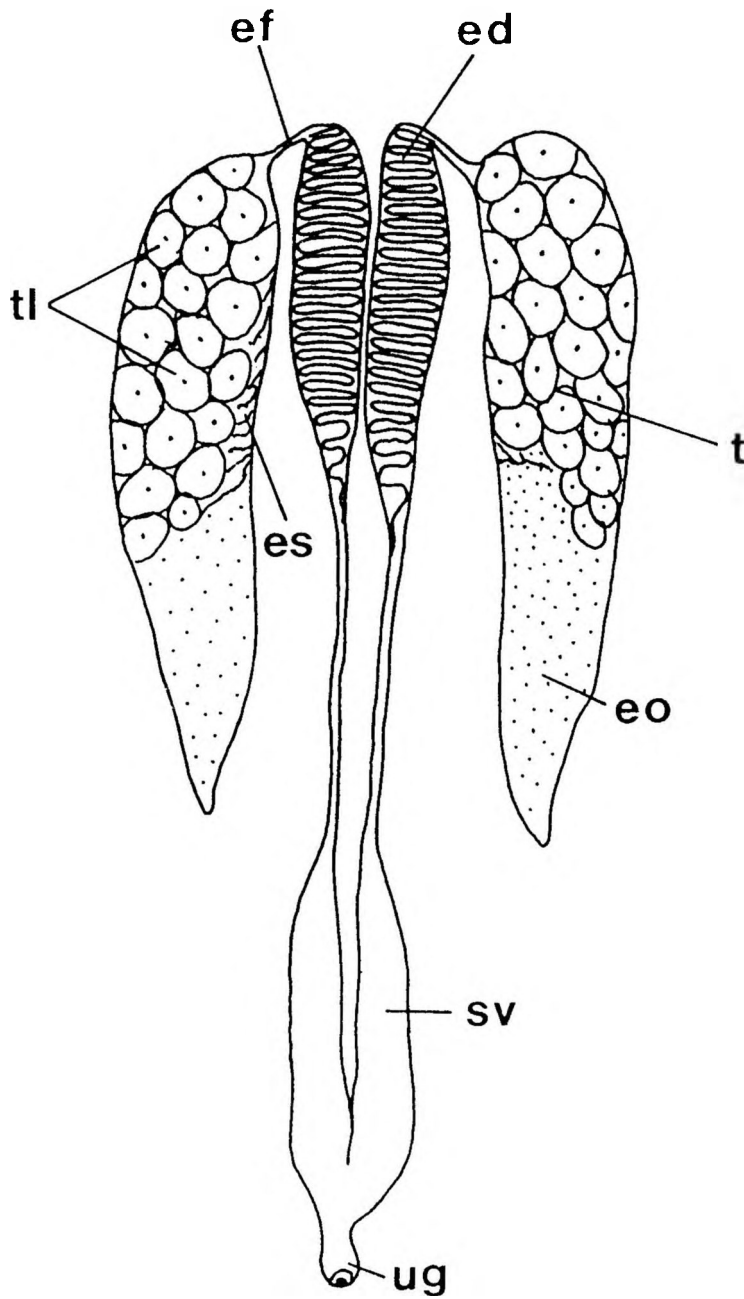


Fig. 7.10 The male reproductive organs in *R. annulatus*  
 ed: epididymis, ef: efferent duct  
 eo: epigonal organ, es: efferent ductule  
 system, sv: seminal vesicle, t: testis,  
 tl: testicular lobules, ug: urogenital  
 papilla



round dome-shaped lobules embedded in epigonal matrix. The lobules are characterized by a centrally situated pin-hole. Each lobule consists of spherical ampullae, arranged in concentric layers in which spermatogenesis occurs (see Fig. 7.11).

The structure of the testes in R. annulatus seems to correspond to the testis of the basking shark (Cethorhinus maximus) as described by Matthews (1950). Mature spermatozoa are discharged from the testes through a complicated ductule system visible on the ventral surface. These ductules converge on the anterior median part of the testis to form one efferent duct (Fig. 7.10). The efferent duct joins the epididymis which is a highly coiled tubule in R. annulatus. Babel (1967) found only one efferent duct in the round stingray, Urolophus halleri. Sieben (1979), studying the histology of the epididymis of R. annulatus, found regional histological zonation of the epididymis. The highly convuled anterior part of the duct consisted of pseudostratified epithelium with stereocilia. Large vacuoles in the epithelial cells were indicative of a secretory function. In the middle regions the lumen widened and was traversed by fingerlike projections of epithelial tissue, that seemed to form canals within the epididymal duct. The sperm in the lumen was arranged in a shuttlecock form. The posterior portion was no longer coiled and epithelial sheets were more pronounced. The zonation and sperm organization in the epididymis suggested sperm maturation outside the testis (Sieben, 1979). Similar

observations of zonation and epithelial folds were made on the epididymis of Cethorhinus maximus (Matthews, 1950) and in Mustelus manazo and M. griseus (Teshima, 1981).

The epididymis passes into the vas deferens. The posterior portion is modified to form the seminal vesicle which is situated ventrally to the functional part of the kidney. From here sperm passes via the urogenital papilla into the cloaca. Two claspers, which function as intromittent organs during copulation, are present in R. annulatus. The length of these organs depended on sexual maturity. (See sec. 7.3.4).

#### 7.3.3.2 Histology of the testis and spermatogenesis.

Histological studies of the testis of R. annulatus revealed that both testes are functional and showed that the dome-shaped circular lobules that were visible on the dorsal surface, are composed of spherical germinal ampullae. (Fig. 7.10 and Fig. 7.11). In each ampulla all the germ elements were in the same stage of differentiation. Each lobule thus corresponded to an entire testes, as described in Squalus acanthias (Simpson, and Wardle, 1967), having concentric zones of ampullae representing all stages of sperm formation. From the centrum of the lobules, the tubulogenic zone, new ampullae arose continuously and migrate towards the periphery of the lobule as spermatogenesis progresses (Fig. 7.11).

Teshima (1981) stated that the two types of testes, the seminiferous tubular type and the lobular type, both possible in the teleost testis, also appears to be present in the elasmobranch testes. On this basis he concluded that the testes of Mustelus manazo and M. griseus consists of many seminiferous tubules and therefore belong to the tubular type. The same conclusion was drawn for the shark, Scoliodon laticaudus studied by Teshima, Ahmad and Mizue (1978). Photomicrographs in both cases, however, revealed only circular ampullae in sections. No longitudinal sections are visible where tubules are cut lengthwise. Fig. 20-II (N) (Teshima, 1981) shows spermatozoa cut at right angles which is rather unlike the description of spermatozoa orientation given by the same author. I therefore disagree with the descriptions of Teshima et al (1978) and Teshima (1981) and find the description of Simpson and Wardle (1967) more acceptable. In the present study serial sections also reveals that the germinal ampullae were spherical. (See Fig. 7.16). Spherical ampullae were also reported by Matthews (1950) in the testis of the basking shark.

According to Teshima (1981) spermatogenesis can be divided into two stages; 1) spermiocytogenesis when spermatogenic cells repeatedly divide and become spermatids and 2) spermiogenesis when the spermatids are transformed to spermatozoa. In the early stages of spermiocytogenesis the internal surface of the germinal ampullae situated at the centrum of a lobule is lined with seminiferous epithelium standing on a basement membrane (Fig. 7.12). The

seminiferous epithelium consists of a single layer of columnar cells. Spermatogonia appear between the seminiferous epithelium and basement membrane. During an initial period of mitotic activity the epithelial cells are pushed towards the lumen by the proliferating spermatogonia. Stanley (1966) considered these epithelial cells to be homologous with mammalian Sertoli cells. Simpson and Wardle (1967) were of the opinion that these cells appear to migrate radially outwards through the germ cell layers during spermatocyte formation to become Sertoli cell nuclei. Teshima (1981) described them as nurse cells supporting the spermatogonia and providing them with nutrition. As Sertoli cells do appear later in the cycle, (also found in R. annulatus) the opinion of Simpson and Wardle (1967) seems the most likely.

Further division of spermatogonia eventually filled almost the entire ampulla with the lumen barely visible (dependent on the level the ampulla was sectioned)(Fig. 7.13). Primary and secondary spermatocytes were the next stages discernible in the migrating ampullae (Fig. 7.14). These cells were the largest of all the spermatogenic cells. Synchronous differentiation of the secondary spermatocytes produced the spermatids.

Spermiogenesis is started by the formation of spermatids. During the transformation of spermatids into spermatozoa, three stages were noticeable. Early spermatids showed a granular appearance, (Fig. 7.15)

FIG. 7.11 Section of a testicular lobule to show the arrangement of the ampullae in different stages of development.

FIG. 7.12 Spermatogonia appear between the seminiferous epithelium and basement membrane  
a: ampullar lumen, bm: basement membrane,  
e: epigonal organ, s: spermatogonia,  
se: seminiferous epithelium

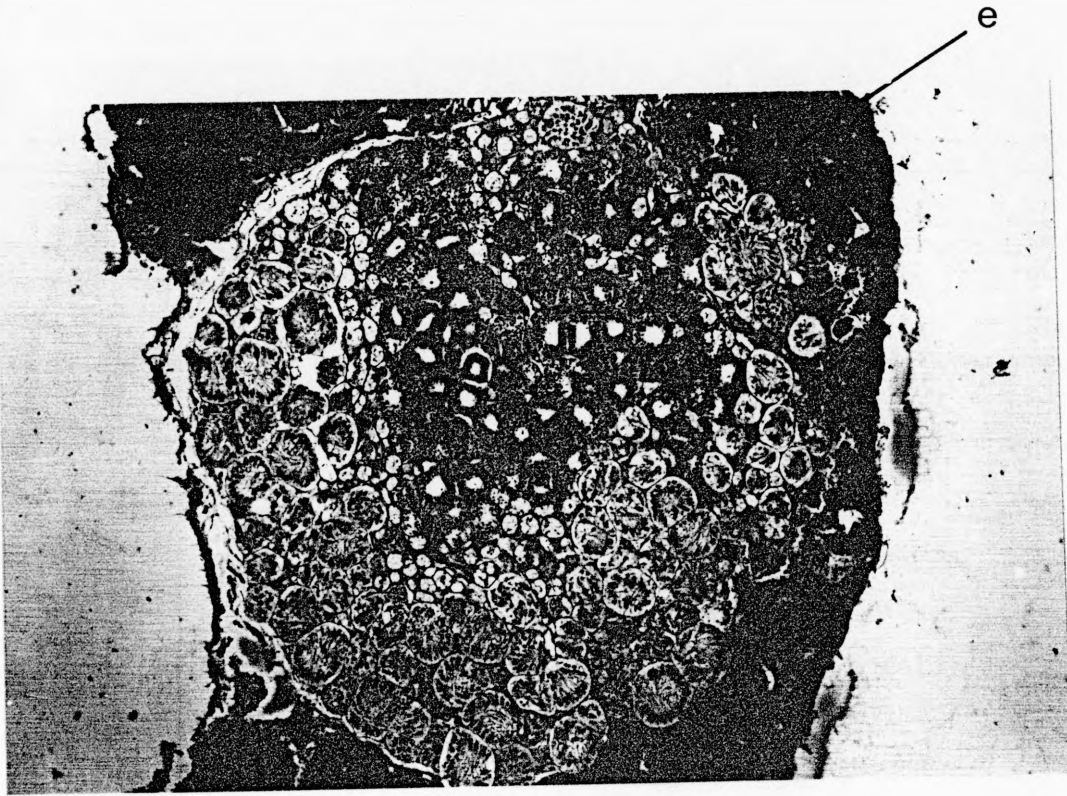


Fig.7.11

x35

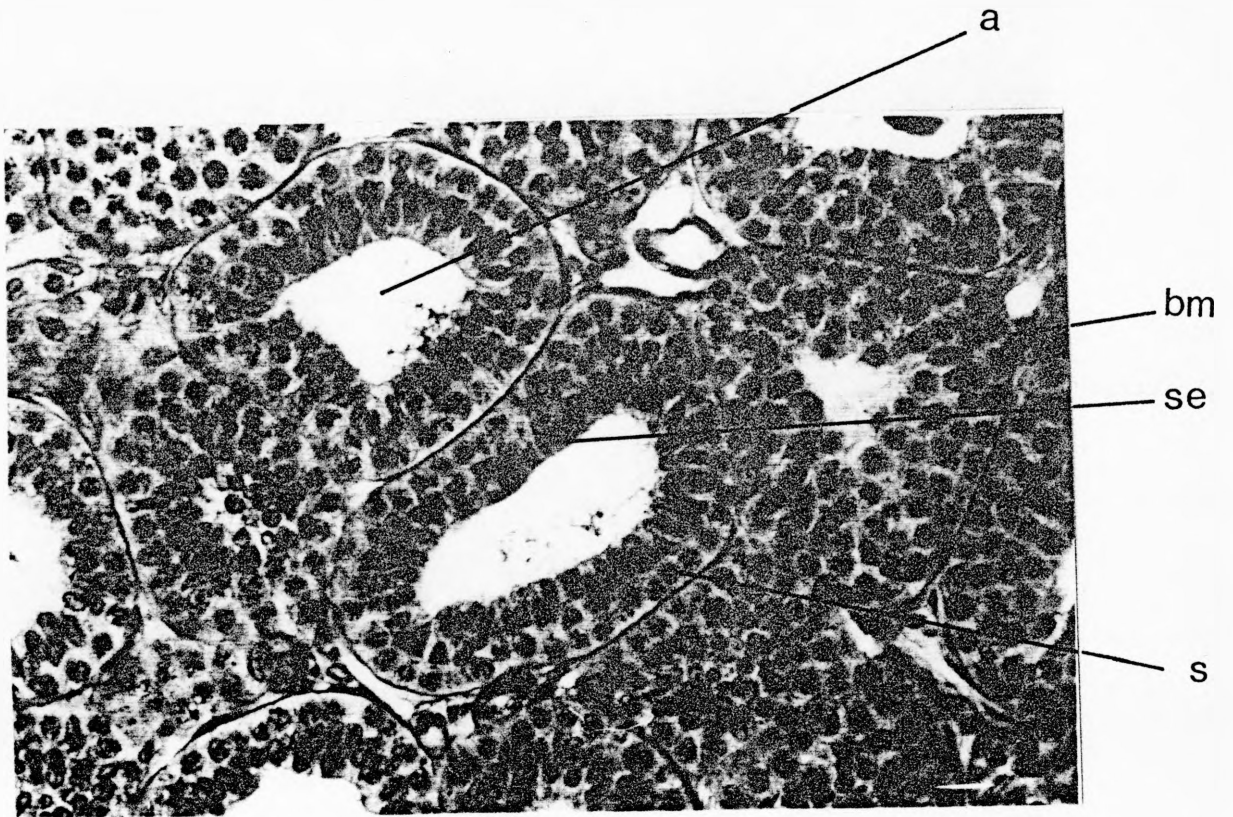


Fig. 7.12.

x495

FIG. 7.13 Spermatogonia and spermatids filling the ampulla.

