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SOUTHERN SHARK ASSESSMENT PROJECT

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ABSTRACT

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This report outlines the aim, objectives and tasks of the Southern Shark Assessment Project (FIRTA Project 85/104) and reviews progress since it began on 1 July 1985.

The project is designed to provide an improved database for management of the southern shark fishery and to determine how yields from the gummy shark and school shark stocks vary with fishing effort and mesh size of gill nets. A summary of progress and selected results produced since the Second Review of the Project held during October 1986 are given under three broad tasks:

(1) implementation of compatible monitoring systems in Victoria, Tasmania, South Australia and Western Australia;

(2) analysis and reporting of available data on school shark, southern saw shark, common saw shark and elephant fish, and refinement of various population parameter estimates for gummy shark;

(3) field sampling of gummy shark and school shark to provide up-to-date age-length keys and estimates of growth, mortality and fecundity.

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A7

SOUTHERN SHARK ASSESSMENT PROJECT

ISSUE STATEMENT

The southern shark fishery is based on several species of temperate-water sharks — a common-property resource consisting mainly of gummy shark, *Mustelus antarcticus*, and school shark, *Galeorhinus galeus*. The fishery currently produces annually about 5000 tonne, live weight, of shark valued at more than $15 million to fishermen in Victoria, Tasmania and South Australia. Most of the catch is marketed in Victoria.

Sharks are generally long-lived, slow-growing animals that produce only a small number of offspring. Therefore the stocks are characterised by a close relationship between parent stock and recruitment and a low capacity to recover in the event of overfishing. Furthermore, sharks bear their young live after a long gestation and the period from birth until they are recruited to the fishery is even longer; consequently several years elapse before the effects of a reduced parent stock are reflected in recruitment. The consequences of management actions may, therefore, be detectable only several years later.

These characteristics along with falls in catch per unit effort for gummy shark and school shark to about 40% of the levels of the early 1970s and the demise of most of the few shark fisheries occurring in other parts of the world, have lead fisheries scientists attending four separate stock assessment workshops during 1983–87, to recommend reduction in fishing effort to the 1982 level.

Catches have been recorded since the origins of the fishery but not until the 1960s were data on fishing effort collected systematically. Since 1970 details of species, sex and length-frequency composition of commercial catches have been monitored in Victoria but not in the other southern states and only recently have daily details of quantities of sharks handled by fish processors been collected routinely.

Tagging and biological studies on school shark were undertaken by the CSIRO during the 1940s and early 1950s. Later, during the mid-1970s, the then Fisheries and Wildlife Division of Victoria (now, the Fisheries Division) undertook similar studies on gummy shark and, to a lesser extent, on school shark.

Stock assessments have been inconclusive and on the basis of reports from the stock assessment workshops, the Southern Shark Task Force recommended that further research and monitoring be undertaken.

FIRTA funds have subsequently been made available to continue investigation of the southern shark for the purpose of providing resource assessments to guide and assist management of the fishery. A regional research unit known as the Southern Shark Assessment Group (SSAG) has been established at the Marine Science Laboratories in Queenscliff, Victoria.

PROGRAM AIM

To improve the database for management of the southern shark fishery and to determine how yields from the gummy shark and school shark stocks vary with fishing effort and mesh size of gill nets.

PROGRAM OBJECTIVES

(1) To establish compatible catch and effort and commercial catch sampling monitoring schemes in Victoria, South Australia, Tasmania and Western Australia and develop a single centrally based data processing system in a research unit in Victoria.

(2) To complete analysis and reporting of available data on school shark, southern saw shark, common saw shark and elephant fish collected opportunistically during the course of the 1973–76 research program for gummy shark (funded by FIRTA).

(3) To provide current age-length keys for gummy shark and school shark.

(4) To express mesh selectivity of monofilament gill nets as a function of age of sharks and mesh size for gummy shark and school shark.

(5) To refine estimates of mortality, growth and movement for gummy shark and school shark.

(6) To determine whether estimates of various parameters of female fecundity and growth of gummy shark and school shark have changed as a result of changes in stock density and age composition since they were last measured during 1973–76 as might be expected as a result of changes in population size and structure.

STATUS OF PROGRAM

The Southern Shark Assessment Project began as scheduled with staff appointments taking effect from 1 July 1985. The Southern Shark Assessment Group (SSAG) consists of Nik Dow, Peter Moulton, Stephen Saddlier, and Terry Walker. A fifth member, Ian Knuckey, was appointed to the SSAG during the period from February 1986 to August 1987.

Besides the to the above objectives, in response to a request from the Southern Shark Task Force, during the fiscal year 1985/86 the SSAG coordinated an electrophoretic study to determine whether more than one species or breeding population of gummy shark occur. Tissue samples were collected from gummy sharks from Western Australia by the Western Australian Marine Research Laboratories and from each of eastern Bass Strait and waters off western South Australia by the SSAG. Laboratory analysis of the tissue samples and interpretation and documentation of the results were undertaken by Murray MacDonald.

Progress of the program is discussed below under each of three broad tasks.

Task 1. Implementation of compatible monitoring systems

In the FIRTA application it was proposed that the SSAG would serve to improve the existing logbook systems and assist in introducing new ones, to collect details of quantities of shark handled by fish processors, and to extend the currently adequate commercial catch sampling program operating within Victoria into the other southern States.

The fisheries management agencies of Victoria, South Australia, Tasmania, Western Australia and the Commonwealth are supporting the endeavours of the SSAG to establish these comprehensive monitoring schemes for the southern shark fishery.

(1.1) Logbook systems

Catch and effort data need to be collected on a shot by shot basis to adequately partition the effort between the various species targeted by shark fishermen and, because the fishermen tend to operate over a wide area, to accurately assign catch and effort geographically.

(1.1.1) Data collection

In the FIRTA application it was proposed that each State would meet the costs of the logbooks and routine processing, whereas field expenses and costs of specialised data analyses incurred by the SSAG would be met from FIRTA funds.

The four States involved and the Australian Fisheries Service have agreed that the logbooks form part of their routine catch and effort system and that the SSAG have access to the data after the logbook information has been entered and validated in State databases.

Victoria has an adequate system for collecting data on a shot by shot basis.

South Australia has an adequate logbook and following requests from the South Australian Department of Fisheries most shark fishermen in that state have changed from the option of submitting monthly summaries to the option of submitting daily information.

Tasmania has facility for collecting only monthly summaries but agreement has been reached between the SSAG, the Tasmanian Department of Sea Fisheries and the Australian Fisheries Service on a logbook design. New logbooks with facility for collecting data on a shot by shot basis will be distributed to Tasmanian based shark fishermen shortly.

Western Australia has introduced a special logbook for collecting data on a shot by shot basis to provide the SSAG with the required data. Western Australia is using its own facilities to distribute and follow up the logbooks.

A number of fishermen have been interviewed by members of the SSAG for the purpose of improving the quality of their returns or following up outstanding returns.

(1.1.2) Data analysis

Shark catch and effort data submitted on returns by fishermen to the fisheries agencies of Victoria, Tasmania and South Australia are routinely entered into data bases maintained by each of the three States. Copies of these data for the period 1979–84 have been transported via computer magnetic tape to a DEC PDP 11/73 computer based with the SSAG at Queenscliff. Copies of data of scale fish taken by gill net or long line, rock lobster and scallops for all vessels engaged in shark fishing during 1979–84 have been also transported. In addition, Commonwealth licensing details of vessels engaged in the shark fishery have been provided to the SSAG by the Australian Fisheries Service.

Using CPM Dbase2 installed on a DEC PDP 11/73 computer available to the SSAG a separate database integrating all of these data has been established. The data have been corrected for double reporting to Victoria and Tasmania by fishermen operating in Bass Strait and weights have been standardised to 'untrimmed carcass weight' (i.e., beheaded and gutted shark with tail and all fins attached).

Computer files of catch and effort data from the four States for the period 1970–78 are available to the SSAG from the earlier shark research program undertaken by the former Fisheries and Wildlife Division.

Summaries have been prepared of catch and effort data provided in special shark logbooks and general fish returns for the period 1970–84 and processor returns for the period 1970–78. For the period 1970–78 the estimates are based on returns submitted by fishermen and information on quantities of shark handled collected from fish processors and auctioneers. For the period 1979–84 the estimates are based on fishermen's returns alone.

Because of the limitations of the CPM database system and the declared policy of the Department of Conservation, Forests and Lands (CFL) to retire its DEC PDP 11/73 computer, the SSAG has redeveloped an enhanced system for management and reporting of shark catch and effort data on the Department's Prime mainframe computer.

(1.2) Commercial catch sampling

(1.2.1) Data collection

The SSAG is using FIRTA funds to equip and pay wages of part-time casual Fish Measurers sampling commercial catches of sharks in South Australia and Tasmania and at the Melbourne Fish Market in Victoria.

During 1985/86 Western Australia used its own funds and staff resources to undertake commercial catch sampling on the South Coast of Western Australia and has made data collected on gummy shark available to the SSAG. Because of financial restraints sampling has been discontinued during 1986/87 and 1987/88.

(1.2.2) Data analysis

A system for management and analysis of shark commercial catch sampling data was developed before commencement of the current project and is based on the PDP 11/73 computer. Several minor changes have been made to the system.

Available data for gummy shark from Victoria for the period 1971–83 and from Tasmania and South Australia for the period 1973–76 have been processed using this system and summarised in Walker 1984b.

Available data for 1984 and 1985 have undergone data validation and preliminary analysis using this system.

The data management and analysis systems for commercial catch sampling will be redeveloped on the CFL Prime computer as an integral part of the new catch and effort system described above.

(1.3) Processor return systems

(1.3.1) Data collection

Tasmania, South Australia and Western Australia routinely collect returns from processors of shark but the resolution of the data for any processor provides only total quantity of each species of shark handled each month.

Victoria has legislation for a return where details of suppliers and quantities of shark purchased on a day by day basis can be collected. Victorian processors have been required to provide this information since 1 October 1985.

Details of daily purchases for the period 1970–78 have been collected in the past as part of the earlier FIRTA funded shark project. Apart from information provided on the mandatory returns in Victoria, the

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SSAG is attempting to collect the same type of information for the period January 1979 to the present in South Australia, Tasmania and Victoria by transcribing records maintained by the processors.

(1.3.2) Data analysis

A system for management and analysis of these data will be developed on the CFL Prime computer as an integral part of the new catch and effort system described above.

(1.4) Integrated data processing

A database system is being developed for integrating reported catch and effort data, processor data and commercial catch sampling data.

The purpose of the database is for providing improved estimates of total catch and total effort, and for determining target effort and length-frequency composition of the catch for any region based on a composite of 1 degree by 1 degree fishing blocks and fishing depth.

Task 2. Analyse and report available data

Although the earlier FIRTA funded study conducted during 1973–76 was designed specifically to investigate the biology and stocks of the gummy shark, considerable data for school shark and somewhat less for southern saw shark, common saw shark and elephant fish were collected opportunistically.

Analyses of data for gummy shark undertaken prior to commencement of the current project are referred to as 'Phase 1 Analysis' and the results of these analyses are given in Walker (1984a).

Most of the data available for school shark have received Phase 1 Analysis but little progress has been made to analyse the data available for the other three species.

The data are being analysed on an Olivetti M24 using the statistical package SAS.

(2.1) School shark (Phase 1 Analysis)

Similar analyses to those described for gummy shark Phase 1 Analysis have been undertaken for school shark (Walker 1986d; Walker and Knuckey 1987).

(2.1.1) Morphometrics

Relationships between total length, various partial lengths, total weight and various partial weights have been completed.

(2.1.2) Tagging

Standard techniques have been applied for estimating von Bertalanffy growth parameters but refined estimates of the growth, movement and mortality parameters are being undertaken as part of the Phase 2 Analyses using a computer model described under Task 2.2.1.

(2.1.3) Ageing.

Age-length keys and estimates of von Bertalanffy growth parameters have been determined for males and females separately from data of sharks aged by microscopic inspection of concentric rings in the centra of their vertebrae.

(2.1.4) Male reproduction

The proportion of male sharks sexually mature within 100 mm length-classes have been estimated from data collected by three separate methods: microscopic inspection of histological transverse sections of testis tissue, macroscopic inspection of testes and macroscopic inspection of seminal vesicles.

(2.1.5) Female reproduction

To quantify female fecundity the following have been determined: the proportion of sexually mature female sharks and the proportion pregnant females within each 100 mm length-class, the number of embryos carried

A3

by pregnant females expressed as a function of length of mother; the period of gestation, sex ratio of embryos, the frequency of pregnancy of mature females, and growth of embryos during gestation.

(2.1.6) **Stomach contents**

Prey of school shark have been quantified from stomach contents by determining the proportion of sharks containing each species of prey item and the frequency and weight of each prey item detected.

(2.1.7) **Gear studies**

Available data from experimental fishing with gill nets and long-lines constructed to test for the effects of mesh size and hanging coefficient of gill nets and effects of hook size on composition of the catch have been analysed.

(2.1.8) **Catch composition/effort summary**

Summaries have been prepared of catch and effort data for the the period 1970–84. However, length-frequency and sex composition data for school shark from commercial catch sampling are available only for the period 1970–72 in Victoria and for 1973–76 in Tasmania and South Australia. It was not possible to obtain representative samples of school shark in Victoria during 1973–84 because large sharks of this species landed illegally during this period were not sold through the Melbourne Fish Market. The available data are still being summarised.

(2.2) **Gummy shark (Phase 2 Analysis of 1973–76 data)**

(2.2.1) **Mortality estimates from tag data**

A new computer model has been developed for estimating natural mortality and catchability of gill nets and hooks while correcting for effects of mesh selectivity and variable fishing effort. Catchability is estimated for each of several regions. In addition, it includes 'reporting fraction' and takes account of movement of the sharks. The model simultaneously provides estimates of growth parameters (see Task 2.2.2; Dow and Kirkwood, in prep.) and movement parameters used to quantify movement between regions (see Task 2.2.3; Dow, in prep.).

The theoretical work associated with this task is complete and preliminary estimates of natural mortality and catchability have been made but final analysis depends on finalising catch and effort estimates to the end of 1987.

In addition, estimates of natural mortality have been made using an unpublished method developed by Mr W. Hearn of the CSIRO (Hearn, in prep.).

(2.2.2) **Revise growth estimates from tag data**

A new computer model which is incorporated into the model described under Task 2.2.1 has been developed to provide revised estimates of growth parameters from tag data correcting for biasing effects of mesh selectivity. Because of the selective characteristics of gill nets, the probability of capture of small sharks is higher for fast growing animals than slow growing animals whereas for large sharks the converse is true.

Instead of making the usual assumption of a normal distribution of length of sharks at any age, a gamma distribution is used to describe the distribution of lengths about the mean curve of length versus age described by the von Bertalanffy parameters (k and Ll). For the gamma distribution the variance in length (i) is proportional to mean length at any age. This assumption enables formulation of a simple model to correct the curve for effects of mesh selectivity which is also described by a gamma function. The maximum likelihood method is used for estimating the values of k, Ll and i instead of the usual non-linear regression least squares method.

