Report to Fishing Industry Research Committee

Investigations of the Gummy Shark, Mustelus antarcticus Günther, from South-eastern Australian waters

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Contents

1. Forward

Investigations of the gummy shark stocks of south-eastern Australia were undertaken by the Fisheries and Wildlife Division of Victoria on behalf of the fisheries agencies of Tasmania, South Australia, Victoria and the Commonwealth under the auspices of the South Eastern Fisheries Committee.

Funds to undertake these investigations were made available from the Fishing Industry Research Trust Account and Victorian sources. The Fishing Industry Research Committee financed field operations aboard F.R.V. "Sarda" and commercial vessels, laboratory operations, sampling of landed commercial catches for length-frequency in Tasmania and South Australia, and establishment of a log-book system in Tasmania, South Australia and Victoria during 1973-76. Funds for sampling landed commercial catches in Victoria during the period from 1970 to the present, for running costs of F.R.V. "Sarda" during field operations and for analysing and reporting the data were met from the Victorian Fisheries Research Fund and the State Treasury.

Most of the analyses so far undertaken and presented in this report were appraised by the South Eastern Fisheries Committee Shark Assessment Workshop held in Melbourne during 7-9 March 1983 (see report of that Workshop attached). Further analyses considered constructive by the Workshop are listed as follows.

(a) Revise mortality estimates from tag release-recapture data presented in Section 4.2 of this report by correcting for effects of mesh selectivity by using results presented in Section 9.1.

Estimates of total mortality presented in this report are biased upwards by the tendency of catchability of sharks tagged and released to decline as the sharks grow larger. Although the estimates of total mortality reflect the rate at which sharks disappear from the catchable stock it is important to account for survival of large sharks escaping the gill nets because of their important contribution to future recruitment. Large sharks produce many more offspring per pregnancy than do small ones.

(b) Provide estimates of catchability and mortality by de Lury analysis and make age specific estimates of catchability and mortality by cohort analysis using data presented in Section 10.

(c) Undertake yield analyses which take account of the dependence of recruitment on stock size. Consideration is being given to adapting existing computer models developed for cetaceans to provide these analyses.

Recommendations to examine hook selectivity data not available at the Workshop and to reanalyse available mesh selectivity data have been undertaken and are presented in this report. The other analyses mentioned will be undertaken over the next 12 months. In addition, further analyses using available catch and effort data will be carried out to describe changes in relative abundance over the geographical distribution and water depth range of gummy sharks.

It is concluded that gummy shark have a longevity of 9-11 years, reach the age at first capture in 3-4 years and reach sexual maturity at 5 years for males and 7 years for females. Gummy sharks produce a small number of offspring and having a 12-15 month period of gestation coupled with a 3-4 year period to reach the exploited phase of the fishery means that the effects on recruitment of fishing of the parent stock are not apparent for 4-5 years. Although effort and catch per unit effort have stabilised in recent years, effort is higher and catch per unit effort is lower than it was for the preceeding 5 years which imply that there could be a further reduction in catch per unit effort if current levels of effort are maintained.

2. Introduction

Shark research cruises were conducted during 211 sea-days between 8 June 1973 and 29 November 1976 over an area on the continental shelf ranging from Streaky Bay, South Australia; Gabo Island, Victoria; and Hobart, Tasmania. Fishing was conducted at 162 separate stations on 155 separate days and involved setting a total of 243,500 metres of gill netting and 39,045 hooks. Twelve separate gill nets, each 250 metres long, of eight different mesh sizes (2-9 inch) and three separate hanging coefficients (0.47-0.67) and hooks of various sizes (2/0-11/0 Mustad) were used.

Fishing operations were directed at the gummy shark, *Mustelus antarcticus* Günther, and during the course at the study a total of 2769 gummy sharks were captured. The species, sex and length of each shark captured was recorded. Those alive and in good condition were tagged and released whereas the remainder were dissected and a number of reproductive parameters and the fullness of the stomach were recorded. From a sample of these, various weights and lengths were recorded and gonads, stomach contents and several vertebrae were removed and preserved for laboratory examination. Besides collecting sharks for biological study the fishing gear was specially designed for several purposes: (a) capture of newborn gummy sharks to detect existence of nursery grounds, (b) test effects of hanging coefficient and mesh size of gill nets on capture rates, (c) test effects of hook size, hook spacing and hook shank-length of long-lines on capture rates, and (d) compare capture rates by long-lines with those of gill nets.

In addition fishermen were accompanied on their vessels during normal commercial operations on three separate occasions. The purposes of these commercial cruises were to record certain biological variables and collect material from a sample of 125 sharks, and record time periods of various phases of operations of setting and hauling gill nets under commercial conditions.

Summaries of period and number of stations, and length of netting set, number of hooks set, depth range and bottom temperature range at the fishing stations for each of seven research cruises are given in Table 2.1; and number of sharks captured, number tagged and released and number of tagged sharks recaptured and reported for each of the research cruises are given in Table 2.2. Period and number of stations, and number of sharks sampled during the three commercial cruises are given in Table 2.3; and position of each station for both the research and commercial cruises are shown in Fig. 2.1.

To collect appropriate commercial catch and effort data on a day by day basis specially designed log-books were issued to shark fishermen in Victoria, South Australia and Tasmania. These returns were used during 1973-76 in South Australia and Tasmania, and from 1973 to 30 May 1978 in Victoria. A slightly modified version of this return was adopted in Victoria on 1 June 1978 and will be used indefinitely. With the exception of South Australia for the period 1970-72, in cases where information on shark catches was not available on the special shark returns the general fishermen's returns from the three states were also used for the period 1970-78.

In addition, processor returns giving production and date of landings have been collected for the period 1970-78, with the exceptions of South Australia and Tasmania for the period since the end of 1976. In these cases only total monthly shark production for each processor is available.

During 1973-76 the sex and length were recorded for 148,958 gummy sharks landed in Victoria, 16,188 landed in South Australia and 26,455 landed in Tasmania as a result of sampling commercial catches in the major ports of landing and other important distribution centres. In addition, 44,848 gummy sharks were measured in Victoria during 1970-72, prior to commencement of the program. Commercial catch sampling has also continued in Victoria since completion of the program in 1976.

3. Morphometrics

In Victoria sharks are landed in the "carcass" form (i.e., beheaded and gutted) while in South Australia and Tasmania they are landed in the "trimmed carcass" form (i.e., carcass with the fins removed). Legislation of these three states has been expressed in terms of total length and the three partial lengths: (a) fifth gill-slit to base of caudal fin, (b) fifth gill-slit to caudal subterminal notch and (c) fifth gill-slit to tip of caudal fin. For these reasons total weight of males (Fig. 3.1) and females (Fig. 3.2), carcass weight (Fig. 3.3), trim weight (Fig. 3.4), and fillet weight (Fig. 3.5) are expressed as a function of total length and each of the three partial lengths. Similarly the recovery rate of carcass weight/total weight (Fig. 3.6), trim weight/total weight (Fig. 3.7), fillet weight/total weight (Fig. 3.8), trim weight/carcass weight (Fig. 3.9), fillet weight/carcass weight (Fig. 3.10), and fillet weight/trim weight (Fig. 3.11) are expressed as functions of the same four lengths. Various relationships between pairs of total length and the three partial lengths are given in Table 3.1.

Relationships between girth and total length for males (Fig. 1.12) and for females (Fig. 3.13) are relevant to mesh selectivity studies reported subsequently, and relationships between liver weight and total length for males (Fig. 3.14) and females (Fig. 3.15) are reported because of the potentially useful commercial products such as liver oil, vitamin A and squaleen that can be extracted from shark livers.

Maximum lengths plotted for all these relationships and all other relationships drawn in this report are 1460 mm for males and 1760 mm for females and the two sexes combined because these were the maximum lengths observed for males and females respectively during field operations.

4. Tagging experiments

During 8 June 1973 - 29 November 1176, 1525 gummy sharks were tagged and released for the purpose of studying movement, mortality and growth and by 31 December 1982, 375 sharks had been recaptured by commercial and recreational fishermen and reported to the Fisheries and Wildlife Division of Victoria.

The tagging program was publicised throughout the shark fishing industry in Victoria, Tasmania and South Australia and shark fishermen were issued with specially printed self addressed postage paid forms with facility for recording position, date and length of recaptured sharks. Fishermen were encouraged to send the recaptured sharks to the Melbourne Fish Market where they could be collected, inspected and measured by research staff.

The tagged and released sharks were captured by hooks on long-lines and by gill nets. They were held in a tank of diameter 1.8 m diameter and 1.0 m deep in preparation for tagging. Because sharks captured by hooks tend to be in better condition than those captured by gill nets, most of the sharks tagged were captured by hooks. Only sharks caught by gill nets judged to be in good condition by their liveliness were tagged and released.

Each shark was tagged by inserting a 50 mm x 20 mm serially numbered yellow plastic Nesbit internal tag (or 33 mm x 9 mm white Nesbit tag for sharks of length less than 600 mm), with one end curved and with a red plastic streamer of approximate length of 150 mm and diameter of 2 mm attached at the other end, into the coelomic cavity with the free end of the streamer protruding out through the body wall. By placing a 15 mm long incision through only the tough skin covering the myosepta fold between the lateral and ventral musculature of the body wall with a sterilised surgical blade and by firmly pushing the tag to tear the connective tissue and the myosepta of the fold, the tag could be inserted while preventing loss of blood and damage to the internal organs, most notably the liver, and musculature. A curved needle was used to seal the incision with a single stitch using soluble surgical catcut and to thread the free end of the streamer through the skin. The free end of the streamer was then tied to the mid-section of the protruding streamer to prevent it from slipping inside the shark.

Besides the streamer to alert fishermen to the presence of the tag, a pair of holes of diameter of 5 mm were punched near the base of the anterior margin of the anterior dorsal fin and red plastic cord similar to the streamer was threaded through the holes and tied with a reef knot on each side of the fin. Finally the incision and the holes were disinfected by spraying with a solution of absolute alcohol containing a trace of malochite green. Before release the sex, length, date, position and condition of the shark were recorded.

4.1 Movement patterns

Of 375 gummy sharks recaptured before the end of 1982 from 1525 tagged and released during 8 June 1973 - 29 November 1976, 346 (208 males and 138 females) had both the recapture position and recapture date reported by fishermen and could be included in an analysis for movement patterns.

The longest period free for any individual shark was a male which was recaptured 2944 days after release 110 km from the site of release, while evidence of the largest movement was exhibited by a female which was recaptured 1003 km from the site of release after 272 days at liberty. Three males and four females were recaptured and reported within ten or less days of release.

A summary of tag release-recapture movement data for each sex for each of the three length-classes 300-949 mm, 950-1099 mm and ≥1100 mm for length at release (Table 4.1.1) indicate that females tend to move further than males and that it is the largest females which move the greatest distances.

Examination of movement of individual sharks indicated that seven females moved west from the Bass Strait region into waters adjacent to South Australia while not a single male exhibited this pattern. Two males released in waters adjacent to eastern Victoria were recaptured off New South Wales. There were insufficient gummy sharks tagged off South Australia and there were no sharks tagged off New South Wales to detect movements back towards Bass Strait.

During field sampling operations it was evident that the youngest age groups of gummy shark were not well represented in the catches suggesting that the new born are not randomly distributed with the older age-groups. It was also evident that many of the catches consisted predominantly of one sex. These observations when taken together with the knowledge that many other species of shark exhibit migration patterns related to time and place of fertilisation, parturition and gestation raise the question of whether such patterns occur for gummy shark.

On the basis that fertilisation and parturition occur during October-December (see Section 7) and that the period of gestation is 12-14 months (see Section 7) there are no readily discernible seasonal patterns for males (Table 4.1.2). On the other hand, given that it is the group of largest (predominantly sexually mature) females that exhibit the greatest movement (Table 4.1.1) it appears that there are seasonal movements by the female population related to the reproductive cycle.

Females tagged and released during October-December and recaptured during January-March exhibited movement to the east, whereas those recaptured at other times of the year moved to the west (Table 4.1.3). By grouping the available female data into 6-monthly-groups based on time of tag release and tag recapture the pattern of a shift by a proportion of the female population to the west during April-September and to the east during October-March is more apparent.

Release period	Recapture period	Sample size	Mean east vector (km)
Oct-Mar	Oct-Mar	50	9.8
	Apr-Sep	39	-102.8
Apr-Sep	Oct-Mar	21	21.6
	Apr-Sep	28	-50.0
Total	Oct-Mar	71	13.3
	Apr-Sep	67	-80.7

North-south movements between northern Bass Strait and southern Tasmania and east-west movements between eastern and western Bass Strait by both males and females and movement by females from Bass Strait to waters off South Australia suggest that the gummy shark of south-eastern Australia form a single breeding stock.

4.2 Mortality

Estimates of instantaneous total mortality, Z, were made by adoption the standard approximation

$$Z = 1/\bar{t}$$

where t is the mean number of years free for the recaptured and reported sharks, and estimates of fishing mortality, F, and natural mortality, M, were made by equations

$$F = (r/R)Z$$

and $M = [(R-r)/R]Z$

respectively, where r is the number of recaptured tagged sharks and R is the number of released sharks.

On the basis of 365 tagged gummy sharks recaptured and reported by fishermen with dates of recapture before the end of 1982 from 1521 tagged sharks (of 1525 tagged and released four were released without recording sex or length) during 8 June 1973 - 29 November 1976, results of the estimates of mortalities for each of three length classes for each sex (Table 4.2.1) and for each of five localities for each sex (Table 4.2.2) are summarised as follows.

(a) Overall Z is 0.55 (i.e., 42% per annum).
(b) Z for males (0.56) does not differ significantly from Z for females (0.54).
(c) Z is significantly affected by length : 0.84 (57%) for gummy sharks of length greater than or equal to 1100 mm > 0.62 (46%) for 950-1099 mm > 0.41 (33%) for 300-949 mm.
(d) Z is significantly affected by locality : 1.21 (70%) for area north of latitude 39°30' South > 0.86 (57%) for Furneaux Group > 0.55 (42%)

for King Island > 0.49 (39%) for Hunter Group > 0.44 (36%) for area south of latitude 40°40' South.

(e) Overall F is 0.13 (12%) and M is 0.42 (34%), and both F and M rise with increasing length of the sharks.

These results depend on a number of assumptions.

(i) There were no tagged sharks remaining in the population after the end of 1982.

(ii) Fishing effort expended by the fishing fleet remained constant for the duration of the period of recapture of tagged sharks.

(iii) Probability of capture of a tagged shark by commercial fishing gear remained constant after recruitment to the exploited phase of the stock.

(iv) There was no emigration of tagged sharks from the range of commercial fishing operations.

(v) Fishermen reported all tagged sharks recaptured.

(vi) There was no initial mortality after release of tagged sharks.

(vii) There was no progressive shedding of tags from tagged sharks or progressive mortality caused by the tags.

As the latest reported recaptured tagged male was 17 October 1981 and latest reported female was 5 May 1982 it can reasonably be assumed that the number of tagged sharks remaining in the population is negligible and that the first assumption holds true.

In relation to the second assumption, fishing effort in Bass Strait where most tagged sharks were released and recaptured increased by about 25% during the period of recapture (see Section 10). This would have had the effect of biasing the results downwards. Correction for this bias would provide slightly higher estimates of mortality.

In the Bass Strait-Tasmania region of the fishery where the majority of recaptured tagged sharks were caught, the fishing gear most commonly used by the industry throughout the period 1973-82 was the gill net of 6-inch mesh-size. Results of analyses of data of mesh selectivity of experimental gill nets (Section 9.1) indicate that the probability of capture of sharks for gill nets of 6-inch mesh-size increase with length until the sharks reach a length of 1106 mm beyond which length the probability of capture decreases. The mean length of release of the tagged sharks was 1002 mm (1013 mm for males and 986 mm for females) which is 105 mm less than length of maximum selectivity of 1106 mm. This means that on average the population of tagged sharks had a mean length less than 1106 mm for 1.2 years in the case of males and for 1.1 years for females while the population had a mean length above 1106 mm for several years. Hence after about one year the overall effect of selectivity is to cause a progressively lower probability of capture of a tagged shark the longer it remains free. This has the effect of biasing the estimate of $\bar{t}$ downwards and hence Z upwards. Violation of the third assumption was the most serious and requires development of a correction technique to provide useful results.

Results of movement of sharks from tag release-recapture data (Section 4.1) indicate that, apart from large females, emigation from the Bass Strait-Tasmania region is not significant. For females, with the presence of shark fisheries in South Australia and Western Australia, demersal trawl and inshore gill net fisheries of New South Wales, deep water demersal trawl fisheries of south-eastern Australia and widespread coastal ocean amateur fishery it is not possible to emigate from the influence of fishing gear.

Evidence has been provided by fishermen to indicate that a small proportion of the tagged sharks recaptured were not reported. This would have had the effect of biasing M upwards and equally biasing F downwards. On the other hand, there is no evidence to indicate that Z was biased by changes in the proportion of recaptured sharks reported over the period from when they were released to the end of 1982. Occasionally the streamer attached to a tag slipped into the coelomic cavity of a shark and the plastic cord attached to the dorsal fin was lost or covered over by skin growth, but, it is unlikely that this would have significantly affected the reporting rate progressively and hence the estimates of Z.

Although no attempt was made to estimate initial tag mortality, there is sufficient evidence to indicate that it was significant. Tagged sharks held in the holding tank on board F.R.V. "Sarda" and underwater cages under favourable weather conditions occasionally died within 24 hours. On the other hand all sharks tagged and held in land based aquaria died within several days. In the aquaria the sharks developed infections in the region of the tag incision which are believed to have been the cause of death. However, there is evidence that this did not occur in natural ocean waters. The effect of an initial tag mortality is the same as that of constant under-reporting of recaptured sharks. M is biased upwards and F is biased downwards while not affecting the estimate of Z.

With respect to the seventh assumption, it was not possible for the internal tags to be shed progressively. Stitching the incision at the time of tagging prevented initial loss of tags and inspection of recaptured sharks indicated that the incision healed within several days and that the presence of a tag and streamer did not cause infection in the region of the incision. It is therefore reasonable to assume that there was no progressive mortality induced by the presence of tags.

An estimate of Z of 0.22 based on 58 tag recaptures during 1952-64 from 562 tagged gummy sharks released by CSIRO during 1952-54 indicates that natural mortality must be less than 0.22 (20%). These results apply to a period when fishing mortality was low and when most were captured by long-lines for which there are no length selectivity effects (see Section 9.2).

4.3 Growth

The von Bertalanffy growth parameters, K and L_∞, were estimated from data for recaptured sharks where all three of release length, recapture length and period of time free were available. Time free was derived from date of recapture reported by fishermen and recapture length was based on either the length reported by fishermen or, when a shark was made available to research staff, the length recorded by research staff (23% of males and 20% of females). Where reported or recorded recapture lengths were partial lengths as a result of removal of heads by fishermen total length was estimated by an appropriate equation given in Table 3.1.

The method adopted to estimate K and L_∞ was that described by Fabens (1965). This method requires the method of least squares to fit the data and assumes that all error is associated with recapture length and that the error is normally distributed with homogenous variance.

The third von Bertalanffy growth parameter, t_o - time at zero length - was estimated by standarising the birthday of all gummy sharks to 1 January and the mean length at birth to 336 mm (derived from the equation describing growth of <u>in utero</u> embryos during the period of gestation given in Fig. 7.3), and by substituting for K, L_∞, time (t=o) and length (l_t= 336) in the von Bertalanffy equation

$$l_t = L_\infty [1-e^{-K(t-to)}].$$

Values of the three von Bertalanffy growth parameters and plots of the relationships between length and age are given for male and female gummy shark in Fig. 4.3.1 and Fig. 4.3.2, respectively. The high correlation coefficient values of 0.91 between K and L_∞ for males and 0.98 for females implies that the estimates of these parameters are highly confounded.

5. Ageing studies

Several vertebrae were removed from the anterior region of the vertebral column of each of 151 male and 195 female gummy sharks, captured by gill nets and hooks, and seven full-term embryos in the field and stored at -15°C. When required for laboratory processing the vertebrae were thawed and separated by using a scalpel. Taking precautions not to mark the surfaces of the centra, most tissues were removed by scalpel, scissors and forceps and the vertebrae were then stored in glycerol at room temperature. Concentric rings present on the centra of vertebrae were stained to improve visibility by immersion in potassium hydroxide (4%) for 12 h and a further 12 h in a solution prepared from alizarine red stain (saturated in 50% glacial acetic acid), white glycerine and chloral hydrate (crystaline 1% aqueous solution) (Galtsoff 1952).

The radius of each of the embryonic middle zone, each annulus, growth zone and outer edge was measured by use of a microscope micrometer and recorded. Relationships between these radii and total length of the sharks are given in Fig. 5.1 for males and Fig. 5.2 for females.

The embryonic middle zone was always found to be present while the first clear annulus outside this zone was not clearly visible for full term embryos. On the basis that the first annulus was present for most new-born sharks it was assumed that the first annulus was laid down at birth and that each subsequent annulus and the growth zone represent one year of age.

On the basis of this method of ageing summaries of number and proportion of sharks within each 1-year age-group for each 100-mm length-class for each of male and female gummy shark are given in Table 5.1 and 5.2 respectively.

For the purpose of estimating the von Bertalanffy growth parameters age was estimated more precisely on the assumption that each shark was born on 1 January and, based on the date of capture, a proportion of the year was added to the number of whole years. The growth parameters were estimated by fitting a curve to length against age using the method of least squares as described by Fabens (1965). Results of these analyses for males and females are given in Fig. 5.3 and Fig. 5.4, respectively.

6. Male reproduction

Length at first sexual maturity of male gummy shark was investigated by three independent methods: microscopic inspection of histological transverse section of testis tissue, macroscopic inspection of testes and macroscopic inspection of seminal vesicles.

For the first method, two or three pieces of tissue (4-8 mm thick) were removed by transverse section from a testis of each of 161 sharks and temporarily stored in Buin's solution. The Buin's solution was renewed every 12 hours for about 36 hours and then replaced with 10% neutralised formalin. In the laboratory the tissue pieces were dehydrated by immersion in a series of alcohol solutions (80-100%), cleared in chloroform and embedded in blocks of paraffin wax. Transverse sections of the embedded testis tissue were cut by use of a Leitz microtome to a thickness of 5-6 μm, mounted on 76 x 26 x 1 mm microscope slides and stained by a process requiring serial treatment with various solutions of xylol, alcohol, Mayer's haemotoxylin and eosin (Luna 1968). The sections were then protected by a cover slips using depex adhesive.

For microscopic inspection a straight line marker (transect) was stuck to the cover slip such that it passed over the germinal origin and centre of the tissue mount. Using an 18-stage coding system based on maturation phases in gametogenesis in seminiferous tubules (of which the testis is largely composed) developed by Mellinger (1965) and using a binocular microscope set at x400 magnification, the number of seminiferous tubules in contact with one edge of the transect at each stage was recorded. In addition, the maximum stage detected from a general scan of the whole section was recorded. Where one or more seminiferous tubules were detected as having reached Stage 16, a shark was classified as sexually mature. The number of immature and number and proportion mature on this basis in each 100-mm length-class are given in Table 6.1.

For the second method, macroscopic inspection of the testes of each of 272 sharks, males were classified into one of the three stages based on general appearance, thickness of testis tissue and relative size of epigonal gland:

Stage 1 - testis pale and thin, and epigonal gland predominant,
Stage 2 - testis darkened and enlarged and epigonal gland predominant, and
Stage 3 - testis darkened and predominant.

By classifying sharks at Stages 1 and 2 as immature and those at Stage 3 as mature, a summary of the number of immature and number and proportion of sharks mature in each 100-mm length-class is provided in Table 6.2.

The third method involved macroscopic inspection of the seminal vesicles and epididymises of each of 374 males and assigning them into stages on the basis of appearance of the walls of the seminal vesicles and presence or absence of semen.

Stage 1 - wall of seminal vesicles translucent and semen absent,
Stage 2 - wall of seminal vesicles opaque and semen present, and
Stage 3 - wall of seminal vesicles opaque and semen absent or negligible.

By classifying Stage 1 sharks as sexually immature and Stages 2 and 3 as mature, a summary of the number of immature and the number and proportion of mature sharks in each 100-mm length-class is given in Table 6.3.

A summary (Table 6.4) of the number of sharks with seminal vesicles partly or completely filled with semen and the number and proportion of sharks with empty seminal vesicles in each 2-month period indicates that the greatest proportion of sharks have empty seminal vesicles during November-December. This provides some evidence that copulation occurs predominantly towards the end of the year. However a summary of available data (Table 6.5) of the number of mature sharks with seminal vesicles less than half full and the number of and proportion more than half full in each 2-month period neither supports nor invalidates this conclusion.

Probit analysis (Table 6.6) was used to determine the relationship (with 95% confidence limits) between proportion of the sharks mature, p, and length, l, for the three independent methods (Fig. 6.1) where

$$p = \text{Probit}^{-1}\ (a + b\log_{10} l)$$

and where a and b are constants. Estimates of length at which 50% are sexually mature, with 95% confidence limits, are tabulated as follows.

Microscopic inspection of histological transverse section of testis tissue	960 mm (916-997 mm)
Macroscopic inspection of testes	950 mm (919-983 mm)
Macroscopic inspection of seminal vesicles	950 mm (925-976 mm)

These results indicate that there is close agreement between the three methods adopted. Combining these results with those of the ageing studies indicates that males are almost 5 years of age when 50% first reach sexual maturity.

7. Female reproduction

Female reproduction of gummy shark was studied by examination of condition of uteri, enlargement of ova in the ovaries, development of oviducal glands, and number and growth of embryos.

Condition of the uteri, U, was classified as one of the first five of the six indicies illustrated and described in Fig. 7.1; development of oviducal glands, O, as Index 1 (not visible), Index 2 (visible but small) and Index 3 (enlarged); and stage of enlargement of ova, G, as Index 1 (ova small follicles), Index 2 (ova 2-4 mm diameter) and Index 3 (ova greater than 4 mm diameter) were all recorded for each of 214 females during 19 November 1974 to 29 November 1976 (Cruises 03-07). The proportion of sharks with each gonad index for each oviducal gland index for each uterus condition index for these data are given in Fig. 7.2. In the field no attempt was made to distinguish between Indicies 3 and 6, both were recorded as Index 3.

From Fig. 7.2 sexual maturation, pregnancy and parturition can be summarised according to the following stages.

1. At birth the uteri are thin tubular structures without visible oviducal glands and the ova are tiny follicles (U=1, O=1 and G=1).
2. Slight enlargement of ova and oviducal glands appear (U=1, O=1-2 and G=1-2).
3. Uteri begin to enlarge posteriorly in an anterior direction (U=1-2, O=2 and G=2).
4. Further enlargement of uteri, oviducal glands and ova (U=2-3, O=2-3 and G=2-3.
5. Enveloped eggs without visible embryos appear in uteri and uterine walls are slightly distended (U=4, O=3 and G=3).
6. Embryos with yolk sacs appear in uteri and, depending on degree of development of the embryos, uterine walls are further distended and become translucent (U=5, O=3 and G=3).
7. Following parturition the distended uterine walls gradually contract to the pre-pregnancy condition described under Stage 4 (U=6, O=3 and G=3).

To develop a theory of the reproductive cycle of females it is necessary to establish firstly, whether the period of embryonic development is seasonal or protracted; secondly, the period of gestation; and thirdly, the pattern of enlargement of ova in the ovaries to determine frequency of pregnancies.

By assigning an embryo length of zero to 209 in utero eggs present in 11 females not carrying any visible embryos during October-December and then using a quadratic equation to describe the relationship between embryo length and day of year for these eggs and 924 enlarged embryos during March-December from 64 pregnant adults (Table 7.1), by multiple regression techniques it was possible to show that embryonic development is seasonal (Fig. 7.3). Eggs present in pregnant adults carrying both eggs and enlarged embryos during the period March-December and 11 eggs from a single adult during May containing only eggs were rejected from the regression analysis. These eggs were darker in colour, crenated and partly dehydrated when compared with those present in uteri of pregnant adults without any visible embryos during October-December. Presumably these were either unfertilised or the developing embryos had died.

On the basis that there was a total of 95 of these unviable eggs present with 924 visible developing embryos, it is concluded that 9% of all eggs entering uteri following ovulation fail to develop into viable embryos. No attempt was made to estimate in utero mortality of embryos because of difficulty in distinguishing between death of embryos by natural causes and death caused by capture of mother.

That no pregnant female was captured with full-term embryos during January-February, when field sampling was intensive, is evidence that parturition is largely complete by January. Fig. 7.3 indicates that the mean length of embryos and hence the average time for the start of gestation is early October. The presence of 209 eggs in the uteri of 11 mothers during October-December provides evidence that gestation must commence and that fertilisation must occur towards the beginning of the October-December period. Other than the one in May mentioned above, no female with only in utero eggs was captured outside this period. These results indicate that the maximum period of gestation for any individual is 15 months but it follows that the average period must be less For the purpose of estimating the von Bertalanffy growth parameter t_0 given in Section 4.3 and for estimates of fecundity presented later in this report, birth of gummy sharks is standardised to 1 January. From the equation given. in Fig. 7.3 the mean length at birth on 1 January is estimated at 336 mm.

Because both ovulation and parturition occur during October-December it might be interpreted that ovulation immediately follows parturition, that the gestation period is 1 year and that females produce young every year. However, examination of the ovaries of five females captured during ovulation (i.e., enlarged ova present in the ovaries and eggs present in the uteri) indicated that the mean diameter of the three largest ova for these sharks (20-23 mm) was about double the mean diameter of the three largest ova of pregnant females with full-term embryos (5-12 mm) during October-December. The presence of non-pregnant females in the population with intermediate diameters (13-19 mm) during January-September is evidence that the ovarian cycle is 2 years.

By posing the hypothesis that ova enlargement occurs over a 2-year period and by adding 365 days to day of year for ovulating females, a strait line relationship was fitted by regression between mean diameter of three largest ova of pregnant females and day of 2-year period (Fig. 7.4). While the mean diameters for the three largest ova for all pregnant females carrying visible embryos (i.e., U=5) readily fit this relationship, the mean diameters for females carrying in utero eggs without visible embryos (i.e., U=4) require special treatment to fit the relationship. Of the nine sharks classified as uterus condition index 4 (Fig. 7.5), four were observed to have at least three enlarged ova in their ovaries and one had only one ovum in its ovary as well as eggs in the uteri (ovulation incomplete), three had completed ovulation only small ova (i.e., mean diameter 5-7 mm) and one observed in May with a mean diameter of 7 mm.

By plotting the relationship with 95% confidence limits on individual shark data given in Fig. 7.4 on the scattergram presented in Fig. 7.5, it is evident that the mean diameter of the three largest ova of the single shark with only eggs in the uteri in May are similar to those of pregnant females with in utero embryos. Hence this one female can be interpreted as being in the same phase of the reproductive cycle as the pregnant females carrying embryos with the distinction that either all the eggs were unfertilised or any developing embryos had died at a stage before they were visible.

The four sharks for which ovulation was complete give some insight into the size of the remaining ova after ovulation. Although the sharks are not as small as would be expected from the plot they are smaller than those expected for females carrying full-term embryos during October-December. This might be taken as further evidence that the ovarian cycle has a period of 2 years. It should be noted that the ova of several sharks included in Table 7.1 were damaged in transit from the field to the laboratory during the early cruises and could not be measured and included in Figs. 7.4 and 7.5.

A scattergram of mean diameter of the three largest ova against day of a 1-year period for sharks with uterus condition indicies 2 and 3 and a plot of the relationship with 95% confidence limits an individual shark data given in Fig. 7.4 is presented in Fig. 7.6.

Sharks with uterus condition indicies 1 and 2 are virgins. The mean diameters of the three largest ova of females with index 1 were less than 2 mm and for most the ovarian cycle had not commenced (not plotted), whereas those with index 2 were all less than 5 mm and therefore in the first half of the 2-year ovarian cycle.

Females with uterus condition index 3 are either virgins with ova enlarging for the first time or females which have previously been pregnant and the ova are passing through the ovarian cycle for the second or more time. The ova of these females can be readily associated with the first or second half of the ovarian cycle. The absence of data points during April, July and August reflect the lack of sampling during these months but the lack of enlarged ova during October-December for the second half of the ovarian cycle provide further evidence that ovulation occurs during this period. The females with medium-sized ova during November-December are either virgins or have recently given birth.

From these results it is concluded that the period of gestation is 12-15 months and that the ovarian cycle is 2 years. If these results are valid then it follows that the maximum frequency of pregnancy is once every two years. A theory of the synchronisation of seasonal development of the largest ova and growth of in utero embryos in relation to uterus condition and sexual maturity is illustrated in Fig. 7.7.