FIG. 7.14 Primary spermatocytes

s: spermatogonia      sp: spermatids

sc: spermatocytes

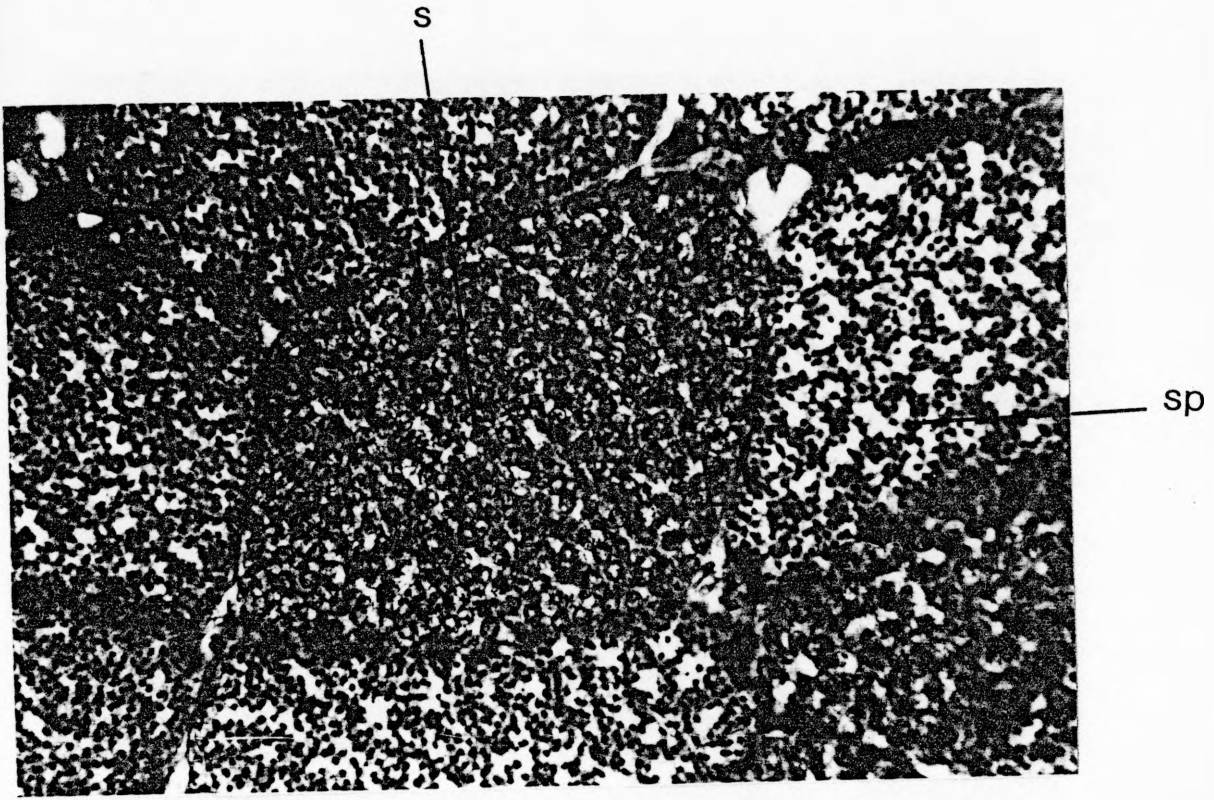


Fig. 7.13

x500



Fig.7.14

x240



FIG. 7.15 Spermatids in three different developmental stages.

The stages are indicated as follows:

- 1) Flagellae start to form
- 2) Spermatids still in random order
- 3) Spermatids arranged along the basement membrane.

FIG. 7.16 Spermatozoa arranged with heads all pointing towards basement membrane. Note the peculiar pattern of the tails.

bm: basement membrane, s: Sertoli cell, l: lumen

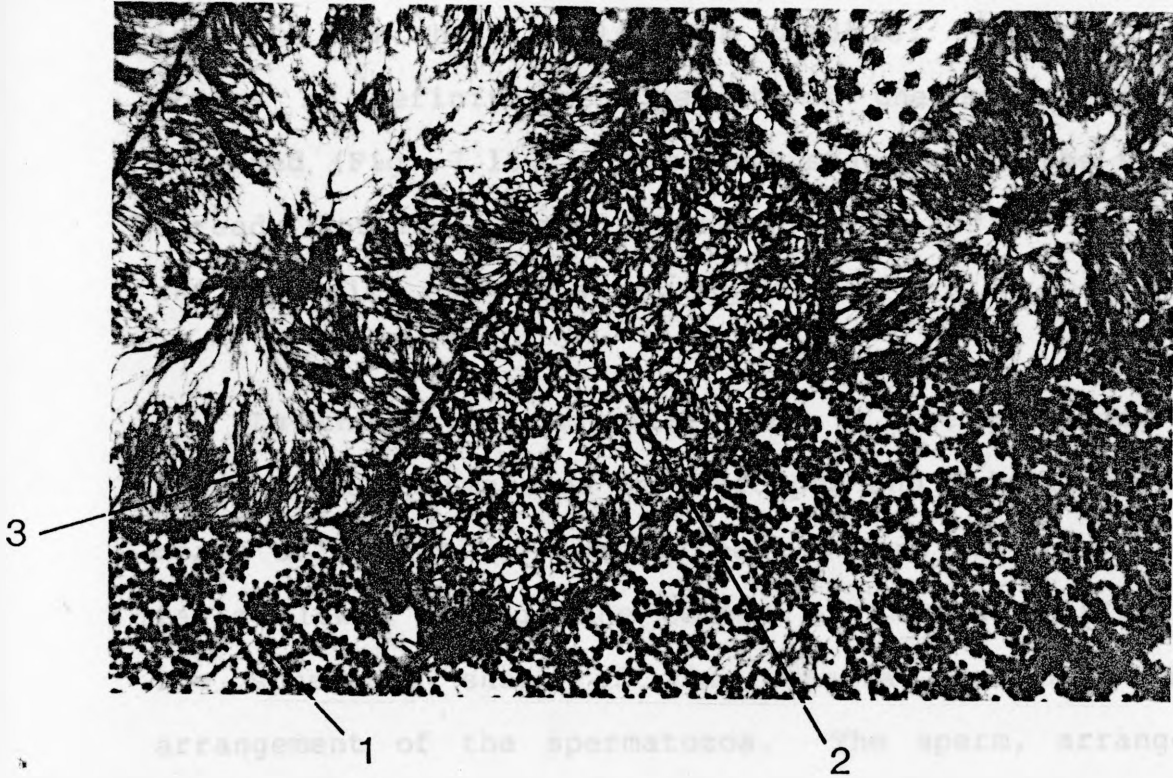


Fig. 7.15

x360

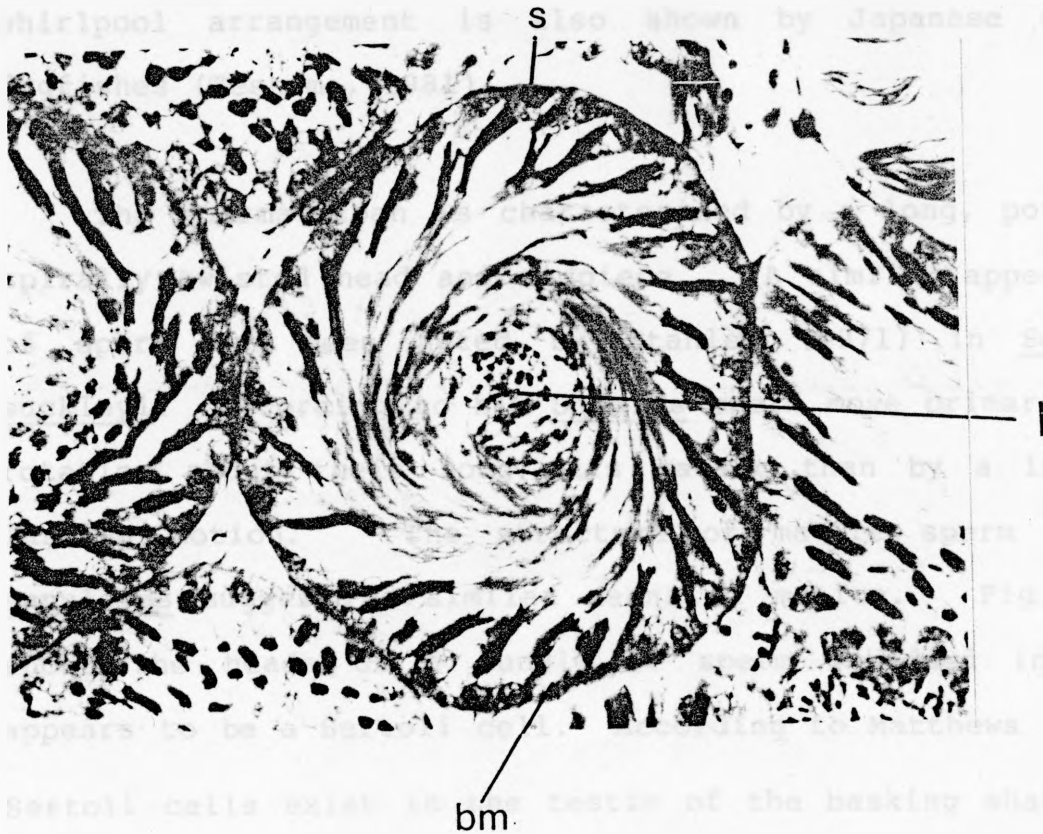


Fig. 7.16

x480

followed by a second stage where the nuclei became slender in form and short tails were visible. During these two stages no definite arrangement of the spermatids can be observed (Fig. 7.15). The last stage shows the spermatids already forming clumps although the heads are still small and the tails not fully developed.

In the mature ampullae, now at the periphery of the lobule, the spermatozoa were grouped and orientated with the heads all pointing towards the basement membrane while the tails flowed towards the centre of the lumen (Fig. 7.16). The spherical shape of the ampullae caused a peculiar arrangement of the spermatozoa. The sperm, arranged with their long axis lying on the radii of the spherical ampulla, showed the tails not only pointing towards the lumen centrum but also spiralling in an anti-clockwise direction. This whirlpool arrangement is also shown by Japanese smooth dogfishes (Teshima, 1981).

The spermatozoan is characterized by a long, pointed, spirally twisted head and midpiece. A similar appearance of sperm has been noted by Stanley (1971) in Squalus suckleyi. According to him Squalus sperm move primarily by rotation about their long axis rather than by a lateral lashing motion. The structure of mature sperm in R. annulatus suggests a similar means of motion. Fig. 7.16 shows the heads of a bundle of sperm imbedded in what appears to be a Sertoli cell. According to Matthews (1950) Sertoli cells exist in the testis of the basking shark and

FIG. 7.17 Mature ampullae showing the collecting tubules for sperm discharge.



FIG. 7.18 Section showing the complex system of collecting ducts traversing the epigonal organ  
e: epigonal organ  
cd: collecting ductules

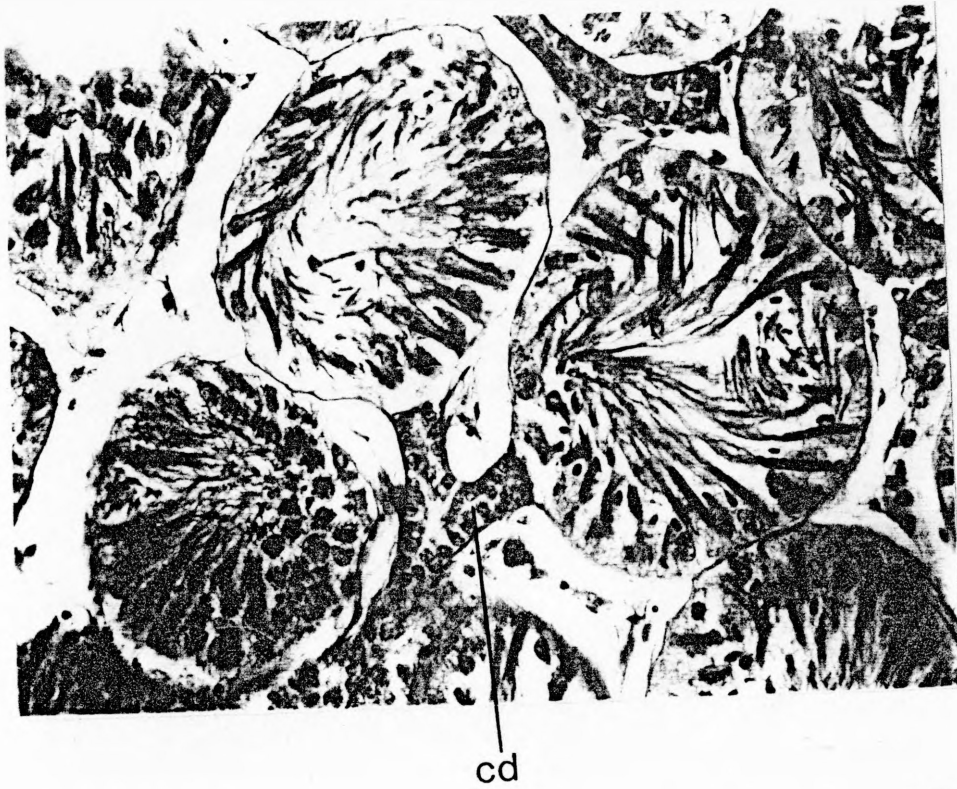


Fig. 7.17

x345

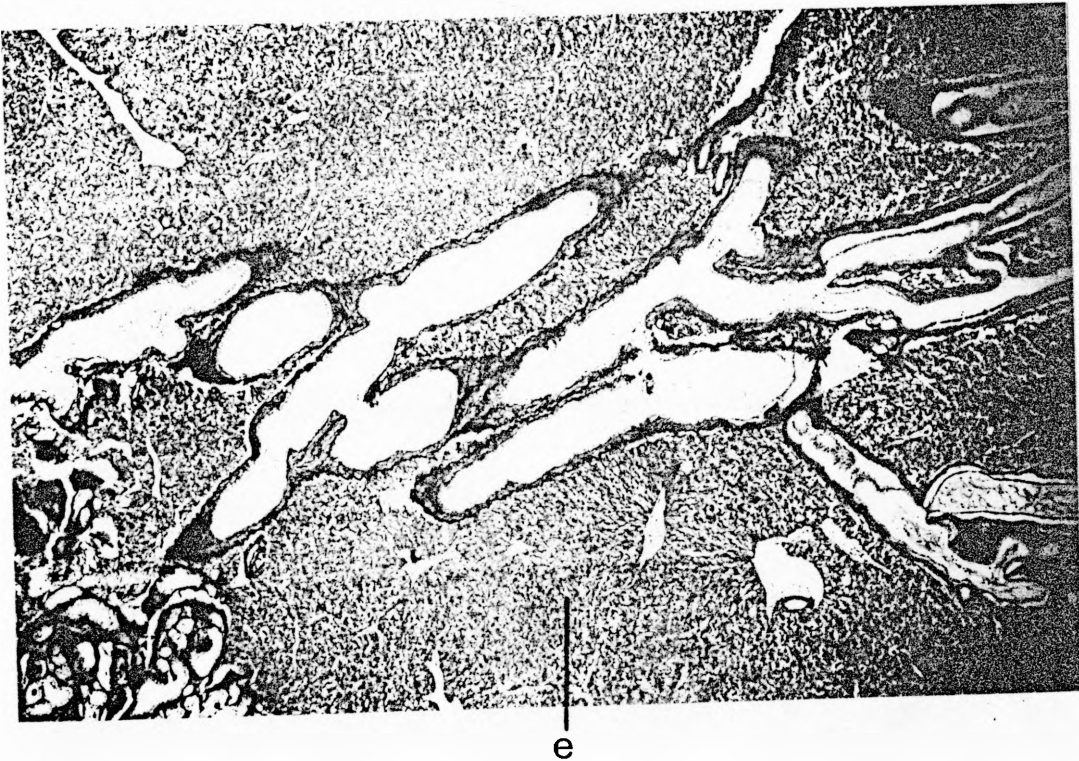


Fig. 7.18

x50

FIG. 7.19 Cross section of a collecting ductule showing remnants of Sertoli bodies and sperm.