Preliminary estimates have been made for males and females separately.

(2.2.3) **Revise movement estimates from tag data**

The computer model described under Task 2.2.1 provides estimates of the proportion of sharks moving between defined regions during various seasons. The parameter estimates along with confidence intervals,

A2

determined by maximum likelihood, are corrected for effects of mesh selectivity and fishing effort. Although preliminary estimates have been made, as for Task 2.2.1 final analysis cannot be completed until catch and effort estimates to the end of 1987 are finalised.

(2.2.4) Surplus yield modelling

Available stock assessment methods which use catch and effort data such as those developed by Schaefer, DeLury and Deriso have been evaluated and found to be unsuitable for the southern shark fishery.

(2.2.5) Preliminary cohort analyses

Preliminary cohort analyses for the purpose of providing estimates of natural mortality and catchability has been completed. This analysis makes use of summaries of available catch and effort, processor and commercial catch sampling length-frequency data, the 1973–76 age-length key and information on sex ratio at birth provided by Phase 1 Analysis.

(2.2.6) Dynamic pool model yield analysis

A new dynamic pool model which provides yield analyses using parameter estimates for growth, natural mortality, catchability, mesh selectivity, fecundity, sex ratio at birth and length-weight relationships is being specially developed for the southern shark fishery. The first stage of the model has been developed under the microcomputer package MULTIPLAN.

Standard Beverton and Holt yield per recruit analyses have been undertaken by using available parameter estimates for growth and mortality and by assuming constant recruitment and knife-edge selection. It has been concluded that this method is invalid for the southern shark fishery because of the underlying assumptions of model.

(2.3) School shark (Phase 2)

Depending on the adequacy of the results of Phase 1 Analysis of Task 2.2, similar analyses to those described for Phase 2 Analysis of gummy shark are being undertaken for school shark. Preliminary results have been prepared under Tasks 2.2.1, 2.2.2, and 2.2.4 (Schaefer analysis only).

In addition the CSIRO has made available to the SSAG the results of a tagging experiment on school sharks released during the 1940s and early 1950s. The school shark results are free of effects of mesh selectivity because most of the school shark tag recaptures, published in Grant et al (1979), occurred when hooks provided the main fishing method, before introduction of gill nets.

(2.4) Other species (Phase 1)

The small quantities of morphometrics, reproduction and tagging data available for southern saw shark, common saw shark and elephant fish are being subjected to the same analyses describe above for school shark Phase 1 Analysis.

Task 3. Population sampling

(3.1) Field sampling

Eleven bimonthly sampling cruises aboard commercial vessels were undertaken during the period from March 1986 to November 1987, where cruises were alternated between Bass Strait and South Australia, have been completed.

The originally planned twelve cruises were reduced to eleven cruises. During the tenth cruise sexually mature sharks of all species and school sharks in general were better represented in the catch than during the earlier cruises. To improve sampling of these animals and to increase the number of sharks sampled from waters off South Australia the ninth and eleventh cruises originally scheduled for Bass Strait were undertaken from South Australia. In addition the duration of the tenth cruise which was undertaken from South Australia was doubled and twelfth cruise was abandoned.

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During each cruise fishermen replace some of their nets with an experimental set of four 500-meter long gill nets of mesh sizes 5, 6, 7 and 8 inches, standardised with a hanging coefficient of 0.60 and with a depth (height) equivalent to the height of a gill net of 6-inch mesh size and 20 meshes deep.

Sex, total length, total weight, fullness of stomach and, depending on sex, gonad and uterine indices, fullness of seminal vesicles, diameters of the three largest ova, and lengths and sexes of embryos are recorded for each gummy shark and school shark caught in the experimental nets. In addition several vertebrae are removed from each animal for the purpose of determining its age in the laboratory. Occasionally when large catches are taken it is necessary to sub-sample the catch.

The objective was to sample 125 gummy sharks and 125 school sharks during each cruise.

(3.2) Laboratory processing of shark vertebrae

The method described by Walker (1984a) for ageing gummy sharks is adequate for gummy sharks but is inappropriate for school shark. Instead of ageing by staining and reading rings on the faces of the centra a method is being developed for ageing school sharks which involves sectioning the vertebrae. This new method is described in Moulton et al (1987).

Routine laboratory processing of vertebrae collected for ageing sharks captured during field sampling will begin shortly.

(3.3) Data analysis (Phase 3)

A computer database using dBase3 has been developed on an Olivetti M24 microcomputer for management and validation of field and laboratory data. Data collected during the eleven completed field cruises and data collected during the earlier 1973–76 study have been entered into the database.

Most data analysis is being undertaken on an Olivetti M24 using the SAS statistical package. Some analyses are undertaken using software available on the DEC PDP 11/73 computer or special software being developed on the Olivetti M24 or the Prime mainframe computers operated by CFL.

The following tasks apply to both gummy shark and school shark. No attempt has been made to completely analyse the data associated with any of these tasks because all of the required data have only recently become available. Nevertheless some of the theoretical work associated with these tasks has been undertaken.

(3.3.1) Current age-length keys

Provide up-to-date age-length keys from ageing sharks collected by the experimental gill nets for each sex separately.

(3.3.2) Current age-length curves

Provide revised age-length curves using ageing data for each sex separately, corrected for the biasing effects of mesh selectivity and test whether parameter estimates have changed significantly since they were last measured during 1973–76.

(3.3.3) Gill net mesh selectivity vs age

Develop appropriate theory and analyse data to describe gill net mesh selectivity as a function of mesh size and age of sharks for each sex separately.

(3.3.4) Current cohort analyses

Revise cohort analyses for the purpose of providing estimates of natural mortality and catchability using available catch and effort data and length-frequency and sex composition data from sampling commercial catches along with 1973–76 age-length keys, current age-length keys (from Task 3.3.1), age-specific mesh selectivities (from Task 3.3.3) and information on sex ratio at birth (from Phase 1 analyses and Task 3.3.6). Attempts will be made to interpolate age-length keys when determining number of animals in each cohort of the annual catches during 1970–87. As in Task 2.2.5 the two independent sets of data for males and females will be incorporated into one Paloheimo cohort analysis.

(3.3.5) **Male reproduction**

Determine relationship of proportion of the male population sexually mature versus age and length of sharks. Test whether parameter estimates have changed significantly since they were last measured during 1973–76.

(3.3.6) **Female reproduction**

Determine proportion of the female population gravid versus age and length of sharks, number of pups produced per gravid female versus age and length, sex ratio at birth and period of ovarian cycle. Test whether parameter estimates have changed significantly since they were last measured during 1973–76.

(3.3.7) **Population and yield modelling**

Extend the population model described under Task 2.2.6 which predicts yields for various levels of fishing intensity using available parameter estimates for growth, natural mortality, catchability, gill net mesh selectivity and fecundity.

Attempts will be made to incorporate changes detected in growth rates, fecundity and, perhaps, natural mortality in response to density changes in the population between the 1973–76 study and the current study.

Attempts will also be made to simulate observed catch and effort trends under non-equilibrium conditions.

RESULTS

Results of analyses undertaken before commencement of the current project in July 1986 of biological data on gummy shark collected during 1973–76 are given in Walker (1984a) and Kirkwood and Walker (1986). Results for monitoring data on gummy shark for the period 1971–83 are given in Walker (1984b).

Since the project started the SSAG has prepared eleven reports for the Third Southern Shark Assessment Workshop held during 28 April – 1 May 1986, five reports for the Fourth Workshop, and eleven reports for the Southern Shark Task Force. For external publication, two manuscripts have been published, two manuscripts have been accepted by journals and are in press, two manuscripts have passed through the CFL internal referee and approval system and been submitted to journals, and six manuscripts are at advanced stages of preparation. In addition, the SSAG has prepared two applications for further external funding of shark research: one to FIRTA to undertake a 3-year project for tagging sharks and one to the Australian Fisheries Service to continue monitoring of commercial catches across southern Australia.

Rather than reproduce all of the results of analyses contained in these documents, the reports will be cited and only summaries or examples of material will be reproduced in the following. Any results presented in the First Review of the Project (Walker 1985a) or the Second Review (Walker 1986a) will not be presented in this Third Review.

Task 1. Implementation of compatible monitoring program

Reported in Second Review (Walker 1986a).

Task 2. Analyse and report available data

(2.1) **School shark (Phase 1 Analysis of 1973–76 data)**

(2.1.1) **Morphometrics**

Reported in Second Review (Walker 1986a).

(2.1.2) **Tagging**

Reported in Second Review (Walker 1986a).

(2.1.3) **Ageing**

Reported in Second Review (Walker 1986a).

(2.1.4) Male reproduction

Length at first sexual maturity of male school 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.

The first method involved transverse sectioning of testis tissue from each of 41 male sharks and staining with Mayer's haemotoxylin and eosin.

In preparation for microscopic inspection, a straight line marker (transect) was attached to the section 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 mainly composed) developed by Mellinger (1965) and using a binocular microscope set at ×400 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. A summary of the number of immature and the number and proportion mature on this basis in each 100 mm length-class is given in Table 2.1.4(1).

The second method required macroscopic inspection of the testes of each of 207 sharks, males were classified into one of three stages based on general appearance, thickness of testis tissue and relative size of epigonal gland:

Stage 1 — testes thin and epigonal gland predominant,

Stage 2 — testes enlarged and epigonal gland predominant, and

Stage 3 — testes 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 the number and proportion of sharks mature in each 100 mm length-class is given in Table 2.1.4(2).

The third method involved macroscopic inspection of the seminal vesicles of each of 207 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 — walls 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 provided in Table 2.1.4(3).

There is reasonably good agreement between the results from the three methods adopted which indicate that most male gummy sharks reach sexual maturity in the 1200–1299 mm length-class.

Scattergrams of clasper length against total length (Fig. 2.1.4(1)) and the ratio of testis weight/total weight against total length (Fig. 2.1.4(2)) appear consistent with the results of the above three methods. Further analyses will be undertaken on these data to determine the relationship between the proportion of the population of males mature against total length.

(2.1.5) Female reproduction

Female reproduction of school shark was studied by examination of the condition of uteri, development of ovidical glands, enlargement of ova in the ovaries, and number and growth of embryos. The condition of the uteri, U, of a female was classified as one of the six indices illustrated in Figure 2.1.5(1); the development of the oviducal glands was classified as Index 1 (not visible), Index 2 (visible but small) or Index 3 (enlarged); and stage of enlargement of the ova was classified as Index 1 (ova small follicles), Index 2 (ova 2–4 mm diameter) or Index 3 (ova greater than 4 mm diameter) for each of 209 females. The proportion of sharks with each of these indices is presented in Table 2.1.5(4).

From Table 2.1.5(4) sexual maturation 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, G=1).

(2) Slight enlargement of ova, oviducal glands appear and the uteri expand from the posterior (U=1–2, 0=1–2, and G=1–2).

(3) Further enlargement of uteri, oviducal glands and ova (U=3, O=3 and G=3)

(4) Enveloped eggs without visible embryos appear in uteri and uterine walls are slightly distended (U=4, O=3 and G=3).

(5) 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).

(6) Following parturition the distended uterine walls gradually contract to the condition before pregnancy described under (4) (U=6, O=3 and G=3).

To develop a theory of the reproductive cycle of females and to determine the frequency of pregnancy it is necessary to determine (a) whether fertilisation, parturition and gestation are seasonal or protracted, (b) the pattern of development of embryos and the period of gestation, and (c) the pattern of enlargement of ova in the ovaries and the period of the ovarian cycle.

Of 226 female school sharks which had their uteri examined, 45 (20%) were judged to be sexually mature (1 had a uterus index U=4, 25 had U=5 and 19 had U=6) (Table 2.1.5(1)). Fig. 2.1.5(3) provides a scattergram of mean length of embryos of 18 pregnant female school shark against day of year. Of these 15 were captured in Bass Strait during the 4-month period from late September to mid-January and 3 from off South Australia during June (Table 2.1.5(2)). These captures are consistent with the hypothesis posed by Olsen (1954) that the females occur in waters off South Australia and New South Wales during the early phases of gestation and then migrate to eastern Bass Strait and southern Tasmania during Spring and Summer for parturition. As the only sampling undertaken outside Bass Strait and southern Tasmania was off South Australia in June 1975, the absence of females in the catch for this sampling cruise which were either ovulating or pregnant with embryos of mean length less than 200 mm is also consistent with this hypothesis.

Fig. 2.1.5(2) provides evidence of seasonality in gestation and the absence of pregnant females with mid-term embryos after mid-January indicates that most births occur prior to this time of the year and that school sharks are born at a mean length of about 320 mm. Linear extrapolation through the data points given in Fig. 7.3 suggest that gestation exceeds 12 months and that ovulation probably occurs about October as for gummy shark.

Fig. 2.1.5(3) provides a scattergram of mean diameter of the three largest ova against day of a 2-year period were 365 was added to day of year for sharks with a mean ova diameter exceeding 15 mm which is the largest value observed for any female carrying full-term embryos. The rational for adding 365 days is that there is clear evidence of gradual enlargement of ova of pregnant females (i.e., U=5) during the period of gestation to a maximum diameter of 15 mm and that non-pregnant mature females which have previously given birth (i.e., U=6) must be well in excess of one year. If it is assumed that ova enlarge linearly with time, these data indicate that the period of the ovarian cycle could be as long as three years. Given the available evidence that both the ovarian cycle and the period of gestation exceed one year, it is concluded that the maximum rate of pregnancy for mature females is once every two years. Observations of the largest ova of diameter of about 47 mm, three times the diameter of ova of pregnant females carrying full-term embryos, support the conjecture that the rate of pregnancy is once every three years.

One female captured during November had a uterus condition of U=4 (Table 2.1.5(1)). The *in utero* eggs of this female had slightly crenated surfaces and tended to be darkened in colour suggesting that they had been in the uteri for a long period. As the mean diameter of the three largest ova was 13 mm, it appears that the ovarian cycle of this shark was synchronous with the pregnant females (see Fig. 2.1.5(3) which would have ovulated more than 12 months earlier.

Of 22 pregnant females collected the number of embryos carried varied widely from 17 to 43 whereas the length range of these females varied narrowly from 1469 to 1674 mm. There is no clear relationship between number of embryos carried and mother length (Fig. 2.1.5(4)) whereas there is a strong correlation between the number of embryos and mother weight (Fig. 2.1.5(5)). In addition to embryos, *in utero* unfertilised eggs are frequently observed. Fig. 2.1.5(6) provides the relationship between the sum the number of embryos and unfertilised eggs carried against mother weight.

Examination of the uteri of the 22 pregnant females indicated that mean number of embryos and unfertilised eggs carried were 29.51 and 0.91, respectively. The mean number of embryos and eggs counted in the right uteri (16.14) were significantly higher than the mean number carried in the left uteri (14.27) whereas the mean number of males detected (13.73) was not significantly different from the number of females detected (15.27) (Table 2.1.5(3)).

(2.1.6) Stomach contents

Reported in Second Review (Walker 1986a).

(2.1.7) Gear studies

During 1973–76 experimental gill nets and long-lines were set at 162 stations.