To determine the length at which females reach sexual maturity the number of sharks with each uterus condition illustrated and described in Fig. 7.1 were recorded for each 100-mm length-class (Table 7.2). Probit analysis (Table 7.3) was used to determine the relationship (with 95% confidence limits) between proportion of sharks, p, for a selected group of uterus condition indicies and length of sharks, l, for each of four groups of uterus condition indicies (Fig. 7.8) where

$$p = c \ \text{Probit}^{-1} \ (a + b\log_{10} l)$$

and where a, b and c are constants. For a population with a 2-year reproductive cycle, the value of c for Fig. 7.8(c), the maximum proportion of the population expected to have either in utero eggs during October-December (90 days) or in utero embryos during January-December (365 days) (see Fig. 7.3), is 0.63 [i.e., c = (90+365)/(2x365) = 0.63]; and the value of c for Fig. 7.8(d), the maximum proportion of the population expected to have only in utero embryos during January-December (365 days), is 0.50 [i.e., c = 365/(2x365) = 0.50]. Estimates of length at which 50% had reached a uterus condition, with 95% confidence limits, are tabulated as follows.

Indicies 2, 3, 4 and 5	1070 mm (1044-1098 mm)
Indicies 3, 4 and 5	1140 mm (1113-1169 mm)
Indicies 4 and 5	1246 mm (1208-1291 mm)
Index 5	1235 mm (1199-1277 mm)

Interpretation of these results with those presented for the ageing studies (Fig. 5.3 and Fig. 5.4) indicate that males reach sexual maturity at 5 years of age whereas for females the ova begin to enlarge at 5 years, first ovulation occurs at 7 years and first partitution at 8 years of age.

The equation used to describe the relationship between sum of number in utero eggs and embryos and mother length (Fig. 7.9) and between number in utero embryos and mother length (Fig. 7.10) is of the form

$$\text{Number} = e^{a+b(\text{Mother length})}.$$

This equation was chosen because it provides for a curvilinear relationship without passing through the origin and is described simply by only two parameters, a and b, which can be readily calculated by linear regression of ln (number) against mother length. Taking natural logarithms of number also has the advantage of providing homogenous variance in ln (number) with increasing mother length which is a prerequisite for linear regression.

Examination of the uteri of 81 pregnant females indicated that the mean number of eggs and embryos in the left uterus (8.27) did not differ significantly from the mean number in the right uterus (8.16), and that from macroscopic inspection of the embryos that the mean number of males (5.83) did not differ significantly from the mean number of females (6.26) (Table 7.4). From these results it can be concluded that the sex ratio of newborn sharks is 1:1.

8. Feeding Studies

The contents of the stomachs were removed from 497 gummy sharks in the field and stored in 70% alcohol. In a laboratory each specimen of prey item was identified to the lowest level of taxon depending on state of digestion and completeness of the specimen; and wet weight, state of digestion and presence or absence of various components (head, trunk, tail, appendages and separate hard parts) were recorded.

A total of 61 separate species of prey items were identified but, in addition, a number of prey items were identified to genus or higher taxon which did not include any of the 61 species. The 61 species consist of one annelid, 29 crustaceans, four cephalopods (other than octopus which were identified only to the level of genus), two bivalves and 25 teleosts.

The mean weight of material per shark was 50 g of which 13 g was a sludge of biotic material which could not be readily identified, and of the 497 sharks, 12% had empty stomachs. Of the prey items which could be identified to class or lower level of taxon, 48% by weight were cephalopods, 33% were crustaceans and 15% were teleosts. The remaining 4% comprised 11 classes.

With respect to state of digestion, prey items were classified as 'nil', 'slight', 'medium' or 'advanced'. Where a specimen of a whole or of part of a prey item was identified, it was classified as 'nil digestion' if there was no degradation by digestion and as 'slight digestion' if degradation was negligible. A specimen of crustacea was classified as 'advanced digestion' where most of the soft tissues were absorbed whereas a specimen of other taxa was given this classification when its species was not readily recognisable from external appearance. 'Medium digestion' applied to intermediate conditions. Complete specimens of crustacea could usually be identified from the exoskeleton for all states of digestion whereas cephalopods and teleosts in a 'medium' or 'advanced' state of digestion could only be identified from those hard parts which could not be readily digested. Specimens of taxa comprised entirely of soft tissues could not be identified when in a medium or advanced state of digestion. When present without soft tissues, bones and otoliths of teleosts, chitinous beaks of cephalopods, chitinous gladii of squid ('pens') and the calcareous portion of gladii of cuttlefish ('cuttle bones') were classified as 'advanced digestion' but also as 'indigestible material'. Other hard parts such as exoskeletons of crustacea, and cartilaginous skulls and sucker rings of cephalopods were not classified as 'indigestible material'. Most prey items classified as echiurids were identified from the presence of probosises which had lengths of about 100-300 mm.

Where a prey item was identified with the head or trunk or, in the case of teleosts, the tail or any of these present together, it was recorded as an individual. On the other hand, where a prey item was identified from appendages, or indigestible material of a cephalopod or teleost, in the absence of a head or trunk or, for teleosts, tail it was not recorded as an individual.

A summary of the number and percentage of sharks containing each prey item, mean number and mean weight per shark for each prey item and percentage of prey items by number and by weight are given in Table 8.1. Presence in sharks and weight of prey items identified from 'indigestible material' are shown in parentheses. For each level of taxon in the table, frequency of sharks containing a prey item and weight and number of prey items identified to that level are added to the sum of prey items identified at lower levels of taxon for each of these three variables and converted to percentages.

Although this table is designed to present the relative importance of the various prey items in the diet of gummy shark it does not account for differing rates and extent of digestion of the prey items. Percentages of prey items for each of the four states of digestion for the major taxonomic classes (cephalopoda, crustacea, teleostei and others) found in the gummy shark (Table 8.2) indicate that resistance to digestion of the specimens in the stomachs depends on the taxonomic class of prey item. High resistance to digestion by a prey item increases the probability of detecting that item and hence biasing the relative importance of the taxonomic group of that prey item in terms of (1) percentage frequency of sharks containing the prey item, (2) weight of the prey item as a percentage of the total weight of stomach contents of all sharks sampled, and (3) number of the prey item as a percentage of the total number of individual organisms identified in the stomachs of the sharks.

In general cephalopods are heavier than organisms of the other classes of prey item and contribute the greatest biomass (36%) to the diet of gummy shark but at any instant the frequency of sharks containing cephalopods (28%) and the frequency of individual cephalopods present (13%) is much less than for crustaceans (percentage frequency of sharks of 67% and percentage frequency of prey item 63%) and teleostei (percentage frequency of sharks of 26% and percentage frequency of prey item of 8%). The other classes which are comprised mainly of echiurids contribute relatively large numbers of organisms (17%) to a high frequency of sharks (17%) but contribute negligible biomass (3%).

From Table 8.2 it is evident that the effects of state of digestion on estimates of relative importance taxonomic group of prey items are to cause relative importance of crustaceans and teleosts to increase with increased digestion, and cephalopods and other classes grouped to decrease. Estimates of relative importance by percentage weight of prey item is less sensitive to effects of varying digestion than estimates of percentage frequency of sharks containing prey item and percentage frequency of prey item.

Contents of stomachs were affected by length of the sharks and by locality and depth of capture.

Although many of the species of prey item were common to both small and large sharks, some of the large sharks contained a number of species of large items which were absent from the small sharks: notably the crustaceans Leptomithrax gaimardii and Jasus novaehollandiae and the species of cephalopoda and teleostei detected. The proportion of sharks containing these species of prey item and the frequency of their occurrence were low but their contribution to the overall biomass of the food intake was relatively high. The mean weight of the stomach contents of sharks of length greater than or equal to 1000 mm (72 g) was more than three times that of sharks less than 1000 mm (22 g).

Notable effects of locality on the relative biomass of prey items in the stomach contents of sharks from five distinct areas - designated Victoria (north of 39°30'S), Furneaux Group, King Island, Hunter Group and Tasmania (south of 40°40'S) - include the presence of the swollen spider crab, L. gaimardii, in sharks collected from Victoria, the Furneaux Group and Tasmania and its absence from sharks collected from more westerly areas (King Island and Hunter Group); the presence of southern rock lobster, J. novaehollandiae, in sharks from King Island and its low frequency in sharks collected from the other areas; and the presence of the paper nautilus, Argonauta nodosa, in sharks from Victoria and its complete absence from sharks collected from the other areas. The southern calamary, Sepioteuthis australis, was an important component in sharks from coastal waters of Victoria and Tasmania, whereas the gould squid, Nototodarus gouldi, was important for waters near Victoria and the Furneaux Group. Although the pebble crab, Ovalipes undecimspinosa, contributed a relatively low biomass to the diet, it had a high frequency of occurrence in sharks from Victoria, Tasmania and King Island but a low frequency for Hunter and Furneaux Groups. The most important prey item in terms of biomass, Octopus spp., and the one in terms of frequency occurrence, the stridulating hermit crab, Clibinarius strigimanus, were abundant for all areas.

Total biomass of stomach contents per shark rose with increasing water depth: 0-19 m (34 g), 20-39 m (40 g), 40-59 m (60 g), and ⩾ 60 m (60 g). Biomass per shark of J. novaehollandiae and the cephalopods followed this trend but for most crustaceans and teleosts there was a trend to initially rise with increasing depth with a reversal of this trend from middle to greater depths. Although gummy sharks are known to occur at depths exceeding 300 m, they are most abundant in waters of depth of 20-39 m. Based on catch and effort data most are taken in depths less than 80 m: about 20% in 0-19 m, 70% in 20-39 m, and 10% in ⩾40 m.

Gummy sharks have numerous rows of blunt flattened teeth arranged like pavement stones suitable for crushing their prey rather than cutting and tearing flesh which is characteristic of pelagic sharks. Within the constraints imposed by this mode of feeding and demersal habitation, the gummy sharks can be characterised as a predator which feeds opportunistically on a wide variety of prey species. The prey species are predominantly epibenthic organisms inhabiting areas of sandy and rocky substrate but, as the sharks increase in size, the prey species include in addition to those found in small sharks larger and more mobile organisms (demersal cephalopods and teleosts) found further up the water column.

9. Gear studies

Experimental gill nets and long-lines were set at 162 stations and, apart from on 7 days when fishing was conducted at more than one station, operations for setting the gear at sea usually started between 0400 h and 0600 h. The nets were set before the long-lines but the long-lines were hauled first. The reasons for leaving the long-lines in the water for shorter periods were twofold. Firstly because it was assumed that fishing power of long-lines declined with time as baits were degraded and lost and, secondly, because gummy sharks captured by long-lines were normally tagged and released and it was preferable to release them as soon after capture as was practicable to keep them in good condition. On the other hand, there were no a priori reasons for assuming a decline in fishing power of the nets with time and because the condition of sharks declines rapidly in nets only a small proportion of sharks captured by this method were tagged and released.

9.1. Gill nets

Twelve gill nets, each of length 250 m, were constructed such that eight had mesh sizes ranging from 2 to 9 inches stepping up in 1-inch intervals and a hanging coefficient of 0.60, two had mesh sizes 6 and 7 inches and a hanging coefficient of 0.53, and two had mesh sizes 6 and 7 inches and a hanging coefficient of 0.67.

Standardisation of depth of nets, d, of various mesh sizes, m, for each of three hanging coefficients, c, was achieved by adjustment between d and c and number of meshes deep of the net, n, by adoption of the relationship

$$c = (1/nm)\sqrt{(nm)^2 - d^2}.$$

Details of depth of net, number of meshes deep, thickness of filaments of webbing and breaking strain of filaments for each of the eight gill nets of 2-inch to 9-inch mesh size of hanging coefficient 0.60 and for each of the 6-inch and 7-inch gill nets for each of the hanging coefficients 0.53 and 0.67 are given in Table 9.1.1.

Each net was constructed of neutral buoyancy green monofilament polyomide webbing which was double knotted and double selvedged; 10-mm (circumference) polypropylene bridle and headline with one 3TV-5 Viny float (128 g wt upthrust) per 5 m; and 6-mm polyethylene lead line with eight 57-g wt lead weights per 5 m. Including upthrust of ropes, total upthrust was about 300 g wt and total weight was about 450 g wt per 5 m of netting: providing a nett weight immersed of 150 g wt per 5 m. Length of headline and attached webbing was 250 m and, to reduce incidence of tangling between headline and lead line when setting the nets to capture sharks at sea, the lead line was made 5% longer than the headline.

A special winch was designed and constructed to provide flexibility with the useage of any of the twelve nets on a particular day and to provide facility to rotate the order in which the nets were set and hauled from day to day so as to reduce variation in fishing time of the different nets. The winch carried five independent spools mounted on the periphery of a large drum (spool rack) which in turn was mounted at its centre shaft on two triangular support frames. By rotating the spool rack any of the five spools could be engaged and locked into a hydraulic power source used for hauling nets. The nets were stored on the spools in groups of two or three nets separated by 100-m lengths of 10-mm polypropylene rope and could be set, with the aid of a brake, by attaching an anchor weight and buoy with buoy line to the first net and by allowing the spool to freewheel while the net was fed over the stern of the vessel. Lead anchor weights weighing 12.5 kg were attached to the ends of all nets and a buoy line with buoy, dahn pole and flag were attached at each end of the fleet of two or three nets from each spool.

Occasionally only the nets of mesh sizes 2 to 5 inches were set to detect the presence of nursery grounds, but generally all twelve nets or the eight nets of mesh sizes ranging from 2 to 9 inches with a hanging coefficient of 0.60 were set at each station.

For 35 stations where all six nets of 6-inch and 7-inch mesh sizes for each of the three hanging coefficients 0.53, 0.60 and 0.67 were set, data of catches by these nets were included in analyses for the effects of hanging coefficient on catch. Mesh sizes of 6 and 7 inches were selected for this experiment because they were the sizes most commonly used commercially and the three hanging coefficients covered the full range used.

Comparison of mean number and mean length of sharks captured by nets of the same mesh size but different hanging coefficient (Table 9.1.2) indicates that number captured is a minimum for a hanging coefficient of 0.60 and increases as hanging coefficient both increases and decreases. Conversely, with the exception of a single net of 7-inch mesh size and hanging coefficient 0.53, length of sharks decrease as hanging coefficient departs from 0.60. Differences in mean length of sharks captured by 6-inch gill nets of different hanging coefficient were statistically significant but differences in number captured by individual nets were not significant.

However, by grouping data for the 6-inch and 7-inch nets for each hanging coefficient separately, differences in both number captured and length of sharks captured become statistically significant.

This is an important finding because in practice it means that, with the exception of South Australian fishermen who have always used a hanging coefficient of 0.50 since adoption of gill nets, the general trend of shark fishermen to change from a hanging coefficient of 0.60 towards 0.50 could have increased the fishing power of the nets and hence the real effort to a greater extent then that indicated by effort data (see Section 10).

For 73 stations where all eight nets of 2 to 9-inch mesh sizes with a hanging coefficient of 0.60 were set the data were included in mesh selectivity analyses. Mean fishing time by each net and results for each sex of gummy shark of mean length of sharks captured with standard error and standard deviation; total number captured with number standardised to number captured per unit length and metre-hour of netting; and length, at which maximum selectivity occurred for each mesh size are given in Table 9.1.3. These results indicate that length of sharks captured increases with increasing mesh size and that the rate of capture initially increases with increasing mesh size to a maximum for the 5-inch net and then decreases with further increase in mesh size.

After standardising the catches of sharks to number captured per 10^5 metre-hour, number of males and females in each 100-mm length-class for each mesh size are summarised in Table 9.1.4 while, after conversion from lengths to ages using the age-length key presented in Table 5.2, number in each 1-year age-group is given in Table 9.1.5.

Field observations of sharks entrapped in nets with mesh sizes such that they could not be enmeshed at the gills and the results presented in Table 9.1.4 indicated that for a given net the selectivity is not a symmetrical curve with respect to length of the sharks. To describe this skewed rather than symmetrical distribution and to overcome the problems of observed zero and theoretically negative selectivity values, while adopting the same three basic assumptions, encountered with traditional methods of analysis (Regier and Robson 1966) a new method was developed. For this method, selectivity, s, in relation to length the sharks, l, is described with the two parameters A and B by the relationship

$$s = (l/AB)\ e^{(A-l/B)}$$

which is the gamma distribution renormalised so that the maximum (mode) is one and where mode = AB and variance = $(A+1)B^2$.

The usual assumptions for mesh selectivity experiments which have been adopted here are summarised as follows.

(i) The nets have equal fishing power.
(ii) Optimal length of sharks captured by a net is proportioned to mesh size. Since length is directly related to girth (Fig. 3.12 and Fig. 3.13) this should be a reasonable assumption for gummy sharks.
(iii) Variance of length of the sharks captured is constant for all nets. From Table 9.1.3 this appears to be true for the 4 to 7-inch mesh sizes for the males and for the 4 to 9-inch mesh sizes for the females.

The method was used to provide estimates of optimal length of selectivity of each sex for each of the nets for which the third assumption holds (Table 9.1.3) (four nets for males and six nets for females) and of selectivity values for each 100-mm length-class for the same nets (Table 9.1.6). Also on the assumption that variance of length of sharks is constant for all mesh sizes, the estimates of variance for nets 4-7 inch for males was 25757 (= standard deviation of 160 mm), for nets 4-9 inch for females was 34588 (= standard deviation of 186 mm) and for nets 4-9 inch for males and females combined was 29693 (= standard deviation of 172 mm). Although results are presented for both males and females, statistical tests for effects of sex on selectivity indicated that sex was not significant. This suggests that catchability of males and females at a given length are equal. No systematic trends were detected by comparing observed catches with expected from the model. This indicates that the assumed model does describe the data adequately.

9.2 Long-lines

Two long-lines for experimentation were each constructed with a main-line of 6-mm (circumference) super saran (sinking rope). Each hook was attached directly to or by way of a 10 cm monal wire trace to a 1 m long snood made of 4 mm orange braided polypropylene (floating rope). The snood was attached to the main-line of the long-line when operated by a 'snood clip' at the end of the snood opposite to the end with the hook attached. Length of the main-lines depended on spacings between the hooks and the number of hooks used which depended on experimental design of tests undertaken. A 50-m length of 6-mm sisal (sinking rope) was inserted between the various sizes and spacings of hooks. Also dependent on experimental design was the size of the hooks: short-shank 2/O, 3/O, 4/O, 5/O, 7/O, 8/O, 9/O and 10/O, and long-shank 11/O Mustad hooks. The monal wire trace was used with short-shank hooks but not the long-shank hooks and thickness and breaking strain of the monal wire used increased with increasing hook size.

When not in use the main-line of each long-line was stored in a wooden box whereas the hooks and snoods were stored in marine alloy racks. Before setting a long-line the hooks were baited with either fresh fish or frozen squid and when setting it the hooks were attached to the main-line by the "snood clips" as the main-line was fed into the sea. Similar to a fleet of gill nets, an anchor weight and buoy line with buoy, dahn pole and flag were secured to each end of the long-line.

Although additional hooks were used throughout the course of the shark investigations, most useage formed part of the comparison of catches of various hook sizes and hook spacings, and of short-shank hooks with those of long-shank hooks described under three separate experiments.

Experiment 1, designed to test for the effects of hook size on catches, was conducted during Cruises 01-04 (9 June 1973 - 24 March 1975). Eight hook sizes of short-shank (Mustad 2/O, 3/O, 4/O, 5/O, 7/O, 8/O, 9/O and 10/O) in groups of 50 hooks were set with a hook spacing of 7.5 m at 42 stations.

Experiments 2 and 3, designed to test together for the effects of hook size, hook spacing and shank-length, were conducted during Cruises 05 - 06 (18 June 1975 - 9 December 1975) and Cruise 07 (14 October 1976 - 20 October 1976), respectively. For these experiments three types of Mustad hooks were used: 50 hooks of 5/O short-shank, 50 of 10/O short-shank and 100 of 11/O long-shank. For each of these experiments two hook spacings were adopted: one for the 5/O and 10/O short-shank hooks and half (50) of the 11/O long-shank hooks and the other for the second half (50) of the 11/O long-shanks hooks only. These four groups of 50 hooks were set 41 times for Experiment 2 and 22 times for Experiment 3.

In Experiment 1, because of the low breaking strain, the monal wire traces for the 2/O hooks were broken occasionally either by sharks or by snagging. Several sharks brought close to the surface during hauling operations were observed breaking the wire trace. This means that results of the number and probably mean length of sharks captured by the 2/O hooks are biased downwards.

Mean fishing time; mean, standard deviation and standard error of length of sharks captured; number captured; and number captured expressed as number per 10^4 m of main-line, number per 10^3 metre-hour of main-line, number per 10^3 hook-lift and number per 10^4 hook-hour for each group of 50 hooks are given for Experiment 1 in Table 9.2.1 and for Experiments 2 and 3, along with hook spacings, in Table 9.2.2.

From the three experiments, by comparing lengths of sharks captured by the different sizes of short-shank hooks, there appears to be a trend for larger hooks to capture larger sharks. However, this was only statistically significant for Experiment 2 and the trend is extremely weak compared to effect of mesh size of gill nets on lengths of sharks captured. It is also concluded that number and length of sharks captured are not affected by size or by shank-length of hooks, and that the number captured is only marginally increased by increasing the spacing of hooks.

During Experiment 1 the long-lines were set together with the gill nets for the purpose of comparing the relative efficiencies of the two methods. However, it soon became apparent that the number of sharks captured was affected by tidal water movement. Gill nets were not effective in areas of strong tidal movement because they tended to bunch and become tangled, whereas long-line catches were low in areas of weak tide. The successive increases in catch from Experiment 1 to Experiment 2 and from Experiment 2 to Experiment 3 were a result of setting the long-lines in areas of progressively stronger tide. An explanation offered to account for the observed increase in catch with increasing tidal movement and for the absence of an effect of hook spacing on the catch for Experiment 2 and 3, is that in areas of strong tide sharks are attracted from within the large area of dispersion of the scent of the bait whereas, in areas of weak tide, they are attracted from within a smaller area.

After standardising the catches of sharks to number captured per 10^4 hooks, the number for each 100-mm length-class for males and females separately for each hook size for Experiment 1 are given in Table 9.2.3. Summaries of number of male and female gummy sharks captured, after standardisation, in each 100-mm length-class are given in Table 9.2.4 and, after conversions from lengths to ages using the age-length key presented in Table 5.2, number in each 1-year age-group for each of Experiments 1, 2 and 3 are given in Table 9.2.5.

As with the gill nets the distributions of the catches of sharks show an absence of particularly small sharks. This suggests that either the gear is not effective at capturing small sharks or they were absent from the areas of experimental fishing.

Interviews with professional inshore net fishermen and offshore trawler fishermen of Victoria, Tasmania and South Australia and catches of some small sharks by the experimental fishing gear, provide evidence that young gummy sharks are widely distributed both inshore and offshore. This evidence along with the results that, with the exception of teleosts and cephalopods eaten by large sharks, small gummy sharks have a diet similar to the larger ones, suggest that gummy sharks do not have specialised nursery grounds.

10. Catch and effort

Use of catch and effort data for stock assessment of gummy shark is complicated by the multi-species composition of the shark catch, deployment of gill nets of various mesh sizes and long-lines by specialist shark fishermen and the significant by-catch of shark taken by estuary and trawler fishermen.

Separation of data of the gummy shark catch from those of school shark, two species of saw shark, elephant fish and a number of other species summed across all methods was not complicated. However, to depict trends in effort it was necessary to firstly, separate the effort directed at gummy shark from the total effort and, secondly, standardise the various units of effort associated with the different types of gear to the units of a single method.

Estimates of total catch of gummy sharks were made by summing catches of individual fishermen landing their catches in Victoria, Tasmania and South Australia. Gummy sharks are landed in New South Wales and Western Australia but production is negligible compared with the other three states and for the purpose of the investigation was ignored.

The catch of each fisherman was estimated from one or more of three sources of data: (a) daily log-book tear-off returns which were issued to 65 Victorian, 23 Tasmanian and 110 South Australian shark fishermen, (b) mandatory monthly returns submitted by fishermen not issued with log-books, and (c) extractions of records kept by processors of daily consignments of shark from fishermen to processors. Fishermen submitting daily log-book returns were exempted from submitting monthly summary returns. Information on catches from fishermen was compared with that from processors and when all or part of a month's production appeared to be missing from a return it was adjusted according to information available from processors.

The first step towards estimating total effort involved treating, without reference to the processor data, (a) data of metre-lifts and metre-hours for gill nets and hook-lifts and hook-hours for long-lines, and catch of each species collected for each day on the daily log-books and (b) data on the monthly returns by dividing the total catch and the total effort given for the month by the reported number of fishing days for the month and assigning the calculated mean catch and mean effort to each of the fishing days. These data of two sources were stored together in computer files with the same format.

Shark fishermen target most of their fishing effort at either gummy shark or school shark, <u>Galeorhinus australis</u> (Macleay). To separate effort 'targeted' at gummy shark from that 'targeted' at school shark, for each mesh size separately gummy shark catch, $c_{(target)}$, and fishing effort, $e_{(target)}$, were summed for days where reported catch of gummy shark exceeded 70% of the reported catch of gummy shark and school shark combined. (Records were ignored for days where any of the information of species of catch, effort or mesh size were missing). Using the estimates of total catch obtained jointly from fishemen's and processor's returns, estimates of total effort directed at gummy shark were be made by the following weighting expression.

$$\text{Total effort}_{(target)} = \text{Total catch} \times e_{(target)}/c_{(target)}.$$

Fishermen submitting log-book returns were requested to report mesh sizes and lengths of gill nets carried on their vessels and, on the basis of relative lengths carried, catch and effort could be assigned to various mesh sizes.

Samples of sex and length-frequency composition of commercial catches of gummy sharks were collected at the major ports of landing and processing and marketing centres in Victoria during the period from 1970 to the present and in Tasmania and South Australia during 1973-76. Estimates of number of sharks and of sex and length-frequency composition of the total catch for selected areas and fishing methods were made by weighting these samples to total catch. This was done with the aid of a computer by matching the samples with the fishermen's return data and using only those samples for which all of the information of locality, weight of catch, fishing method and, if the method was gill netting, mesh size was available.

Various summaries of estimates made from the commercial catch, effort and sex-length-frequency data and several sections of the biological data presented for each year during the period 1971-81 for Bass Strait and western Victoria and during 1973-76 for Tasmania, eastern South Australia and western South Australia. (See Fig. 10.1 for designation of localities). The first of these (Table 10.1) gives catch, effort standardised to one or more of 6-inch, 7-inch and 8-inch gill nets, and catch per unit effort. Although mesh size was not monitored during 1971-72 it was assumed that all gill nets used had a mesh size of 7 inches in the areas designated Bass Strait and western Victoria. The second (Table 10.2) contains estimates of number of males, females, pregnant females, in utero embryos, sex ratio and mean weight and mean length of each sex of gummy shark in the commercial catch and percentage of estimated catch by weight matched with sex-length-frequency samples. The number of pregnant females was calculated from the number of females captured at each length and from the relationship between proportion of females pregnant and length of sharks given in Fig. 7.8 (d). The number of in utero embryos was calculated from estimates of number of females pregnant at each length and the relationship between number of in utero embryos and length of mother presented in Fig. 7.10. By applying the age-length key presented in Table 5.2 to the number of sharks in the commercial catch within each 100-mm length-class, the number of sharks in each 1-year age-group was estimated. These estimates for males and females are given in Table 10.3 and Table 10.4 respectively, while estimates of the sum of the two sexes within each age-group are presented in Table 10.5.

Prior to the 1970s shark was a long-line fishery based on the school shark. During the latter half of the 1960s gill nets gradually replaced long-lines and, with the exception of eastern South Australia and western South Australia, by the early 1970s most shark fishermen were using gill nets. With this change of method gummy shark became more accessible and with the ban on large school sharks in September 1972 the gummy shark became the primary target shark species. Although school sharks taken by long-lines still remain the major target species in South Australia, gill nets have been further phased in and gummy shark catches have increased since 1972 in that region.

Table 10.1 indicates that Bass Strait and western Victoria are the main areas for gummy shark production where fishing effort directed at gummy shark rose rapidly during the early 1970s, remained fairly constant during the mid-1970s and climbed to a high plateau for the period 1978-81. Catch per unit effort in terms of both weight and number of sharks fell steadily until 1978 and then stabilised.

Notable trends from Table 10.2 are the marked increase in proportion and number of females in the catch, the large increase in size of sharks captured during 1971-73 and equally large decline during 1973-76 to a relatively constant size and the low proportion (currently about 10%) of sexually mature females in the catch. Although not presented the proportion of mature males in the catch is about 60%.

The higher catches of males than females for Bass Strait and western Victoria and, conversely, the higher catches of females than males in South Australia during the first half of the 1970s is evidence that for the unfished population males were more abundant than females in the eastern region whereas females were more abundant in the western region of the range of distribution of gummy sharks. These observations are consistent with results presented for movement from tagging data in Section 4.1 which indicate that there is a greater tendency for females, particularly large ones, than males to move westwards. However, these data are affected by the effects of mesh size on length-frequency distribution of the sharks captured and require further analysis correcting for these effects by using the results of mesh selectivity presented in Section 9.1. For example the higher catches of females than males from South Australia may be more a reflection of the useage of 8-inch gill nets, which are particularly effective at catching large females (see Section 9.1), than of the distribution of the sharks.

The increase in size of sharks captured over the period 1971-73 was probably caused by increasing numbers of sharks captured by 7-inch gill nets selecting for larger than average sized sharks and less by long-lines whereas the decline in size immediately following a peak in 1973 was a result of the combined effects the mean size of sharks in the population falling and a change from 7-inch to 6-inch mesh sizes of gill nets used by the fishermen in Bass Strait and western Victoria.

Table 10.3 shows that currently over 80% of males in the catch are within the four-year age-range 3-6 years while Table 10.4 indicates that over 80% of females are within the three year range 3-5 years. That such a large proportion of the catch is well below the mean age at first sexual maturity - 5 years for males and 7 years for females (see Section 7) - raises the question of whether sufficient parent stock are surviving to maintain recruitment.

Taking the middle of the age-range 3-5 years as the period for the bulk of the sharks to reach the exploited phase of the fishery and adding 1 year for the period of gestation it can be assumed that the effects of fishing on recruitment will not be apparent for about 4-5 years. With the 30% increase in effort for Bass Strait and the 60% increase for western Victoria (Table 10.1) and the 15% increase in the number of females captured for the two regions (Table 10.2) for the period 1978-81 above the levels for the preceeding 5-year period, it is likely that at current levels of effort there will be some decline in the catch per unit effort over the next 5 years.

11. References

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12. Figures and Tables

Table 2.1. Period and number of stations, and length of netting set, number of hooks set, depth range and bottom temperature range at the fishing stations for each of seven research cruises.

Cruise	Period	Number of stations	Length of netting (m)	Number of hooks	Depth range (m)	Bottom temp. range (°C)
01	9 Jun 1973-12 Jul 1973	23	34500	11090	5-75	11.2-15.4
02	17 Sep 1973-20 Oct 1973	24	26250	12000	11-77	11.9-15.1
03	19 Nov 1974-12 Feb 1975	29	49500	2000	7-55	14.3-20.9
04	15 Mar 1975-24 Mar 1975	9	21000	359	16-53	15.9-18.1
05	18 Jun 1975-21 Jul 1975	16	30000	1400	15-59	12.3-15.9
06	24 Sep 1975- 9 Dec 1975	38	47500	6576	11-79	12.7-17.8
07	13 Oct 1976-16 Dec 1976	23	34500	5620	7-75	11.8-16.0
Total	9 Jun 1973-16 Dec 1976	162	243250	39045	5-79	11.2-20.9

Table 2.2. Number of sharks captured, number tagged and released, and number of tagged sharks recaptured for male and female gummy shark for each seven research cruises.

Cruise	Number captured			Tag releases			Tag recaptures		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
01	407	311	718	180	110	290	72	39	111
02	335	259	594	146	90	236	46	31	77
03	309	165	474	121	80	201	21	15	36
04	110	64	174	61	30	91	7	6	13
05	6	17	23	6	9	15	1	3	4
06	258	269	527	231	239	470	48	44	92
07	149	110	259	136	86	222	32	10	42
Total	1574	1195	2769	881	644	1525	227	148	375

Table 2.3. Period and number of stations, and number of male and female gummy shark sampled during each of three commercial cruises.

