

**THE COMMERCIAL FISHERY FOR SHARKS IN THE SOUTH-WESTERN
CAPE, WITH AN ANALYSIS OF THE BIOLOGY OF THE TWO PRINCIPAL
TARGET SPECIES, CALLORHINCHUS CAPENSIS Dumeril AND
GALEORHINUS GALEUS Linn.**

by

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DECLARATION

I hereby declare that the planning of the operations of this project was jointly carried out by myself and Assoc Prof C L Griffiths. All samples and data collection (except where the help of various other people is acknowledged in text), analysis, and write-up of the following are all my own work. However, it must be clearly stated that without the guidance of Assoc Prof C L Griffiths and the insights provided by Dr L J V Compagno this project could never have been completed.

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February 1992

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GENERAL ABSTRACT

The South African shark fishery began in World War 2, based on a demand for shark liver oil. The initial landings are estimated at 3750 tons per annum, but have since declined to approximately 820 tons of shark, principally Galeorhinus galeus, with an additional 800 tons of Callorhynchus capensis. The fishery for the later species has largely only developed since 1980.

The fisheries for both of the principal species are dependent for their commercial success on fishing schools of breeding aggregations and in both cases the catch is mainly taken in breeding and nursery areas.

G. galeus is a largely ichthyophagous species, which forms schools of fish of similar size. After sexual maturity, which is reached at a minimum TL of 1 278 mm (8,5y) for males, and a minimum TL of 1 371 mm (9,9y) for females, these schools further assort to include only mature fish of one sex. They are highly mobile and may be migratory. Fecundity is low in newly sexually mature fish but gradually increases with increasing size, although a mathematical relationship for this could not be established. The maximum number of pups recorded in this study was 20. Age was established by counts of depositional rings in vertebral centra, and the growth rate described by the formula:

$$L(t) = 1601,378016 (1 - e^{-0,16207 (t+1,327677)}).$$

C. capensis, which is common in catches on soft substrates from 1-366 m, has a catholic diet dominated by invertebrate benthic organisms. High concentrations of the fish only occur inshore (<50 m). These aggregations consist of juveniles and post-sexual maturity fish migrating inshore annually to breed. Breeding occurs all year round with a peak in summer. Sexual maturity (50%) is attained at FL 429 mm in males (3,17y) and FL 494 mm in females (4,2y). Fecundity is also relatively low with a maximum of 22 viable eggs being recorded. Age is estimated by counts of serially deposited cones of dentine in the dorsal spine. Age estimates are validated by cone margin characteristics and by length-frequency analysis. Growth curves are described by the formulae:

$L(t)=1989,37537 (1-e^{0,051465(t+0,605681)})^{0,5201111}$ for females and

$L(t)=658,64095(1-e^{0,170824(t+0,72077)})^{0,593056}$ for males.

The shark fishery is complex and multi-species, and controls cannot be applied to it as a single entity. While the fishery for C. capensis appears to be less likely to collapse, the fishery for other shark species is rapidly declining. The principal problem is that both fisheries utilise breeding fish and operate principally in nursery areas.

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GENERAL INTRODUCTION

Sharks form a part of the catches of virtually the entire spectrum of fisheries in the S.W. Cape. While often regarded as little more than a nuisance, frequently dumped and not recorded as part of the catch, they are also commercially landed. With declining catches of more lucrative species, deliberate targeting on shark is on the increase. There is a general perception, especially among fishermen, that sharks are superabundant and stocks are impossible to damage, that it is a new unexploited fishery, and anyway that eliminating sharks is by way of a public service, as this will improve fishing and remove a menace to bathers.

All of the above ideas are misconceptions. Sharks are an old and already overexploited resource. The vital role of shark species as top carnivores and scavengers within the marine ecosystem is ignored, as is the fact that most of the commonly caught species (ie. St. Josephs, smooth houndsharks, spiny dogfish and catsharks) would be physically incapable of attacking bathers. Even the more dangerous looking sharks such as vaalhaai (Galeorhinus capensis) and thresher sharks (Alopias spp) lack suitable dentition for large prey items.

However, the prevalence of these attitudes is clearly shown by the fact that no restrictions on the landings of sharks exist. The knowledge that sharks generally are slow growing and have low fecundities, and have a poor track record of supporting long-term fisheries, facts which are widely reported in scientific literature, as well as the obvious parallel of the role of shark species in the marine ecosystem to that of predators and scavengers in a terrestrial ecosystem, make a mockery of this lack of control. There is, it is to be admitted, a lack of basic information on South African shark fishing, and on the biology of many of the species concerned. In the following chapters an attempt is made to provide some of the baseline information needed to take steps to conserve this ecologically and commercially valuable resource.

Since much of the exploitation of sharks is commercial in nature, and hence any decision on restricting catches will affect the livelihood of fishermen, the subject is approached from a fisheries viewpoint. It is the opinion of the author that, while shark stocks have already been severely affected by fishing pressure, the current populations could, with rational management, provide a sustainable yield.

CHAPTER 1

THE FISHERY FOR SHARKS IN THE S.W. CAPE, WITH EMPHASIS ON THE BIOLOGY OF THE SOUPFIN SHARK, GALEORHINUS GALEUS (LINN.)

ABSTRACT

The South African shark fishery originated during World War 2, and has shown periodic economically driven fluctuations thereafter, the overall trend being a gradual reduction of catch from an estimated 3750 tons in 1952 to approximately 820 tons in 1988. The line, gill net, demersal trawl and kingklip longlining fisheries have all taken a share of the annual shark catch, the last two as an incidental bycatch. The main landing site for targeted shark fishing is Gans Baai, but smaller volumes are landed at virtually all South-Western Cape ports. The principal component of these landings is the soupfin shark, Galeorhinus galeus.

G.galeus is a principally ichthyophagous species, which aggregates in monosex, size-assorted schools which are highly mobile and apparently migratory. Sexual maturity in males is reached at a minimum TL of 1 278 mm (8,5 y) and in females at a minimum TL of 1 371 mm (9,9 y). Fecundity is low, the maximum recorded number of pups being 20. Age was estimated by counts of depositional rings in vertebral centra. Growth is described by the formula:

$$L(t)=1601,378(1-e^{-0,162(t+1,328)}).$$

Management of the shark resource is complex, since it is impacted by a number of unrelated fisheries. The principal species utilised is slow growing and not very fecund, making it a fragile fisheries target. The schooling habit of this species also make it very easy to exploit. It should be protected during its summer pupping season and serious consideration should also be given to imposing a maximum landed size or weight for individual fish, to preclude problems with bioaccumulated mercury.

INTRODUCTION

Shark first became a commercial fisheries target in the South-Western Cape during World War 2, shark liver oil being utilised as an alternative to cod liver oil as a source of vitamin A (Archer 1949, Roedel and Ripley 1950, Compagno 1984) while the cod fisheries in the North Sea were disrupted by the war. The species principally targetted was Galeorhinus galeus, the soupfin shark or "Vaalhaai". The soupfin shark is a common, cosmopolitan, continental shelf species, and has historically been one of the most frequently exploited chondrichthyan species (Compagno 1984). Fisheries for G.galeus occur/ed off the coasts of S-E Australia (Olsen 1954, 1981,1984, Hughes 1981) California (Ripley 1946, Roedel and Ripley 1950), and Uruguay (Kreuzer and Ahmed 1978) and these provide valuable comparative models for the South African fishery. The Californian fishery reached its heyday in 1950, but the species remains a minor target today (pers. comm. D.Ebert, 1988). The Australian G.galeus fishery, which has been active since World War 2, has avoided collapse by changing gear from longlines to gill nets and by taking a high percentage of another species (Mustelus antarcticus). The limited information on the Uruguayan fishery suggest that it has also diversified its species base. The general impression conveyed is thus one of fragility, and not of a fishery which can just be left to manage itself.

Many other shark species have also been taken by the South African shark fishery. In South-Western Cape waters these have included Carcharhinus brachyurus, the copper shark, and various Mustelus spp. (smooth hound sharks). G.galeus and these other species have also increasingly become targets for a burgeoning recreational fishery (Pers. comm. H. Frazer, Western Province Light Tackle Boat Angling Club, 1988). Very little is,

however, known about the current status of the shark fishery and of its possible effects on the stocks of target species. The aim of this paper is to examine the history and methods of catching shark in South - Western Cape waters, as well as to give details of the age and growth, distribution, diet and reproductive history of the principal target species, G.galeus.

The biology of G.galeus and of Squalus acanthias (spiny dogfish) are perhaps the best reported of all chondrichthyan species, because of their importance as fisheries targets. However, considerable differences of opinion, and gaps in knowledge still exist, particularly about migration patterns and reproductive biology. The issue of age and growth is also of paramount importance from a fisheries point of view. Studies on tag returns from the fishery off South - Eastern Australia (Grant et al 1979) have established von Bertalanffy parameters and shown G.galeus to be long lived and slow growing. However, sizes at maturity and maximum sizes reported by Olsen (1954) for Australian and by Ripley (1946) for Californian stocks differ considerably. This must affect length at age assessments. It is therefore important to establish independent ageing parameters for South African stocks. Tagging, while effective, is an expensive and long term method of achieving this objective, so was not adopted. Moreover, sharks lack the otoliths, operculae or scales with annuli often used in teleost aging. Alternatives such as tooth replacement rates (Moss 1967, 1972), vertebral number (La Marca 1966), cross-sectional counts of the rings in fin spines (Holden and Meadows 1962), length -frequency analysis (Olsen 1954), and counting of bands in vertebral centra (Stevens 1975, Thorson and Lacy 1982, Caillet et al 1983b, Gruber and Stout 1983, Pratt and Casey 1983, Smith 1984, Davenport and Stevens 1988, Walter & Ebert 1991) have been used. G.galeus does not have fin spines and as our samples were derived largely from commercial catches, routine examination of vertebral counts

were not feasible. Thus the reading of vertebral bands, the most well established method of chondrichthyan aging, was adopted.

METHODS

Specimens of G.galeus and other sharks were obtained from commercial and recreational fishermen between Still Baai (34° 24'S 21° 25'E) and Laaiplek (32° 44'S 18° 12'E) during the period April 1987 - September 1989. The bulk of material was taken from fisheries based in Gansbaai and Table Bay. However, small numbers of specimens were obtained from most ports in the S-W Cape. Further material and information was obtained from demersal cruises of the Sea Fisheries Research Institute vessel *R.S.Africana* and shark catching cruises of the R.S. Sardinops and R.V. Trachurus. Demersal and linefish catch records held by Sea Fisheries Research Institute were also analysed. Shark fishermen and processors were interviewed for further information and historical data.

The fish were weighed on a 50 kg Salter spring balance and a variety of body measurements taken from each specimen, as indicated on Figure 1. The testes or ovaries and stomachs were then removed. All material was either frozen or preserved in 10 % buffered formalin in sea water and brought back to the laboratory for processing. A Sartorius top loading balance accurate to 0,01g was used for all weights taken in the laboratory.

Testes or ovaries were visually assessed, and indexed according to the condition scale shown in Table 1 before being individually weighed. Ova were dissected out, counted and the diameter of the largest egg measured. If females were in pup, the uteri were opened, the number of pups, and TL, FL and sex of each recorded in order of occurrence anterior to posterior.

Gut contents were examined on a fine mesh sieve. All items were rated according to the digestion index in Table 2. All discrete items rated at 4 or less in the digestion index were then weighed, and if sufficiently intact, measured.

A block of 4-6 vertebral centra was collected from each of 400 specimens, the bulk of which were commercially caught. This necessitated taking the vertebrae from directly behind the head of each fish, so as not to lower its commercial value. In other studies (Caillet et al 1983a, Casey et al 1983, 1985, Schwartz 1983, Davenport and Stevens 1988) vertebrae were taken from directly below the origin of the first dorsal fin. All specimens were kept frozen at -20° for bulk processing. As much tissue as possible was cut away and the centra separated before boiling for three minutes and scraping away all remaining extraneous material. The centra were then air dried and placed in glass vials with silica gel to complete the drying process.

Some rings were externally visible on the concave surfaces of the vertebral centra, but these were not adequate for aging in G.galeus, as they were very difficult to resolve clearly. Ring enhancement with silver nitrate at concentrations from 1% - 4 % (according to methods described by Stephens 1975, Rossouw 1984, Caillet et al 1986) was thus attempted. The results achieved with material from G.galeus were poor at best. The staining technique described by Davenport and Stephens (1988) for Carcharinus tilstoni and C. sorrah was then attempted. The concentration of ninhydrin and timing of staining described totally overstained G.galeus vertebrae. After a series of trials the following technique was found to give optimum results, but will probably have to be further adapted for other species:

A brief surface etching by total immersion in sodium hypochlorite for 1 hour was followed by staining with ninhydrin 0,1 % in 96 % ethyl alcohol. Each vertebral centra was then placed concave face down and immersed to approximately half its height in the stain. The container was sealed to prevent evaporation and then left for four hours. The vertebral centrum was then ground away transversely with a belt sander, the cut face polished on fine water paper and the ring count made immediately under a dissecting microscope. The easy visibility of these rings appeared to be a transient feature, so it was advisable to photograph them immediately. Fading visibility could be partially overcome by brushing the cut surface with 96% alcohol and overstaining could be corrected by putting the cut vertebral sections back into 96 % alcohol until the banding was more easily visible.

RESULTS

A: HISTORY OF THE FISHERY

The early history of the South-Western Cape shark fishery is not well documented. No records are available of catches made during World War 2, when the fishery was initiated. The earliest written reference is from the 1947 Sea Fisheries Annual Report, where mention is made of "larger shark boats". Personal communication with some of the older fishermen (W. Stephen- Jennings 1988, Capt. de Villiers 1989) suggests that these larger vessels were almost certainly longliners using fixed gear. However, both handlining and bottom set gill nets were also extensively used. An annual report of 1948 (Director of Fisheries, 1950) provides the first record of landings at 250 000 G.galeus. No masses are recorded, but the average mass of G.galeus in the fishery at its inception would almost certainly have exceeded the present average of approximately 15 kg, as this is a long lived

and slow growing species (Grant et al 1979, Olsen 1984). Thus it is possible to estimate that landings exceeded 3 750 tons. Two points of caution must, however, be added to this figure: i) often only the livers were landed; ii) it was common practice to add the livers of less desirable species (such as mustelids) to liver drums to make weight (pers. comm. W. Stephen-Jennings, 1988).

In 1948 a quota of 250 000 sharks was set to protect the fishery, but in 1949 no restriction was actually required because of a decline in demand. By 1950 the fishery was described as having "practically ceased" (Director of Fisheries 1952). In 1952 Vitamin A was artificially synthesised (Olsen, 1981) sounding the death knell for the shark liver oil industry, particularly as shark liver oil's vitamin A content was highly variable (Ripley 1946, Archer 1949). More recently increases in the price of synthetic vitamin A have led to a revival of the industry in Madras, India (Pers. Comm. L.J.V. Compagno, South African Museum 1992), but there is no sign of this occurring in South Africa as yet.

A second phase of the fishery developed as markets were opened up for dried and later for frozen shark flesh. Dried meat went to Central Africa (Director of Fisheries 1956), while the frozen product was sold to Europe, the Far East, and Australia. A drop in the sales of dried shark affected the fishery from 1968-1972, possibly as a result of the decolonisation of Africa, and the political unacceptability of South African products. As a result more of the catch was sold frozen.

By 1973, reported landings were 144 832 sharks. However, alarm about the high levels of bioaccumulated mercury in shark flesh (Walker 1976, Caton 1981, Olsen 1981, 1984) subsequently made it difficult to find markets for

this product. This severely restricted the local linefishery for some years, and entirely stopped trawl landings. Demersal trawlers began reporting shark landings again in 1979 (Director of Sea Fisheries 1980). At least one major company restricted the maximum weight of shark purchased to 7 kg to ensure a relatively low level of bioaccumulated mercury. Sharks of this size would still be legally acceptable for sale in Victoria, the state which has the highest shark consumption in Australia. The maximum legal length of G.galeus in this state is 1120 mm (Walker 1976), which is equivalent to an approximate mass of 6,9 kg for males (Table 3).

Sharks of all sizes are now purchased from line fishermen, longliners and gill netters at various ports. It has not been possible to discover their destination. However, as most of the traditional markets for frozen shark flesh have stringent mercury regulations (Table 3), new markets must have been found or the regulations evaded. Thus, at present there are no economic restraints on the fishery, except for a relatively poor price. Despite this, the reported annual catch has steadily declined since the early 1980's, as shown in Fig. 2. It is plain that most of the present South African landed catch would exceed almost all maximum permitted mercury levels, and could not be legally exported to conventional markets.

B: METHODS AND GEAR.

Four discrete fisheries catch shark in the S-W Cape. Two of these never deliberately target sharks, but land them as an incidental bycatch. These fisheries are:-

- i) The demersal trawl fishery: The amount of shark landed in comparison to other species is small, sharks making up 0,2 - 0,3 % of the total catch by

mass in the period 1979-1987 (Director of Sea Fisheries 1981-1983, Marine Development Branch 1983-1984, Chief Directorate Marine Development 1984-1986, and unpublished records of Demersal Section, Sea Fisheries Research Institute) This, combined with the relatively low selling price, means that sharks are of little importance to the demersal trawl industry. Because of the size of the fishery, however, the effect of demersal trawling on the overall shark catch is considerable (Table 4), averaging 36,7 % by mass over the period 1982-1988.

Inshore trawlers capture the bulk of the shark catch (Table 5). Much of this is taken by sole-directed operations and landed at Mossel Bay. Examination of the catch from one such vessel showed that it consisted of small G.galeus, small mustelids and Squalus spp.. As the sharks are landed in a headed, finned and gutted form accurate species identifications are not always possible.

- 4
- ii) The kingklip longlining fishery: This took place over broken ground where trawling would be difficult. Fish baits are used. Following the prohibition of catching hake as well as kingklip, attention was shifted from deeper reefs to those in approximately 80 fathoms. These conditions suit the diet and habitat preferences of G.galeus and substantial amounts were sometimes caught (Pers. Comm. D. Japp, SFRI, 1989). The fishery has subsequently been terminated, but shark are now being taken by pelagic tuna longliners, particularly for shark fins for the oriental market (Pers. comm. L.J.V. Compagno, South African Museum).
 - iii) Linefishing. This is the principal fishing method for G.galeus, both as a targetted and incidental catch. Gans Baai is the principal centre,

landing an average of 65 % of the total South African line caught shark catch. The catch is heavily affected by the availability of more lucrative targets, shark catches being minimal when snoek (Thyrsites atun) or kob (Argyrosomus spp) are available. The handline fishery for shark appears to have been in a state of decline since about 1978, when a maximum of 800 tons of shark were landed (Fig.3). There are, however, undoubtedly economic factors involved as well, specifically better prices for all other fish, which can often be caught with less effort than shark.

Historically, sharks were caught on cord lines using a single, fixed 450 g sinker with a 6-8 cm chain trace and a single hook, size 11/0 or larger (Capt. de Villiers 1989). Heavy gauge nylon of ca 100 kg breaking strain is now more widely used, and hook sizes are often a great deal smaller, down to 8/0. Fish baits, usually harder or pilchard, are almost always used. The sharks are caught on traditional grounds and occur at different grounds at various times of year.

Shark-directed longlining has been conducted out of Gans Baai, Kalk Bay, Saldanha Bay, and Laaiplek. Efforts in Gans Baai and Kalk Bay have been abandoned for economic reasons, while longlining has been prohibited within the confines of Saldanha Bay. Small scale longlining operations continue out of Laaiplek, mainly in shallow water (1-4 fathoms) between Laaiplek and Dwaarskersbos. Single bottom set lines, buoyed and anchored at both ends, are used. The snoods are fixed, and are usually 30-50 cm long, and 1-3 m apart. Hook size varies between 8/0 and 10/0. Hook number seldom exceeds 100 hooks. Bait is almost always harder.

Catch composition varies greatly with site and season. For the Laaiplek area the catch is heavily biased to small G.galeus 450-700 mm in total length, and Notorhynchus cepidanius. The catch of the Saldahna Bay fishery was almost entirely dominated by Mustelus spp., with a seasonal variation in size. Juveniles are almost always present but large, pregnant females are common only during the late summer months.

- iv) Gill netting: This is principally a west coast fishery, targetted mainly on the St. Joseph shark, Callorhynchus capensis (Freer and Griffiths in prep). A proportion of larger sharks are also taken (Table 6), but are not targets, as they badly damage and tangle the monofilament gill nets used. The South Eastern Australian shark fishery also uses monofilament nets, but targets small G.galeus and gummy sharks (Mustelus antarcticus). The nets used are also far longer, at 600-800 m (Hughes 1981) than South African nets, which have a stretched mesh size of 178 mm, a fall of 3 m and are 150 m long. The nets are bottom set and anchored and bouyed on both ends. The float to lead ratio is approximately 1:3.

The chondrichthyan catch as a whole is shown in Table 7. This table indicates that attention should be focussed on the smooth hound sharks, as they are caught by three fisheries and are also the third most frequently caught species. Mustelids have also become a major alternative target in S-E Australia, and their relative importance in South African fisheries seems likely to expand. The data presented in Table 7 also highlights the fact that almost all species are caught by more than one fishery. The problems of managing such a multi-species fisheries have yet to be solved, particularly as this is both a multi-species, and

multi-sectored fishery. It is impractical to consider it as a unit and effective management can only be achieved by treating each species as a separate entity.

C: BIOLOGY OF G.GALEUS

The largest G.galeus recorded by this study was a female of 1734 mm TL, and a mass of 25 kg. The greatest mass recorded (30,5 kg) was a heavily pregnant female of 1 620 mm TL, showing how body mass can be substantially affected by reproductive state. The normal length weight relationships of the species are described by the formulae:

$$\text{Mass (kg)} = 566,073 * e(2,207 * 10^{-3} * \text{TL}) \quad (r^2=0,96) \text{ for males}$$

$$\text{and Mass (kg)} = 659,052 * e(2,896 * 10^{-3} * \text{TL}) \quad (r^2=0,95) \text{ for females}$$

Length and weight parameters for the 183 females and 192 males examined are depicted in Fig. 4. The length- mass relationships of the sexes do not visibly differ until the onset of sexual maturity, when females exhibit a dramatic increase in girth. Mature female mass is generally greater than male mass at length because they are either heavily gravid or have enlarged livers, probably as a reserve of nutrients for the physiologically heavy burden of viviparity.

Formulae for the interrelationships of the various measurements shown in Figure 1 are given in Table 8. Some of these relationships may be of value in fisheries management and enforcement. For example dorsal 1 insertion - dorsal 2 origin is a measurement that can be taken even on a headed,

finned carcass. Using the formulae in Table 8 reasonable estimates of all the other parameters may be derived. During bleeding to improve flesh quality, when the caudal artery and vein are opened, the tail is often severed. Precaudal length (PCL) can then be effectively used to derive other, more standard measurements.

AGE ESTIMATION

Readings of depositional bands of the vertebral centra gave fairly consistent results for young fish. However, the long lifespan and slow growth of this species made readings of centra from older fish unreliable. Only 58 of the centra passed the three identical independent readings requirement set. Figure 5 shows the growth curve derived from these data, assuming that ring deposition is annual.