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.

Details of construction and operation of these nets are described in Walker (1986d).

Gill net mesh selectivity

Reported in Second Review (Walker 1986a).

Gill net hanging coefficient

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 effect 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.

Insufficient school sharks were captured during this experiment to draw any conclusion on the effect of hanging coefficient on catch rates.

Long-lines

Two long-lines were used for undertaking three separate experiments testing effects of hook size, shank length and spacings between the hooks on catch rates.

Details of construction and operation of these long-lines and the results of the experiments are described in Walker and Knuckey (1987).

Experiment 1, designed to test for the effect of hook size on catches, was conducted during Cruises 01–04 (9 June 1973 – 24 March 1975). Eight 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 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 remaining 50 11/O long-shank hooks. 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 and 3/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 and 3/O hooks are biased downwards.

The results are given for Experiment 1 in Table 2.1.7(1) and for Experiments 2 and 3 in Table 2.1.7(2).

From the three experiments, by comparing lengths of sharks captured by the different sizes of short-shank hooks, there was a strong trend for the larger hook sizes to catch larger sharks. This effect is much stronger than that for gummy shark (see Walker 1984a). Catch per hook-hour increased by only 7% by doubling hook spacing from 5 m to 10 m but increased by 50% when further doubling hook spacing from 10 m to 20 m.

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 became apparent that the number of sharks captured was affected by tidal water movement. Gill nets were not effective in areas of strong currents caused by tide because they tended to lean, drift and become tangled, whereas long-line catches were low in areas of weak tide. The successive increases in catch rates from Experiment 1 to Experiment 2 and from Experiment 2 to Experiment 3 were probably 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 current, 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.

As with the gill nets the distribution of the catches of sharks shows an absence of particularly small sharks which can be explained by the characteristic of small school sharks to inhabit shallow inshore 'nursery grounds'.

Gummy shark (Phase 2 Analysis)

(2.2.1) Revise mortality estimates from tag data

Reported in Second Review (Walker 1986a).

(2.2.2) Revise growth estimates from tag data

Reported in Second Review (Walker 1986a).

(2.2.3) Revise movement estimates from tag data

Preliminary estimates of the movement parameters for gummy shark released in Bass Strait have been made but final estimates cannot be made until estimates of catch and effort have been finalised.

(2.2.4) Catch composition/effort modelling

Reported in Second Review (Walker 1986a).

(2.2.5) Preliminary cohort analysis

Reported in Second Review (Walker 1986a).

(2.2.6) Dynamic pool yield analysis

Beverton and Holt Yield per Recruit Analysis

Reported in Second Review (Walker 1986a).

Special 'yield per female born model'

Reported in Second Review (Walker 1986a).

Task 3. Population sampling

(3.1) Field sampling

Data summaries are available for the first eight cruises. During these cruises a total of 1259 gummy sharks and 595 school sharks were sampled (Tables 3.1(1a) and 3.1(1b).

The fishing sites for the eight completed cruises are given in Fig. 3.1(1).

Histograms of catch per unit effort versus length of shark for gummy shark from Bass Strait [Fig. 3.1(2a)] and South Australia [Fig. 3.1(2b)] and for school shark from Bass Strait [Fig. 3.1(2c)] and South Australia [Fig. 3.1(2d)] indicate that sharks occurring off South Australia are generally larger than those occurring in Bass Strait.

Summaries of available data on male reproduction of gummy shark and school shark are given in Tables 3.1(2a), 3.1(2b), 3.1(3a), 3.1(3b), 3.1(4a), 3.1(4b), 3.1(5a) and 3.1(5b), and Figures 3.1(3a), 3.1(3b), 3.1(4a) and 3.1(4b), and on female reproduction are given in Tables 3.1(6a) and 3.1(6b).

(3.2) Laboratory Processing of Vertebrae for Ageing Sharks

Shark vertebrae have been collected routinely and although considerable preparatory work has been done routine laboratory processing has not yet begun.

(3.2) Electrophoretic study of gummy shark

Reported in Second Review (Walker 1986a).

SPECIFIC ACHIEVEMENTS SINCE PREVIOUS REVIEW (OCTOBER 1986)

Task 1 Implementation of Compatible Monitoring Program

(1) The SSAG has continued to receive and collate fishermen's catch and effort data from Western Australia, South Australia, Tasmania and Victoria.

(2) A new fishermen's shark return has been designed and agreed to the Tasmanian Department of Sea Fisheries, the Australian Fisheries Service and the SSAG.

(3) The SSAG has continued to collect details of daily landings of shark from fish processors in South Australia, Tasmania and Victoria.

(4) The SSAG has continued to maintain schemes for sampling commercial catches of shark in Tasmania, South Australia and Victoria for sex and length-frequency composition.

(5) The SSAG has redeveloped a computer system on the CFL Prime computer for collation and reporting of shark catch and effort data from Victoria, Tasmania, South Australia and Western Australia.

(6) Available commercial catch sampling for gummy shark and school shark collected during 1984 and 1985 have been validated and received preliminary analysis.

Task 2 Analyse and report available data

School shark (Phase 1 Analysis of 1973–76 data)

(1) Available data for male reproduction have been analysed under Task 2.1.4.

(2) Available data for female reproduction have been analysed under Task 2.1.5.

(3) Available data for gill net hanging coefficient have been analysed under Task 2.1.7.

(4) Available data for longline hook selectivity have been analysed under Task 2.1.7.

Gummy shark and school shark (Phase 2 Analysis of 1973–76 data)

(1) A new computer model for providing parameter estimates of growth, natural mortality, region specific catchabilities, tag reporting rate and probability of movement between various defined regions from tagging data correcting for effects of changing fishing effort and gear selectivity is complete. Preliminary analyses have been undertaken on the data (Tasks 2.2.1, 2.2.2, 2.2.3 and 2.3).

Task 3. Population sampling

(1) Bimonthly sampling cruises aboard commercial vessels have been completed (i.e., Tasks 3.1 and 3.2 are complete).

(2) All data collected during the eleven completed field cruises have been entered into a computer data-base in preparation for statistical analysis.

(3) Systems have been developed on an Olivetti M24 using the statistical package SAS for analysing and summarising available data.

(4) Procedures for embedding, sectioning and staining of shark vertebrae have been established for routine ageing of sharks.

RESEARCH PLAN

At the Third Southern Shark Assessment Workshop, held mid-1986, it was concluded that the standard Beverton and Holt yield per recruit, Schaefer, DeLury and Deriso stock assessment techniques are not appropriate for the southern shark stocks. As a consequence, particularly in view of the peculiarities associated with shark and gill net fisheries, which in a world-wide context have not been intensively studied, the SSAG is endeavouring to develop new stock assessment techniques. In particular the SSAG is currently pursuing an approach which combines a non-equilibrium dynamic pool model with catch composition and effort time series data.

In developing this approach it has become apparent that there are two uncertainties which have not been addressed by research in the past or by the current FIRTA funded project.

The first was pointed out by consultants Walters and Hilborn who visited Australia recently to advise on fisheries research and management. Referring to unpublished data from overseas, they suggested that the abundance of a declining stock of schooling fish like sharks is probably better represented by $(cpue)^2$ than by cpue which traditionally has been used as an index of relative abundance. This means that instead of the recruited biomass declining to about 40% of the level at the beginning of the 1970s as indicated by cpue, it has declined to about 10%. Although not identified as a task under the current FIRTA project, available catch and effort data are being analysed to determine whether the spacial distribution of the sharks is being reduced by fishing.

The second uncertainty relates to movement and distribution patterns of the sharks. Previous tagging experiments provide evidence of movement of sharks out of Bass Strait and there is strong evidence that sharks occurring outside Bass Strait are generally larger than those occurring inside. In view of these patterns and the tendency for fishermen to use gill nets of larger mesh size outside than inside Bass Strait, the Third Southern Shark Assessment Workshop concluded that a model of the fishery should be divided into a number of zones and include incorporate migration of sharks between the zones. The Workshop recommended that a carefully designed tagging program be initiated across the entire area of the fishery to quantify the movement patterns. In response to a request from the Southern Shark Task Force, the SSAG prepared an appropriate tagging research proposal and submitted for FIRTA funding.

Furthermore, in response to a request from the Southern Shark Task Force, the SSAG coordinated an electrophoretic study to investigate breeding structure of gummy shark stocks. The request, experimental design, field sampling and laboratory analyses were all undertaken during the 1985/86 fiscal year.

PROGNOSIS FOR MEETING PROGRAM OBJECTIVES

Progress is running close to schedule and there is no reason to conclude at this stage that all six objectives will not be met.

At a broader level, as mentioned above most of the available standard stock assessment techniques have been found inappropriate for the southern shark fishery and a more definitive assessment depends on whether the SSAG can successfully develop more appropriate models. The first and simplest step of development is establishing a dynamic pool model with fixed biological parameter values. This has been completed successfully. The second step is to vary certain density dependent parameter values (growth, fecundity and natural mortality) in the model with changes in stock abundance; the third step is to include time series of catch composition and fishing effort data; and the fourth step is to introduce a number of separate regions to take account of geographic variations in mesh sizes for commercial fishing gear and in the distribution and movement patterns of the sharks.

In moving towards meeting its objectives the SSAG has already developed a number of new techniques which will be of interest to the scientific community involved in fisheries resource assessment.

PROGRAM SCHEDULE

Task	1985/86 JAS	1985/86 OND	1985/86 JFM	1985/86 AMJ	1986/87 JAS	1986/87 OND	1986/87 JFM	1986/87 AMJ	1987/88 JAS	1987/88 OND	1987/88 JFM	1987/88 AMJ
(1) Fishery monitoring												
(1.1) Log-book system												
(1.1.1) Data collection												
Development	—	—										
Routine			—	—	—	—	—	—	—	—	—	—
(1.1.2) Data processing												
Development	—	—										
Routine			—	—	—	—	—	—	—	—	—	—
(1.2) Commercial catch sampling												
(1.2.1) Data collection												
Development	—	—										
Routine			—	—	—	—	—	—	—	—	—	—
(1.2.2) Data processing (Phase 2)												
Development		—	—									
Routine		—	—	—	—	—	—	—	—	—	—	—
(1.3) Processor return system												
(1.3.1) Data collection												
Development	—											
Routine	—	—	—	—	—	—	—	—	—	—	—	—
(1.3.2) Data processing												
Development		—	—									
Routine				—	—	—	—	—	—	—	—	—
(1.4) Integrated data processing												
Development			—	—								
Routine					—	—	—	—	—	—	—	—
(2) Analyse and report available data												
(2.1) School shark (Phase 1)												
(2.1.1) Morphometrics			—	—								
(2.1.2) Tagging (growth, movement & mortality)			—	—								
(2.1.3) Ageing			—	—								
(2.1.4) Male reproduction			—	—								
(2.1.5) Female reproduction			—	—								
(2.1.6) Stomach contents			—	—								
(2.1.7) Mesh selectivity			—	—								
(2.1.8) Catch composition/effort summary			—	—								
(2.2) Gummy shark (Phase 2)												
(2.2.1) Revise tag mortality estimates			—	—								
(2.2.2) Revise tag growth estimates			—	—								
(2.2.3) Revise tag movement estimates			—	—								
(2.2.4) Catch composition/effort modelling			—	—								
(2.2.5) Preliminary cohort analysis			—	—								
(2.2.6) Dynamic pool yield analysis			—	—								
(2.3) School shark (Phase 2)					—	—	—	—				
(2.4) Three other shark species (Phase 1)					—	—	—	—				
(3) Population sampling												
(3.1) Field sampling development	—	—										
(3.2) Field sampling routine			—	—	—	—	—	—	—	—		
(3.3) Data analysis (Phase 3)					—	—	—	—	—	—	—	—

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External publication

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Table 2.1.4(1). Proportion of male school sharks mature from microscopic inspection of histological transverse sections of testes tissue.

Length class (mm)	Number of sharks			Proportion mature
	Immature	Mature	Total	
<700	3	0	3	
700–799	5	0	5	0.0000
800–899	1	0	1	0.0000
900–999	3	0	3	0.0000
1000–1099	4	0	4	0.0000
1100–1199	2	0	2	0.0000
1200–1299	1	2	3	0.3333
1300–1399	1	2	3	0.3333
1400–1499	2	8	10	0.8000
>1500	2	5	7	0.7143
Total	24	17	41	

Table 2.1.4(2). Proportion of male school sharks mature from macroscopic inspection of testes.

Length class (mm)	Number of sharks					Proportion mature
	Immature			Mature	Total	
	Stage 1	Stage 2	Total	Stage 3		
<700	45	0	45	0	45	0.0000
700–799	18	0	18	0	18	0.0000
800–899	17	0	17	0	17	0.0000
900–999	13	0	13	0	13	0.0000
1000–1099	23	1	24	0	24	0.0000
1100–1199	8	10	18	0	18	0.0000
1200–1299	0	10	10	6	16	0.3750
1300–1399	0	0	0	10	10	1.0000
1400–1499	0	0	0	25	25	1.0000
> 1500	0	0	0	21	21	1.0000
Total	124	21	145	62	207	

Table 2.1.4(3). Proportion of male school sharks mature from macroscopic inspection of seminal vesicles.