Cruise	Period	Number of stations	Number sampled		
			Male	Female	Total
11	12 Dec 1973-18 Dec 1973	9	12	30	42
12	6 Mar 1974- 6 Mar 1974	2	14	3	17
13	12 May 1974-14 May 1974	6	24	42	66
Total	12 Dec 1973-14 May 1974	17	50	75	125

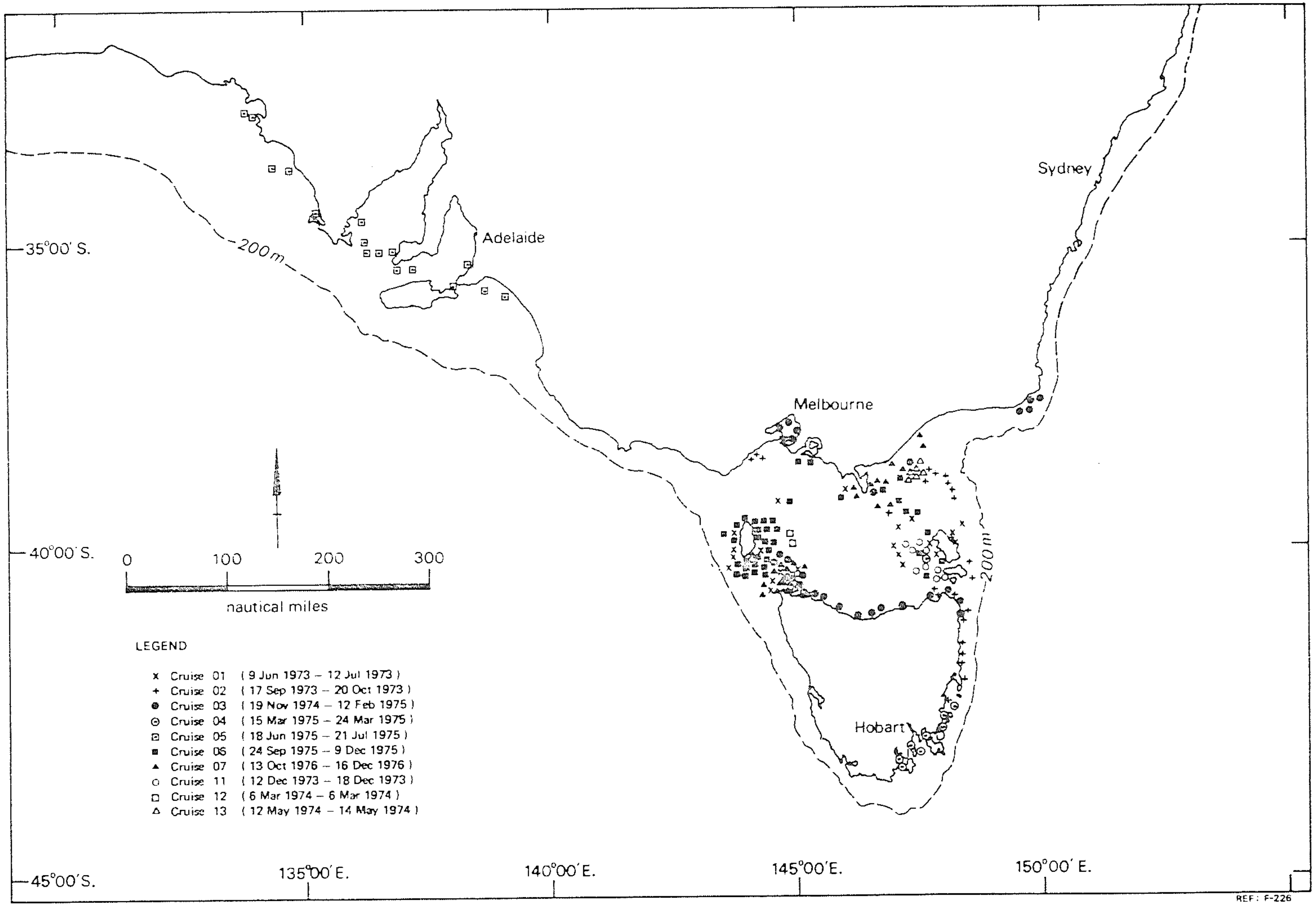

Fig. 2.1. Positions of fishing stations for each sampling cruise.

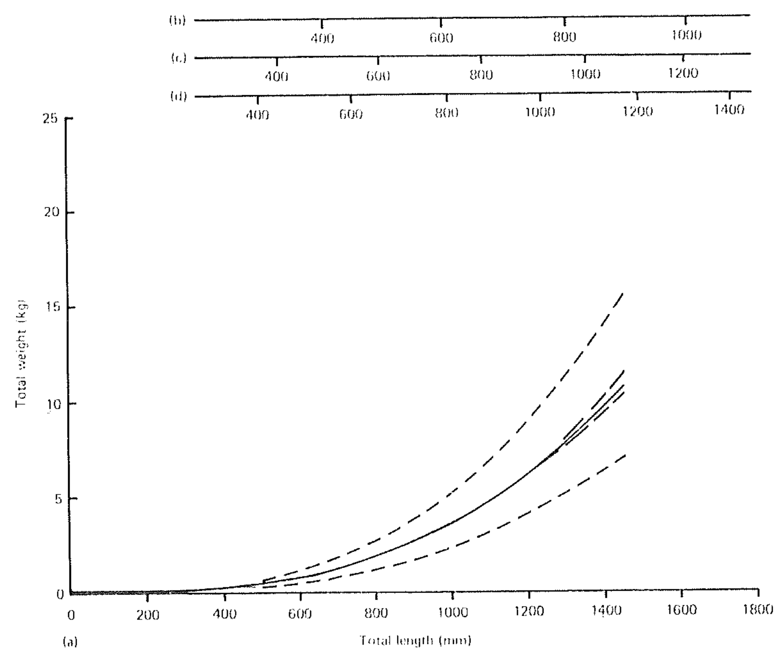

Fig. 3.1. Relationship [with 95% confidence limits on the mean curve (——) and individual shark data (----)] between total weight, w, and total length, l, for male gummy shark. Abscissa axes for three partial lengths are drawn and values for a and b (with standard error) for the equation $w = al^b$ are given in the following tabulation:

Total or partial length	a	b	n	r^2 [A]	e.m.s. [B]
(a) Total	4.52×10^{-9}	2.96 ± 0.04	548	0.93**	4.05×10^{-2}
(b) Base of caudal fin [C]	1.61×10^{-8}	3.01 ± 0.06	55	0.98**	2.52×10^{-2}
(c) Caudal subterminal notch [C]	4.62×10^{-9}	3.12 ± 0.05	151	0.97**	2.72×10^{-2}
(d) Tip of caudal fin [C]	3.15×10^{-9}	3.13 ± 0.06	52	0.98**	2.54×10^{-2}

[A] Coefficient of determination between ln(w) and ln(l). $**P<0.01$.
[B] Error mean square for regression of ln(w) against ln(l).
[C] Partial length measured from fifth gill-slit.

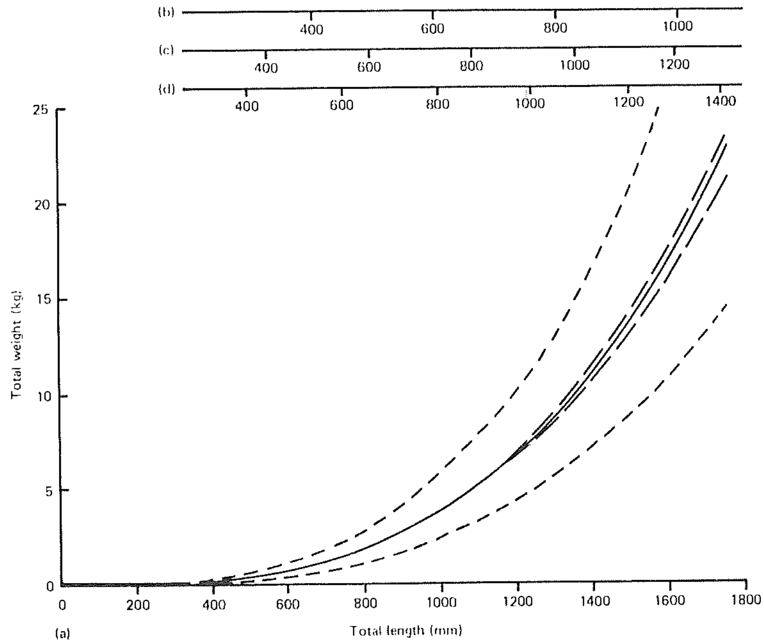

Fig. 3.2. Relationship [with 95% confidence limits on the mean curve (——) and individual shark data (----)] between total weight, w, and total length, l, for female gummy shark. Abscissa axes for three partial lengths are drawn and values for a and b (with standard error) for the equation $w = al^b$ are given in the following tabulation:

Total or partial length	a	b	n	r^2 [A]	e.m.s.[B]
(a) Total	1.22×10^{-9}	3.16 ± 0.03	531	0.95**	4.75×10^{-2}
(b) Base of caudal fin[C]	3.41×10^{-9}	3.27 ± 0.06	38	0.99**	2.54×10^{-2}
(c) Caudal subterminal notch[C]	2.66×10^{-9}	3.21 ± 0.03	191	0.98**	2.35×10^{-2}
(d) Tip of caudal fin[C]	7.59×10^{-10}	3.36 ± 0.06	37	0.99**	2.60×10^{-2}

[A] Coefficient of determination between ln(w) and ln(l). **P<0.01.
[B] Error mean square for regression of ln(w) against ln(l).
[C] Partial length measured from fifth gill-slit.

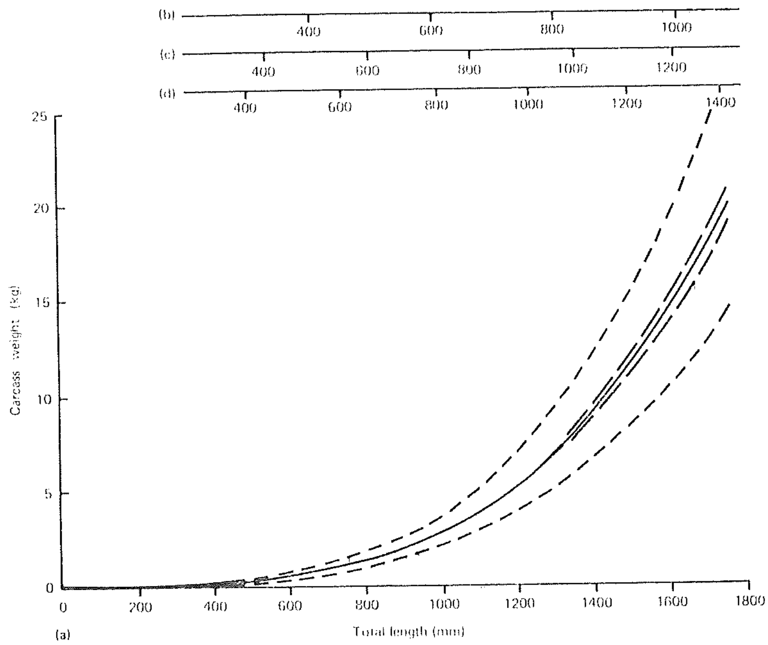

Fig. 3.3. Relationship [with 95% confidence limits on the mean curve (——) and individual shark data (----)] between carcass weight, w, and total length, l, for gummy shark. Abscissa axes for three partial lengths are drawn and values for a and b (with standard error) for the equation $w = al^b$ are given in the following tabulation:

Total or partial length	a	b	n	r^2 [A]	e.m.s.[B]
(a) Total	9.24×10^{-11}	3.49 ± 0.03	356	0.98**	2.47×10^{-2}
(b) Base of caudal fin[C]	8.57×10^{-10}	3.40 ± 0.04	91	0.99**	1.90×10^{-2}
(c) Caudal subterminal notch[C]	4.12×10^{-10}	3.43 ± 0.03	340	0.98**	3.01×10^{-2}
(d) Tip of caudal fin[C]	1.57×10^{-10}	3.51 ± 0.03	87	0.99**	1.25×10^{-2}

[A] Coefficient of determination between ln(w) and ln(l). **P<0.01.
[B] Error mean square for regression of ln(w) against ln(l).
[C] Partial length measured from fifth gill-slit.

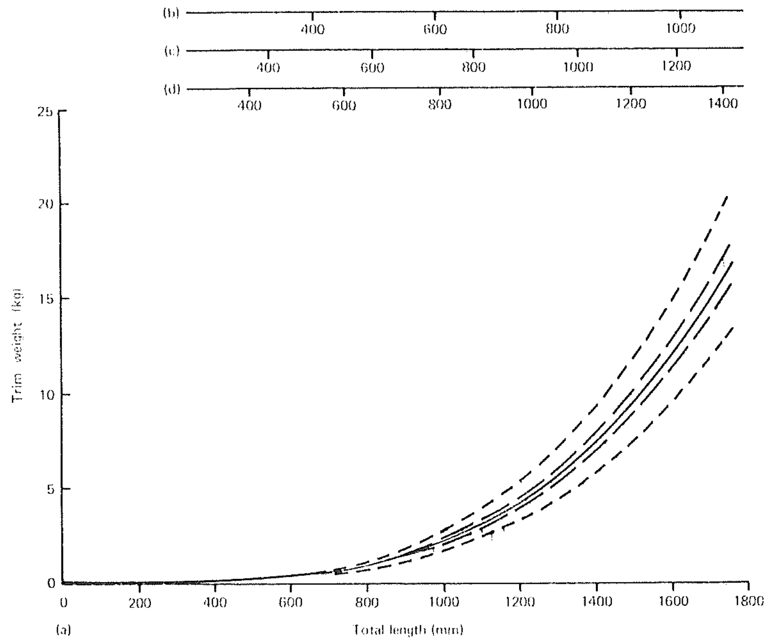

Fig. 3.4. Relationship [with 95% confidence limits on the mean curve (——) and individual shark data (----)] between trim weight, w, and total length, l, for gummy shark. Abscissa axes for three partial lengths are drawn and values for a and b (with standard error) for the equation $w = al^b$ are given in the following tabulation:

Total or partial length	a	b	n	r^2 A	e.m.s. B
(a) Total	3.20×10^{-11}	3.61 ± 0.03	89	0.99**	1.37×10^{-2}
(b) Base of caudal fin C	5.05×10^{-10}	3.46 ± 0.04	88	0.99**	2.03×10^{-2}
(c) Caudal subterminal notch C	1.24×10^{-10}	3.58 ± 0.04	88	0.99**	1.80×10^{-2}
(d) Tip of caudal fin C	9.03×10^{-11}	3.57 ± 0.03	84	0.99**	1.34×10^{-2}

A Coefficient of determination between ln(w) and ln(l). **P<0.01.
B Error mean square for regression of ln(w) against ln(l).
C Partial length measured from fifth gill-slit.

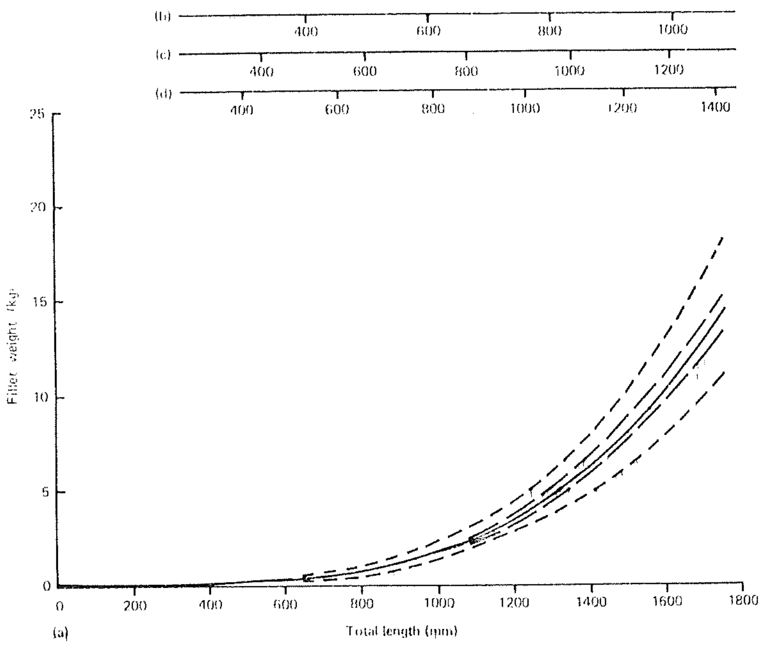

Fig. 3.5. Relationship [with 95% confidence limits on the mean curve (——) and individual shark data (----)] between fillet weight, w, and total length, l, for gummy shark. Abscissa axes for three partial lengths are drawn and values for a and b (with standard error) for the equation $w = al^b$ are given in the following tabulation:

Total or partial length	a	b	n	r^2 [A]	e.m.s.[B]
(a) Total	1.27×10^{-11}	3.71 ± 0.03	94	0.99**	1.46×10^{-2}
(b) Base of caudal fin[C]	2.22×10^{-10}	3.56 ± 0.04	92	0.99**	2.18×10^{-2}
(c) Caudal subterminal notch[C]	5.24×10^{-11}	3.68 ± 0.04	93	0.99**	1.88×10^{-2}
(d) Tip of caudal fin[C]	3.77×10^{-11}	3.67 ± 0.03	88	0.99**	1.55×10^{-2}

[A] Coefficient of determination between ln(w) and ln(l). **P<0.01.
[B] Error mean square for regression of ln(w) against ln(l).
[C] Partial length measured from fifth gill-slit.

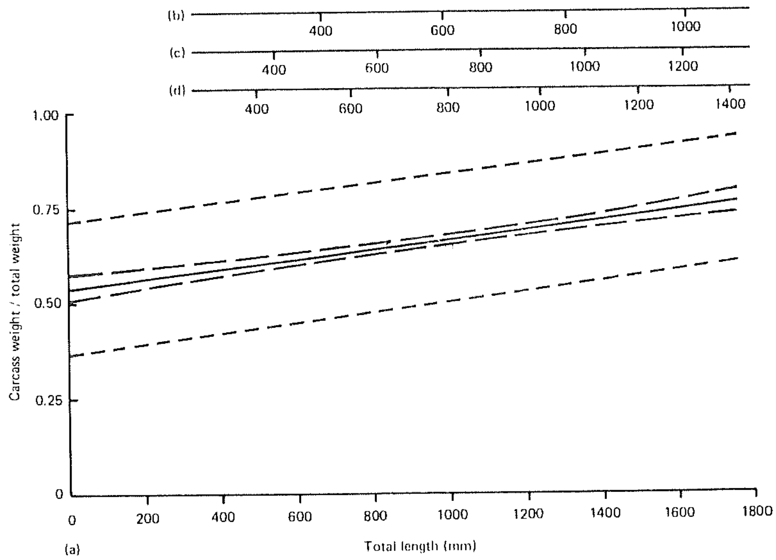

Fig. 3.6. Relationship [with 95% confidence limits on the mean curve (——) and individual shark data (----)] between proportion carcass weight/total weight, p, and total length, l, for gummy shark. Abscissa axes for three partial lengths are drawn and values for a and b (with standard error) for the equation p = a+bl are given in the following tabulation:

Total or partial length	a	b	n	r^2 [A]	e.m.s.[B]
(a) Total	5.40x10-1	(1.28±0.16)x10-4	351	0.16**	7.40x10-3
(b) Base of caudal fin[C]	4.46×10^{-1}	$(2.93\pm0.53)\times10^{-4}$	91	0.25**	8.55×10^{-3}
(c) Caudal subterminal notch[C]	5.33×10^{-1}	$(1.85\pm0.22)\times10^{-4}$	331	0.17**	7.60×10^{-3}
(d) Tip of caudal fin[C]	4.41×10^{-1}	$(2.27\pm0.42)\times10^{-4}$	87	0.26**	8.37×10^{-3}

[A] Coefficient of determination between p and l. **P<0.01.
[B] Error mean square for regression of p against l.
[C] Partial length measured from fifth gill-slit.

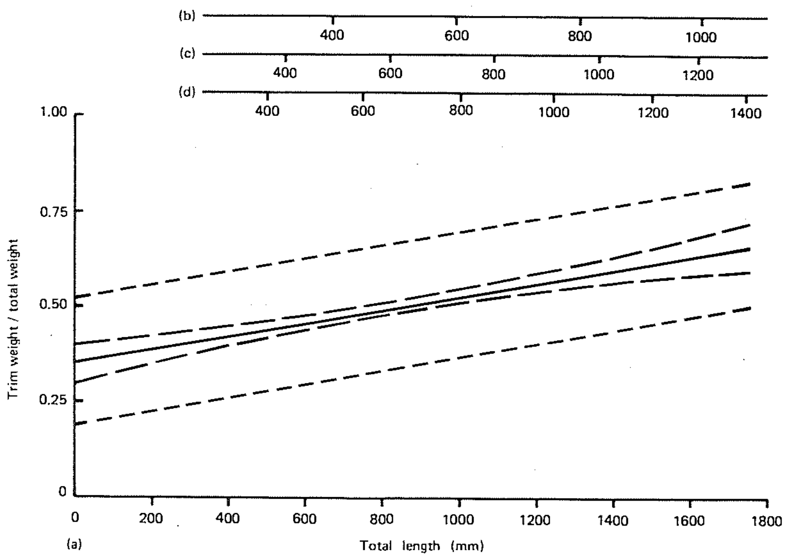

Fig. 3.7. Relationship [with 95% confidence limits on the mean curve (———) and individual shark data (----)] between proportion trim weight/total weight, p, and total length, l, for gummy shark. Abscissa axes for three partial lengths are drawn and values for a and b (with standard error) for the equation p = a+bl are given in the following tabulation:

Total or partial length	a	b	n	r^2 [A]	e.m.s.[B]
(a) Total	3.51×10^{-1}	$(1.79 \pm 0.28) \times 10^{-4}$	89	0.32**	6.30×10^{-3}
(b) Base of caudal fin[C]	3.51×10^{-1}	$(2.99 \pm 0.46) \times 10^{-4}$	88	0.33**	6.34×10^{-3}
(c) Caudal subterminal notch[C]	3.46×10^{-1}	$(2.57 \pm 0.40) \times 10^{-4}$	88	0.33**	6.32×10^{-3}
(d) Tip of caudal fin[C]	3.46×10^{-1}	$(2.31 \pm 0.36) \times 10^{-4}$	84	0.33**	6.20×10^{-3}

[A] Coefficient of determination between p and l. **P<0.01.
[B] Error mean square for regression of p against l.
[C] Partial length measured from fifth gill-slit.

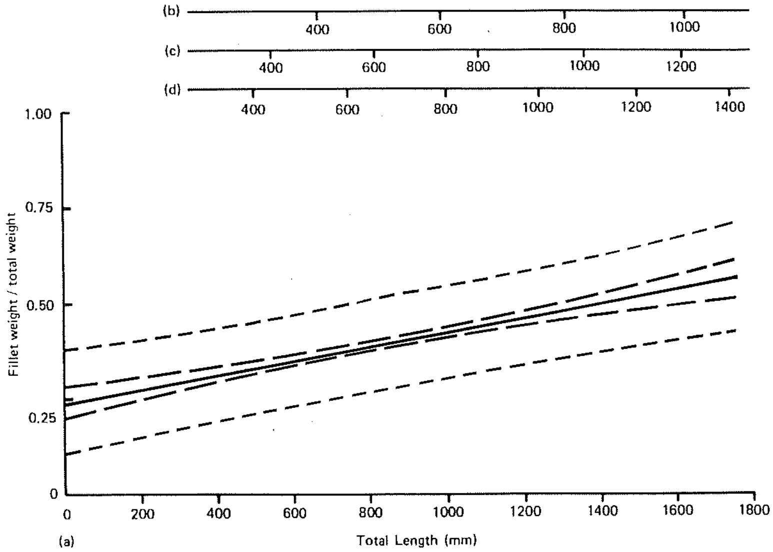

Fig. 3.8. Relationship [with 95% confidence limits on the mean curve (——) and individual shark data (----)] between proportion fillet weight/total weight, p, and total length, l, for gummy shark. Abscissa axes for three partial lengths are drawn and values for a and b (with standard error) for the equation p = a+bl are given in the following tabulation:

Total or partial length	a	b	n	r^2 A	e.m.s.B
(a) Total	2.38×10^{-1}	$(1.87 \pm 0.21) \times 10^{-4}$	94	0.45**	3.90×10^{-3}
(b) Base of caudal finC	2.40×10^{-1}	$(3.10 \pm 0.36) \times 10^{-4}$	92	0.45**	3.98×10^{-3}
(c) Caudal subterminal notchC	2.34×10^{-1}	$(2.66 \pm 0.31) \times 10^{-4}$	93	0.46**	3.91×10^{-3}
(d) Tip of caudal finC	2.35×10^{-1}	$(2.41 \pm 0.28) \times 10^{-4}$	88	0.45**	3.81×10^{-3}

A Coefficient of determination between p and l. **P<0.01.
B Error mean square for regression of p against l.
C Partial length measured from fifth gill-slit.

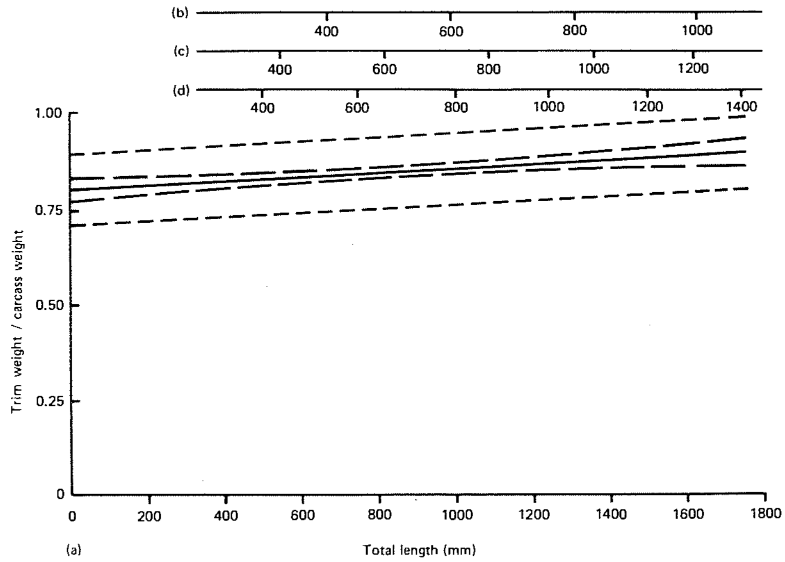

Fig. 3.9. Relationship [with 95% confidence limits on the mean curve (——) and individual shark data (----)] between proportion trim weight/carcass weight, p, and total length, l, for gummy shark. Abscissa axes for three partial lengths are drawn and values for a and b (with standard error) for the equation p = a+bl are given in the following tabulation:

Total or partial length	a	b	n	r^2 [A]	e.m.s.[B]
(a) Total	7.98×10^{-1}	$(5.60 \pm 1.61) \times 10^{-5}$	87	0.13**	2.09×10^{-3}
(b) Base of caudal fin[C]	8.00×10^{-1}	$(8.91 \pm 2.70) \times 10^{-5}$	86	0.11**	2.12×10^{-3}
(c) Caudal subterminal notch[C]	7.99×10^{-1}	$(7.53 \pm 2.31) \times 10^{-5}$	86	0.11**	2.12×10^{-3}
(d) Tip of caudal fin[C]	7.98×10^{-1}	$(6.89 \pm 2.18) \times 10^{-5}$	82	0.11**	2.20×10^{-3}

[A] Coefficient of determination between p and l. **$P<0.01$.
[B] Error mean square for regression of p against l.
[C] Partial length measured from fifth gill-slit.

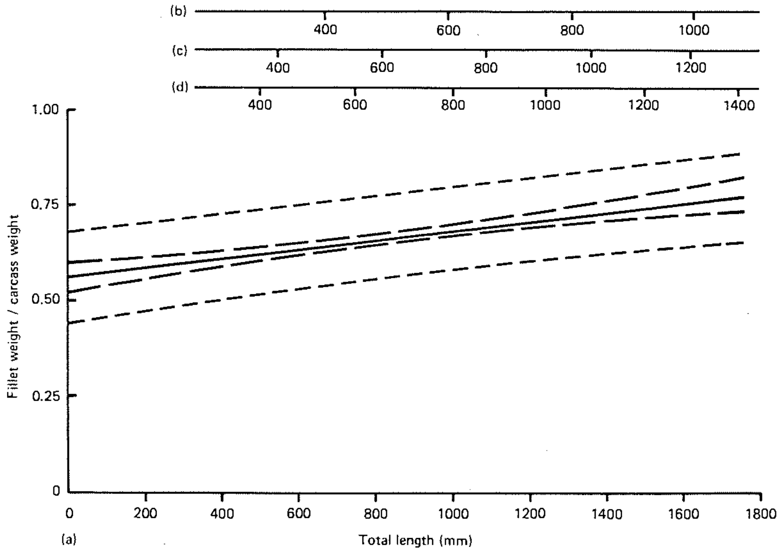

Fig. 3.10. Relationship [with 95% confidence limits on the mean curve (———) and individual shark data (----)] between proportion fillet weight/carcass weight, p, and total length, l, for gummy shark. Abscissa axes for three partial lengths are drawn and values for a and b (with standard error) for the equation p = a+bl are given in the following tabulation:

Total or partial length	a	b	n	r^2 [A]	e.m.s.[B]
(a) Total	5.64×10^{-1}	$(1.19 \pm 0.19) \times 10^{-4}$	92	0.29**	3.17×10^{-3}
(b) Base of caudal fin[C]	5.69×10^{-1}	$(1.90 \pm 0.32) \times 10^{-4}$	90	0.28**	3.17×10^{-3}
(c) Caudal subterminal notch[C]	5.66×10^{-1}	$(1.61 \pm 0.26) \times 10^{-4}$	92	0.29**	3.18×10^{-3}
(d) Tip of caudal fin[C]	5.66×10^{-1}	$(1.49 \pm 0.26) \times 10^{-4}$	86	0.28**	3.26×10^{-3}

[A] Coefficient of determination between p and l. **$P<0.01$.
[B] Error mean square for regression of p against l.
[C] Partial length measured from fifth gill-slit.

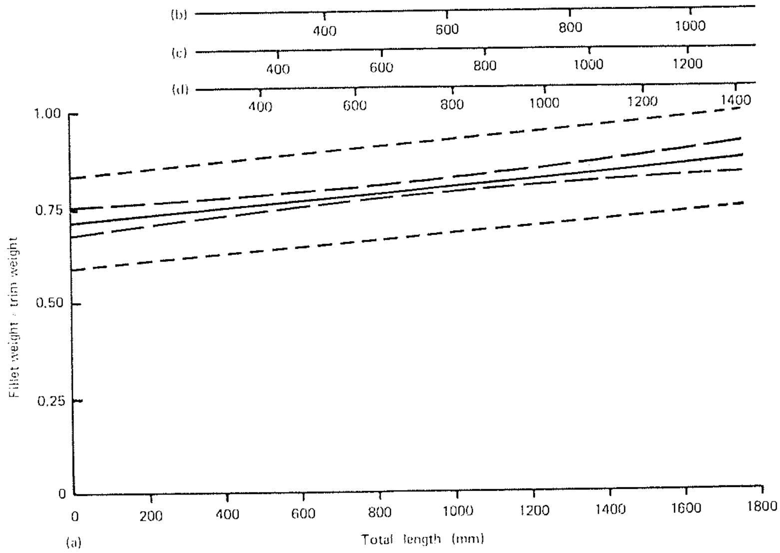

Fig. 3.11. Relationship [with 95% confidence limits on the mean curve (——) and individual shark data (----)] between proportion fillet weight/trim weight, p, and total length, l, for gummy shark. Abscissa axes for three partial lengths are drawn and values for a and b (with standard error) for the equation p = a+bl are given in the following tabulation:

Total or partial length	a	b	n	r^2 [A]	e.m.s.[B]
(a) Total	7.11×10^{-1}	$(9.01 \pm 2.07) \times 10^{-5}$	88	0.18**	3.55×10^{-3}
(b) Base of caudal fin[C]	7.13×10^{-1}	$(1.46 \pm 0.35) \times 10^{-4}$	87	0.17**	3.61×10^{-3}
(c) Caudal subterminal notch[C]	7.10×10^{-1}	$(1.26 \pm 0.30) \times 10^{-4}$	87	0.17**	3.59×10^{-3}
(d) Tip of caudal fin[C]	7.1×10^{-1}	$(1.15 \pm 0.28) \times 10^{-4}$	83	0.18**	3.65×10^{-3}

[A] Coefficient of determination between p and l. **P<0.01.
[B] Error mean square for regression of p against l.
[C] Partial length measured from fifth gill-slit.