FIG. 7.20 Degenerating ampullae  
bv: bloodvessels, cd: collecting ductule  
da: degenerating ampulla

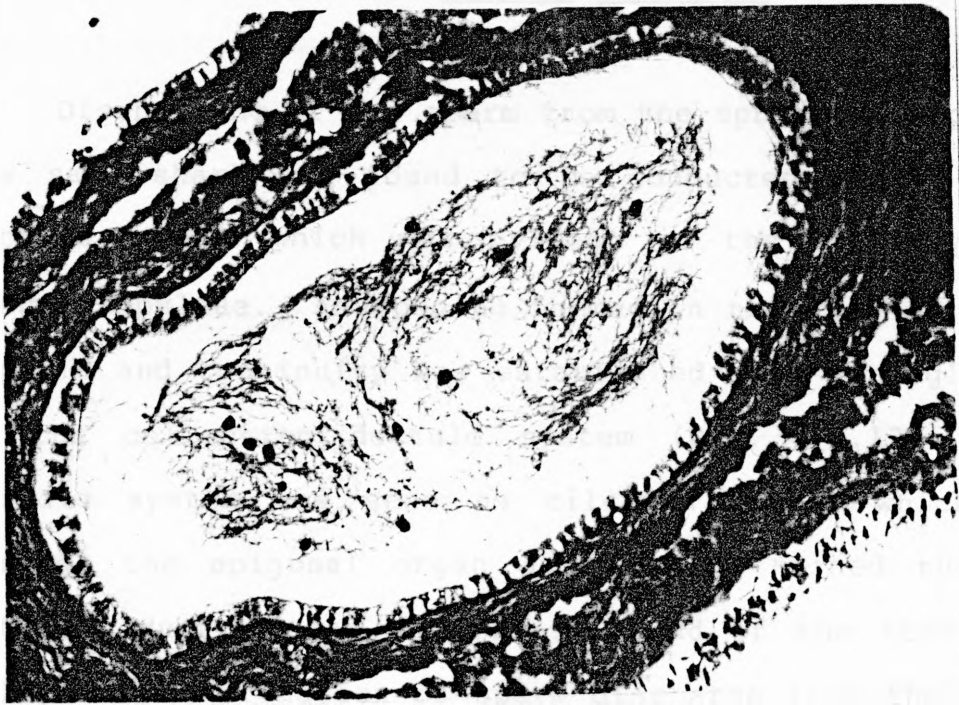


Fig. 7.19

x310

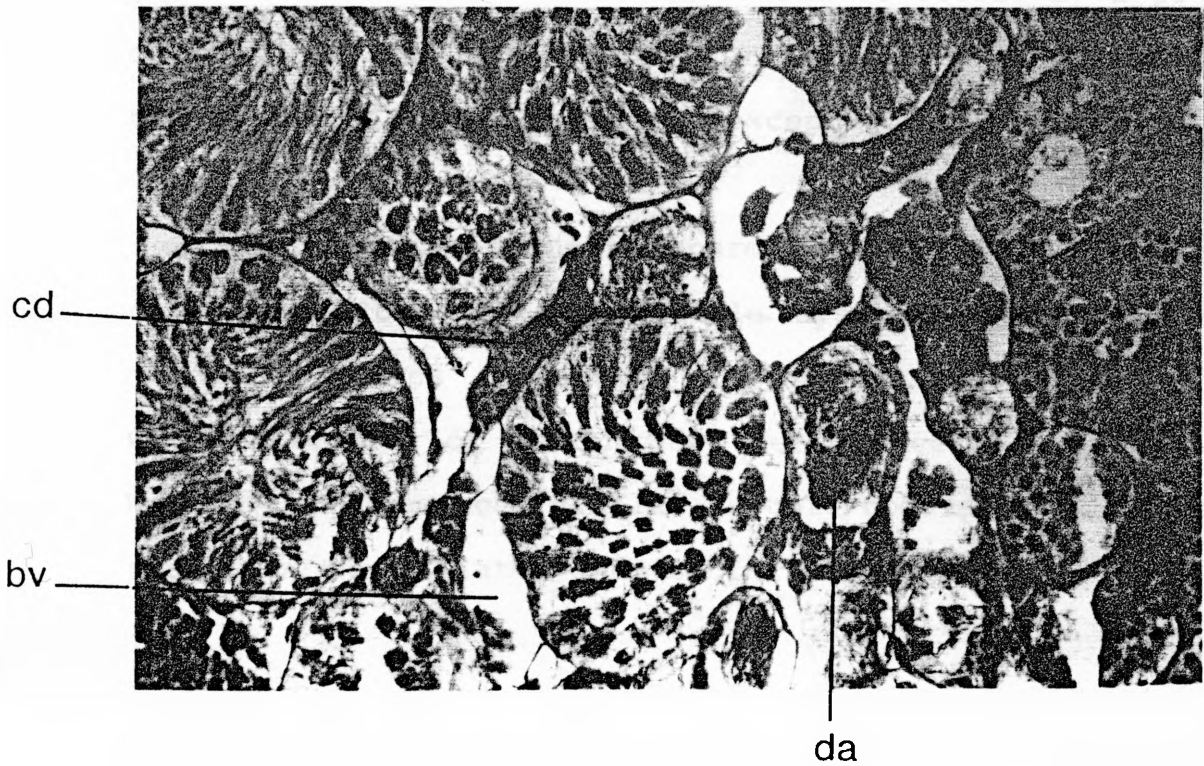


Fig. 7.20

x300

Simpson and Wardle (1967) noticed Sertoli cells in ripe ampullae in the spurdog, Squalus acanthias.

Discharging of the sperm from the spherical ampullae in the sand shark was found to be conducted via a ciliated ductule system which was evident in the vicinity of all mature ampullae. An opening formed in the wall of the ripe ampulla and continuity was established with a single branch of the collecting ductule system (Fig. 7.17 ). This ductule system was seen as ciliated canals which passed through the epigonal organ and finally joined the single efferent duct at the anteromedian end of the testis (Fig. 7.18). No explanation of sperm discharge from the ampullae was given by Teshima et al (1978) or Teshima (1981) and this once again questions the nature of the seminiferous tubules as described by them. Simpson and Wardle (1967) noted that each ampulla in Squalus acanthias has a single duct, which joins a network of similar ducts and is closed by a plug of cells until the ripe stage is reached. This is more like the situation in R. annulatus except for the plug of cells.

The bundles of mature sperm separate from the Sertoli cells and flow into the ductule system. The presence of discrete 'bodies' together with spermatozoa (Fig. 7.19) were indicative of broken down Sertoli cells. Simpson and Wardle (1967) noticed similar Sertoli bodies, mixed with the sperm, in the ciliated canals of the spurdog.



After the sperm has been discharged the germinal follicle contracted, degenerated and was finally resorbed. Once again the presence of Sertoli nuclei similar to those in Fig. 7.19 was noticed in these degenerating ampullae (Fig. 7.20).

#### 7.3.3.3 The gonadosomatic index (G.S.I.) and the breeding cycle of the male.

In the males the G.S.I. reached a maximum in November and a minimum in May-June (Fig. 7.9).

All stages of spermatogenesis were found in the testes of all adult males throughout the year. However, the ampullae containing spermatozoa dominated between the months September to November. Although a maximum G.S.I. value was reached in November no ripe running males were observed or with sperm in the seminal vesicles prior to this or after until January. Discharge of spermatozoa in marine teleosts occurs when the value of the G.S.I. starts descending or is descending from the maximum (Yamamoto, 1953, cited in Teshima, 1981). Thus a time lag was found between peak G.S.I. (peak sperm production) and the observation of ripe running males (indicating active mating) in R. annulatus. During the period November to January spermatozoa was thus discharged from the testis and stored in the vesicula seminalis, resulting in a descend of the G.S.I. A similar lag was found by Teshima (1981) in the Japanese smooth dogfishes, Mustelus manazo and M. griseus. This lag between the maximum value in G.S.I. and ripe running was due to the structural

differences in the reproductive systems of teleosts and elasmobranchs according to the latter author. Sperm discharged from the testis are accumulated in the seminal vesicles.

The G.S.I. value continued to descend until a minimum value was reached in May-June which would suggest the end of the mating period for R. annulatus (Fig. 7.9). Mating would only start after parturition in the females since the spermatozoa must reach the nidamental gland at the head of the oviduct in order that the eggs may be fertilized before they are enclosed by the candle membranes. Thus the mating period for R. annulatus is suggested to take place between April and June. No actual observations of mating or any indicative signs (e.g. scars of bleeding claspers) were noticed during the study period. Mating procedures seems to be more gentle in batoids than in large feral sharks where bleeding claspers of males and scarred fins of females are often observed during the mating season (Budker, 1971). The method of copulation in sand sharks that are benthic probably differs from pelagic sharks where benthic support is lacking and consequently necessitates a firm hold onto each other by means of claspers and teeth.

The early discharge of sperm from the testis for accumulation in the seminal vesicles before the onset of the mating period (Fig. 7.21) is probably an indication that sperm maturation does take place outside the testis (see sec. 7.3.3).

An ascending G.S.I. after May-June indicated the onset of a new cycle and consequently production of sperm for the next mating season.

#### 7.3.4 Length and age at maturity

##### The female

No mating scars were observed in the pelvic region of the females examined in this study. Consequently the occurrence of pregnancy, signs of distinct ova in the ovaries and expansion of the uterus to form a flaccid sac rather than a thin, tight walled tube were regarded as indicative of sexual maturity. The length at maturity was accordingly determined.

The smallest gravid female observed was 615mm in total length. The latter specimen was captured in June 1979 and the presence of small ovarian eggs (ca. 5-10mm in diameter) suggested that this specimen was entering the first breeding cycle on reaching maturity. The ripe eggs would only be ovulated in June the next year. Wallace (1967a) recorded gravid female R. annulatus between 681mm and 894mm total length. The length at maturity for specimens obtained in the present study is suggested to be between 615 and 650mm total length and 3+ years of age (Chapter 6).

##### The male

Some methods have been used to assess the age at maturity in male elasmobranchs. Teshima (1981) used the relationship between clasper length and body length while

calcification of clasper cartilages are widely used as an indication of sexual maturity in male elasmobranchs.

Although males are considered to be mature when the claspers are fully grown and the clasper cartilages rigid from calcification, sperm is often present in elasmobranchs with immature (soft) claspers (Bass et al, 1973). Histological studies of the testis of male R. annulatus revealed that spermatozoa were already present in the ampullae in a specimen of 510mm total length. This could be the onset of adolescence that Wallace (1967a) referred to in male R. annulatus. He estimated the onset of adolescence to occur at a total length in the region of 500mm while sexual maturity is attained at about 590mm.

The relationship between total body length and clasper length (inner measurement taken) is shown in Fig. 7.22. This reveals that the clasper length increases as the sand shark grows. The empiric growth curve further indicates a slow increase in clasper length before 525mm total length is reached. This is followed by a period of rapid growth with a total length increase from 525mm to 580mm. Growth of the clasper continues after this period of rapid growth but at a slower linear rate. According to Teshima et al (1971, cited in Teshima, 1981) the clasper length in Mustelus manazo increased rapidly as the shark reached maturity, but grew at a much slower rate after reaching maturity.

Fig. 7.22 thus suggests that for specimens obtained in the present study adolescence in R. annulatus is reached at a total length of about 525mm and sexual maturity at about 580mm with inner clasper length ca. 80mm. The period between these events were characterized by a rapid increase of the claspers at a rate of about 0,66 cm per 1cm increase in total body length. Teshima (1981) reported a rate of about 0,7cm per 1cm increase in body length for Mustelus manazo and M. griseus.

The distinction between soft and hard claspers was often a matter of uncertainty, however the length for claspers turned hard was estimated between 75-80mm clasper length. Regression of total body length versus clasper length (inner measurement) gave the following equation:

$$y = 720 + 124 \ln x \quad (n = 228; \quad r = 0,914)$$

(See Chapter 4) substitution of total body length at maturity as obtained from Fig. 7.22 results in a clasper length of 69mm. This regression is obviously affected by the data for immature specimens and hence the lower value for clasper length than that derived from the empirical curve.

A combination of the results of the two methods would be a good indication of the body length or clasper length at sexual maturity and it is therefore estimated that male R. annulatus mature at about 580mm total length and claspers become rigid at about 70mm.

From Table 6.2 (Chapter 6) the length at maturity is reached at three years of age.

#### 7.3.5 Reproductive strategy

From this study it is estimated that R. annulatus can produce an average of 24 young in a lifetime. This low fecundity in turn would require a high competitive ability of sand sharks in the surf zone. Some correlates in R. annulatus which suggest K-selection are slower development, delayed reproduction (mature after three years of age), repeated reproduction (females breed every year) and the length of life (average of six years). This would indicate that R. annulatus is a K-strategist with the population size fairly constant in time (Krebs, 1978). Being viviparous, and producing relatively few and a large embryos which stay resident in the surf zone for at least three years, the survivorship is probably type I. This would mean little loss from the population of young individuals and then high losses of older organisms. The growth curve, suggested for R. annulatus in this study (see chapter 6) supports the latter statement.

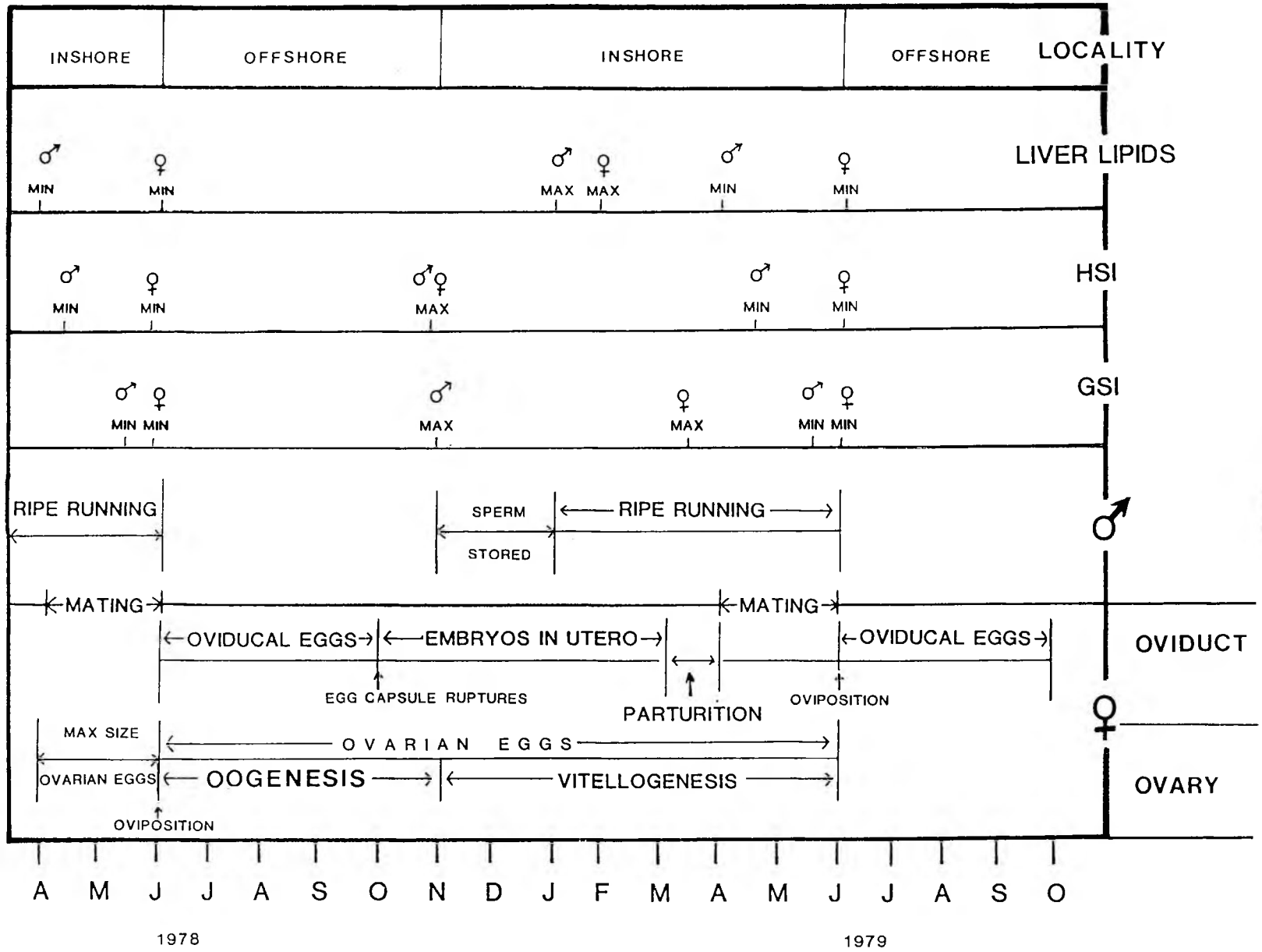


FIG. 7.21 A diagrammatic presentation of the breeding cycles in male and female *R. annulatus* with correlated events.