Length class (mm)	Number of sharks					Proportion mature
	Immature	Mature			Total	
	Stage 1	Stage 2	Stage 3	Total		
<700	45	0	0	0	45	0.0000
700–799	18	0	0	0	18	0.0000
800–899	17	0	0	0	17	0.0000
900–999	13	0	0	0	13	0.0000
1000–1099	24	0	0	0	24	0.0000
1100–1199	18	0	0	0	18	0.0000
1200–1299	10	4	2	6	16	0.3750
1300–1399	0	4	6	10	10	1.0000
1400–1499	1	13	11	24	25	0.9600
>1500	1	14	6	20	21	0.9524
Total	147	35	25	62	207	

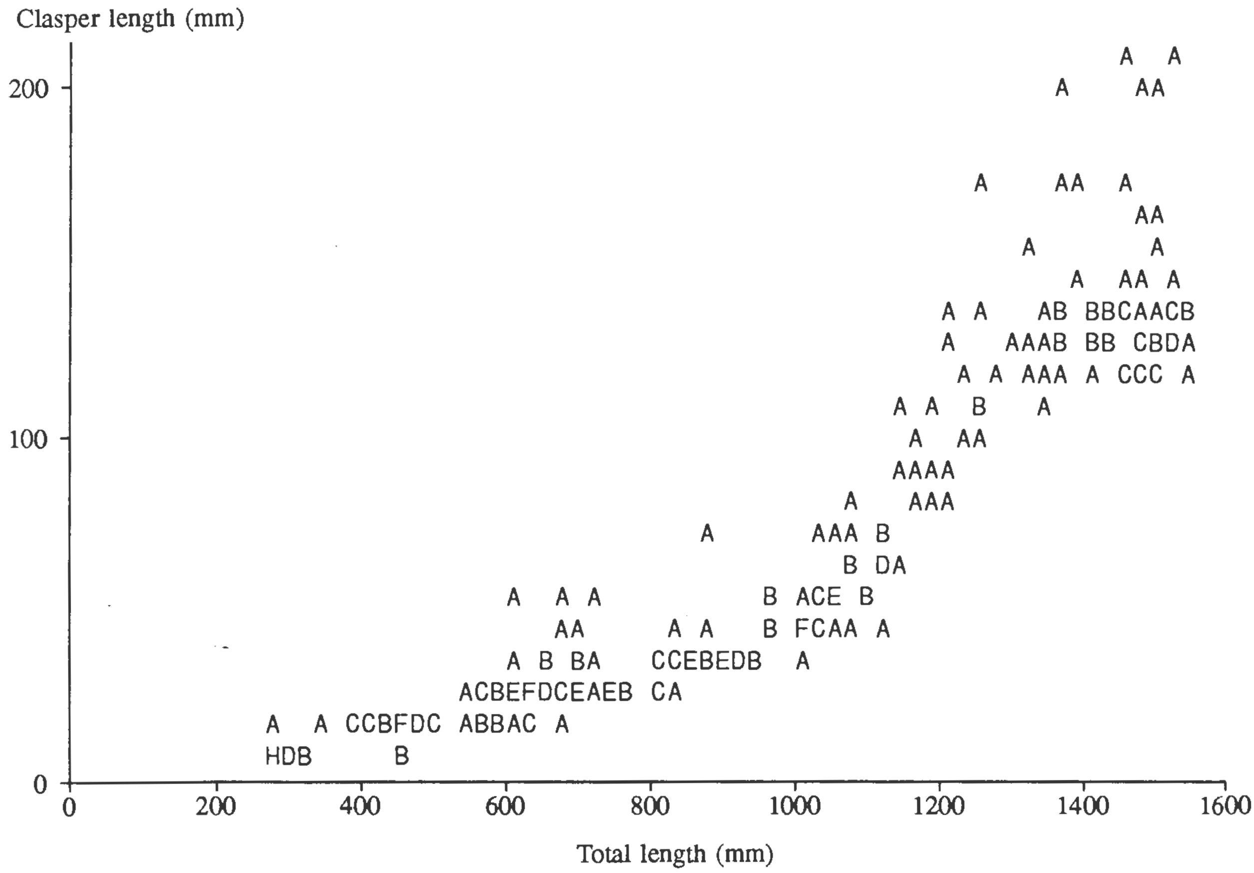


Fig 2.1.4(1). Scattergram of clasper length against total length of male school sharks (A represents 1 observation, B represents 2, etc).

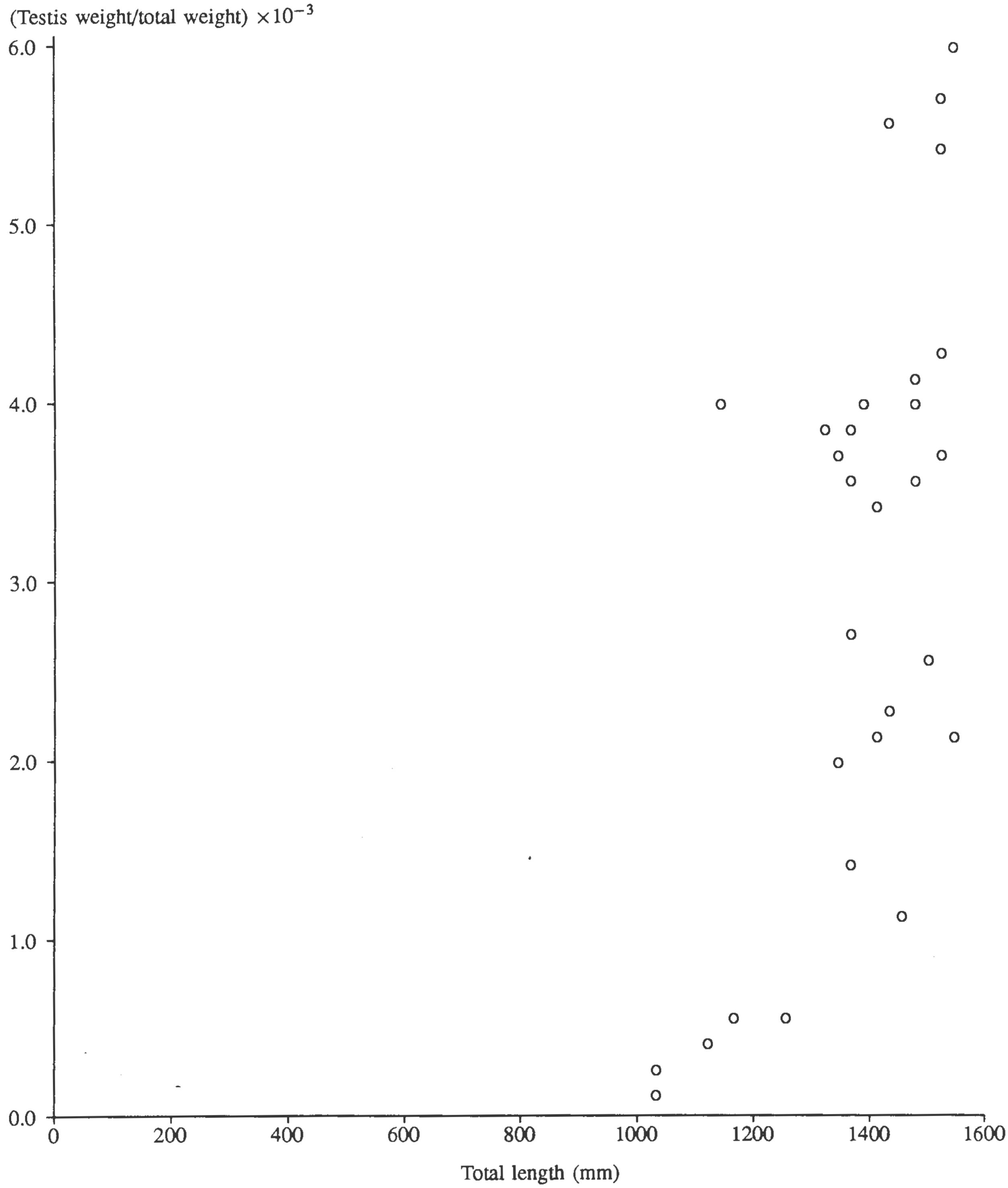


Fig 2.1.4(2). Scattergram of testis weight/total weight against total length of male school sharks.

Table 2.1.5(3). Mean number (with standard error) of eggs and of each sex of embryos in the left and right uteri of 22 pregnant school sharks.

Eggs or sex of embryos	Mean number of eggs and embryos (with standard error) for each uterus		
	Left uterus	Right uterus	Total
Eggs	0.45±0.13	0.45±0.16	0.91±0.17
Embryos			
Male	6.27±0.73	7.45±0.50	13.73±0.98
Female	7.09±0.78	8.18±0.56	15.27±1.16
Unknown[A]	0.45±0.45	0.05±0.05	0.50±0.45
Total	13.82±1.00	15.68±0.69	29.50±1.53
Grand Total	14.27±0.95	16.14±0.70	30.41±1.48

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

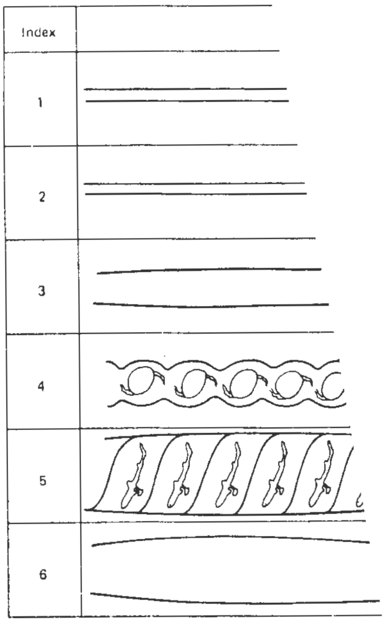


Fig. 2.1.5(1). Description of uteri for each uterus condition index for female school shark.

Table 2.1.5(4). Proportion of female school sharks examined with each gonad, oviducal gland and uterus condition index.

Uterus condition index	Proportion of sharks with each gonad index for each oviducal gland index								
	O = 1			O = 2			O = 3		
	G=1	G=2	G=3	G=1	G=2	G=3	G=1	G=2	G=3
U = 1	0.55	0.05		0.14	0.02				
U = 2									
U = 3									0.02
U = 4									<0.01
U = 5									0.13
U = 6									0.06

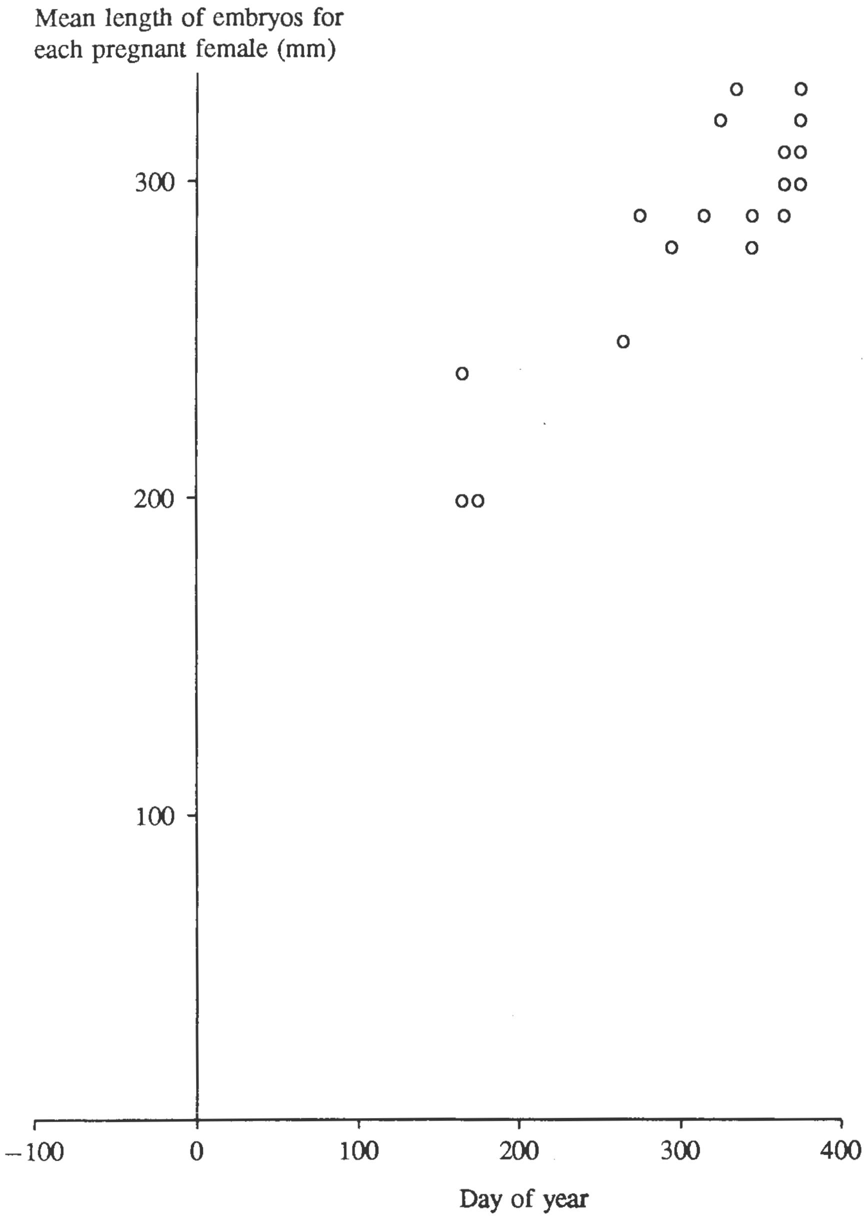


Fig. 2.1.5(2). Scattergram of mean length of *in utero* embryos in 18 pregnant female school sharks against day of year.

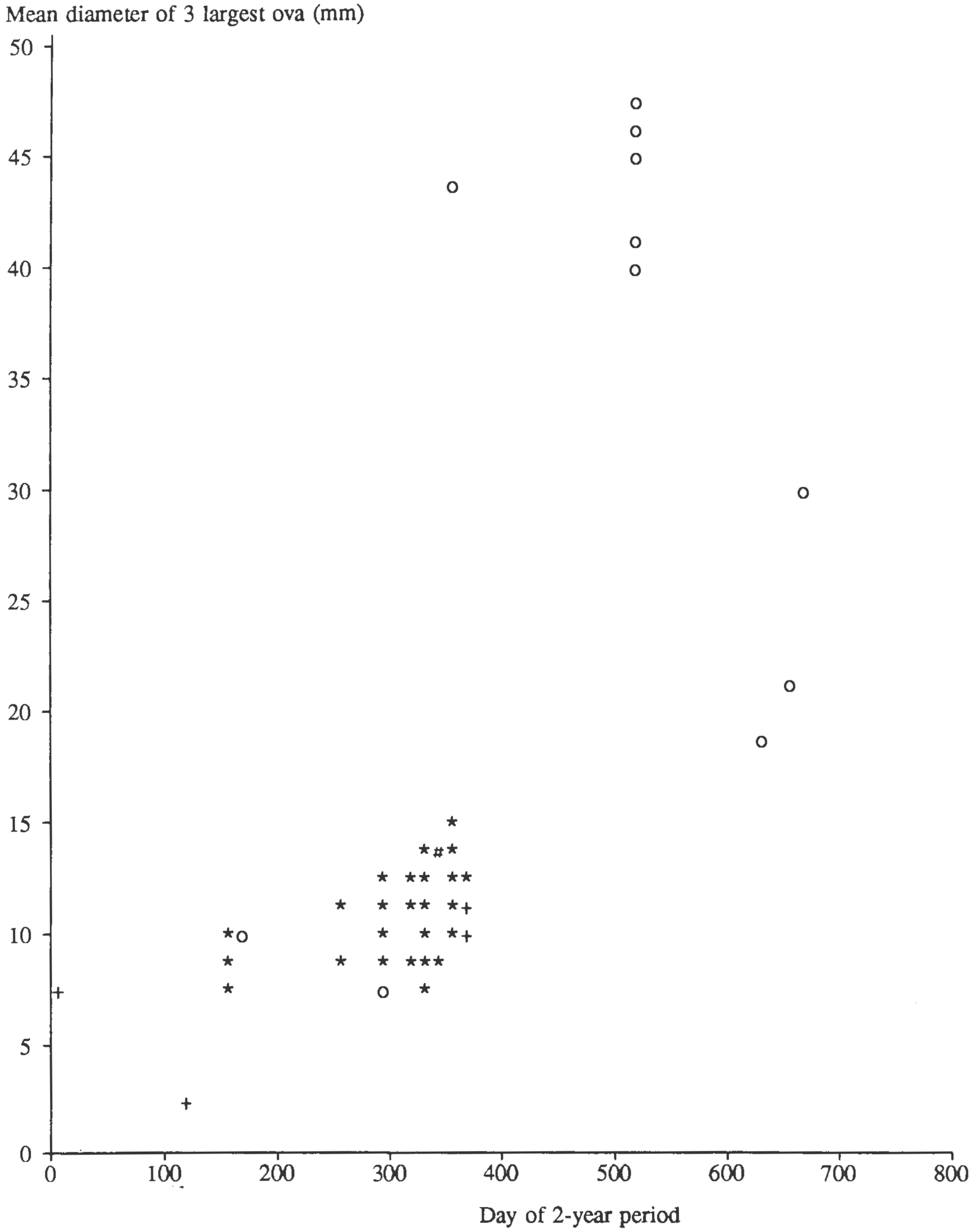


Fig. 2.1.5(3). Scattergram of mean diameter of three largest ova against day of 2-year period for female school sharks with uterus condition indices 3 (+), 4 (#), 5 (*) and 6 (o). (Where mean ova diameter exceeded 15 mm, 365 days were added to day of the year).