Using the computer programme PC Yield II (Punt and Hughes 1989) the following values were derived for the von Bertalanffy growth equation:

$$L(t)=1601,378(1-e^{-0,162(t+1,328)})$$

Validation of this growth rate may be attempted from examination of length-frequency samples, as shown in Figure 6. As the species schools in sex and size assorted groups most of our length- frequency data covered a small number of year classes. In the juvenile school sampled two clearly separate cohorts can be seen, the average length of fish in the younger cohort being 619 mm TL, or by calculation 1,7 y old. The second cohort, with a mean length of 795 mm TL was calculated to be 2,9 years old. Bearing in mind that regressions are prone to predictive errors on either extreme of their curve, this lends support to the possible annual nature of the depositional

bands. In the adult size classes the pattern becomes too vague to identify cohorts.

The characteristics of the centrum edge as used by Tanaka and Mizue (1979) and Rossouw (1984) were not easy to discern accurately, especially in the older fish. This method was thus only applied to 18 of the specimens in the 2-3 band range. Proportional estimates of band development, made with the help of a graticule, were used to visually estimate the edge as a proportion of the previous ring.

These results (Table 9) imply that band deposition is initiated in midsummer, this being the period of rapid deposition, the band being at least half its full width before the fifth month, with slower growth thereafter.

DIET

The guts of 375 specimens were examined. The results are shown in Table 10 and indicate that G.galeus is principally ichthyophagous.

Reef fish species in the diet varied enormously. The most common species were carpenter, Argyrozona argyrozona, followed by hottentot, Pachymetopon blochii. The most common pelagic fish in the diet were pilchard, Sardinops ocellata, closely followed by anchovy, Engraulis japonicus. The common octopus, Octopus vulgaris, was the most common cephalopod prey item, but this is biased by the large proportion of stomach contents examined from the area between Robben Island and Blouberg, where octopus appeared to be particularly abundant, even being caught on handlines. All identified species which occurred more than 10 times are listed in Table 12.

While the diet of juveniles remains similar in terms of food categories to that of adults (Table II), the actual elements, with the exception of the crayfish, Jasus lalandii differ a great deal. Juveniles, however, take double the number of soft shelled crayfish that do adults. All the species taken by juveniles are smaller, and more characteristic of sheltered embayments.

It was not possible to establish frequency of feeding from the digestion states of the stomach contents. However, as a high percentage of stomachs contained food items in varying digestion states, foraging is probably continuous. Fully digested remains, especially cephalopod beaks, occur on their own and in combination with other food items so often as to suggest that they have a long retention time. Indeed, the eroded condition of some otoliths indicated that they remain in the stomach until they are at least partially broken down.

REPRODUCTION

While sharks are in many ways considered primitive, this is certainly not the case in terms of their reproductive strategies. All shark species practice internal fertilisation and many are viviparous, while those that are oviparous lay few, large eggs encased in a horny shell, thus still making a considerable physiological investment in each offspring. There is evidence that some species, including G.galeus, have premating rituals, bite marks being frequently found around the pelvic fin area of sexually mature females. Possibly the evolution of internal fertilisation has forced the development of premating rituals, as it would be virtually impossible for the male to insert the claspers without at least minimal co-operation on the part of the female. In G. galeus slight twisting of the clasper causes a cartilaginous, barb-like

structure to stand out from the clasper shaft, probably ensuring that once copulation has been initiated the female cannot easily interrupt it.

Perhaps because mating can result in major injury to females, sexually segregated schooling has evolved. This only occurs after the onset of sexual maturity, juveniles being found in mixed sex schools, and sub-adult females occasionally with sexually mature male schools. Mature female schools appear to migrate out of the commercial catch area for most of winter. A similar phenomenon was reported by Olsen (1954) in the Australian fishery. He postulated that pregnant females migrated over the edge of the continental shelf to take advantage of lower temperatures to maintain their energy budget. While no G.galeus were caught by the deep trawls (>400 m.) of the R.S.Africana, there can be no doubt that females do migrate out of the catch area. Winter catches thus only contain females below the size of sexual maturity, resulting in a marked seasonal variation in sex ratio (Fig. 7).

Sexual maturity for males was reached at a minimum length of 1 278 mm TL corresponding to a calculated age of 8,5 years. The transition from reproductive state M2 to M3 was marked by the claspers reaching their length at maturity of Cl = 64 mm, CO = 60 mm, and CW = 22 mm (see Fig 1 for an explanation of measurements). No further clasper development was observed in larger fish. The attainment of sexual maturity of females is at a greater size, mass and age than in males. Mature females also no longer occur with male schools, develop a nidamental gland and show marked development of the ovary. The smallest recorded gravid female had a TL of 1 341 mm, corresponding to a calculated age of 9,9 years.

The monthly mean gonosomatic index (GSI) values for males, calculated as testes mass divided by body mass and expressed as a percentage, are given in Fig.8. This would suggest that mating occurred in May. This is confirmed by visual assessment of reproductive state, mature males being stage 4 in April and May, and stage 5 in June - August. The monthly GSI for females could not be calculated because mature females were absent from the catch in winter.

Fecundity, as in most elasmobranchs, is low. The minimum recorded number of pups was eight, in a female of 1 547 mm TL, while the maximum was 20 in a female with a very similar TL of 1 553 mm. This suggests that, in contrast to many other fish species, size may only be one of the factors controlling the number of offspring. The maximum number of developing ova recorded was 37 in a female of TL 1 631 mm. As with pup numbers, there can be great variability in the number of eggs carried by females within the same size class. However, a general trend of increasing female fecundity with size (Fig. 9) can be described by the formula:

$$\text{egg no.} = 107,763 + (0,0878 \times \text{TL}) \quad (r^2=0,78)$$

The intergestation "resting" period, as suggested by Olsen (1954, 1984) does not always occur, as two females of approximately 11 years old were examined which were carrying both embryos and viable developing ova. One large female of approximately 20 years old was caught carrying neither pups nor any developing ova.

The sex ratio amongst the 203 unborn pups examined was 1:1,09 (male:female). Pups from 298 mm TL appear ready for birth, as captured females release living pups from this size up onto the deck (n = 53). The mean pup size thus released was 307 mm TL. A slight increase in size

toward the posterior of the uteri was generally noted, with a maximum range of 8 mm. Pups are dropped in late December and January in the Gans Baai area, from whence most of our pregnant females came. However, various fishermen from other areas report catching heavily pregnant females in February and March (pers. comm. B.Bennett, University of Cape Town 1988, H.Frazer 1989 and S. de Lange, Light Tackle Boat Angling Club 1989). Incomplete sampling of the female population did not allow direct estimation of gestation period, but by taking the time from the period of maximum testes development and condition rating in males to the pupping time, gestation cannot be less than six months.

For Gansbaai it is estimated that females comprise 41,6 % of the catch by mass. Only 72,7 % of female catch comprises mature individuals relative to 87,3 % of male catch. It must be noted that this is an assesment of the mass contribution to total landings. Fig. 10 shows actual size-frequency distributions of males and females in the catch. It is plain that for a relatively low mass contribution, a high toll in future recruitment is being extracted in the form of immature females. The bulk of female catch in the larger size classes is also dependent upon the capture of heavily pregnant females taken over a restricted period of the year.

DISTRIBUTION

In a schooling species which assort by sex and size as appeared to be the case in our G. galeus samples, population structure within small units of the catch is rather meaningless. However, by viewing combined results the following generalisations can be made. (i) The sex ratio in the catch of juveniles (which sort by size and not sex) was in all samples slightly biased toward females. (ii) The subadult and adult catches were biased toward

male fish, except during midsummer (December) in Gans Baai, when mature females predominated, many of these being pregnant.

G. galeus appear to be present throughout the area between Walvis Bay and Cape Agulhas at all times of the year (as evidenced by R.S. Africana demersal trawling). However sexually mature females are seasonally absent from the catch. While it is difficult to show evidence of this in males, Table 13 shows some evidence of longshore migration of mature females. Juveniles are caught in shallow embayments including Struis Baai, St. Helena Bay, Walker Bay and False Bay.

Two possible scenarios may be postulated: Firstly that all females follow a regular round the Cape migration; which is rather difficult to accept, given two facts, firstly that Saldanha Bay is not the northern limit of distribution of the species on the west coast, and secondly that the tagging records of Australian G.galeus reported in Olsen (1984) do not bear out this sort of directionally patterned migration. However, Ripley (1946) records a southward pupping migration into warmer waters off the coast of Mexico. The second alternative is that schools migrate northward in winter, but that this may be up either the east or west coast, with the fish returning to pup in the southern Cape in summer. Possibly this "migration" may simply be the tracking of warmer water, or of food sources.

It seems probable that the migration routes of each sex are also distinct. For example only females were caught at a site off Whale Rock and at another site off Scarborough on three sampling ventures, whereas only males were caught between Robben Island and Blouberg on the same occasions.

Even less information is available on the depth distribution of G. galeus. Much of the line caught material came from 3 - 40 m. Kingklip longliners,

however, have caught G.galeus with lines set at ca 160 m (pers. comm. D.Japp 1989). The limits of depth of recorded specimens from demersal trawls of the R.S. Africana was 300 m.

DISCUSSION

A: BIOLOGY

The diet of G.galeus covers such a broad spectrum of species that it is unlikely to limit the distribution or density of sharks. G.galeus is plainly an efficient, highly mobile predator and can adapt itself to a variety of environments and prey species. Being principally ichthyophagous high levels of bioaccumulated mercury are likely to occur, especially in larger individuals.

Both Ripley (1946) and Olsen (1984) suggest that there are major movements of the population of G.galeus off the coasts of California and South-East Australia. Olsen (1984) considers this to be largely an on-offshore pattern, whereas Ripley (1946) describes longshore movement. While evidence is far from conclusive, catch records would seem to indicate that at least reproductively mature females migrate seasonally along the South African coast. Both Olsen (1954, 1984) and Ripley (1946) also suggest this may be a temperature mediated behaviour pattern. The fact that there are predictable pupping migrations in and around Walker Bay makes this schooling species particularly vulnerable to fishing pressures at a stage of the life cycle when protection would be of great value.

While it is difficult to prove that recruitment is density- dependent there is some supportive evidence. Firstly, South African stocks appear to have failed to recover to previous levels despite considerable lay-off periods (Fig.

2). This also appears to hold true of the G. galeus fishery in California, which underwent a brief renaissance in the early 1980's, but rapidly depleted stocks (Pers. comm. L.J.V. Compagno, South African Museum, 1992). Secondly, as G.galeus is an aplacental viviparous species with a low fecundity (Fig. 9) and with the neonates being ca 350 mm in length, juvenile mortality would seem unlikely to be a major factor determining population density. Rather, a fairly direct stock-recruit relationship might be expected.

Little is known of the relative effects of predation, disease and fishing mortality on G.galeus but it is known to be long lived, the oldest tagged specimen recorded by Grant et al (1979) being at least 48 years old. The principal cause of mortality is thus probably fishing.

B: THE FISHERY

It is clear that on the basis of the life histories, and the dismal record of most shark fisheries (Holden, 1974), there is no justification in allowing sharks to remain as unlimited species in the commercial catch. It is also unacceptable for shark of any species to receive any further processing at sea other than bleeding, gilling and gutting, as this makes subsequent identification and size control very difficult.

The Mustelus spp catch in Saldanha Bay - Langebaan requires urgent management attention, in order to conserve this potentially valuable resource. This is plainly a major nursery area of this species on the West Coast. While longlining within the bay has been stopped, angling competitions continue to make substantial landings (frequently 2-3 tons of Mustelus spp, many of them females in pup) which are subsequently sold. It

would be difficult to justify the wastage of such a volume of fish were it not sold, yet the sale of the catch violates the principles of recreational fishing. Both the recreational and commercial capture of this species needs careful monitoring. A summer closed season could at least help to prevent the catch of mature females in pup. A similar closed midsummer season could only be of benefit to G.galeus. In view of mercury level standards the fishery will eventually shift towards juvenile fish. Let us therefore take steps to ensure that these are plentifully available.

It is in the interest of both the public and the long-term future of the industry that various standards be applied to shark catches. A statutory maximum level of free mercury should be applied. In order to make this legally practical either a maximum length or maximum mass should be set for each species, based on average mercury loads. This should be applied on a species by species basis, as preferred diet will greatly affect the level of bio-accumulated mercury. For example Mustelus antarcticus, an Australian smooth houndshark which has a similar diet to our own houndsharks, has far lower mercury levels than similar sized G.galeus (Walker 1976) and has made an increasing contribution to the Australian fishery as a result (Caton 1981). It is clear that pollutant levels (Forrester et al 1972), locality (Glover 1979) and temperature (Lyle 1986) also effect the levels of mercury and other heavy metals, especially in primarilly ichthyophagous species.

A handling code, as set out in the F.A.O. manual on shark processing and handling (Kruetzer and Ahmed 1978) ensuring that all shark are bled and kept cool to reduce urea content, and slow down the breakdown of urea to ammonia, would improve the flesh quality. This could only lead to wider acceptance of shark as a eating fish, and could substantially enhance its

value in a marketplace, which is becoming steadily more discerning and concerned with issues of health and quality.

9/ While it is easy to conceive ideas on rational management of shark populations by the linefishery, it is difficult to extend these to other fisheries. The effect of inshore trawling on nursery areas of G.galeus, and other shark species, must be considerable, indeed the cartilagenous fish bycatch has been estimated at 22 000 tons by Compagno et al (1989). However, since sharks are an incidental bycatch in this large, economically valuable fishery, it is unlikely that the shark bycatch can be substantially reduced. However, any attempt at targetted trawling for any chondrichthyan species (including C.capensis) should be extremely carefully reviewed. The information about damage to shark stocks can be added to the body of evidence favouring the creation of marine reserve areas in some of the bays so important for the recruitment of many of our marine species.

Gill netting is a minor cause of mortality at present, and is unlikely to increase substantially, since fishermen tend to avoid concentrations of larger sharks because of the consequent damage to nets. As a precaution, the number of entrants to this fishery should, nevertheless continue to be strictly limited, and the landings monitored. Only if the composition of these landings should change need any further management options be considered. Longlining for shark, unless on a breeding ground, or major nursery area, is unlikely to be cost effective, and thus will hopefully be restricted by economic considerations.

The lack of reliable catch data on volumes and species has been one of the great frustrations of this program. While the linefish and net permit returns required by Sea Fisheries assist with quantification, they often lack reliability

and verifiability. We suggest a second tier of statistical input. Fish processors, especially those handling shark, are relatively few in number. In addition, they usually have fixed premises, are by and large accommodating, and far better record keepers than individual fishermen. They offer an excellent potential source of accurate statistics as there is no informal market, and they often have strong vested interests in local conservation, if only to protect their positions.

In conclusion, generally sharks may be viewed as a risky last-resort fisheries species. The effects of trawl and gill net landings offset and mask a slowly declining linefish landing. Unfortunately, while economics would normally dictate the collapse of a directed fishery, the fact that sharks are a bycatch in so many fisheries means that fishing pressure on sharks will continue. The gill net fishery for Callorhinchus capensis is a more viable alternative, but still needs careful monitoring.

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LEGENDS TO TABLES:

- Table 1: Stages of reproductive maturity in male and female G.galeus.
- Table 2: Digestion index for stomach content items in shark stomachs.
- Table 3: Statutory permitted maximum mercury levels for fish products imported into various potential shark markets. (After Kreuzer and Ahmed 1978 and Walker, 1976) and the corresponding TL and mass of G.galeus in S-W Cape waters.
- Table 4: Proportion of shark in the catch of the demersal trawl fleet, and the percentage of total shark landings this makes up. (Report of the Chief Directorate Marine Development of South Africa 1982, 1985, and unpublished internal records)
- Table 5: The percentage of the total demersal catch of shark landed by inshore and offshore directed trawlers. (Information drawn from internal records of the demersal section of Sea Fisheries Research Institute.)
- Table 6: Large shark mass and as a percentage of the total gill net catch.
- Table 7: Major shark species landed in South African fisheries - Based on samples taken during 1987-1989. (T = Trawl; G = Gill; LL = Longline; L = Handline)
- Table 8: Interrelationships between morphometric parameters of G.galeus.
- Table 9: Characteristics of the centrum edge: estimates of proportional development.
- Table 10: Major elements in the diet of 375 G.galeus by percentage occurrence, percentage number and percentage mass.
- Table 11: Diet of Juvenile (less than 900 mm TL.) G.galeus as compared to adults and subadults. (a) Percentage number of items. (b) Most common prey species.
- Table 12: Prey items recorded more than 10 times in G.galeus stomachs.
- Table 13: Evidence of reproductive longshore migration of female G.galeus

Table 1

Male		
Stage	1	Immature, no gonad development
	2	Immature, testes developing, no semen sac visible
	3	Mature, testes fully developed, semen sacs empty
	4	Reproductively active, testes engorged, semen sac partially full
	5	Ripe and running, testes engorged, semen sac full, semen may be extruded from vent by slight pressure on abdomen.
	6	Post reproductive, testes not engorged, semen sac full of lumpy, curdled appearing sperm which may be extruded under pressure.

Female		
Stage	1	Immature, no gonad development
	2	Immature, ovaries developing, no nidamental gland visible
	3	Mature, ovaries have "sago grain" appearance, nidamental gland developed
	4	Mature, carrying ova 10-20 mm diameter round
	5	Mature, carrying ova 25-40 mm diameter round
	6	Mature, carrying ova 40 mm diameter +, ovoid
	7	Mature, carrying embryos < 200 mm TL.
	8	Mature, carrying term embryos, or just post-partum
	9	Mature, ovary large but no ova developing.

Table 2

Stage	1:	item virtually intact
	2:	scales lost, cephalopod skin coming off
	3:	skin broken, partial digestion
	4:	gut cavity open, some loose flesh and bone
	5:	flesh fragments, bone fragments, otoliths, beaks

Table 3

COUNTRY	MERCURY PPM.	TL (mm)		MASS (g)	
		male	female	male	female
Sweden	0,1	852,5	752	3914	3504
W.Germany	0,1	852,5	752	3914	3504
Japan	0,4	1126	1093	6931	7439
U.S.A.	0,5	1179	1162	7743	8663
Australia	0,5	1179	1162	7743	8663
Italy	0,7	1262	1272	9209	11044

Table 4

Year	Percentage of trawl landings by mass	Percentage of total shark catch taken by trawl
1982	0,3	34,9
1983	0,3	44,1
1984	0,2	35,5
1985	0,2	31,0
1986	0,2	36,2
1987	0,3	42,8

Table 5

	Offshore	Inshore
Sharks as % total catch	7,2 %	92,8 %
<u>C. capensis</u>	91 %	50,4
Other sharks	9 %	49,6

Table 6

YEAR	<u>C.CAPENSIS</u> MASS	MASS OTHER SHARKS	%
1984	400 141	67 046	14,4
1985	642 535	41 858	6,1
1986	432 140	41 780	8,8
1987	454 000	30 655	6,3
1988	374 000	31 193	7,7

Table 7

SPECIES	COMMON NAME	PERCENTAGE MASS	MAJOR FISHERY
<u>Callorhynchus capensis</u>	St. Joseph shark	62,7	T+G
<u>Galeorhinus galeus</u>	Soufin shark	24,9	L+LL
<u>Carcharhinus brachyurus</u>	Copper shark	2,4	L+LL
<u>Mustelus sp.</u>	Smooth hound shark	7,8	LL+L+G
<u>Notorhynchus cepidanius</u>	Gill cow shark	1,1	L+G
<u>Alopias vulpinus</u>	Thresher shark	0,1	L+G
<u>Squalus sp.</u>	Spiny dogshark	0,9	T

Table 8

Y	FORMULAE	r ²	df
Mass males (kg)	= 566,0729*e(2,20775*10 ⁻³ *TL)	0,96	234
Mass females(kg)	= 659,0519*e(2,89683*10 ⁻³ *TL)	0,95	198
Mass (g)	= 11108,7 + Girth*48,99125	0,79	349
FL (mm)	= 104,2299 + TL*0,792097	0,83	431
PCL (mm)	= 70,01912 + TL*0,7472	0,94	425
PCL (mm)	= 71,43875 + FL*0,86971	0,93	424
D1-D2 (mm)	= 28,59586 + TL*0,23956	0,81	423
D1-D2 (mm)	= 33,09142 + FL*0,272535	0,8	424
D1-D2 (mm)	= 12,25945 + PCL*0,314836	0,84	419

Table 12

COMMON NAME	SPECIES	% OCCURRENCE
silver	<u>A. argyrozona</u>	18
pilchard	<u>Sardinops ocellata</u>	17
harder	<u>Liza</u>	9
hottentot	<u>Pachymetopon blochii</u>	3
octopus	<u>O.vulgaris</u>	13
crayfish	<u>J.lalandii</u>	1
squid	<u>Loligo sp.</u>	11
goby	<u>G.bibarbatus</u>	7
cuttlefish	<u>S. officinalis</u>	5
anchovy	<u>E. japonicus</u>	6
snoek	<u>Thyristes atun</u>	6
mackerel	<u>Scomber japonicus</u>	4
fingerfin	<u>Cheilodactylus brachydactylus</u>	1
St. Joseph	<u>C.capensis</u>	2
jacobebeer	<u>Sebastichthys capensis</u>	1
catshark	<u>Poroderma sp.</u>	1

Table 13

Month	Reproductive condition	Place	n
December	G7	Gans Baai	42
January	G8	Hangklip	1
February	G7	False Bay	2
February	G3	Scarborough	3
March	G4	Table Bay, Whale rock	2
May	G5	Saldanha	1
May	G5+	Stilbay	1
October	G8	Saldanha	1
November	G6	Struis baai	2

LEGENDS TO FIGURES:

- Fig. 1: Standard measurements made on Galeorhinus galeus specimens.
- Fig. 2: Historical tendencies in the landings of shark in South Africa compiled from Director of Fisheries (1950-1957), Division of Fisheries (1958-1961), Division of Sea Fisheries (1963-1964), Director of Sea Fisheries (1968-1983), Marine Development Branch (1983-1984), Chief Directorate Marine Development (1984- 1986), unpublished internal reports and processors reports.
- Fig. 3: Annual shark landings by the South African linefishery, as derived from Report of the Chief Directorate Marine Development of South Africa 1982, 1986, and unpublished internal records of the Linefish Section of Sea Fisheries Research Institute.
- Fig. 4: Length-weight relationships of G.galeus males and females.
- Fig. 5: Length at age curve for G.galeus derived from depositional band readings in vertebral centra.
- Fig. 6: Length frequency histograms for three of the largest samples of Galeorhinus galeus. growth increments calculated from depositional rings in the centrum, as shown in Fig 5.
- Fig 7: Monthly variations in the sex ratios of the landed catch of G.galeus.
- Fig. 8: Monthly GSI of mature males, calculated by dividing testes and semen sac mass by total body mass.
- Fig. 9: Relationship between number of fertile eggs and increasing TL for 46 female G.galeus
- Fig. 10: Catch composition of male and female G.galeus showing size at 50 % sexual maturity.
- Fig 11: Length frequencies of three total landings at Gans baai during the months of March, June and July of 1988. Only males were present in all of these samples.
- Fig 12: Age structure of the G.galeus population as represented in the catch.

