FAO Fisheries Synopsis No. 139
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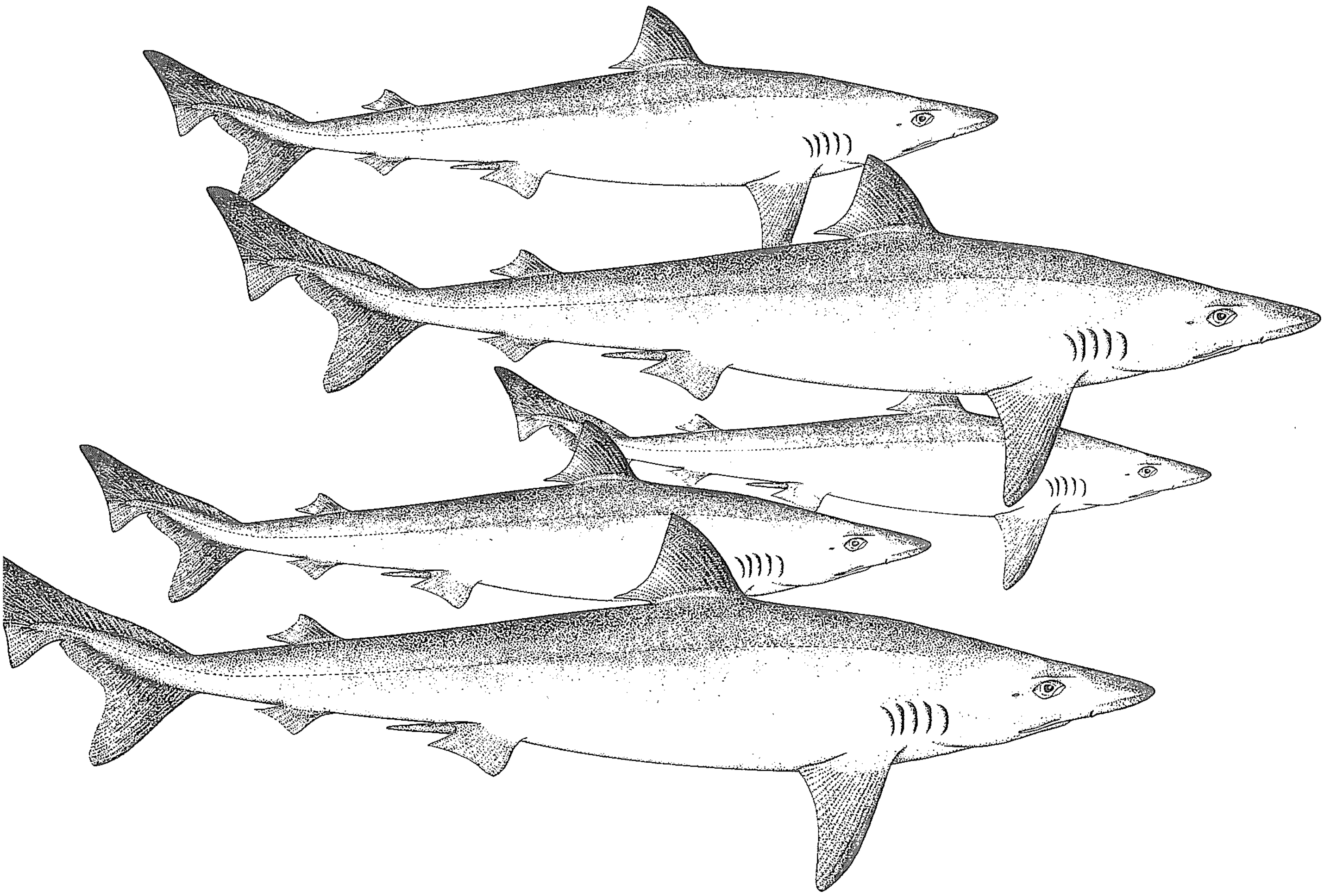
FIR/S139
SAST - School shark - 1,08(04)011,04

SYNOPSIS OF BIOLOGICAL DATA ON THE SCHOOL SHARK
Galeorhinus australis (Macleay 1881)



FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

SYNOPSIS OF BIOLOGICAL DATA ON THE SCHOOL SHARK
Galeorhinus australis (Macleay 1881)

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome 1984

M-43

ISBN 92-5-102085-X

PREPARATION OF THIS SYNOPSIS

The author's original studies on school shark were carried out while being a Senior Research Scientist with the CSIRO, Division of Fisheries and Oceanography, Cronulla, New South Wales, and continued during his service as Director of the Department of Fisheries and Fauna Conservation, South Australia.

The CSIRO Editorial and Publishing Service kindly granted permission to reproduce from the Australian Journal of Marine and Freshwater Research, Volume 5(3), 1954, synopsis Figures 2-6, 8, 14-22, from Volume 10(2), 1959, synopsis Figure 23, and from Volume 30, 1979, synopsis Figures 7 and 24.

Very recently, the scientific name of the school shark has been found to be Galeorhinus galeus, and this name will be used in the forthcoming FAO species catalogue, Sharks of the World (FAO Fish. Syn. 125, Vol. 4). Unfortunately, it was too late to include the new name in this publication.

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ABSTRACT

This synopsis consolidates all the available published data on the biology, growth, migration and population dynamics of an elasmobranch species which has been exploited for food for nearly 60 years in southeastern Australian waters. This shark species is also fished commercially in New Zealand.

Tagging results show that there is an homogeneous stock of low fecundity, slow maturing and long-lived school sharks which can live to, at least, 53 years of age in southeastern Australian waters. Adult school sharks accumulate naturally occurring mercury in their flesh in excess of legal maximum concentrations.

There is no uniform management strategy by the five fisheries authorities for the widely ranging stock of school sharks in southeastern Australian waters.

Distribution:

Author
FAO Fisheries Department
FAO Regional Fisheries Officers
Regional Fisheries Councils and Commissions
Selector SM

For bibliographic purposes this document should be cited as follows:

Olsen, A.M., 1984 Synopsis of biological data on the school shark, Galeorhinus australis (Macleay 1881). FAO Fish.Synop., (139):42 p.

CONTENTS

1. IDENTITY

1.1 Nomenclature

1.1.1 Valid name

Galeorhinus australis (Macleay)*. Proc. Linn.Soc.N.S.W., 6(2), 1881, 354-5.

1.1.2 Objective synonymy

Galeus australis Macleay, 1881.

1.2 Taxonomy

1.2.1 Affinities

- Suprageneric

Phylum Vertebrata
 Subphylum Craniata
  Superclass Gnathostomata
   Class Elasmobranchii
    Subclass Selachii
     Order Lamniformes
      Suborder Scyliorhinoidei
       Family Carcharhinidae

- Generic

Genus Galeorhinus Blainville, 1816. Bull. Soc.Philom., Paris, 8:121.

Genotype Squalus galeus (Linnaeus), 1758:234.

The generic concept adopted here is compounded from Fowler, H.W. (1941) and Compagno, L.J.V. (1970).

Body moderately long, slender, body cavity about 1/2 total length.

Head moderate, over 1/5 of total length in adults, snout obtuse, depressed. Eyes low on sides of head, orbit almost twice as long as high, with nictitating membrane present, internal in adults and subadults. Mouth wide, crescentic, with short labial fold on each jaw. Nostrils, small and separated, are closer to mouth than snout tip. Teeth alike in two jaws, triangular, outwardly inclined, notched with serrations on outer edges.

Last gill opening above pectoral. Spiracle small, behind eye. First dorsal above space between pectorals and ventrals; second dorsal above anal. Caudal rather short, with single notch; subcaudal lobe present, not very remote from notch behind subcaudal. No pit at caudal base. Large to moderate or small, smooth sharks, known as topes, feeding largely on fishes and found in most warm seas. Young about 20-40 in summer.

- Specific (Figure 1)

McCulloch, A.R., Proc.Linn.Soc.N.S.W., 46(4), 1921, 457-72, pl. 37, Figures 5-7. Type specimen UANM No. 39972, Australian Museum. Total length 1 420 mm. Head and body skinned out. Type locality: Port Jackson, N.S.W. (Macleay, W., 1881).

- Diagnosis

Galeorhinus australis: description compounded from Fowler, H.W., Bull.U.S.Nat.Mus., 100(13), 1941, 188-90 and McCulloch, A.R., Proc.Linn.Soc. N.S.W., 46(4), 1921, 457-72, pl. 37, Figures 5-7.

Body: Moderately long, slender.

Head: About 5.5 in total length.

Snout: Rather attenuate, obtusely pointed and depressed, translucent at tip; preoral length 2.4 in length of head to first gill opening. Lateral edges anterior to the nostrils are moderately sharp.

Nostrils: Much nearer upper lip than end of snout, space between 1.44 in distance from tip of snout; anterior margin of each has a small lobule projecting backward. Internarial 1.3 in dentary width; front nasal valve with two short points.

Mouth: Crescentic, anterior margin of mouth in advance of eye; width of mouth equal to distance from end of snout. A longer upper and a shorter lower labial fold present at each angle. Dentary width 2.75 in head length.

Eye: External nictitating membrane present in juveniles, internal in adults and subadults. Eye length about 3 in distance from end of snout; skin above eye forms an imperfect fold.

Spiracle: A small slit located about 0.5 eye length behind eye.

Gill openings: Equidistant, subequal, fourth widest and equal to eye length, fifth is smallest, both openings located above and behind insertion of pectoral base.

Teeth: About three series of functional teeth in upper jaw, teeth are smallest anteriorly and largest laterally. Centre cusp of each lateral tooth is oblique, there is a sharper angle at junction with basal portion posteriorly than anteriorly; both anterior and posterior edges of base are serrated, but former less strongly so than latter. Teeth of lower jaw are similar to those of upper, but are rather less strongly serrated.

* Now Galeorhinus galeus (see note under "Preparation of this Synopsis")

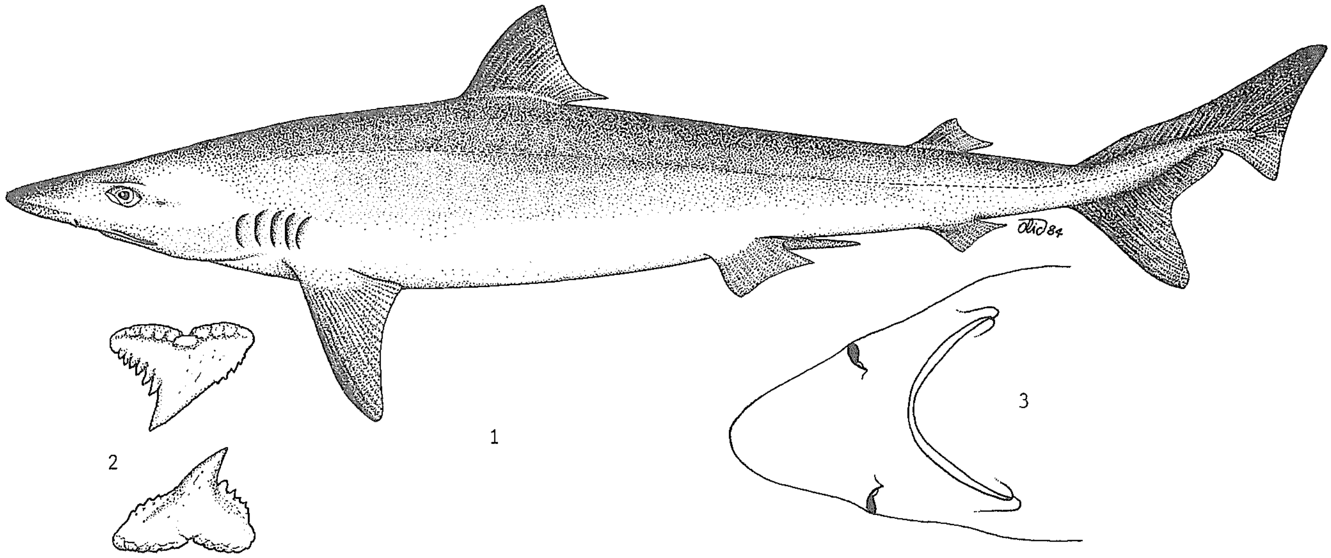

Figure 1 (1) School shark Galeorhinus australis (Macleay), lateral view
(2) Upper and lower teeth of the same specimen
(3) Under surface of the head of the same specimen

Scales: Tricarinate, with three short points of which median longest.

First dorsal fin: Equidistant from anterior bases of pectoral and ventral fins; upper angle is obtusely pointed, and posterior angle is produced into a sharp point. First dorsal origin behind end of pectoral base, front edge 1.8 in head, hind lobe ends in slender point.

Second dorsal fin: Origin slightly before anal origin; second dorsal and anal are small and subequal in size and shape.

Anal fin: Commences below middle of second dorsal; front edge 4.8 in head, hind lobe ends in a slender point behind.

Pectoral fin: Obtusely pointed and, when laid back, tip almost reaches position below vertical from middle of first dorsal fin.

Caudal fin: Longer than head, subcaudal lobe half fin length and usually with well developed subcaudal lobe giving a characteristic double-tailed appearance. No pits on caudal peduncle.

Colour: Light grey to grey-brown on back and upper surfaces, paler to whitish below. Fins similar colour to upper parts.

Ovoviviparous producing up to 41 living young.

Figure 1 shows McCulloch's (1921) illustration of this species.