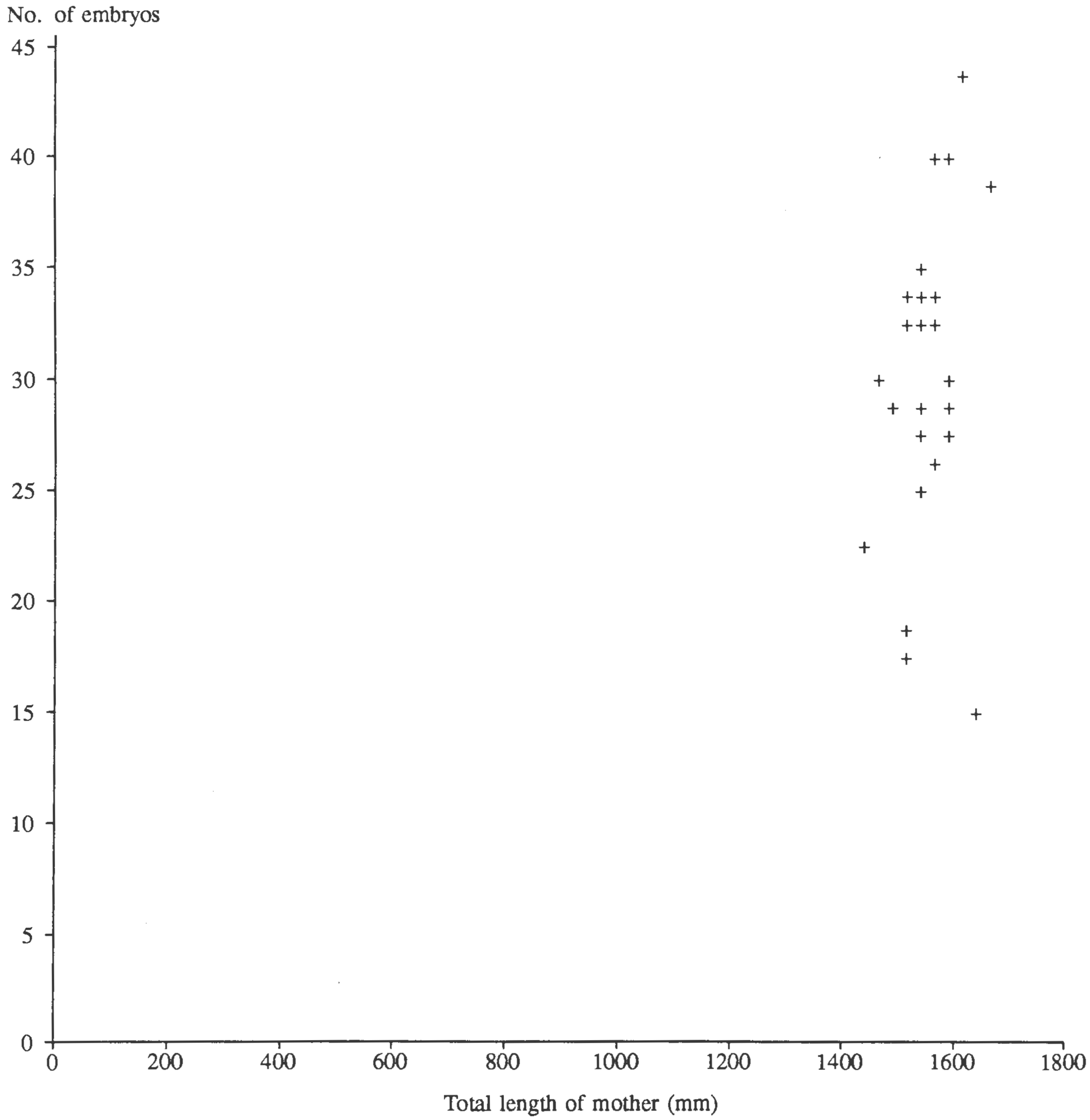


Fig 2.1.5(4). Plot of *in utero* embryos against total length of mother female school sharks.

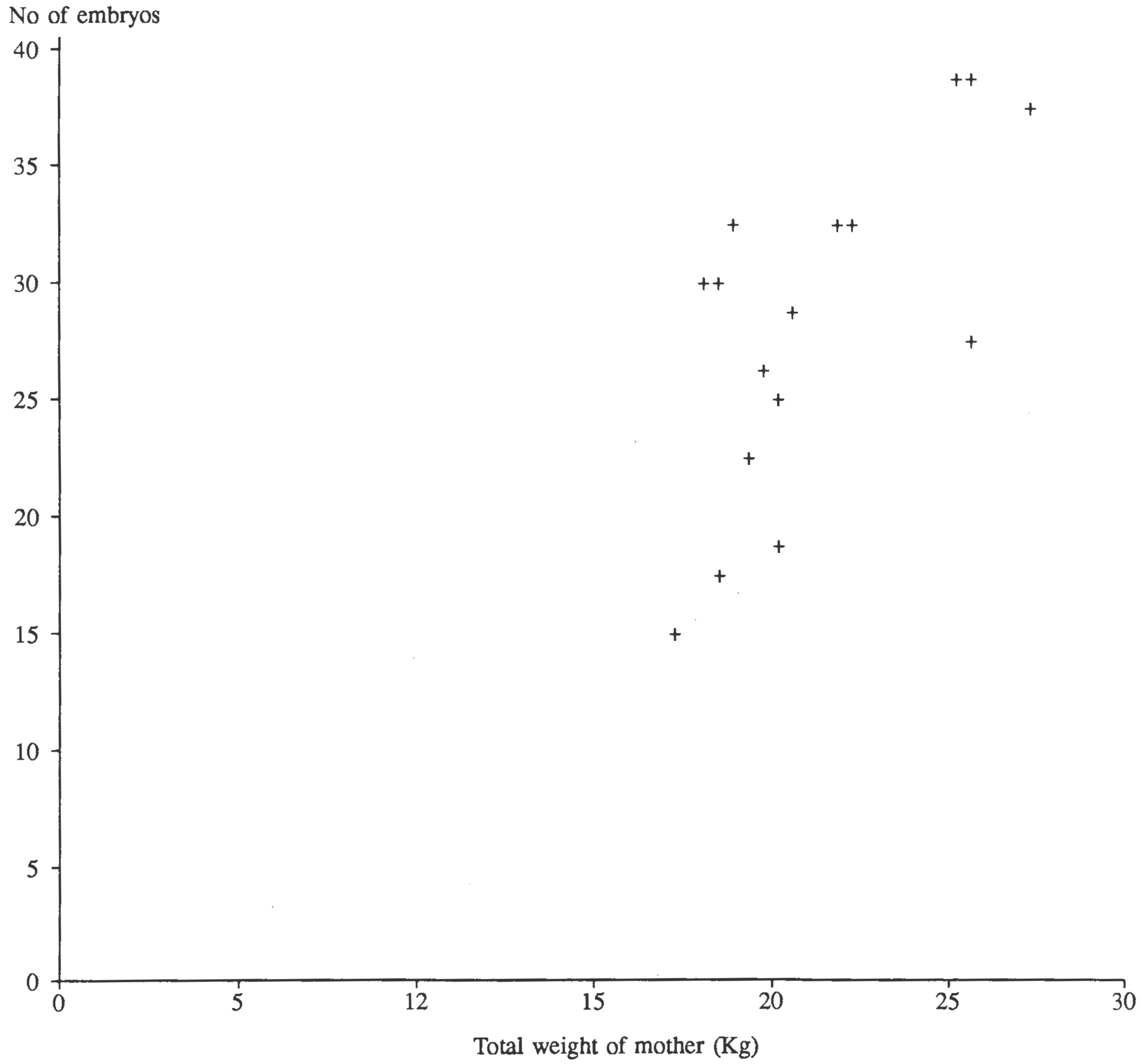


Fig 2.1.5(5). Relationship between number of in utero embryos, m, and total weight of mother, w, female school sharks. Values for a and b (with standard errors) for equation $m = a + bw$ are given in the following tabulation:

a	b	n	r^2 [A]	e.m.s.[B]
−6.86 (9.39)	1.64 (0.43)	16	0.47**	28.4

[A]coefficient of determination between m and w.

**$p < 0.01$

[B]Error mean square for the regression of m against w.

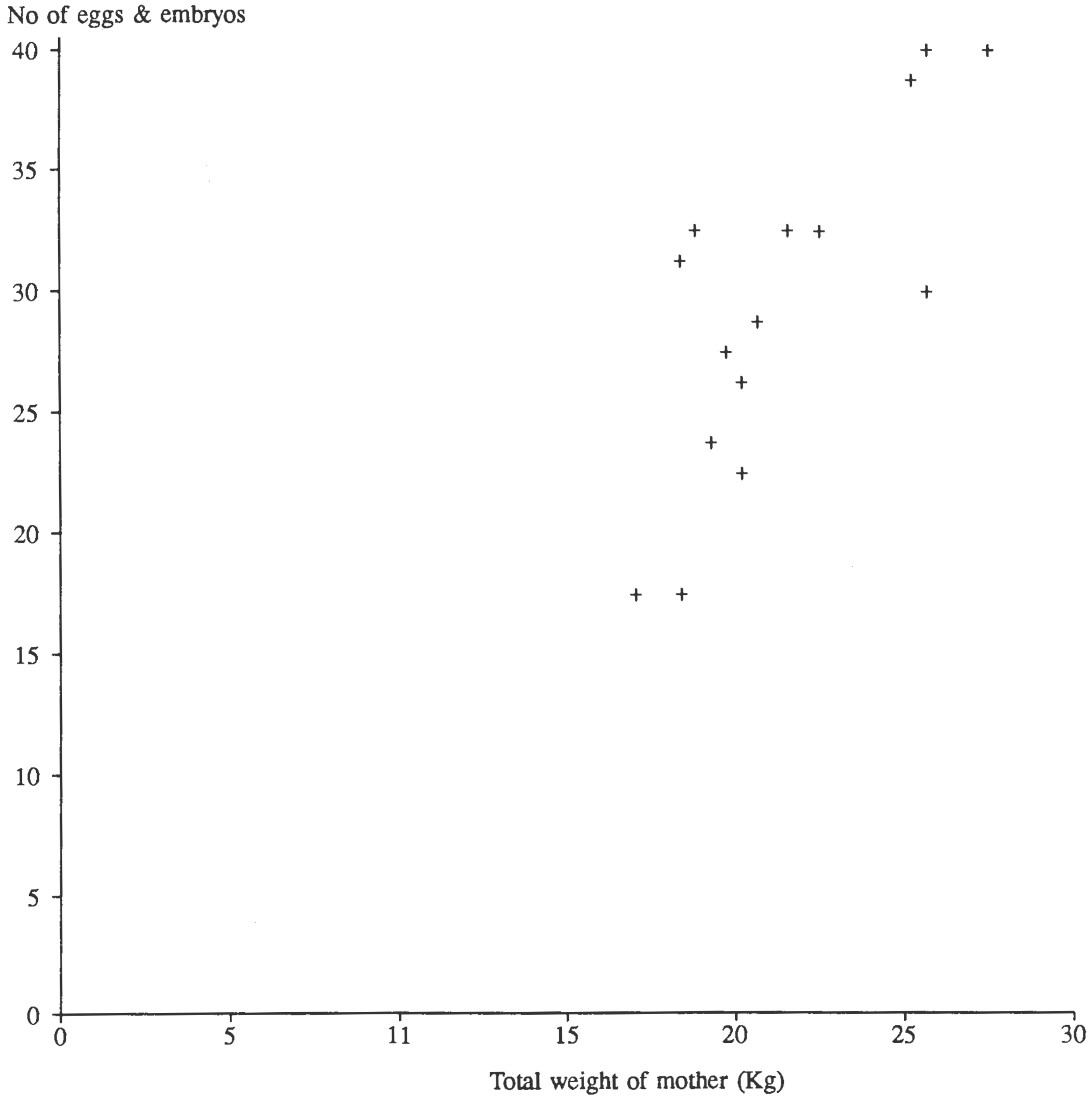


Fig 2.1.5(6). Relationship between sum of number of in utero eggs and embryos, g, and total weight of mother, w, female school sharks. Values for a and b (with standard errors) for equation $g = a + bw$ are given in the following tabulation:

a	b	n	r^{2} A	e.m.s.B
−6.59 (8.59)	1.68 (0.40)	16	0.53**	23.8

Acoefficient of determination between g and w.

**$p < 0.01$

BError mean square for the regression of g against w.

18

Table 2.1.7(1). Catches of school sharks taken by short-shank galvanised hooks of eight sizes ranging from Mustad 2/O to 10/O (Experiment 1).

(Eight groups of each hook size (50 hooks each, placed 7.5 m apart) were set 42 times)

Variable	Sex	2/O	3/O	4/O	5/O	7/O	8/O	9/O	10/O	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	m	650	541	658	897	1090	908	673	1232	881
captured (mm)	f	543	592	659	649	811	567	942	1020	753
	m & f	597	568	659	815	997	737	846	1113	819
Standard deviation of	m	169	60	166	374	379	483	142	324	379
length of sharks	f	53	118	186	288	359	127	459	483	353
captured (mm)	m & f	131	96	173	362	387	384	392	426	372
Standard error of	m	76	23	48	94	101	171	64	98	43
length of sharks	f	24	42	52	102	136	45	153	129	42
captured (mm)	m & f	41	25	35	74	84	96	105	85	30
Total number of	m	5	7	12	16	14	8	5	11	78
sharks captured	f	5	8	13	8	7	8	9	14	72
	m & f	10	15	25	24	21	16	14	25	150
Number of sharks	m	3.2	4.4	7.6	10.2	8.9	5.1	3.2	7.0	6.2
captured per 10^4	f	3.2	5.1	8.3	5.1	4.4	5.1	5.7	8.9	5.7
meter of main-line	m & f	6.3	9.5	15.9	15.2	13.3	10.2	8.9	15.9	11.9
Number of sharks	m	8.3	12.0	19.7	27.4	23.3	13.4	8.2	17.6	16.2
captured per 10^5	f	8.3	13.7	21.4	13.7	11.7	13.4	14.8	22.4	15.0
meter-h of main-line	m & f	16.7	25.7	41.1	41.1	35.0	26.8	23.0	40.0	31.2
Number of sharks	m	2.4	3.3	5.7	7.6	6.7	3.8	2.4	5.2	4.6
captured per 10^3	f	2.4	3.8	6.2	3.8	3.3	3.8	4.3	6.7	4.3
hook-lift	m & f	4.8	7.1	11.9	11.4	10.0	7.6	6.7	11.9	8.9
Number of sharks	m	6.2	9.0	14.8	20.5	17.5	10.1	6.2	13.2	12.2
captured per 10^4	f	6.2	10.3	16.0	10.3	8.7	10.1	11.1	16.8	11.2
hook-hour	m & f	12.5	19.3	30.8	30.8	26.2	20.1	17.2	30.0	23.4

Table 2.1.7(2). Catches of school sharks taken by each of short-shank and long-shank hooks of two sizes with various hook spacings (Experiments 2 and 3).