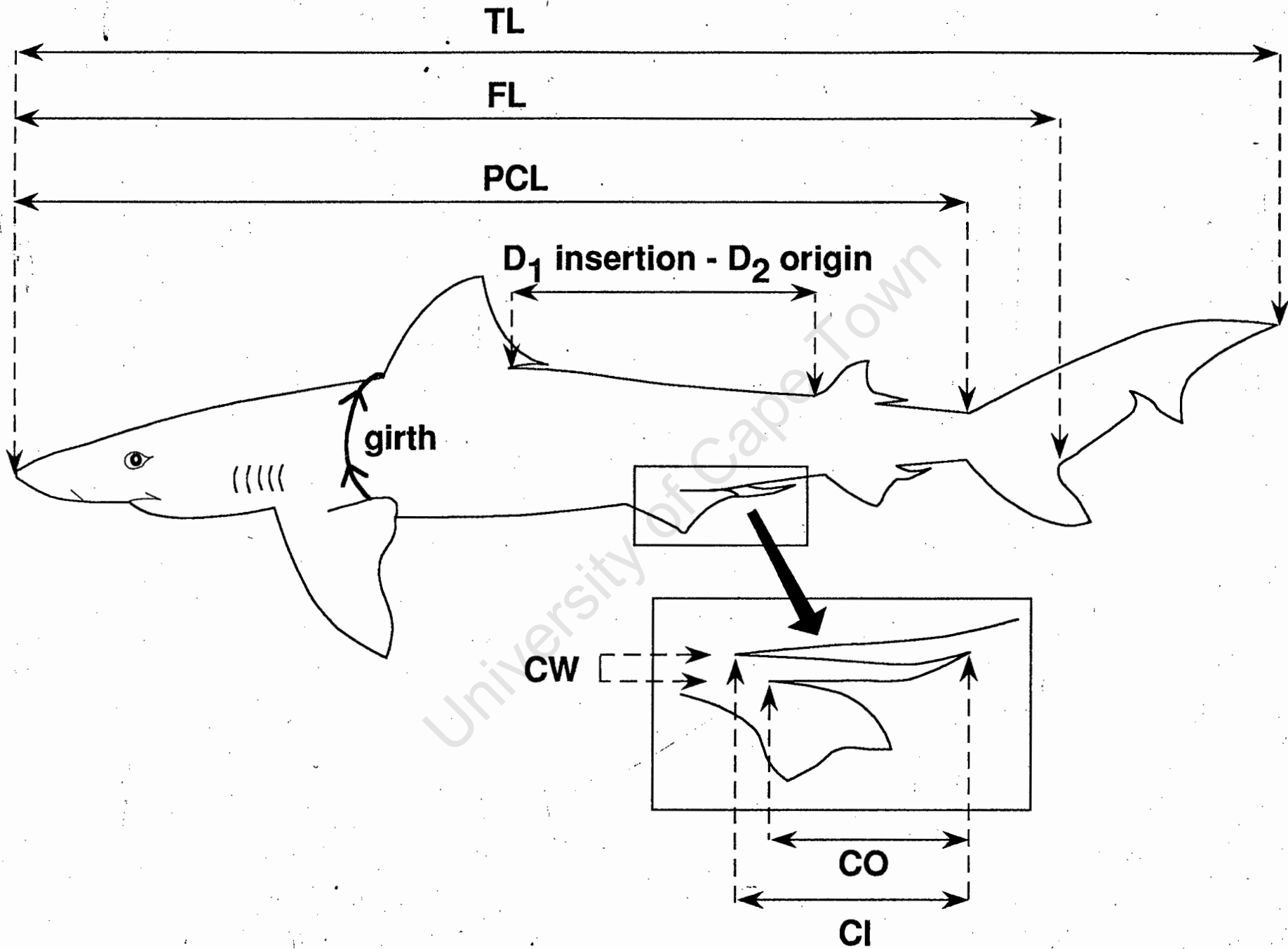


Fig 1

Fig 2

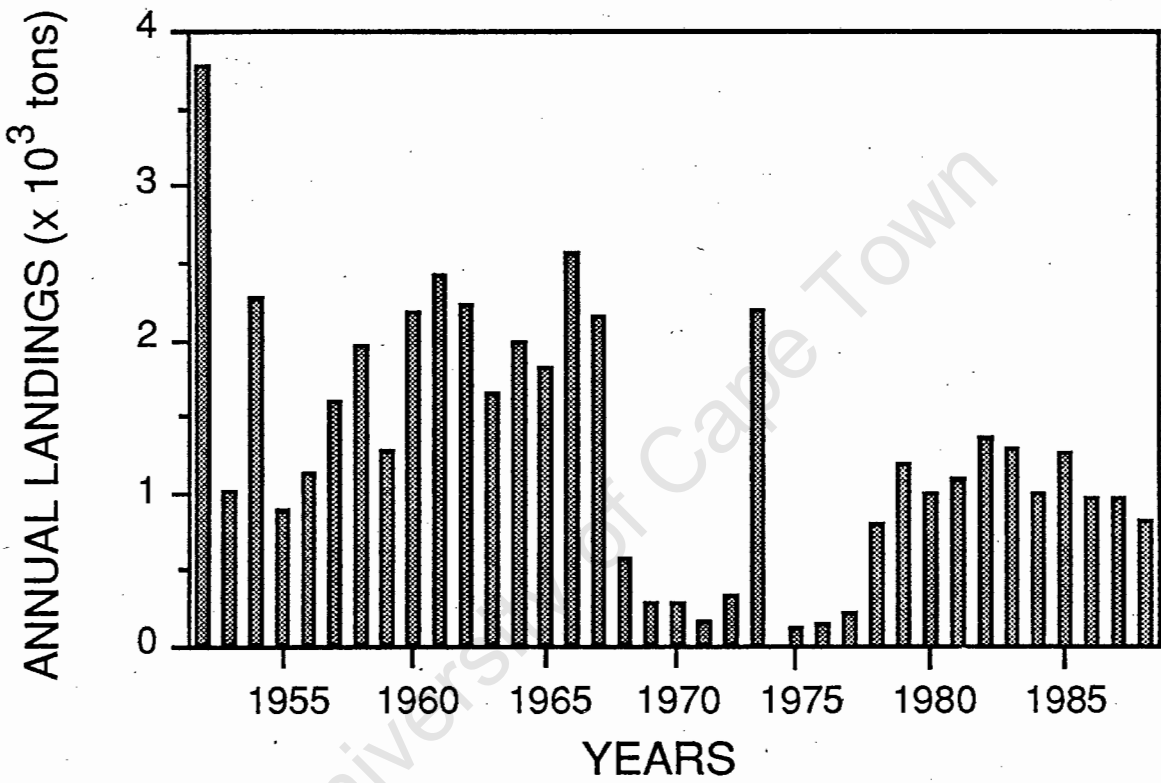


Fig 3

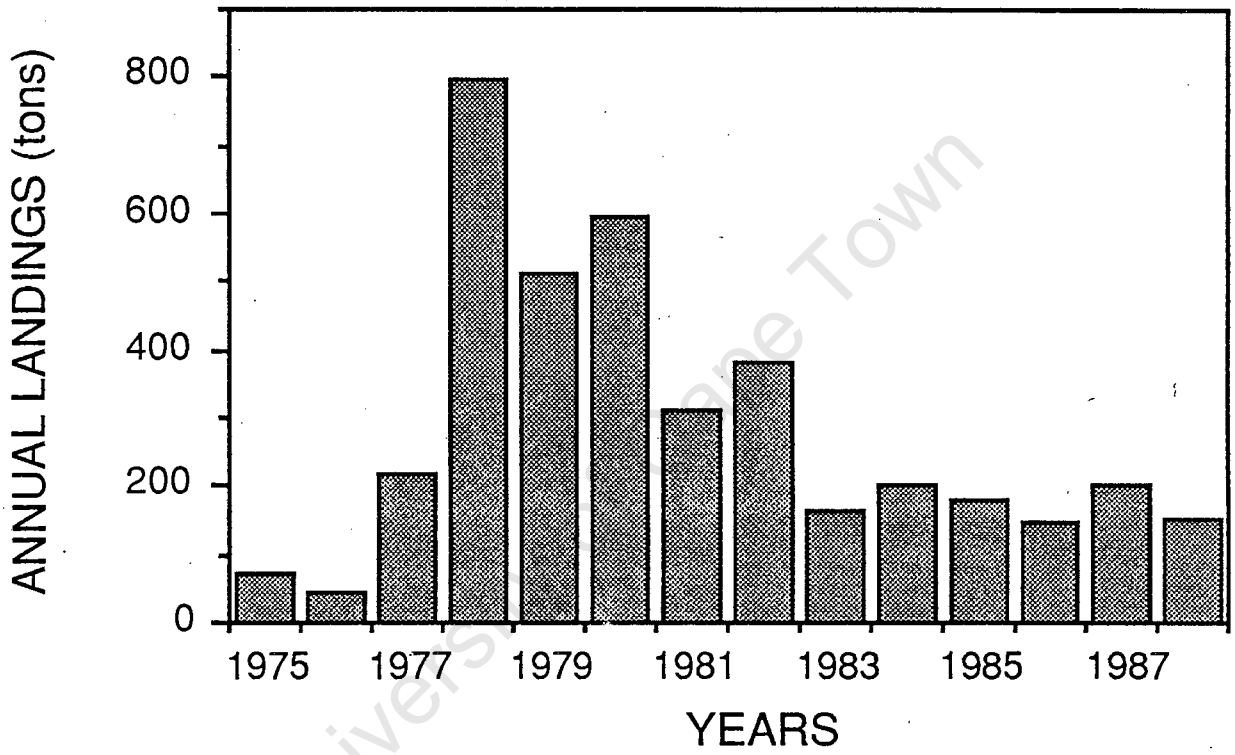


Fig 4

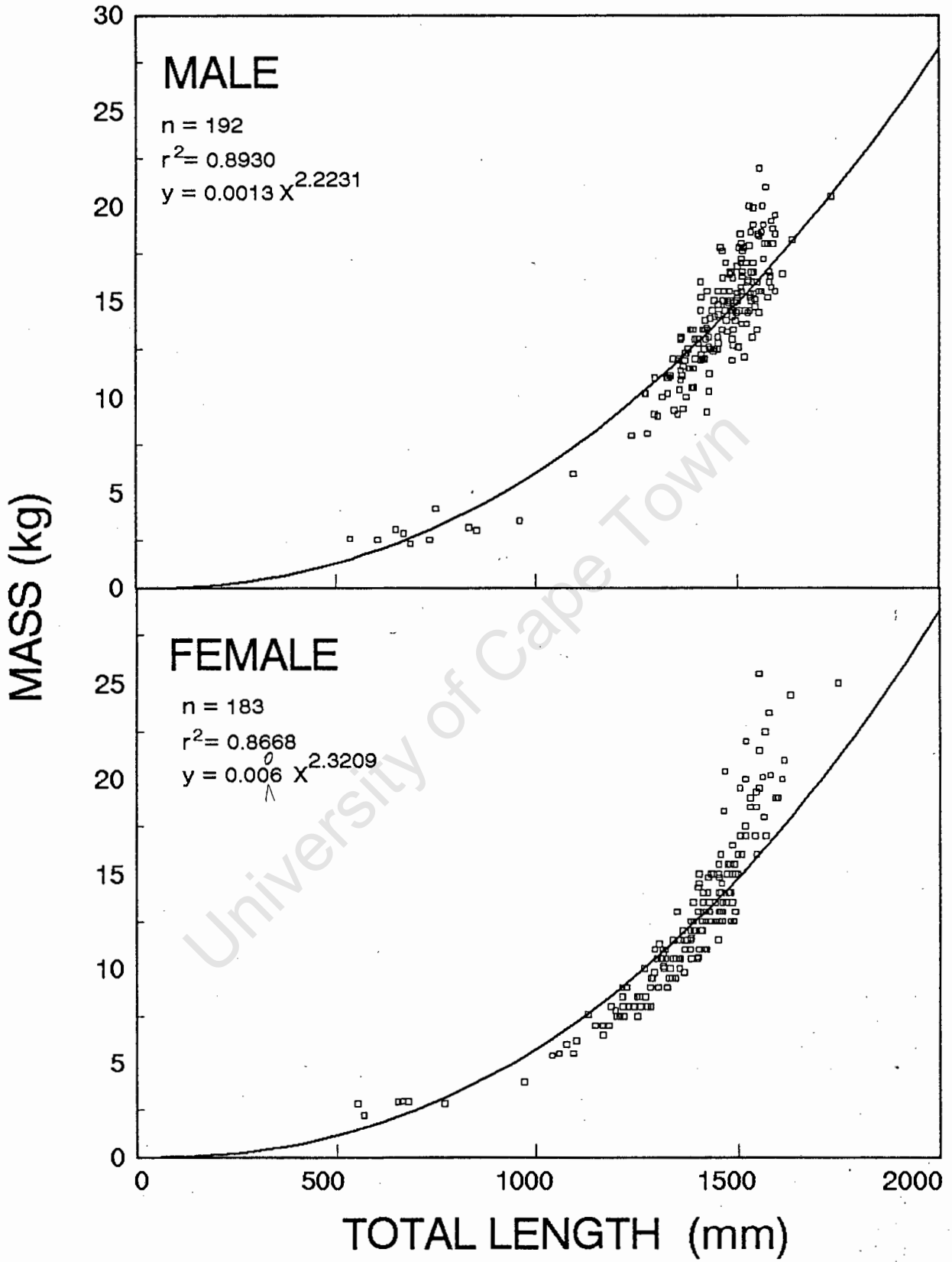
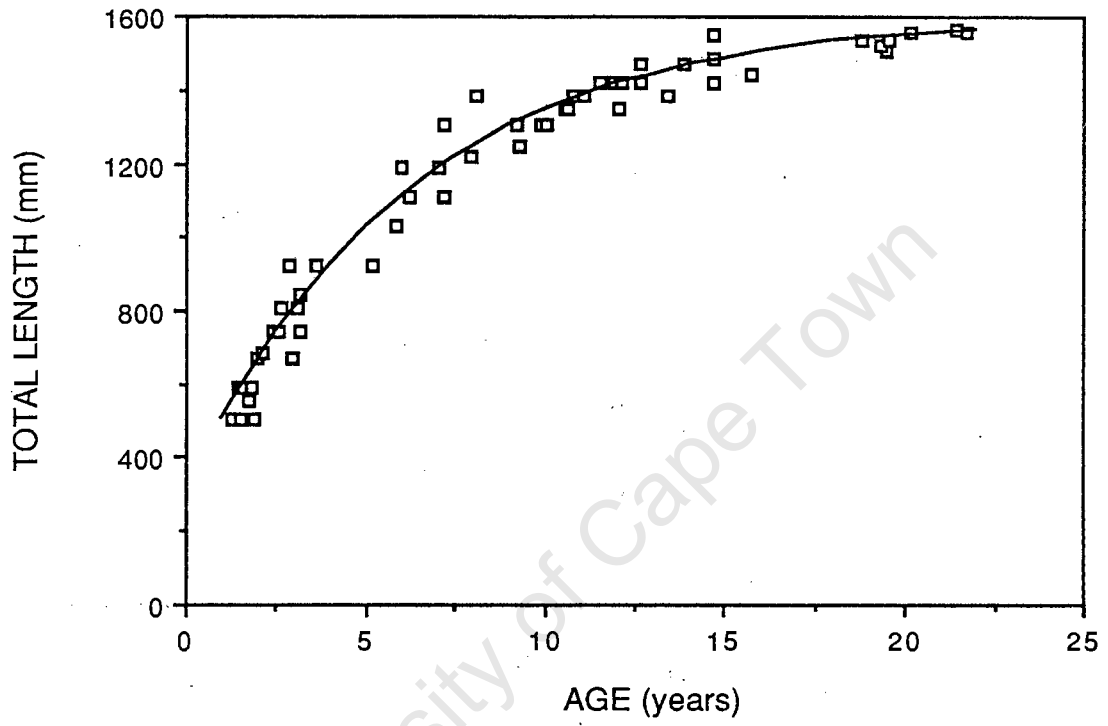
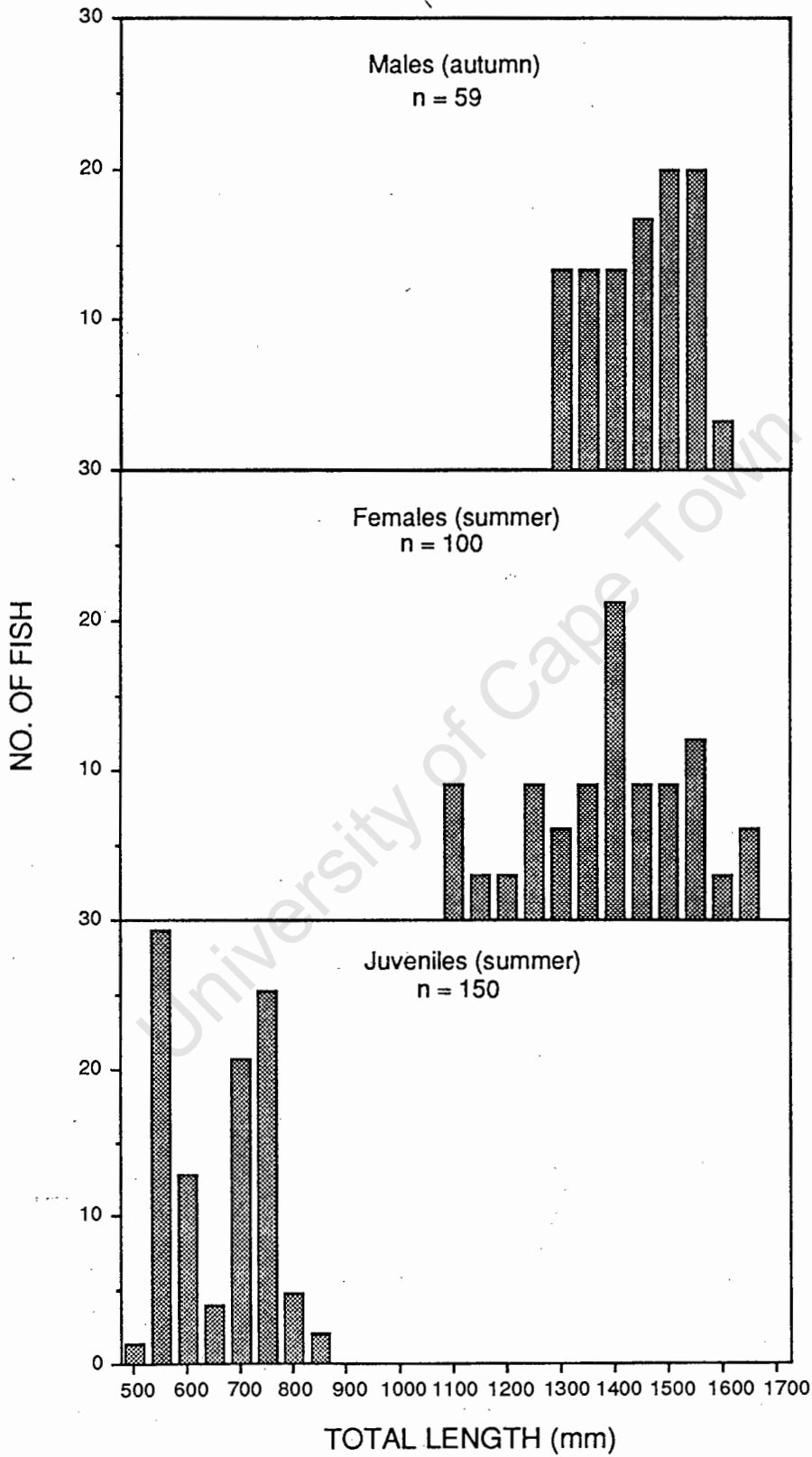
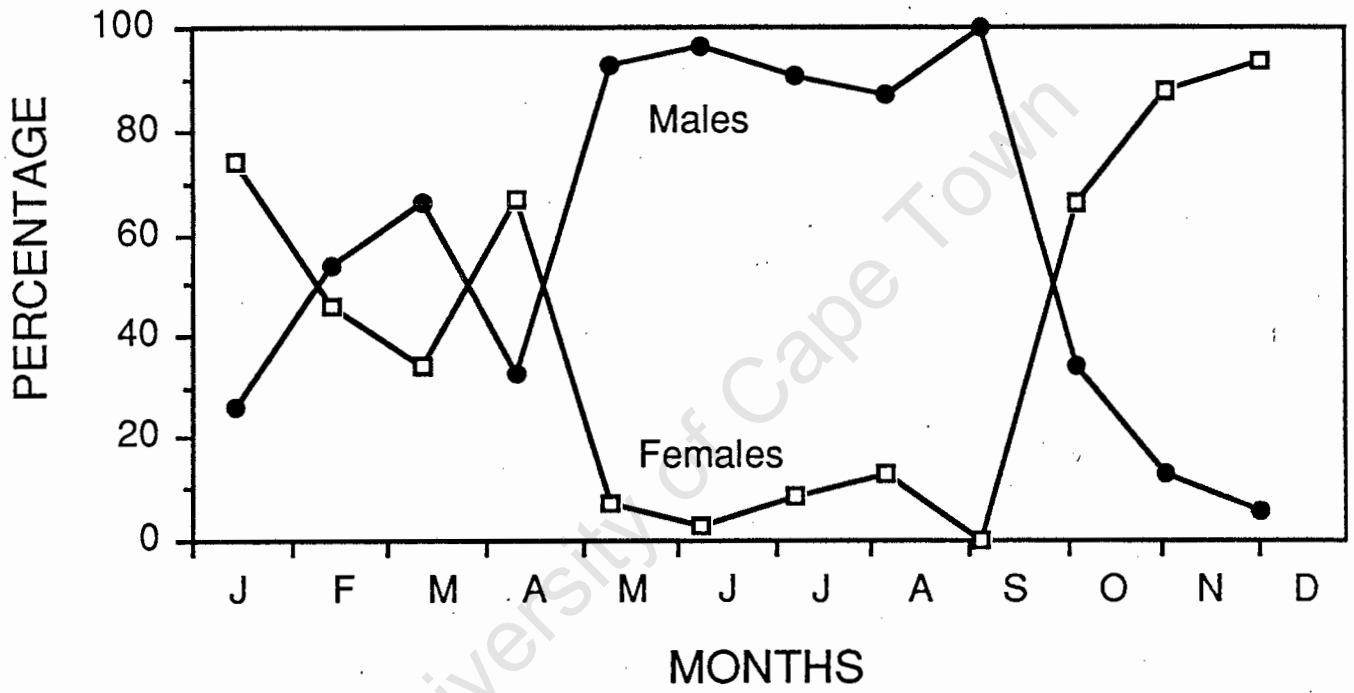