– Subjective synonymy

Squalus rhinophanes	Code (Rosa Jr., 1965) Area of occurrence (Section 2.1)
1807. Peron, F., an inadequate description. In 1807 Peron caught two sharks in Adventure Bay, Tasmania (617), and wrote: "Deux Squales de 19 à 25 décimètres de longueur [6 à 8 pieds], furent les seuls poissons nouveaux que j'y pus découvrir: l'un d'eux (Squalus rhinophanes, N.) est remarquable par la transparence extraordinaire de son long museau;" This was considered an inadequate description.	Adventure Bay, Tasmania (617)
Galeus sp.	
1873. McDonald, J., recorded the presence of a shark like the North Atlantic tope and gave an inadequate description.	Flinders Island, (Tasmania 4.9.3)
Galeus canis	
1865. Dumeril, A.M.A., recorded this species but no description given.	Coasts of New Holland (610)

1870. Gunther, A., catalogued but did not describe this species, specimens reported to come from Antarctic Ocean and Indian Ocean, and young from Tasmania.	Tasmania (617)
1872. Klunzinger, C.B., recorded species from new location. No description.	Murray River, South Australia (613)
1872. Castelnau, F. de, recorded species from new location.	Hobsons Bay, Victoria (614)
1872. Hector, J., recorded species from New Zealand but gave no description.	New Zealand (630)
1872. Hutton, F.W., gave a brief description.	New Zealand (630)
1882. Johnston, R.M., gave a brief, but inadequate description, referring it to *Galeus canis* in his catalogue of species.	Tasmania (617)

Galeus australis

1880. Ramsay, E.P., species named, but no description *nom. nudum.*	Port Jackson, New South Wales (615)
1881. Macleay, W., complete description given with types lodged in Macleay Museum, Sydney. Type locality.	Port Jackson, New South Wales (615)
1882. McCoy, W., description given with figures.	Hobsons Bay, Victoria (614)
1889. Ogilby, J.D., new locality given only.	North of Pt. Stephens, New South Wales (615)
1908. Ogilby, J.D., new locality given only.	Moreton Bay, Queensland (616)

Galeorhinus australis

1898. Ogilby, J.D., first listed under this species name.	New South Wales (615)
1899. Waite, E.R., listed a new location for this species.	Morna Point, New South Wales (615)
1921. McCulloch, A.R., gave an excellent description and figures.	New South Wales (615)
1929. Young, M.W., recorded an extension of species to Chatham Island. No description.	Chatham Island (637)
1953. Munro, I.S.R., explanation for transfer to genus *Galeorhinus* (incorrectly attributed to A.M. Olsen).	

Notogaleus australis

1931. Whitley, G.P., brief description only for transfer to new genus.

1932. Whitley, G.P., very brief description and reason for genus name change.

1940. Whitley, G.P., description and figures of the school shark are given.

1943. Whitley, G.P., comment made that Peron's brief description (Section 1.2.2) referred to school shark and accordingly claimed *Galeus australis* Macleay as a synonym.

(*Notogaleus rhinophanes* Whitley, 1943 pro *Squalus rhinophanes* Peron, 1807 *species dubia*.)

1945. Whitley, G.P., a brief description of the shark and some of its biology.

1.2.2 Taxonomic status

There is still some confusion about the number of species in the genus *Galeorhinus*. Compagno (1970) believed that the following four species:

G. australis (continental shelf, southern Australia and New Zealand)

G. zygopterus (continental shelf, western America and Canada)

G. chilensis (continental shelf, Chile and Peru)

G. vitaminicus (continental shelf, Uruguay and Brazil) are synonyms of G. galeus "but the validity for this hypothesis cannot be tested at present because of insufficient material" (Compagno, 1970, p. 83)

1.2.3 Subspecies

No data available.

1.2.4 Standard and vernacular names

Country	Standard common name	Vernacular name
Australia	school shark	snapper shark, sharp-tooth shark, pencil shark (W.A.), tope
New Zealand	school shark	tope, school shark

The flesh, as fillets, is marketed under the name of "flake" along with the flesh of other sharks, the main species being:

Furgaleus ventralis (Whitley)	whiskery shark
Pristiophorus cirratus (Latham)	common sawshark
Mustelus antarcticus (Gunther)	gummy shark
Pristiophorus nudipinnis (Gunther)	southern sawshark

1.3 Morphology

1.3.1 External morphology

Snout rather long, equal to width of mouth, anteriorly almost translucent. Teeth acute, coarsely serrated, depressed. Gill slits small. Spiracle minute, nictitating membrane present internal in adults and subadults. First dorsal fin equidistant from pectoral and ventral; second dorsal and anal fins subequal; ventral originating well behind middle of length. A characteristic "double-tailed" appearance of caudal fin (Whitley, 1940). See Section 1.2.1, Specific diagnosis and Figure 1.

- Proportional measurements

See Section 3.2.3, Figure 6.

1.3.2 Cytomorphology

No information.

1.3.3 Protein specificity

No information.

2. DISTRIBUTION

2.1 Total Area

School sharks have been recorded from Australian coastal waters south of latitude 27°S, coastal waters of New Zealand and Chatham Island, and Lord Howe Island (Figure 2 and Table I).

2.2 Differential Distribution

2.2.1 Juveniles - southeastern Australian waters (613, 614, 615 and 617)

- Areas of occurrence and seasonal variations

Newborn sharks ("pups") and juveniles up to 3+ years of age are found in summer months (December-March) in marine dominated environments of shallow bays and estuaries in Victoria and Tasmania (Olsen, 1954, p. 393).

During the colder winter months of July-September, juveniles (1-2+ years) may be found in suitable deep coastal bays and inshore waters of Victoria, Tasmania and South Australia.

There is a generalized movement of older juvenile sharks from "nursery" areas into the waters of eastern Bass Strait (4.9.3) (Olsen, 1954, pp. 384-6).

There are no data for western Australia (612), or New Zealand waters (631).

A similar distribution of 0-1+ juveniles to that in southeastern Australia occur in inshore waters of North Island of New Zealand (Garrick and Paul, 1975).

2.2.2 Adults - southeastern Australian waters (613, 614, 615 and 617)

- Areas of occurrence and seasonal and annual variations

Adults occur in schools throughout the distribution range of the species, and the schools tend to be predominantly male or female only, except in May-June, when mixing takes place in deep waters on edge of continental shelf.

Seasonal: Mostly adults of both sexes present in larger numbers in South Australian and

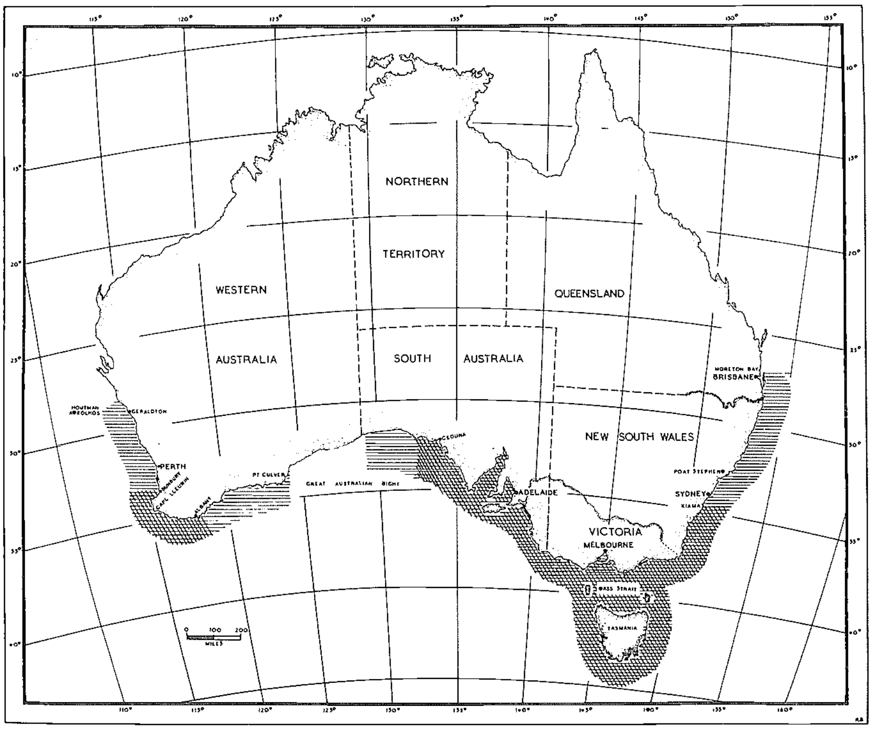

Figure 2 Distribution of G. australis and limits of the existing school shark fishery in Australian waters

Table I

Areas of occurrence of school shark

Land areas	Code (Rosa Jr., 1965)
Western Australia	612
South Australia	613
Victoria	614
New South Wales	615
Queensland	(rare) 616
Tasmania	617
New Zealand	630
Chatham Island	637
Lord Howe Island	615
Water areas	
Southern Ocean, Great Australian Bight, Tasman Sea, Southwestern Pacific Ocean	P.S.E.
Eastern Bass Strait	4.9.3
Western Bass Strait	1.6.3

New South Wales waters in colder months (July-September); less dense populations in southern waters of Victoria and Tasmania in those winter months (Olsen, 1954, 1959).

Annual: Full-term gravid females move into preferred "nursery" areas in protected bays and estuaries of Victoria and Tasmania in November and December to release their young (Olsen, 1954).

Studies on school sharks in New Zealand waters (630) show that only gravid females move into nursery grounds in November-December to release their young, whereas males always remain offshore (Garrick and Paul, 1975).

2.3 Determinants of Distribution Changes

2.3.1 Effects of ecological determinants

- Juveniles

Shelter: In channels of estuaries and open bays of low energy regimes with subtidal flats of aquatic angiosperm ecosystems (Zosteraceae) of Tasmania and Victoria.

Tides: Tidal movements in channels influence feeding behaviour, i.e., flood tides induce active feeding in one bay, whereas ebb-tides induce active feeding in other bays (Olsen, 1954).

Salinity and water chemistry: Juveniles show a tolerance to a range of salinities and phosphate phosphorus in "nursery" areas.

Pittwater, Tasmania

1949

December: 33.93°/oo
January: 35.93°/oo

1950

February: 36.35°/oo
March: -
April: 35.79°/oo

1951

December: -
January: 35.41°/oo
February: -
March: 36.91°/oo
April: 34.25°/oo

Phosphate phosphorus: December 1949 - April 1950 4-31 ug/l
Nitrate nitrogen: February - April 1950 2-3 ug/l

- Adults

Temperatures: Movements of both sexes to edge of continental shelf and/or migration to more northern latitudes of South Australia and New South Wales coincide with approach of winter months and falling temperatures of inshore bottom waters in Tasmania and southern Victoria.

Reversal of migration pattern of both sexes in the spring months coincides with rise in shelf bottom-water temperatures in southern latitudes of Tasmania and Victoria. Full-term gravid females are not found in inshore in Tasmania and Victoria when bottom-water temperatures are below 14°C (Olsen, 1961).

Northward extension of range into Moreton Bay area, Queensland (616) from New South Wales waters (615) in 1908 (Ogilby, 1908) was probably due to a temporary northerly penetration of a cold-water regime.

Depth: Found on continental shelf and continental slope to depth of 600 m (Cowper and Downie, 1957; Smith, 1980).

2.3.2 Behavioural determinants

- Reproductive stimulus: mating response of ovulating females and "running ripe" males to seek areas on edge of continental shelf of Victoria and Tasmania.
- Selection of "nursery" areas by full-term gravid females for birth of young ("pups").
- Feeding: adults congregate in rocky areas or reefs to feed on octopus, or to seek concentrations of bottom feeding fish.

2.4 Hybridization

2.4.1 Hybrids

No information.

3. BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.1.1 Sexuality

Heterosexual: The male is distinguished from the female by the presence of "claspers" which are two rod-like extensions of inner edge of the ventral fins and serve as an intromittent organ. Females have unmodified ventral fins.

3.1.2 Maturity

Age at which sexual maturity is first reached:

Males: Sexually mature at age 8+ years (Olsen, 1954).

Females: Sexually mature at age 10+ years (Olsen, 1954).

Size and weight at sexual maturity: smallest mature male encountered was 120 cm total length, approximately 8.2 kg in total weight; all males over 132 cm total length were mature.

Smallest mature female, based on maximum ova diameter, was 135 cm, approximately 13.3 kg in total weight; smallest gravid female caught was 144.5 cm total length (Olsen, 1954).

3.1.3 Mating

In May-June "running ripe" males and ovulating females migrate to edge of continental shelf, and there is circumstantial evidence that copulation then occurs in these deep waters (Olsen, 1954).

3.1.4 Fertilization

Internal: Male introduces spermatozoa by means of the claspers. The two half channels on the claspers are adpressed to form a canal through which spermatozoa are forced into the cloaca and thence to the oviducts of the female.

3.1.5 Gonads

Males have paired testes extending along dorsal surface of coelomic cavity. The testes vary greatly in size depending on state of maturity, stage of reproductive cycle and time of year.

Females have unpaired large single ovary suspended by a mesentery from anterior dorsal surface of coelomic cavity. Ova of varying diameters present in ovarian tissue. Ovulation appears to occur in May-June period when ova 45-50 mm diameter are present in about only one half of mature females (Olsen, 1954).

3.1.6 Breeding (nativity)

School sharks are ovoviviparous.

- Relation between maternal size and fecundity

Mean maternal length, 155 cm; mean number of full-term young, 28.4; (sample: 33 gravid females, 942 full-term embryos).

The relationship between number of full-term embryos E, and the total length (cm) of female L, is expressed by the following regression equation fitted by least squares method (Figure 3):

$$E = -50.0 + 0.505\ L$$

For each 1.2-5 cm increase in length of the mother the number of "pups" carried increases by one (95% confidence limit)(Olsen, 1954).

Smallest gravid female, 144.5 cm total length, carried 17 "pups". Largest gravid female, 168 cm total length, carried 31 "pups". Female 159 cm total length, carried 41 "pups", greatest number of "pups" recorded from a female (Olsen, 1954).

The relationship between total length (cm) of mother and the mean length of the full-term embryos is shown in Figure 4. The gravid females were caught in Tasmanian waters and mostly in Pittwater (617).

- Natal (birth) season (when young have no external yolk sac present)

	Victoria	Southern Tasmania
Beginning	October	December (early)
Peak	November	December/January
End	December (late)	January (late)

- Natal time of day (release of "pups")

No information.

- Sequence of giving birth to "pups"

No information.