Variable	Sex	Experiment 2					Experiment 3				
Hook shank length		Short	Short	Long	Long	Total	Short	Short	Long	Long	Total
Hook size		5/O	10/O	11/O	11/O		5/O	10/O	11/O	11/O	
Hook spacing (m)		10	10	10	20	5	5	5	10		
Number of hooks		50	50	50	50	200	50	50	50	50	200
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	m	1183	1193	1124	1179	1170	942	987	933	954	956
captured (mm)	f	1111	1162	1176	1112	1139	884	935	908	892	909
	m & f	1151	1180	1224	1151	1176	925	966	920	935	938
Standard deviation of	m	198	253	235	224	228	129	137	98	115	238
length of sharks	f	285	294	254	242	264	133	180	155	129	445
captured (mm)	m & f	241	269	243	233	245	131	156	129	121	340
Standard error of	m	36	40	37	30	18	24	23	20	19	21
length of sharks	f	57	56	45	37	23	38	38	31	33	52
captured (mm)	m & f	32	33	28	23	14	20	21	18	17	24
Total number of	m	31	40	41	57	169	30	34	24	35	123
sharks captured	f	25	28	32	42	127	12	22	25	15	74
	m & f	56	68	73	99	296	42	56	49	50	197
Number of sharks	m	15.1	19.5	20.0	13.9	68.5	54.5	61.8	43.6	31.8	47.9
captured per 10^4	f	12.2	13.7	15.6	10.2	12.9	21.8	40.0	45.4	13.6	30.2
metre of main-line	m & f	27.3	33.2	35.6	24.1	30.1	76.4	101.8	89.1	45.5	78.2
Number of sharks	m	35.1	44.2	45.9	31.2	39.1	166.8	187.3	132.6	100.7	146.9
captured per 10^5	f	28.3	31.0	35.8	23.0	29.5	66.7	121.2	138.2	43.2	92.3
metre-h of main-line	m & f	63.4	75.2	81.7	54.3	68.7	233.5	308.5	270.8	143.8	239.2
Number of sharks	m	15.1	19.5	20.0	27.8	20.6	27.3	30.1	21.8	31.8	28.0
captured per 10^3	f	12.2	13.7	15.6	20.5	15.5	10.9	20.0	22.7	13.6	16.8
hook-lift	m & f	27.3	33.2	35.6	48.3	36.1	38.2	50.9	44.5	45.5	44.8
Number of sharks	m	35.1	44.2	45.9	62.5	47.1	83.4	93.7	66.3	100.7	86.0
captured per 10^4	f	28.3	31.0	35.8	46.0	35.4	33.4	60.6	69.1	43.2	51.7
hook-hour	m & f	63.4	75.2	81.7	108.5	82.4	116.8	154.3	135.4	143.8	137.8

Table 3.1(1a). Number of sharks caught during Cruises 10–17.

Species of shark	Cruise	Shots	Number of sharks caught										
			5-inch		6-inch		7-inch		8-inch		Total		
			f	m	f	m	f	m	f	m	f	m	m & f
Gummy shark	10	14	55	68	21	30	10	8	4	0	90	106	196
	11	16	9	32	15	9	6	10	16	4	46	55	101
	12	10	16	23	9	11	0	4	1	1	26	39	65
	13	13	15	11	13	8	10	11	8	2	46	32	78
	14	19	155	144	83	70	19	22	19	7	276	243	519
	15	12	80	17	77	4	44	4	27	3	228	38	266
	16	6	4	13	2	3	0	1	0	0	6	17	23
	17	6	2	1	1	2	2	2	1	0	6	5	11
	Total	96	336	309	221	147	91	62	76	17	724	535	1259
School shark	10	14	83	82	22	22	4	1	2	1	111	106	217
	11	16	0	0	0	1	0	2	0	0	0	3	3
	12	10	6	8	19	9	17	6	4	2	46	25	71
	13	13	4	3	3	1	3	1	0	1	10	6	16
	14	19	22	24	11	17	1	9	3	14	37	64	101
	15	12	5	10	15	7	4	1	4	2	28	20	48
	16	6	0	1	1	2	0	2	1	1	2	6	8
	17	6	20	14	18	19	22	22	11	5	71	60	131
	Total	96	140	142	89	78	51	44	25	26	305	290	595

Table 3.1(1b). Number of sharks caught during Cruises 10–17.

Species of shark	Cruise	Shots	Number of sharks caught										
			5-inch		6-inch		7-inch		8-inch		Total		
			f	m	f	m	f	m	f	m	f	m	m & f
Common saw shark	10	14	6	19	4	15	3	2	3	1	16	37	53
	11	16	0	0	0	0	0	0	0	0	0	0	0
	12	10	25	42	23	23	22	9	7	9	77	83	160
	13	13	2	1	1	0	2	0	0	0	5	1	6
	14	19	12	22	9	10	4	4	6	0	31	36	67
	15	12	4	6	2	3	1	0	4	0	11	9	20
	16	6	14	26	6	11	5	1	3	5	28	43	71
	17	6	2	0	1	0	1	1	2	1	6	2	8
	Total	96	65	116	46	62	38	17	25	16	174	211	385
Southern saw shark	10	14	2	30	2	6	6	4	5	4	15	44	59
	11	16	0	0	0	0	0	0	0	0	0	0	0
	12	10	3	8	3	2	0	1	0	0	6	11	17
	13	13	3	4	0	1	0	1	0	0	3	6	9
	14	19	10	15	6	9	2	5	2	0	20	29	49
	15	12	0	0	2	0	0	0	1	2	3	2	5
	16	6	3	6	2	1	0	2	0	0	5	9	14
	17	6	2	1	0	0	0	0	1	0	3	1	4
	Total	96	23	64	15	19	8	13	9	6	55	102	157
Elephant fish	10	14	2	5	2	4	8	19	4	2	16	30	46
	11	16	0	0	1	1	0	0	0	3	1	4	5
	12	10	0	0	0	1	0	0	0	0	0	1	1
	13	13	1	0	0	0	1	0	0	0	2	0	2
	14	19	0	75	1	38	0	8	1	12	2	133	135
	15	12	0	0	0	0	0	0	0	0	0	0	0
	16	6	0	0	0	0	0	0	0	0	0	0	0
	17	6	0	0	0	0	0	0	0	0	0	0	0
	Total	96	3	80	4	44	9	27	5	17	21	168	189

Table 3.1(2a). Proportion of gummy shark mature from macroscopic inspection of testes.

Length class (mm)	Number of sharks					Proportion mature
	Immature			Mature	Total	
	Stage 1	Stage 2	Total	Stage 3		
<600	0	0	0	0	0	0.0000
600–699	8	0	8	0	8	0.0000
700–799	30	1	31	0	31	0.0000
800–899	55	1	60	2	62	0.0323
900–999	41	16	57	3	60	0.0500
1000–1099	21	15	36	25	61	0.4100
1100–1199	0	13	13	45	58	0.7759
1200–1299	0	1	1	31	32	0.9688
1300–1399	0	0	0	11	11	0.7143
1400–1499	0	0	0	3	3	1.0000
1500–1599	0	0	0	0	0	–
>1600	0	0	0	0	0	–
Total	159	47	206	120	218	

Table 3.1(2b). Proportion of school shark mature from macroscopic inspection of testes.

Length class (mm)	Number of sharks					Proportion mature
	Immature			Mature	Total	
	Stage 1	Stage 2	Total	Stage 3		
<600	1	0	1	0	1	0.0000
600-699	10	0	10	0	10	0.0000
700-799	20	0	20	0	20	0.0000
800-899	50	0	50	0	50	0.0000
900-999	36	0	36	0	36	0.0000
1000-1099	15	0	15	1	16	0.0625
1100-1199	14	1	15	0	15	0.0000
1200-1299	10	3	13	6	19	0.3158
1300-1399	2	4	6	15	21	0.7143
1400-1499	0	0	0	15	15	1.0000
1500-1599	0	0	0	14	14	1.0000
>1600	0	0	0	1	1	1.0000
Total	158	8	166	52	218	

Table 3.1(3a). Proportion of gummy shark mature from macroscopic inspection of seminal vesicles

Length class (mm)	Number of sharks					Proportion mature
	Immature	Mature			Total	
	Stage 1	Stage 2	Stage 3	Total		
<600	0	0	0	0	0	0.0000
600-699	8	0	0	0	8	0.0000
700-799	32	0	0	0	32	0.0000
800-899	57	3	0	3	60	0.0500
900-999	52	5	3	8	60	0.1333
1000-1099	29	29	5	34	63	0.5397
1100-1199	5	48	3	51	56	0.9107
1200-1299	0	30	1	31	31	1.0000
1300-1399	0	9	0	9	9	1.0000
1400-1499	0	3	0	3	3	1.0000
1500-1599	0	0	0	0	0	–
>1600	0	0	0	0	0	–
Total	183	127	12	139	322	–

Table 3.1(3b). Proportion of school shark mature from macroscopic inspection of seminal vesicles.

Length class (mm)	Number of sharks					Proportion mature
	Immature	Mature			Total	
	Stage 1	Stage 2	Stage 3	Total		
<600	1	0	0	0	1	0.0000
600-699	10	0	0	0	10	0.0000
700-799	20	0	0	0	20	0.0000
800-899	52	0	0	0	52	0.0000
900-999	36	0	0	0	36	0.0000
1000-1099	15	1	0	1	16	0.0625
1100-1199	15	0	0	0	15	0.0000
1200-1299	8	8	0	8	16	0.5000
1300-1399	1	19	1	20	21	0.9524
1400-1499	0	15	0	15	15	1.0000
1500-1599	0	15	0	15	15	1.0000
>1600	0	1	0	1	1	1.0000
Total	158	59	1	60	218	–

Table 3.1(4a). Number of sharks with partly of 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 with spent seminal vesc.
	Stage 2	Stage 3	Total	
Jan-Feb	nd	nd	nd	–
Mar-Apr	77	8	85	0.0941
May-Jun	6	2	8	0.2500
Jul-Aug	17	2	19	0.1053
Sep-Oct	13	0	13	0.0000
Nov-Dec	12	0	12	0.0000

Table 3.1(4b). Number of sharks with partly of completely filled seminal vesicles (Stage 2) and number and proportion of sharks with spent cominal vesicles (Stage 3) in each 2-month period of the year from macroscopic inspection for male school shark.

Period of year	Number of sharks			Proportion with spent seminal vesc.
	Stage 2	Stage 3	Total	
Jan-Feb	nd	nd	nd	–
Mar-Apr	10	0	10	0.0000
May-Jun	29	0	29	0.0000
Jul-Aug	1	0	1	0.0000
Sep-Oct	17	0	17	0.0000
Nov-Dec	2	0	2	0.0000

Table 3.1(5a). 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 sharks			Proportion mature with vesicles $> \frac{1}{2}$ full
	Seminal vesicles		Total	
	$< \frac{1}{2}$ full	$> \frac{1}{2}$ full		
Jan-Feb	nd	nd	nd	–
Mar-Apr	28	57	85	0.6706
May-Jun	3	6	9	0.6667
Jul-Aug	7	12	19	0.6316
Sep-Oct	2	11	13	0.8462
Nov-Dec	3	9	12	0.7500

3.1(5b). 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 school shark.

Period of year	Number of sharks			Proportion mature with vesicles $> \frac{1}{2}$ full
	Seminal vesicles $< \frac{1}{2}$ full	Seminal vesicles $> \frac{1}{2}$ full	Total	
Jan-Feb	nd	nd	nd	–
Mar-Apr	5	5	10	0.5000
May-Jun	3	26	29	0.8966
Jul-Aug	0	2	2	1.0000
Sep-Oct	1	16	17	0.9412
Nov-Dec	1	1	2	0.5000

Table 3.1(6a). Number of female gummy sharks with each uterus condition index.

Length class (mm)	No of sharks with each uterus condition index						
	1	2	3	4	5	6	Total
<800	31	20	0	0	0	0	51
800-899	15	64	2	0	0	0	81
900-999	7	76	1	0	1	0	85
1000-1099	5	86	2	1	1	0	95
1100-1199	2	55	15	1	2	1	74
1200-1299	0	24	37	3	0	0	64
1300-1399	0	1	10	2	15	3	31
1400-1499	0	0	1	0	10	4	15
1500-1599	0	0	0	0	6	2	8
>1600	0	0	0	0	2	3	5
Total	58	326	68	7	37	13	509

Table 3.1(6b). Number of female school sharks with each uterus condition index.

Length class (mm)	No of sharks with each uterus condition index						
	1	2	3	4	5	6	Total
<800	16	17	0	0	0	0	33
800-899	41	6	0	0	0	0	19
900-999	21	18	0	0	0	0	38
1000-1099	15	15	0	0	0	0	30
1100-1199	2	19	0	0	0	0	21
1200-1299	1	21	0	0	0	0	22
1300-1399	0	22	0	0	0	0	22
1400-1499	0	4	9	0	1	2	16
1500-1599	0	0	4	0	1	7	12
1600-1699	0	0					
>1700	0	0	1	0	0	4	5
Total	96	120	14	0	2	13	218

Fig. 3.1(1) Fishing sites for population sampling Cruises 10 – 17 during Feb 1986 – Apr 1987.