Table 3.1. Values for a and b (with standard error) for various relationships between pairs of total length and three partial lengths, l_1 and l_2, for the equation $l_2 = a + b\, l_1$ (lengths measured in mm) for gummy shark.

l_1	l_2	a	b	n	r^2 [A]	e.m.s. [B]
l_{TL} [C]	l_{BCF} [D]	-1.55×10	$(6.21 \pm 0.04) \times 10^{-1}$	93	1.00**	1.39×10^2
l_{BCF}	l_{TL}	2.65×10	1.61 ± 0.01	93	1.00**	3.58×10^2
l_{TL}	l_{STN}	-8.36	$(7.42 \pm 0.03) \times 10^{-1}$	346	0.99**	3.17×10^2
l_{STN} [E]	l_{TL}	1.48×10	1.34 ± 0.01	346	0.99**	5.71×10^2
l_{TL}	l_{TCF}	-1.76	$(8.05 \pm 0.04) \times 10^{-1}$	89	1.00**	1.18×10^2
l_{TCF} [F]	l_{TL}	3.02	1.24 ± 0.01	89	1.00**	1.82×10^2
l_{STN}	l_{BCF}	-1.47×10	$(8.55 \pm 0.03) \times 10^{-1}$	93	1.00**	3.52×10
l_{BCF}	l_{STN}	1.75×10	1.17 ± 0.00	93	1.00**	4.84×10
l_{TCF}	l_{BCF}	-1.50×10	$(7.72 \pm 0.03) \times 10^{-1}$	89	1.00**	4.57×10
l_{BCF}	l_{TCF}	1.99×10	1.29 ± 0.01	89	1.00**	7.70×10
l_{TCF}	l_{STN}	-4.42×10^{-1}	$(9.04 \pm 0.02) \times 10^{-1}$	89	1.00**	1.65×10
l_{STN}	l_{TCF}	6.03×10^{-1}	1.11 ± 0.00	89	1.00**	2.00×10

[A] Coefficient of determination between l_2 and l_1. ** $P<0.01$.
[B] Error mean square for regression of l_2 against l_1.
[C] Total length.
[D] Partial length of fifth gill-slit to base of caudal fin.
[E] Partial length of fifth gill-slit to caudal subterminal notch.
[F] Partial length of fifth gill-slit to tip of caudal fin.

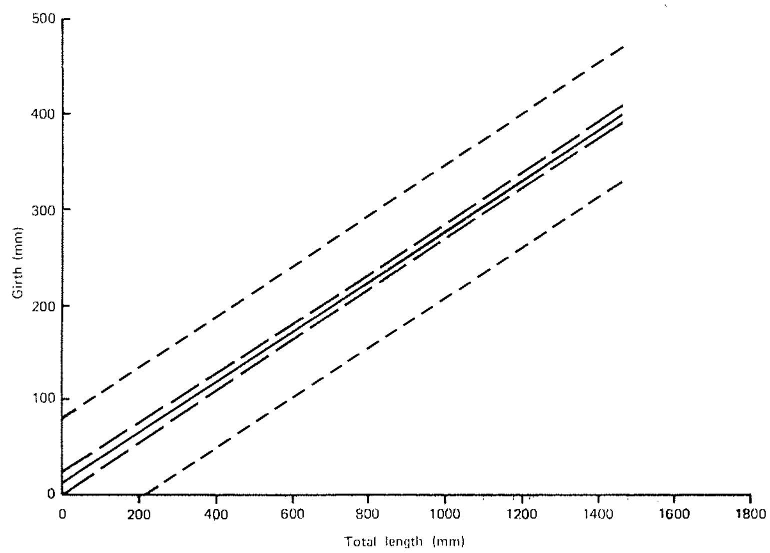

Fig. 3.12. Relationship [with 95% confidence limits on the mean curve (——) and individual shark data (----)] between girth, g, and total length l, for male gummy shark. Values for a and b (with standard error) for the equation w = a+bl are given in the following tabulation:

a	b	n	r^2 [A]	e.m.s.[B]
1.41x10	2.64±0.01	717	0.72**	1.23×10^3

[A] Coefficient of determination between g and l. **P<0.01.
[B] Error mean square for regression of g against l.

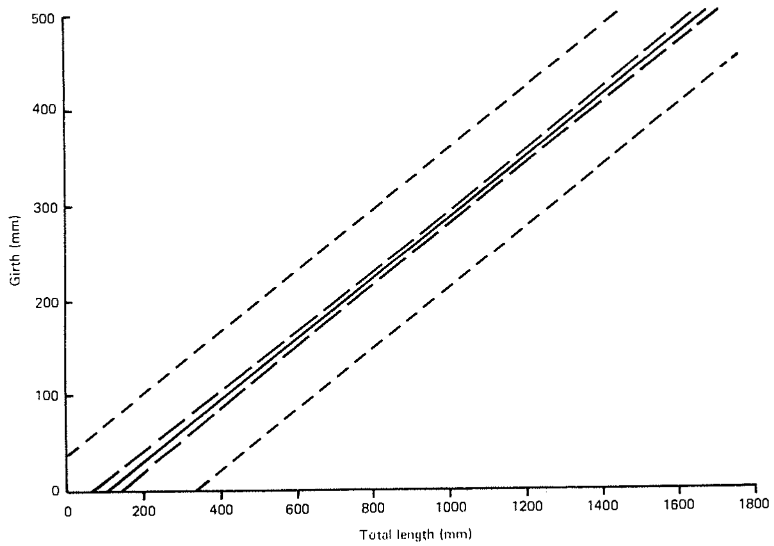

Fig. 3.13. Relationship [with 95% confidence limits on the mean curve (———) and individual shark data (----)] between girth, g, and total length l, for female gummy shark. Values for a and b (with standard error) for the equation g = a+bl are given in the following tabulation:

a	b	n	r^2 [A]	e.m.s.[B]
-3.13×10	$(3.17 \pm 0.05) \times 10^{-1}$	610	0.86**	1.38×10^{3}

[A] Coefficient of determination between g and l. **P<0.01.
[B] Error mean square for regression of g against l.

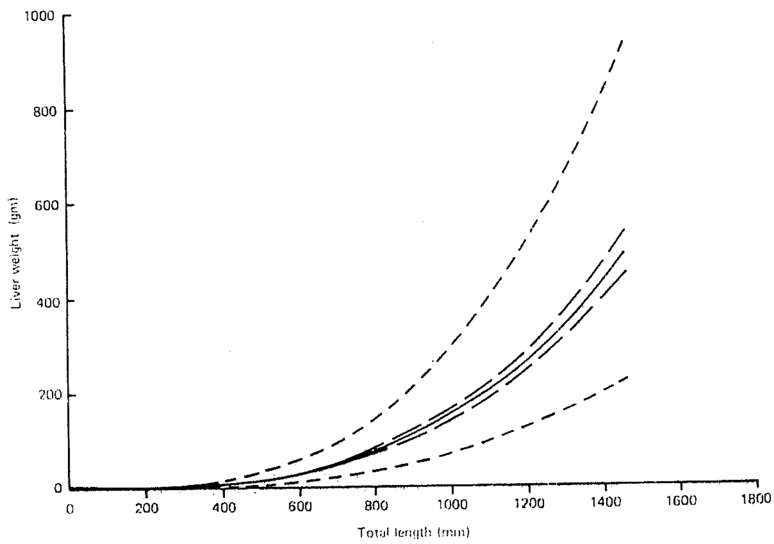

Fig. 3.14. Relationship [with 95% confidence limits on the mean curve (—— ——) and individual shark data (----)] between liver weight, w, and total length l, for male gummy shark. Values for a and b (with standard error) for the equation $w = al^b$ are given in the following tabulation:

a	b	n	r^2 [A]	e.m.s.[B]
5.28×10^{-8}	(3.14 ± 0.08)	216	0.86**	1.38×10^{-1}

[A] Coefficient of determination between ln(w) and ln(l). **P<0.01.
[B] Error mean square for regression of ln(w) against ln(l).

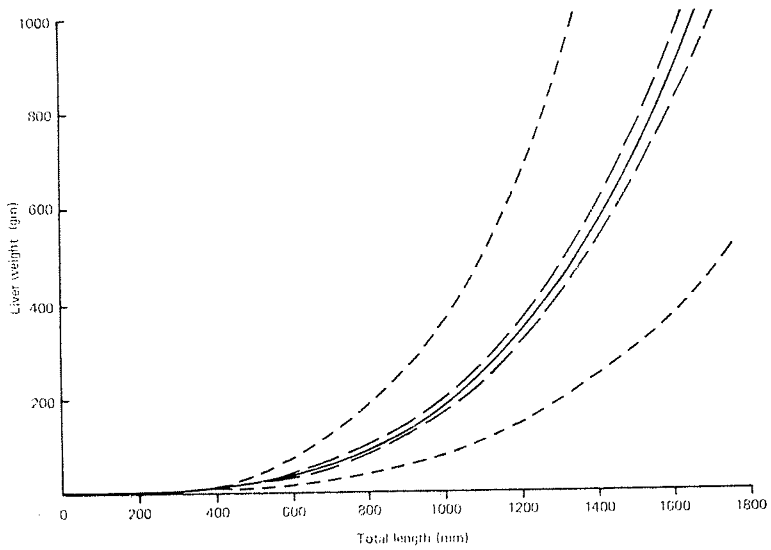

Fig. 3.15. Relationship [with 95% confidence limits on the mean curve (——) and individual shark data (----)] between liver weight, w, and total length, l, for female gummy shark. Values for a and b (with standard error) for the equation $w = al^b$ are given in the following tabulation:

a	b	n	r^2 [A]	e.m.s.[B]
1.18×10^{-8}	(3.39 ± 0.07)	294	0.90**	1.30×10^{-1}

[A] Coefficient of determination between ln(w) and ln(l). **P<0.01.
[B] Error mean square for regression of ln(w) against ln(l).

Table 4.1.1. Summary of tag release-recapture movement data for each sex for each of three length-classes of length at release for gummy shark.

Length class (mm)	Sex	Sample Size	Mean ± standard error								
			Release length (mm)	Time free (days)	Dispersion (km^2/day)	Distance	Direction (° N)	North Vector (km)	East Vector (km)	Displacement (km)	Velocity
300- 949	Male	62	831± 87	918±77	53.3± 23.5	92.5±11.9	23	32.7±13.0	13.9± 9.5	35.5	38.8
	Female	70	845± 76	839±74	37.2± 11.0	105.6±20.5	332	38.6±14.5	-20.2±18.5	43.6	51.9
	Total	132	839± 81	875±53	44.7± 12.4	99.4±12.2	353	35.9± 9.8	- 4.2±10.9	36.1	41.3
950-1099	Male	83	1020± 40	578±49	47.5± 23.0	47.6± 6.6	29	15.1± 5.9	8.3± 5.7	17.2	29.7
	Female	34	1029± 47	588±20	41.6± 18.6	86.6±24.1	311	16.5±16.8	-19.1±22.5	25.2	42.8
	Total	117	1022± 42	581±17	45.8± 17.1	58.9± 8.5	1	15.5± 6.7	0.4± 7.7	15.5	19.8
>1100	Male	63	1185± 78	410±42	48.0± 15.7	51.6± 7.9	336	2.0± 8.6	- 0.9± 5.5	2.2	5.4
	Female	34	1229±115	317±54	300 ±140.8	111.0±35.7	318	59.3±19.9	-53.5±32.5	79.9	252.0
	Total	97	1201± 94	377±33	136 ± 51.4	172.4±13.7	319	22.1± 9.3	-19.3±12.1	29.3	77.8
Total	Male	208	1014± 11	628±35	49.4± 12.2	62.2± 5.2	24	16.4± 5.3	7.2± 4.0	17.9	28.5
	Female	138	985± 15	649±48	103.2± 36.3	102.2±14.8	324	38.3± 9.8	-28.1±13.5	47.5	73.2
	Total	346	1002± 9	636±28	70.8± 16.3	78.2± 6.7	345	25.1± 5.1	- 6.8± 6.0	26.0	40.9

Table 4.1.2. Summary of tag release-recapture movement data for each combination of release quarter and recapture quarter of the year for male gummy shark.

Quarter		Sample Size	Mean ± standard error								
Release	Recapture		Release length (mm)	Time free (days)	Dispersion (km^2/day)	Distance (km)	Dirn (°N)	North Vector (km)	East Vector (km)	Displace-ment (km)	Velocity (m/day)
Jan-Mar	Jan-Mar	4	988±148	1162±460	11.9± 9.2	105.7±69.0	4	90.9±74.5	6.9± 11.6	91.2	78.4
Jan-Mar	Apr-Jun	6	939± 93	754±283	1.2± 0.5	22.8±10.0	45	8.9± 6.7	8.8± 11.3	12.5	16.6
Jan-Mar	Jul-Sep	2	682±162	743±537	117.0±118.5	252.0± 7.2	355	149.7± 4.1	-12.0±202.4	150.2	202.2
Jan-Mar	Oct-Dec	6	1049± 47	895±178	27.2± 23.1	78.4±27.1	333	48.2±34.3	-24.4± 14.3	54.0	60.3
Apr-Jun	Jan-Mar	7	985± 50	666±153	97.4± 83.5	95.3±53.7	289	-8.3±41.5	24.4± 50.6	25.8	38.7
Apr-Jun	Apr-Jun	13	1026± 33	499±105	2.8± 0.8	24.2± 5.4	76	-3.3± 3.7	-13.1± 7.0	13.5	27.1
Apr-Jun	Jul-Sep	6	1075± 39	483±144	32.6± 32.1	57.4±15.2	60	23.1±25.6	39.8± 42.4	46.1	95.4
Apr-Jun	Oct-Dec	9	1063± 40	639±198	11.5± 9.2	39.0±12.4	52	13.7±10.2	17.7± 13.3	22.4	35.1
Jul-Sep	Jan-Mar	14	1049± 36	605±102	11.7± 9.5	34.5±10.0	357	10.9±12.7	-0.5± 4.5	10.9	18.0
Jul-Sep	Apr-Jun	11	1088± 31	422± 79	2.8± 1.0	27.5± 5.7	36	13.7± 6.4	9.8± 6.1	16.9	40.0
Jul-Sep	Jul-Sep	10	1009± 45	411±117	162.5±164.9	56.9±19.0	351	45.3±18.6	-6.9± 11.4	45.9	111.7
Jul-Sep	Oct-Dec	21	1058± 40	484± 82	33.4± 22.1	51.5±13.9	305	-4.2±17.3	6.0± 4.8	7.3	15.1
Oct-Dec	Jan-Mar	24	1031± 30	486±128	90.3± 35.6	80.4±22.6	28	31.1±24.1	16.2± 12.5	35.1	72.2
Oct-Dec	Apr-Jun	15	1009± 45	584±106	64.6± 41.8	82.2±24.3	278	-2.0±21.6	14.9± 24.3	15.1	25.9
Oct-Dec	Jul-Sep	17	964± 27	530± 75	14.5± 6.0	49.8±11.2	4	6.1±12.1	0.4± 11.4	6.1	11.5
Oct-Dec	Oct-Dec	43	979± 23	815± 77	61.1± 32.5	73.8± 8.6	31	15.1±11.9	9.0± 7.4	17.6	21.6

Table 4.1.3. Summary of tag release-recapture movement data for each combination of release quarter and recapture quarter of the year for female gummy shark.

Quarter		Sample Size	Mean ± standard error								
Release	Recapture		Release length (mm)	Time free (days)	Dispersion (km^2/day)	Distance (km)	Dirn (°N)	North Vector (km)	East Vector (km)	Displacement (km)	Velocity (m/day)
Jan-Mar	Jan-Mar	5	826± 80	525±183	11.0± 7.3	65.3± 37.1	4	32.2± 35.4	2.3± 30.5	32.3	61.5
Jan-Mar	Apr-Jun	4	892± 18	1060±671	95.0± 63.7	288.7±217.3	306	170.7±126.8	-232.0±176.9	288.0	271.7
Jan-Mar	Jul-Sep	3	1129± 64	672±481	1.8± 1.6	33.9± 28.4	16	28.2± 28.8	-8.0± 11.1	29.3	43.6
Jan-Mar	Oct-Dec	4	977± 74	814±240	6.4± 6.1	47.1± 36.3	18	38.6± 33.4	-12.9± 19.7	40.7	50.0
Apr-Jun	Jan-Mar										
Apr-Jun	Apr-Jun	6	1121±102	817±366	17.1± 14.3	99.1± 75.5	294	35.2± 44.6	-78.5± 64.8	86.0	105.3
Apr-Jun	Jul-Sep	4	957± 81	1153±510	39.4± 38.2	176.4±154.7	309	102.5±108.8	-127.2±116.5	163.4	141.7
Apr-Jun	Oct-Dec	1	880±	879	5.0	66.6	306	39.3	-53.7	176.4	200.7
Jul-Sep	Jan-Mar	8	992± 46	544±186	8.9± 4.6	50.1± 18.6	26	20.7± 19.7	9.9± 15.6	22.9	42.1
Jul-Sep	Apr-Jun	10	926± 62	567±111	57.7± 46.6	79.0± 36.2	325	45.5± 16.8	-31.7± 37.2	63.9	112.7
Jul-Sep	Jul-Sep	8	1100± 71	203±117	263.9±122.2	53.2± 11.8	334	26.4± 15.2	-13.1± 13.7	29.5	145.3
Jul-Sep	Oct-Dec	12	1083± 49	545±198	35.7± 17.1	71.5± 15.2	55	25.1± 18.9	35.8± 12.9	43.7	80.2
Oct-Dec	Jan-Mar	21	916± 28	767±135	50.7± 25.3	112.2± 34.2	70	14.0± 26.3	38.6± 3.2	41.1	53.6
Oct-Dec	Apr-Jun	18	1035± 47	560± 78	299.6±177.9	119.2± 59.5	299	68.6± 45.0	-123.0± 11.8	140.8	251.4
Oct-Dec	Jul-Sep	14	973± 51	677±130	276.5±263.3	118.9± 70.6	306	43.7± 32.0	-60.3± 67.9	74.5	110.0
Oct-Dec	Oct-Dec	20	950± 33	703±107	26.5± 10.1	86.9± 29.0	334	28.7± 20.1	-13.8± 27.9	31.8	45.2

Table 4.2.1. Approximate estimates of total mortality from tag release-recapture data for each sex for each of three length-classes of length at release for gummy shark.

Length-class of length at release (mm)	Sex	Mean length at release (mm)(±s.e.)	Number released	Number recaptured	Mean period of freedom (days)(±s.e.)	Instantaneous mortality			Annual mortality		
						Total(Z)	Fishing(F)	Natural(M)	Total	Fishing	Natural
300- 949	Male	821 ± 13	373	64	930 ± 116	0.393	0.067	0.325	0.32	0.06	0.28
	Female	840 ± 10	350	73	878 ± 75	0.416	0.087	0.329	0.34	0.08	0.28
	Total	831 ± 8	723	137	902 ± 53	0.405	0.077	0.328	0.33	0.07	0.28
950-1099	Male	1020 ± 4	302	86	587 ± 49	0.621	0.177	0.445	0.46	0.16	0.36
	Female	1028 ± 8	161	35	602 ± 80	0.606	0.132	0.474	0.45	0.12	0.38
	Total	1025 ± 4	463	121	592 ± 41	0.617	0.162	0.455	0.46	0.15	0.37
>1100	Male	1183 ± 9	204	69	467 ± 50	0.781	0.264	0.517	0.54	0.23	0.40
	Female	1227 ± 18	131	38	378 ± 61	0.965	0.280	0.689	0.62	0.24	0.50
	Total	1198 ± 9	335	107	436 ± 40	0.838	0.267	0.570	0.57	0.23	0.43
Total	Male	1013 ± 11	879	219 (25%)	650 ± 35	0.562	0.140	0.422	0.43	0.13	0.34
	Female	986 ± 15	642	146 (23%)	682 ± 49	0.535	0.122	0.413	0.41	0.11	0.34
	Total	1002 ± 9	1521	365 (24%)	662 ± 29	0.551	0.132	0.419	0.42	0.12	0.34

Table 4.2.2. Approximate estimates of total mortality from tag release-recapture data for each sex of sharks both released and recaptured within each of five localities for gummy shark.

Locality	Sex	Mean length at release (mm) (±.s.e)	Number released	Number recaptured	Mean period of freedom (days)(± s.e.)	Total mortality	
						Instantaneous	Annual
Victoria North of 39° 30'S	Male	1043 ± 39	101	21	310 ± 66	1.177	0.69
	Female	1065 ± 55	45	8	284 ± 58	1.285	0.73
	Total	1049 ± 32	146	29	303 ± 50	1.205	0.70
Furneaux Group	Male	1043 ± 19	105	35	418 ± 55	0.873	0.58
	Female	1035 ± 29	100	33	436 ± 76	0.837	0.57
	Total	1039 ± 17	205	68	427 ± 46	0.855	0.57
King Island	Male	995 ± 19	214	39	592 ± 75	0.616	0.46
	Female	972 ± 31	230	38	730 ± 73	0.500	0.39
	Total	984 ± 18	444	77	660 ± 52	0.553	0.42
Hunter Group	Male	1013 ± 15	235	62	744 ± 59	0.490	0.39
	Female	941 ± 24	142	22	719 ± 155	0.508	0.40
	Total	994 ± 13	377	84	738 ± 59	0.495	0.39
Tasmania South of 40° 40'S	Male	990 ± 32	220	47	803 ± 95	0.455	0.37
	Female	946 ± 38	118	26	866 ± 144	0.422	0.34
	Total	974 ± 25	338	73	825 ± 79	0.442	0.36
Total	Male	1013 ± 11	879	219	650 ± 35	0.562	0.43
	Female	986 ± 15	642	146	682 ± 49	0.535	0.41
	Total	1002 ± 9	1521	365	662 ± 29	0.551	0.42

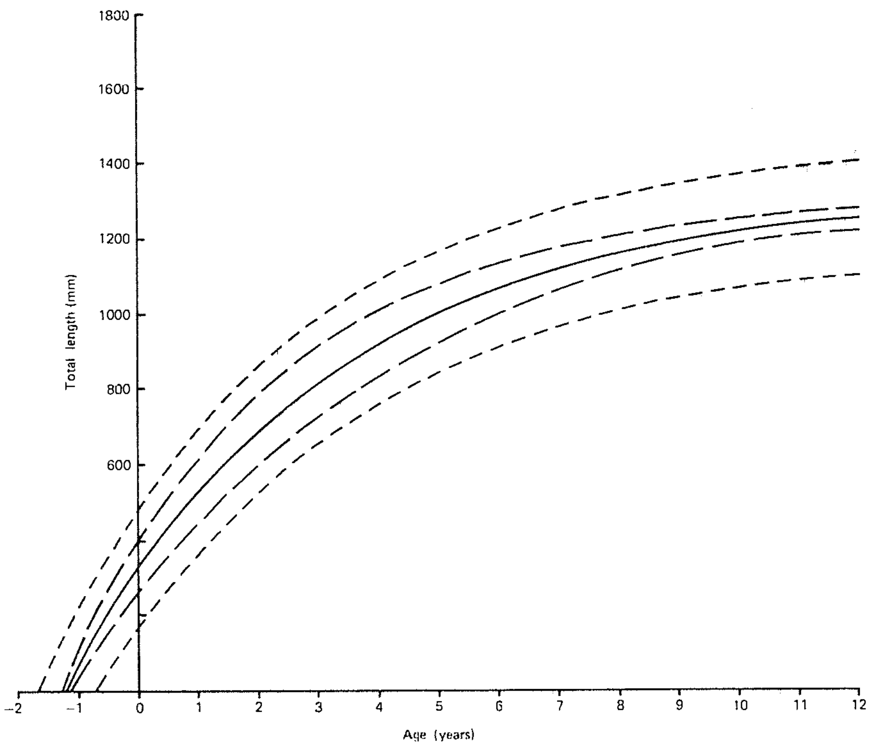

Fig. 4.3.1. Relationship [with 95% confidence limits on the mean curve (——) and individual shark data (----)] between total length, l, and age, t, from tag release-recapture experiments for male gummy shark. Values for the von Bertalanffy parameters k (with standard error), L_∞ (with standard eror) and t_0 for the equation $l = L_\infty[1-e^{-k(t-t_0)}]$ are given in the following tabulation:

k	L_∞	t_0	n	e.m.s.[A]
0.232±0.034	1314±40	-1.27	144	5286

[A] Error mean square for regression of recapture length against release length and time free.

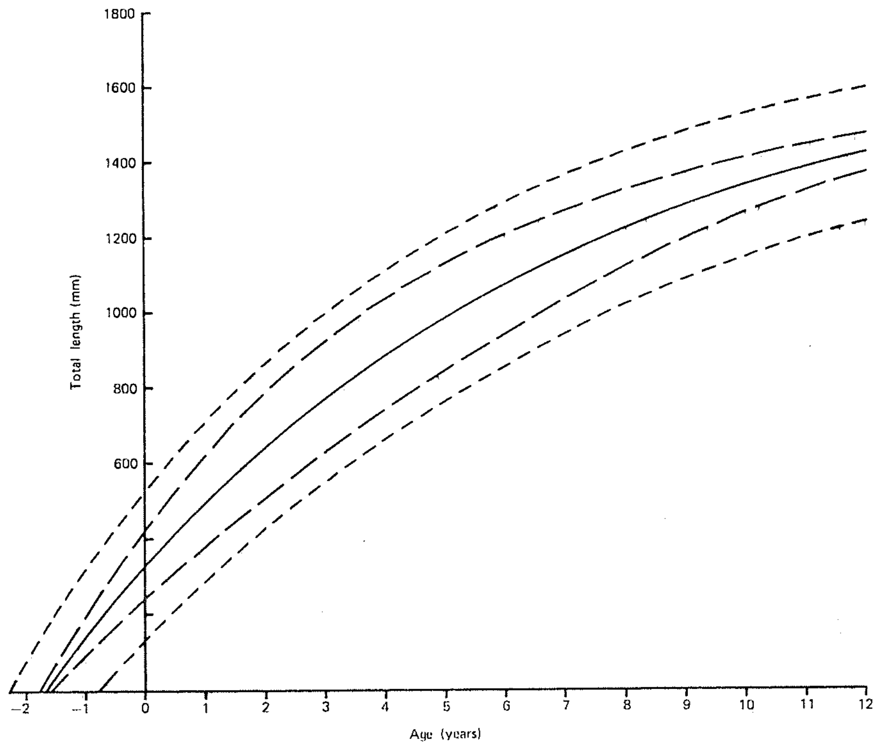

Fig. 4.3.2. Relationship [with 95% confidence limits on the mean curve (——) and individual shark data (----)] between total length, l, and age, t, from tag release-recapture experiments for female gummy shark. Values for the von Bertalanffy parameters k (with standard error), L_∞ (with standard error) and t_o for the equation $l = L_\infty[1-e^{-k(t-t_o)}]$ are given in the following tabulation:

k	L_∞	t_o	n	e.m.s.[A]
0.127±0.033	1730±171	−1.70	110	7555

[A] Error mean square for regression of recapture length against release length and time free.

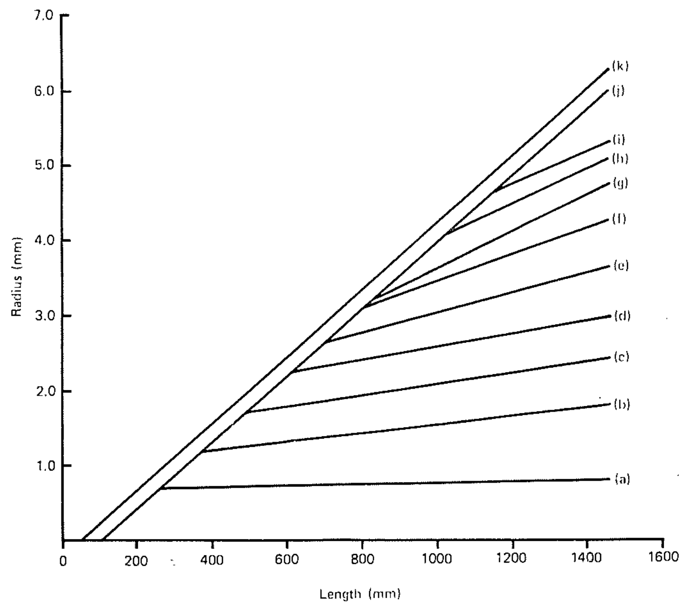

Fig. 5.1. Relationship between radius of each of the embryonic middle zone, each annulus, growth zone and outer edge, r, and total length, l, for male gummy shark. Values of a and b (with standard error) for the equation $r = a+bl$ are given in the following tabulation:

	Variable	a	b	n	r^2 [A]	e.m.s. [B]
(a)	Embryonic middle zone	6.92×10^{-1}	$(6.21\pm3.60)\times10^{-5}$	145	0.02	8.35×10^{-3}
(b)	Annulus 1	9.95×10^{-1}	$(5.61\pm0.87)\times10^{-4}$	150	0.22**	4.61×10^{-2}
(c)	Annulus 2	1.39	$(7.00\pm1.24)\times10^{-4}$	146	0.18**	7.98×10^{-2}
(d)	Annulus 3	1.75	$(8.37\pm1.64)\times10^{-4}$	135	0.16**	1.15×10^{-1}
(e)	Annulus 4	1.77	$(1.26\pm0.26)\times10^{-3}$	105	0.19**	1.50×10^{-1}
(f)	Annulus 5	1.70	$(1.73\pm0.32)\times10^{-3}$	83	0.27**	1.53×10^{-1}
(g)	Annulus 6	1.21	$(2.41\pm0.35)\times10^{-3}$	52	0.48**	1.01×10^{-1}
(h)	Annulus 7	1.70	$(2.31\pm0.62)\times10^{-3}$	22	0.41**	1.16×10^{-1}
(i)	Annulus 8	2.14	$(2.17\pm1.22)\times10^{-3}$	8	0.34*	7.20×10^{-2}
(j)	Growth zone	-4.66×10^{-1}	$(4.43\pm0.14)\times10^{-3}$	126	0.89**	1.07×10^{-1}
(k)	Outer edge	-2.55×10^{-1}	$(4.47\pm0.12)\times10^{-3}$	151	0.90**	9.85×10^{-2}

[A] Coefficient of determination between r and l. *$P<0.05$, **$P<0.01$.
[B] Error mean square for regression of r against l.

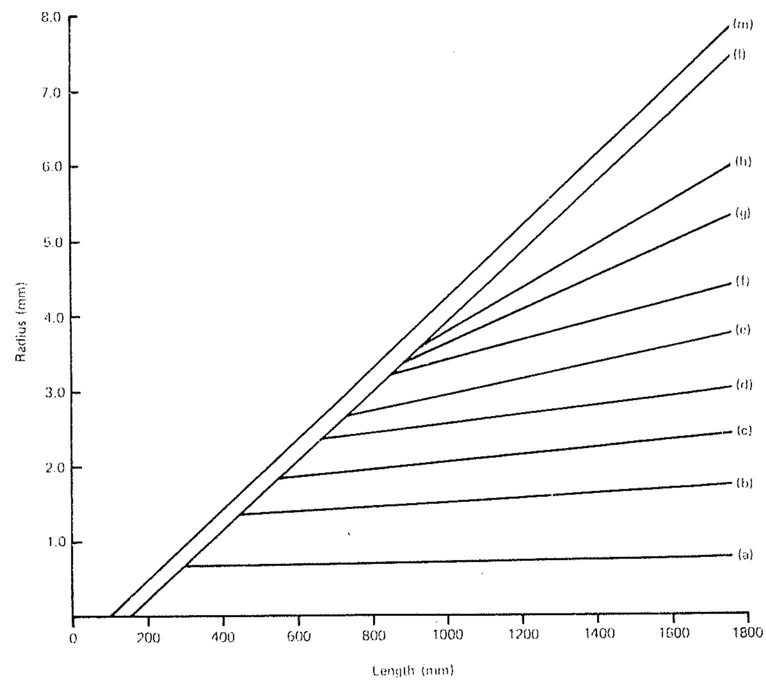

Fig. 5.2. Relationship between radius of each of the embryonic middle zone, each annulus, growth zone and outer edge, r, and total length, l, for female gummy shark. Values of a and b (with standard error) for the equation r = a+bl are given in the following tabulation:

	Variable	a	b	n	r^2 [A]	e.m.s.[B]
(a)	Embryonic growth zone	6.82×10^{-1}	$(5.45 \pm 2.03) \times 10^{-5}$	187	0.04	6.21×10^{-3}
(b)	Annulus 1	1.26	$(2.76 \pm 0.56) \times 10^{-4}$	194	0.11**	4.76×10^{-2}
(c)	Annulus 2	1.63	$(4.33 \pm 0.75) \times 10^{-4}$	191	0.15**	7.93×10^{-2}
(d)	Annulus 3	1.98	$(5.88 \pm 1.08) \times 10^{-4}$	180	0.14**	1.39×10^{-1}
(e)	Annulus 4	1.95	$(1.01 \pm 0.14) \times 10^{-3}$	154	0.26**	1.77×10^{-1}
(f)	Annulus 5	2.09	$(1.32 \pm 0.22) \times 10^{-3}$	118	0.24**	2.32×10^{-1}
(g)	Annulus 6	1.39	$(2.21 \pm 0.36) \times 10^{-3}$	83	0.32**	2.77×10^{-1}
(h)	Annulus 7	7.95×10^{-1}	$(2.95 \pm 0.47) \times 10^{-3}$	62	0.39**	3.08×10^{-1}
(i)	Annulus 8	-2.01×10^{-1}	$(3.88 \pm 0.71) \times 10^{-3}$	38	0.45**	3.26×10^{-1}
(j)	Annulus 9	-2.58	$(5.65 \pm 1.36) \times 10^{-3}$	19	0.50**	3.49×10^{-1}
(k)	Annulus 10	-5.45×10^{-1}	$(4.34 \pm 3.00) \times 10^{-3}$	9	0.23	4.91×10^{-1}
(l)	Growth zone	-7.16×10^{-1}	$(4.62 \pm 0.13) \times 10^{-3}$	174	0.89**	2.20×10^{-1}
(m)	Outer edge	-4.72×10^{-1}	$(4.70 \pm 0.12) \times 10^{-3}$	195	0.89**	2.24×10^{-1}

[A] Coefficient of determination between r and l. **$P<0.01$.
[B] Error mean square for regression of r against l.