- Factors influencing natal time (relėase of "pups")

Temperature: gravid females carrying full-term embryos do not enter "nursery" areas until bottom-water temperatures are above 14°C. During November-January, preferred bottom-water temperatures occur later at inshore areas in Tasmania

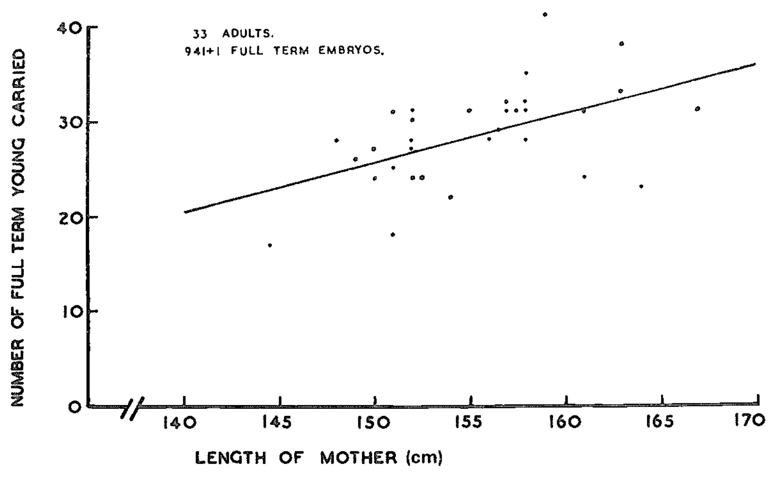

Figure 3 Relationship between the total length of the mother and the number of full-term young carried

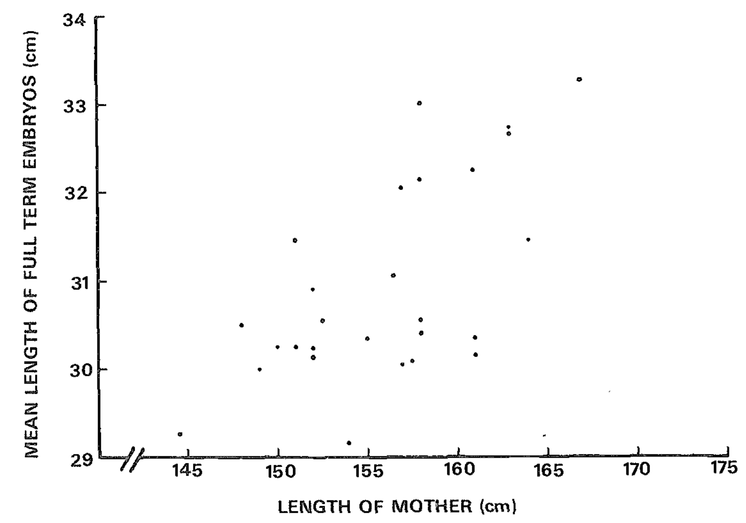

Figure 4 Relationship between total length of mother and the mean length of full-term embryos

than in Victoria, and hence there may be some difference in times of release of "pups" in Tasmanian nursery areas.

- Relation of the time of breeding (release of "pups") to that of related and/or associated species

No information.

- Location and type of nursery areas

Embayments on low energy coastlines and channels in protected bays support populations of preferred food species for newly-born young in Victoria (614), Tasmania (617)(Olsen, 1954) and New Zealand (630)(Garrick and Paul, 1975). No known "nursery" areas occur in South Australia (613).

- Ratio and distribution of sexes on spawning ("nursery") grounds

Only gravid females present (Olsen, 1954; Garrick and Paul, 1975).

- Nature of mating act

No data.

- Induction of spawning (parturition)

Considered to be instinctive and only when young are ready for release. No newly-born "pups" with an external yolk sac present are found in "nursery" areas. All "pups" have umbilical slit closed (Olsen, personal observation).

3.1.7 Spawn (ova and spermatozoa)

Maximum diameter of ova is 50 mm (June). In May-June males are also "running ripe" and schooling of both sexes occurs along areas of continental shelf (Olsen, 1954, Table 5).

3.2 Pre-Adult Phase

3.2.1 Embryonic phase

June: Ova 45-50 cm diameter and seminal fluid was found in necks of two uteri of female 150 cm total length (Olsen, 1954).

July-November: Embryos with external yolk sacks are retained in uteri until parturition; there is an inverse relationship between diameter of yolk sac and length of embryo (Olsen, personal observation).

December: Yolk sac absorbed, umbilical slit closed, embryos fully grown and ready for release.

- Gestation period

von Bertalanffy parameter t_0

- males	1.2545	15-16 months
- females	1.2818	
- combined	1.2669	

However, "since t_0 is a mathematical parameter and unless one is certain that the estimated von Bertalanffy curve also fits the *in utero* growth, it should not be taken as the gestation period" (Grant, Sandland and Olsen, 1979).

On the basis of field observations made on mature females and lengths of embryos in all months throughout southeastern Australian waters over six years, it is believed that the gestation period is six months: June-December. This period is one of the shortest in female elasmobranchs and could be a response to high environmental temperatures (10°-22°C).

Holden (1974) considers "that fish in the intermediate stages of gestation were absent" from catches in the biological study.

- Rates and period of development

Length observations on 941 full-term embryos indicate no difference in size from right and left uteri; length of every fourth embryo decreases by approximately 1 mm from the posterior end of the uterus forwards. No size difference between male and female embryos within mother. Size range of normal full-term embryos varied from 260 to 350 mm, mode 300 mm (Figure 5). Maximum range in lengths of embryos from any mother was 50 mm (Olsen, 1954).

3.2.2 Juvenile phase

- Survival proportions between sexes

Full-term embryos - 54 males to 46 females;

Second year juveniles - 46 males to 54 females (Olsen, 1954, pp.379-80).

- Parental care after birth

None.

A mother, after giving birth to its young, almost immediately heads back for open sea. No indications of cannibalism.

- Time of first feeding

Foraging commences a short time (1-2 days) after birth (Olsen, personal observation).

- Type of feeding

Predator of annelids, crabs and small crustaceans (Olsen, 1954, p. 359).

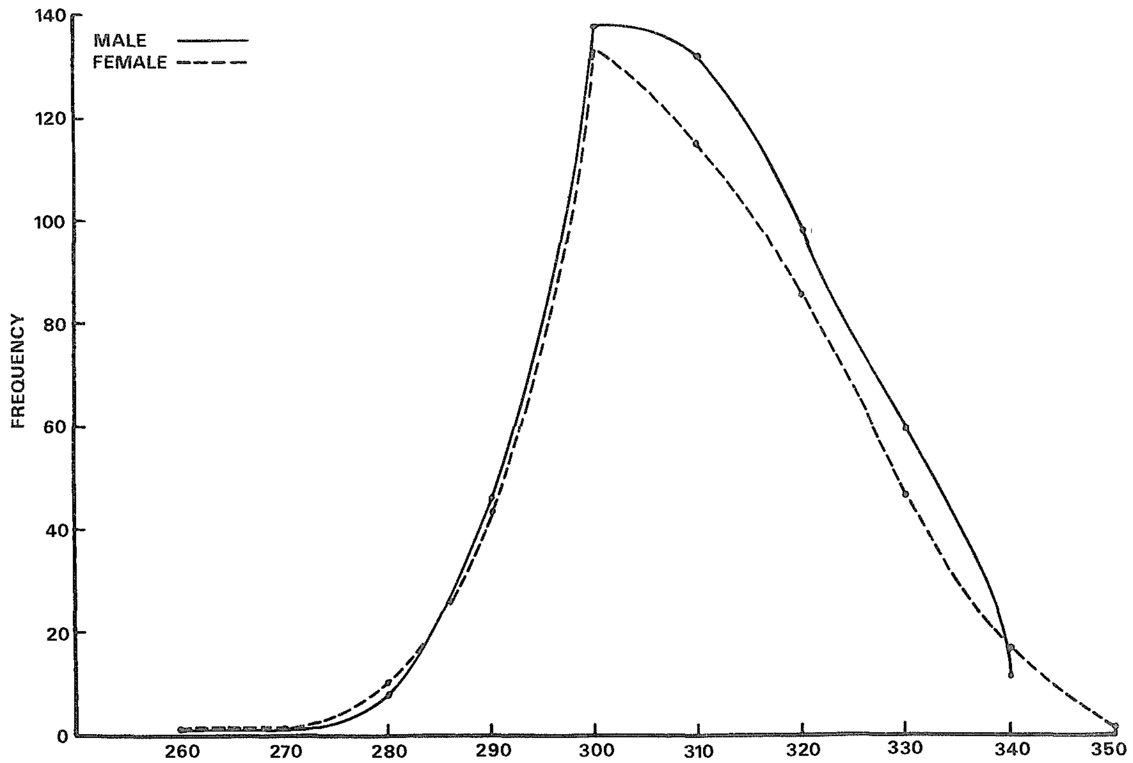

Figure 5 Length frequencies of full-term embryos

3.2.3 Adolescent phase

From an extensive series of partial and total length measurements of whole sharks, it was shown that growth was isometric (Figure 6). From these data regression formulae were calculated (least squares method) for converting partial length measurements of dressed carcases to total lengths.

Regression formulae from:

Tip of nose to ventral base of tail
$Y = 1.2x + 6.3$

Middle of 1st gill slit to tip of tail
$Y = 1.17x + 2.8$

Middle of 5th gill slit to tip of tail
$Y = 1.24x + 3.6$

Middle of 5th gill slit to ventral base of tail
$Y = 1.758x + 1$

Middle of 5th gill slit to subterminal notch of tail
$Y = 1.498x + 2.35$

Y = total length (cm) and x = partial length (cm)(Olsen, 1954).

- Differences from adults in diet and feeding

See Section 3.4.2.

3.3 Adult Phase

3.3.1 Longevity

Average life expectancy: Not known, but will have been reduced following intensified fishing pressure since 1973 on immature school sharks in eastern Bass Strait (see Section 5.4).

Maximum age: In excess of 53 years. The maximum age has been determined from tagging results (see Table II).

3.3.2 Hardiness

- Limits to tolerance to changes in environment

School sharks are fished in waters between Latitudes 33°-44°S and Longitudes 133°-151°E, waters of which are derived from a number of different water masses with salinities ranging from 34.60°/oo to 37.00°/oo and combinations of temperatures ranging from 10° to 22°C.

3.3.3 Competitors

- Juveniles

In "nursery" areas, annelid, crustacean and small teleost prey species are also prey species of following commercial teleosts:

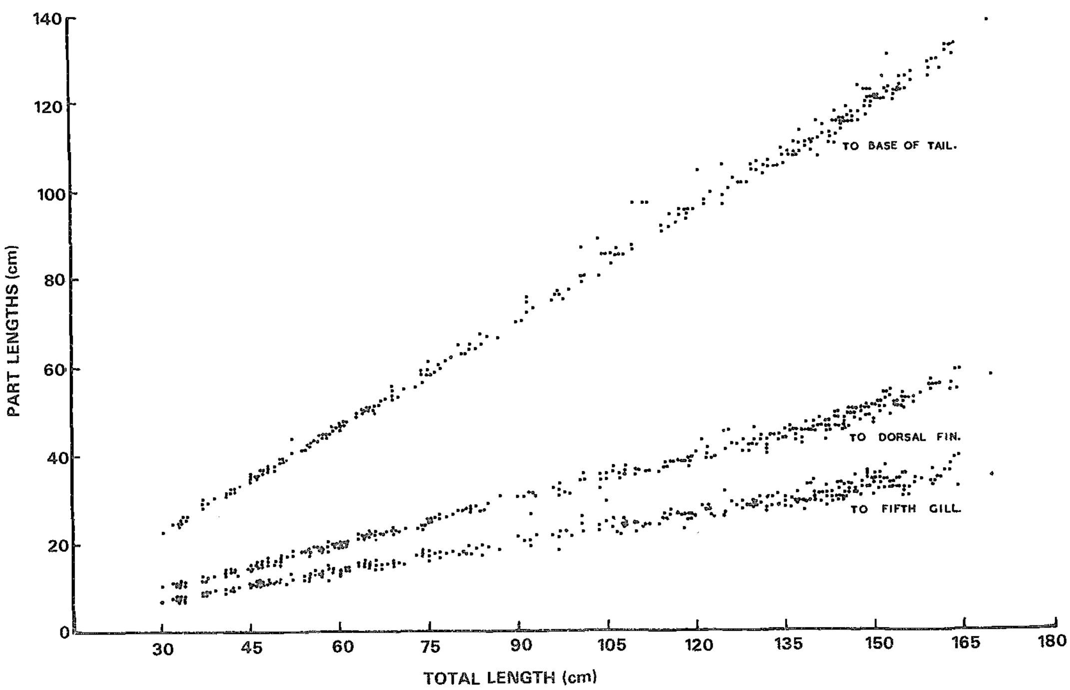

Figure 6 Relationship between total and partial lengths of school sharks

Table II

Age determination from tagging recoveries

Tag No.	Sex	Release		Recapture			
		Total length (cm)	Estimated age (years)	Total length (cm)	Duration of freedom years	months	Estimated age (years)
105	F	154	20	167 (calc.)	33	2	53+
360	M	119	7	149 (calc.)	32	5	39+
1342	M	141.5	12	-	29	4	41+
331	M	136	11	-	27	8	38+
1356	M	139	12	-	26	7	38+
636	M	107	6	147 (calc.)	25	7	31+

The largest school shark measured was 174 cm and would be expected to be older than 53 years

(a) flathead, Trudis bassensis (Cuv. and Val.) and related species.

(b) snapper, Chrysophrus auratus (Bloch and Schneider) and non-commercial leatherjackets (Aluteridae), toad fishes (Tetraodontidae) and box fishes (Ostraciontidae), and some small skates and rays, (Urolophidae and Rajidae).

- Adults

Gummy sharks, Mustelus antarcticus, are competitors in open seas, particularly around reef areas where both species compete for octopus, certain crustacean species and scale fish (Olsen, personal observation).

Gummy sharks are caught on fishing grounds where fishing gear is set for school sharks, i.e., longlines and large mesh gillnets.