TOTAL LENGTH VS CLASPER LENGTH

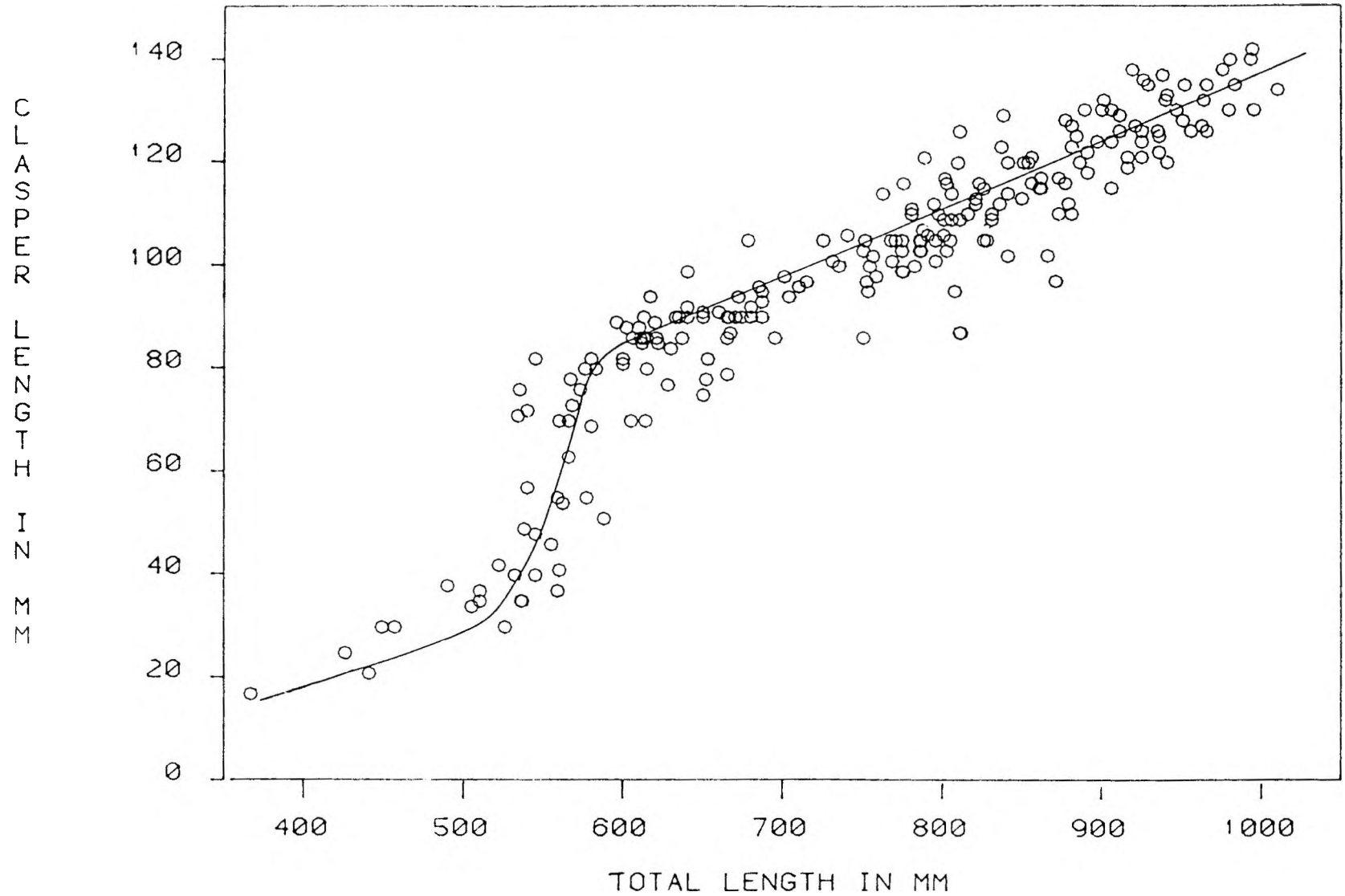


FIG. 7.22 The relationship between total body length and clasper length in R. annulatus.



## CHAPTER 8

## NUTRITION

8.1 INTRODUCTION

Analysis of stomach contents of fishes not only reveals which prey organisms are taken but also reveals many aspects of the ecology and behaviour of the predator (Hickey, 1975). These studies may also assist in describing the biotic environment in which the predator lives, e.g., the availability and abundance of prey organisms. Thus by understanding the predators present and their trophic positions, the flow of energy through an ecosystem can be visualized (Quasim, 1972; Hickey, op. cit).

The feeding biology of elasmobranchs has received little attention in the past and the majority of studies were concentrated on larger species of sharks and species of commercial value, e.g., Squalus suckleyi (Chatwin and Forrester, 1953), Squalus acanthias (Bonham, 1954; Holden, 1966) and potentially dangerous sharks caught in nets off bathing beaches (Bass et al, 1973, 1975a, b, c, d, 1976). Wallace (1967a, b, c) noted stomach contents of batoids of the east coast of Southern Africa.

The sand shark is the most important macropredator in the intertidal and surf zones of the sandy beaches of Algoa Bay (Rossouw, 1979). Although it plays an important rôle in the food web, including the beach macrofauna of this

ecosystem (McLachlan et al, 1981), no quantitative data on the food of R. annulatus have been published. In this study the diet of R. annulatus as well as food selection by different size classes of sandsharks were investigated. Laboratory feeding studies to quantify food intake and utilization were also attempted but were not successful because sandsharks refused to eat in captivity.

## 8.2 MATERIALS AND METHODS

A total of 232 stomachs was collected over a period of 23 months. Only specimens captured by angling and beach seine netting in the surf zone off the three sandy beach sampling areas (see Fig. 2.1) were used for quantitative analysis. The stomach contents of specimens that were captured by trawl nets offshore were only identified and noted.

The stomachs were removed immediately after capture and preserved in 10% neutral formalin. Immediate removal was essential to prevent further digestion of the stomach contents. (Animals that were kept in a refrigerator for a few days before the stomachs were removed not only showed advanced stages of digestion of the stomach contents but also signs of putrefaction).

The points method (Ricker, 1971), as modified and employed by Coetzee and Baird (1981), was used in this study to quantify the composition of the stomach contents. The food items were sorted and identified in a Petri-dish with a

1-mm grid marked on its base. Each food category was kept in a separate block of the grid marked on the Petri-dish. After counting the number of blocks a specific food category occupied, it was then expressed as a fraction of the total number of blocks occupied by the complete stomach contents. Large prey items were macerated and spread out to achieve the same height as the smaller items. The stomach contents were, wherever possible, identified to species level. Evaluations of the stomach contents excluded the bait used by anglers. No account was taken of the fullness of the stomachs and those containing only a clear fluid, bait or sand were recorded as empty.

The contribution of each item to the diet was calculated by summing all the fractions of each item and expressing it as a percentage of all the stomach contents examined. In addition, the frequency of occurrence method (Ricker, 1971) was employed where the occurrence of each different food item was noted and expressed as a percentage of the total number of stomachs used for analysis.

The relative importance of prey species was indexed by multiplying occurrence (percent of stomachs containing that prey species) by the value obtained using the points method (percent bulk contribution of the prey species to the diet). This index of relative importance (IRI') is based on the method suggested by Pinkas et al (1971), but differs in that percentage by number and volume was replaced by percentage bulk (volume of prey species in entire diet). (The points

method eliminated the necessity to count the actual number of prey species in the stomach contents). For this analysis specimens of R. annulatus were divided into three size classes with the following total lengths: 400-600mm; 600-800mm; and >800mm.

### 8.3 RESULTS AND DISCUSSION

#### 8.3.1 Methods of stomach contents analysis

In a review on the methods of stomach contents analysis and their application, Hyslop (1980) states that it is evident that no one method of stomach contents analysis gives a complete picture of dietary importance. He further suggested that the best measure of dietary importance is one where both the numbers and bulk of a food category are recorded. This suggested the use of the points method, the occurrence method and the 'index of relative importance' method in which the values obtained from the former two methods are combined.

The points method, as modified by Coetzee and Baird (1981), although subjective, was found to have the advantage of being simple and rapid to apply. The volumetric nature of this method gave an indication of the contribution of a food category to the diet in terms of bulk.

The occurrence method (Ricker, 1971) was quick to employ when food items were readily identifiable and required the minimum of apparatus. Because the method does not relate to size, volume or mass of the food items, it

tends to overemphasize the contribution of small food items but provides a qualitative picture of the entire diet.

The 'importance' of items in a diet will vary according to the index used and the attributes it was designed to measure (Hyslop, 1981). The aim of this study was to compare diets of different size classes of R. annulatus and therefore 'importance' of a food category was taken to mean the amount (number) and bulk (volume) in the diet. Windell (1971) stated that indices combining values from different sources are more representative than indices using one source. Such a measure of the 'index of relative importance' was suggested by Pinkas et al (1971); by incorporating percentage by number (N), volume (V) and the frequency of occurrence (F) of a specific food category in the formula:

$$\text{IRI} = (\% N + \% V) \times \% F$$

The points method (as employed in this study) included the number and volume of a specific food item in the individual stomachs examined. To obtain the index of relative importance of the prey species of R. annulatus the former method was modified, to:

$$\text{IRI}' = (\% \text{ points method}) \times \% F$$

Thus both the points method and the frequency of occurrence method could be employed to provide an index of relative importance that would comply with the aims of the study.

Tricas (1979) applied the IRI (Pinkas et al, 1971) to cephalopod prey in the diet of blue sharks and the different

cephalopod species were ranked according to the index value. Van Blaricom (1977), studying the feeding habits of the rays, Myliobatis and Urolopsis, indexed the importance of the prey species by multiplying prey frequency by mean percent volume of stomach contents for the given species. The principle prey items then received a ranking accordingly. Instead of making use of such a ranking system, the IRI' of each food category was expressed as a percentage of the total diet in this study. This gave a more general index that is easily comparable.

#### 8.3.2 Food composition

Table 8.1 shows the composition of the stomach contents of R. annulatus, according to the three methods used to assess the dietary importance of the various prey items.

The major prey organism in all three size classes of sand shark was the benthoplanktonic mysid, Gastrosaccus psammodytes. The next most important prey species were the sand mussels, Donax spp., which included Donax serra and Donax sordidus. This is also shown in the pie-diagrams in Fig. 8.1 and Fig. 8.2.

A high incidence of polychaetes, isopods and amphipods is shown by the occurrence method, although the contribution of these items according to the points method is low. This is a direct result of the over-emphasis by the frequency of occurrence method of the contribution of small organisms to the diet (Ricker, 1971).

TABLE 8.1 The composition of the stomach contents of *R. annulatus*.

Food Component	POINTS METHOD (%)				OCCURRENCE METHOD (%)				COMBINED INDEX OF RELATIVE IMPORTANCE (%)			
	TOTAL LENGTH (MM)				TOTAL LENGTH (MM)				TOTAL LENGTH (MM)			
	400-600	600-800	> 800	All length classes	400-600	600-800	> 800	All length classes	400-600	600-800	> 800	All length classes
POLYCHAETA	2,4	4,6	4,7	3,2	6,7	16,4	10,5	11,7	0,2	1,3	1,7	0,8
CRUSTACEA												
Isopoda	1,6	1,1	2,1	1,7	31,1	22,9	12,3	21,4	0,7	0,5	1,0	0,8
Amphipoda	2,3	1,4	0,7	1,5	55,6	36,0	8,8	31,9	1,9	0,9	0,2	1,0
<i>Gastrosaccus psammodytes</i>	57,3	45,6	24,8	41,8	97,8	85,2	54,4	77,3	83,2	69,5	48,2	70,5
<i>Macropetasma africanum</i>	4,4	20,4	18,2	15,2	15,6	34,4	22,9	25,2	1,0	12,6	14,9	8,3
<i>Emerita austroafricana</i>	5,4	0,2	2,0	2,4	6,7	3,3	5,3	4,9	0,5	<0,1	0,4	0,2
<i>Ovalipes punctatus</i>	5,6	13,2	21,1	13,8	28,9	19,6	31,5	26,4	2,4	4,6	23,8	8,0
MOLLUSCA												
<i>Donax</i> spp.	13,5	11,9	10,7	11,8	44,5	49,2	19,3	27,4	9,0	10,5	7,4	9,5
TELEOSTEI												
Fish larvae	1,6	-	9,5	3,9	13,3	-	5,3	5,5	0,3	-	1,6	0,4
MISCELLANEOUS												
Unidentified remains	6,0	1,6	6,2	4,7	8,9	3,3	3,5	4,9	0,8	0,1	0,8	0,5

Although isopods are small items and should, like mysids, be easily ingested, relatively few were taken by sandsharks. Isopods were found to occur in low numbers on the local sandy beaches (McLachlan, 1977b).

### 8.3.3 Differential predation of length classes and it's implications.

Although the same food items were taken by all size classes of R. annulatus, there was a marked difference in their preferences for certain items (Table 8.1).

The IRI' for G. psammodytes was very high (83,2%) for group I sandsharks (400-600mm) and decreased to 48,2% for group III (>800mm). Table 8.2 shows the mean sex composition of G. psammodytes found in the stomach contents of three size classes of R. annulatus. In group I female mysids were predominant. These were mostly brooding females containing eggs or developing young. In group II females still predominated while in group III juvenile mysids were in the majority.