Table 5.1. Number of sharks within each 1-year age-group for each 100-mm length-class for each of male and female gummy shark.

Sex	Length-class (mm)	Number of sharks within each 1-year age-group													
		0	1	2	3	4	5	6	7	8	9	10	11	12	Total
	<600	1	3	1											5
	600- 699			2	5	1									8
	700- 799		1	2	14	1	1								19
	800- 899			4	3	5	3	1							16
Male	900- 999			1	5	8	8	6	2						30
	1000-1099				3	5	6	6	3						23
	1100-1199				1	2	11	9	1	2	1				27
	1200-1299						2	6	7	3					18
	>1300							2	1	1	1				5
	Total	1	4	10	31	22	31	30	14	6	2				151
	<600	1	3	2		1									7
	600- 699			3	3	1									7
	700- 799			4	7	5									16
	800- 899			2	5	8	7								22
	900- 999				7	9	4		1						21
Female	1000-1099				3	6	8	2	2						21
	1100-1199				1	4	8	7	2	2					24
	1200-1299						4	5	6	5	1		1		22
	1300-1399					1	2	2	8	4		1			18
	1400-1499						1	1	3	4	6	2	1	1	19
	1500-1599							4	1	2	2	3			12
	>1600					1	1		1	2	1				6
	Total	1	3	11	26	36	35	21	24	19	10	6			195

Table 5.2. Proportion of sharks of each 1-year age-group within each 100-mm length-class for each of male and female gummy shark.

Sex	Length-class (mm)	Proportion of sharks within each 1-year age-group													
		0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Male	<600	0.200	0.600	0.200											1.000
	600- 699			0.250	0.625	0.125									1.000
	700- 799		0.053	0.105	0.737	0.053	0.052								1.000
	800- 899			0.250	0.187	0.313	0.187	0.063							1.000
	900- 999			0.033	0.167	0.267	0.267	0.200	0.066						1.000
	1000-1099				0.130	0.217	0.261	0.261	0.131						1.000
	1100-1199				0.037	0.074	0.408	0.333	0.037	0.074	0.037				1.000
	1200-1299						0.111	0.333	0.389	0.167					1.000
	>1300							0.400	0.200	0.200	0.200				1.000
Female	<600	0.143	0.428	0.286		0.143									1.000
	600- 699			0.429	0.428	0.143									1.000
	700- 799			0.250	0.437	0.313									1.000
	800- 899			0.091	0.227	0.364	0.318								1.000
	900- 999				0.333	0.429	0.190		0.048						1.000
	1000-1099				0.143	0.286	0.381	0.095	0.095						1.000
	1100-1199				0.042	0.167	0.333	0.292	0.083	0.083					1.000
	1200-1299						0.182	0.227	0.273	0.227	0.045		0.046		1.000
	1300-1399					0.056	0.111	0.111	0.444	0.222		0.056			1.000
	1400-1499						0.053	0.053	0.158	0.210	0.316	0.105	0.053	0.052	1.000
	1500-1599							0.333	0.083	0.167	0.167	0.250			1.000
	>1600					0.167	0.167		0.167	0.333	0.166				1.000

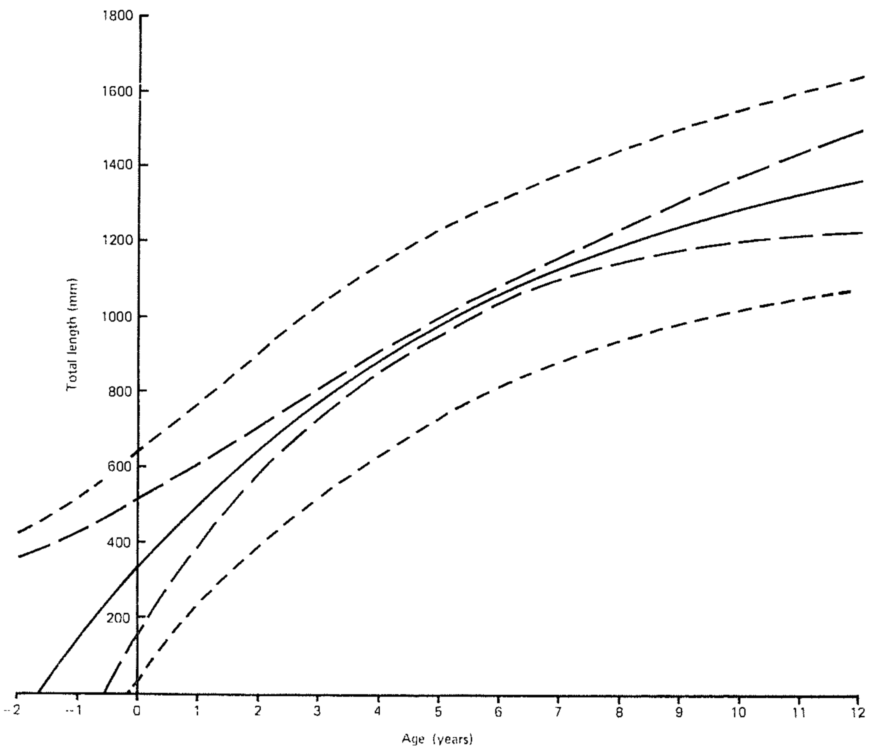

Fig. 5.3. Relationship [with 95% confidence limits on the mean curve (——) and individual shark data (----)] between total length, l, and age, t, from microscopic inspection of vertebral centra annuli for male gummy shark. Values for the von Bertalanffy parameters k, L_∞ and t_o with standard errors for the equation $l = L_\infty[1-e^{-k(t-t_o)}]$ are given in the following tabulation:

k	L_∞	t_o	n	e.m.s.[A]
0.147±0.058	1578±243	-1.61±0.840	151	16230

[A] Error mean square for regression of l against t.

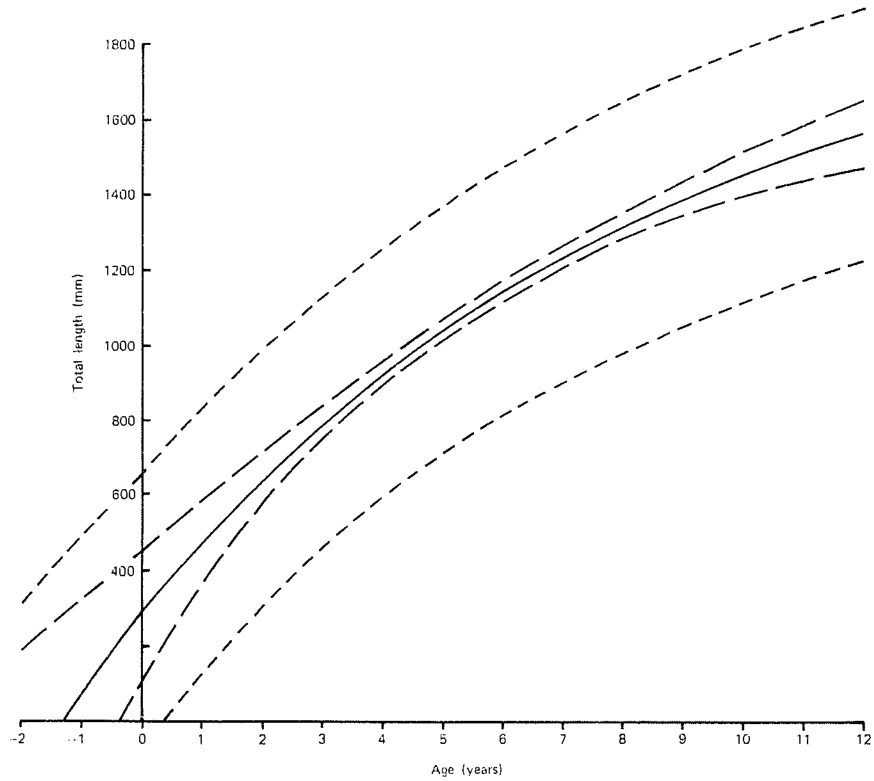

Fig. 5.4. Relationship [with 95% confidence limits on the mean curve (———) and individual shark data (----)] between total length, l, and age, t, from microscopic inspection of vertebral centra annuli for female gummy shark. Values for the von Bertalanffy parametres k, L_∞ and t_o with standard errors for the equation $l = L_\infty[1-e^{-k(t-t_o)}]$ are given in the following tabulation:

k	L_∞	t_o	n	e.m.s.[A]
0.122±0.035	1945±240	-1.312±0.632	195	27989

[A] Error mean square for regression of l against t.

Table 6.1. Number of immature and number and proportion of mature sharks in each 100-mm length-class from microscopic inspection of histological transverse section of testis tissue for male gummy shark.

Length-class (mm)	Number of sharks			Proportion of sharks mature
	Immature	Mature	Total	
<700	7	0	7	0.000
700 - 799	13	1	14	0.071
800 - 899	10	4	14	0.286
900 - 999	17	12	29	0.414
1000 - 1099	7	22	29	0.759
1100 - 1199	4	32	36	0.889
1200 - 1299	2	23	25	0.920
>1300	0	7	7	1.000
Total	60	101	161	-

Table 6.2. Number of immature (Stages 1 and 2) and number and proportion of mature (Stage 3) shark in each 100-mm length-class from macroscopic inspection of testes for male gummy shark.

Length-class (mm)	Number of sharks					Proprotion of sharks mature
	Immature			Mature	Total	
	Stage 1	Stage 2	Total	Stage 3		
<700	30	1	31	0	31	0.000
700 - 799	25	2	27	5	32	0.156
800 - 899	14	16	30	24	54	0.444
900 - 999	12	28	40	22	62	0.355
1000 - 1099	2	13	15	23	38	0.605
1100 - 1199	1	2	3	32	35	0.914
1200 - 1299	0	0	0	18	18	1.000
>1300	0	0	0	2	2	1.000
Total	84	62	146	126	272	-

Table 6.3. Number of immature (Stage 1) and number and proportion of mature (Stages 2 and 3) sharks in each 100-mm length-class from macroscopic inspection of seminal vesicles for male gummy shark.

Length-class (mm)	Number of sharks					Proprotion of sharks mature
	Immature	Mature			Total	
	Stage 1	Stage 2	Stage 3	Total		
<700	38	0	0	0	38	0.000
700 - 799	36	5	0	5	41	0.122
800 - 899	37	23	1	24	61	0.393
900 - 999	48	20	6	26	74	0.351
1000 - 1099	18	26	10	36	54	0.667
1100 - 1199	5	31	22	53	58	0.914
1200 - 1299	1	29	8	37	38	0.974
>1300	0	9	1	10	10	1.000
Total	183	143	48	191	374	-

Table 6.4. Number of sharks with partly or completely filled seminal vesicles (Stage 2) and number and proportion of sharks with spent seminal vesicles (Stage 3) in each 2-month period of the year from macroscopic inspection for male gummy shark.

Period of year	Number of sharks			Proportion of sharks with spent seminal vesicles
	Stage 2	Stage 3	Total	
Jan - Feb	17	3	20	0.150
Mar - Apr	24	3	27	0.111
May - Jun	31	1	32	0.031
Jul - Aug	3	0	3	0.000
Sep - Oct	15	4	19	0.211
Nov - Dec	53	37	90	0.411

Table 6.5. Number of mature sharks with seminal vesicles less than half full and number and proportion with seminal vesicles more than half full in each 2-month period of the year for male gummy shark.

Period of year	Number of mature sharks			Proportion of mature sharks with seminal vesicles > 1/2 full
	Seminal Vesicles		Total	
	< 1/2 full	> 1/2 full		
Jan - Feb	10	9	19	0.474
Mar - Apr	17	4	21	0.190
May - Jun	nd[A]	nd	nd	nd
Jul - Aug	nd	nd	nd	nd
Sep - Oct	4	5	9	0.555
Nov - Dec	55	15	70	0.214

[A] no data.

Table 6.6. Estimates of proportion of sharks (with 95% confidence limits) for each 100-mm length-class for each of three independent methods of determining sexual maturity for male gummy shark.

Method of determining sexual maturity	Length-class (mm)	Mid-point (mm) l	$\log_{10}$ (l) x	Probit Y	Var(Y)	δY[A]	95% confidence limits on Probit		Proportion and 95% confidence limits		
							Y - δY	Y + δW	p	p - δp	p + δp
Microscopic inspection of histological transverse section of testis tissue	<700	650	2.813	2.574	0.161	0.981	1.593	3.555	0.008	0.001	0.007
	700 - 799	750	2.875	3.465	0.082	0.699	2.766	4.164	0.062	0.013	0.201
	800 - 899	850	2.929	4.244	0.037	0.473	3.771	4.717	0.224	0.110	0.388
	900 - 999	950	2.978	4.936	0.018	0.326	4.611	5.262	0.475	0.349	0.603
	1000 - 1099	1050	3.021	5.559	0.016	0.307	5.253	5.866	0.712	0.510	0.806
	1100 - 1199	1150	3.061	6.126	0.027	0.402	5.723	6.528	0.870	0.765	0.937
	1200 - 1299	1250	3.097	6.645	0.048	0.537	6.108	7.181	0.950	0.866	0.985
	>1300	1350	3.130	7.124	0.077	0.678	6.445	7.802	0.983	0.926	0.998
Macroscopic inspection of testes	<700	650	2.813	3.063	0.050	0.547	2.517	3.610	0.026	0.007	0.082
	700 - 799	750	2.875	3.794	0.023	0.373	3.421	4.167	0.114	0.057	0.202
	800 - 899	850	2.929	4.433	0.010	0.250	4.184	4.683	0.285	0.207	0.376
	900 - 999	950	2.978	5.001	0.007	0.211	4.791	5.212	0.502	0.417	0.584
	1000 - 1099	1050	3.021	5.512	0.011	0.261	5.251	5.774	0.696	0.599	0.780
	1100 - 1199	1150	3.061	5.977	0.021	0.350	5.627	6.327	0.836	0.735	0.908
	1200 - 1299	1250	3.097	6.403	0.033	0.447	5.956	6.850	0.920	0.830	0.968
	>1300	1350	3.130	6.796	0.049	0.543	6.253	7.339	0.964	0.895	0.993
Macroscopic inspection of seminal vesicles	<700	650	2.813	2.816	0.046	0.525	2.291	3.341	0.015	0.003	0.049
	700 - 799	750	2.875	3.639	0.022	0.364	3.275	4.003	0.087	0.042	0.159
	800 - 899	850	2.929	4.359	0.010	0.244	4.114	4.603	0.261	0.188	0.346
	900 - 999	950	2.978	4.998	0.006	0.191	4.807	5.189	0.499	0.424	0.575
	1000 - 1099	1050	3.021	5.573	0.008	0.221	5.352	5.794	0.717	0.638	0.787
	1100 - 1199	1150	3.061	6.096	0.015	0.296	5.801	6.392	0.864	0.788	0.918
	1200 - 1299	1250	3.097	6.576	0.024	0.382	6.194	6.957	0.942	0.884	0.975
	>1300	1350	3.130	7.018	0.037	0.468	6.551	7.486	0.978	0.940	0.994

A SY = t_{n-2} Var (Y)

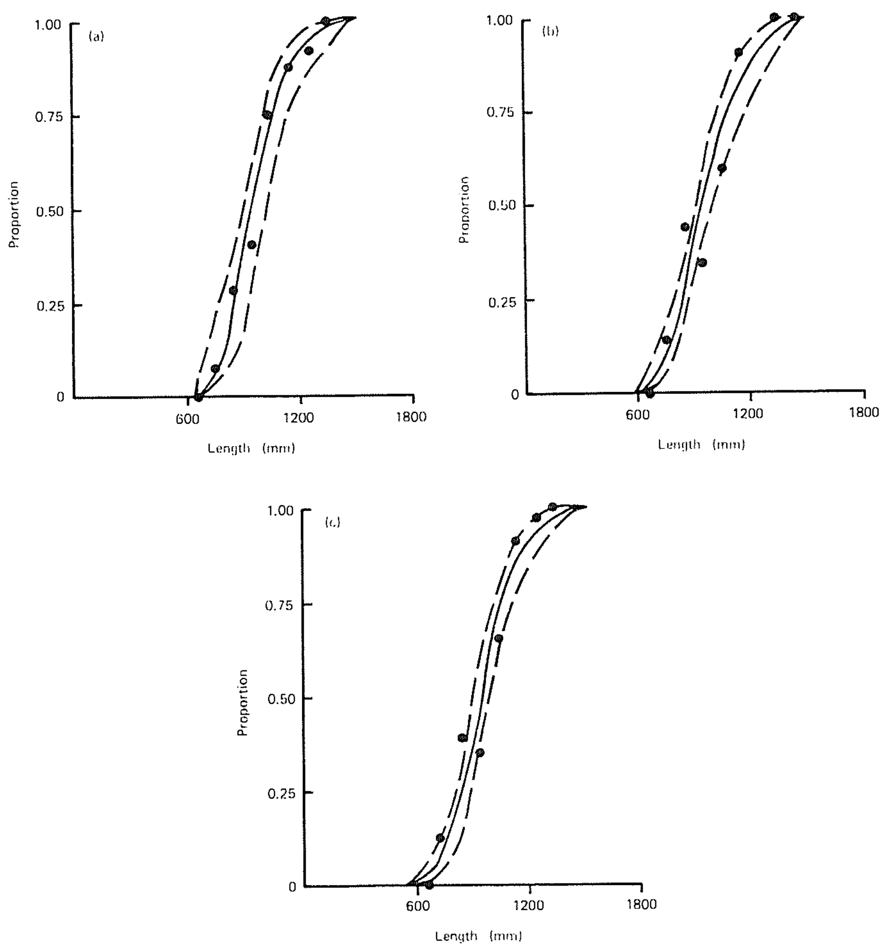

Fig. 6.1. Relationships [with 95% confidence limits on the mean curve (— —)] between proportion of sharks sexually mature, p, and length, l, from three independent methods for male gummy shark. Values for a and b (with standard error) for the equation $p = \text{Probit}^{-1}(a+b\log_{10}l)$ are given in the following tabulation:

	Method	a	b
(a)	Microscopic histological section of testis tissue	-37.74	14.33±0.25
(b)	Macroscopic inspection of testes	-30.02	11.76±0.60
(c)	Macroscopic inspection of siphons	-34.42	13.24±0.72

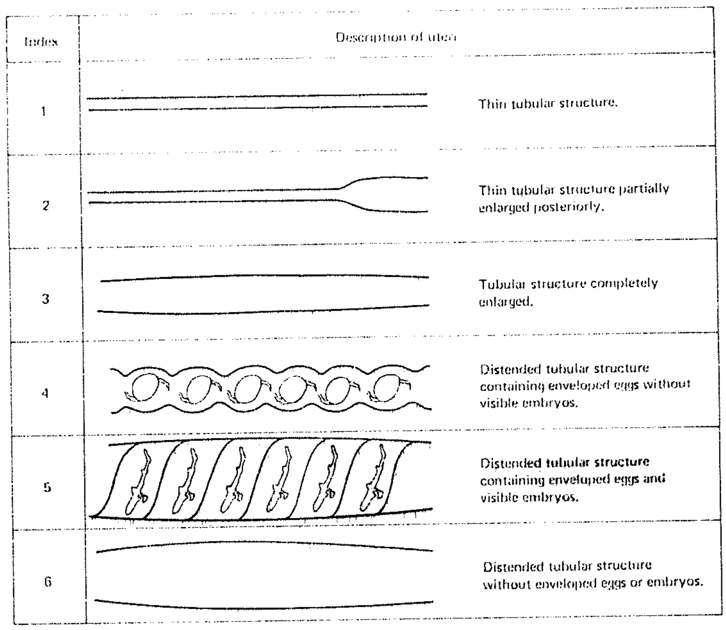

Fig. 7.1. Description of uteri for each uterus condition index for female gummy shark.

Uterus condition index	Proportion of sharks with each gonad index for each oviducal gland index								
	O[A]=1			O=2			O=3		
	G[B]=1	G=2	G=3	G=1	G=2	G=3	G=1	G=2	G=3
U=1	0.19	0.21		0.03	0.14				
U=2					0.01			0.02	0.04
U=3									0.13
U=4									0.03
U=5									0.20
U=6									

Fig. 7.2. Proportion of sharks with each gonad index for each oviducal gland index for each uterus condition index for female gummy shark.

[A] Oviducal gland index.
[B] Gonad index.

Table 7.1. Number of pregnant adults and *in utero* eggs and embryos for each month for female gummy shark.

Month	Number		
	Pregnant adults	*In utero* eggs	*In utero* embryos
October			
November	4	68	
December	7	141	
Sub-total 1[A]	11	209	
January			
February			
March	1	1	5
April			
May	17[B]	32[B]	177
June	16	12	326
July	10	11	96
August			
September	4	5	55
October	7	13	121
November	4	5	33
December	7	16	111
Sub-total 2[C]	66	95	924
Total	77	304	924

[A] Total for period October-December for adults which carry only *in utero* eggs.
[B] The 11 eggs and 0 embryos carried by one pregnant adult during May were excluded from the multiple regression analysis of embryo length against day of year presented in Fig. 7.3.
[C] Total for period January-December for adults which carry *in utero* embryos.

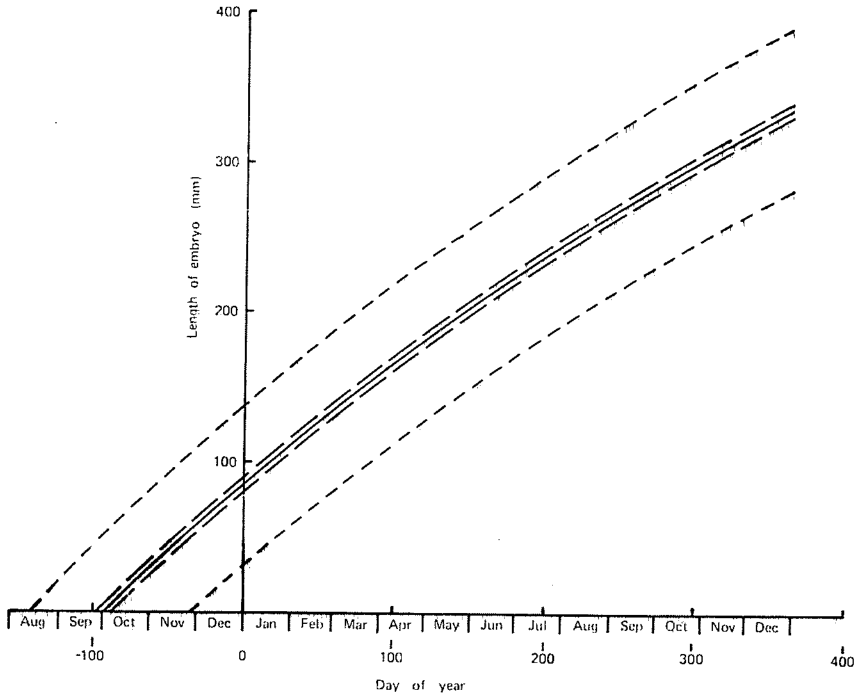

Fig. 7.3. Relationship [with 95% confidence limits on the mean curve (—·—) and individual shark data (----)] between total length of *in utero* embryos, l, and day of year, t, for female gummy shark. Values for a, b (with standard error) and c (with standard error) for the equation $l = a+bt+ct^2$ are given in the following tabulation:

a	b	c	n	r^2 [A]	e.m.s.[B]
8.41x10	$(8.80 \pm 0.07) \times 10^{-1}$	$(-5.20 \pm 0.20) \times 10^{-4}$	1133	0.93**	750.8

[A] Coefficient of determination. **P<0.01.
[B] Error mean square for multiple regression of l against t and t^2.

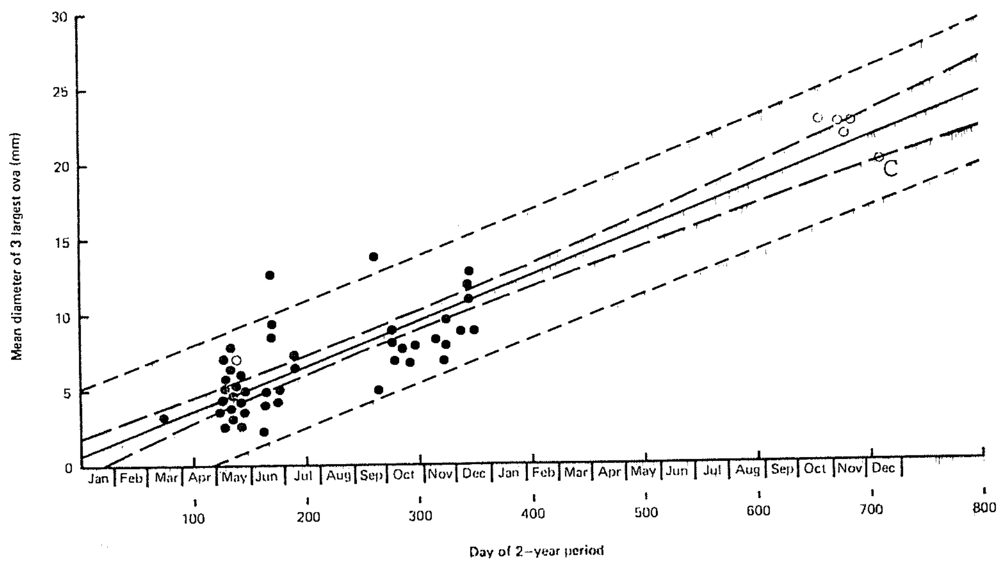

Fig. 7.4. Relationship [with 95% confidence limits on the mean curve (——) and individual shark data (----)] between mean diameter of the three largest ova, d, and day of 2-year period, t, of sharks with uterus condition indicies 4 and 5 (o U = 4; ● U = 5) for female gummy shark. Values for a and b (with standard error) for the equation d = a+bt are given in the following tabulation:

a	b	n	r^2 [A]	e.m.s.[B]
7.80×10^{-1}	$(2.94 \pm 0.18) \times 10^{-2}$	53	0.84**	4.43

[A] Coefficient of determination between d and t. **P<0.01.
[B] Error mean square for regression of d against t.
[C] Largest only of three largest ova diameters of 22, 7 and 6 mm.

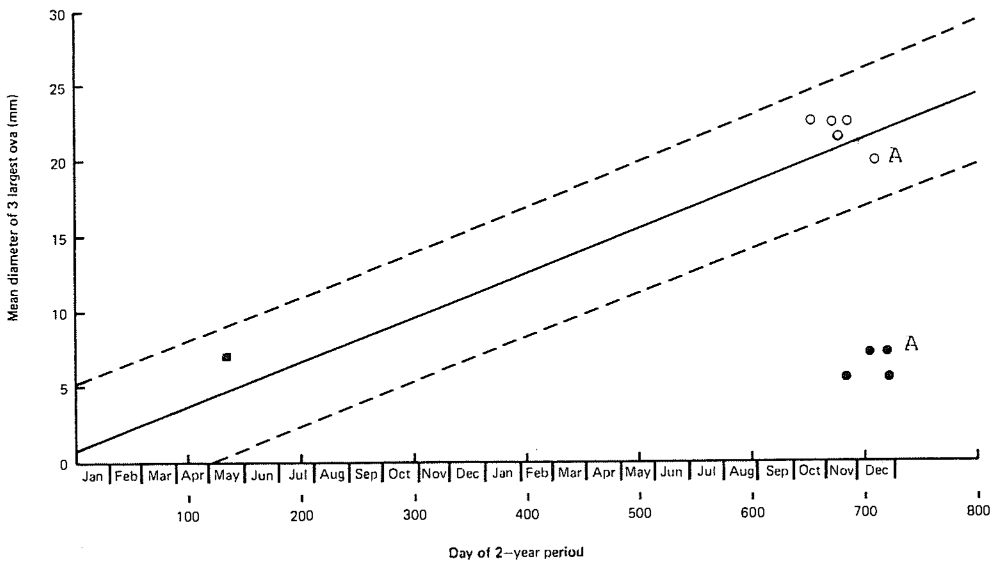

Fig. 7.5. Scattergram of mean diameter of the three largest ova against day of 2-year period for sharks with uterus condition index 4 (o ovulation incomplete; ● ovulation complete; ■ eggs in uteri all unfertilised) and relationship [with 95% confidence limits on individual shark data (----)] between mean diameter of the 3 largest ova and day of 2-year period for sharks with uterus condition indicies 4 and 5 for female gummy shark.

[A] Single shark with three largest ova diameters of 22 mm (o), and 7 and 6 mm (mean 6.5 mm o).

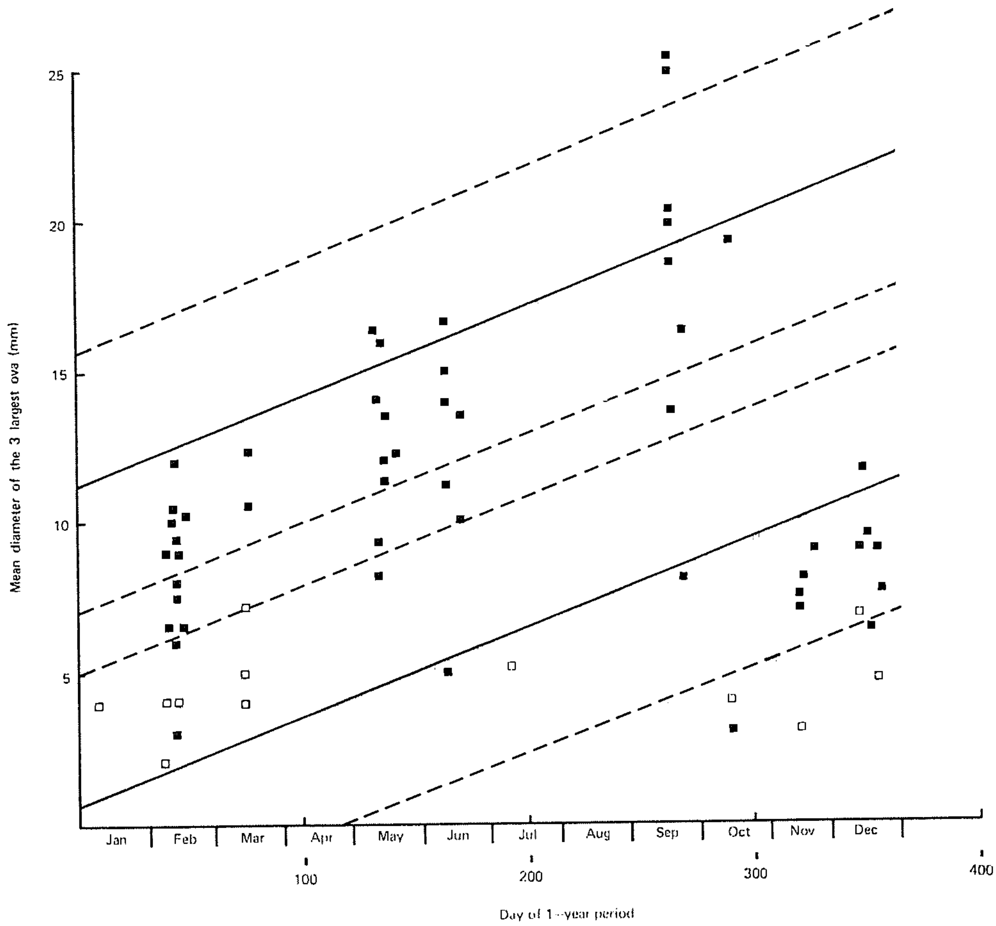

Fig. 7.6. Scattergram of mean diameter of the 3 largest ova against day of 1-year period for sharks with uterus condition indicies 2 and 3 (□ U = 2; ■ U = 3) and relationship [with 95% confidence limits on individual shark data (----)] between mean diameter of the 3 largest ova and day of 2-year period for sharks with uterus condition indicies 4 and 5 for female gummy shark.