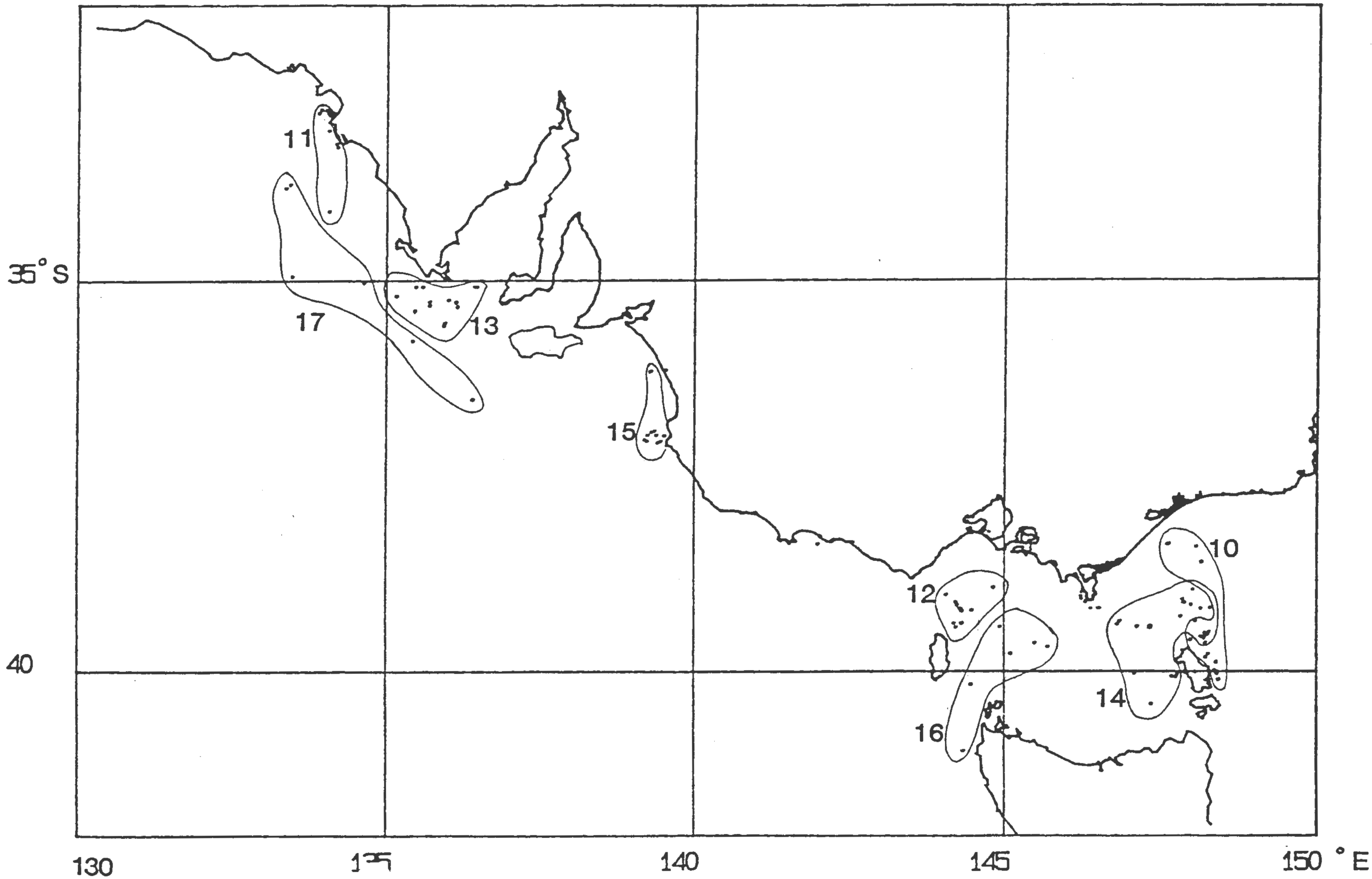


Fig. 3.1(2a) Gummy shark - Bass Strait

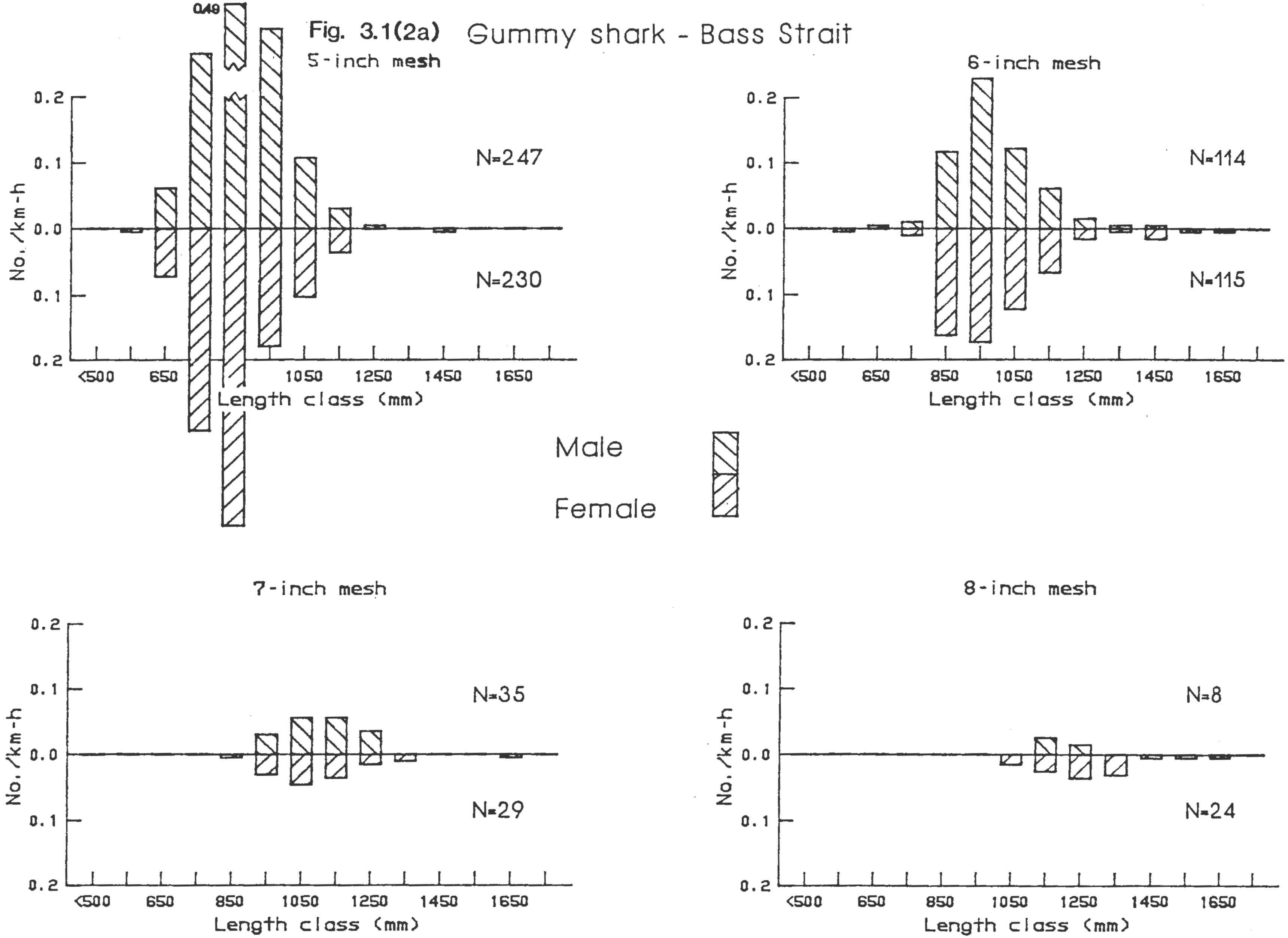


Fig. 3.1(2c) School shark - South Australia

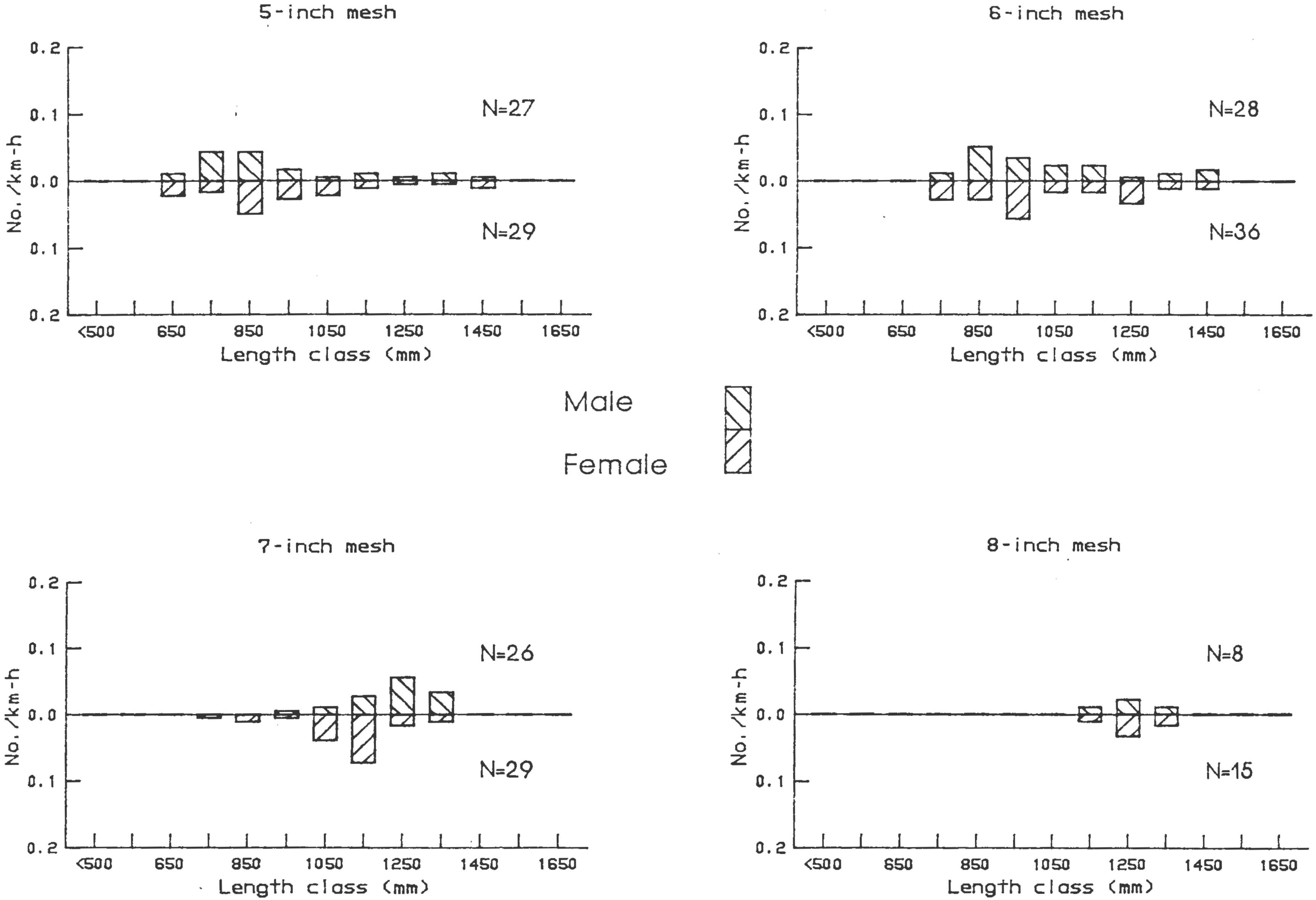
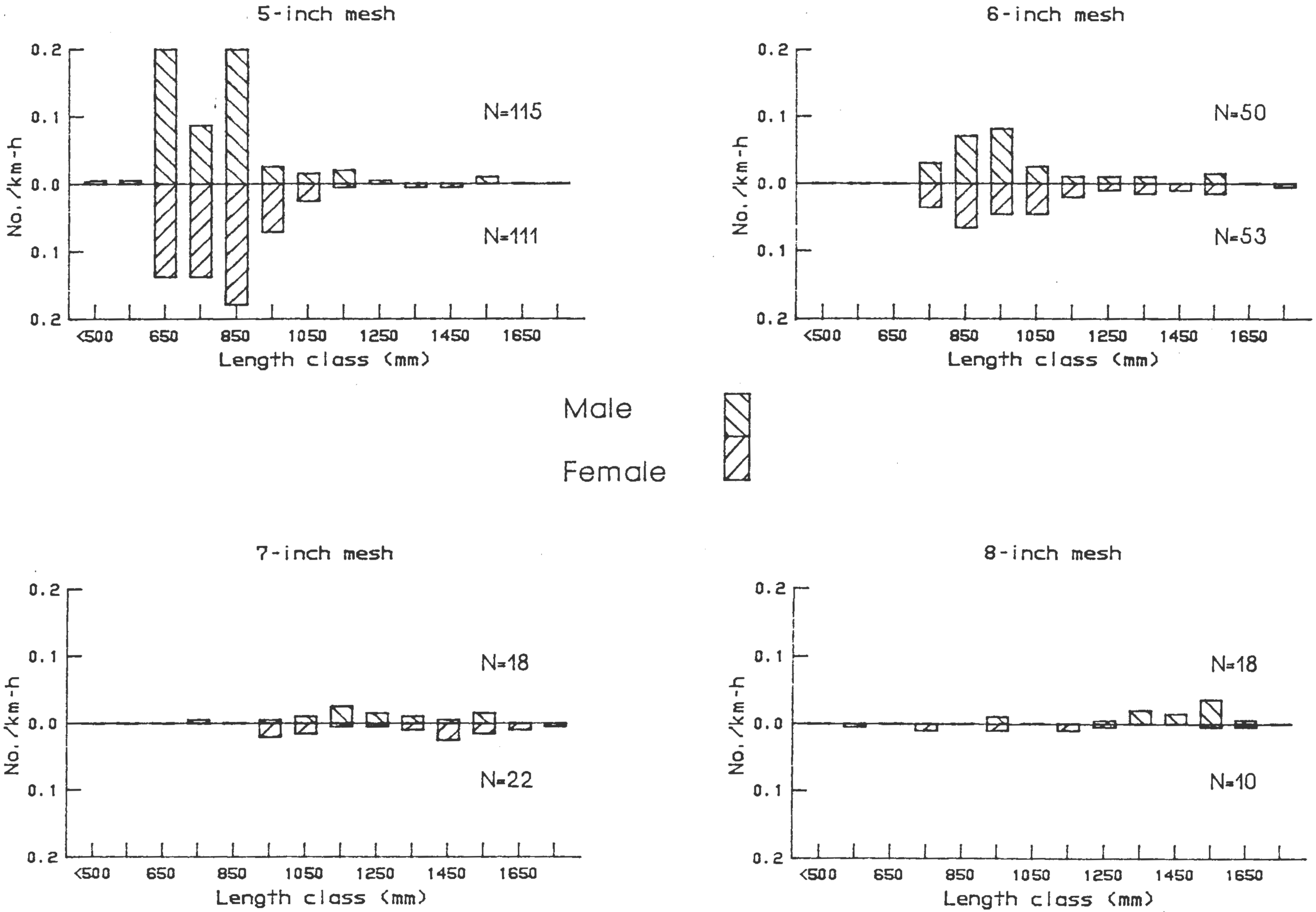