3.3.4 Predators

- Juveniles

During tagging experiments in "nursery" areas, Pacific gulls, Larus pacificus, have been seen to catch and subsequently tear and eat flesh of recently released tagged small or juvenile school sharks still swimming in very shallow waters. A New Zealand porbeagle shark, Lamna whitleyi, was caught with two 44.4-cm school sharks in its stomach (Whitley, 1940, p. 117).

- Adults

No specific predator is known for school sharks although they are attacked, when caught in nets or on longlines, by the seven-gilled shark, Notorhynchus cepedianus (Olsen, 1953, p. 101). Other predatory sharks, such as white pointers also attack hooked or meshed school sharks (Olsen, personal observation; Walker, personal observation). Sea-lice (Eurydicidae) attack hooked or netted sharks leaving only skin and cartilage at times.

3.3.5 Parasites, diseases, injuries and abnormalities

- Parasites and diseases

Examination of body cavity and gut contents of 600 school sharks showed almost total absence of helminth parasites. Only once was a larval tetrarhynchid cestode found in the body cavity. Occasionally dead nematodes are found in the gut but these are referable to fish eaten by sharks (Olsen, 1954, p. 360).

- Injuries and abnormalities

Occasionally sharks bearing wounds and scars from teeth marks are caught, but incidence is low. Rusty shark hooks may be found embedded in the jaws.

Two adult females were found, each with only one functional uterus, one the right, the other the left. The non-functional uteri contained coalesced degraded egg yolks giving the appearance of a dark yellow-brown structureless tumour.

Three-quarters of undeveloped eggs or embryos, dead from arrested development, present in other females examined, occurred in anterior third of the uteri. These abnormalities did not seem to affect development of surviving embryos (Olsen, 1954, p. 376). One female, carrying full-term embryos, also had some unextruded ova, 35 mm in diameter which were undergoing ovarian resorption.

3.4 Nutrition

3.4.1 Feeding

- Time of day

No evidence for any specific feeding time.

- Place or general area

The normal preferred feeding habitat is reef, rough or "foul" bottom, where the school sharks seek actively for food. They are essentially bottom foragers as the stomach contents are mostly freshly caught fish, some of which are semi-pelagic species, and cephalopods (Olsen, 1954).

- Variation of feeding habits with availability, season, age, size, sex, physiological condition

Both sexes concentrate oil reserves in liver tissue and female livers are at maximum size and oil content of liver is highest at time of ovulation, i.e., in May and June when copulation is believed to take place.

The liver of females is smallest in size and weight (226-454 g) at parturition, i.e., December. The oil in liver apparently serves as a reserve food supply during period of gestation. Heaviest adult female liver weighed 5.55 kg (196 oz). Heaviest adult male liver weight 2.26 kg (80 oz)(Olsen, 1954, pp. 336-7). The fluctuation in liver weight for sharks of same size was considerably less in males than in females and was influenced markedly by sexual development and stage of pregnancy in female. Figures 21 and 22 show relationship of cleaned weight to liver weight for the two sexes.

3.4.2 Food

- Types eaten and their relative importance in the diet

Stomach contents of 600 school sharks of all sizes were examined from throughout fishery and 444 stomachs contained food, but in six digestion had advanced too far for recognition. Fish and cephalopods were present in 92% of stomachs examined. Soft shelled stages of spiny lobster occurred in 2% of the stomachs (Olsen, 1954).

- Juveniles

Fish and cephalopods comprised 88% of diet which was supplemented with annelids, molluscs and crustaceans found in "nursery" environments (Olsen, 1954, pp. 358-9).

Volume of food eaten during given feeding period - no information.

- Adults

Seventeen species of fish identified, predominant ones being barracouta, *Leionura atun* (Euphrasen), and jack mackerel, *Trachurus declivis* (Jenyns), which are considered pelagic species but they do feed at or near bottom at times. Nearly all other fish species were bottom dwellers and often restricted to reef conditions.

Squid and octopus are also preferred food species.

Only twice were other elasmobranchs found in stomach contents and their ingestion was considered to be accidental (Olsen, 1954, p. 358).

Pregnant females do not contain food in stomachs in "nursery" areas (Olsen, personal observation).

3.4.3 Growth rate

- Relative and absolute growth pattern and rates

The growth of elasmobranchs is so slow that use of the modal length frequency techniques have been found to be of limited value, particularly for older fish. Consequently, absolute age of elasmobranchs is difficult to obtain and, as a result, there is little known about growth of most elasmobranchs (Grant, Sandland and Olsen, 1979, pp. 626-7).

The growth rate of school sharks was determined using a combination of known techniques, including length frequencies of juvenile sharks and mark and recapture methods for older sharks. The period between mid-November and mid-March was selected as being most suitable for age analysis by Petersen method (using length frequencies) for, depending on latitude and environmental conditions in "nursery" areas, most young sharks are born by end of January. An arbitrary birth date of 1 January was selected as best fitting data; 300 mm was modal length at birth for both sexes (Figure 5).

Adult females released their young in Port Sorell (Tasmania, 617) on one occasion as much as four weeks earlier than in estuaries of southern Tasmania. Thus, juveniles in Bass Strait "nursery" areas could be as much as a month older than those in the south and hence initially their modal or mean length could be greater than those from southern estuaries. However, this size difference may not always exist if, as often occurs, mean size of adult females in southern areas is greater and full-term embryos are larger (Figure 4). The chance variations are soon obscured by mixing of migrating former estuarine populations. With adequate intermingling, the size range within an age group tend towards a normal distribution (Olsen, 1954).

- Juveniles

Shortly after birth, there is no difference in mean lengths of two sexes (300 mm on 1 January) (Figure 5), nor can any difference in mean lengths be detected within samples collected over a period of two years (Olsen, 1954, Table 7).

There was no significant difference between mean monthly growth increments in different size groups of male and female tagged juvenile sharks in estuaries and on this evidence rate of growth is taken to be same for both sexes in these environments (Olsen, 1954, Table 9).

In estuarine populations of Pittwater and Port Sorell (Tasmania) and Portarlington (Victoria) newly born "pups" are present in the January-March period. The populations in two Tasmanian estuaries showed a mean monthly increment of approximately 10 mm/month. Both were sampled monthly, Portarlington only annually (Figure 14).

The increment of 10 mm/month was taken as representing mean monthly length increase of 0+ population and hence in 12 months the accumulated increment of 120 mm would establish 450 mm as modal length of one-year old sharks. Such a mode for one-year old sharks was consistently present at Pittwater and occasionally in Port Sorell but was not found at Portarlington. The prominent modal length of 580 mm at Portarlington and, to a lesser extent Pittwater, represented modal length of juvenile school sharks two years of age.

- Growth from tagging results from school sharks of all sizes

Gulland and Holt (1959) and Fabens (1965) have devised methods of estimating parameters K and L_∞ of the von Bertalanffy growth equation (von Bertalanffy, 1938, 1957) from tagging data. These methods do not require a knowledge of absolute age of individuals. The procedure devised by Fabens (1965) requires only that size of tagged fish at release and recapture and their duration of liberty be known. Data were obtained from tagging 6 502 school sharks of all sizes; 2 928 sharks were double tagged with internal and external tags and remainder with external tags only (Table III). The type of external tags used had a much shorter life expectancy (order 2-3 years) while internal tags have been recovered after 33+ years.

Size at recapture of a tagged individual accompanied 225 of 574 returns, but only 103 could be accepted for analysis. These fish cover a wide bracket of size range of the species and their periods of freedom range between 21 and 9 106 days (approximately 25 years)(Table IV) (Grant, Sandland and Olsen, 1979). Since that analysis was made, three internally tagged male sharks have been recaptured after 27+, 29+ and 32+ years of freedom and a female after 33+ years (see Section 3.3.1).

Table III

Number of school sharks internally tagged throughout the duration of the tagging programme (after Grant, Sandland and Olsen, 1979)

Year	Males	Females	Unsexed	Total
1942	15	8	-	23
1943	-	2	-	2
1944	-	1	-	1
1945	1	-	-	1
1946	-	-	-	-
1947	-	-	-	-
1948	-	-	-	-
1949	132	111	2	245
1950	451	388	6	845
1951	532	497	9	1 038
1952	85	76	1	162
1953	262	146	3	411
1954	-	-	-	-
1955	-	-	85	85
1956	-	-	115	115
Total	1 478	1 229	221	2 928

The von Bertalanffy growth parameters K and L_∞ were estimated from the model by the method of least squares (Fabens, 1965).

$$y = x + (L_\infty - x)\,[1 - \exp(-Kd)]$$

Where y = length at recapture; x = length at release; d = duration of liberty; L_∞ = maximum theoretical length attained; K = rate of change of length increment.

A summary of these results appears in Table V.

t_0 of the von Bertalanffy equation cannot be estimated from recapture data alone; t_0 is solved using derived parameters K and L_∞ in the following equation:

$$t_0 = t + \left(\frac{1}{K}\right) \ln \frac{(L_\infty - L_t)}{(L_\infty)}$$

Table IV

Recoveries of internally tagged school sharks indicating the numbers recovered of each sex during progressive intervals of freedom (after Grant, Sandland and Olsen, 1979)

Years free	Males	Numbers recovered Females	Unsexed	Total
0-1	54	67	2	123
1-2	20	22	4	26
2-3	19	14	1	34
3-4	18	13	1	32
4-5	19	10	3	32
5-6	12	9	2	23
6-7	18	11	3	32
7-8	12	12	4	48
8-9	9	10	1	20
9-10	9	5	2	16
10-11	7	6	2	15
11-12	3	2	1	6
12-13	6	6	–	12
13-14	10	6	1	17
14-15	4	4	2	10
15-16	9	2	1	12
16-17	6	3	–	9
17-18	2	1	–	3
18-19	3	4	–	7
19-20	3	–	–	3
20-21	4	3	–	7
21-22	4	1	–	5
22-23	2	1	1	4
23-24	2	–	–	2
24-25	1	1	–	2
Total	256	213	31	500

Table V

von Bertalanffy growth equation parameters for both sexes separately and combined (after Grant, Sandland and Olsen, 1979)

Parameter	Males	Females	Sexes combined
Number of records	53	50	103
Correlation coefficient	0.963	0.966	0.964
Estimate of L_∞ (cm)	158.33	161.83	160.04
Standard deviation	1.82	2.24	1.42
Estimate of K (per year)	0.1675	0.1600	0.1639
Standard deviation	0.0087	0.0108	0.0068
t_o (years)	-1.2545	-1.2818	-1.2669

where t_o = hypothetical time at which the fish would have been zero length according to the von Bertalanffy equation; L_t = length at t_o years of age; t = age in years; K and L_∞ as defined above.

The estimated parameters of the von Bertalanffy equation were used to estimate age of each individual at time of tagging by solving equation for t_o, substituting length at release for L_t. By adding known time at liberty to this estimated age at release, the age of each release individual at recapture was estimated. This is a reasonably reliable procedure especially when fish are released at relatively young ages, as the final estimate of age consists mainly of a large known quantity and a small estimated quantity with relatively small variance. The L_∞ for each sex and combined data are reasonably close to known upper size limit of the species and several tagged specimens of both sexes were recovered at 160 cm and above (Grant, Sandland and Olsen, 1979, p. 629).

Table VI shows the calculated rate of growth of the school shark and Figure 7 shows the calculated growth curve for the combined sexes.

Table VI

Calculated rate of growth of school shark for combined sexes (after Grant, Sandland and Olsen, 1979)

Age (year)	von Bertalanffy predicted lengths	Age (year)	von Bertalanffy predicted lengths
0	30.0	12	141.85
1	49.7	13	144.6
2	66.4	14	146.9
3	79.5	15	148.9
4	92.5	16	150.6
5	102.7	17	152.0
6	111.4	18	153.2
7	118.8	19	154.3
8	125.0	20	155.1
9	130.3	30	159.1
10	134.8	40	159.9
11	138.6		

<u>Condition factors</u>: No data. However, school sharks from western Australian sources, size for size, tend to be lighter in weight than school sharks from southeastern Australian waters (Figures 15 and 16).

<u>Relation of growth to feeding, etc.</u>: No information.

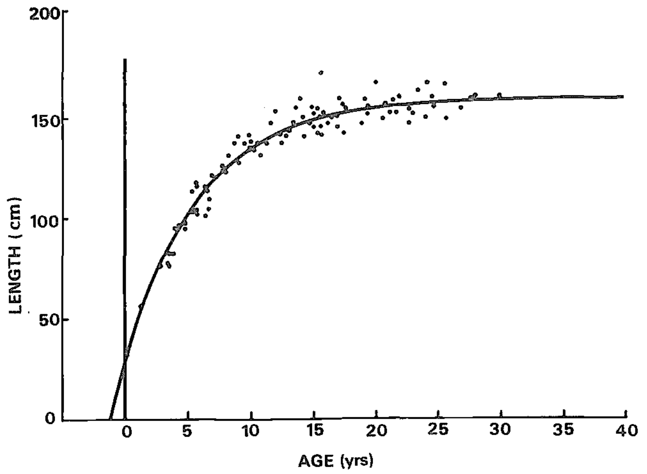

Figure 7 Calculated growth curves of *G. australis* for the combined sexes

Relation of growth to population density: No information.

Food growth relations: Results of tagging of school sharks showed there is no seasonal slowing down of growth.

3.4.4 Metabolism

No information.

3.5 Behaviour

3.5.1 Migrations and local movements

- Juveniles

Local movements - mostly from "nursery" areas into channels (Figure 8) before moving into adjacent deeper waters for first winter and in certain estuaries a return in late spring/early summer months. Older juveniles (2+ years) exhibit a haphazard migration to eastern Bass Strait area (4.9.3) or to warmer waters in winter (Figure 9). Longest direct migration male 58.5 cm total length 1 120 km (700 mi) in 544 days. For information about further returns see Olsen, 1954, pp. 381-91.

In Kaipara Harbor, New Zealand (631) juveniles (0+ years) do not return to their "nursery" areas (Garrick and Paul, 1975).