Wooldridge (1981) found a clear pattern of intraspecific zonation of the sand burrowing beach mysid, G. psammodytes. This was evident during the day when this species is confined to the intertidal and surf zone of sandy beaches. It extends for a distance of at least 50 meters from the water's edge into the surf. The females move progressively inshore as the brood develops so that those females bearing



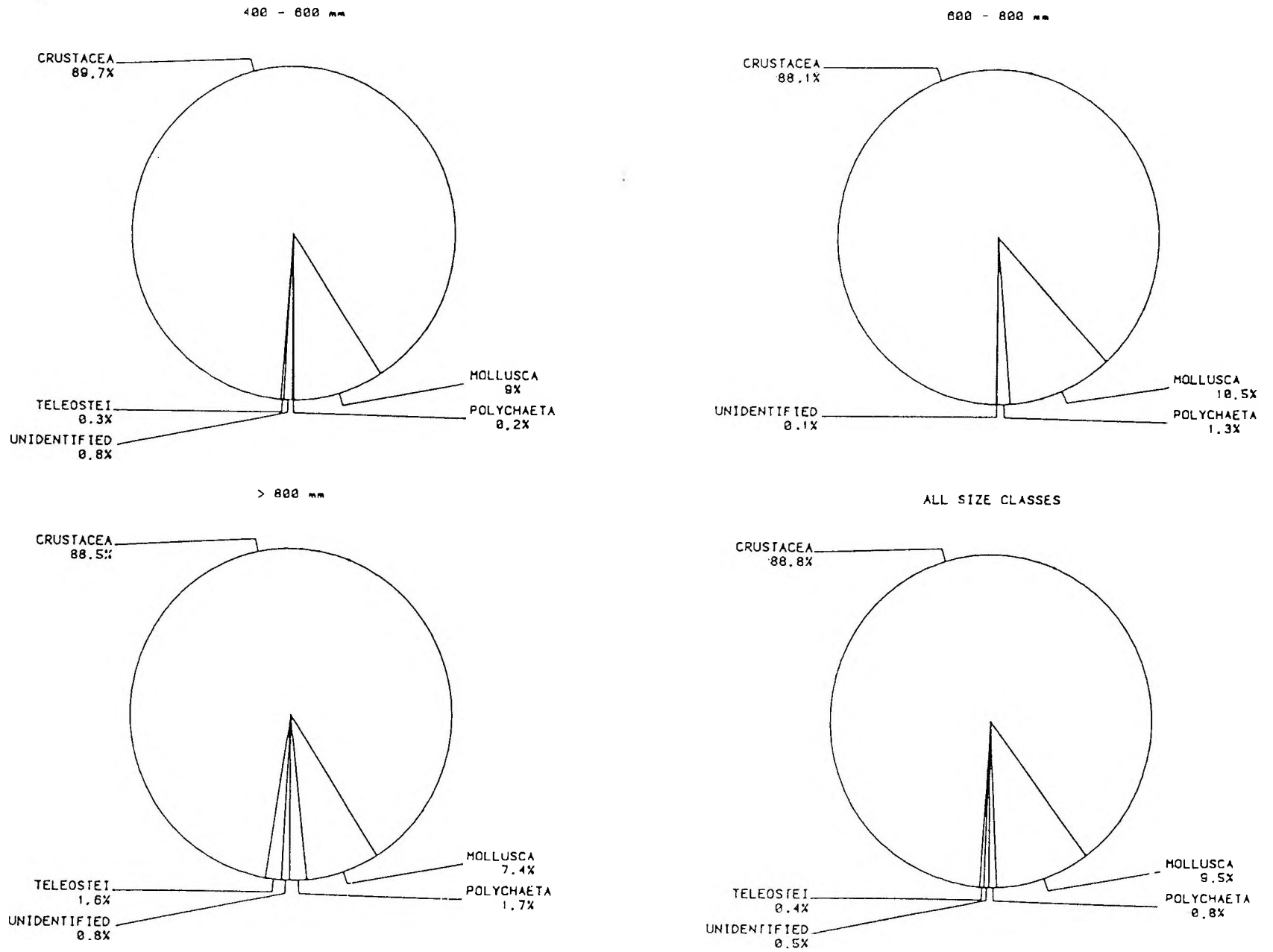


FIG. 8.1 The composition of the stomach contents of *R. annulatus* (IRI' method).

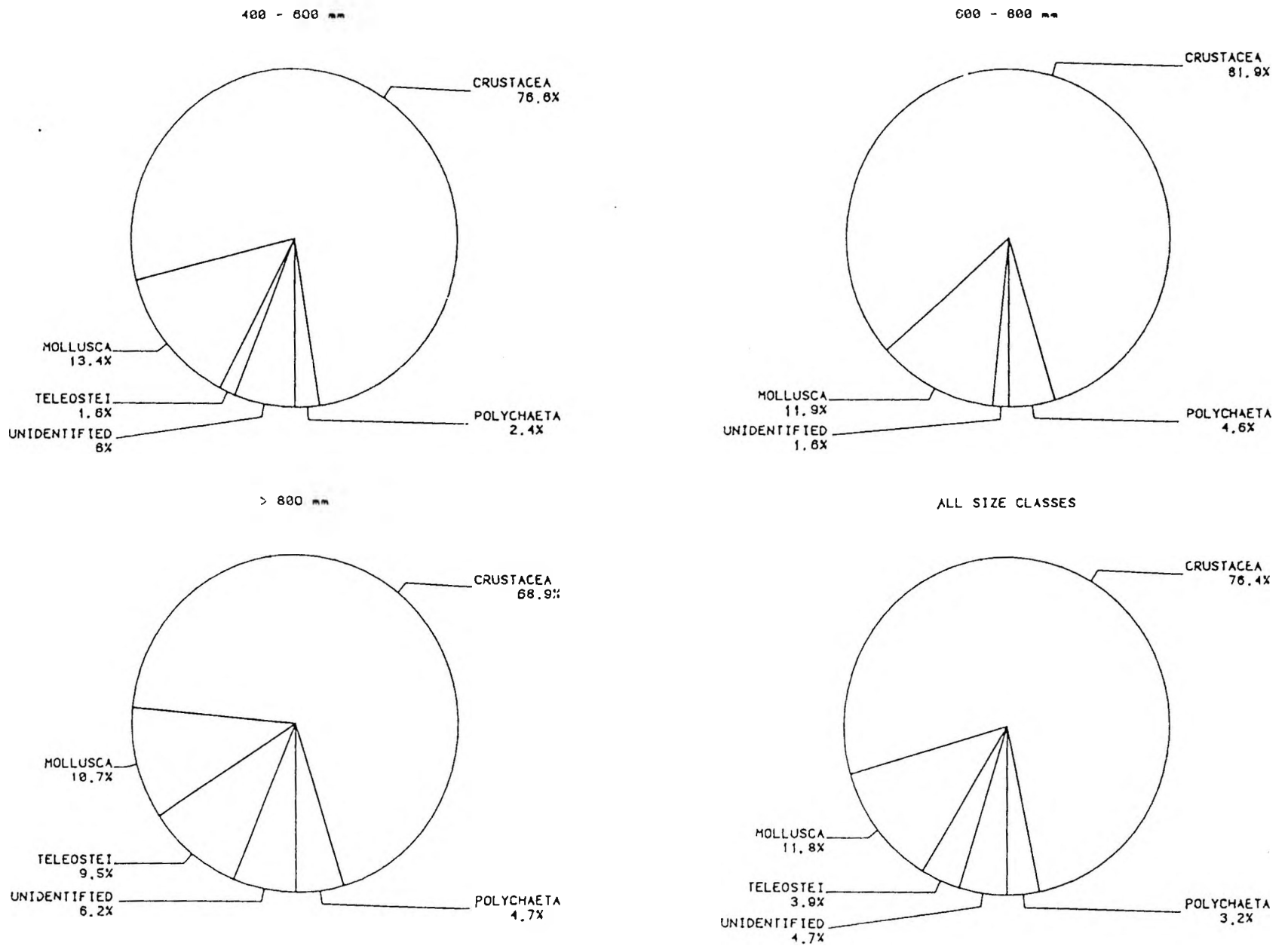


FIG. 8.2 The composition of the stomach contents of *R. annulatus* (Points method).

eggs or developing young are most abundant in the swash zone. Males and juveniles occur in greatest numbers furthest offshore i.e. in the shallows. The composition of mysids in the stomach contents of R. annulatus therefore reveals predation by different size classes in different zones. The smaller sand shark feed closest inshore near the waters edge, while the larger ones feed further from the water's edge in the surf zone.

G. psammodytes is a tidal migrant (McLachlan, et al, 1979) and becomes planktonic at night. The relative freshness of the mysids in the stomachs examined could be due to the fact that all angling operations started early in the morning when planktonic activity by mysids had ceased and they were thus more readily available for consumption by the sand shark. During very turbulent conditions with severe sand movement, the mysid population becomes concentrated in a narrower band inshore (Wooldridge, 1981). The high standard deviations in Table 8.2 are thus probably a direct result of variable surf conditions modifying the zonation of G. psammodytes and consequently affected this differential predation by sand shark.

Table 8.1 reveals a second major shift in the 'preference' of a food item in the case of the penaeid, Macropetasma africanum. The highest IRI' (14,9%) was for the biggest size class of sand shark. M. africanum occurs in greatest numbers in the inner turbulent zone (Cockcroft, pers. comm.) being the region just inside the area where

TABLE 8.2 Sex composition of Gastrosaccus psammodytes found in the stomach contents of R. annulatus of three size classes (total length in mm).

GROUP I	400 - 600 mm	(n = 36)		
	Sex		$\bar{x}$	SD
	♀		12	11,5
	♂		3	4,6
	J		5	4,2
GROUP II	600 - 800 mm	(n = 46)		
	Sex		$\bar{x}$	SD
	♀		11	10
	♂		4	4,7
	J		6	2,3
GROUP III	> 800 mm	(n = 22)		
	Sex		$\bar{x}$	SD
	♀		1	1,6
	♂		2	4,5
	J		7	7,4

$\bar{x}$  = mean numbers per stomach

SD = standard deviation

J = juveniles

n = number of stomachs examined

approaching waves first break. The three-spotted swimming crab, Ovalipes punctatus, showed an IRI' increase from 2,4% for the small size class sandsharks to 23,8% for the biggest size class (Table 8.1). This is probably due to smaller size classes of sandsharks not being able to handle these large crabs as only the larger crabs occur in the surf zone (Du Preez, 1981). Smaller sandsharks are thus probably not capable of capturing the highly mobile Macropetasma or large Ovalipes.

The sizes of Donax spp. taken by all size classes of R. annulatus never exceeded 10mm shell length. These smallest size classes of Donax spp. are concentrated around the extreme low water of spring tides level at the beach. Larger individuals form a distinct band which occurs just above MW during spring and migrates down to LW during neaps (McLachlan and Hanekom, 1979). The smaller size classes of Donax spp. seem to be the most readily available to R. annulatus and are consumed by all sandsharks irrespective of length (Table 8.1). No significant difference in the amount taken by different size classes of sandsharks was apparent ( $p > 0,005$ ).

Availability of prey to predators is determined by the abundance of the prey which depends on the distribution of the prey species in the water, the coincidence of the feeding areas of the predator and its prey, and on the behaviour, activity and size both of the prey and predator (Popova, 1967). The distribution and subsequent availability

of the major prey species (G. psammodytes, M. africanum, O. punctatus and Donax spp.) were reflected in the stomach contents of different classes of R. annulatus. This suggests a dynamic zonation of the sands hark and consequently a size dependent feeding selectivity. While all sizes of sand sharks are highly mobile and capable of feeding in different parts of the surf zone, the Gastrosaccus data suggests that there is a tendency for the smaller sand sharks to feed in shallower water than the larger individuals. However, considerable overlap and movement back and forth must occur. Seine netting operations usually yielded only small individuals while anglers, casting near or beyond the area of breaking waves, more often caught big specimens. This separation may be considered a form of dynamic zonation of size classes for feeding purposes.

#### 8.3.4 Offshore diet

Stomach contents of sand sharks captured by ottertrawl, were not used for quantitative analysis but revealed a different diet to those caught inshore. All the stomachs investigated were filled with the prawn, Callinassa gilchristi. This is an offshore species which does not occur in the shallow water close to the coast.

#### 8.3.5 Empty stomachs

Table 8.3 shows the number of stomachs examined and the number of empty stomachs found in the present study. No incident of regurgitation of food was witnessed when

TABLE 8.3 Stomachs examined in R. annulatus

Size class	No. Examined	No Empty	%
400 - 600 mm	56	3	5,4
600 - 800 mm	80	9	11,3
> 800 mm	96	20	20,8
TOTAL	232	32	13,8

specimens were captured and empty stomachs could not be attributed to this. The state of digestion of the various stomach contents was the same in any one animal. This would imply an intermittent feeding habit where, after filling the stomach, further ingestion of food ceases until digestion is complete (Holden, 1966).

Of the 29 empty stomachs recorded for the last two size classes (600-800mm and >800mm), 20 were from pregnant females (Table 8.3). All these females were captured in February and March, these being the last two months before the onset of parturition (Chapter 7). Cannibalism is known to exist among elasmobranchs and during this investigation a 940mm male specimen was found to contain a small specimen of R. annulatus in the stomach. Females may cease feeding for a few days prior to parturition. It is, however, also expected that it will be those sand sharks which have fasted longest that will take the bait more readily during angling operations. The pink prawn, Callinassa kraussi was the most popular bait used by anglers and was most readily taken by sand sharks.

Cessation of feeding is probably to protect their own young and is complemented by offshore migrations of adults. This apparently commences soon after the young have been liberated in the shallow water. Post partum females were rarely encountered during angling operations.



## CHAPTER 9

## LIVER AND LIVER LIPIDS

## 9.1 INTRODUCTION

Over the past few years hepatic studies in elasmobranchs have captivated the attention of a number of authors. Different aspects of the liver have been investigated and consequently a variety of correlated functions have been attributed to this organ. The lack of a swimbladder in elasmobranchs stimulated investigations for a substitute which resulted in the liver being of major importance for maintenance of hydrostatic balance in pelagic sharks (Bone and Roberts 1969; Baldrige, 1970, 1972; Craik, 1978). According to these authors buoyancy control is achieved by accumulation of liver oil, the size of the liver and specific density of the oil.

Shark liver oil has formed the basis of valuable fisheries in the past. Banjo (1979) studied the livers of Carcharias taurus and Sphyrna diplana and paid particular attention to the potential uses of the lipid.

The hepatosomatic index (liver weight as a percentage of body weight, HSI) was noticed to be higher in elasmobranchs than in osteichthyes (Oguri, 1978a) and histochemical observations confirmed that the accumulation of fat droplets in hepatic cells were responsible for liver enlargement with total length in the rabbitfish, Chimaera

monstrosa (Oguri 1978a, b). HSI increase with total body length has also been observed in Raja radula and Raja polystigma (Capapé, 1979, 1980). Craik (1978) was the first to demonstrate annual variation in the HSI in the lesser spotted dogfish, Scyliorhinus canicula. He included HSI as one of the parameters associated with vitellogenesis.

In the present study the liver of R. annulatus was investigated for constituents that could be correlated with its benthic habits and breeding strategy. An attempt was made to quantify the contribution of hepatic lipids to the formation of the large yolky eggs in the female.

## 9.2 MATERIALS AND METHODS

A total of 257 livers were obtained from April 1978 to March 1980 from sand sharks collected as described in Chapter 3. After the specimens were weighed, standard length measurements taken and sexed, the livers were removed. The wet weight and colour of the livers were recorded and the hepatosomatic index (HSI)(liver weight as a percentage of body weight) was calculated. The livers were then stored in sealed containers at  $-20^{\circ}\text{C}$  until required for analysis.

The frozen samples were freeze dried (4 days) and moisture content of the livers in the fresh state was determined by weight loss during freeze drying. The freeze dried material was then homogenised with an electrical coffee grinder (Moulinex Super-Junior S) and left in open containers for four days to air-equilibrate. Moisture

determinations were performed on 2g duplicate samples (24h at 100°C).

Liver lipid extraction was done by diethylether extraction with the Soxtec system (Tecator Sweden)(procedure: boiling 15 min; rinsing 30 min; evaporation 15 min). Extraction was done in duplicate on each sample and after correction for moisture the mean of the two values were taken.

The lipid content of the liver was then expressed as percentage of dry weight. The results were grouped according to the total body length of the animal that the liver was removed from, into the following size classes 400-600mm, 600-800mm and 800->1000mm for males and females. Females >600mm and males >500mm were considered mature (see Chapter 7). Statistical comparisons were made by Student's t-test except where otherwise stated.

### 9.3 RESULTS AND DISCUSSION

The relatively small livers (1-5,7% of body weight) of R. annuatus collected over a period of 24 months not only showed marked seasonal variations in size (HSI) but also revealed an annual cycle (Fig. 9.1). In order to investigate the size of the liver and the reasons for the variations in greater detail the following aspects were considered.