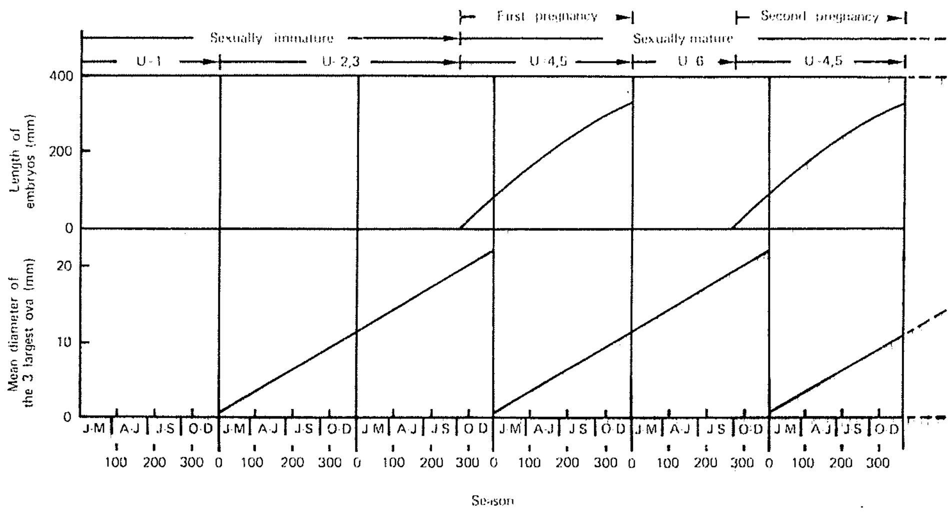

Fig. 7.7. Theory of seasonal development of largest ova and growth of <u>in utero</u> embryos in relation to uterus condition index and sexual maturity of female gummy shark.

Table 7.2. Number of sharks for each uterus condition index and in each 100-mm length-class for female gummy shark.

Length-class (mm)	Number of sharks for each uterus condition index					
	1	2	3[A]	4	5	Total
<800	53	0	0	0	0	53
800 - 899	41	1	0	0	1	43
900 - 999	42	6	1	1	1	51
1000 - 1099	26	9	5	1	2	43
1100 - 1199	12	8	13	1	3	37
1200 - 1299	2	2	15	1	9	29
1300 - 1399	0	1	10	3	6	20
1400 - 1499	0	0	4	2	13	19
>1500	0	0	9	1	10	20
Total	176	27	57	10	45	315

[A] Includes sharks categorised with uterus condition index 6.

Table 7.3. Estimates of proportion of sharks (with 95% confidence limits) for a selected group of uterus condition indicies for each 100-mm length-class for each of four groups of uterine condition indicies for female gummy shark.

Group of uterus condition indicies	Length-class (mm)	Mid-Point (mm)	$\log_{10}$ (l)	Probit	Var(Y)	δY[A]	95% confidence n limits on Probit		Proportion and 95% confidence limits					
									Uncorrected			Corrected		
		l	x	Y			Y-δY	Y+δY	p'	p'-δp'	p'-δP'	p	p-δp	p+δp
	<800	750	2.875	2.041	0.098	0.764	1.277	2.805	0.002	0.001	0.014	0.002	0.001	0.014
	800 - 899	850	2.929	3.084	0.046	0.525	2.558	3.609	0.028	0.007	0.082	0.028	0.007	0.082
	900 - 999	950	2.978	4.010	0.020	0.342	3.668	4.352	0.161	0.092	0.258	0.161	0.092	0.258
2,3,4 & 5	1000 - 1099	1050	3.021	4.844	0.011	0.257	4.587	5.100	0.438	0.340	0.540	0.438	0.340	0.540
	1100 - 1199	1150	3.061	5.601	0.016	0.309	5.292	5.910	0.726	0.615	0.819	0.726	0.615	0.819
	1200 - 1299	1250	3.097	6.296	0.031	0.432	5.864	6.727	0.903	0.806	0.958	0.903	0.806	0.958
	1300 - 1399	1350	3.130	6.937	0.054	0.569	6.368	7.506	0.974	0.914	0.994	0.974	0.914	0.994
	1400 - 1499	1450	3.161	7.532	0.083	0.706	6.826	8.238	0.994	0.967	0.998	0.994	0.967	0.998
	>1500	1550	3.190	8.088	0.117	0.837	7.250	8.925	0.999	0.988	0.999	0.999	0.988	0.999
	<800	750	2.875	1.264	0.135	0.900	0.364	2.164	0.001	0.000	0.002	0.001	0.000	0.002
	800 - 899	850	2.929	2.381	0.069	0.644	1.737	3.025	0.004	0.001	0.024	0.004	0.001	0.024
	900 - 999	950	2.978	3.374	0.031	0.434	2.940	3.808	0.052	0.020	0.117	0.052	0.020	0.117
	1000 - 1099	1050	3.021	4.268	0.014	0.292	3.975	4.560	0.232	0.153	0.330	0.232	0.153	0.330
3,4 & 5	1100 - 1199	1150	3.061	5.080	0.013	0.274	4.806	5.353	0.532	0.423	0.638	0.532	0.423	0.638
	1200 - 1299	1250	3.097	5.824	0.023	0.367	5.457	6.191	0.795	0.676	0.883	0.795	0.676	0.883
	1300 - 1399	1350	3.130	6.511	0.042	0.499	6.012	7.010	0.935	0.844	0.978	0.935	0.844	0.978
	1400 - 1499	1450	3.161	7.149	0.068	0.637	6.512	7.785	0.984	0.935	0.997	0.984	0.935	0.997
	>1500	1550	3.190	7.744	0.099	0.771	6.973	8.516	0.997	0.977	0.999	0.997	0.977	0.999
	<800	750	2.875	1.769	0.090	0.708	1.061	2.476	0.001	0.001	0.006	0.001	0.000	0.004
	800 - 899	850	2.929	2.565	0.051	0.536	2.030	3.101	0.008	0.002	0.029	0.005	0.001	0.018
	900 - 999	950	2.978	3.274	0.028	0.394	2.880	3.667	0.042	0.017	0.091	0.027	0.011	0.058
	1000 - 1099	1050	3.021	3.911	0.015	0.288	3.623	4.198	0.138	0.084	0.211	0.087	0.053	0.133
4 & 5	1100 - 1199	1150	3.061	4.490	0.010	0.235	4.255	4.725	0.305	0.228	0.392	0.192	0.144	0.247
	1200 - 1299	1250	3.097	5.021	0.001	0.090	4.931	5.110	0.508	0.473	0.544	0.320	0.298	0.343
	1300 - 1399	1350	3.130	5.511	0.017	0.309	5.201	5.820	0.695	0.580	0.794	0.438	0.365	0.500
	1400 - 1499	1450	3.161	5.966	0.027	0.387	5.578	6.353	0.833	0.718	0.912	0.525	0.453	0.575
	>1500	1550	3.190	6.390	0.040	0.470	5.920	6.860	0.918	0.821	0.969	0.578	0.517	0.610
	<800	750	2.875	1.504	0.129	0.849	0.654	2.353	0.001	0.000	0.004	0.000	0.000	0.002
	800 - 899	850	2.929	2.381	0.073	0.641	1.741	3.022	0.004	0.001	0.024	0.002	0.001	0.012
	900 - 999	950	2.978	3.161	0.039	0.465	2.696	3.626	0.033	0.011	0.085	0.017	0.005	0.042
5	1000 - 1099	1050	3.021	3.863	0.019	0.330	3.533	4.192	0.128	0.071	0.210	0.064	0.036	0.105
	1100 - 1199	1150	3.061	4.500	0.012	0.255	4.245	4.755	0.309	0.225	0.403	0.154	0.113	0.202
	1200 - 1299	1250	3.097	5.085	0.013	0.266	4.819	5.351	0.534	0.428	0.637	0.267	0.214	0.319
	1300 - 1399	1350	3.130	5.624	0.021	0.339	5.286	5.963	0.734	0.612	0.832	0.367	0.306	0.416
	1400 - 1499	1450	3.161	6.125	0.034	0.435	5.691	6.560	0.869	0.755	0.941	0.435	0.378	0.470
	>1500	1550	3.190	6.593	0.051	0.536	6.057	7.128	0.944	0.855	0.983	0.472	0.427	0.492

[A] $\delta Y = t_{n-2}$ Var(Y)

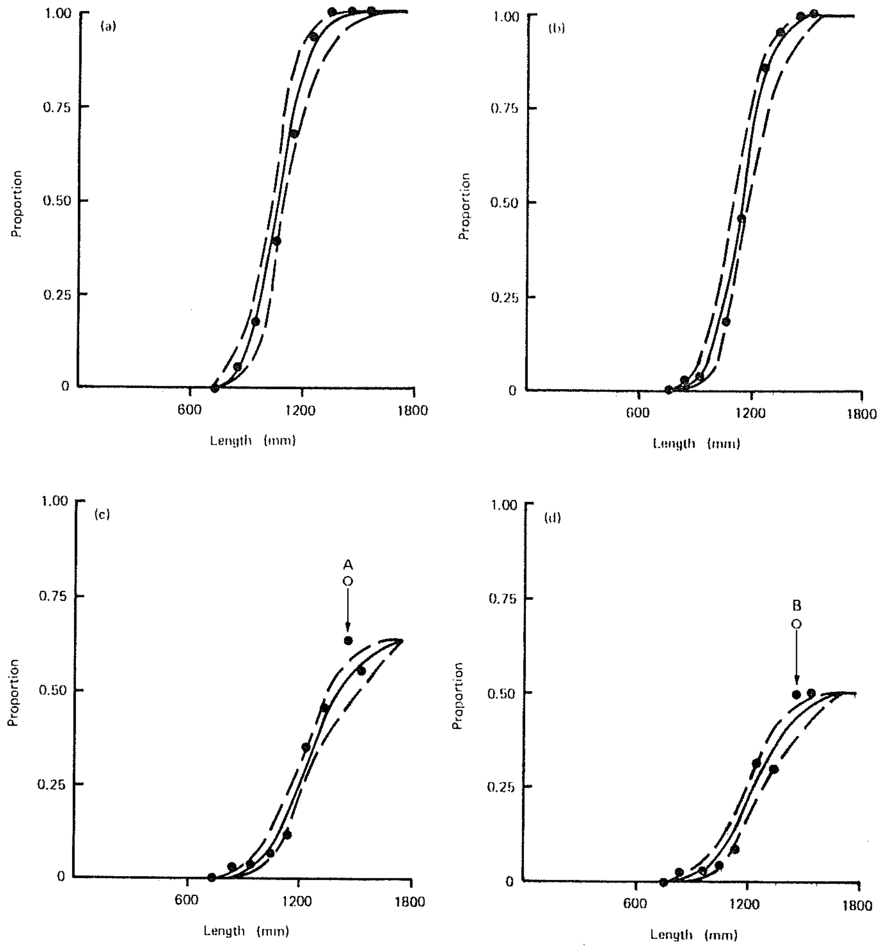

Fig. 7.8. Relationship [with 95% confidence limits (— —)] between proportion of sharks, p, for a selected group of uterus condition indicies and length, l, for each of four groups of uterus condition indicies for female gummy shark. Values for a, b (with standard error) and c for the equation $p = c\ \mathrm{Probit}^{-1}\ (a + b \log_{10} l)$ are given in the following tabulation:

	Group of uterus condition indicies	a	b	c
(a)	2, 3, 4 and 5	-53.10	19.18±0.26	1.00
(b)	3, 4 and 5	-57.83	20.55±0.24	1.00
(c)	4 and 5	-40.38	14.66±0.48	0.63
(d)	5 only	-40.90	16.14±0.34	0.50

[A] Value of 0.79 (denoted by o) was altered to 0.63 to permit probit analysis.

[B] Value of 0.68 was altered to 0.50.

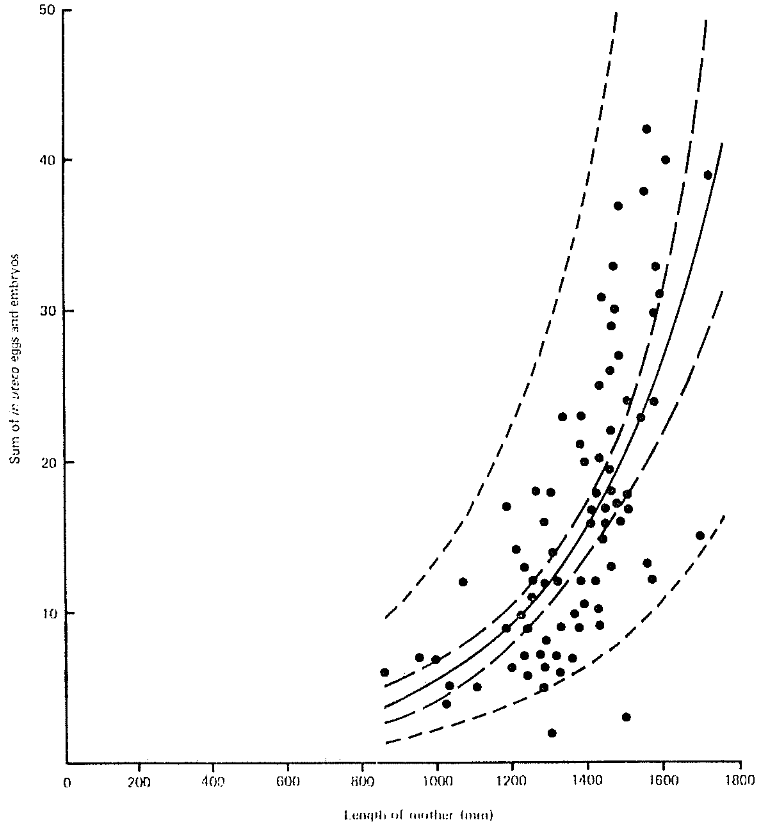

Fig. 7.9. Relationship [with 95% confidence limits on the mean curve (——) and individual shark data (----)] between sum of in utero eggs and embryos, g, and total length of mother, l, for female gummy shark. Values for a and b (with standard error) for the equation $g = e^{a+bl}$ are given in the following tabulation:

a	b	n	r^2 [A]	e.m.s.[B]
-9.38×10^{-1}	$(2.64 \pm 0.29) \times 10^{-3}$	81	0.52**	0.20

[A] Coefficient of determination between ln(g) and l. **P<0.01.
[B] Error mean square for regression of ln(g) against l.

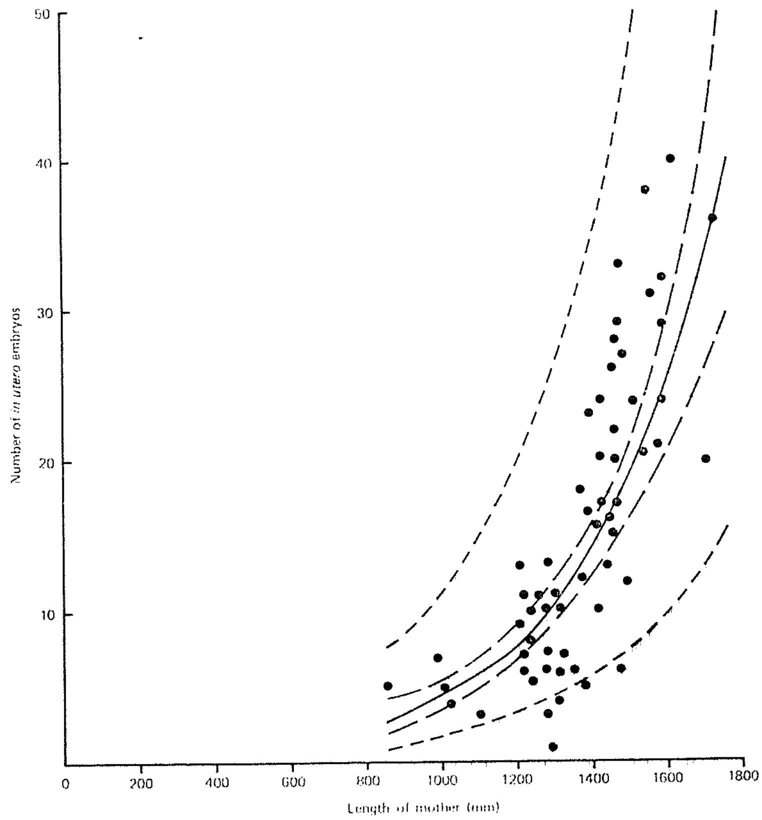

Fig. 7.10. Relationship [with 95% confidence limits on the mean curve (—·—) and individual shark data (----)] between number of *in utero* embryos, m, and total length of mother, l, for female gummy shark. Values for a and b (with standard error) for the equation $m = e^{a+bl}$ are given in the following tabulation:

a	b	n	r^2 [A]	e.m.s.[B]
-1.404	$(2.88 \pm 0.32) \times 10^{-3}$	66	0.56**	0.20

[A] Coefficient of determination between ln(m) and l. **P<0.01.

[B] Error mean square for the regression of ln(m) against l.

Table 7.4 Mean number (with standard error) of eggs and of each sex of embryos in the left and right uteri of 81 pregnant gummy shark.

Eggs or sex of embryos	Mean number of eggs and embryos (with standard error) for each uterus		
	Left uterus	Right uterus	Total
Eggs	2.28±0.44	1.85±0.40	4.13±0.81
Embryos			
Male	2.72±0.32	3.11±0.33	5.83±0.60
Female	3.16±0.35	3.10±0.32	6.26±0.64
Unknown[A]	0.11±0.05	0.10±0.05	0.21±0.08
Total	5.99±0.63	6.31±0.57	12.30±1.16
Grand total	8.27±0.61	8.16±0.50	16.43±1.07

[A] Embryos too small to determine sex by macroscopic inspection.

Table 8.1. Number and percentage of gummy sharks containing each prey item, mean number and mean weight of each prey item per shark, and percentage of prey items by number and by weight for each taxon. (Indigestible material given in parentheses).

Taxon of prey items	Sharks containing prey items		Mean per shark		Percentage of prey items	
	Number	Percentage	Number (10^{-3})	Weight (mg)	By number	By weight
Annelida	9	1.8	10	33	0.5	0.1
Chaetopoda	9	1.8	10	31	0.5	0.1
Polychaeta	1	0.2	2	2	0.1	<0.1
Glyceridae	1	0.2	2	2	0.1	<0.1
Glycera americana Leidy	1	0.2	2	2	0.1	<0.1
Echiuroidea	57	11.5	241	488	12.5	1.0
Arthropoda	332	66.8	1229	12305	63.5	24.5
Crustacea	332	66.8	1229	12305	63.5	24.5
Decapoda	307	61.8	1103	12103	57.0	24.1
Dromiidae	2	0.4	2	21	0.1	<0.1
Cryptodromia octodentata (Haswell)	2	0.4	2	21	0.1	<0.1
Leucosiinae	15	3.0	62	217	3.2	0.4
Philyra undecimspinosa (Rathbun)	15	3.0	62	217	3.2	0.4
Portunidae	124	24.9	547	3439	28.3	6.8
Ovalipes australiensis (Edwards)	45	9.1	201	1723	10.4	3.4
Macropipus corrugatus (Pennant)	49	9.9	233	405	12.0	0.8
Nectocarcinus integrifons (Latreille)	30	6.0	111	894	5.7	1.8
Nectocarcinus tuberculosus (Edwards)	3	0.6	2	417	0.1	0.8
Xanthidae	14	2.8	24	95	1.2	0.2
Pilumnus tomentosus (Latreille)	13	2.6	22	93	1.1	0.2
Actumnus setifer (de Haan)	1	0.2	2	2	0.1	<0.1
Goneplacidae	8	1.6	12	116	0.6	0.2
Carcinoplax meridionalis (Rathbun)	8	1.6	12	116	0.6	0.2
Grapsidae	2	0.4	14	55	0.7	0.1
Plagusia chabrus (Linnaeus)	2	0.4	14	55	0.7	0.1
Hymenosomatidae	5	1.0	6	39	0.3	0.1
Elamena truncata (Stimpson)	5	1.0	6	39	0.3	0.1
Majidae	51	10.3	117	1940	6.0	3.9
Leptomithrax gaimardii (Rathbun)	43	8.7	95	1864	4.9	3.7
Naxia spinosa (Hess)	8	1.6	22	76	1.1	0.2
Scyllaridae	26	5.2	64	606	3.3	1.2
Ibacus incisus (Peron)	26	5.2	64	606	3.3	1.2
Palinuridae	42	8.5	34	2876	1.8	5.7
Jasus novaehollandiae (Holthius)	42	8.5	34	2876	1.8	5.7
Paguridae	139	28.0	137	2512	7.1	5.0
Paguristes sulcatus (Baker)	1	0.2	2	5	0.1	<0.1
Clibinarius strigimanus (White)	135	27.2	133	2462	6.9	4.9
Dardanus arrosor (Herbst)	5	1.0		310		0.1
Synalpheidae	12	2.4	68	159	3.5	0.3
Crangon novaezelandiae (Miers)	7	1.4	54	129	2.8	0.3
Crangon villosus (Olivier)	3	0.6	10	15	0.5	<0.1
Rhynchocinetidae	1	0.2	2	1	0.1	<0.1
Rhynchocinetes rugulosus (Stimpson)	1	0.2	2	1	0.1	<0.1
Peneidae	1	0.2	2	<1	0.1	<0.1
Stomatopoda	40	8.0	99	165	5.1	0.3
Squillidae	40	8.0	99	165	5.1	0.3
Squilla spp.	1	0.2	2	<1	0.1	<0.1
Squilla laevis (Hess)	11	2.2	20	70	1.0	0.1
Squilla miles (Hess)	6	1.2	14	26	0.7	0.1
Squilla oratoria inornata (Tate)	1	0.2	2	4	0.1	0.1
Austrosquilla spp.	4	0.8	10	10	0.5	<0.1
Austrosquilla vercoi (Hale)	2	0.4	4	7	0.2	<0.1
Austrosquilla perpasta (Hale)	6	1.2	12	11	0.6	<0.1
Austrosquilla osculans (Hale)	8	1.6	28	33	1.4	<0.1
Isopoda	6	1.2	22	12	1.1	<0.1
Eurydicicidae	5	1.0	16	4	0.8	<0.1
Cirolana woodjonesi (Hale)	5	1.0	16	4	0.8	<0.1
Sphaeromidae	1	0.2	4	4	0.2	<0.1
Cymodoce gaimardii (Edwards)	1	0.2	4	2	0.2	<0.1
Eubranchiatae	1	0.2	2	3	0.1	<0.1

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Table 8.1 (Continued)

Taxon of prey items	Sharks containing prey items		Mean per shark		Percentage of prey items	
	Number	Percentage	Number (10^{-3})	Weight (mg)	By number	By weight
Mollusca	152(42)	30.6(8.5)	272	18362(173)	14.1	36.5(0.3)
Gastropoda	10	2.0	18	351	0.9	0.7
Neogastropoda	1	0.2	2	165	0.1	0.3
Volutidae	1	0.2	2	165	0.1	0.3
Archaeogastropoda	1	0.2		13		<0.1
Haliotidae	1	0.2		13		<0.1
Pelecypoda	7(3)	1.4(0.6)	6	27(11)	0.3	<0.1(<0.1)
Anisomyaria	1(1)	0.2(0.2)		2(2)		<0.1(<0.1)
Pectinidae	1(1)	0.2(0.2)		2(2)		<0.1(<0.1)
Pecten alba (Tate)	1(1)	0.2(0.2)		2(2)		<0.1(<0.1)
Eullamellibranchiata	2(2)	0.4(0.4)		9(9)		<0.1(<0.1)
Veneridae	1(1)	0.2(0.2)		1(1)		<0.1(<0.1)
Notocallista dimenensis (Hanley)	1(1)	0.2(0.2)		1(1)		<0.1(<0.1)
Laternulidae	1(1)	0.2(0.2)		8(8)		<0.1(<0.1)
Cephalopoda	137(39)	27.6(7.8)	245	17904(162)	12.7	35.6(0.3)
Decapoda	37(12)	7.4(2.4)	56	144(144)	2.9	7.7(0.3)
Sepiidae	11(5)	2.2(1.0)	10	877(137)	0.5	1.7(0.3)
Sepia braggi (Verco)	1(1)	0.2(0.2)		<1		<0.1
Loliginidae	13(4)	2.6(0.8)	20	1628(4)	1.0	3.2
Sepioteuthis australis Quoy & Gaimard	12(3)	2.4(0.6)	20	1628	1.0	3.2
Omnastrephidae	14(3)	2.8(0.6)	26	1374(3)	1.3	2.7
Nototodarus gouldi (McCoy)	14(3)	2.8(0.6)	26	1374	1.3	2.7
Octopoda	98(29)	19.7(5.8)	183	12608(18)	9.5	25.1
Octopodidae	86(29)	17.3(5.8)	163	11945(18)	8.4	23.8
Octopus spp.	86(29)	17.3(5.8)	163	11945(18)	8.4	23.8
Argonautidae	14	2.8	20	663	1.0	1.3
Argonauta nodosa Solander	14	2.8	20	663	1.0	1.3
Chordata	125(54)	25.2(10.9)	175	6000(622)	9.0	11.9(1.2)
Ascidiacea	9	1.8	16	253	0.8	0.5
Salpida	1	0.2		11		<0.1
Elasmobranchii	4(1)	0.8(0.2)	6	91(12)	0.3	0.2
Galeoidae	1	0.2	2	53	0.1	0.1
Orectolobidae	1	0.2	2	53	0.1	0.1
Orectolobus spp.	1	0.2	2	53	0.1	0.1
Squaloidae	1(1)	0.2(0.2)		12(12)		<0.1
Squalidae	1(1)	0.2(0.2)		12(12)		<0.1
Batoidei	2	0.4	4	26	0.2	0.1
Rajidae	1	0.2	2	6	0.1	<0.1
Raja spp.	1	0.2	2	6	0.1	<0.1
Teleostei	128	25.8(11.5)	153	5655(609)	7.9	11.2(1.2)
Clupeiformes	3	0.6	24	11	1.2	<0.1
Clupeidae	1	0.2	2	3	0.1	<0.1
Engraulidae	1	0.2	2	2	0.1	<0.1
Engraulis australis antipodum Gunther	1	0.2	2	2	0.1	<0.1
Aplochitonidae	1	0.2	20	6	1.0	<0.1
Lovettia seali (Johnston)	1	0.2	20	6	1.0	<0.1
Anguilliformes	6	1.2	12	90	0.6	0.2
Leptocephalidae	2	0.4	4	16	0.2	<0.1
Leptocephalus wilsoni (Bloch & Schneider)	1	0.2	2	3	0.1	<0.1
Poutawa habenata Richardson	1	0.2	2	13	0.1	<0.1
Echelidae	3	0.6	6	74	0.3	0.2
Muraenichthys spp.	3	0.6	6	74	0.3	0.2
Ophichthyidae	1	0.2	2	<1	0.1	
Beloniformes	2	0.4	4	80	0.2	0.2
Hemiramphidae	2	0.4	4	80	0.2	0.2
Hyporamphus melanochir (Valenciennes)	2	0.4	4	80	0.2	0.2
Mugiliformes	2	0.4	4	78	0.2	0.2
Mugildae	1	0.2	2	76	0.1	0.2
Myxus elongatus Gunther	1	0.2	2	76	0.1	0.2
Atherinidae	1	0.2	2	3	0.1	<0.1

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Table 8.1 (Continued)

Taxon of prey items	Sharks containing prey items		Mean per shark		Percentage of prey items	
	Number	Percentage	Number (10^{-3})	Weight (mg)	By number	By weight
Perciformes	59(34)	11.9(6.8)	60	2202(444)	3.1	44.0(0.9)
Gempylidae	27(19)	5.4(3.8)	14	757(236)	0.7	1.5(0.5)
Leionura atun (Euphrasen)	19(14)	3.8(2.8)	8	700(207)	0.4	1.4(0.4)
Lepidopidae	1	0.2	2	8	0.1	<0.1
Lepidopus lex Phillipps	1	0.2	2	8	0.1	<0.1
Platycephalidae	8(3)	1.6(0.6)	8	271(63)	0.4	0.5(0.1)
Neoplatycephalus spp.	2(2)	0.4(0.4)		107(61)		0.2(0.1)
Platycephalus spp.	2	0.4	2	83	0.1	0.2
Triglidae	6(5)	1.2(1.0)	4	148(43)	0.2	0.3(0.1)
Chelidonichthys kumu (Lesson & Garnot)	1	0.2	2	87	0.1	0.2
Paratrigla spp.	2(2)	0.4(0.4)		11(11)		<0.1
Paratrigla vanessa (Richardson)	2(2)	0.4(0.4)		41(26)		0.1(0.1)
Scorpaenidae	1	0.2	2	18	0.1	<0.1
Neosebastes scorpaenoides Guichenot	1	0.2	2	18	0.1	<0.1
Callionymidae	3(1)	0.6(0.2)	4	142(31)	0.2	0.3(0.1)
Callionymus spp.	2(1)	0.4(0.2)	2	34(31)	0.1	0.1(0.1)
Callionymus papilio Gunther	1	0.2	2	109	0.1	0.2
Carangidae	11(3)	2.2(0.6)	16	282(32)	0.8	0.6(0.1)
Trachurus spp.	5(1)	1.0(0.2)	6	141(9)	0.3	0.3
Trachurus mccullochi Nichols	1	0.2	4	52	0.2	0.1
Usacaranx georgianus (C & V)	1	0.2	2	40	0.1	0.1
Seriola grandis Castelnau	1(1)	0.2(0.2)		10(10)		<0.1
Pomatomidae	1(1)	0.2(0.2)		10(7)		<0.1
Pomatomus saltator (Linneaus)	1(1)	0.2(0.2)		10(7)		<0.1
Mullidae	1	0.2	2	58	0.1	0.1
Upeneichthys porosus (C & V)	1	0.2	2	58	0.1	0.1
Emmelichthyidae	1	0.2	2	177	0.1	0.4
Plagiogeneion macrolepis McCulloch	1	0.2	2	177	0.1	0.4
Chironemidae	1(1)	0.2(0.2)		17(4)		<0.1
Threpterius spp.	1(1)	0.2(0.2)		17(4)		<0.1
Histiopteridae	1(1)	0.2(0.2)		43(21)		0.1
Anthiidae	1	0.2	2	55	0.1	0.1
Caesioperca spp.	1	0.2	2	55	0.1	0.1
Blenniidae	1(1)	0.2(0.2)		6(6)		<0.1
Pictiblennius tasmanianus (Richardson)	1(1)	0.2(0.2)		6(6)		<0.1
Clinidae	1	0.2	4	212	0.2	0.4
Petraites johnstoni (Saville-Kent)	1	0.2	4	212	0.2	0.4
Labriformes	3	0.6	4	1290	0.2	2.6
Labridae	2	0.4	2	1260	0.1	2.5
Pseudolabrus spp.	1	0.2	2	1260	0.1	2.5
Scoridae	1	0.2	2	30	0.1	0.1
Heteroscarus acroptilus (Richardson)	1	0.2	2	30	0.1	0.1
Tetraodontiformes	17(6)	3.4(1.2)	26	1489(71)	1.3	3.0(0.1)
Tetraodontidae	4	0.8	8	778	0.4	1.6
Contusus richei (Freminville)	3	0.6	6	710	0.3	1.4
Ostraciontidae	1	0.2	4	120	0.2	0.2
Aracana aurita (Shaw)	1	0.2	4	120	0.2	0.2
Monacanthidae	12(6)	2.4(1.2)	14	592(71)	0.7	1.2(0.1)
Meuschenia spp.	3(3)	0.6(0.6)		69(53)		0.1(0.1)
Penicipelta vittiger (Castelnau)	6(1)	1.2(0.2)	10	477	0.5	1.0
Other (Miscellaneous)	13	3.0	6	66	0.6	0.1
Porifera	2	0.4		10		<0.1
Coelenterata	3	0.6				<0.1
Hydrozoa						<0.1
Bryozoa	2	0.4		4		<0.1
Echinodermata	3	0.6	6	47	0.3	0.1
Holothuroidea	2	0.4	4	30	0.2	0.1
Algae	5	1.0		6		<0.1
Phaeophyceae	4	0.8		5		<0.1
Rhodophyceae	1	0.2				<0.1
Spermatophyta	1	0.2				<0.1
Monocotyledoneae	1	0.2				<0.1
Zosteraceae	1	0.2				<0.1
Unidentifiable material[A]	377	75.9		13024		25.9
Empty	62	12.5				
Total	497	100.0	1934	50279(795)		100.0(1.6)

[A] Mainly sludge of biotic material.

Table 8.2. Percentage frequency of sharks containing prey items, percentage weight of prey items and percentage frequency of prey items for each of four states of digestion of the major taxonomic classes detected in the stomach contents of gummy sharks.