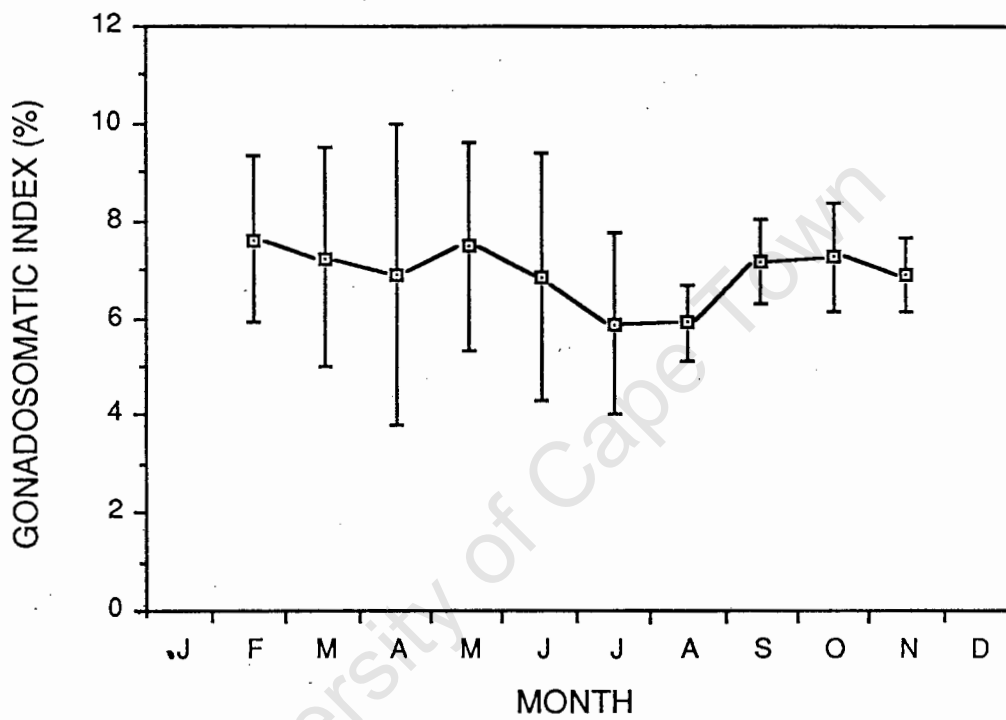
Fig 5

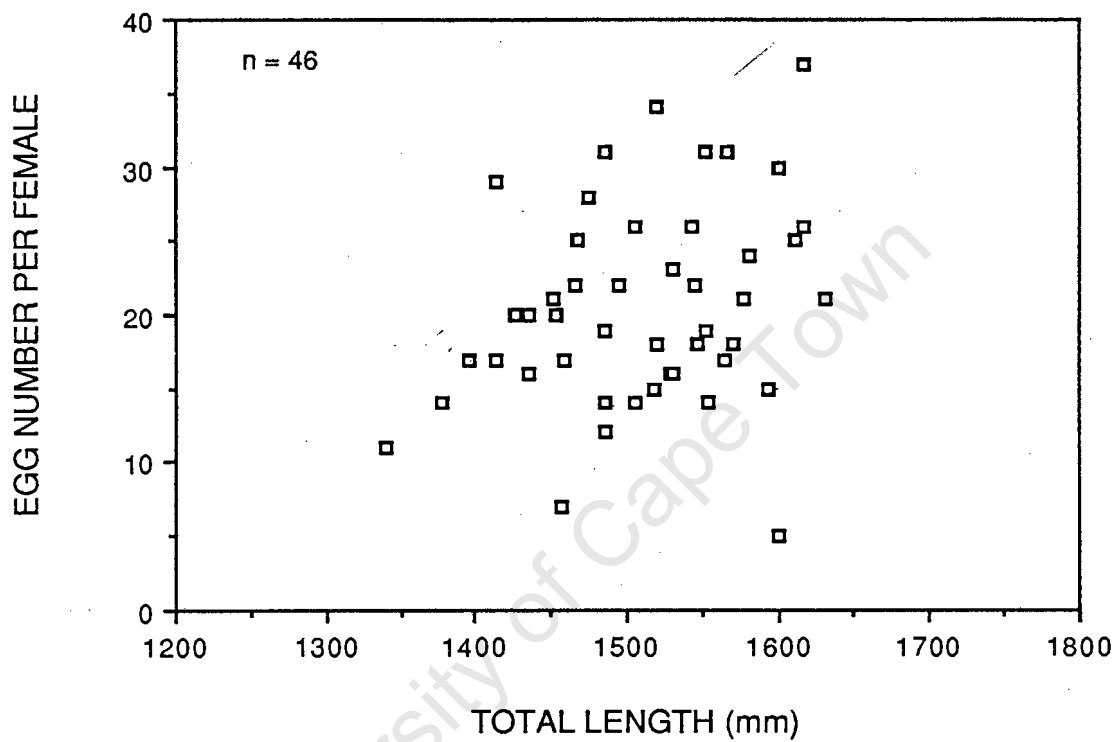


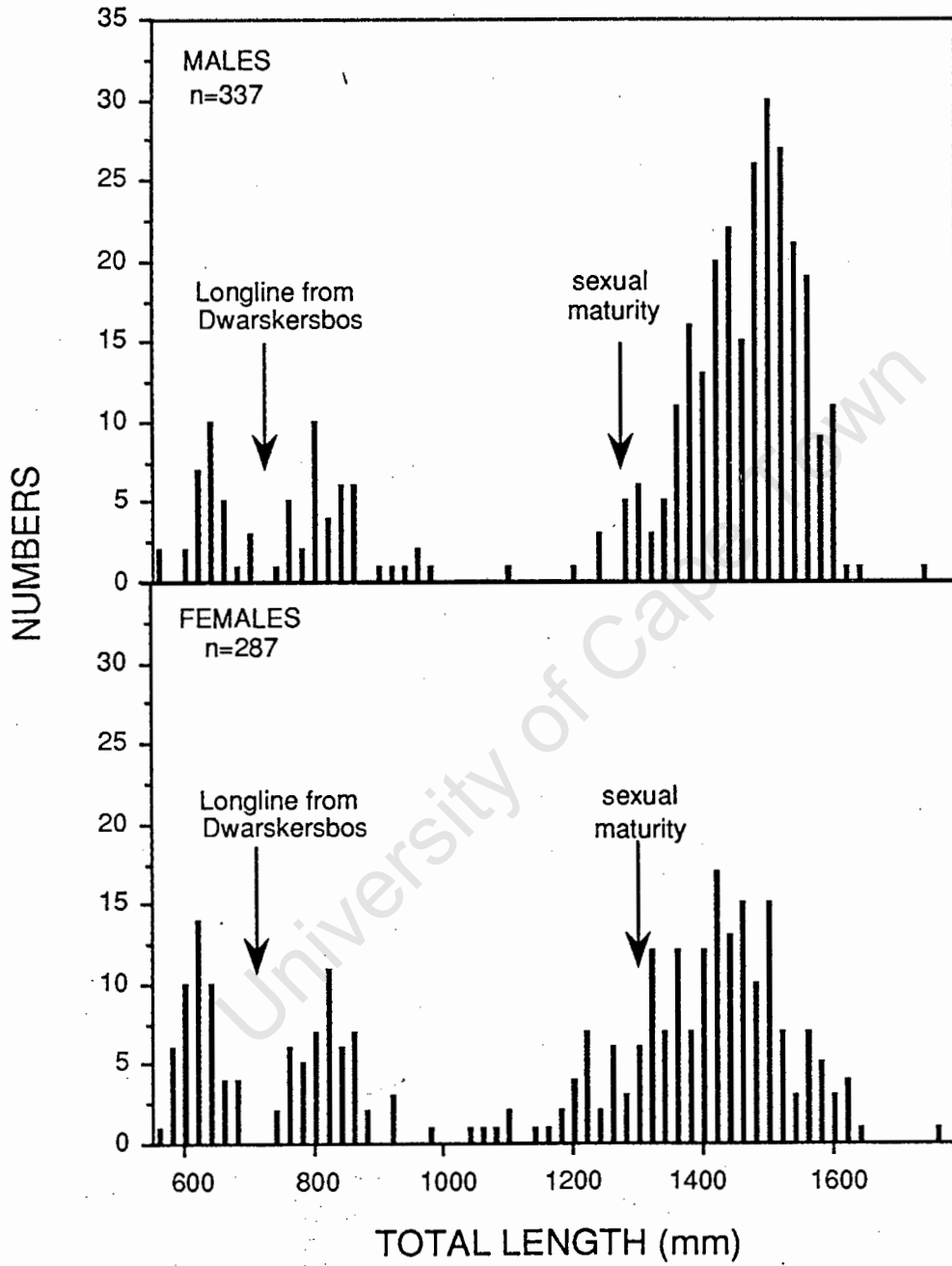
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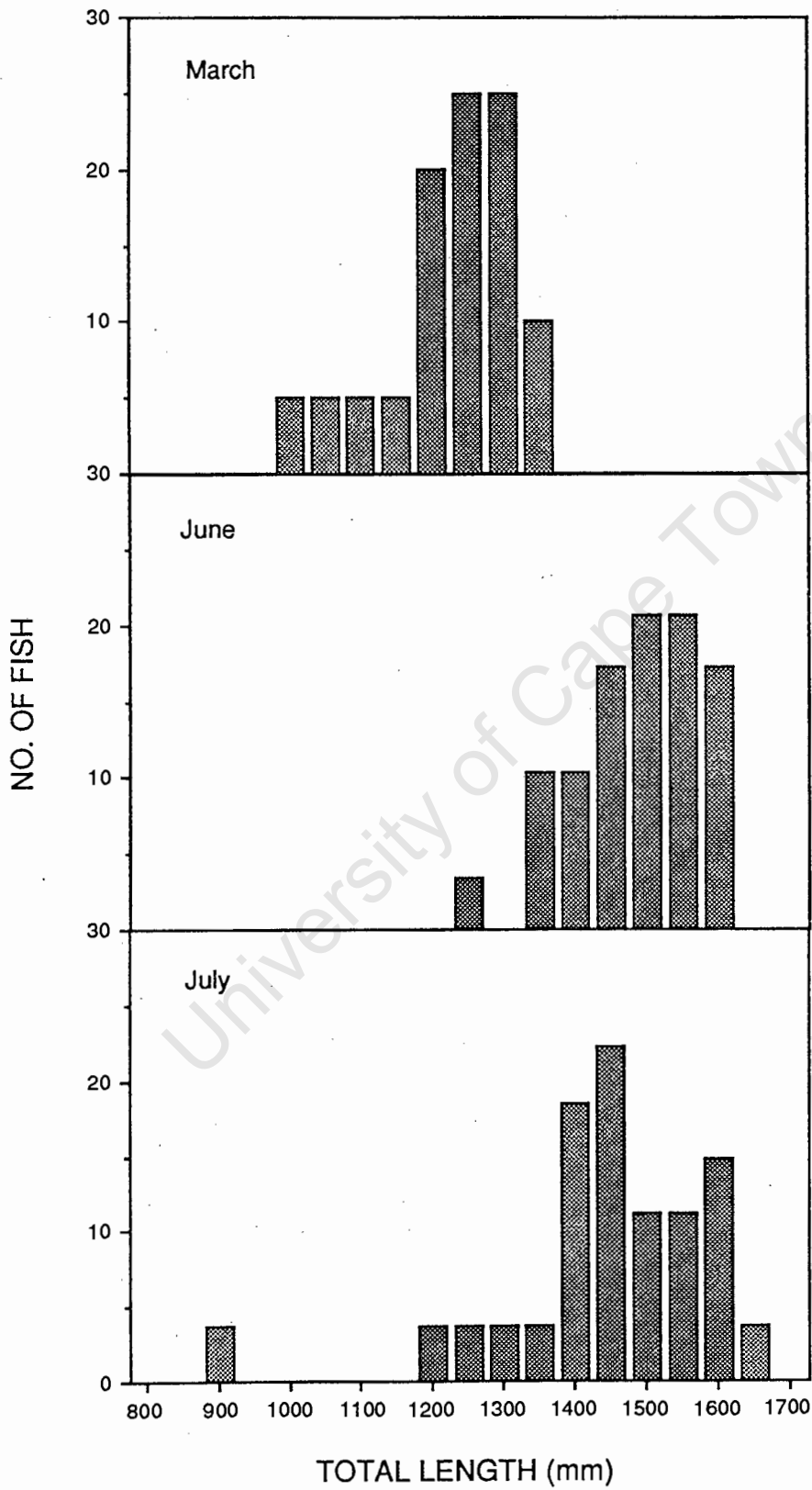


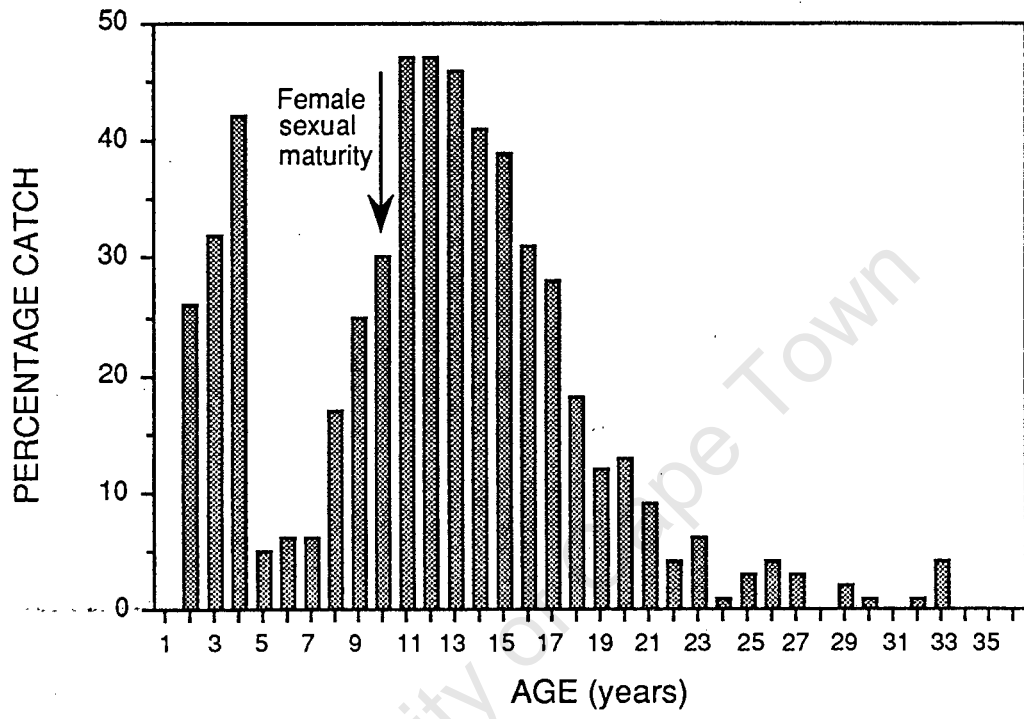












CHAPTER 2

THE FISHERY FOR, AND GENERAL BIOLOGY OF, THE ST. JOSEPH SHARK CALLORHINCHUS CAPENSIS (DUMERIL) IN THE SOUTH WESTERN CAPE, SOUTH AFRICA

ABSTRACT

Callorhynchus capensis are caught by a directed gill net fishery off the western Cape coast and also incidentally in shallow water trawls on both south and west coasts. The fishery only became established in the early 1980's and landings have subsequently stabilised at approximately 800 tons per year, 23 - 33 % of this being as the bycatch of trawling operations, especially out of Mossel Bay. The gill net fishery is centered in St. Helena Bay, and because of restriction to large mesh sizes (178 mm stretched mesh) and specific local conditions, takes very little bycatch. Both trawl and gill operations, however, take place in nursery areas of C. capensis and other shark species.

C. capensis occurs widely off the southern African coast, from 1 - 366 m depth, but large numbers are only caught inshore (<50 m). The depth distribution is affected by sexual maturity, catches of immature fish being limited to shallow waters. Fifty percent sexual maturity occurs at FL 435 mm for males (3,3 y) and 496 mm for females (4,2 y). Post maturity fish have an annual onshore- offshore migration cycle, with the bulk of mature fish aggregating inshore in summer to breed and lay eggs. They then disperse to deep water where unlaidd eggs are resorbed and energy reserves accumulated in the liver. The largest number of viable eggs recorded was 22. C. capensis primarily occur on soft substrata and their diet consists principally of invertebrate associated with soft substrata.

The relatively fast growth, early sexual maturity and reasonably high fecundity of this species make it a safer fisheries target than most other chondrichthyan species. It is alarming, however, that the fishery is restricted to nursery areas.

INTRODUCTION

Callorhinchus species are small sharks of the sub-class Holocephali, distinct from selachian sharks in that the jaw forms an integral part of the skull. They are an apparently primitive group of chondrichthyans which make an early appearance in the fossil record. Their general appearance seems to have undergone little major change since then. The genus Callorhinchus is common on the continental shelves of temperate southern oceans. In South African waters the genus is represented by a single species, Callorhinchus capensis, the St. Joseph shark.

A Callorhinchus fishery is known to exist in South America, although information on catches is not available. C. milii is the target of a large and long-running fishery off the coast of New Zealand (Gorman 1963, Coakley 1971, 1973) although this now appears to be undergoing a decline (Sullivan 1977). The New Zealand catch is principally landed by inshore trawl, with fishing effort being directed mainly at nursery and breeding grounds in sheltered embayments. For the first 15 years of the fishery, reasonably stable landings of 800 -1100 tons were recorded, during which time the fleet was operated out of only a few ports and only took adult fish. The fish were taken on their breeding grounds in summer, when they appeared to exhibit shoaling behaviour, facilitating their capture. The fishery declined when it was extended to wider areas and became a year round activity, turning to juveniles when shoals of breeding adults were not available.

The St. Joseph shark is the most common chondrichthyan landed by seine or gill nets off the S.W.Cape coast of South Africa (Director of Sea Fisheries 1982-1983, Marine Development Branch 1983-1984, Chief Directorate Marine Development 1984-1986). It is also common in demersal trawl catches (Sea Fisheries Research Institute unpublished records 1983-1987). Despite this, very little is known of its

biology, or of the exact nature and composition of the catches. Accordingly, it was suggested at a meeting of the Linefish Steering Committee of 1982 that this species receive some attention. As a result the present study was instigated with a view to investigating the general biological background of C.capensis from a fisheries perspective. While specimens of the fish have been reported from as far afield as Natal and Namibia, the principal area of commercial landings is in the S.W. Cape, between Mossel Bay and Elands Bay. These were thus taken as the limits of the study area.

MATERIALS AND METHODS

To obtain data on the fishing methods used to capture C.capensis, and on the geographical distribution of the catches, questionnaires were taken to five major fisheries centres at which landings of St. Joseph sharks were known to be made. Thirty-two permit- holding net fishermen and six processors were visited and questioned. This was supplemented by a review of all available internal records (various processors, principally: B.P. Marine, Uranus Visseryre, Protea Visseryre), unpublished internal records of the Linefish Section of Sea Fisheries Research Institute on the net fishery, and unpublished records of monthly landings by area of the demersal fishery (Demersal Section, Sea Fisheries Research Institute).

Biological material was obtained from commercial catches, largely from Uranus Visserye at Laaiplek, from three of the biannual demersal research cruises of the R.S.Africana and by our own gill netting activities. Gill netting was confined to Saldahna Bay and St. Helena Bay and only took place if no commercial landings had occurred by the end of the third week of any particular month. The gill net was in all respects a standard commercial net of nylon monofilament with a stretched

mesh of 178 mm, a length of 150 m and a fall of 3 m. Some smaller fish were also provided by Mr J.Petty, a commercial seine net operator in False Bay.

The length (total, fork, precaudal, and interdorsal) of each fish was taken on a measuring board with the fish placed on its right side, straightened, with the proboscis bent up against the baseplate of the measuring board (as recommended by Coakley 1973). Girth at the origin of the first dorsal was measured with a tape measure. Mass was taken using Petzl 10 kg or 2,5 kg spring balances. Guts, gonad material, nidamental glands, livers and semen sacs were removed and then preserved in 10 % buffered formalin in sea water, or frozen fresh for laboratory examination.

The fragments of items in gut contents were identified as far as possible, counted, and the volume of each component estimated. As C.capensis has extremely powerful, crushing dentition, with which it reduces prey items to very small fragments (Ribbink 1971), it was not usually possible to weigh or volumetrically assess discrete items individually.

The sexual maturity of each animal was staged according to the scheme shown in Table 1. The egg masses of sexually mature females were weighed, the developing eggs counted, and the diameter of the largest egg measured. The number and mass of unlaidd eggs undergoing resorption was then noted. The mass of the nidamental gland, which becomes engorged before the secretion of shell cases, was also recorded. The mass of the liver provided a further index of reproductive condition, as the liver acts as an energy reserve for breeding fish. The colour and condition of the semen plug, a hard waxy plug of semen retained by the female, was also noted.

In mature male C.capensis the testes and semen sacs were weighed and the colour of the semen in the sacs indexed as an indication of mating time. The mass

of the liver was also recorded, as an indication of reproductive condition and for comparison with the mass of female livers.

RESULTS

HISTORY OF THE FISHERY

C.capensis was considered as a trash fish until relatively recently, the large quantities accidentally caught in seine nets for harder (Liza richardsonii) being either dumped, buried or given away (pers. comm. Mr. Tolken 1988, Mr J. Petty 1989). Thus there are no records of catches prior to 1979. The species gradually became accepted for drying and also, to a limited extent, for the production of frozen fillets from larger fish (pers. comm. Mr A. Smit 1987, Mr B. Pedro 1987). The first mention of tonnages landed was in 1979 when a catch of 587 tons of a combination of "shark and St. Joseph" by the demersal fleet was recorded (Director of Sea Fisheries 1982). The first gill net catches recorded are of 263 tons in 1981 as a bycatch of the drift and seine net fishery (Director of Sea Fisheries 1983). Thereafter reported landings increased dramatically up to 1983, but have now stabilised in the region of 700-900 tons per year (Fig.1).

In 1982 all gill net permits were cancelled, but it was possible to exchange these for "shark net permits", in other words, for gill nets of 178 mm stretched mesh, intended for the catching of St. Joseph sharks only. To the fishermen involved in the net fishery on the west coast, this species is now of some importance, although it is less financially lucrative than harder netting in which seine nets are pulled up onto the beach. Gill netting for sharks largely occurs within the environs of St. Helena Bay, where 80,2 % of all net permits are held. As of 1991 there were 694 potential or licensed shark nets. However, only some 55 of these were in fact in

use. (Pers. comm. C. Wilke, SFRI 1992). No one person may hold more than four of these net permits and nets may not be set within 500 m of the high tide mark.