- Adults

General dispersal throughout range of fishery but most tend to move inshore in summer and offshore at approach of winter; considerable numbers (in schools) also migrate to warmer northern waters of South Australia and New South Wales before returning south in late spring (Figures 10 and 11). The numerals represent total number of school sharks released at the various tagging locations. Additional data on movements from tag recoveries received since 1954 are shown in Figures 9, 10 and 11.

There is no shift of total adult population over a short period of time from one region to another within the geographical range of the species.

- Gravid females

See Section 2.2.2.

3.5.2 Schooling

- Extent of schooling habits

Longlines and mesh nets set over long distances may have catches of sharks concentrated at intervals along these commercial gears. These distributions are believed to indicate the discrete nature of schools. Their schooling behaviour is the basis for their common name - school shark.

- Juveniles

Even in recently released young in "nursery" areas there seems to be a tendency towards aggregation by these small sharks. Factors supporting this schooling behaviour interpretation is that small sharks either bite on baited handlines or are meshed in nets in preferred places, or no catches are made at all (Olsen, personal observation).

- Pre-adults

Concentrations in schools of limited size range and usually of one sex mainly occur in eastern Bass Strait waters (4.9.3) though these schools do exhibit migrations into warmer northern waters in winter and a return in late spring.

- Adults

Travel in schools composed of individuals of a limited size range and usually predominantly of one sex (except during May and June in deep water for mating purposes)(Olsen, 1954, tagging results).

The school sharks may move in schools of more than 100 individuals. Experimental fishing with short longlines, i.e., 300 hooks spaced 8 m apart have produced 100 sharks spread more or less evenly along the whole of the 1 200 fathom length of baited longline laid along the seafloor. In South Australian waters fishermen follow and set longlines daily ahead of migrating schools for as long as a fortnight at a time.

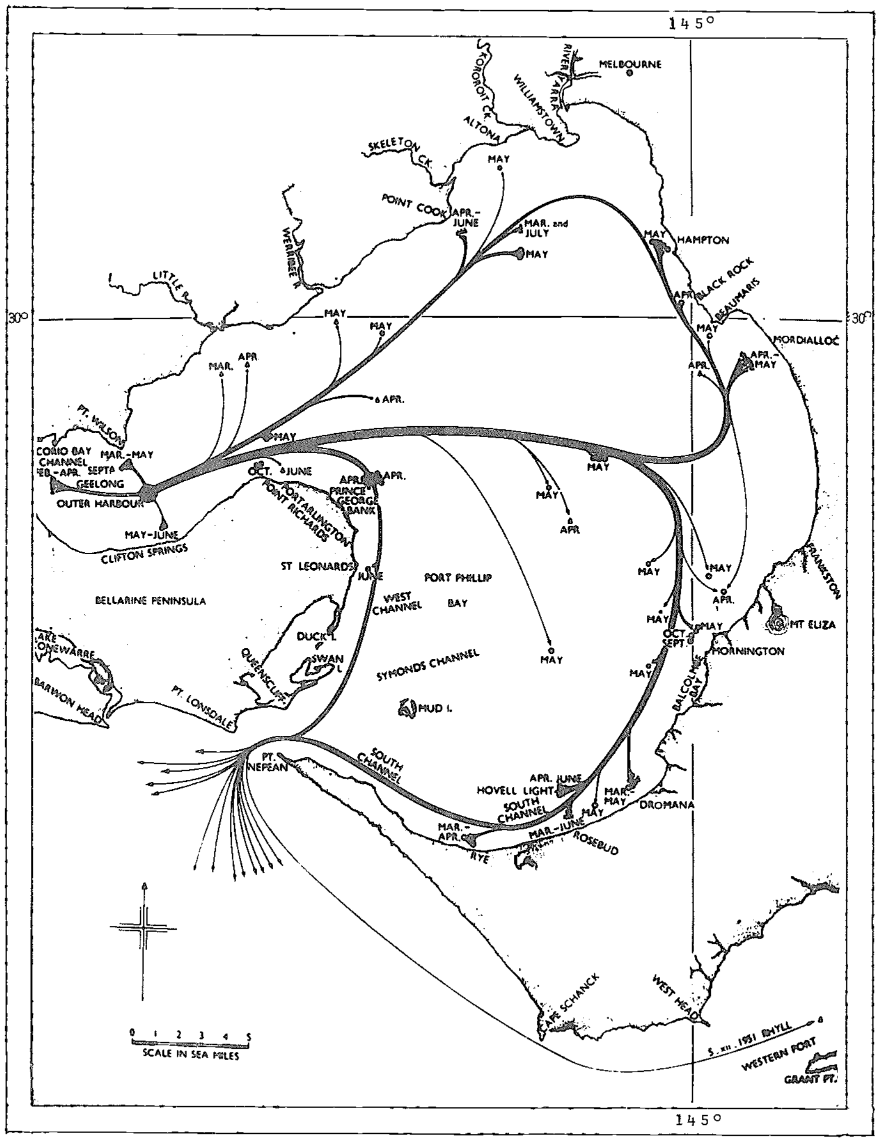

Figure 8 Main migration routes in channels out of Port Phillip Bay (from Olsen, 1954)

Tag returns indicate that composition of schools of sharks is constantly changing due to individuals leaving one school and joining another. Colour variants are believed to represent recently arrived immigrants to a school.

Tag recoveries indicate a complete mixing of sharks from all areas of southeastern Australia. There is no evidence from tagging of mixing of western Australian and New Zealand stocks of Galeorhinus australis with the southeastern Australian stock. No tagged sharks have been recovered outside southeastern Australian waters.

- Vertical movements

School sharks are bottom feeders and individuals have been caught on continental slope to 600 m depth (Smith, 1980). There is no evidence to show regular or periodic vertical movements in a water column.

- Size density and behaviour of schools in relation to:

(a) time of day - no information

(b) geographic location - see Section 3.4.1 Feeding

(c) season - see Section 3.5.1 Behaviour

(d) oceanographic factors - see Section 3.5.1 Behaviour

(e) physiological conditions - see Section 3.4.1 Feeding

(f) aggregation - no data

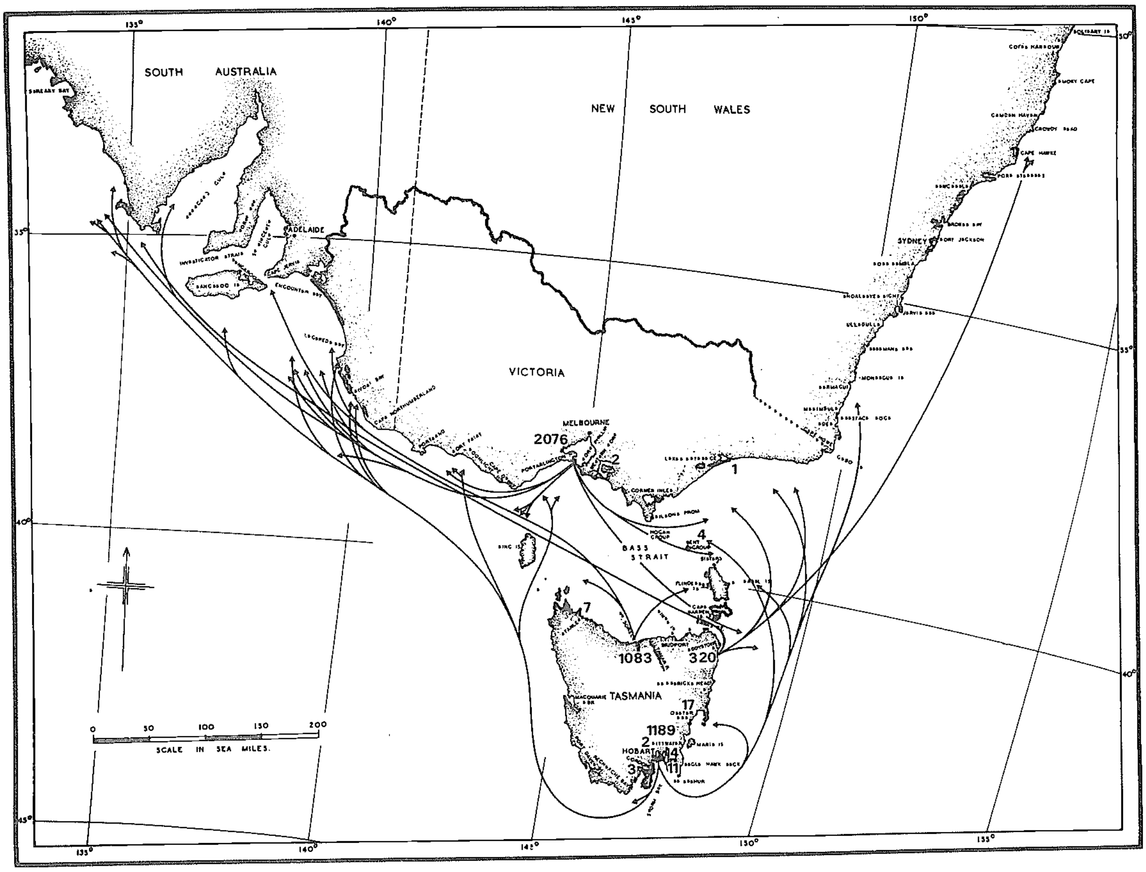

Figure 9 Migration of juvenile tagged sharks from inshore centres (post 1954)

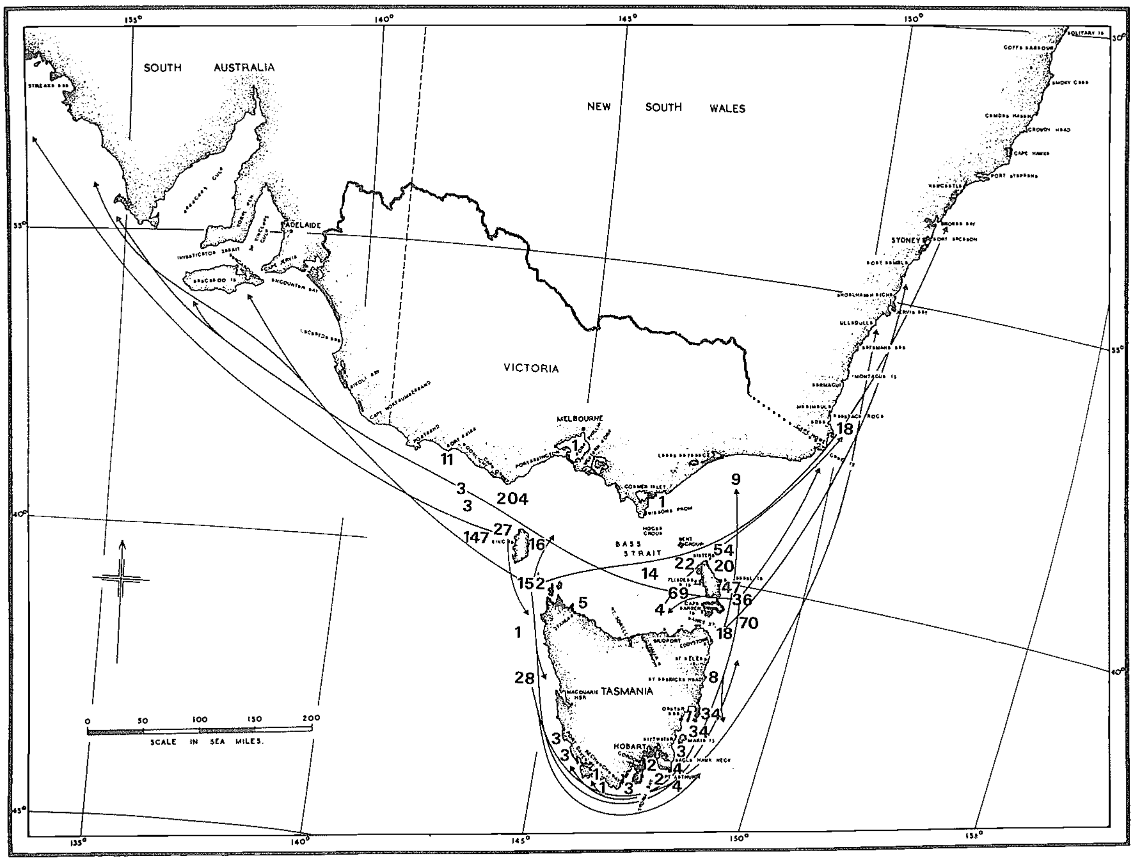

Figure 10 Migration of tagged sharks from offshore positions (post 1954)

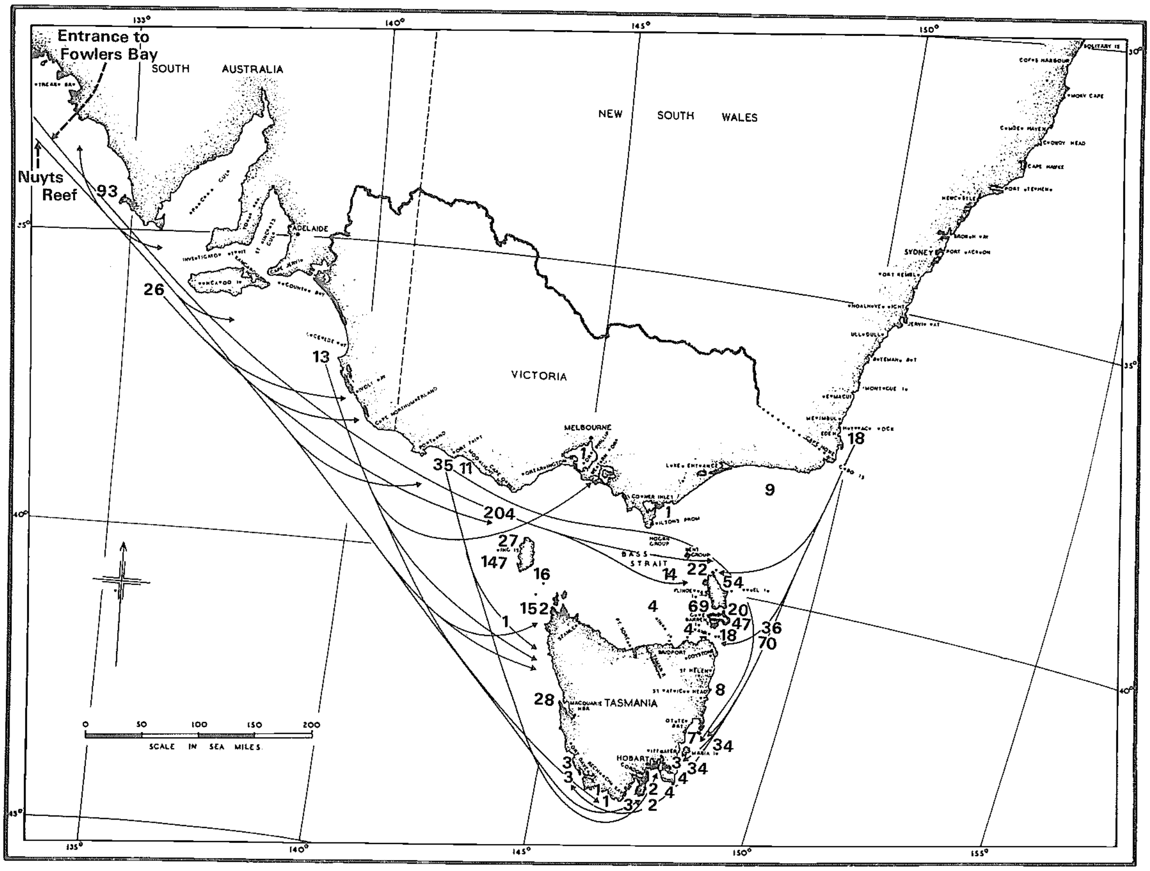

Figure 11 - Southward migration of tagged sharks from offshore positions in waters off South Australia, Victoria and New South Wales

3.5.3 Responses to stimuli

- Mechanical and olfactory

No information.