# HEPATOSOMATIC INDEX

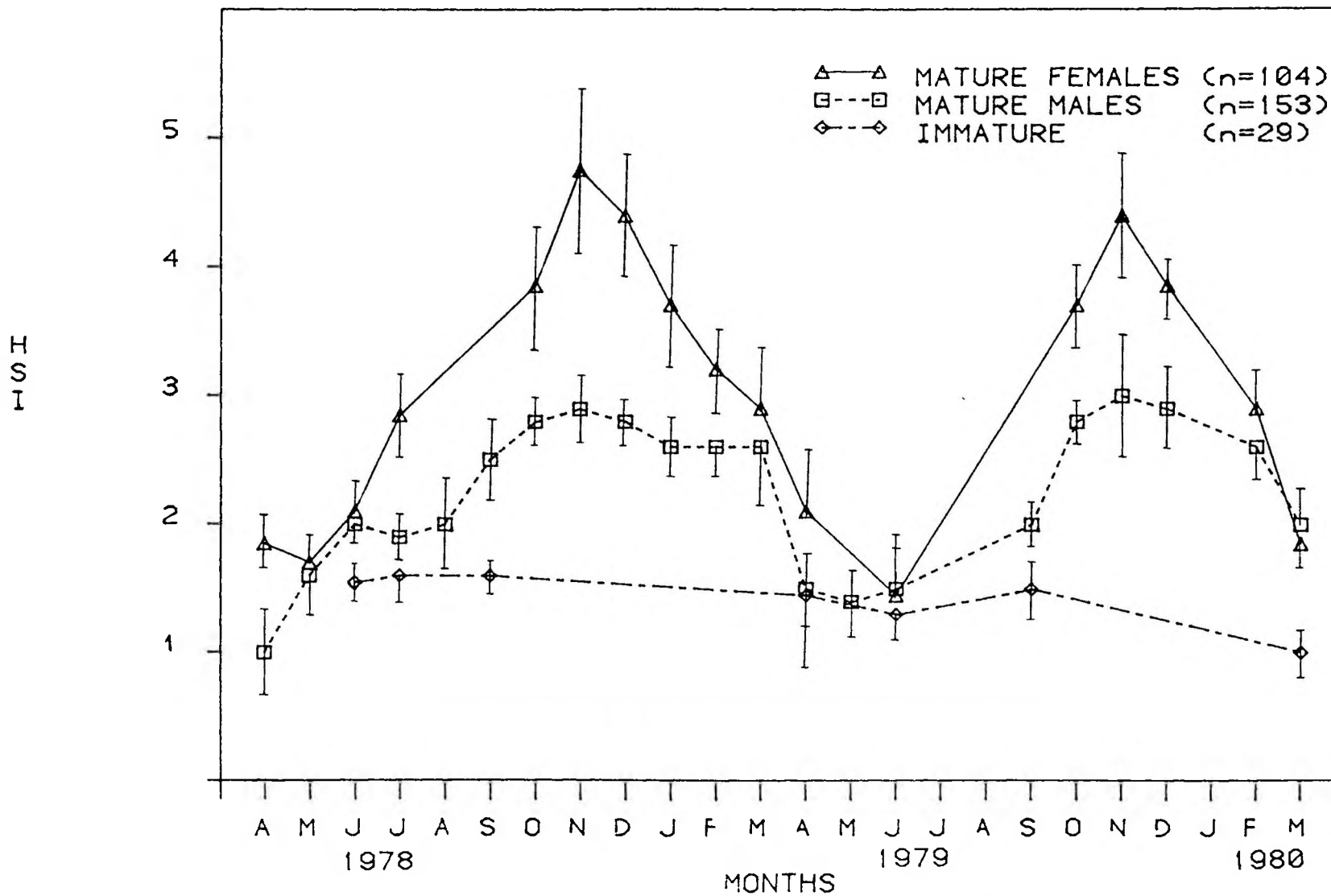


FIG. 9.1 The seasonal variation in hepatosomatic index of *R. annulatus*. Means  $\pm$  standard deviation.

### 9.3.1 Buoyancy

Bone and Roberts (1969) investigated the density of 18 species of elasmobranchs and found that a significant amount of static lift is provided by the livers of some species. The percentage liver weight of pelagic sharks varied between 6,5% and 23% of the body weight while bottom-dwelling elasmobranchs investigated did not exceed 5,7%. In the present study the maximum percentage liver weight of R. annulatus was 5,8% and the minimum 1% of the body weight (Fig. 9.1). After discussing the significance of density differences between different species, Bone and Roberts (1969) concluded that the density of elasmobranchs can be related to their habits. Bottom-dwelling elasmobranchs which only swim at intervals, require little static lift from their livers. The percentage liver weight of R. annulatus falls within the range of bottom-dwelling elasmobranchs as reported by Bone and Roberts (1969) and therefore suggests high density and consequently the sand shark can be expected to be relatively inactive when feeding on the bottom albeit shallow or deep water. It is, however, suggested that the dorsoventrally flattened body with incorporation of the pectoral fins in R. annulatus (and other batoids), provides a large lifting surface which would compensate static lift from the livers. Active swimming and darting movements (as observed for sand sharks in the aquarium) are therefore possible.

Thus the size of the liver in R. annulatus is typical of a bottom-dweller and does not provide a significant amount

of static lift. Therefore the seasonal variations not expected to influence hydrostatic and/or hydrodynamic equilibrium.

### 9.3.2 Reserve lipid for reproduction

The seasonal variation in the HSI in mature females, mature males and immature specimens (sexes combined) is given in Fig. 9.1. In both males and females maximum values in HSI were reached in November and minimum values in May-June. The difference between maximum and minimum values was significant ( $p < 0,001$ ) in both sexes. Comparison between sexes at the minimum of this cycle showed no significant difference but at the maximum the HSI of the female exceeded that of the male ( $p < 0,001$ ). The apparent seasonal variation in the HSI of immature specimens was not statistically significant.

Several previous workers have found that female elasmobranchs have relatively larger livers than males (Hickling, 1930, cited in Bone and Roberts, 1969; Olsen, 1954). From Fig. 9.1 it is evident that the relative size of the female liver will only exceed that of the male during those periods prior to and after reaching maximum values in the HSI. Approaching and at minimum values the HSI does not differ significantly and the difference in relative size of male and female livers will not be apparent. Craik (1978a) was the first to demonstrate seasonal variations in the HSI in the dogfish, Scyliorhinus canicula. He noticed that the variation in the HSI is greater in the female than in the male but neglected to comment on the fact that liver size in

females are only larger than in males at certain times of the year.

Thus a more correct statement would be that females attain a relatively larger liver than males during certain periods in the annual variations in the HSI.

Relative liver size was demonstrated by several authors to increase with total body length and body weight. Oguri (1978a), on obtaining specimens of the rabbit fish, Chimaera monstrosa, had a wide range of body weights and divided the specimens into three groups according to weight. He demonstrated an increase in the HSI from 4.34% in the small fish to 15.9% in the large group. Increase in the HSI with increasing body length has been demonstrated in the rays, Raja polystigma and R. radula by Capapé (1979, 1980). To demonstrate this, large numbers of specimens with a wide range in total length are required within the same season not to mask seasonal variation of the liver size. Insufficient numbers of sand sharks caught in any one month prevented demonstration of increasing HSI with increasing length in this study. The immature specimens, however, did not show significant seasonal variation (Fig. 9.1) and maintained a level equal to the mature 'spent' level. Craik (1978), showed that the HSI of immature female dogfish exceeded that of mature females. This is however questioned by the present author in view of the present investigation as well as the lines of evidence by Oguri (1978a) and Capapé (1979, 1980).

The cyclic increase and decrease in the HSI can be attributed to the fluctuation of the total lipid content of the liver. Increase in liver weight is primarily caused by accumulation of lipid reserves in the liver. This has long been known (Day, 1889, cited in Bone and Roberts, 1969) and demonstrated experimentally by Bone and Roberts (1969) for several species and Oguri (1978a) for Chimaera monstrosa. Craik (1978) calculated that 67% of the increase in the HSI in Scyliorhinus canicula between minimum and maximum HSI values, was due to increase in the total amount of lipid in the liver. Fig. 9.2 and Fig. 9.3 show the seasonal variation in the percentage of total liver lipids in male and female R. annulatus. Superimposed on the seasonal variation in the HSI (Fig. 9.1) it is demonstrated that an increase in the HSI is closely associated with a corresponding increase in the amount of total lipid content in the liver.

Due to the variation in the liver lipid content, which apparently occurs in all elasmobranchs, comparison with species investigated by previous workers were difficult. Bone and Roberts (1969) gave values for batoids investigated but neglected to mention when the species were caught or whether the lipid content was expressed on a dry or wet liver basis. For comparison it was only possible after Craik's (1978a) data was compared with that of Bone and Roberts (1969) for Scyliorhinus canicula indicates that the latter authors expressed their data as percentage of wet weight. Two Raja spp. investigated by them had 27,8% and 25,5%



LIPID CONTENT MALES

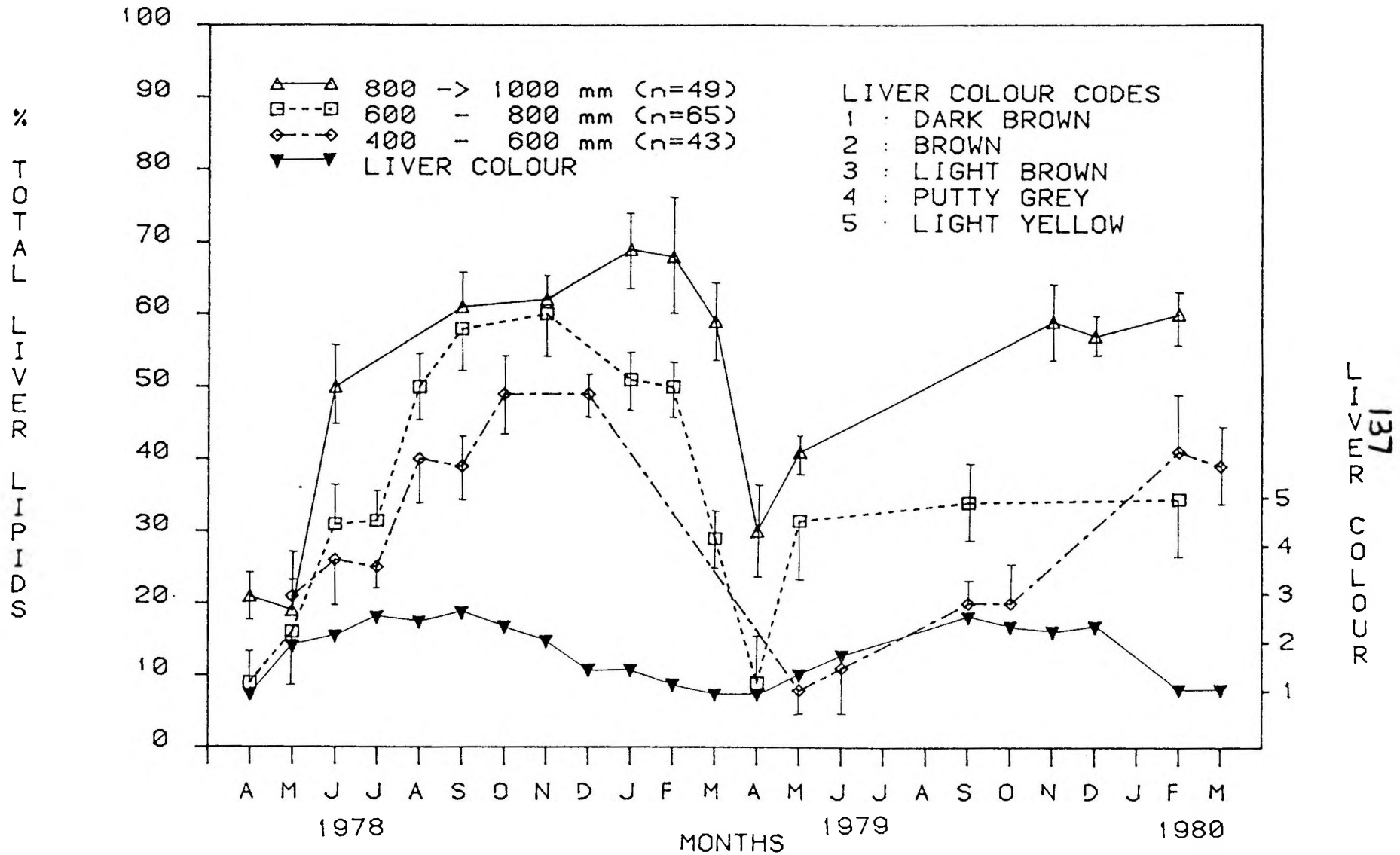


FIG. 9.2 Seasonal variation in the percentage total liver lipids and liver colour in *R. annulatus* (males). Means + standard deviation.

137  
LIVER COLOUR

LIPID CONTENT FEMALES

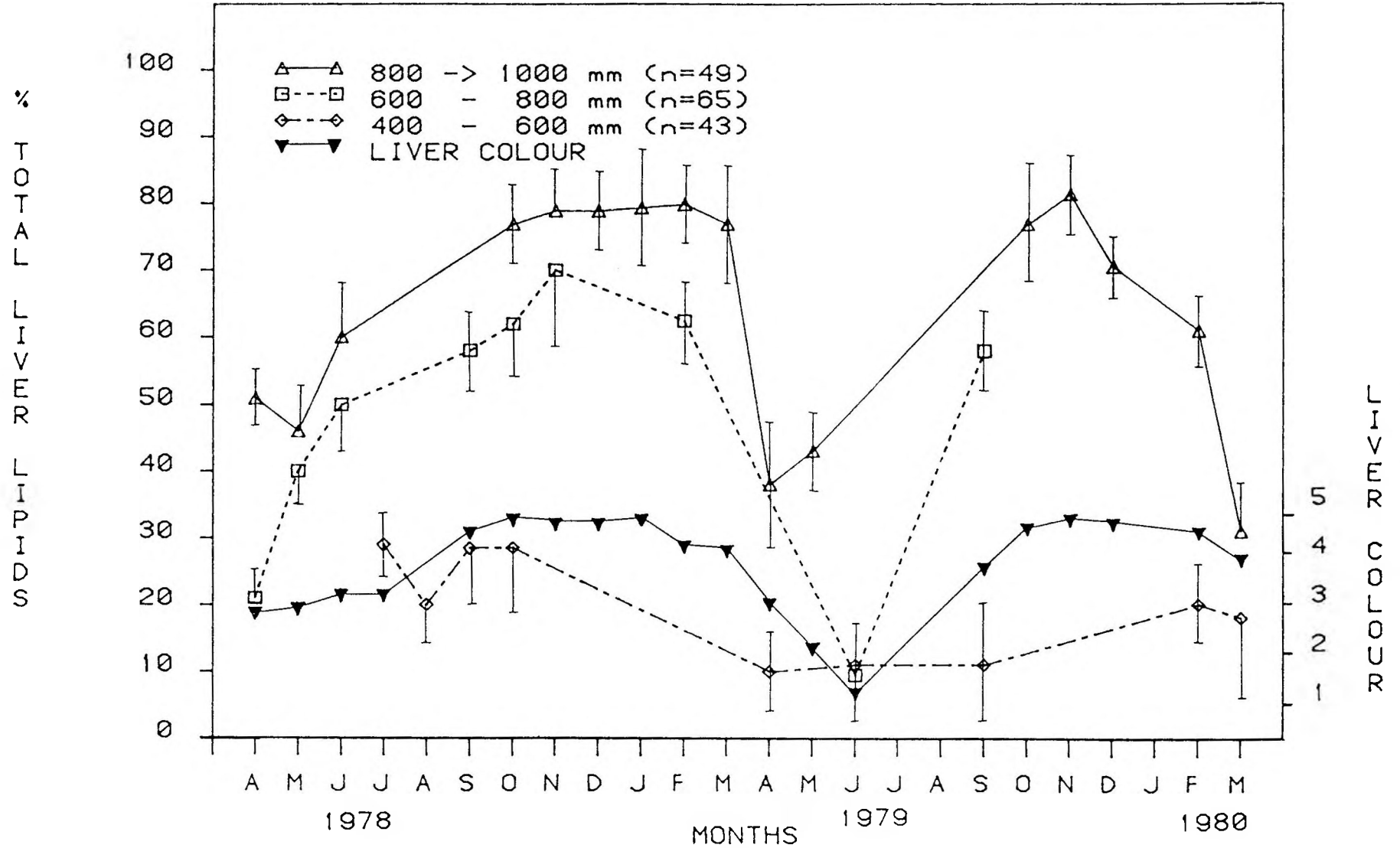


FIG. 9.3 Seasonal variation in the percentage total liver lipids and liver co-our in *R. annulatus* (females). Means  $\pm$  standard deviation. For liver colour codes see Fig. 9.2.