The standard gear used is 178 mm stretched mesh knotted monofilament nylon net, with a fall of 3 m and a total length of not more than 150 m. The nets are bottom set and are anchored and buoyed at both ends. Float to lead ratio is approximately 1:3. Set times are very short, in the region of 20 - 30 mins per set. If the nets are set for a longer time, isopods (Eurydice longicornis) tend to devour any fish taken. Vessels used range from small dingies (3-5 m) with single outboard engines and a set of oars to small fishing boats (5-8 m) with diesel inboard engines. These vessels usually carry about four nets each. Crew are usually two or at most three fishermen. The amount of effort directed at C.capensis depends on the availability of harder as an alternative and more lucrative target species. The filling of anchovy quotas by the purse seine fishery also releases more fishermen into the C.capensis fishery.

Operations usually take place in very shallow water of one to four fathoms. All net sets occur during daylight, the boats normally all being in by 14h00. This allows the processors to handle the catch on the same day. The initial sets of the day are usually made in four separate directions, forming a box of net. This determines the direction in which the fish are moving, and thereafter the nets are set across this direction. The best setting sites are determined by wind speed and direction (the best areas in strong winds being in the lee, but in light winds being on the windward side of the bay), water colour (ideally murky), and the presence of seals (which is considered indicative of fish). However, seals can also be so destructive to the catch and the nets that fishermen are forced to move. While few use fish finders or echo sounders, the local fishermen have an extensive knowledge of the underwater topography of their areas, which undoubtedly plays a very significant role in site selection.

C.capensis catches are usually spread out irregularly along the net, rather than occurring in aggregations. Most C.capensis are caught on or near the lead line and are very seldom gilled, but usually tangled in the net, often by the dorsal spine, or the tentaculum in the case of mature males. Unless attacked by seals, other sharks or isopods, the caught sharks are alive and usually in good condition when the net is lifted. The catch of C.capensis in a specific area consists largely of one sex and of a narrow size range.

Catch Composition

The overall catch in these gill nets comprises 98 % chondrichthyan species, including small Isurus oxyrinchus, Mustelus palumbes, Notorynchus cepedianus, Rhinobatos annulatus and Myliobatis aquila. The rays and sandsharks are returned live to the water and the sharks kept for sale. The proportion of landed catch by mass which is not C.capensis varies greatly but averaged 12,7 % and never exceeded 19 % in 16 samples from Laaiplek (each comprising the total day catch of a single vessel).

Small C.capensis (<250 mm FL.) are also usually returned and appear to swim off without difficulty. Personal experience shows very small numbers of bony fish to be caught in short daylight sets. Two species which are occasionally taken are Chelidonichthys capensis (Cape gurnard), and small Merluccius capensis (shallow water hake). The relative proportions of these species taken by gill operations in St. Helena Bay are shown in Fig. 2 and compared to a catch taken in the same area by demersal trawl by the R.S. Africana. The depth of the gill sets was approximately 10 m and the average trawl depth 39 m. Callorhynchus capensis makes up the main part of both catches, but gill netting is less effective in catching hake and gurnard, and more effective at catching larger sharks, which may be attracted to the gill nets by the struggles of other fish. Mesh size is also a major factor, several of

the 13 species landed by trawl being too small to become entangled in a 178 mm gill net. However, gill net avoidance, or depth preferences, must also play a role, as approximately 60 % of the gurnard caught by trawl were of a suitable size to be gilled.

The size composition of C.capensis caught in gill and trawl fisheries within the same area are compared in Fig. 3. What is clear from these diagrams is the lower proportion of smaller fish recovered in the gill net catch relative to the trawl fishery. This could be attributed to three factors (i) the smaller mesh size of trawl nets (ii) the active fishing of the trawl as opposed to the passive set of gill nets (in the latter net avoidance may greatly alter the catch composition, whereas trawling actively sweeps fish into the net bag), or (iii) minor differences in water depth or substratum preferences.

Selective targetting by gill netting (both as a function of the fishermen and the gear) made the assessment of size composition and sex ratios in the catch an unreliable estimator of true population parameters. However, an indication was obtained of which population sectors the fishery would effect.

Stage 1 or newborn (Table 1) fish (in which the yolk slit was still visible) were only caught in beach seines, probably indicating that newly hatched C.capensis are confined to very shallow water. The smallest fish taken was from a beach seine at Macassar, False Bay, and had a FL of 162 mm.

Stage 2 or immature fish (showing no development of secondary sexual characteristics) fell into the size range ca 250 - 380 mm FL in males, and ca 250 - 400 mm FL in females. The length frequency data presented in Fig. 3 suggests that this section of the population is not yet fully recruited into the gill net fishery, in spite of its abundance.

Stage 3 fish with developing sexual characteristics were 385 - 440 mm FL in males and 405 - 485 mm FL in females. These formed a high proportion of the catch because they are more available to shallow water gill net operations in winter.

Stage 4 fish are a more important part of the catch in summer, when large females move inshore to breed and this may influence the sex ratio of catches (Fig 4). Males and females seem to occur in largely discrete aggregations, and these mature female fish are deliberately targeted. They are generally larger and easier to remove from the gill net, facilitating quicker handling and thus larger day catches. The tentaculum of late stage 3 and stage 4 males greatly increases the catchability of these fish as it tangles very easily in the net, but also slows handling as they are more difficult to remove from the net.

All fish are landed whole. None of the chondrichthyan catch appears to be sold informally, as there is no local market for it.

DEMERSAL TRAWL

Considerable landings of Callorhinchus capensis are also made by the demersal trawl industry, as shown in Table 2. Much of this is taken by sole-directed effort in shallow embayments, particularly on the east coast, between Cape Agulhas and Mossel Bay.

The total annual trawl catch from 1983 - 1985 averaged 222 tons, with an average of 17,5 % (39,7 ton) coming from Grid Square references 34°S 21°E, and 16,4 % (36 ton) from the adjoining 34°S 20°E. St. Helena Bay, the centre of gill net effort, reported relatively low catches and a low catch per unit effort (CPUE). However, in this case CPUE is not an accurate assessment of abundance as effort is not

directed at C.capensis. The area east of Mossel Bay receives increasingly less trawl effort, and no gill net effort. It is this area, however, that reports the highest trawl CPUE for C.capensis. Thus, it is evident that C.capensis, representing between 0,13- 0,3 % of the total annual trawl catch, is of minor importance in the overall trawl fishery. But, as the total demersal fishery is so large, C.capensis landings are significant relative to the gill net fishery and hence may affect fishermen in the gill net industry immensely.

Trawled C.capensis are landed headed, definned and gutted, with external sexual organs removed. This makes assessment of the catch difficult.

DISTRIBUTION

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The distribution of C.capensis extends from Natal, where it is rare (Van der Elst 1988) to at least extreme northern Namibia (17°44'S, 11°44'E) (pers comm. L.J.V. Compagno, South African Museum, 1992). The range may also extend into Angolan waters although no confirmed records are available from this area. The species appears almost ubiquitous on soft substrata in depths of up to 366 m, occurring less frequently as depth increases. Table 3 clearly shows the reduction in probability of finding C.capensis in trawl samples taken at increasing depths. The size composition data from the same samples (Fig 5) further shows that population structure changes with depth, with juveniles being restricted to inshore areas, while Fig. 6 illustrates that total population density is also inversely proportional to depth.

At depth greater than 150 m, there were rarely more than 1-3 C.capensis per trawl sample, but all were sexually mature. Only female fish were found below 250 m.

HABITAT REQUIREMENTS

Our knowledge of the habitat preferences of C.capensis was largely garnered from our own experience with gill netting, as well as by observation of commercial sets. From recordings of the conditions, total catches, and bycatches of 111 gill net sets, the following conclusions were reached: Firstly, that C.capensis has a marked preference for low sea activity areas, usually with soft substrata. Secondly, that it was more active at night than by day. Thirdly, it preferred cold, murky water. All fishermen reported that C.capensis was never caught in fresh or brackish water.

STOMACH CONTENTS

Gut content analysis show this species to feed on benthic invertebrates from soft substrata. Table 4 indicates the proportions of major prey categories in the stomachs of 841 fish examined. Identifications of species and habitats were made using Day (1969) and Branch and Branch (1981), as well as by comparison to material in grabs and dredges from the main fishing areas.

The bulk of material in the gut content samples was obtained from commercial gill net catches in St. Helena Bay, a limited area where a large part of the catch consists of juvenile fish. Gut contents from any single catch from any area were remarkably uniform. For instance stomachs of all 41 C.capensis taken in one demersal trawl contained remains of stomatopods only, while in another the stomachs of all but one of 22 fish contained only the remains of the fish Sufflogobius bibarbatatus and Maurollicus muelleri.

PARASITES

In all but five of the C.capensis examined, the unusual cestode parasite, Gyrocotyte plana, (Linton 1924) was found. Most commonly (94 %) two parasites were found per stomach regardless of the size of the fish. No other macroscopic internal parasites were observed. Only one skin parasite, a copepod adhering to the edge of a wound, was recorded. As external fish parasites are relatively common on the other elasmobranchs in the catches, it would seem that the mucus of C.capensis must provide effective protection against them.

REPRODUCTION

C.capensis males develop three distinct secondary sexual characteristics, in the following order:

- (i) The claspers, at first barely visible protruberances (ca 2 mm) on the inner margin of the pelvic fin, eventually develop to a mean length of 89 mm.
- (ii) Two pre-pelvic grappers or tentacula develop.
- (iii) A frontal tentaculum erupts from the middle of the forehead and becomes armoured with denticles. The hardening of these denticles coincides with the onset of sexual maturity at ca 435 mm FL.

Internal male reproductive organs comprise paired testes, yellowish - white kidney shaped organs which increase in mass from <3 g in immature fish to a mean of 15,4 g each (range 6,7-53,8g) in mature fish. The change from stage 3 to stage 4 in the population is abrupt, within 15 mm FL. The wide range of testis mass, depended on both fish size and the stage of seminal ripeness, reaching a maximum mass just before the semen sacs begin to become engorged.

The testes are joined by a convoluted epididymus to paired seminal vesicles or semen sacs. Semen is discharged from these sacs through a common sinus. The mass of the semen sacs is inversely related to that of the testes. Sperm is retained in spermatophores, which are approximately 1 mm in diameter and are easily visible in the forest green gelatinous matrix of semen. The semen appears to harden and thicken to some extent on contact with sea water.

The smallest sexually mature male had a FL of 429 mm, corresponding to a calculated age of 3,17 years. Attainment of 50 % sexual maturity occurs by 435 mm with a calculated age of 3,3 years (Freer and Griffiths, 1993). A monthly gonosomatic index of the combined mass of the testes and semen sacs is depicted in Fig. 7 and shows that the peak of mating occurs over an extended period in summer. A few fish with full or partially full semen sacs were found throughout the year.

Females do not develop external sexual characteristics. The only external signs of sexual maturity are an increase in the scatter of the girth to body length relationship. There is certainly no sign of the massive increase in girth reported for *C. milli* by Gorman (1963). Another indicator is the presence of seminal plugs in almost all sexually mature females in inshore waters. Internally, the Stage 2 / Stage 3 transition is marked by the development of the nidamental gland. The paired ovaries also develop from a weight of less than 1g up to a maximum of 140 g each. In four of 841 fish examined one of the ovaries failed to develop. Paired oviducts pass ova down to the nidamental glands, where each egg is inserted into a partially secreted leathery egg case. The secretion of this large egg case (about 180 mm long) may limit the number of eggs laid in any one season. Before the onset of sexual maturity it is difficult to find the nidamental gland, but in sexually mature females it has a mean mass of 29,4 g and can weigh up to 80 g. Two eggs are then

passed into separate uteri (or extended oviducts), which shape the egg case and then out of a common urogenital sinus. The plug of semen must, however, first either be removed or lost. The egg case is an elongate oval with a central swelling containing the egg surrounded by a broad laminar frill which is smooth on one surface and "hairy" on the other (Fig. 8). There are no structures to attach it to weed or to the substratum. As the chosen reproductive areas are open sands and muds in low wave activity areas perhaps attachment is either impractical or unnecessary. It is assumed that if the "hairy" face is upward then the convex structure of the egg case will keep it on the bottom. However, unless the egg case is actually buried in the substratum in some way, it is hard to see how it could not be washed out during gestation. Repeated attempts to dredge up an egg case failed, and thus information on their distribution was not obtained. Stranded egg cases were, however, noted at Fishhoek, Blouberg Strand and Dwarskersbos in fairly large numbers. Some of these had been dislodged during storms and contained partially developed embryos in an advanced stage of decomposition. Several live egg cases were also recorded in the nets of trek-net fishermen in False Bay.

The semen plug begins as a hard, slightly translucent, dark green, waxlike substance, then undergoes a serial colour change, becoming paler green and eventually lemon yellow. The actual time span involved is impossible to determine, as not all females are fertilised simultaneously. The maximum viable egg diameter recorded was 35 mm. When eggs are near this stage the semen plug is custard yellow, and has become a great deal softer and is no longer translucent, but opaque and reduced in size. At any stage of summer plugs in different stages of development can be found. This, along with the gonosomatic index of males, indicates that the mating season is protracted. Mating may possibly occur more than once in a season. Sexual maturity is reached at a minimum length of 464 mm FL (calculated 3,58 years), and 50 % sexual maturity is attained at 496 mm (calculated at 4,2 years.) The largest fish in this study was 900 mm FL, and at least

12 years old as estimated by spine section readings (almost certainly an underestimate). This implies that the reproductive life of this species may extend to at least seven years. The maximum egg number of females increases rapidly with age (Fig. 9), reaching an apparent ceiling at ca 22 eggs. Further increase in egg number may be constrained by the physiological problems associated with producing large eggs and large egg cases.

Seasonal changes in the gonosomatic index of females (calculated by dividing ovary mass by body mass) are shown in Figure 10. Some part of the mature population was reproductively active throughout the year, but a reproductive peak was reached in summer. The highest proportion of mature females carrying eggs being resorbed was observed in the winter months. These fish almost never had semen plugs. If plugs were found they were fresh, and eggs were in the final stages of resorption.

The relationships between liver mass and body mass and between nidamental gland and body mass were analysed in a similar fashion. The liver becomes engorged after mature females move into deeper water. At this stage ova are small (ca 2mm diameter) and unlaid eggs are being resorbed (present as ca 35-52 mm diameter watery eggs or shrivelled yolk remains). None of the fish in deep water have semen plugs. After the females return to shallow water, the eggs begin to develop and the mass of the liver is correspondingly reduced (Fig. 11). The nidamental glands then become engorged to secrete the egg case. The gland presumably returns to normal size quite soon after the egg case is secreted. Only a statistically insignificant drop in the mean mass of the nidamental gland occurs in February and March, but the variability in mass in these months is extreme. The pattern thus developed is shown in Fig. 12. By combining the information on depth distribution (Figs 5-6) and Figs 9-12, the female reproductive pattern can be inferred, as shown in Fig.13. The main features of this cycle are for adult females

to migrate into deeper waters during winter, where they disperse to feed and build up body reserves. During summer these fish aggregate in shallow embayments, where egg laying takes place.

MORTALITY

Predators known to take C.capensis include Cape fur seals, which can frequently be seen attacking this species in nets, and various larger shark species. C.capensis has been positively identified in the gut contents of Carcharinus brachyurus, Notorynchus cepedianus, and Galeorhinus galeus during the course of this study. Ebert (1989) has also recorded C. capensis in the diet of the bull shark, Hexanchus griseus.

DISCUSSION

The inshore migratory behaviour of C.capensis results in high concentrations of fish on the nursery areas, which lie in shallow sheltered bays. It is these concentrations that make the fish a worthwhile specific target, but they also make it vulnerable to overexploitation. If St. Helena Bay is the optimum area and centre for C.capensis breeding, the population could be greatly reduced before the fishery became adversely affected. More information is needed on the size and catch composition in other bays outside the main gill net fishery. However R.S. Africana trawl data and internal records of landings per grid square of Sea Fisheries Demersal Section seem to indicate that other nursery areas do exist. It is thus probable that the gill net fishery is restricted by relatively easy operating conditions, rather than being based on the optimum nursery area.

It is relevant that the New Zealand fishery for C.milii remained stable until there was a large increase in fishing area and a reduction in the acceptable minimum size of fish (Coakley 1971, 1973, Sullivan 1977). Certain parts of the inshore embayments at the centre of their fishery (and main breeding grounds) are now completely protected. This, in theory, should increase recruitment. It is notable that the New Zealand fishery is principally an inshore trawl operation. Gill netting is a minor seasonal facet. Trawling does take a far broader cross-section of the population, as it is not size selective. It may also severely disturb bottom sediments on which the eggs may be laid.

Gill netting is currently extremely unpopular with the South African public because of the extensive publicity given to the damage caused by tuna gill netting. However, with the restrictive conditions of short set times, and the large mesh size used for gill netting for C.capensis this method must be considered infinitely less damaging to the stocks and grounds than a trawling operation would be.

The regulation prohibiting gill net sets within 500 m of the shore is ineffectual and virtually impossible to enforce. Fishermen find it a source of considerable resentment and it is frequently disregarded. In spite of this it should be retained as it does prevent the clash between recreational and commercial interests. In addition the legislation largely precludes the use of gill nets in turbulent water in and around the surf zone. There is little chance of effective targetting on C.capensis in this area. As evident from our night sets, in conditions of poor visibility, gill nets fish more effectively and a great deal less selectively. Therefore excluding them from this area probably prevents a great deal of abuse of net permits.

From the fisheries point of view it is apparent that the dietary requirements of C.capensis are extremely catholic and unlikely to limit the distribution or numbers of

fish in any way. The diet is, however, definitely biased toward soft substratum invertebrates dwelling in open mud or sand areas, which the species is morphologically well adapted to exploit (Ribbink 1971). It is notable that these are also the areas in which both trawl and gill netting operations usually occur. Ophiuroids and black mussels (Choromytilus meridionalis and Mytilus galloprovincialis) are both hard substratum organisms which were occasionally found and may indicate that the diet described here merely reflects the area of capture, rather than the actual dietary range of the fish.

The diet has two implications for the fishery. Firstly, bioaccumulated mercury levels are not likely to be as high as in primarily ichthyophagous sharks. Secondly the species is potentially a good vector for returning disease organisms and industrial heavy metal pollutants to man (Glover 1979, Forrester et al 1972, Walker 1976). The vector for the gyrocotylid parasite found in all C.capensis stomachs must be an extremely common diet item, but has not been identified.

Sexual maturity is reached at a relatively early age and fecundity is relatively high compared to other chondrichthyan target species. This overcomes some of the problems cited by Holden (1974), which limit chondrichthyan fisheries. In addition the depth/distribution ensures that juveniles are less likely to be taken by trawl, while at the same time they are rejected by the gill net fishery. None-the-less the operation of a trawl fishery in the nursery areas has serious implications as the catch of reproductively immature fish is high and disturbance of eggs could be considerable. Even if juveniles are returned to the water, the mechanical damage to the fish by long trawl periods, abrasion and handling reduce their chances of survival.

The eggs of C.milii have incubation periods of ten months (Coakley 1971), while an incubation time of 9-12 months has been reported for the chimera, Hydrolagus

colliei (Johnson and Horton 1972). It would be logical to assume that the eggs of the morphologically very similar C.capensis have a similarly long incubation period. C.capensis is reproductively active throughout the year, with a distinct peak in summer and thus egg cases in some stage of development must always be present. This strategy is relatively widespread among oviparous chondrichthyans in temperate waters (Wourms 1977). A similar situation occurs with Hydrolagus colliei, with the peak being in late summer and fall (Dean 1906 in Wourms 1977). The reported "breeding migration" of C.milii occurs in summer (Coakley 1971, 1973). This would coincide with the inshore aggregation of the peak breeding season of C.capensis. This is unlike the other major shark species taken by local fisheries, where a clearly defined breeding season can be identified and possible protection offered during this period e.g. Galeorhinus galeus (Olsen 1984), Squalus acanthias (Holden and Meadows 1962) and Mustelus species (Griffiths and Freer, 1993).

The function of the semen plug remains unclear. Attempts to activate the spermatophores embedded in it by mechanically opening them failed. Similarly application of weak acid or alkaline solution or fluid from the oviduct of a fresh-killed female had no effect. If viable sperm exists within the spermatophores embedded in the plug, control of their release must be achieved by an as yet unknown hormonal or enzymatic system. Sexually mature males in reproductively active condition occur inshore, therefore semen storage would seem redundant. Sperm storage has been reported for various Chondrichthyan species (Richards et al 1963 in Wourms 1977) although evidence for it in the only holocephalian species (Hydrolagus colliei) examined was inconclusive (Stanley 1963). A slow release of semen would suit the serial egg development necessitated by the large egg cases of this species.

The large eggs and long incubation of C.capensis ensure that the precocial juveniles are less subject to the juvenile mortality than most fish. However, C.capensis seems to be a diet item of most of the larger shark species examined, and is certainly frequently eaten by Cape fur seals.

ACKNOWLEDGEMENTS

Financial support for this program was provided via the Sea Fisheries Fund (SEFREF) of the Sea Fisheries Research Institute. Our thanks go particularly to Mr. A. Smit of Uranus Visserye, Mr B. Pedro of B.P.Marine, and the various members of WP Light tackle Boat Angling Club for their help and interest in this programme. Sea Fisheries Research Institute kindly provided otherwise unavailable specimens from deeper water from their demersal research programmes. The help of their staff, in terms of both logistic support and advice, were invaluable. Sandy Tolosana and Jillian Villacastin kindly assisted with preparation of the final manuscript and figures. Finally, most thanks go to Barbara Freer for her help at all the stages of this project.

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LEGENDS TO TABLES

- Table 1: Definitions of stages of sexual maturity in C.capensis
- Table 2: The percentage of C.capensis in the landings by the demersal trawl fleet and the percentage of total C.capensis landings by this method.
- Table 3: C. capensis percentage occurrence in trawl samples. (*R.S. Africana* demersal trawl records, cruises 065 - 067)
- Table 4: Diet of C.capensis based on analysis of 841 stomach contents.

TABLE 1

STAGE	DESCRIPTION	NAME
1.	Yolk sac slit still visible	Newborn
2.	Immature	Juvenile
3.	Secondary sexual characteristics developing	Adolescent
4.	Potentially reproductively mature	Adult

TABLE 2

Year	Percentage of total trawl landings by mass	Percentage of total <i>C. capensis</i> catch taken by trawl
1983	0,3	23,0
1984	0,13	32,0
1985	0,22	33,0
1987	0,2	30,9

TABLE 3

Depth range	0-99 m	100-199 m	200-299 m	300-399 m
Percent occurrence	86	59	36	14

TABLE 4

	Bivalves	Gastropods	Crustaceans	Polychaetes	Fish
% by no.	39,2	4,65	52,8	2,42	0,9
% vol.	45,5	5,28	44,9	2,00	2,27
most freq species	<i>Phaxas decipens</i>	<i>Nassarius speciosus</i>	<i>Iphnoe sp.</i>	-	<i>Engraulis japonicus</i>

LEGENDS TO FIGURES

- Fig.1: Reported landings of C.capensis from 1981-1988, compiled from annual reports of: Director of Sea Fisheries (1982-1983), Marine Development Branch (1983-1984), Chief Directorate Marine Development (1984-1986), unpublished records held by Sea Fisheries Research Institute and various processors internal records. Only catches which could be established as being solely C.capensis are reflected.
- Fig 2: Comparison of species composition of trawl and gill net catches made off Sandy Point, St. Helena Bay. Based on the mass proportions of the day catch of one gill net vessel (830 kg) and of the total catch of a single 30 minute trawl by R.S. Africana (1525 kg).
- Fig 3: Comparison of the size composition of trawled and gill netted catches of C.capensis off Sandy Point, St. Helena Bay. Trawl n = 368, Gill n = 210.
- Fig. 4: Monthly fluctuations in the sex ratio of C.capensis in gill net catches.
- Fig. 5: Numerical and size distribution of C.capensis as affected by depth.
- Fig. 6: Percentage of total catch and mass of catch at depth for C. capensis catches from R.S. Africana cruises 065 and 066.
- Fig. 7: Mean monthly gonadosomatic index of mature male C.capensis. Gonadosomatic indices were calculated by dividing the sum of testes and semen sac mass by the mass of the fish. Upper and lower 95% confidence limits are indicated.