- Environmental

Temperature: Only rarely are young sharks caught in "nursery" areas or estuaries where minimum bottom water temperatures fall below 8°C. No young sharks have been caught by handlines or in small mesh nets in waters where temperature was below 7.4°C. It is inferred that minimum bottom water temperatures of their preferred range lie between 7.4° and 8.0°C (Figure 12). The upper limit off preferred range does not exceed 22°C (Olsen, personal observation).

Gravid females: No gravid female shark with full-term embryos has ever been caught in "nursery" areas in which bottom-water temperatures were less than 14°C (Olsen, personal observation).

In the deepest estuary, George Bay, winter minimum bottom-water temperatures never fell below 10°C and juveniles were present throughout year. On the other hand, when bottom-water temperatures at Port Sorell were as low as 8.6°C (July 1949), no juveniles were netted or handlined during any of the monthly experimental fishing operations in that estuary. However, in late spring, young sharks (1+ years) would follow a flooding tide of sea water above 10°C into lower reaches of Port Sorell estuary and return seaward on ebb tide (Olsen, personal observation).

This was not the case in Pittwater estuary which has greatest expanse of shallow water and least tidal range. In 1950 and again in 1951, five juveniles were caught in the entrance channel when bottom-water temperatures were between 7.4° and 8.0°C. There was an incoming tide and it is believed these young sharks entered Pittwater from adjacent, deeper Frederick Henry Bay where they may have become conditioned to temperatures slightly less than 10°C.

In most estuaries in Tasmania there is a daily fluctuation in bottom-water temperatures caused by such influences as tides and prevailing weather conditions. The daily range may be as much as 2.75°C. In Figure 13 is shown not only range in bottom-water temperatures (shaded area) registered during one day's fishing per month over a two and a half year period at Pittwater but also total number of sharks caught on that fishing day.

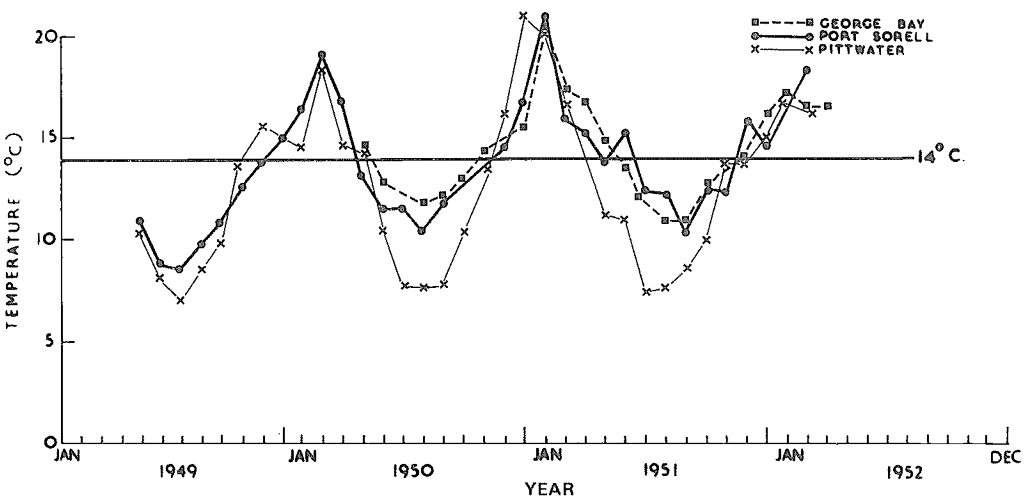

Figure 12 Monthly bottom-water temperatures in three Tasmanian estuaries (from Olsen, 1961)

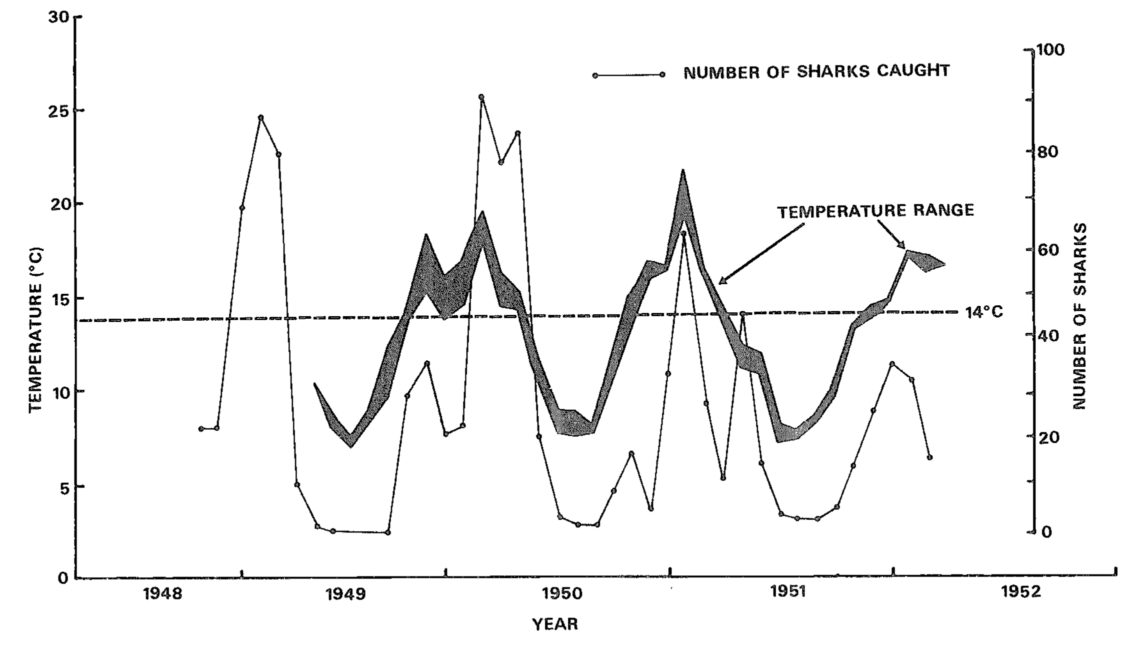

Figure 13 Range in bottom-water temperatures and number of sharks caught, Pittwater, Tasmania (from Olsen, 1961; see also Section 2.3.1 Determinants of distribution changes)

Optical: No information.

4. POPULATION

4.1 Structure

4.1.1 Sex ratio

- Sex ratio of population

		Male	:	Female
(i)	Full-term embryos in uteri	491	:	450
(ii)	Recently born "pups"	54	:	46
(iii)	Juveniles (2 years)	46	:	54
(iv)	Adults (from tagging data)	1	:	1

- Sex ratio of the catch

Because of schooling behaviour of G. australis, catch may be composed of all males or all females or varying proportions of either depending on season of year and location of catch.

- Variations of ratio with size, age and season

During May-June breeding period, proportion of males to females appears to be similar along sections of continental shelf of Victoria and Tasmania (see Section 3.1.6).

- Sex ratio on or near "nursery" areas

Only gravid females are caught in deeper channels leading into "nursery" areas.

4.1.2 Age composition

- Nursery and estuarine areas

Some "nurseries" support only 0+ year class whereas other "nurseries" support older year groups, thus:

Port Sorrel (Tasmania 617)	0+ and 1+ juveniles
Pittwater (Tasmania 617)	0+, 1+, 2+ juveniles
George Bay (Tasmania 617)	0+, 1+, 2+, 3+ juveniles
Portarlington (Victoria 614)	0+, 2+ juveniles

- Eastern Bass Strait waters (4.9.3)

Immature school sharks predominate.

- Tasmanian, South Autralian, New South Wales and western Bass Strait waters (617, 613, 615 and 1.6.3)

Mostly mature fish in continental shelf waters.

- Age at first capture

Victoria (614)	2+ years
South Australia (613)	2+ years
Tasmania (617)	2+ years
New South Wales (615)	3+ years
Australian proclaimed waters[1/]	2+ years

4.1.3 Size composition

- Nursery areas

	Modal frequencies (January-March period)
Port Sorell (617)	32 cm, 45 cm
Pittwater (617)	32 cm, 45 cm, 60 cm
George Bay (617)	32 cm, 45 cm, 60 cm, 70 cm
Portarlington (614)	36 cm, 58 cm

(all modes are less than legal minimum length in most States)

Length frequencies of juveniles in three "nursery" areas in 1948-50 are plotted in Figure 14. This study has not been repeated and hence no recent data are available for comparison.

- Open sea

Eastern Bass Strait (4.9.3)
(from 71 cm to maximum recorded length 174 cm)

Western Bass Strait (1.6.3)
(from 71 cm to maximum recorded length 174 cm)

Tasmanian waters (617)
(from 71 cm to maximum recorded length 174 cm)

South Australian waters (613)
(from 71 cm to maximum recorded length 174 cm)

New South Wales waters (615)
(from 91 cm (36 in) to maximum recorded length 174 cm)

School sharks of a limited range of sizes tend to aggregate into schools, and hence modal

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1/ For definition see Australian Government Gazette, Fisheries Notice No. 65, 17 August 1976

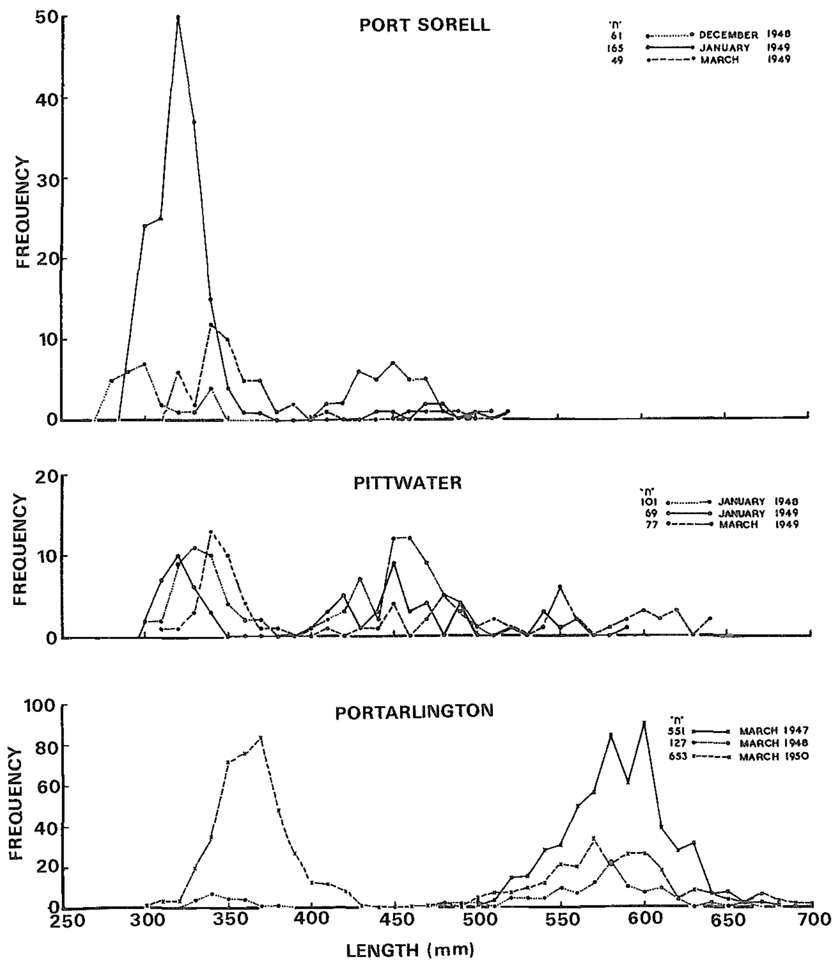

Figure 14 Length frequencies of juveniles in two Tasmanian and one Victorian "nursery" areas, 1948–50 (from Olsen, 1954)

length of each commercial catch landed varies from port to port and season to season.

Also legal minimum and maximum total lengths for school sharks apply in Victoria (614). In other States and in Australian proclaimed waters, there is no legal maximum total length for school sharks.

– Size at first capture

Legal minimum length (total length)

71 cm – Victoria (614)

71 cm – South Australia (613)

71 cm – Tasmania (617)

71 cm – Australian proclaimed waters adjacent Victoria, Tasmania and South Australia

91 cm – New South Wales (615)

Juveniles are fully protected in nominated "nursery" (closed) areas in Tasmania.