TABLE 9.1 Mean maximum and minimum values of liver composition in female R. annulatus.

Month	HSI	Liver wt (g) (wet)	% water	Liver wt (g) (dry)	Lipid (g) (dry wt)	Lipid (% of dry wt)	n
Nov.	4,8	120	40	72	54	75	12
June	1,5	30	60	12	2,4	20	17

n = number of specimens

TABLE 9.2 Egg composition of an average fully developed ovarian egg in R. annulatus

Wet wt (g)	Water % of total wt	Dry wt (g)	Lipid % of dry wt	Lipid (g)
20 g	50	10	11,2	1,12

liver lipid content. R. annulatus showed a liver lipid content of 45% (% of wet liver weight) at maximum HSI. The difference could be due to a phase difference in the annual cycle or reproductive strategy. Scyliorhinus canicula had a liver lipid content of 39,7% at peak HSI (Craik, 1978a). This lower value than that seen for R. annulatus will be discussed later.

Several investigators in the past speculated that the change in the HSI could be due to reproductive activities. Capapé (1979, 1980) working on Raja spp. calculated condition coefficients for these species and noted that the coefficient depended on liver and gonad ponderal changes. He assumed that the changes in the condition coefficient were subjected to reproductive cycle changes. Banjo (1979), in his studies on the composition of the liver oil of Carcharias taurus and Sphyrna diplana, noticed a sharp decline in the oil content in the livers at a time when the sharks sampled contained many gravid specimens. He attributed this to possible spawning activities. Craik (1978a), describing the annual cycle of vitellogenesis in Scyliorhinus canicula found variations in several parameters associated with vitellogenesis. Seasonal variation in the HSI and lipid content of the liver was seen to be in synchrony with plasma estradiol levels which in turn caused a variation in the rate of vitellogenin synthesis by the liver.

The difference in the maximum lipid content of female

R. annulatus in November and the minimum in June was significant ( $p < 0,001$ ) and indicated considerable loss of hepatic lipids between these months. Table 9.1 shows aspects of the liver composition of mature females in November 1978 and June 1979 when maximum and minimum values in the HSI and percentage total liver lipids were observed. Calculations based on this data show that the HSI decreased by 69% and a concomitant decrease in the percentage of liver lipids of 73%. The liver lost 51,6g of lipids indicating a 96% lipid loss. The maximum liver lipid content in mature females show a rapid decrease from February to a minimum value in June. This period was found to coincided with vitellogenesis in R. annulatus (see Chapter 7, Fig. 7.21). Fig. 9.3 shows that the variation in the 400-600mm size class of females did not adhere to the variation of the 600-800mm and 800-71000mm size class. The last two size classes were considered mature. The variation in the immature size class was statistically not significant. The non-significant variation of the percentage total liver lipids in immature females indicated that hepatic lipids could be utilized for reproductive products.

The composition of fully developed ovarian eggs (ca 30mm in diameter) is given in Table 9.2. The following calculation was based on averages and is an attempt to quantify the amount of liver lipids utilized for egg production (see Table 9.1 and Table 9.2). A female sand shark weighing 2500g produces 10 eggs. The total lipid content of all the eggs is 11,2g. Assuming a 100%

efficiency of transfer this would imply a direct contribution of only 21,7% of hepatic lipid reserves to the lipid stores of the eggs. The variation in seasonal liver lipid contents is therefore only partially explained by demands for egg formation.

Since annual variation in the HSI and total liver lipid content occurred simultaneously in both sexes, it is unlikely that liver lipids are used mainly for reproduction.

The contribution of liver lipids to reproduction in the male was not estimated in this study but it is probable that the greater variation in the HSI and liver lipid content in the female is because of a greater energy consumption for vitellogenesis and consequently a need for larger lipid reserves.

The higher liver lipid reserves shown by R. annulatus than S. canicula could possibly be explained by the fact that the latter has a low vitellogenic rate and oviposition continues throughout the year. The nutritive demands of vitellogenesis is thus distributed over most of the year and metabolic disruption is thereby minimized (Craik, 1978a). R. annulatus produces yolk equal to 200g over a period of seven months (see Fig. 7.21) which would suggest higher energy consumption and larger reserves of lipid. S. canicula produced 234g of yolk over a period of one year (Craik, op. cit).

It is suggested that the rest of the liver lipid is utilized for metabolic functions.

No significant variation was found to occur in the HSI and total liver lipid content in immature specimens (Fig. 9.1 and 9.3). The size class 400-600mm total length in males was considered mature (Fig. 9.2) and shows a similar significant variation as the other two size classes between the minimum value in April-May and the maximum in January ( $p < 0,001$ ). This indicated correlation of lipid variation with reproductive activities. The contribution, however, was shown to be only 21,7% and it is therefore suggested that liver lipid reserves are primarily utilized for maintenance in R. annulatus.

### 9.3.3 Liver colour

Throughout the sampling period variation in the colour of the livers of R. annulatus was noticed. The colour varied from a deep dark brown to light yellow. Five colour categories were chosen and given a score from one to five to assess the average colour on a monthly basis. The categories chosen were dark brown (score 1), brown, light brown, putty grey and light yellow (score 5). In Fig. 9.2 and Fig. 9.3 the seasonal colour variation is shown for males and females respectively. This variation showed a striking synchrony with the variation in the total liver lipid content in both sexes. The livers of male specimens

never reached a score higher than three, thus the livers did not show a putty grey or light yellow colour. In the female specimens grey and light yellow livers were observed from the months November to January in both years. The female livers contained more liver lipids per liver weight than the males. It therefore seems that the higher liver lipid concentration in the liver, the lighter the livers become in appearance. This would also imply that the liver colour is size dependent in R. annulatus. Small immature specimens all exhibited dark brown livers. Banjo (1979) noted that dark brown mottled livers in Carcharias taurus and Sphyrna diplana contained less oil than the cream coloured ones. Liver colour can therefore be used as an index of lipid.



## CHAPTER 10

## NOTES ON OTHER ELSAMOBANCHS

## 10.1 SPECIES RECORDED IN ALGOA BAY

During the study period all the elasmobranchs obtained during sampling operations were identified and where possible numbers, sexes, total body lengths and biological data that included stomach contents and reproductive state were recorded. Table 10.1 is a checklist of the species obtained by angling and trawling in Algoa Bay with an indication of abundance. In the present study 26 species were caught by angling in the surf zone off sandy beaches and 20 species by trawling. Hecht (1976) reported 17 species of elasmobranchs captured by trawling in Algoa Bay from April 1974 to May 1975 while working on the biology of six trawl fish species. He recorded only three species as abundant, namely Squalus acanthias, S. acutipinnis (Syn. S. megalops) and Raja rhizacanthus (Syn. R. clavata). Coetzee (1978) sampling off St. Croix island (see Fig. 2.1) in Algoa Bay recorded 15 species and Lasiak (1982) found only 10 species in the surf zone off Kings Beach captured by beach seine netting.

## 10.2 NOTES ON MOST ABUNDANT SPECIES CAUGHT IN THE SURF ZONE

Elasmobranchs form an important component as predators in the surf zone (Rossouw, 1979) and considerable

contribution in terms of biomass has been reported for those species present (Lasiak, 1982). The most abundant species will be discussed with short notes on their occurrence, seasonality and general biology.

#### 10.2.1 Dasyatis pastinacus

Next to R. annulatus, the blue ray, D. pastinacus was the most abundant elasmobranch caught by anglers during this study period. Lasiak (1982) found that the blue ray contributed 17,4% in terms of biomass to the total catch of surf-zone fish at Kings Beach compared to R. annulatus which dominated with 22,5%. Eighty seven specimens compared to the 404 specimens of R. annulatus were caught during this study.

The appearance of D. pastinacus in the surf zone during September and disappearance towards June-July suggested that the blue ray has a migratory habit similar to R. annulatus and invades the shallow waters annually to liberate its young.

Gravid females, ranging in disc width length 540-650mm and mass 8,5-10,5kg were captured from September to November. Only the left ovary is functional and left uteri walls were thick (ca. 1,5cm) and expanded. The uteri were dark red in colour due to high vascularity and the inside was layered with trophonemata that resembled a thick velvet. The trophonemata were about 3mm long and covered the whole inside of the uterus. The eggs which averaged

about four per litter were all encased in one capsule. After the case ruptured, embryos with attached yolk sacs were visible. Later stages indicated that after absorption of the yolk the uterus secretes a yellow substance (uterine milk) which the embryos absorbed via the mouth. It has also been observed that some of the trophonemata, which by then had lengthened considerably, penetrated the spiracula of the embryos. Thus the mode of reproduction represents an aplacental viviparous type with placental analogues, in this case uterine trophonemata.

Only two specimens of the 42 examined contained food in the stomach. In each of these stomachs one small Ovalipes punctatus, the three spotted-swimming crab, was found.

Due to large numbers recorded in summer this species is considered an important visitor to the surf zone and further investigation is of importance for sandy beach ecology.

#### 10.2.2 Gymnura natalensis

The butterfly ray, G. natalensis seemed to be more abundant in the surf zone during summer months as 20 of the 25 specimens obtained in this study was caught in February 1979. The males caught in February, ranging in disc width 113,5-130cm and clasper length from 87mm-105mm, all appeared sexually mature as semen was present in the vesicula seminalis. Only the left testis seemed to be functional.

The females caught ranged 103-190cm disc width. Only one female (disc width 109cm) caught in March was gravid, containing eight embryo's, four in each uterus. Long villi lined the uterine walls and some of these villi were inserted deep into the spiracula of the embryos. Thus it seemed that a placental analogue in the form of these long trophonemata served to transfer uterine 'milk' to the unborn young.

All stomachs examined were empty.

### 10.2.3 Pteromylaeus bovinus

The duckbill ray was caught by anglers throughout the year, although more specimens were caught during the summer months. This species grows to a large size and the biggest recorded during this study had a mass of 81kg.

No pregnant females were obtained.

The stomach contents recorded were dominated by the sand mussel, Donax serra. Sand mussels were consumed in large numbers by the duckbill ray. The dental plates in both jaws are made up of transverse teeth and are used to crush large sand mussel shells.

Wallace (1969) recorded this species throughout the year although it was most common during the summer months. Stomach contents he recorded included remains of teleosts, crabs, gastropod molluscs and fragments of brown rock mussel shells (Perna perna).

#### 10.2.4 Carcharhinus brachyurus

The copper shark, Carcharhinus brachyurus was often caught by shore anglers during the summer months. Bass et al. (1975) reported C. brachyurus to reach as far north as Natal during the winter months. All the specimens (57) recorded in this study were immature and no information on breeding data could be obtained. Bass et al. (op. cit.) found pregnant females in Natal with average litter size of 16 embryos. Seasonality of breeding and length of gestation period was not apparent from the few data available to him. Twenty of 57 stomachs examined contained food. Food items included fish larvae, cuttlefish (Sepia sp.) and squid (Loligo sp.).

Southward migration of juveniles seems to occur in this species but due to a lack of information on their movements this cannot be confirmed.

#### 10.2.5 Carcharhinus obscurus

The dusky shark, Carcharhinus obscurus, was common in the surf zone during the summer months. All the specimens (62) recorded were immature and only 10 specimens had food in their stomachs. Food items recorded were fish larvae, squid (Loligo sp.) and crabs (Ovalipes punctatus).

The size range of specimens caught varied between 120 and 208 cm total length. Of the 62 specimens 47 were immature males. This dominance of males was also observed

This sexual segregation among both the adult and the young was noted as a striking feature of the distribution pattern. Davies and Joubert (1967) conducted a tagging program based in Durban, concentrating on young C. obscurus caught in or near the surf zone. Thirty of these specimens were recovered from Algoa Bay and westward. They also found that the direction of movement of the migrant dusky sharks is related to sex, for there is a tendency for males to move southwards from Durban and females northwards. The migration southwards occurred during the summer months and hence the higher numbers recorded for dusky sharks during November-January in the present study. Since this study began in March 1978 a progressive increase in the number of dusky sharks has been recorded by word of anglers and angling reports. Bass et al (1973) reported that the southern Natal coast is a primary nursery area for the dusky shark. The increase in numbers of immature C. obscurus observed in Algoa Bay over the past few years could be due to more shark nets installed off bathing beaches in Natal during this period. It seems that the nets tend to keep out potential predators and consequently the mortality rate of young dusky sharks born close inshore dropped considerably. This could have resulted in increasing numbers of migrating juveniles occurring in Algoa Bay.

This species is therefore considered to be an important predator in the surf zone during the summer months and more information on the feeding habits is needed.

TABLE 10.1 A checklist of the species obtained during this study with an indication of means of capture and abundance.

	<u>Common name</u>	<u>Angling</u>	<u>Trawler</u>	<u>Abundant</u> /	<u>Rare</u>
Class:	Chondrichthyes				
Family:	Charcharhinidae				
	<u>Carcharhinus brachyurus</u>	copper shark	X	X	
	<u>Carcharhinus brevipinna</u>	longnose blackfin shark	X		X
	<u>Carcharhinus obscurus</u>	dusky shark	X	X	
	<u>Galeorhinus galeus</u>	soupfin shark	X		X
	<u>Mustelus mustelus</u>	plain smoothhound	X	X	
	<u>Mustelus palumbes</u>	whitespotted smoothhound	X		X
	<u>Triakis megalopterus</u>	sharptooth smoothhound	X		X
Family:	Sphyrnidae				
	<u>Sphyrna zygaena</u>	smooth hammerhead		X	X
Family:	Odontaspidae				
	<u>Odontaspis taurus</u>	spotted ragged-tooth	X	X	
Family:	Lamnidae				
	<u>Isurus oxyrinchus</u>	mako	X		X
Family:	Scyliorhinidae				
	<u>Halaaelurus natalensis</u>	tiger catshark	X	X	
	<u>Haploblepharus edwardsii</u>	puffadder shyshark	X	X	
	<u>Haploblepharus fuscus</u>	brown shyshark	X		X
	<u>Proderma africanum</u>	striped catshark	X	X	
	<u>Poroderma pantherium</u>	leopard catshark	X	X	
	<u>Scyliorhinus capensis</u>	yellowspotted catshark	X	X	
Family:	Squalidae				
	<u>Squalus acanthias</u>	spiny dogfish	X	X	
	<u>Squalus fernandinus</u>	big-eye spiny dogfish	X	X	
Family:	Pristiophoridae				
	<u>Pliotrema warreni</u>	sixgill sawshark		X	X

TABLE 10.1 (continued)

	<u>Common name</u>	<u>Anqing</u>	<u>Trawler</u>	<u>Abundant</u> /	<u>Rare</u>
Family: Rhinobatidae					
	<u>Rhinobatos annulatus</u>	lesser guitarfish	X	X	
	<u>Rhynchobatus djeddensis</u>	giant guitarfish	X		X
Family: Rajidae					
	<u>Raja wallacei</u>	blancmange skate		X	X
	<u>Raja clavata</u>	thornback skate		X	
	<u>Raja miraletus</u>	twineye skate		X	
	<u>Raja alba</u>	spearnose skate	X	X	
Family: Myliobatidae					
	<u>Myliobatus aquila</u>	eagleray	X	X	
	<u>Pteromylaeus bovinus</u>	bullray	X	X	
Family: Dasyatidae					
	<u>Dasyatis brevicaudatus</u>	short-tail stingray	X		X
	<u>Dasyatis pastinacus</u>	blue stingray	X	X	
	<u>Dasyatis thetidis</u>	thorntail stingray		X	X
	<u>Gymnura natalensis</u>	backwater butterflyray	X	X	
Family: Torpedinidae					
	<u>Narke capensis</u>	onefin electric ray		X	X
	<u>Torpedo fuscomaculata</u>	blackspotted electric ray	X	X	X
Family: Chimaeridae					
	<u>Callorhynchus capensis</u>	elephantfish		X	



## CHAPTER 11

## GENERAL CONCLUSION

In Algoa Bay, the high energy sandy beaches and their adjacent surf zones, may function as viable ecosystems with surf zone phytoplankton as the producers, macrofauna as consumers and interstitial fauna as decomposers (McLachlan, 1980a, McLachlan et al, 1981). In terms of numbers and biomass, the sand shark, R. annulatus, was the most important marine predator in the surf zone off sandy beaches in Algoa Bay (Rossouw, 1979; Lasiak 1982). Fig. 11.1 shows a food web for the beach macrofauna of a sandy beach in Algoa Bay constructed by McLachlan et al (1981). More than 80% of the diet in the sand shark consisted of crustaceans resident in the surf zone (see Figs. 8.1 and 8.2).