Fig. 8: Egg case of C.capensis.

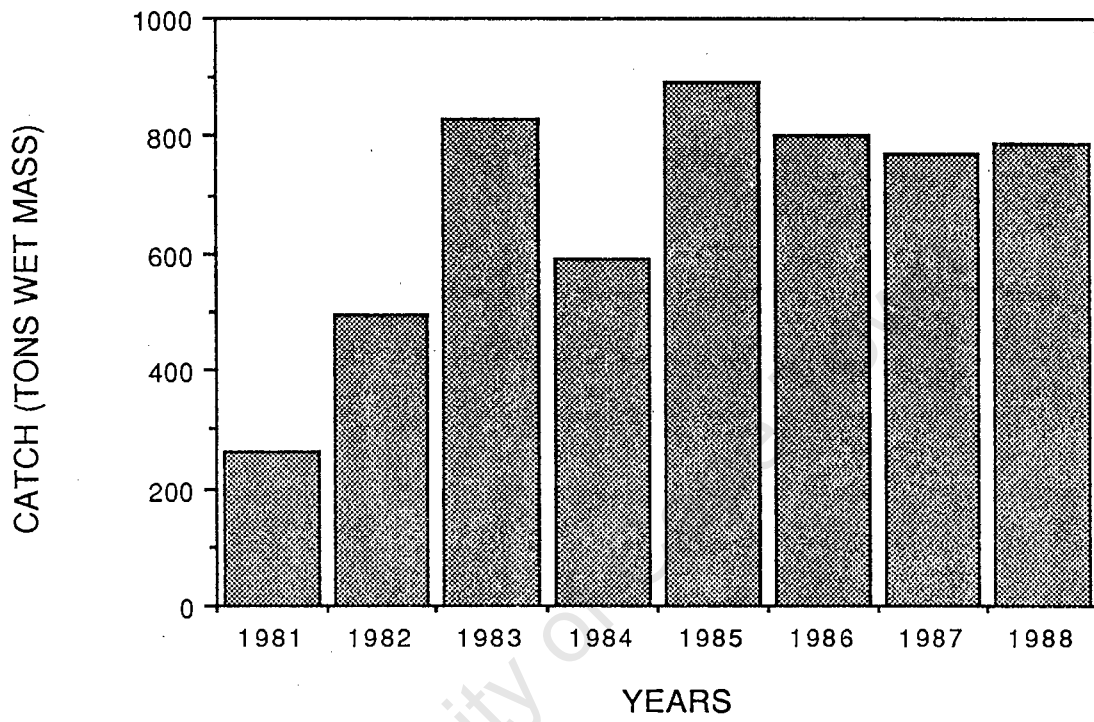
Fig. 9: The relationship of age to maximum egg number. Maximum egg number was established by extracting the highest number recorded in each half year class.

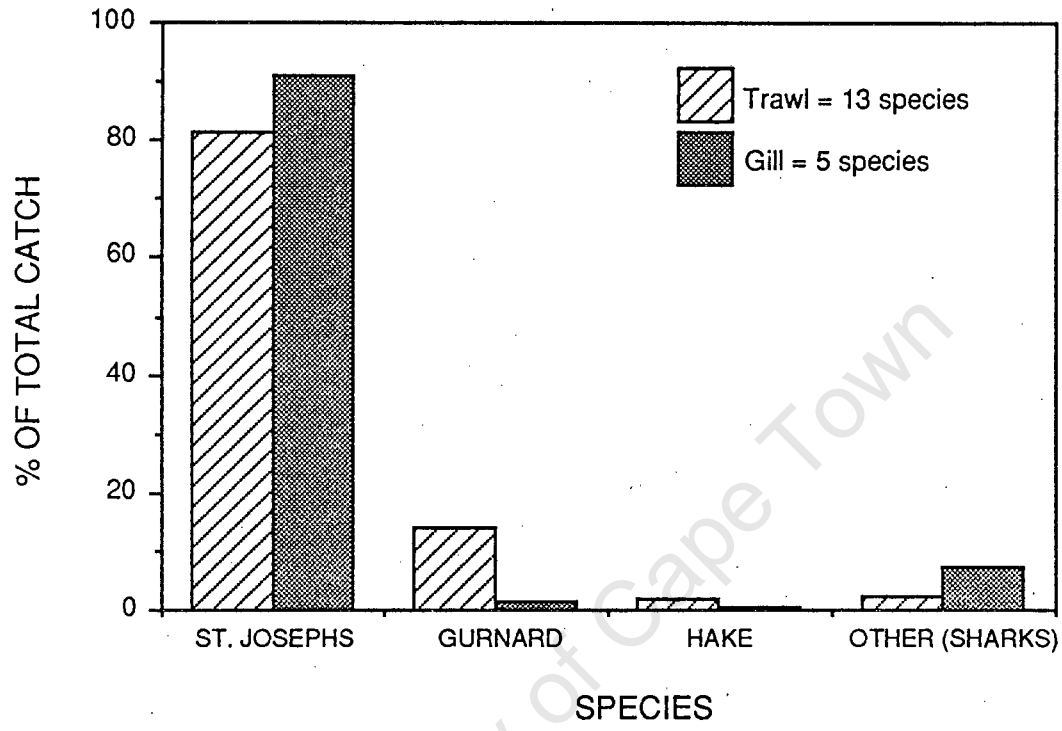
Fig. 10: Mean monthly gonosomatic indices of reproductively mature female C.capensis and upper and lower 95 % confidence limits.

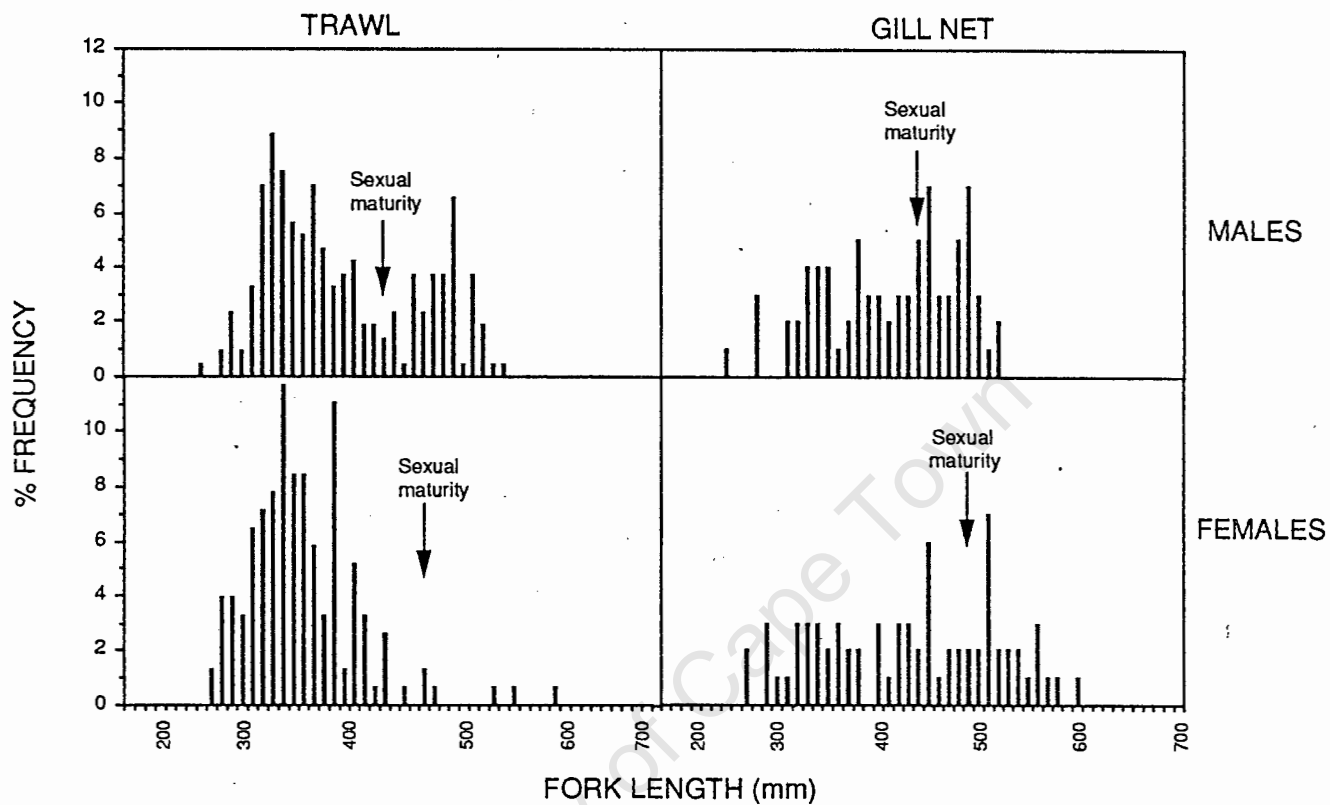
Fig. 11: Mean monthly liver mass/body mass proportions of reproductively mature female C.capensis and upper and lower 95 % confidence limits.

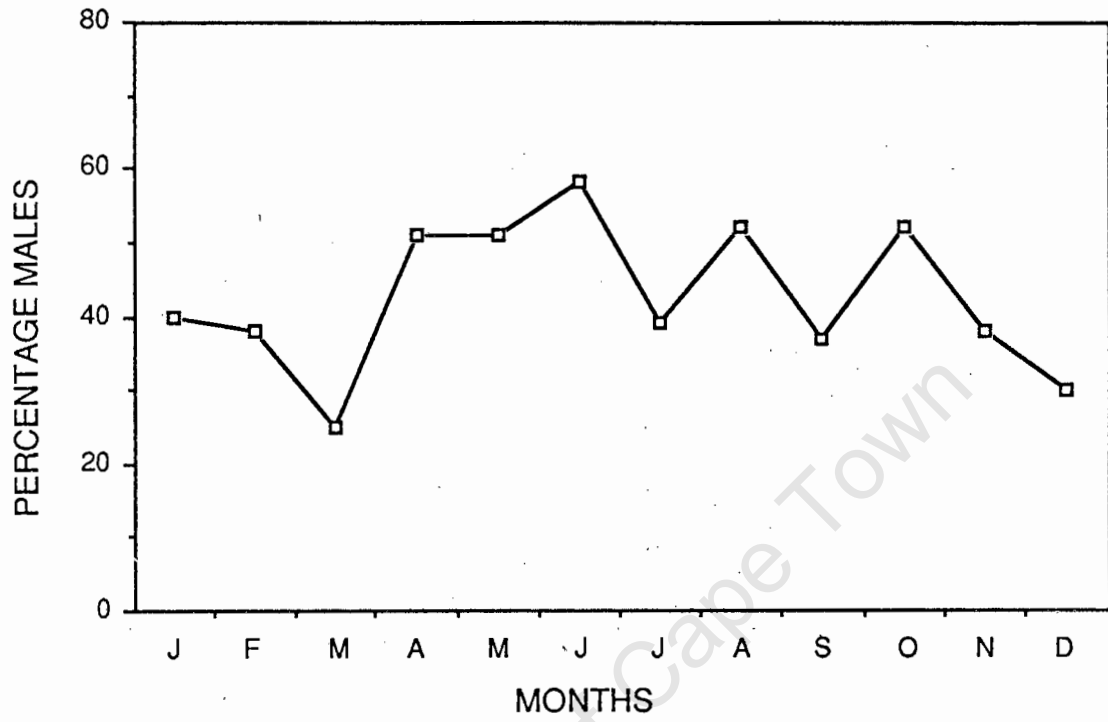
Fig. 12: Monthly variation in the standard deviation about mean of the nidamental gland / body mass ratio.

Fig. 13: Diagrammatic representation of the seasonal reproductive cycle of female C.capensis.

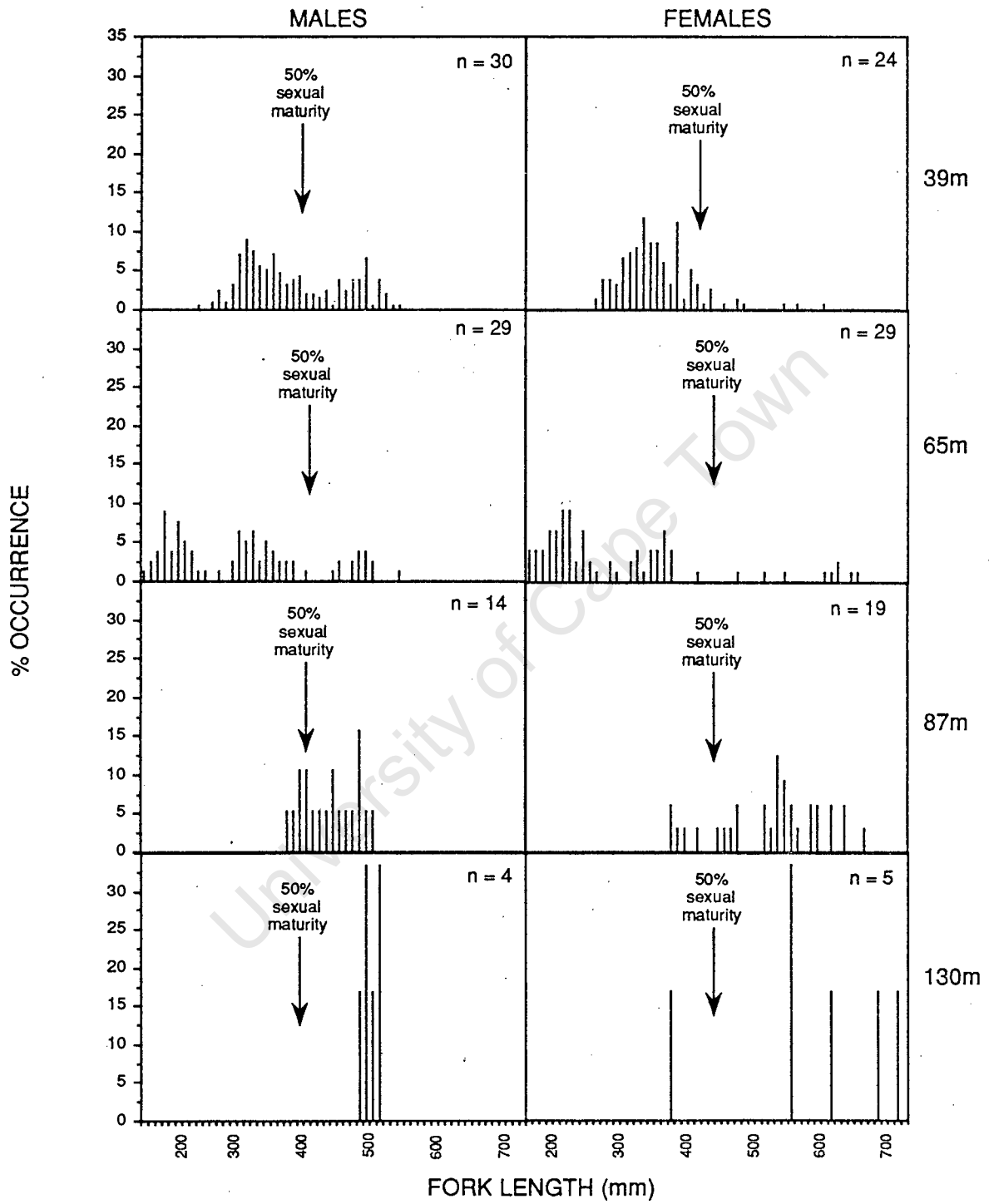


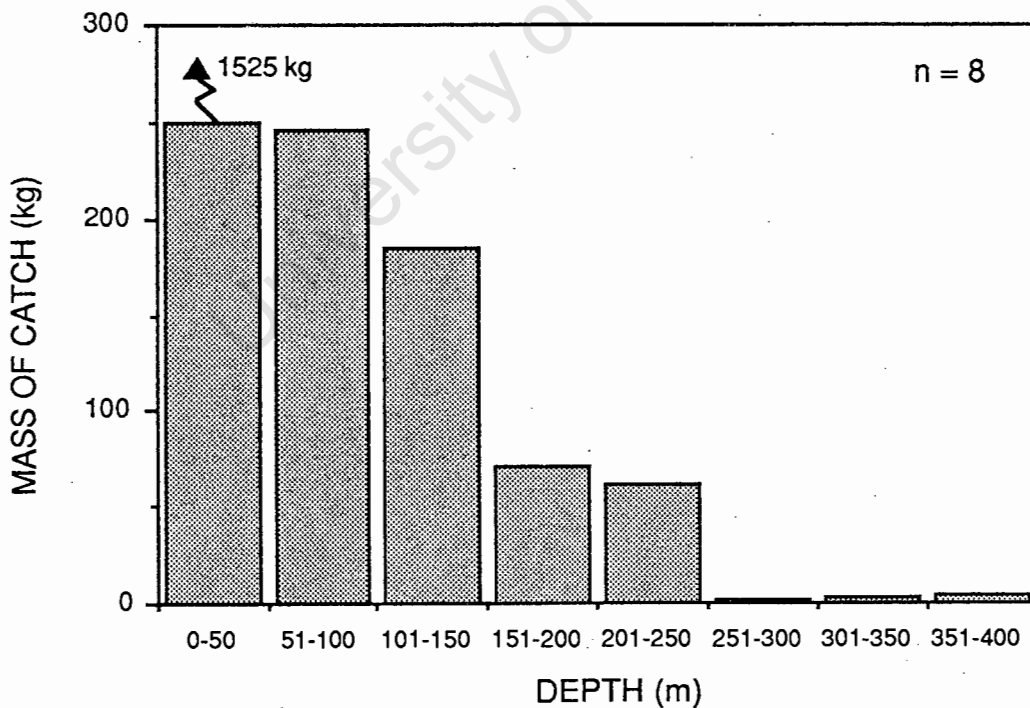
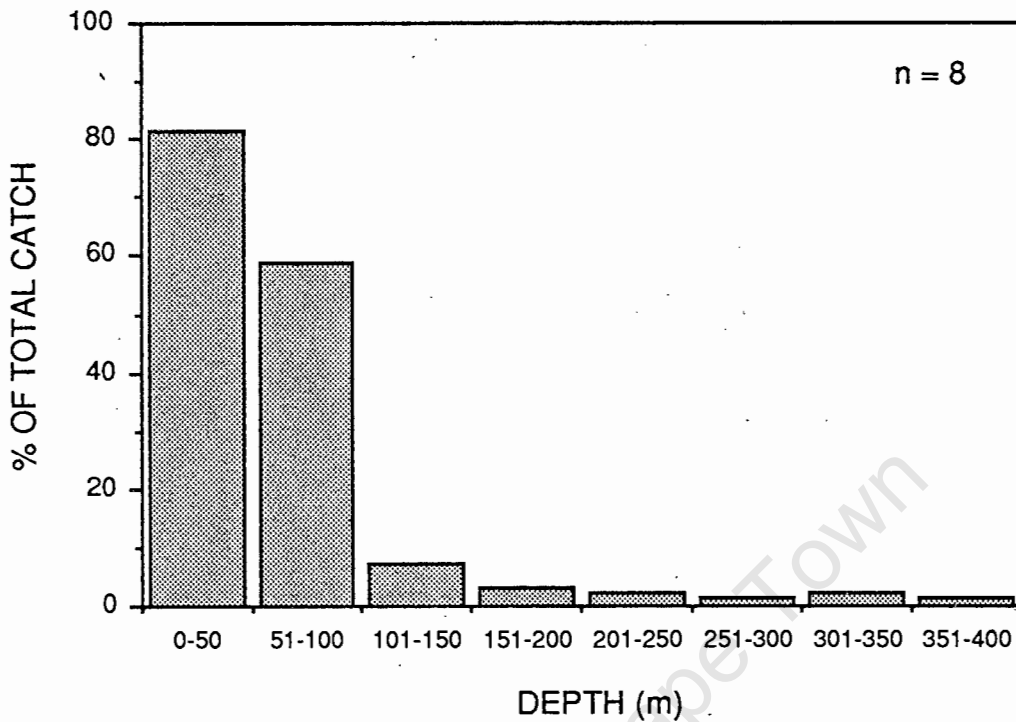