– Size at maturity

Length of smallest sexually mature male	120 cm (running "milt")
Length of smallest sexually mature female	135 cm (based on ovarian egg diam)
Length of smallest gravid female caught	144.5 cm (17 "pups") (Olsen, 1954)

– Maximum size (length)

Male	– 163 cm	(field research studies)
Female	– 170 cm	(field research studies)
?	– 174 cm	(commercial catch)

Females of the school shark grow to a greater size and weigh more than the males. Similar observations have been made about females of other elasmobranch species (Olsen, 1954, p. 363 and Table 3).

– Length and weight relationships

See Table VII.

Table VII

Relationships of length and weight of male and female school sharks (Olsen, 1954)

	Unit	Formulae - length and weight relationships			
		Males	Fig. No.	Females	Fig. No.
Total length (z) Total weight (y)	cm lb	$\log y = 0.827 + 3.169 (\log z - 1.940)$ or $y = 4.80 \times 10^{-6} z^{3.17}$	15	$\log y = 0.804 + 3.178 (\log z - 1.925)$ or $y = 4.86 \times 10^{-6} z^{3.18}$	16
Total length (z) Cleaned weight (y)	cm lb	$\log y = 1.071 + 3.204 (\log z - 2.072)$ or $y = 2.71 \times 10^{-6} z^{3.20}$	17	$\log y = 1.059 + 3.233 (\log z - 2.066)$ or $y = 2.39 \times 10^{-6} z^{3.23}$	18
Total weight (z) Cleaned weight (y)	lb lb	$\log y = 1.082 + 1.014 (\log z - 1.259)$ or $y = 0.639 z^{1.01}$	19	$\log y = 1.061 + 1.012 (\log z - 1.256)$ or $y = 0.617 z^{1.01}$	20
Cleaned weight (z) Liver weight (y)	lb oz	$y = 0.0476 x^2 + 1.07 z$	21	$y = 0.0763 x^2 + 1.02 z$	22

The length and weight relationship equations show there are no appreciable differences between the sexes

Figures 15-22 show these relationships graphically (Olsen, 1954)

The broken lines above and below the power curves represent 99% confidence limits