Variable	Taxonomic class	Percentage for each state of digestion					
		Nil	Slight	Medium	Advanced	Total	Indigestible[A]
Percentage frequency of sharks containing prey items	Empty stomach					12.5	
	Cephalopoda	4.0	4.0	9.1	9.3	27.6	7.8
	Crustacea	5.0	17.9	28.4	48.1	66.8	0.0
	Teleostei	0.4	1.6	8.0	8.9	25.8	11.5
	Other[B]	4.6	8.7	4.2	1.4	17.5	0.0
	Unidentifiable	0.6	0.0	3.0	77.7	81.3	0.0
	Total	13.3	29.6	42.5	55.9	100.0	18.3
Percentage weight of prey items	Empty stomach	0.0	0.0	0.0	0.0	0.0	0.0
	Cephalopoda	4.0	5.5	15.1	11.0	35.6	0.4
	Crustacea	2.3	5.0	4.8	12.4	24.5	0.0
	Teleostei	0.0	3.9	5.1	2.3	11.3	1.2
	Other	0.7	0.8	0.8	0.4	2.7	<0.1
	Unidentifiable	0.0	0.0	0.5	25.4	25.9	0.0
	Total	7.0	15.2	26.3	51.5	100.0	1.6
Percentage frequency of prey items	Empty stomach	0.0	0.0	0.0	0.0	0.0	0.0
	Cephalopoda	2.3	2.4	4.4	3.5	12.6	0.0
	Crustacea	3.8	11.7	17.6	29.9	63.0	0.0
	Teleostei	0.1	1.1	4.0	2.6	7.8	0.0
	Other[B]	3.0	10.7	2.2	0.7	16.6	0.0
	Unidentifiable	0.0	0.0	0.0	0.0	0.0	0.0
	Total	9.2	25.9	28.2	36.7	100.0	0.0

A Included in advanced state of digestion
B Predominantly class echiuroidea.

Table 9.1.1. Depth of net, number of meshes deep, thickness of filaments of webbing and breaking strain of filaments for each of eight gill nets of 2-inch to 9-inch mesh size of hanging coefficent 0.60 and for each of 6-inch and 7-inch gill nets for each of the hanging coefficients 0.53 and 0.67.

Hanging coefficient	Mesh size (inch)	Depth of net (cm)	Number of meshed deep	Thickness of webbing filaments (mm)	Breaking strain (Newton)
	2	171	42	0.47	101
	3	171	28	0.57	146
	4	171	21	0.66	193
0.60[A]	5	171	17	0.74	240
	6	171	14	0.81	285
	7	171	12	0.87	326
	8	171	10	0.90	348
	9	171	9	1.05	467
0.53	6	181	14	0.81	285
	7	181	12	0.87	326
0.67	6	158	14	0.81	285
	7	158	12	0.87	326

[A] Not exact for 5-inch (0.61), 8-inch (0.54) and 9-inch (0.56) gill nets.

Table 9.1.2. Mean fishing time and mean (with standard error) of number and length of gummy sharks captured for six gill nets of 6-inch and 7-inch mesh sizes for each of the three hanging coefficients 0.53, 0.60 and 0.67 set at 35 separate fishing stations.

Variable	Mesh size (inch)	Mean and standard error for nets of each hanging coefficient.			
		0.53	0.60	0.67	Total
Mean fishing time per station (h)	6	6.06	6.20	5.92	6.06
	7	5.70	5.79	5.75	5.75
	Total	5.88	5.99	5.84	5.90
Mean number captured per station	6	4.03 ± 1.27	2.94 ± 0.70	3.74 ± 0.80	3.57 ± 0.29
	7	2.51 ± 0.54	2.11 ± 0.64	2.43 ± 0.57	2.35 ± 0.22
	Total	3.27 ± 0.38	2.53 ± 0.30	3.09 ± 0.28	2.96 ± 0.18
Mean length (m)	6	1029 ± 11	1082 ± 11	1059 ± 12	1054 ± 7
	7	1217 ± 19	1211 ± 14	1208 ± 13	1212 ± 9
	Total	1102 ± 12	1136 ± 10	1117 ± 10	1117 ± 6

Table 9.1.3. Mean fishing time by each of eight gill nets of mesh sizes ranging from 2 to 9 inches and summary of results of catch of sharks by each net for male and female gummy shark.

Variable	Sex	2-inch	3-inch	4-inch	5-inch	6-inch	7-inch	8-inch	9-inch	Total
Mean fishing time (h)		5.94	5.88	5.66	5.76	6.00	5.76	5.75	5.78	5.82
Mean length of sharks captured (mm)	Male	690	723	811	963	1051	1209	1247	1337	983
	Female	547	634	788	967	1036	1222	1354	1514	983
	Combined	626	678	799	964	1046	1213	1310	1491	983
Standard deviation of length of sharks captured (mm)	Male	291	200	144	135	117	101	82	47	201
	Female	136	274	145	173	129	144	160	148	286
	Combined	235	239	144	146	121	117	142	151	238
Standard error of length of sharks captured (mm)	Male	119	54	15	10	11	12	18	27	9
	Female	61	40	14	21	17	25	30	33	16
	Combined	71	34	10	9	9	12	21	31	8
Total number of sharks captured	Male	6	25	98	176	115	65	20	3	508
	Female	5	25	100	68	54	32	28	20	332
	Combined	11	50	198	244	169	97	48	23	840
Number of sharks captured per 10^4 m of gill net	Male	3.29	13.70	53.70	96.44	63.01	35.62	10.96	1.64	34.79
	Female	2.74	13.70	54.79	37.26	29.59	17.53	15.34	10.96	22.74
	Combined	6.03	27.40	108.49	133.70	92.60	53.15	26.30	12.60	57.53
Number of sharks captured per 10^5 · metre-hour of gill net	Male	5.53	23.30	94.87	167.42	105.02	61.83	19.06	2.84	59.82
	Female	4.61	23.30	96.81	64.69	49.31	30.44	26.68	18.96	39.10
	Combined	10.14	46.60	191.68	232.11	154.33	92.27	45.74	21.80	98.92
Length of shark at maximum selectivity (mm)	Male	370	556	741	926	1111	1296	1482	1667	
	Female	368	551	735	919	1103	1287	1470	1654	
	Combined	369	553	737	922	1106	1291	1475	1659	

Table 9.1.4. Number of sharks captured per 10^5 metre-hour of gill nets for each of eight mesh sizes ranging from 2 to 9 inches for each 100-mm length-class for male and female gummy shark.

Sex	Length-class (mm)	Number of sharks captured per 10^5 metre-hour for each mesh size								
		2-inch	3-inch	4-inch	5-inch	6-inch	7-inch	8-inch	9-inch	Total
	<400	0.92	0.93							1.85
	400- 499	0.92	4.66							5.58
	500- 599	0.92	5.59	5.81						12.32
	600- 699		2.80	13.55						16.53
	700- 799		0.93	30.98	15.22					47.13
	800- 899	0.92		21.30	49.47	12.79				84.48
	900- 999	0.92	3.73	11.62	39.95	21.92	1.90			80.04
	1000-1099	0.92	1.86	7.74	27.59	35.62	6.66	0.95		81.34
Male	1100-1199		1.86	2.90	26.64	21.00	19.03	2.86		74.29
	1200-1299		0.93		7.61	11.87	23.78	11.44		55.63
	1300-1399				0.95	1.83	9.51	3.81	2.84	18.94
	1400-1499						0.95			0.95
	1500-1599									
	1600-1699									
	≥1700									
	Total	5.52	23.29	93.90	167.43	105.03	61.83	19.06	2.84	478.90
	<400	0.92								0.92
	400- 499		4.66							4.66
	500- 599	1.84	10.25	5.81						17.90
	600- 699	1.84	2.80	22.27						26.91
	700- 799		1.86	23.23	8.56					33.65
	800- 899		1.86	26.14	22.83	7.31				58.14
	900- 999			11.62	7.61	11.87	0.95			32.05
	1000-1099			4.84	11.42	17.35	5.71	1.91		41.23
Female	1100-1199		0.93	1.94	7.61	6.39	7.61	1.91		26.39
	1200-1299		0.93	0.97	3.81	3.65	9.51	6.67	2.84	28.38
	1300-1399				0.95	1.83	2.85	5.72	1.90	13.25
	1400-1499				1.90	0.91	1.90	4.76	1.90	11.37
	1500-1599						1.90	2.86	6.64	11.40
	1600-1699							2.86	3.79	6.65
	>1700								1.90	1.90
	Total	4.60	23.29	96.82	64.69	49.31	30.43	26.69	18.97	314.80
	<400	1.84	0.93							2.77
	400- 499	0.92	9.32							10.24
	500- 599	2.76	15.84	11.62						30.22
	600- 699	1.84	5.60	35.82						43.26
	700- 799		2.79	54.21	23.78					80.78
	800- 899	0.92	1.86	47.44	72.30	20.10				142.62
	900- 999	0.92	3.73	23.24	47.56	33.79	2.85			112.09
	1000-1099	0.92	1.86	12.58	39.01	52.97	12.37	2.86		122.57
Total	1100-1199		2.79	4.84	34.25	27.39	26.64	4.77		100.68
	1200-1299		1.86	0.97	11.42	15.52	33.29	18.11	2.84	84.01
	1300-1399				1.90	3.66	12.36	9.53	4.74	32.19
	1400-1499				1.90	0.91	2.85	4.76	1.90	12.32
	1500-1599						1.90	2.86	6.64	11.40
	1600-1699							2.86	3.79	6.65
	>1700								1.90	1.90
	Total	10.21	46.58	190.72	232.12	154.34	92.26	45.75	21.81	793.70

Table 9.1.5. Number of sharks per 10^5 metre-hour of each sex captured by gill nets of each of eight mesh sizes ranging from 2 to 9 inches for each 1-year age-group for each of male and female gummy shark.

Sex	Age-group (years)	Number of sharks captured per 10^5 metre-hour for each mesh size								
		2-inch	3-inch	4-inch	5-inch	6-inch	7-inch	8-inch	9-inch	Total
	1	1.94	7.87	5.71	0.81					16.33
	2	1.09	4.27	14.08	15.29	3.92	0.06			38.71
	3	0.44	3.37	38.34	31.72	11.46	1.89	0.32		87.54
	4	0.74	1.94	14.99	34.92	19.13	3.37	0.42		75.51
	5	0.66	2.40	12.00	39.62	27.43	12.65	2.69		97.45
	6	0.48	2.17	6.97	30.09	26.16	20.56	6.53	1.14	94.10
Male	7	0.18	0.92	2.27	10.39	11.89	13.04	5.44	0.57	44.70
	8		0.30	0.37	3.43	3.90	7.47	2.88	0.57	18.92
	9		0.07	0.11	1.18	1.15	2.79	0.87	0.57	6.74
	10									
	11									
	12									
	Total	5.53	23.31	94.84	167.45	105.04	61.83	19.15	2.85	480.00
	1	1.38	7.44	2.90						11.72
	2	1.78	7.16	19.81	4.22	0.66				33.63
	3	0.79	2.47	30.25	15.40	8.36	1.46	0.35		57.08
	4	0.66	3.95	27.47	18.85	13.88	3.47	1.67	1.06	70.99
	5		1.07	13.18	16.49	14.23	7.03	3.93	1.78	57.71
	6		0.48	1.25	4.37	4.60	5.97	4.08	3.17	23.92
Female	7		0.33	1.44	3.84	4.70	5.55	6.17	3.42	25.45
	8		0.29	0.38	2.10	1.96	4.14	5.37	4.47	18.71
	9		0.04	0.04	0.77	0.45	1.35	2.76	2.79	8.20
	10				0.25	0.20	0.84	1.53	1.97	4.79
	11		0.04	0.04	0.28	0.22	0.54	0.56	0.23	1.91
	12				0.10	0.05	0.10	0.25	0.10	0.60
	Total	4.61	23.27	96.76	64.65	49.31	30.45	26.67	18.99	314.71
	1	3.32	15.31	8.61	0.81					28.05
	2	2.87	11.43	33.89	19.51	4.58	0.06			72.34
	3	1.23	5.84	68.59	45.21	19.82	3.35	0.67		144.62
	4	1.40	5.89	42.46	53.75	33.01	6.84	2.09	1.06	146.50
	5	0.66	3.47	25.18	56.11	41.66	19.68	6.62	1.78	155.16
	6	0.48	2.65	8.22	34.46	30.76	26.53	10.61	4.31	118.02
Total	7	0.18	1.25	3.71	14.23	16.59	18.59	11.61	3.99	70.15
	8		0.59	0.75	5.53	5.86	11.61	8.25	5.04	37.63
	9		0.11	0.15	1.95	1.60	4.14	3.63	3.36	14.94
	10				0.25	0.20	0.84	1.53	1.97	4.79
	11		0.04	0.04	0.28	0.22	0.54	0.56	0.23	1.91
	12				0.10	0.05	0.10	0.25	0.10	0.60
	Total	10.14	46.58	191.60	232.10	154.35	92.28	45.82	21.84	794.71

Table 9.1.6. Estimates of selectivity by gill nets of six mesh sizes ranges from 4 to 9 inches for catches of sharks for each 100-mm length-class for male and female gummy shark.

Sex	Length-class (mm)	Selectivity for each mesh size					
		4-inch	5-inch	6-inch	7-inch	8-inch	9-inch
	<400						
	400-499	0.11					
	500-599	0.45	0.03				
	600-699	0.87	0.17				
	700-799	0.99	0.54	0.05			
	800-899	0.77	0.92	0.24	0.01		
	900-999	0.44	0.97	0.63	0.07		
Male	1000-1099	0.20	0.71	0.96	0.30		
	1100-1199	0.07	0.38	0.94	0.70		
	1200-1299	0.02	0.16	0.64	0.98		
	1300-1399	0.01	0.05	0.32	0.90		
	1400-1499		0.01	0.12	0.58		
	1500-1599			0.04	0.27		
	>1600			0.01	0.09		
	<400						
	400-499	0.17					
	500-599	0.49	0.05				
	600-699	0.85	0.22	0.01			
	700-799	1.00	0.55	0.07			
	800-899	0.89	0.88	0.27	0.02		
	900-999	0.63	1.00	0.60	0.10		
Female	1000-1099	0.38	0.86	0.91	0.31	0.03	
	1100-1199	0.19	0.59	0.99	0.65	0.12	
	1200-1299	0.09	0.35	0.83	0.94	0.36	0.04
	1300-1399	0.04	0.16	0.55	0.99	0.69	0.15
	1400-1499	0.01	0.07	0.30	0.80	0.96	0.40
	1500-1599		0.03	0.14	0.51	0.97	0.74
	>1600		0.01	0.05	0.27	0.76	0.97
	<400						
	400-499	0.13					
	500-599	0.47	0.04				
	600-699	0.86	0.20	0.01			
	700-799	1.00	0.56	0.06			
	800-899	0.82	0.91	0.26	0.01		
	900-999	0.51	0.99	0.63	0.09		
Total	1000-1099	0.26	0.77	0.95	0.32	0.02	
	1100-1199	0.11	0.46	0.97	0.69	0.12	
	1200-1299	0.04	0.22	0.72	0.97	0.38	0.03
	1300-1399	0.01	0.09	0.41	0.94	0.75	0.16
	1400-1499		0.03	0.18	0.67	0.99	0.44
	1500-1599		0.01	0.07	0.36	0.91	0.81
	>1600			0.02	0.15	0.62	1.00

Table 9.2.1. Summary of results of comparison of catches of sharks by short shank galvanised Mustard hooks of eight sizes ranging from 2/0 to 10/0 for male and female gummy shark for Experiment 1.

Variable	Sex	2/0	3/0	4/0	5/0	7/0	8/0	9/0	10/0	Total
Mean fishing time (h)		3.81	3.70	3.86	3.71	3.81	3.79	3.87	3.97	3.81
Mean length of sharks	Male	976	965	964	983	1029	1018	966	1011	989
captured (mm)	Female	944	864	928	909	975	915	934	963	931
	Total	964	932	950	956	1007	981	957	992	968
Standard deviation of	Male	163	275	255	228	166	146	213	151	205
length of sharks	Female	166	239	280	200	192	158	184	106	193
captured (mm)	Total	162	266	387	219	177	156	204	137	202
Standard error of	Male	36	49	48	43	31	27	39	27	14
length of sharks	Female	48	62	68	50	44	38	53	24	17
captured (mm)	Total	28	39	39	33	26	23	31	19	11
Total number of	Male	21	31	28	28	28	30	30	32	228
sharks captured	Female	12	15	17	16	19	17	12	20	128
	Total	33	46	45	44	47	47	42	52	356
Number of sharks	Male	10.00	14.76	13.33	13.33	13.33	14.29	14.29	15.24	13.57
captured per 10^4	Female	5.71	7.14	8.10	7.62	9.05	8.09	5.71	9.52	7.62
metre of main-line	Total	15.71	21.90	21.43	20.95	22.38	22.38	20.00	24.76	21.19
Number of sharks	Male	26.25	39.90	34.53	35.95	35.00	37.69	36.90	38.38	35.57
captured per 10^5	Female	15.00	19.30	20.96	20.54	23.75	21.37	14.76	24.00	19.96
metre-hour of main-line	Total	41.25	59.20	55.49	56.49	58.75	59.06	51.66	62.38	55.53
Number of sharks	Male	10.00	14.76	13.33	13.33	13.33	14.29	14.29	15.24	13.57
captured per 10^3	Female	5.71	7.14	8.10	7.62	9.05	8.09	5.71	9.52	7.62
hook-lift	Total	15.71	21.90	21.43	20.95	22.38	22.38	20.00	24.76	21.19
Number of sharks	Male	26.25	39.90	34.53	35.95	35.00	37.69	36.90	38.38	35.57
captured per 10^4	Female	15.00	19.30	20.96	20.54	23.75	21.37	14.76	24.00	19.96
hook-hour	Total	41.25	59.20	55.49	56.49	58.75	59.06	51.66	62.38	55.53

Table 9.2.2. Summary of results of comparison of catches of sharks during two separate experiments by each of short-shank and long-shank hooks of two hook sizes with various hook spacings for male and female gummy shark.

Variable	Sex	Experiment 2					Experiment 3				
Hook shank length		Short	Short	Long	Long	Total	Short	Short	Long	Long	Total
Hook size		5/0	10/0	11/0	11/0		5/0	10/0	11/0	11/0	
Hook spacing (m)		10	10	10	20		5	5	5	10	
Number of times set		41	41	41	41	41	22	22	22	22	22
Mean fishing time (h)		4.31	4.41	4.36	4.45	4.38	3.27	3.30	3.29	3.16	3.25
Mean length of sharks captured (mm)	Male	952	981	1033	985	987	942	987	933	954	956
	Female	940	996	945	1044	985	884	935	908	891	909
	Total	945	989	981	1019	986	925	966	920	935	938
Standard deviation of length of sharks captured (mm)	Male	134	107	121	132	125	129	137	98	114	122
	Female	108	202	117	190	168	133	180	155	129	153
	Total	120	164	126	170	150	131	156	129	121	136
Standard error of length of sharks captured (mm)	Male	23	16	21	21	10	23	23	20	19	11
	Male	17	29	17	25	12	38	38	31	33	18
	Total	14	17	14	17	8	20	21	18	17	10
Total number of shark captured	Male	34	42	33	41	150	30	34	24	35	123
	Female	40	49	48	56	193	12	22	25	15	74
	Total	74	91	81	97	343	42	56	49	50	197
Number of sharks captured per 10^4 metre of main-line	Male	16.58	20.49	16.10	10.00	14.63	54.54	61.82	43.64	31.82	44.73
	Female	19.51	23.90	23.41	13.66	18.83	21.82	40.00	45.45	13.64	26.91
	Total	36.09	44.39	39.51	23.66	33.46	76.36	101.82	89.09	45.46	71.64
Number of sharks captured per 10^3 m hour of main-line	Male	38.48	46.46	36.92	22.47	33.41	166.81	187.33	132.63	100.69	137.62
	Female	45.27	54.20	53.70	30.69	42.99	66.72	121.21	138.16	43.15	82.80
	Total	83.75	100.66	90.62	53.16	76.40	233.53	308.54	270.79	143.84	220.42
Number of sharks captured per 10^3 hook-lift	Male	16.58	20.49	16.10	20.00	18.29	27.27	30.91	21.82	31.82	27.95
	Female	19.51	23.90	23.41	27.32	23.54	10.91	20.00	22.73	13.64	16.82
	Total	36.09	44.39	39.51	47.32	41.83	38.18	50.91	44.55	45.46	44.77
Number of sharks captured per 10^4 hook-hour	Male	38.48	46.46	36.92	44.94	41.76	83.40	93.66	66.32	100.69	86.01
	Female	45.27	54.20	53.70	61.39	53.74	33.36	60.61	69.08	43.15	51.75
	Total	83.75	100.66	90.62	106.33	95.50	116.76	154.27	135.40	143.84	137.76

Table 9.2.3. Number of sharks captured per 10^4 hook-hour of short shank hooks of each of eight hook sizes ranging from 2/0 to 10/0 Mustad hooks for each of 100-mm length-class for male and female gummy shark for Experiment 1.

Sex	Length-class (mm)	Number of sharks captured per 10^4 hook-hour for each hook size								
		2/0	3/0	4/0	5/0	7/0	8/0	9/0	10/0	Total
	<400			1.23						0.15
	400- 499	1.25	1.29		2.57					0.64
	500- 599		2.57	1.23	1.28			1.23		0.79
	600- 699		2.57	2.47				1.23		0.78
	700- 799		3.86	6.17	2.57	2.50	2.51	6.15	3.60	3.42
	800- 899	5.00	6.44	1.23		7.50	5.03	8.61	4.80	4.83
Male	900- 999	5.00	9.01	3.70	12.84	1.25	10.05	3.69	9.59	6.89
	1000-1099	13.75	6.44	4.93	3.85	10.00	6.28	3.69	9.59	7.32
	1100-1199		2.57	9.87	10.27	6.25	6.28	4.92	7.20	5.92
	1200-1299	1.25	5.15	2.47		7.50	7.54	4.92	2.40	3.90
	1300-1399			1.23	2.57			2.46	1.20	0.93
	>1400									
	Total	26.25	39.90	34.53	35.95	35.00	37.69	36.90	38.38	35.57
	<400									
	400- 499		1.29	1.23						0.32
	500- 599			1.23	2.57					0.47
	600- 699	1.25	5.15	3.70		1.25	1.26	2.46		1.88
	700- 799	2.50	2.57	1.23	2.57	2.50	3.77		1.20	2.04
	800- 899	2.50	1.29	2.47	3.85	5.00	7.54	3.69	7.20	4.19
Female	900- 999	2.50	2.57	3.70	5.13	6.25	3.77	3.69	7.20	4.35
	1000-1099	2.50	2.57	1.23	2.57	5.00	2.51	2.46	6.00	3.11
	1100-1199	3.75	1.29	1.23	3.85		1.26	1.23	2.40	1.88
	1200-1299		2.57	2.47		1.25		1.23		0.94
	1300-1399			2.47		1.25	1.26			0.62
	>1400					1.25				0.16
	Total	15.00	19.30	20.96	20.54	23.75	21.37	14.76	24.00	19.96
	<400			1.23						0.15
	400- 499	1.25	2.58	1.23	2.57					0.96
	500- 599		2.57	2.46	3.85			1.23		1.26
	600- 699	1.25	7.72	6.17		1.25	1.26	3.69		2.66
	700- 799	2.50	6.44	7.40	5.14	5.00	6.28	6.15	4.80	5.46
	800- 899	7.50	7.72	3.70	3.85	12.50	12.56	12.30	12.00	9.02
	900- 999	7.50	11.58	7.40	17.97	7.50	13.82	7.38	16.79	11.24
	1000-1099	16.25	9.01	6.17	6.42	15.00	8.80	6.15	15.59	10.43
Total	1100-1199	3.75	3.86	11.10	14.12	6.25	7.54	6.15	9.60	7.80
	1200-1299	1.25	7.72	4.93		8.75	7.54	6.15	2.40	4.84
	1300-1399			3.70	2.57	1.25	1.26	2.46	1.20	1.55
	>1400					1.25				0.16
	Total	41.25	59.20	55.49	56.49	58.75	59.06	51.66	62.38	55.53

Table 9.2.4. Number of sharks captured per 10^4 hook-hour of hooks for each of three separate experiments for each 100-mm length-class for male and female gummy shark.

Sex	Length-class (mm)	Experiment 1	Experiment 2	Experiment 3
Male	<400	0.15		
	400- 499	0.64		
	500- 599	0.79		
	600- 699	0.78		1.40
	700- 799	3.42	3.06	7.69
	800- 899	4.83	6.12	18.88
	900- 999	6.89	12.81	23.78
	1000-1099	7.32	11.97	25.17
	1100-1199	5.92	5.85	7.69
	1200-1299	3.90	1.39	0.70
	1300-1399	0.93	0.56	0.70
	>1400			
	Total	33.57	41.76	86.01
Female	<400			
	400- 499	0.32		0.70
	500- 599	0.47		
	600- 699	1.88	0.28	2.80
	700- 799	2.04	5.29	7.69
	800- 899	4.19	12.25	18.18
	900- 999	4.35	15.04	6.99
	1000-1099	3.11	10.30	8.39
	1100-1199	1.88	4.18	4.20
	1200-1299	0.94	3.62	2.80
	1300-1399	0.62	1.11	
	1400-1499	0.16	1.11	
	1500-1599		0.28	
	>1600		0.28	
	Total	19.96	53.74	51.75
Total	<400	0.15		
	400- 499	0.96		0.70
	500- 599	1.26		
	600- 699	2.66	0.28	4.20
	700- 799	5.46	8.35	15.38
	800- 899	9.02	18.38	37.06
	900- 999	11.24	27.84	30.77
	1000-1099	10.43	22.27	33.56
	1100-1199	7.80	10.02	11.89
	1200-1299	4.84	5.01	3.50
	1300-1399	1.55	1.67	0.70
	1400-1499	0.16	1.11	
	1500-1599		0.28	
	>1600		0.28	
	Total	55.53	95.50	137.76

Table 9.2.5. Number of sharks captured per 10^4 hook-hour of hooks for each of three separate experiments for each 1-year age-group for male and female gummy shark.

Sex	Age-group (years)	Experiment 1	Experiment 2	Experiment 3
	0	0.32		
	1	1.13	0.16	0.41
	2	2.30	2.27	6.65
	3	6.23	7.32	17.60
	4	5.66	8.53	18.87
Male	5	7.68	10.38	20.08
	6	7.23	8.71	15.59
	7	3.34	3.29	5.56
	8	1.27	0.77	0.83
	9	0.41	0.33	0.42
	10			
	11			
	12			
	Total	35.57	41.76	86.01
	0	0.11		0.10
	1	0.34		0.30
	2	1.92	2.55	4.97
	3	4.62	11.87	12.40
	4	5.65	16.37	15.63
Female	5	4.22	12.95	12.20
	6	1.14	3.29	2.66
	7	1.22	3.78	2.24
	8	0.54	1.80	0.99
	9	0.09	0.60	0.13
	10	0.05	0.25	
	11	0.05	0.23	0.13
	12	0.01	0.05	
	Total	19.96	53.74	51.75
	0	0.43		0.10
	1	1.47	0.16	0.71
	2	4.22	4.82	11.62
	3	10.85	19.19	30.00
	4	11.31	24.90	34.50
Total	5	11.90	23.33	32.28
	6	8.37	12.00	18.25
	7	4.56	7.07	7.80
	8	1.81	2.57	1.82
	9	0.50	0.93	0.55
	10	0.05	0.25	
	11	0.05	0.23	0.13
	12	0.01	0.05	
	Total	55.53	95.50	137.76

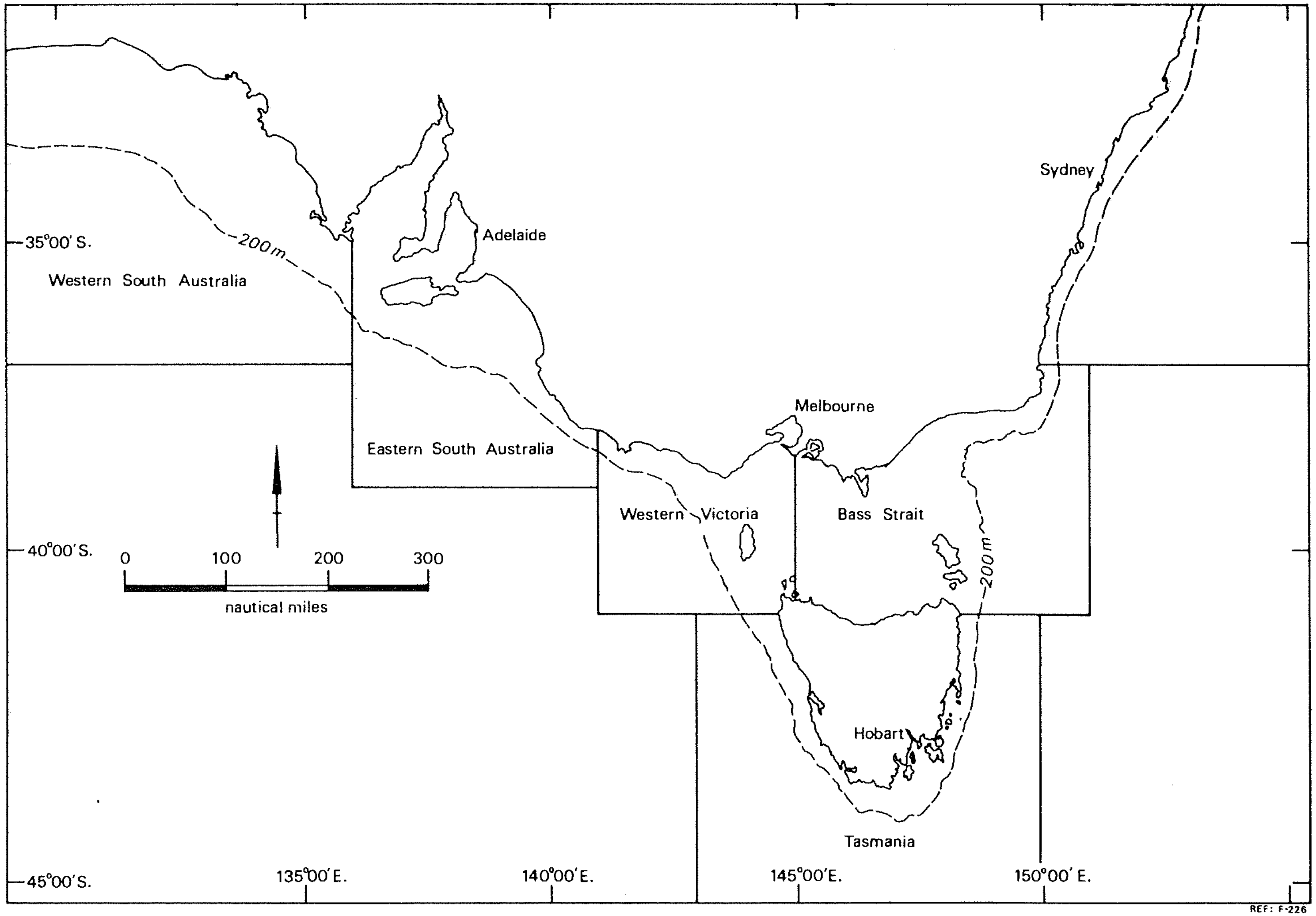

Fig. 10.1. Localities for summaries of catch and effort data.

Table 10.1. Catch, effort and catch per unit effort, standardised to one or more of to 6-inch, 7-inch or 8-inch gill nets, for each year during the period 1971-81 for Bass Strait and western Victoria and during 1973-76 for Tasmania, eastern South Australia and western South Australia for commercial catches of gummy shark.

Area	Year	Catch		Fishing effort[B] (10⁶ metre-lifts)		Catch per 10³ metre-lifts			
		Weight[A] (Tonne)	Number (Thousands)	6-inch	7-inch[C]	Weight[A] (kg) 6-inch	Weight[A] (kg) 7-inch[C]	Number 6-inch	Number 7-inch[C]
Bass Strait	1971	802	217		3.6		222		60
	1972	961	201		5.3		181		38
	1973	1301	260	10.7	12.5	122	104	24	21
	1974	1236	295	13.1	13.9	95	89	23	21
	1975	942	268	13.1		72		20	
	1976	899	280	9.4		96		30	
	1977	1029	322	12.5		82		26	
	1978	994	293	16.8		59		17	
	1979	740	216	14.8		50		15	
	1980	899	242	15.7		57		15	
	1981	822	244	13.8		59		18	
Western Victoria	1971	363	85		1.6		231		53
	1972	475	89		4.6		102		19
	1973	476	88	6.3	5.7	75	83	14	15
	1974	454	106	6.0	5.8	76	78	18	18
	1975	563	141	4.8		118		29	
	1976	431	128	3.9		111		33	
	1977	544	154	5.5		99		28	
	1978	524	139	8.4		62		17	
	1979	394	117	9.1		43		13	
	1980	413	109	9.0		46		12	
	1981	365	126	6.1		59		20	
Tasmania	1973	152	30		1.4		109		21
	1974	151	15	1.2		126		18	
	1975	100	17	0.8		125		19	
	1976	93	12	1.3		72		16	
Eastern South Australia	1973	260	30		0.6		433		50
	1974	142	23		1.0		142		15
	1975	155	15		2.1		74		8
	1976	99	21		0.5		198		24
Western South Australia	1973	91	15		0.2		455		75
	1974	86	13		0.6		143		22
	1975	47	10		0.3		157		33
	1976	28	4		0.3		93		13

[A] Beheaded and gutted carcass.