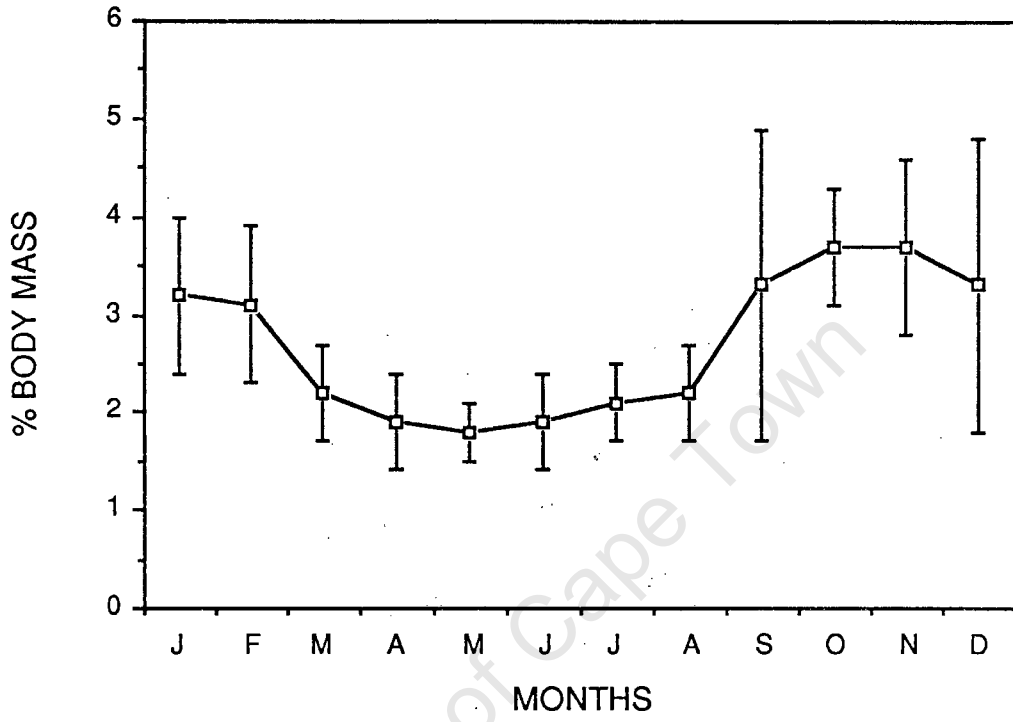




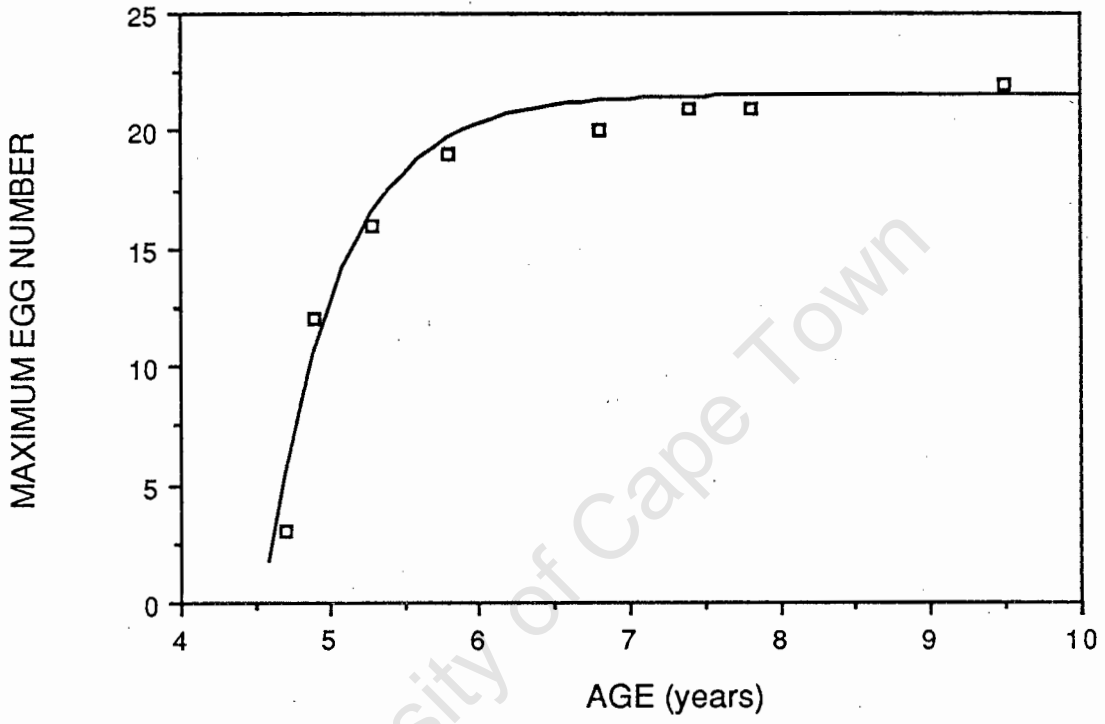
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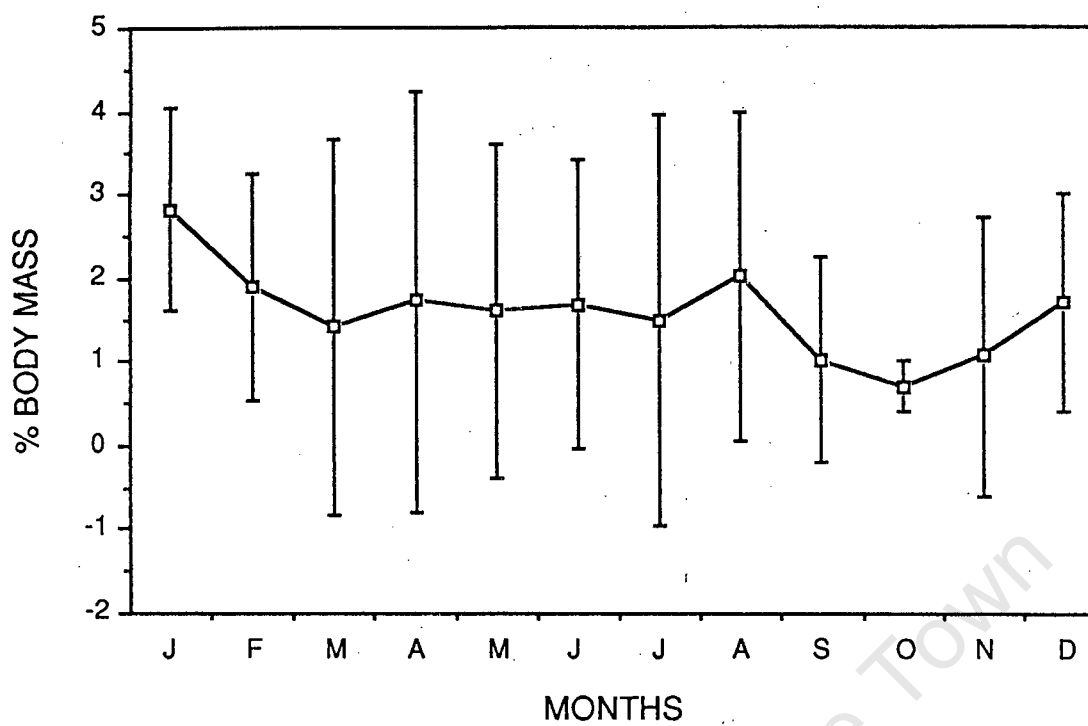




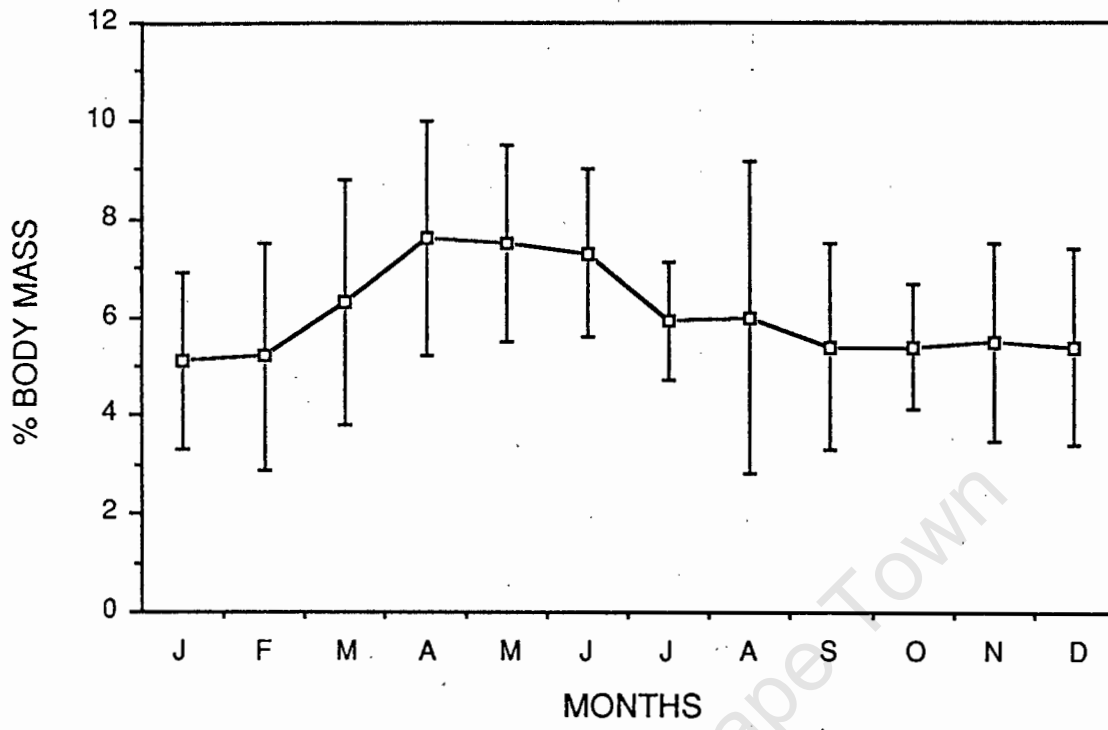




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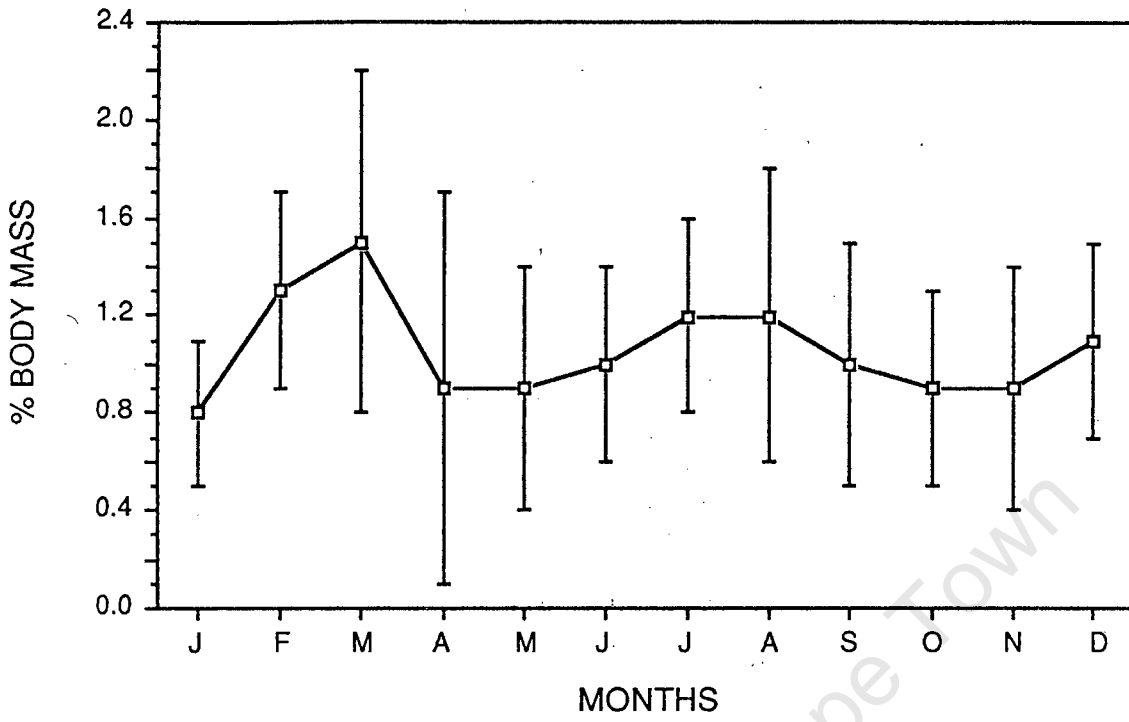


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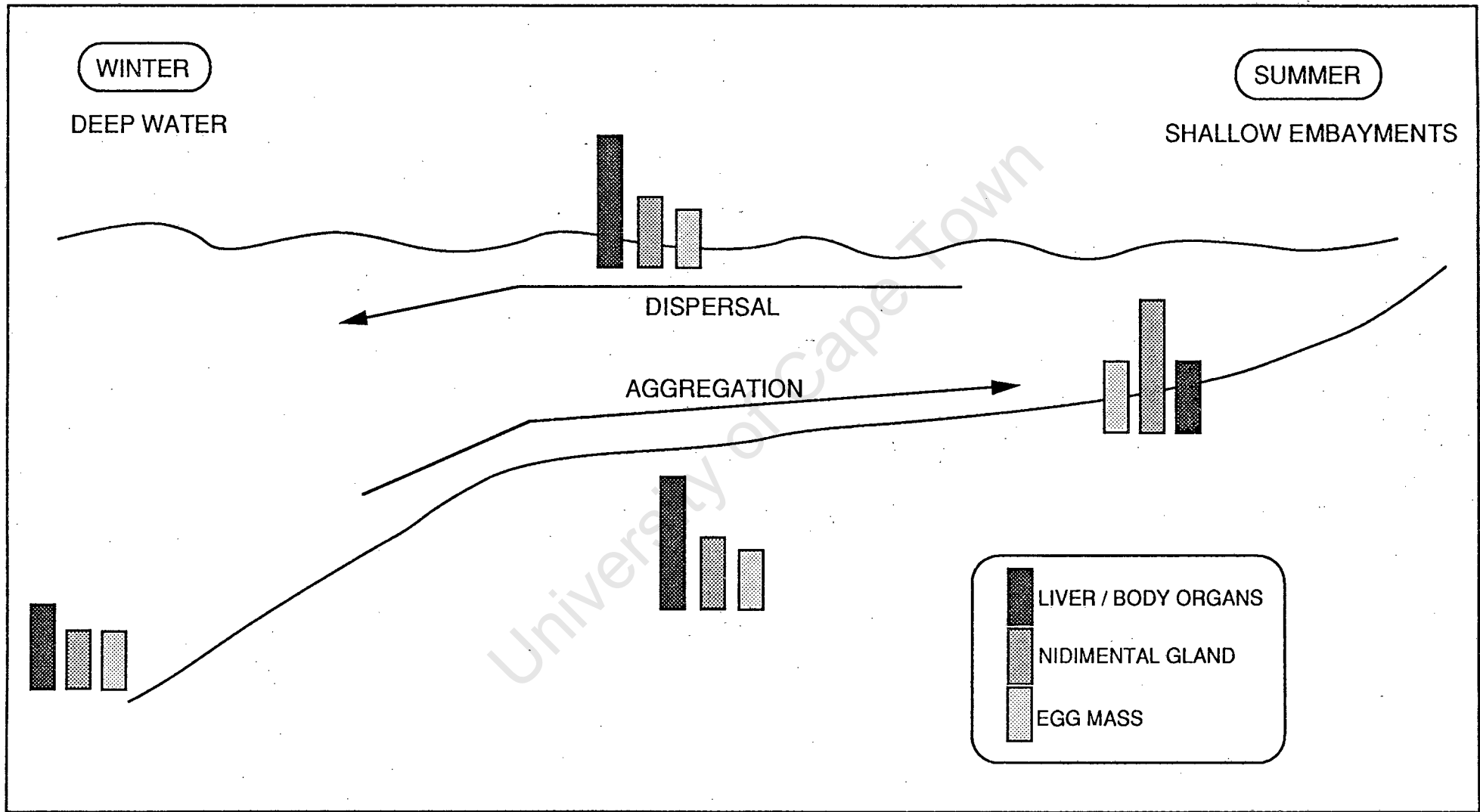


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Fig 12



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CHAPTER 3

ESTIMATION OF AGE AND GROWTH IN THE ST. JOSEPH SHARK, CALLORHINCHUS CAPENSIS (DUMERIL).

ABSTRACT

Age and growth of Callorhynchus capensis are estimated by counts of the serially deposited cones of dentine in the dorsal spine. Age estimates are validated by cone margin characteristics. There is a significant difference between the growth rates of males and females. Growth curves are described by the formulae $L(t)=1089,375(1-e^{-0,0515(t+0,606)})^{0,520}$ for females and $L(t)=658,641(1-e^{-0,171(t+0,721)})^{0,593}$ for males. The relationship between spine length and age is described by the equation : $S(t)=162,594 (1-e^{-0,254(t+1,434)})$, this relationship being applicable to both sexes. Age to mass relationships differ greatly between the sexes over the length range sampled, being best described by a von Bertalanffy curve for males : $M(t)=2,155(1-e^{-0,483(t+13,131)})$ and a linear relationship for females : $M(t)=0,399(t+0,098)$. The relatively greater mass of older females reflects the tremendous increase in female girth and therefore mass following the onset of sexual maturity.

INTRODUCTION

The genus Callorhinchus has a wide distribution in the shallow temperate waters of the southern hemisphere, occurring off the coasts of New Zealand (Gorman 1963), Chile and Argentina, Australia and southern Africa (Smith and Heemstra 1986). Off the South- Western Cape coast of South Africa the St. Joseph shark, C. capensis is commonly caught in trawl, seine and gill net fisheries, particularly in waters <100 m. depth (Freer and Griffiths in press). The species has long been discarded as a trash fish, but since approximately 1980 (pers. comm. Mr. A Smit, Uranus Visserye 1987) it has been accepted by processors for salting and drying and in the case of larger fish, for processing into frozen fillets.

At present there are no direct controls on the amounts or sizes of St. Joseph sharks taken by the various fisheries. Moreover, no information exists as to the age and growth of these animals, although this is an essential parameter required for rational management of the fishery. In the absence of scales or usable otoliths, vertebral centra (Cailliet et al 1986, Walter & Ebert 1991) or spines (Holden & Meadows 1962, Ketchen 1975, Sullivan 1977,) have been used to estimate ages in chondrichthyan fishes. Successful estimates of age for a related species, C. milii, a major fisheries target off the coast of New Zealand, have been made by Sullivan (1977) using serial deposition of cones of dentine on the dorsal spine. The vertebral centra of C. capensis were examined, but showed no obvious signs of serial depositional characteristics. A study was therefore initiated to test whether the dorsal spine could be used as a possible age indicator in this species.

MATERIALS AND METHODS

Spines were removed from 760 fish collected between April 1987 and July 1989. The principal source of specimens was the landed catch of commercial gill net fishermen based on the Cape West coast. Samples were collected on a monthly basis. If commercial landings were made material was collected from the following processors: Uranus Visserye, Laaiplek; BP Marine, Sandy Point and Protea Visserye, Vredenburg. If no material was available by the end of the third week of any month, directed gill netting operations were carried out. Small specimens of C.capensis were also provided by Mr. J. Petty, from seine net catches in False Bay. Spines were also collected from specimens taken by demersal cruises of the Sea Fisheries Research Institute vessel *R.S. Africana* and during various angling competitions.

Fork length was used as a standard measurement of length in all calculations, as the tips of the tails were frequently lost in larger fish. The measurement was taken to the nearest mm as suggested by Coakley (1971) on a measuring board, with the highly flexible snout bent flat against the board end plate. Mass was taken on site using either a 2.5 kg or 10 kg spring balance. The base of the dorsal spine was then simply cut away from the fish, and the spines stored dry in numbered envelopes. Based on the methods described by Sullivan (1977) an attempt was made to read annual growth rings on spines by cutting and polishing transverse sections. However, it was found that transverse sections approximately 0,1 mm thick were far easier to read. Spine deposition occurs in cones on the inside of the spine, with dentine being secreted by cells in the central lumen (Holden & Meadows 1962). It was therefore necessary to establish the position of the tip of the lumen, in order to choose the ideal sectioning position at which all dentine layers would be visible and easy to read (Fig. 1). Serial sectioning from the tip of twenty spines of a range of sizes established that the ideal section position was at

a spine width of 1,8 - 2,0 mm. This, however, did vary slightly with the length of the spine, so that approximately five sections about this point were taken from each spine. Width was chosen as a measure of location rather than distance from the spine tip because of considerable erosion of spine tips in many larger fish. As final preparation of these spines was very time consuming only a subsample of 30 spines per month from St Helena Bay, as well as an additional 40 spines from other localities, were thin sectioned.

Spines were embedded in polyester resin and sectioned using the method described by Hecht and Smale (1986). They were then mounted on glass slides and read under a dissecting microscope with a combination of diffuse transmitted light and side lighting. In all cases more than one section was examined. The number of bands was counted and the proportion of the inner band that had developed estimated by measuring its width using a graticule and comparing this to the width of the next innermost band. This was only really practical in sections showing only two and three bands. Sections were read by the same reader on three independent occasions. Only where the values read were within 0,2 of each other were the results used. This resulted in the discarding of many specimens as the proportional development of the outer band was difficult to estimate precisely. However, 155 repeat readings did fall within the constraints set.

The estimated proportions of the innermost depositional band, relative to that of the next band were examined seasonally. This proportion served as a validation of the annual nature of the dentine cone deposition, in much the same way as centrum edge characteristics have been used by Tanaka and Mizue (1979) and Rossouw (1984). Whenever more than 40 specimens from the same catch were available a length-frequency sample was also taken to attempt to validate age estimates made by spine sectioning. The lengths of all spines sectioned were

also measured, and related to the length of the fish, as a possible quick aging mechanism.

RESULTS

Sections from spines of the smallest fish obtained appeared as one broad dark band around the tip of the lumen. Within this dark band thin distinct rings could sometimes be discerned, these rings being more easily visible on sections from the spines of small fish. With increasing size more bands became visible, while the outer bands become narrower and less distinct. It is thus probable that the outer bands are lost or become indistinguishable in older fish. While this reduces the overall usefulness of this method it remains a valuable tool for the ageing of most of the commercial catch. Figure 2 illustrates this band development in fish of increasing size.

Assuming that the bands are annual the following growth curves were derived using PC-Yield ii (Punt and Hughes 1989).

$$\text{Female: } L(t) = 1089,375 \cdot (1 - e^{-0,0515(t+0,606)})^{0,520}$$

$$\text{Male: } L(t) = 658,641(1 - e^{-0,171(t+0,721)})^{0,593}$$

where $L(t)$ is defined as the fork length (mm) at time t (year).

Males and females show relatively slight differences in length at age, especially during the juvenile stages (Fig. 3). This is, however, not the case when fish mass is considered, female mass at age far exceeding that of males after the onset of sexual maturity (Fig. 4). This is largely due to an increase in female girth at this stage, usually the result of a distended liver and a large egg mass. However, seasonal changes in gonad and liver mass result in broad scatter in the post

sexual maturity mass / age relationship (Fig. 4) The following relationships best fitted these data:

$$\text{Female: } M(t)=0,399(t+0,0978)$$

$$\text{Male: } M(t)=2,155(1-e^{-0.483t+13,131})$$

where $M(t)$ is defined as mass (kg) at time t .

Whilst the Von Bertalanffy equation used to describe the male mass / age relationship may be more biologically correct, the seasonal changes in body mass of sexually mature females mean that a simple linear relationship more accurately predicts mass at age for females.

Total spine length was also related to band number (Fig. 5) allowing this parameter to be used as a possible quick aging technique, calling only for retention of the spine for later measurement, instead of time consuming field sexing, weighing and measuring. A reasonable fit (despite the fact that sex can not be determined from the spine) can be described as:

$$S(t)=162,594(1-e^{-0,254(t+1,434)})$$

Where $S(t)$ (mm) is defined as spine length a time t (year).

Whole C. capensis dorsal spines are often the only identifiable remnant from this soft-fleshed cartilaginous species in the stomach contents of predators such as larger sharks. A relationship of this type is hence the only one that could be used to estimate the original age and hence (via Fig 3) size of these prey items.

Seasonal variations in the width of the inner band as a ratio of the next band for two and three banded sections are shown in Figure 6. Spines which have a greater number of bands could unfortunately not be read in this way. The diagram does appear to indicate progressive formation of an annual band starting in April of each year and reaching its maximum width by about October. While there is considerable scatter about the mean, this can probably be attributed to the extended breeding season of C.capensis. Fish within the same cohort may thus be born at widely differing times of year.