A dorsoventrally flattened body seems like an ideal adaptation to feed in very shallow water. Flat fish, e.g. the plaice, Pleuronectes platessa and the common dab Limanda limanda, have been shown to feed off the sandy beaches in Scotland (Poxton et al, 1982). Differential predation of different length classes of sand sharks resulted from a dynamic zonation of different size classes in the surf zone. The smallest individuals fed closest to the shoreline where they were often seen to occur in water as shallow as 20cm. Although the sand shark is not a permanent resident of the surf zone, about eight months of the year are spent inshore

by migrant adults. During this period the shallow water is also utilized as a nursery area. It was recorded that females ceased to feed only a month prior to parturition while the rest of the time active feeding by both sexes occurred in the surf zone. The reasons why sand sharks migrate to shallow water during the summer months are not clear and can only be speculated on. It may be to avoid predators of the newborn young. The newborn young were observed to feed exclusively on the mysid, Gastrosaccus psammodytes, which occurred in the surf zone. The absence of this species in deep water, indicated by stomach contents of sand sharks trawled offshore, is probably an important reason for liberating the young in an area where abundant and consumable food is present for the young. The adults captured offshore during the winter months fed exclusively on the prawn, Callinassa gilchristi. This species, attaining a length of ca. 10cm, would be physically too big for the young sand sharks to handle. The adults were seen to change diet on reaching shallow water and consumed mainly small crustaceans. It is therefore suggested that the main reasons for R. annulatus to utilize the surf zone as a nursery area are to provide the young with 1) a safe environment and 2) with ample food resources. This probably explains the rather "senseless" migration from a stable, calm, deep sea environment to an unstable turbid surf zone area.

The highly successful existence of the sand shark in the surf zone could be attributed to several adaptations. A suction-crushing feeding mechanism enables the species to

is especially beneficial to the smaller sand sharks which often prey in very shallow water. Thus all the areas in the surf zone would be available for feeding.

In a physically controlled environment such as a high energy sandy beach one would expect animals to be generalists, e.g. predatory and omnivorous fish. The stomach contents of R. annulatus, however, revealed that they are fairly specialized feeders and were at the top of the food chain in the surf zone. Further, their reproductive strategy is of the K-type which is normally associated with more specialist species. They therefore appear to be specialist species which would be more characteristic of biologically accommodated communities with more potential competition and narrow niches. It is difficult to evaluate the extent of competition they may face in the surf zone. No other batoid eats Gastrosaccus and it forms only a minor part of the diet of teleosts (Lasiak, 1982).

The duckbill ray, Myliobatis aquila and the bullnose ray, Pteromylaeus bovinus feed predominantly on large Donax spp. which burrow in the sand. The blue ray, Dasyatis pastinacus, feeds on large specimens the swimming crab, Ovalipes which occur furthest offshore in the surf zone (Du Preez, 1981). The teleost benthic feeders, the white steenbras, Lithognathus lithognathus and the beardman, Umbrina capensis, were seen as the only competitors feeding in the same area of the surf zone as R. annulatus. Lithognathus spp. fed predominantly on Macropetasma africana, Donax spp.,

polychaetes and Gastrosaccus psammodytes in that order of importance. The major food items of U. apensis were polychaetes, Callianassa kraussi, juvenile Ovalipes, M. africana and Donax spp. (Lasiak, 1982).

Fig. 11.2 illustrates the feeding niches of the benthic feeders in the surf zone. From this it seems that there is some dietary overlap between R. annulatus and the other benthic feeders. Further, R. annulatus has a relatively broad food niche. It therefore appears that R. annulatus is a less specialised feeder than its morphology and reproductive strategy would indicate. It is, nevertheless, far from being a generalist.

To conclude, sand sharks can be seen as visitors to sandy beaches although they stay long enough to have an important rôle in the food chain, where they are important predators. The amount of energy they export out of the system due to migration still needs to be quantified. Adaptations suited to the environmental conditions existing in the surf zone make R. annulatus a successful predator in this dynamic zone. On the other hand the species is equally well adapted to deep sea conditions where the winter months are spent.

It is hoped that this study, will stimulate further investigations of the elasmobranchs, especially those occurring off sandy beaches, to enrich our scanty knowledge of these highly successful predators.

DUNES LAND  
BEACH  
SURF  
SEA

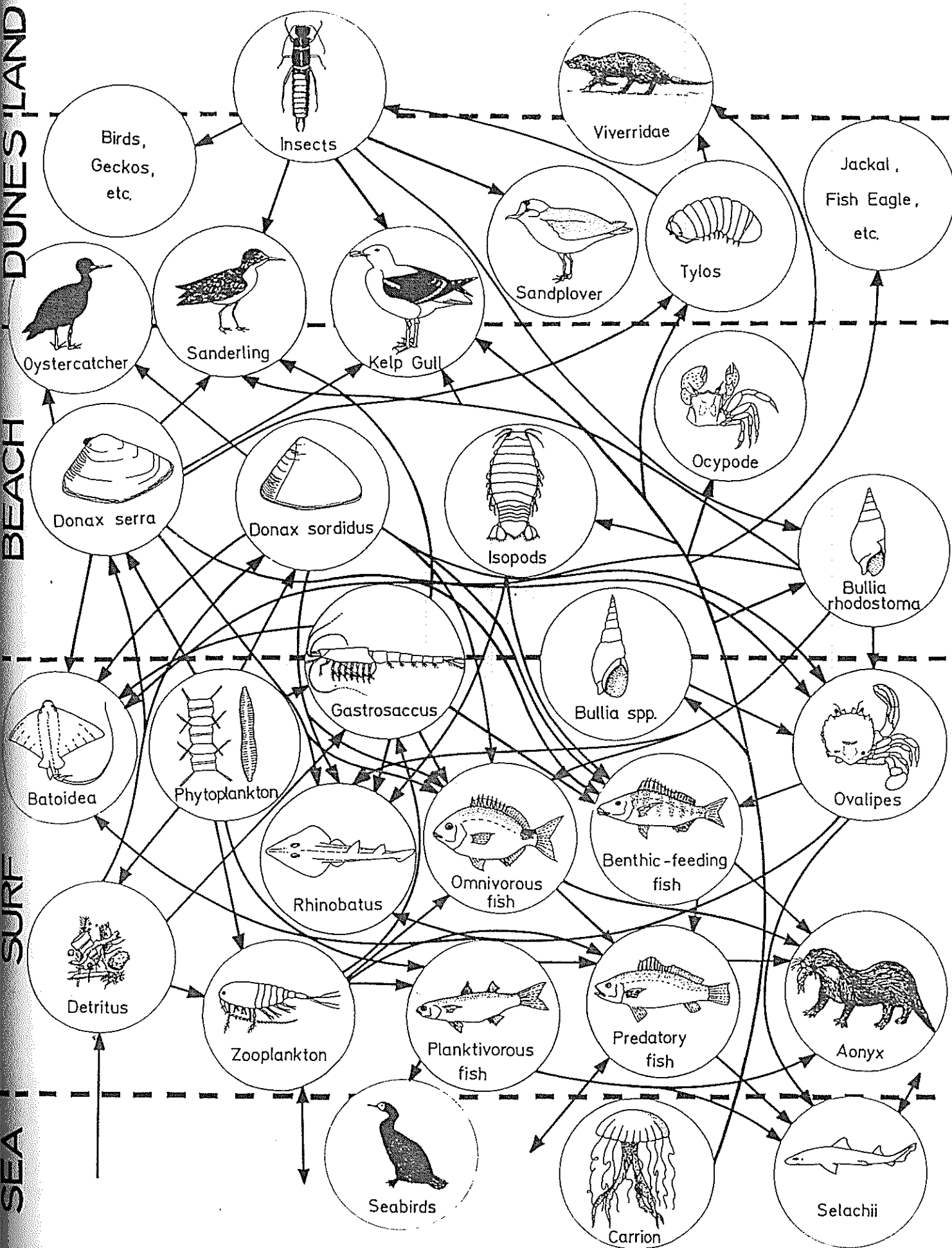







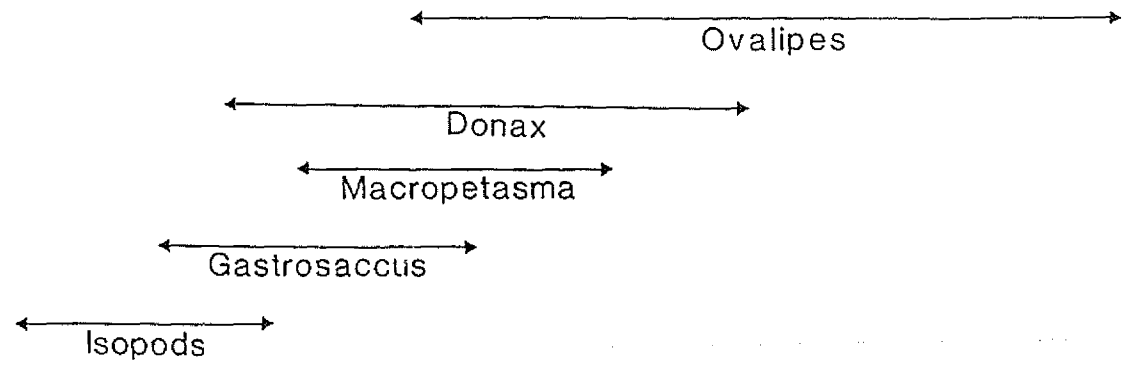
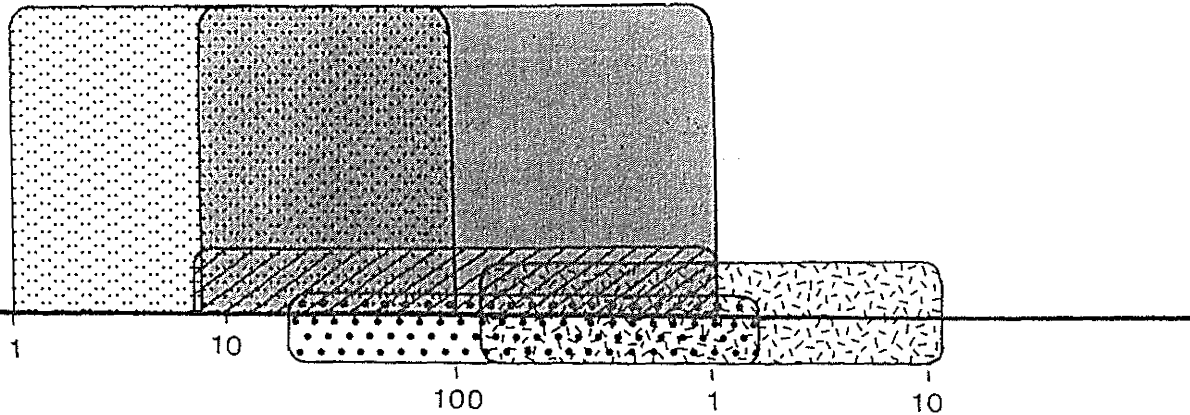
FIG. 11.1 Food web for the beach macrofauna of a sandy beach in Algoa Bay. from McLachlan et al, 1981.

WATER SURFACE

PREY HABITAT

BOTTOM

-  *R. annulatus*
-  *M. aquila* and *P. bovinus*
-  *D. pastinacus*
-  *Lithognathus* sp
-  *U. capensis*



PREY SIZE (Dry mass)

FIG. 11.2 Feeding niches of benthic predators in the surf zone off sandy beaches.

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APPENDIX 1. Dates, locality, number of anglers and hours fished recorded when samples were collected.

Date	Location	No. anglers	Hours fished	Temp. °C
9. 4.1978	St. Georges Beach	12	4	19,5
29. 4.1978	Sundays Surf	14	4	19,5
20. 5.1978	St. Georges Beach	11	4	16,0
28. 5.1978	Van der Riets	9	4	15,0
11. 6.1978	Van der Riets	17	4	14
24. 6.1978	St. Georges Beach	14	4	14
8. 7.1978	St. Georges Beach	18	4	14
22. 7.1978	Van der Riets	11	3	17
13. 8.1978	St. Georges Beach	11	4	15,5
27. 8.1978	Van der Riets	18	4	15,5
24. 9.1978	Van der Riets	10	4	17
30. 9.1978	St. Georges Beach	27	4½	17
22.10.1978	Van der Riets	10	4	18,5
29.10.1978	St. Georges Beach	9	4	18,5
18.11.1978	St. Georges Beach	12	4	20
19.11.1978	Sundays surf	13	4	18
10.12.1978	St. Georges Beach	7	3	21
17.12.1978	Van der Riets	4	4	20
14. 1.1979	St. Georges Beach	23	4	20
21. 1.1979	Van der Riets	10	4	18,5
11. 2.1979	St. Georges Beach	22	4	21
17. 2.1979	Van der Riets	16	4	23,5
4. 3.1979	Van der Riets	16	4	20,5
11. 3.1979	St. Georges Beach	6	3	22

## APPENDIX 1. (continued)

Date	Location	No. anglers	Hours fished	Temp. °C
8. 4.1979	St. Georges Beach	13	4	21,5
22. 4.1979	Van der Riets	7	4	18,5
6. 5.1979	St. Georges Beach	8	4	17,5
13. 5.1979	Van der Riets	14	4	16,5
3. 6.1979	St. Georges Beach	9	4	16
17. 6.1979	St. Georges Beach	9	4	14
28. 7.1979	Van der Riets	20	4	14
29. 7.1979	St. Georges Beach	2	2½	16,4
11. 8.1979	St. Georges Beach	9	1	15
19. 8.1979	St. Georges Beach	6	2	15
8. 9.1979	St. Georges Beach	10	3	15
16. 9.1979	St. Georges Beach	6	3	19
27.10.1979	St. Georges Beach	15	4	19,8
10.11.1979	Sundays Surf	1	4	19,5
9.12.1979	Van der Riets	3	4	21,2
1. 3.1980	St. Georges Beach	15	3	23,2

Summary

Total outings .....	40
Total anglers .....	466
Total sand sharks caught	340
Mean CPUE 0,19 sand sharks/man/hour	
Mean hours fished per angler .....	3,85 hours
Total mass sand sharks caught .....	494,5kg
Mean mass caught per angler per hour	0,28kg
Total man hours fished .....	1795 hours

APPENDIX 2. Dates, locality and depth recorded when samples were collected by otter trawl.

Date	Locality	Depth (meters)
26. 6.1978	34°03'S; 25°45'E	54 - 72
24.10.1978	"	54 - 72
22. 1.1979	"	54 - 63
30. 4.1979	"	54 - 63
2. 7.1979	"	63 - 72
4. 9.1979	"	45 - 54
12.11.1979	"	45 - 54