Fig. 3.1(2d) School shark - Bass Strait



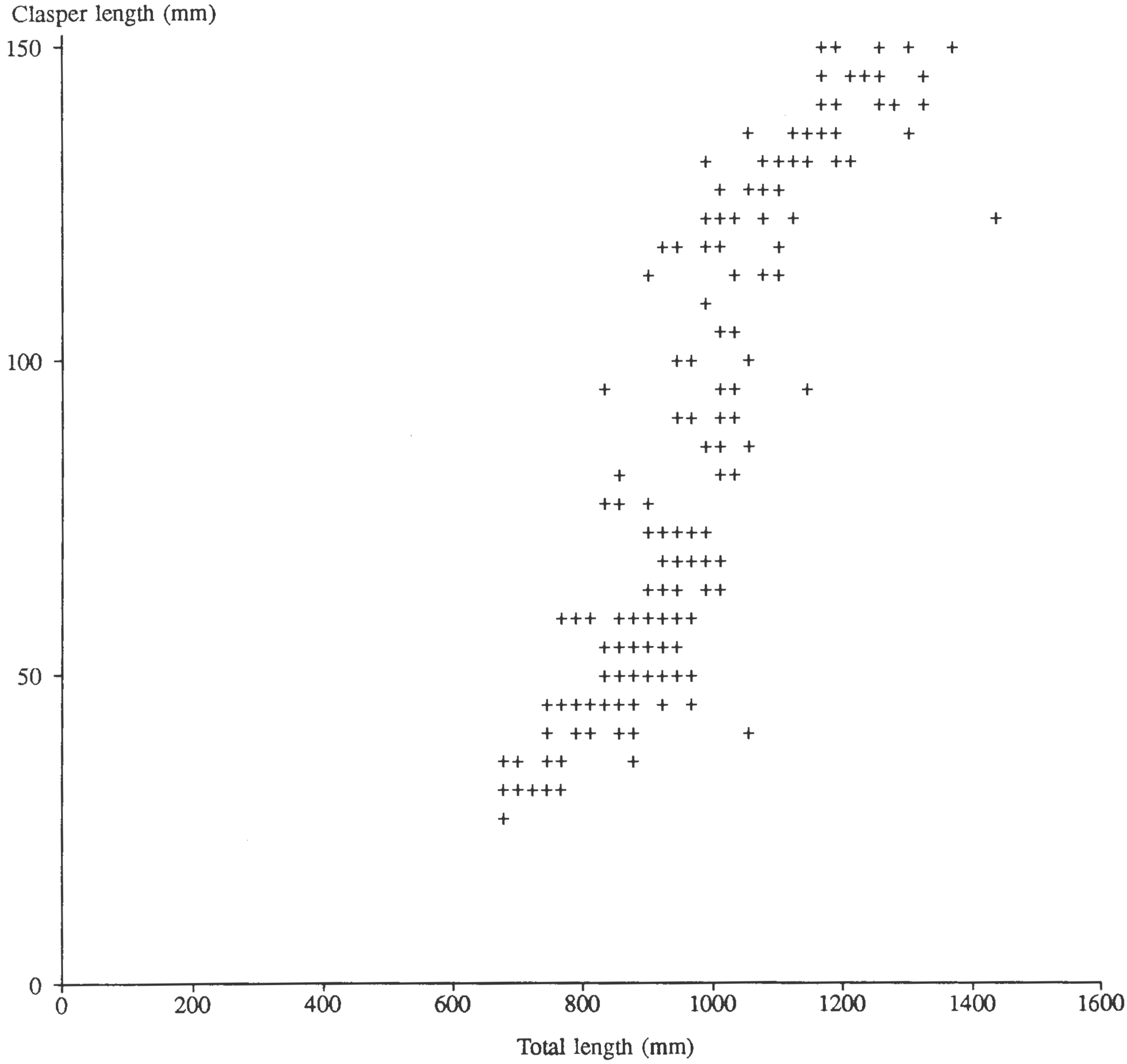


Fig. 3.1(3a). Scattergram of clasper length against total length of male gummy shark

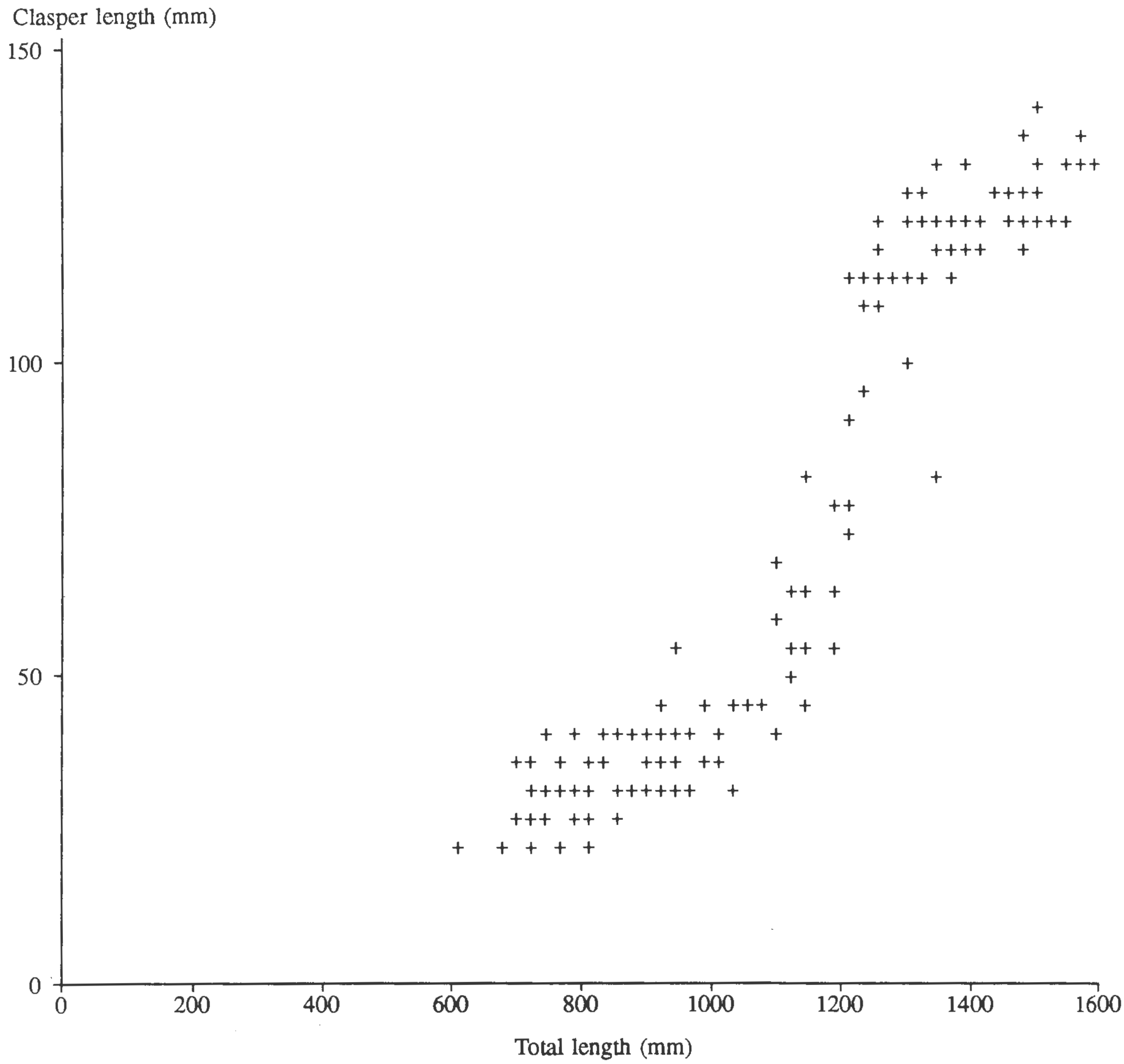


Fig. 3.1(3b). Scattergram of clasper length against total length of male school sharks.

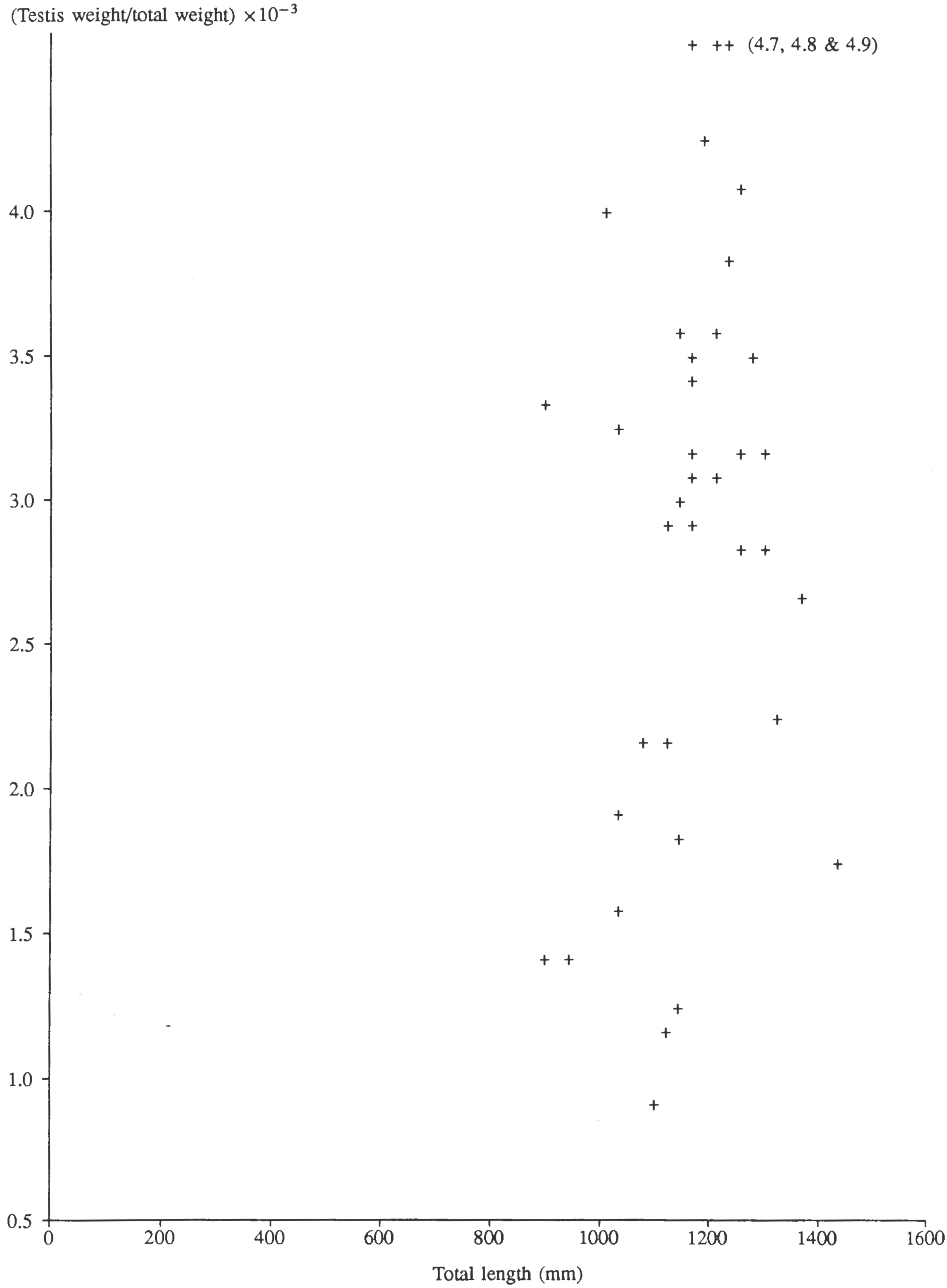


Fig. 3.1(4a). Scattergram of testis weight/total weight against total length of male gummy sharks.

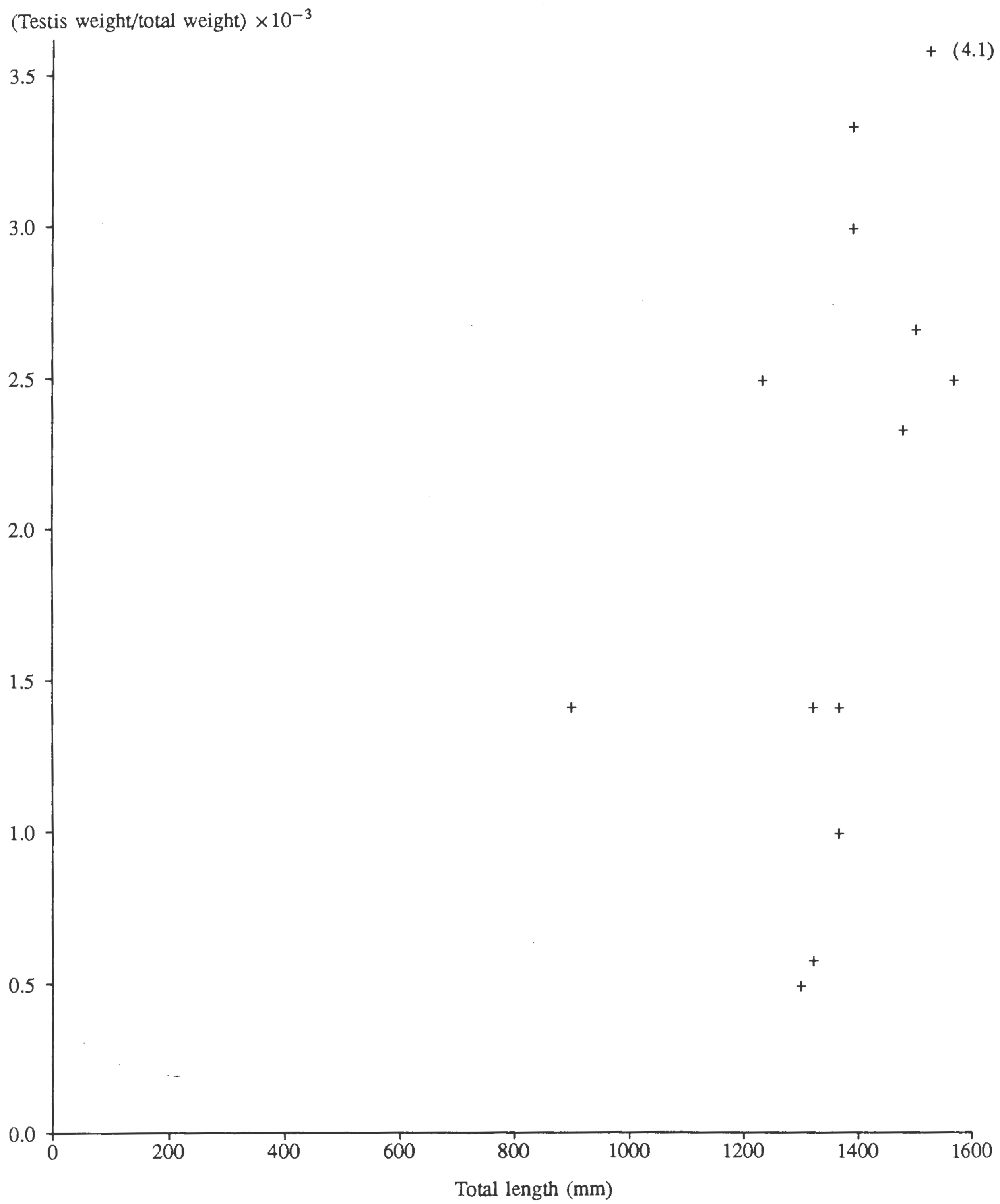


Fig. 3.1(4b). Scattergram of clasper length against total length of male school sharks.