In a further attempt to validate the age determination length- frequency samples were examined (Fig.7). While 38 catches were examined, only gill net catches from the same site, off Dwarskeersbos, in 2-4 fathoms of water, with a sample size of $n > 100$ and including at least 2 cohorts are shown. As the fish were caught in gill nets a measure of size selectivity is shown, with cohort 1 not usually being recruited into the fishery. The wide birthdate range and selectivity of fishing techniques make interpreting these length-frequency data difficult. Two facts are apparent: Firstly, the initial cohort(s), as estimated in the growth curve, is largely not represented. Secondly, in summer the subadult population is greatly reduced, possibly being located in water depths too deep for effective bottom set gill netting. This results in the bi- modal appearance of the graph as the catch now consists of resident juveniles and breeding adults that have migrated into the shallows to mate or lay eggs. It is concluded that, although peaks are apparent in the size frequency distribution, and these can be inferred as conforming to year classes 2 and above (as shown in Fig 3), they are not sufficiently distinct to use to validate the growth curves.

DISCUSSION.

Growth estimates obtained in this study are slower than those of Sullivan (1977), who studied the growth rates of Callorhinchus milii from New Zealand. Three possible factors may explain this: i) The sample in this programme was far larger, and taken over an extended time period thus giving more accurate results. ii) Thin sectioning allows very clear band readings to be made and reduces the possibility of errors with older fish, resulting in a reduced estimate of growth. iii) C.milii may in reality display a faster growth rate than C.capensis.

Material was particularly lacking from year 0+ fish as these are not part of the commercially landed catch. The two major sources of error are reading rings as bands in very small fish and the thinning and presumably eventual loss of the initial depositional cone. Great difficulty was found in accurate, consistent readings of the spine sections of larger fish with 4+ bands, 68 % of total rejections coming from this section of our sample. As there were considerably fewer 4+ banded specimens than younger fish this shows the limited value of spine sections in the age assesment of older specimens of C.capensis.

The spine length to age relationship makes this a powerful tool for rapid age assesment even of damaged specimens. This method, however, also suffers from inaccuracies due to spine breakages and erosion in larger specimens. Spine sectioning thus remains necessary for accurate results.

The large standard deviations in inner band margin proportions shown in Fig. 6, especially in summer fish, are easily explained in terms of serial spawning. Each cohort has a widely spread individual birthdate distribution. With the passage of time some growth compensation is bound to occur, but the data used came from two and three banded sections. Thus, if sampled in November, two fish of the

same cohort but different hatch dates may have different band counts (ie.: an early hatch fish may have 3,1 bands. A later hatched fish of the same cohort may only have 2,9 bands). However, the cone inner margin study could describe the inner margin proportions of fish from the same cohort as either very high or very low (ie. 0,1 or 0,9). If viewed seasonally the pattern of summer cone initiation becomes clear. Further validation techniques, especially tagging combined with tetracycline injection (Holden and Vince 1973; Smith 1984; Davenport and Stevens 1988) are, however, undoubtedly needed.

Assuming that the banding is annual, as suggested by our validation techniques, the growth curve calculated from these data indicates that compared to most other chondrichthyan target species, C.capensis is quite fast growing. Holden (1974) points out that slow growth rates are one of the major limiting factors in shark fisheries. Therefore, this information, together with the fecundity of this species (Freer & Griffiths, this volume) make it a more safely exploitable target than most elasmobranch species.

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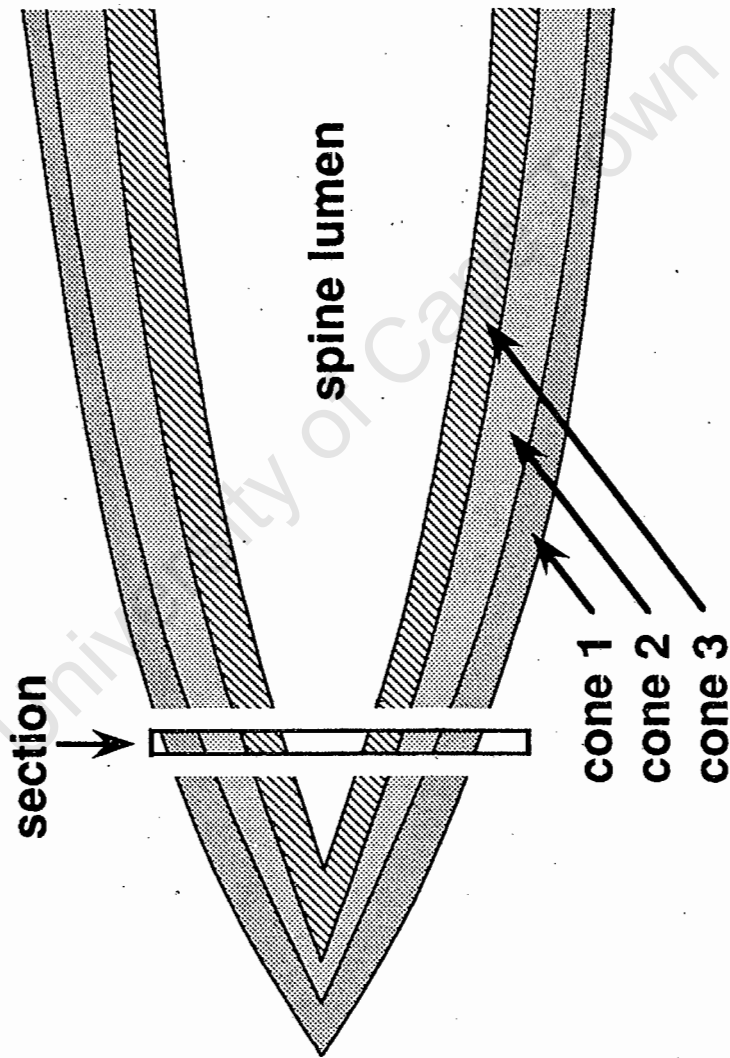
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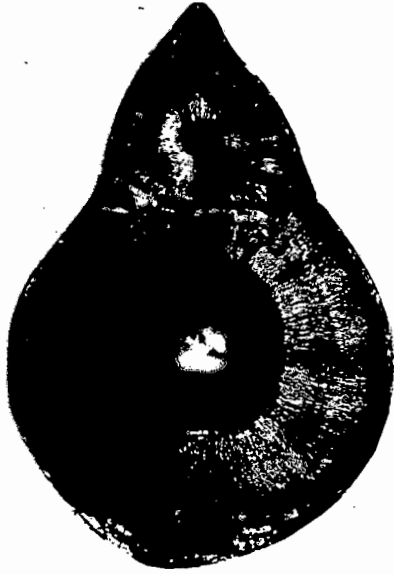
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LEGENDS TO FIGURES

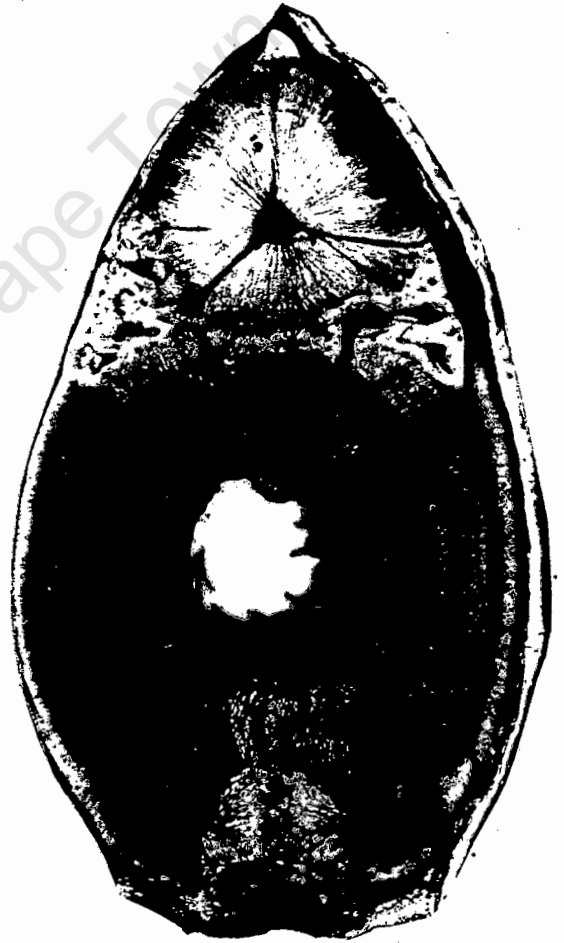
- Figure 1:** Diagrammatic representation of the dentine layer structure of the spines of C.capensis in longitudinal section, showing the ideal transverse sectioning position.
- Figure 2:** Thin sections of transversely sectioned spines from 1, 2 and 3 year old female C. capensis.
- Figure 3:** Relationship between band count^(year) and fork length of male (n = 61) and female (n = 94) C.capensis. Actual data points and best fits are shown.
- Figure 4:** Relationship between band count and mass of male (n = 175) and female (n = 234) C.capensis.
- Figure 5:** Spine length of C.capensis compared to age of fish as measured from transverse sections of the spine. Sexes combined (n = 148).
- Figure 6:** Seasonal deposition patterns of dentine in C.capensis spines, based on fish with two and three bands.
- Figure 7:** Length frequency distributions of C.capensis catches from Dwarskeersbos during four months of the year. Males and females shown separately.



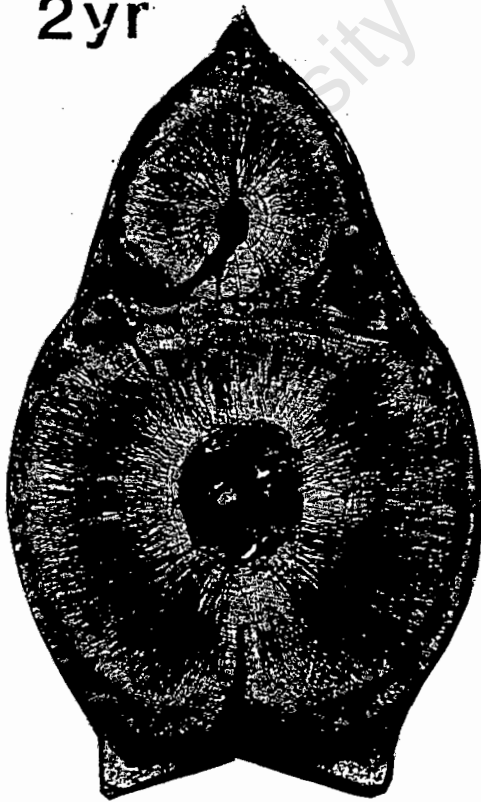
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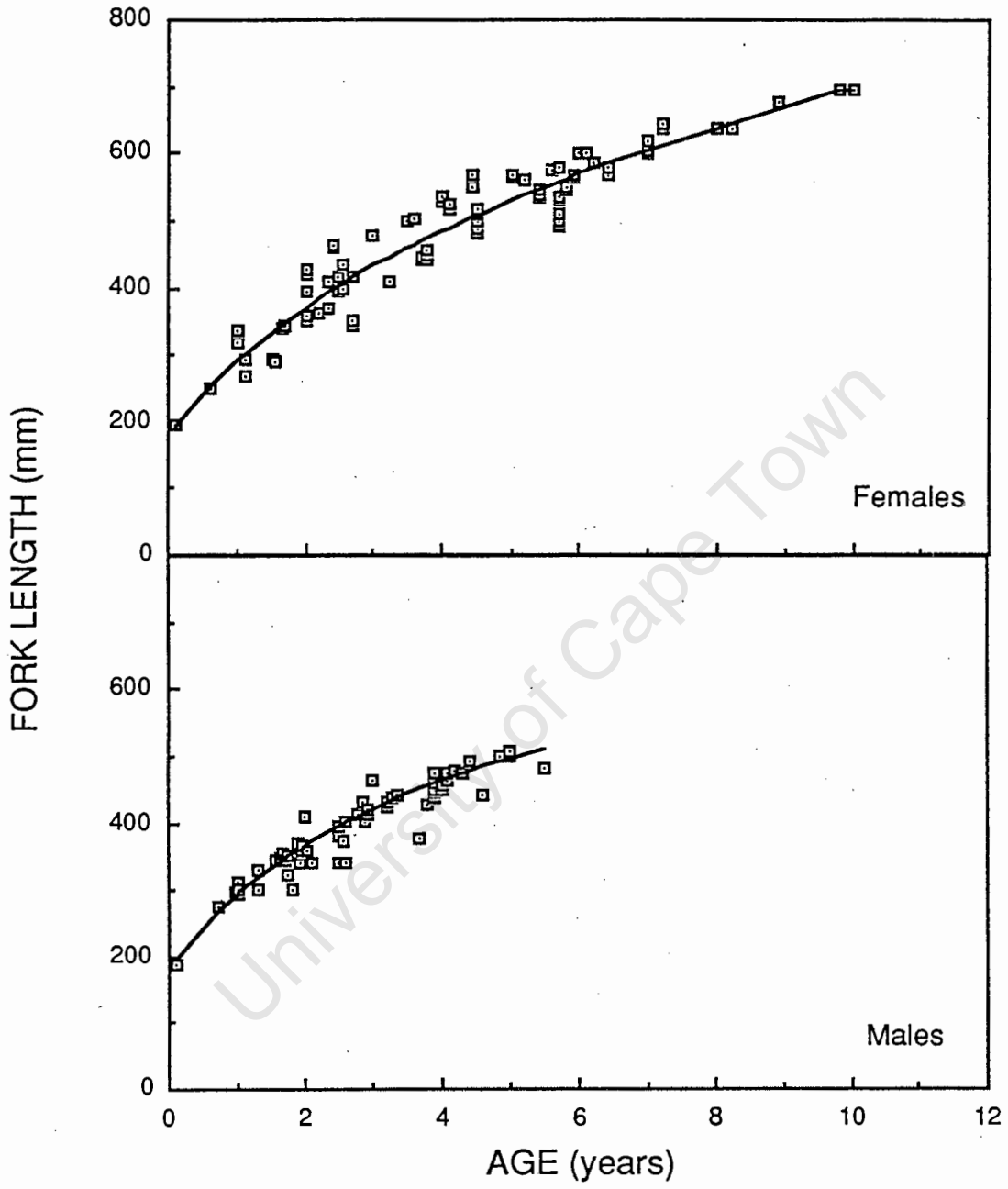


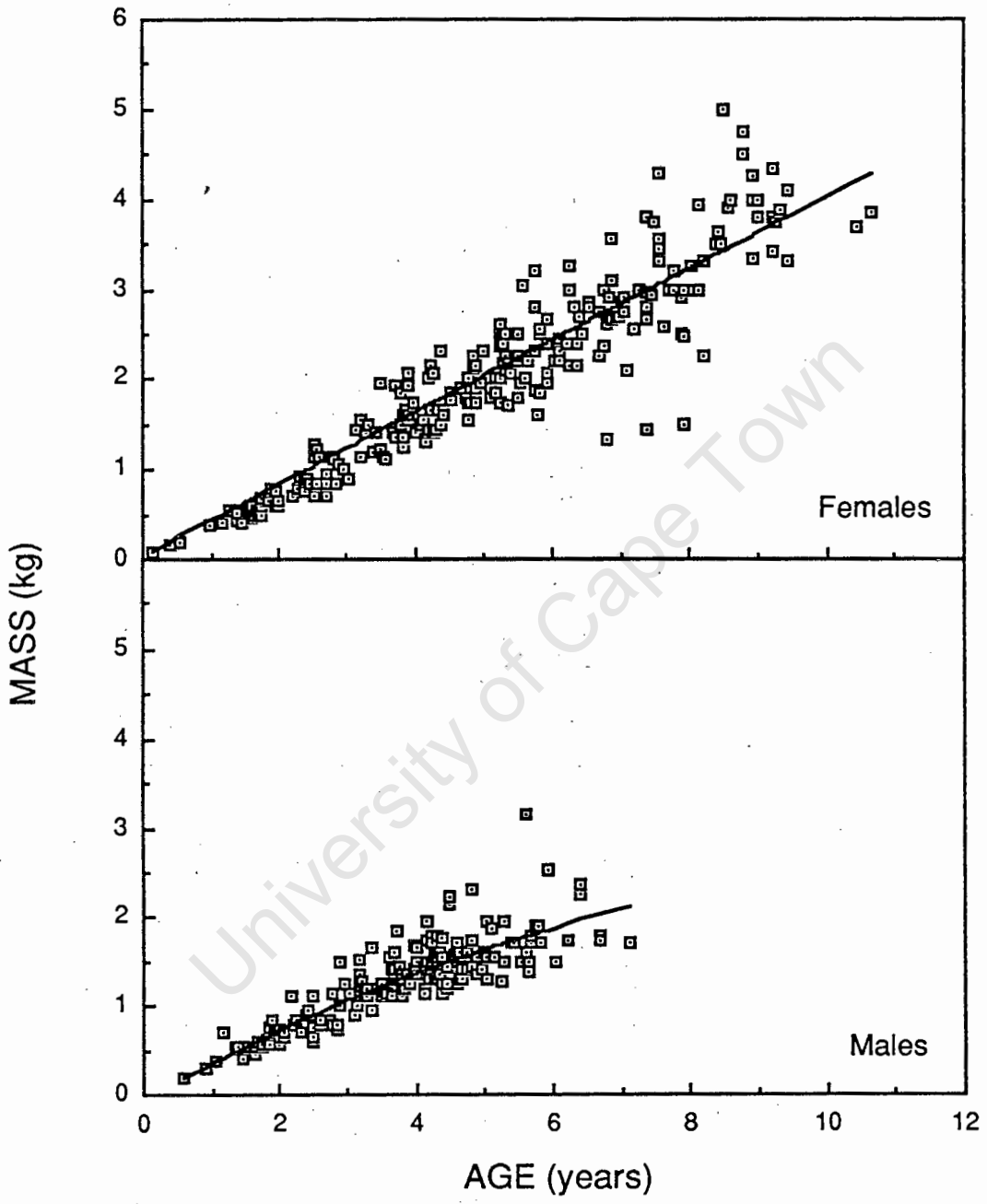
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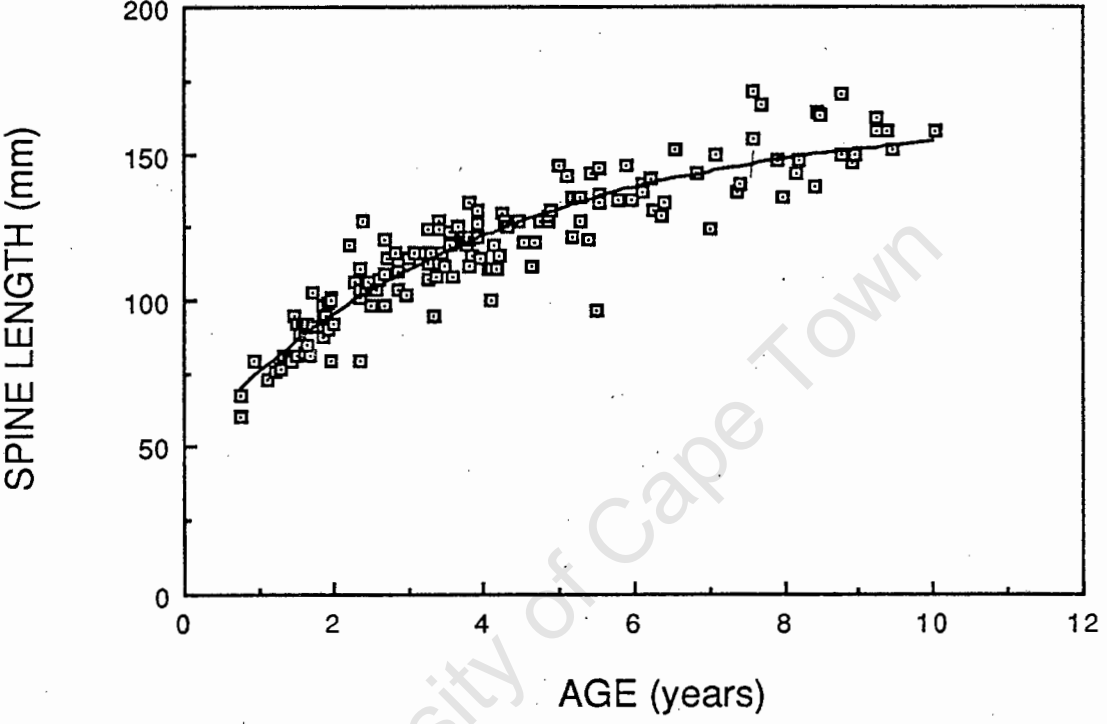


2 yr

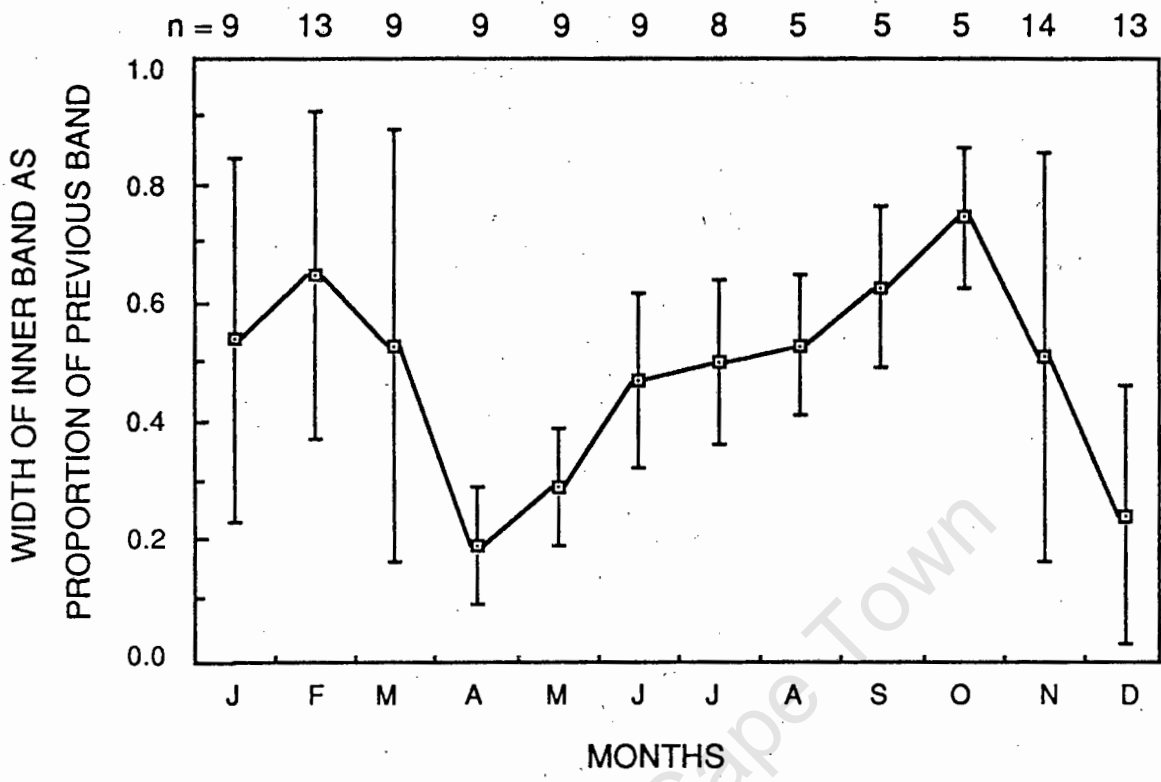








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