[B] Effort adjusted to a single mesh size and adjusted to targeting on gummy shark (i.e., gummy shark catch >70% of sum of gummy shark and school shark catch).

[C] Mesh size of 8 inches for eastern South Australia and western South Australia.

Foot note: Estimates presented for the period 1978-81 may be revised.

Table 10.2. Estimates of number of males, females, pregnant females, in utero embryos, sex ratio, and mean weight and mean length of each sex of gummy shark in the commercial catch and percentage of catch sampled for each year during the period 1971-81 for Bass Strait and western Victoria and for 1973-76 for Tasmania, eastern South Australia and western South Australia.

Area	Year	Number captured (Thousands)				Sex ratio[B]	Mean weight(kg)[A]		Mean length (mm)		Percentage Sampled
		Males	Females	Pregnant	Embryos		Male	Female	Male	Female	
	1971	139	78	7	58	0.56	3.8	3.5	1067	1036	4.3
	1972	125	76	12	117	0.61	4.8	4.8	1154	1145	5.9
	1973	143	117	23	246	0.82	4.6	5.4	1141	1192	5.0
	1974	177	119	17	201	0.67	5.8	4.7	1070	1129	3.4
Bass	1975	141	127	12	101	0.90	3.4	3.6	1039	1059	2.7
Strait	1976	143	137	10	76	0.96	3.2	3.2	1015	1025	3.7
	1977	161	161	11	82	1.00	3.2	3.2	1023	1029	1.6
	1978	146	147	12	107	1.01	3.3	3.5	1032	1047	0.5
	1979	99	117	10	76	1.18	3.3	3.5	1035	1052	1.0
	1980	113	131	13	120	1.16	3.5	3.8	1023	1071	1.1
	1981	133	162	7	51	1.21	2.8	2.8	988	984	1.9
	1971	54	31	3	39	0.57	4.6	3.7	1111	1031	5.6
	1972	54	35	6	71	0.65	5.3	5.3	1190	1177	4.7
	1973	45	43	8	100	0.95	5.2	5.7	1186	1203	9.7
	1974	46	60	9	134	1.30	3.5	4.9	1028	1114	1.9
Western	1975	77	64	7	65	0.83	4.0	4.0	1087	1083	1.6
Victoria	1976	68	60	5	41	0.88	3.3	3.4	1031	1041	1.7
	1977	91	63	5	43	0.69	3.5	3.5	1059	1051	1.8
	1978	69	70	7	63	1.01	3.6	3.9	1064	1083	0.6
	1979	53	64	5	42	1.21	3.3	3.5	1028	1047	1.6
	1980	47	62	6	60	1.32	3.5	4.0	1054	1087	1.0
	1981	58	68	3	21	1.17	2.9	2.9	998	1001	1.0
	1973	14	16	3	28	1.14	5.0	5.0	1160	1158	1.3
	1974	14	9	3	49	0.64	5.4	8.5	1166	2291	8.2
Tasmania	1975	7	8	2	26	1.14	7.3	6.3	1276	1225	9.3
	1976	7	14	2	15	2.00	4.8	4.2	1137	1106	0.2
Eastern	1973	8	22	7	118	2.75	8.7	8.7	1383	1369	1.5
South	1974	6	9	3	57	1.50	9.4	9.1	1370	1364	6.2
Australia	1975	5	12	4	77	2.40	8.1	9.1	1345	1376	10.3
	1976	4	9	3	41	2.25	7.7	8.0	1327	1334	5.4
Western	1973	5	10	2	28	2.00	5.5	6.3	1197	1245	9.1
South	1974	4	9	2	29	2.25	6.9	6.6	1283	1262	20.3
Australia	1975	8	2	3	3	0.25	4.6	5.5	1138	1189	0.7
	1976	1	3	1	13	3.00	5.3	7.6	1200	1330	2.7

[A] Beheaded and gutted carcass.
[B] Female/male.

Footnote: Estimates presented for the period 1978-81 may be revised.

Table 10.3. Number of males in each 1 year age-group of commercial catches of gummy shark for each year during the period 1971-81 for Bass Strait and western Victoria and during 1973-76 for Tasmania, eastern South Australia and western South Australia.

Area	Year	Number of sharks in each age-group												
		0	1	2	3	4	5	6	7	8	9	10	11	Total
	1971	28	409	6085	17023	20600	32238	34954	16669	8131	3419			139556
	1972		23	1021	7372	12068	30145	38572	20433	11071	4314			125019
	1973		38	2152	9218	14916	34826	43120	21908	12265	4980			143422
Bass	1974		235	5762	20533	28609	43491	45666	20297	8903	4204			177701
Strait	1975		88	5109	17208	26476	36204	34399	14546	5099	2096			141225
	1976		109	6666	19029	28843	36142	32761	13489	4057	1667			142762
	1977		64	5984	20998	33177	41506	37671	16092	3864	1325			160682
	1978		41	5622	17959	28760	38356	34863	14536	4594	1478			146010
	1979		19	3687	12092	19390	26015	23972	10268	3012	973			99426
	1980		20	3312	12579	20347	29839	28745	12197	4356	1704			113100
	1981		86	8064	19765	30465	33855	27825	10309	1885	878			133133
	1971		206	2087	6963	5318	10159	14295	7892	4560	2167			53646
	1972		14	219	2383	3852	12061	17682	9575	5830	2680			54295
	1973		1	122	1956	3379	9928	14532	8756	4740	1728			45141
Western	1974		153	2721	7288	8085	10289	10248	4931	2013	754			46482
Victoria	1975		50	1909	7749	11755	20189	20806	8872	4026	1769			77126
	1976		91	2905	9109	12856	17289	16013	6535	2208	943			67949
	1977		10	1880	9795	16072	25243	23837	9813	3392	1176			91220
	1978		3	1581	7098	11787	19007	18175	7676	2849	932			69108
	1979		13	2197	6741	10688	13463	12519	5336	1641	665			53264
	1980		1	1074	5302	8755	12234	12088	5507	1614	599			47173
	1981		15	2731	8186	13121	15136	12828	5102	884	296			58299
	1973			218	866	1474	3168	4379	2083	1315	758			14262
Tasmania	1974			262	1003	1676	2819	4058	2043	1158	710			13729
	1975		1	113	295	469	729	2224	1350	904	657			6743
	1976		4	60	595	930	1975	2071	634	435	304			7007
Eastern	1973				11	23	310	3119	1889	1531	1243			8126
South	1974				224	384	799	2209	1133	833	698			6282
Australia	1975			2	58	105	458	1843	1015	826	653			4962
	1976				43	79	377	1438	820	643	486			3886
Western	1973			38	251	426	1031	1726	1033	603	289			5398
South	1974			8	77	132	420	1277	775	548	370			3606
Australia	1975		2	98	564	905	1965	2467	1369	683	235			8288
	1976				12	24	168	216	138	78	12			647

Footnote: Estimates presented for the period 1978-81 may be revised.

Table 10.4. Number of females in each 1-year age-group of commercial catches of gummy shark for each year during the period 1971-81 for Bass Strait and western Victoria and during 1973-76 for Tasmania, eastern South Australia and western South Australia.

Area	Year	Number of sharks in each age-group												Total
		0	1	2	3	4	5	6	7	8	9	10	11	
	1971			2185	13837	21006	20293	8482	7046	3754	686	376	391	78057
	1972			367	7245	15930	19821	12494	11735	7509	1686	917	942	76645
	1973			327	7521	16634	27928	20379	21642	14566	3652	2255	1841	116748
Bass	1974			1178	14392	24807	29441	15666	16227	9983	3551	2169	1424	118839
Strait	1975			1380	20958	34009	34589	14305	13044	6568	1258	617	754	127483
	1976			2083	26465	40922	37057	12220	11884	5001	688	345	492	137157
	1977			1453	31062	48652	44538	14640	13778	5386	794	284	578	161164
	1978			993	27454	42596	38666	14221	13752	6257	1453	921	747	146999
	1979			774	19857	32554	33083	12837	11620	5166	597	313	506	117306
	1980			1132	20919	34419	35330	15062	14336	7320	1270	858	717	131363
	1981			3674	36088	53774	44016	10007	10639	2842	306	193	218	161756
	1971			1978	5988	7636	6584	2914	2767	1852	641	335	242	30935
	1972			192	2577	5361	8659	6167	5875	4157	1155	604	565	35311
	1973			51	2616	5966	10181	7622	7511	5334	1669	982	721	42653
Western	1974			1777	8701	13366	13013	6079	7837	5436	1757	1124	501	59612
Victoria	1975			576	9099	15553	17962	8365	6943	3812	1034	469	509	64322
	1976			869	11190	17174	15776	5952	5519	2492	416	272	240	59899
	1977			557	10544	17463	17976	6906	5813	2579	381	144	237	62599
	1978			280	10232	17403	19521	9186	8059	4290	752	340	489	70353
	1979			385	11677	18377	17084	6144	6335	2710	374	217	265	63568
	1980			252	8957	15330	17204	8308	6837	3689	766	475	413	62230
	1981			725	15013	22558	18603	4464	5058	1245	132	46	124	67969
	1973			50	1435	2776	4056	2725	2704	1782	372	231	221	16352
Tasmania	1974				253	758	1441	1635	1682	1549	874	654	199	9045
	1975			44	621	1240	1660	1027	1612	1134	367	198	133	8036
	1976			89	1761	3135	3927	2158	1897	1112	144	77	118	14418
Eastern	1973				105	979	2924	3665	5434	4532	2190	1386	676	21891
South	1974			34	263	848	1424	1452	1589	1642	1040	641	222	9155
Australia	1975			3	279	1034	1894	2019	2522	2379	1342	856	298	12625
	1976				162	637	1412	1529	1818	1545	758	498	215	8574
Western	1973			5	379	1003	2028	1750	2210	1560	387	254	185	9761
South	1974				383	902	1695	1550	2097	1503	557	351	229	9267
Australia	1975			10	123	249	386	251	323	210	66	42	31	1689
	1976				9	90	429	545	891	674	294	176	122	3229

Footnote: Estimates presented for the period 1978-81 may be revised.

Table 10.5. Number of males and females combined in each 1-year age-group of commercial catches of gummy shark for each year during the period 1971-81 for Bass Strait and western Victoria and during 1973-76 for Tasmania, eastern South Australia and western South Australia.

Area	Year	Number of sharks in each age-group												
		0	1	2	3	4	5	6	7	8	9	10	11	Total
Bass Strait	1971	28	409	8270	30860	41606	52531	43436	23714	11885	4106	376	391	217613
	1972		23	1388	14617	25998	49966	51066	32168	18580	6000	917	942	201664
	1973		38	2480	16739	31550	62754	63499	43550	26832	8632	2255	1841	260170
	1974		235	6940	34926	53416	72933	61333	36524	18886	7754	2169	1424	296540
	1975		88	6489	38167	60485	70793	48704	27590	11667	3354	617	754	268708
	1976		109	8748	45494	69766	73199	44981	25373	9058	2355	345	492	279919
	1977		64	7437	52060	81828	86043	52311	29870	9250	2120	284	578	321846
	1978		41	6555	45413	71356	77021	49084	28289	10651	2931	921	747	293009
	1979		19	4462	31949	51944	59098	36809	21888	8178	1569	313	506	216732
	1980		20	4444	33498	54766	65170	43807	26533	11675	2974	858	717	244463
	1981		86	11738	55854	84239	77871	37832	20948	4727	1184	193	218	294889
Western Victoria	1971		206	4065	12951	12954	16743	17209	10659	6412	2808	335	242	84582
	1972		14	411	4960	9212	20720	23849	15450	9987	3834	604	565	89606
	1973		1	173	4572	9345	20109	22155	16268	10073	3396	982	721	87794
	1974		153	4498	15989	21451	23302	16328	12768	7469	2511	1124	501	106094
	1975		50	2485	16848	27308	38151	29171	15815	7839	2803	469	509	141448
	1976		91	3773	20298	30030	33065	21965	12054	4701	1359	272	240	127848
	1977		10	2437	20339	33535	43219	30743	15626	5971	1558	144	237	153819
	1978		3	1861	17330	29191	38327	27360	15736	7140	1684	340	489	139461
	1979		13	2582	18418	29065	30547	18663	11671	4351	1039	217	265	116832
	1980		1	1326	14258	24085	29437	20396	12343	5303	1364	475	413	109403
	1981		15	3456	23200	35679	33739	17293	10159	2129	429	46	124	126268
Tasmania	1973			268	2301	4250	7224	7104	4787	3097	1131	231	221	30614
	1974			262	1255	2434	4260	5693	3725	2707	1584	654	199	22774
	1975		1	157	916	1709	2389	3251	2963	2038	1024	198	133	14779
	1976		4	149	2356	4065	5902	4229	2531	1546	447	77	118	21425
Eastern South Australia	1973				116	1002	3234	6784	7323	6063	3432	1386	676	30017
	1974			34	488	1232	2223	3661	2723	2475	1738	641	222	15437
	1975			5	337	1140	2353	3862	3537	3205	1995	856	298	17587
	1976													
Western South Australia	1973			43	631	1428	3060	3476	3244	2163	677	254	185	15159
	1974			8	460	1033	2115	2827	2872	2052	927	351	229	12873
	1975		2	108	687	1153	2351	2718	1692	892	300	42	31	9977
	1976				21	114	596	761	1029	752	306	176	122	3876

Footnote: Estimates presented for the period 1978-81 may be revised.

SOUTH EASTERN FISHERIES COMMITTEE

SHARK ASSESSMENT WORKSHOP

7-9 MARCH 1983
MELBOURNE

PROCEEDINGS

<u>SOUTH EASTERN FISHERIES COMMITTEE</u>
<u>SHARK ASSESSMENT WORKSHOP</u>
<u>MELBOURNE, MARCH 7-9, 1983</u>

<u>SUMMARY</u>

1. In 1977 on the basis of interim results from the Victorian shark research programme the S.E.F.C. Shark Research Group expressed concern about a declining trend in catch per unit effort for gummy shark and levels of mortality rates which could imply that the stock was in danger of collapse.

2. Yearly catch per unit effort since then seems to have stabilised. While revised estimates of total mortality rate from tagging studies are apparently higher, they have been biased upwards because of strong length selectivity by gill nets. Thus the concern expressed in 1977 has not been substantiated but, at the same time, no clear indication is available on the state of the gummy shark stock nor of the consequences of the current levels of fishing.

3. Shark are generally long-lived, slow growing animals producing a small number of offspring so should be characterised by a close parent stock/recruit production relationship and a slow recovery capacity in the event of overfishing. Furthermore, the long gestation period and subsequent time until pups are recruited causes a 4 to 5 year lag before effects of a reduced parent stock are reflected in recruitment. While catch rates appear stable at present (to 1981), it must be recognised that such lag effects are operative. A further declining trend in catch rates could possibly occur at present catch levels and would need to be viewed with concern. Catch per unit effort is approximately half the initial level and may well be lower; this low level for a "slow response" animal like shark is worrying.

4. Interpretation of some key results of gummy shark studies is still unclear because of the important influence of gear selectivity whose parameters the workshop was unable to establish in the time available.

   Reduced vulnerability of larger fish to the main commercial mesh size used may be a major factor in maintaining recruitment.

5. There was a large amount of data available from the Victorian shark research programme and major analyses had been made in preparation for the workshop. Substantial further progress was achieved towards the development of a stock assessment but difficulties were encountered in making effective adjustments for gear selectivity. Activities to address this and other problems have been identified, which should facilitate conclusion of a stock assessment. It is anticipated that this could be accomplished within 12 months. Essential preparatory work must be undertaken before May as key personnel will be unavailable later in the year.

6. Tagging studies suggest that there is no reason to assume more than one stock of gummy shark exists in south-eastern Australia. To assist future assessments of the stock in the long term it will be important to improve the catch, effort and catch composition (sex and length) data collections from the fishery, especially in South Australia and Tasmania. Data of this kind are only available for 1973 - 1976 in

these States and since 1970 in Victoria. This placed an important limitation on the analysis of the state of the stock and will continue to hinder future assessments.

SOUTH EASTERN FISHERIES COMMITTEE
SHARK ASSESSMENT WORKSHOP
MELBOURNE, MARCH 7-9, 1983

REPORT

CHAIRMAN'S INTRODUCTION

The workshop was chaired by Dr K. Radway Allen. Participants, agenda, and background documentation are listed in annexes I, II and III respectively. The Chairman emphasised that the prime objective of the workshop was to develop a stock assessment for gummy shark and to review the condition of school shark, adding comments as appropriate on the effects of fishing on the stocks. Management implications would be a matter for subsequent consideration by the Shark Research Group of SEFC or that Committee itself. For that purpose it would be necessary for the workshop to develop a formal report on the results of its discussions. Background information tabled at the workshop would be appended rather than incorporated in the report itself.

DESCRIPTION OF SHARK FISHERY AND OVERVIEW OF PROBLEMS

An introductory summary of the history of the shark fishery, its status, the mercury problem, research and management was available by way of the 40 minute film "Sharking" produced by the Fisheries and Wildlife Division, Victoria, in conjunction with the Media Centre of the Royal Melbourne Institute of Technology.

The draft Situation Report (Walker and Caton, 1980), developed by the SEFC Shark Research Group, also contains summary information on these matters. Key aspects have been the development of a longline fishery initially (1920s) targetting on school sharks, the expansion during the second world war to provide vitamin A from shark liver oil, an expansion after 1964 with the progressive use of gillnets which increased the exploitation of gummy shark, the discovery in 1972 of high mercury content in large school shark diverting heavy effort to the gummy shark grounds, a decline in gummy shark catches until 1977 and finally the apparent stabilisation of catches at around the 1977 level. A decision in 1977 to introduce catch restraints because of concern about gummy shark condition lapsed, but recently South Australia has sought action because of concern about school shark catch rates.

The workshop should provide a means of addressing these issues, superceding the assessment supported by the Shark Research Group in 1977 (Walker, 1977).

REVIEW OF DATA AVAILABLE ON GUMMY SHARK

Data pertinent to the gummy shark items of the agenda were available in a summary prepared for the workshop (Walker, 1983). A graph of gummy shark carcase production for Victoria, Tasmania and South Australia from 1955-1975 was available (Walker, 1977; p. 1.7) as were details of mortality estimates from a previous tagging experiment on gummy shark by CSIRO (Walker, 1977; p 1.3), details of hanging coefficient tests for shark gill nets (Walker, 1982 (a); pp 2-3), and details of the 14 most commonly occurring prey items for gummy shark (Walker, 1982 (b); p 4).

Sampling of commercial catches for length frequency and sex composition was carried out for the Victorian fishery from 1970 and for the South Australian and Tasmanian fisheries from 1973-76. In the latter period a log book gathering daily catch and effort information was in use for the Victorian, South Australian and Tasmanian fisheries as part of the project funded by F.I.R.T.A. After 1976 the log collections and commercial catch sampling lapsed in South Australia and Tasmania. Total catch data for the period of the study have been developed with the aid of processors records.

GENERAL BIOLOGY AND STUDIES OF MORPHOMETRICS ON GUMMY SHARK

Various morphometric relationships are available (Walker, 1983, figs. 1.1-1.15). The main features noted were the increased fillet weight relative to body weight as length increased, and the fact that weights of landings were reported differently in Victoria (carcase weight) and other States (trim weight).

Gummy shark were found to prey on a wide variety of epibenthic animals, predominently crustaceans and cephalopods. There was not the marked change in diet with length evident for school shark (from molluscs, polychaetes and other invertebrates of soft bottom areas of estuaries to fast swimming pelagics such as jack mackerel, squid and snoek), suggesting that specialised "nursery" areas need not be required.

GEAR STUDIES

(a) Hanging Coefficient

Modifications in the hanging coefficient of gill nets change their efficiency (Walker, 1982 (a), pp 2-3). There has been a trend in Victoria from a coefficient of 0.6 to 0.53, representing an increase in efficiency of as much as 50%. In contrast, fishermen in South Australia have hung gear with a coefficient of 0.5 since gill nets were introduced. The introduction of light buoys has lead to a further increase in efficiency as gear can be hauled at night.

One feature associated with reductions in catch rates was the increase in number of sets made; reduced time clearing nets shortened hauling time to the extent that additional sets could be made during a 24 hour period. An examination of catch per fishing hour might be an appropriate way to study the implications of this development as there may be some relationship between soak time and rate of catch.

(b) Mesh Selectivity by Length

Selectivity of gill nets (Walker, 1983, tables 8.1-8.3) complicated the determination of size composition of the population and created problems in the determination of parameters such as mortality rates from tag returns. Attempts to overcome this by comparing catch rates of panels of different mesh size, set concurrently, were complicated by uncertainties in modelling the size distribution of catches. Re-analysis of selectivity by length data is necessary. The previous approach assumed selection followed a normal distribution and this was found to be inappropriate due to the tangling effects for large shark in nets particularly with the smaller mesh sizes. Examination of the right and left hand sides of the selectivity distribution separately may be possible.

TAGGING STUDIES

(a) Movement

Distribution of the main gummy shark fishing grounds is shown in annex IV. They are located on the continental shelf in areas shallower than 80 metres, whereas school shark are predominantly distributed in deeper waters of the shelf and slope (to 300m). The main concentration appears to be located in waters adjacent to eastern Vicotria, eastern Bass Strait and around the Furneaux Group, King Island and the Hunter Group. Moderate catches are taken off the west coast of South Australia, the area between Kangaroo Island and the south east of South Australia, and off the east coast of Tasmania. Minor catches are taken off western Victoria and from the south and west coasts of Tasmania. There are negligible trawl or Danish seine catches off eastern Victoria and southern New South Wales.

Tag release and recapture data indicated mixing of shark across the Bass Strait area and into New South Wales, Southern Tasmania and the central and western areas of South Australia. On this basis it appeared that there was no reason to assume more than one stock exists. While it seemed that the most westerly migrations were undertaken by large females, it was not possible to reach firm conclusions about movement trends as returns were not standardised according to the distribution of sampling effort and fishing effort; it is desirable that this analysis should be done.

(b) Mortality

Estimates of mortality from tag release and recapture were available (Walker 1983, table 4.1). Total mortality rates (Z) of 0.56 for males and 0.54 for females were obtained, but doubt was expressed about the values of fishing mortality rates (F) and natural mortality rates (M) derived. M values (.33 to .70) were higher than the Z value (0.22) obtained in the previous CSIRO experiment (Walker 1977, p 1.3) whereas, if an M value in the order of that Z was appropriate, the estimates of F would be extremely high. Furthermore, determination of the true Z in experiments of this kind is difficult if there is substantial selectivity by size. Preliminary estimates of selectivity by the fishing mesh used predominantly by the industry (6") suggest that these apparent Z values are over-estimates because larger animals are less likely to be caught. It was noted that effort (Walker 1983, Section 9) showed a 25% increase from the 1973-76 period to the 1977-80 period, which would require an adjustment upward of the apparent Z values obtained by approximately 0.08.

Comparison of recoveries of tags released at specific localities indicated that, while approximately the same proportions were obtained, they were caught more quickly from some release areas and generated substantially higher apparent Z values (see Walker, 1983 table 4.2).

(c) Growth

Walker (1983) figs. 3.1 and 3.2 provided age/length curves from tagging experiments and gave von Bertalanffy growth parameter values for males and females respectively. Estimates of L were 1314 mm for males compared with an observed maximum length of 1460 mm, and 1730 mm for females compared with an observed maximum of 1760 mm. Adjustment for mesh selectivity effects was not possible; the growth estimates for females especially would have been depressed as a result of the greater probability of fishermen recapturing slow-growing than fast-growing sharks.

For males, the growth curve derived from tagging data agreed well with that derived from inspection of annuli on vertebral centra but the curves for females did not agree as well (Walker, 1983, figs. 3.1, 3.2, 5.1, 5.2). Reliable historic information would be useful to examine the possibility that density dependent mechanisms associated with growth rates are involved in the response of the stock to exploitation, but data from the previous CSIRO tagging study were insufficient for this purpose. An examination of the size distribution of tagged fish or of field samples taken in 1953/54 might provide an indication, at least, of the maximum size of shark recorded at that time.

Difficulties usually encountered in the interpretation of annuli in older animals suggest that the age-length relationships derived from tagging studies are more reliable for the determination of L than those derived from direct ageing studies. Adopting these values for L implies adoption of the respective K values associated with them. For the purpose of yield analysis it would be reasonable to adopt a range of feasible L values.

MESH SELECTIVITY BY AGE

Determination of selectivity by age requires further examination.

In the age-length key, the distribution of lengths is not necessarily that in the population because of severe selectivity effects in the collection of age data. Attempts to convert mesh selectivity relative to length to a mesh selectivity relative to age were unsatisfactory because both the age-length key and the mesh selectivity relative to length were based on samples subject to selectivity influences. A cohort analysis might provide a more informative approach to examination of age specific selectivity by assisting in the interpretation of the selectivity trials and their influence on the estimation of other parameters.

REPRODUCTION STUDIES

Studies of size at maturity for males (Walker, 1983, Section 6) gave a consistent value of about 950 mm for the mean length of sexual maturity from both histological and macroscopic investigations of testes and macroscopic examination of seminal vesicles. A field examination of seminal vesicles to check for the mating season indicated that November-December was the most likely period, if absence of sperm is indicative. Seasonal changes in testes weight might provide a further indicator. Claspers apparently do not become engorged in the way that those of other shark species do during the mating period.

The reproductive cycle of female gummy shark was interpreted from changes in ova and embryo size with time (Walker, 1983, section 7). The relationship between embryo size and month indicated a gestation period of 12-15 months. The diameter of the largest ova in the ovary of pregnant fish together with the proportion of mature females which were pregnant at a particular time was consistent with the assumption that individual females give birth every second year. Mean length at maturity for females was about 1250 mm and number of young produced from each pregnancy rose yearly with weight of female.

CATCH, EFFORT AND SEX-LENGTH FREQUENCY COMPOSITION DATA

Tabulations of catch and effort data (Walker, 1983, Section 9) were derived from special daily logs (See Annex V) from co-operating fishermen, monthly catch returns from other fishermen, and processors returns of daily purchases from individual fishermen. These data were available for Zones F (Bass Strait; See Annex IV) and D (waters adjacent to Western Victoria) for years 1971-80 and for 1973-76 for Zones B, C and E. Effort was adjusted to a single mesh size and to that targetting on gummy shark.

Examination of adjusted catch rates in all zones indicates a decline between 1973 and 1978 to an apparently stable level.

These data were used to estimate catches and catch rates in various length-classes. Catches of pregnant females and their embryos were calculated. Although not presented at the workshop data for 1970, 1981 and 1982 are available for Zones F and D. There has been a progressive increase in the ratio of females to males in the catch in Zones F and D. Mean individual weights and lengths of each sex in the catch have changed noticably over the 10 years. Thus the total catch figures reflect either exploitation of different components of the population or a change in its structure.

COHORT ANALYSIS

Difficulties in making adjustments for effects of mesh selectivity influence most aspects of the development of a gummy shark stock assessment. Reasonable estimates are available of total catch by age for each year and zones for which adequate catch sampling was undertaken. Most of the catch comes from the area for which good catch, effort and catch composition (sex and size) information is available. It would be a reasonable first approach to carry out a cohort analysis on females for this area in isolation. It may be possible to confine estimates to the mature population or to the population above age at first capture. Attempts were made to carry out cohort analyses with parameter values arising from the data described above but it was not possible to complete them during the workshop.

Further examination of the independent sets of mesh selectivity information for 6 inch and 7 inch nets is necessary. Cohort analysis should give results equivalent to a selectivity analysis but there will be some complications in comparisons because the former relates to selectivity by age whereas the latter relates to selectivity by length and they do not convert easily.

Despite the limited period of age composition and the relatively large age span of cohorts present (13 years for 12 ages) a cohort analysis using the standard "Pope" technique should be undertaken, as it would provide an independent estimate of selectivity. Software available at CSIRO would probably be suitable so consultation for development of an analysis would be appropriate. There is limited catch and catch composition information for years prior to 1970 but it appears that catches were substantial in that period. The data on total catches by number in Walker, 1977, which assume a mean shark weight of 3.5 kg should be used initially. Absence of effort data prior to 1973 suggests the use of a de Lury approach using total catch data; analysis of the 1973-80 data may indicate appropriate de Lury parameters for the broader study. Further consultation about appropriate procedures will be required. An age-structured population model developed for cetaceans (Allen, unpub.) may be applicable to sharks. Further consultation would be appropriate.

STOCK RECRUIT RELATIONSHIP

It has not been possible to determine useful measures of stock or recruitment. Generally it is accepted that if the stock is able to support a fishery then some compensatory mechanisms must operate to enhance recruitment to juvenile stocks when the population is reduced. This would probably operate through mortality rates, age at maturity or fecundity. Canadian studies on spiny dogfish (Wood, et. al., 1979) suggested that changes in juvenile mortality rate could maintain a yield from the stock. It also appears that compensatory growth changes could influence fecundity and support a yield (Allen, 1983). Variations in size at maturity have been observed for stocks of other shark species but it is not clear if these are geographic variations in distribution or associated with exploitation.

For gummy shark it should be noted that there is a 4 - 5 year lag between mating and recruitment. Comprehensive data on the fishery is limited to the period 1970-1982 so that the time series would be likely to be inadequate to identify relationships between stock size and recruitment even if estimates of population size were available. It would be difficult to relate any observed trends in female recruitment to influences prior to 1970.

The best estimates of parameters for growth and size dependent fecundity in recent years were used to examine the effects of juvenile mortality on long-term juvenile production. Assuming an adult natural mortality rate of 0.2, the results indicated that a juvenile mortality rate of 0.82 would lead to exact replacement of an unexploited stock.

SOUTH EASTERN FISHERIES COMMITTEE
SHARK ASSESSMENT WORKSHOP
MELBOURNE, MARCH 7-9, 1983

SUMMARY OF FURTHER DATA ANALYSIS SUGGESTED

- Mesh selectivity data should be re-analysed
- Mortality estimates from tagging should be re-analysed to correct for effort changes and effects of selectivity.
- Selectivity effects on growth parameters should be examined; this may usefully be approached by simulation.
- Hook selectivity data should be examined.
- Further consideration should be given to the derivation of age selectivity curves from available data.
- Changes in sex ratio should be examined; an attempt at modelling changes would be desirable.
- A cohort analysis by the Pope technique should be carried out.
- Further examination of yield per recruit, for example by VISICALC procedures, is desirable.
- Consideration should be given to analysis of catch and effect data by the de Lury method.
- Analyse movement data by correcting for the effects of varying fishing effort.

SOUTH EASTERN FISHERIES COMMITTEE ANNEX. I

SHARK ASSESSMENT WORKSHOP

MELBOURNE, MARCH 7-9, 1983

AGENDA/TIMETABLE

Day 1

0900-0930	Introduction and Chairman's remarks
0930-1030	Description of shark fishery and overview of problems
1030-1130	Review of data available on gummy shark
1130-1230	General biology and studies of morphometrics on gummy shark
1230-1330	Lunch
1330-1500	Gear studies - Hanging coefficient - Mesh selectivity by length
1500-1700	Tagging studies - Movement - Mortality - Growth

Day 2

0900-1000	Ageing studies - Age-length key - Mesh selectivity by age
1000-1130	Reproduction studies
1130-1300	Catch and effort data
1300-1400	Lunch
1400-1530	Commercial catch sampling - Sex-length composition - Sex-age composition
1530-1700	Cohort analysis

Day 3

0900-1000	Stock/recruitment relationship
1000-1100	Yield analysis
1130-1230	Stock Assessment Analysis
1230-1330	Lunch
1330-1600	Discussion of school shark - Review of published and reported data - Victorian tag data
1600-1700	Review of Report of Workshop

SOUTH EASTERN FISHERIES COMMITTEE

ANNEX. II

SHARK ASSESSMENT WORKSHOP

MELBOURNE MARCH 7-9, 1983

ATTENDANCE AND VENUE

Attendance

Dr K. Radway Allen (Chairman)
Dr G. Kirkwood, CSIRO
Dr J. Stevens, CSIRO
Mr T.I. Walker, Victoria
Dr P. Sluczanowski, South Australia
Mr A.E. Caton (Rapporteur), Dept. Primary Industry

Venue

7th Floor Conference Room
Fisheries and Wildlife Division
Ministry for Conservation
240 Victoria Parade
East Melbourne Vic.

SOUTH EASTERN FISHERIES COMMITTEE

SHARK ASSESSMENT WORKSHOP

MELBOURNE, MARCH 7-9, 1983

ANANEX. III

LIST OF BACKGROUND DOCUMENTS

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