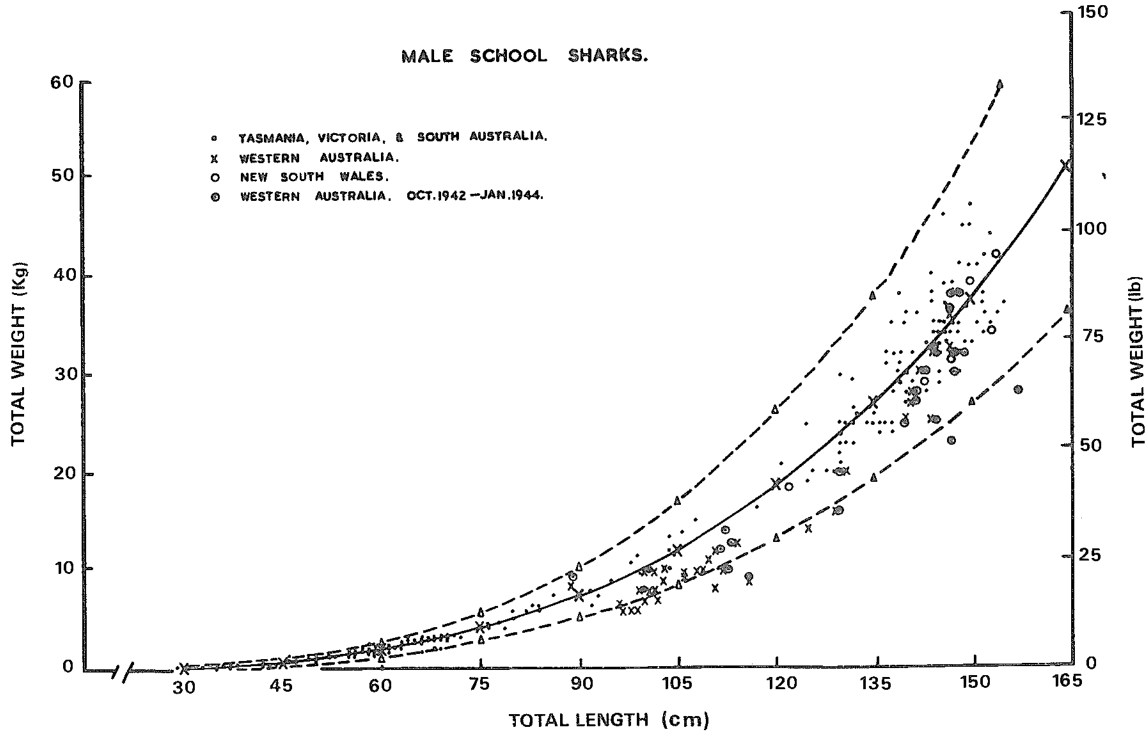

Figure 15 Relationship of male total length to total weight

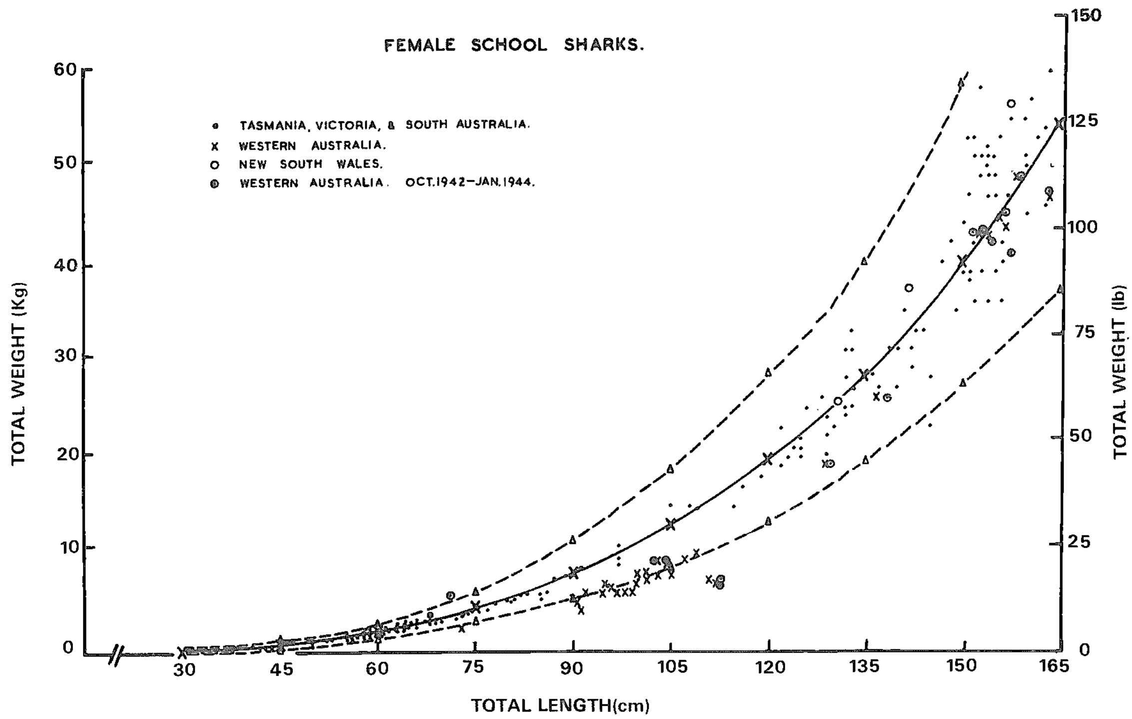

Figure 16 Relationship of female total length to total weight

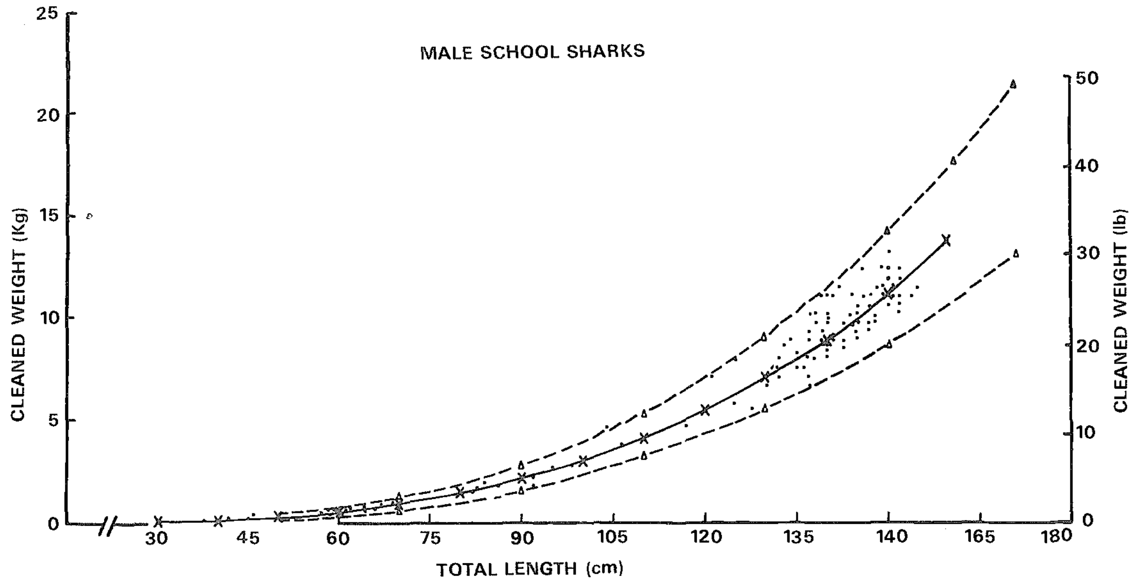

Figure 17 Relationship of male total length to cleaned weight

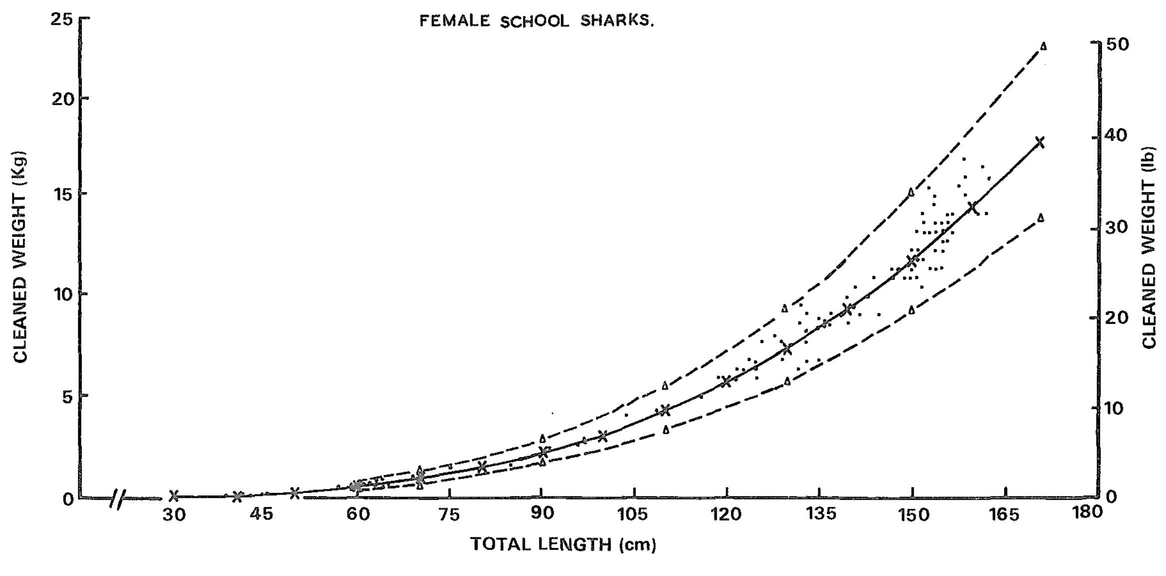

Figure 18 Relationship of female total length to cleaned weight

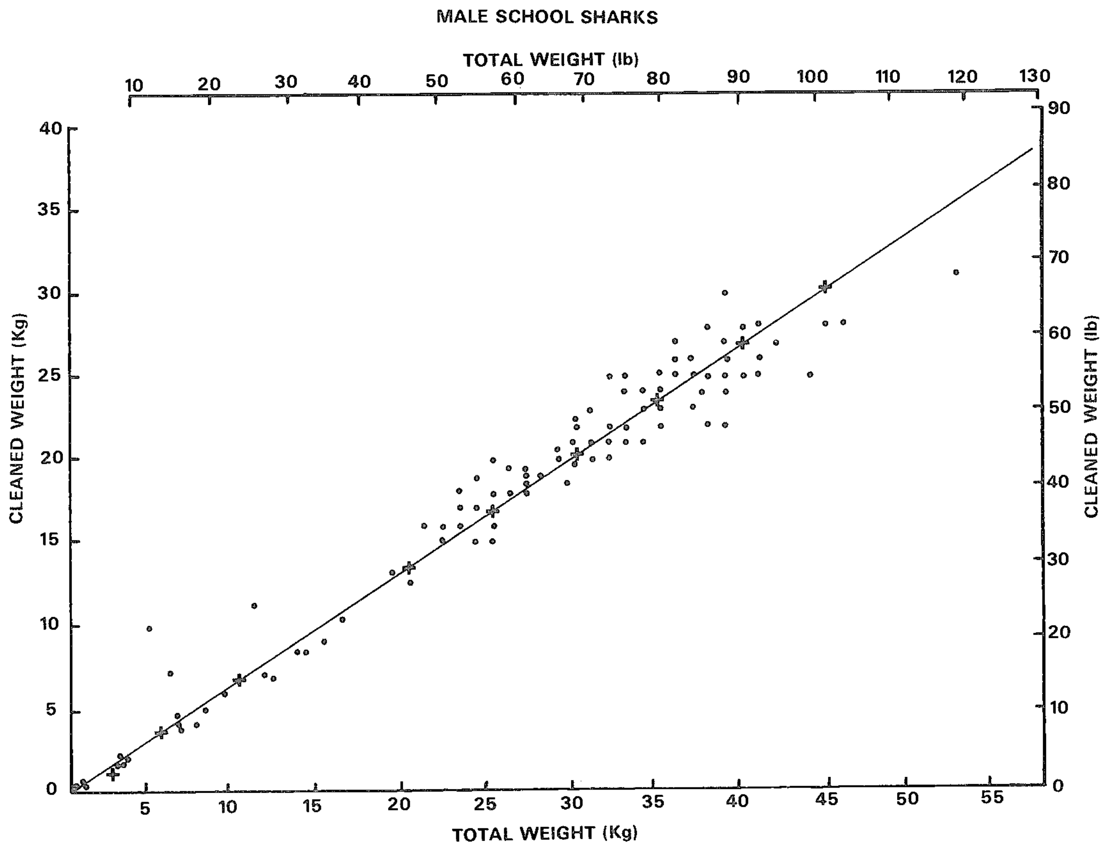

Figure 19 Relationship of male total weight to cleaned weight

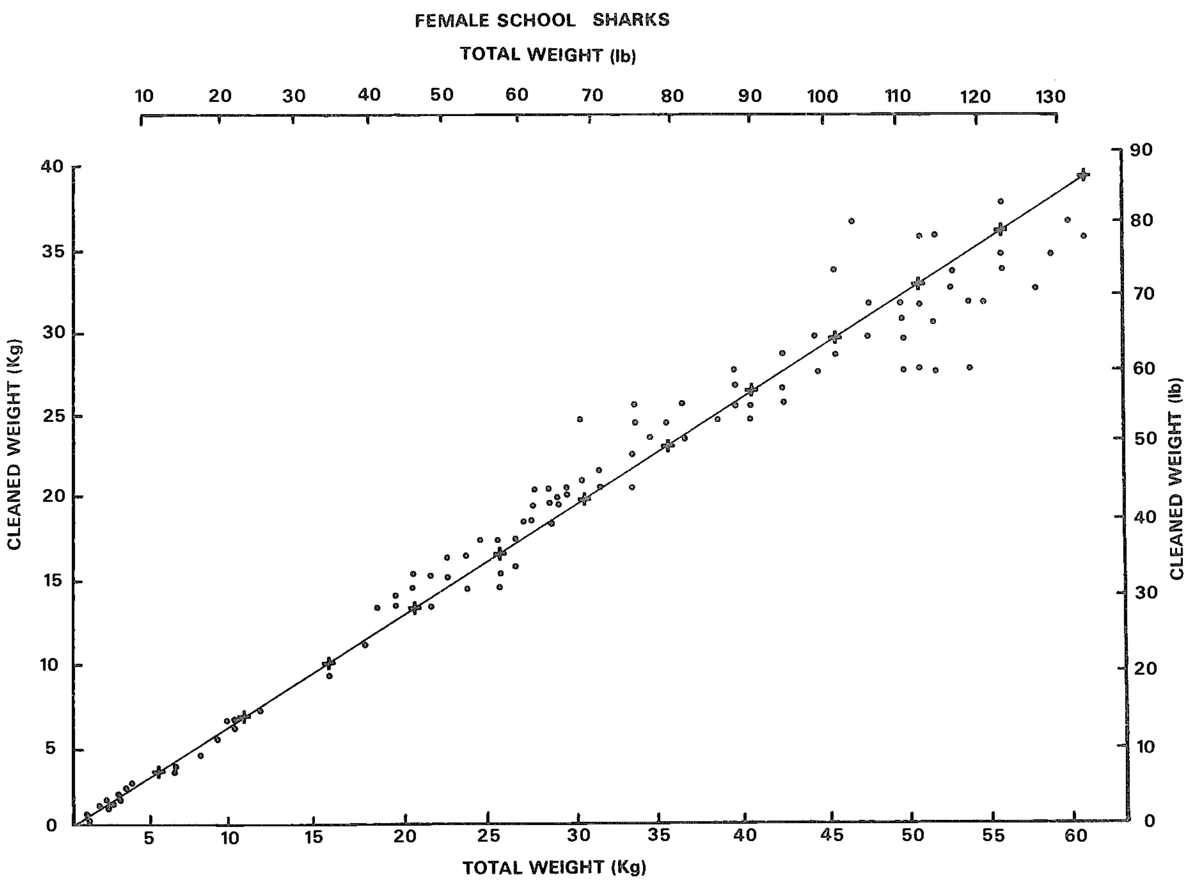

Figure 20 Relationship of female total weight to cleaned weight

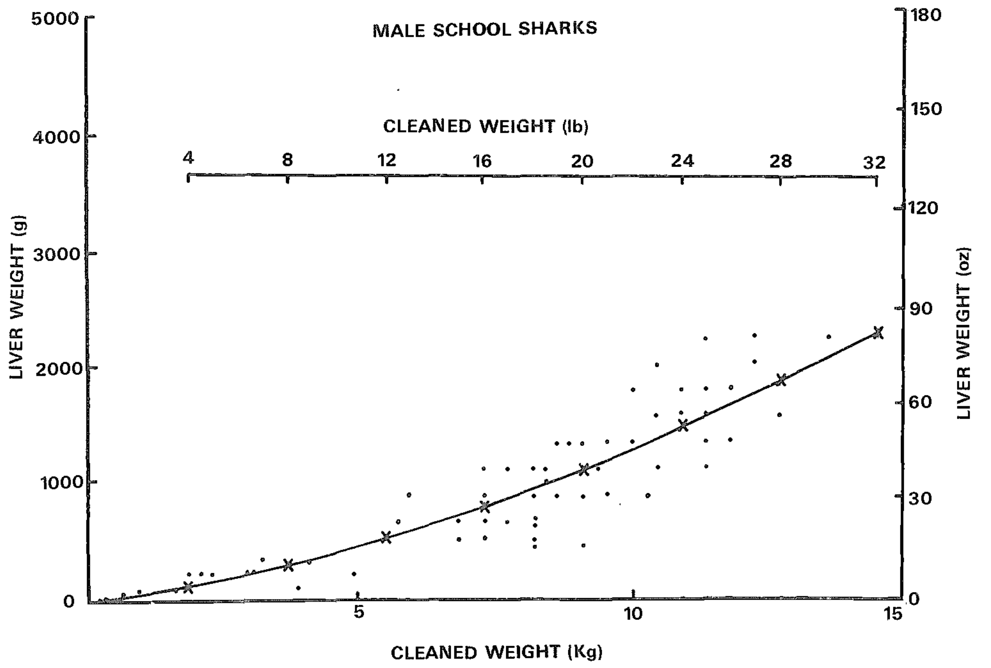

Figure 21 Relationship of male cleaned weight to liver weight

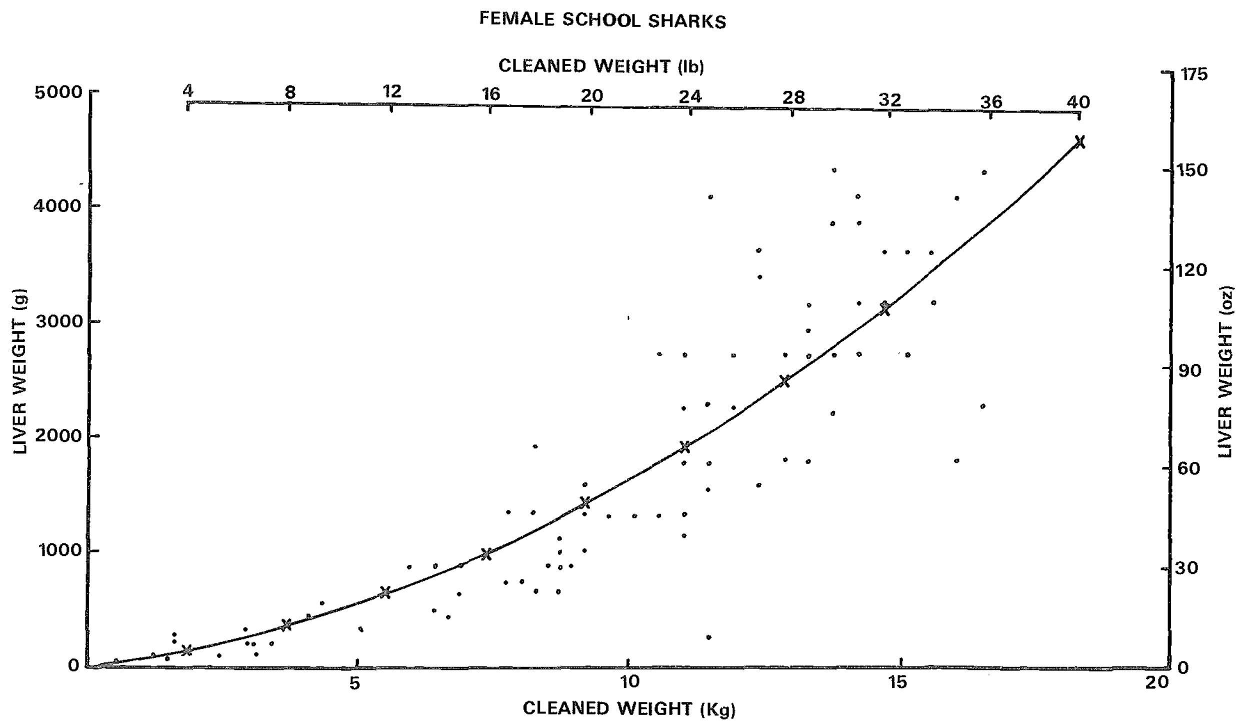

Figure 22 Relationship of female cleaned weight to liver weight

4.2 Abundance and Density of Population

4.2.1 Average abundance

No estimate (see Section 4.5 Dynamics of Population).

4.2.2 Changes in abundance

Juveniles in "nursery" areas: The following table indicates changes in abundance of juveniles in two Tasmanian "nursery" areas, situated some 550 km apart, over a four-year period. These "nurseries" were sampled regularly and the handlining method was used throughout experiment for catching juveniles for tagging purposes (Olsen, 1954, 1959).

Table VIII

The number of line-hours to catch one juvenile shark (January-March) in two "nurseries"

Year	Port Sorell	Pittwater
1948	2.57	0.73
1949	2.11	4.73
1950	8.1	9.75
1951	20.86	4.27
1952	-	8.9

Figure 23 shows annual yields of shark, mostly school shark, from Port Phillip Bay, Victoria (614) from 1934 to 1956. Initially, the fishery concentrated on gravid female school sharks but after about 1945 the greater proportion of catch comprised juvenile school sharks. The situation in Port Phillip Bay was typical of other similar inshore areas in Victoria and Tasmania. In recent years the total catch of all shark in Port Phillip Bay has further declined.

The abundance of juveniles declined due to fishing pressures on:

(i) adult gravid females in Bass Strait and elsewhere inshore during early development of fishery, and from

(ii) intensified fishing of juveniles in Port Phillip Bay and other such similar environments around coasts of Victoria and Tasmania during period 1940-50 (Olsen, 1959).

Adolescent and adult stocks: Changes in abundance are difficult to quantify. However, need to make changes in fishing practice and equipment in order to sustain catches in mid-1940 period, do reflect reduced availability of stocks inshore (Table XI).

Mesh nets and longlines were used inshore initially, but with transfer of fishing into offshore waters, only longlines were used. From 1964 large mesh nets were reintroduced and have since largely displaced longlining methods except along edge of the continental shelf (Olsen, 1981; Hughes, 1981).

4.2.3 Average density

No information.

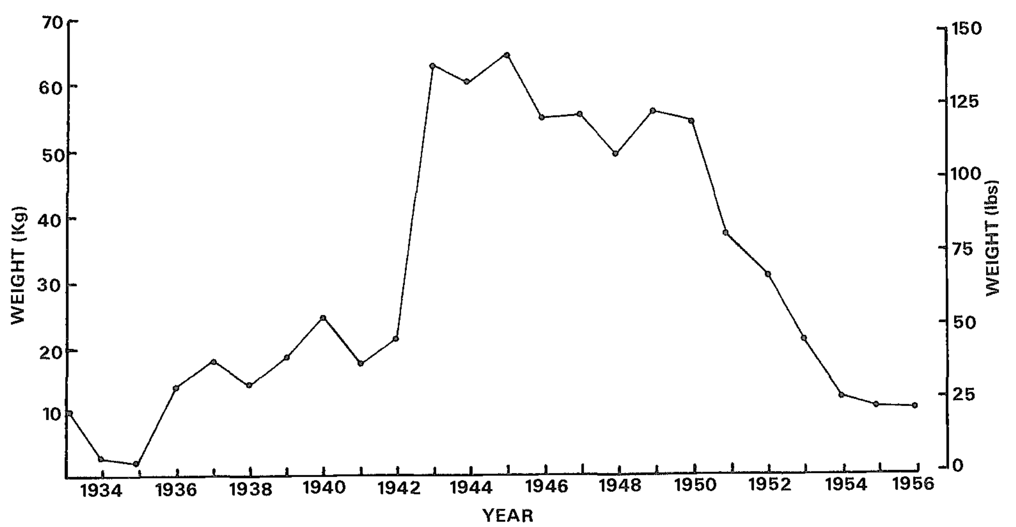

Figure 23 Catch of shark, Port Phillip Bay, Victoria, 1933-56 (from Olsen, 1959)

4.2.4 Change in density

No information.

4.3 Natality and Recruitment

4.3.1 Reproduction rates

The sex ratio of adults is 1:1 (Section 4.1.1) but only half the adult females breed each year (Section 3.1.5), thus average recruitment per year is one quarter of mean number of full-term embryos carried per adult female = 28.4 young. Recruitment = 7 "pups" per year per mature adult. There is direct relationship between mean length of mother (cm) and mean number of young carried. This relationship is expressed as y = -50.0 + 0.505 x where y = number of full-term young carried and x = mean length of mother (cm). The maximum number of full-term young carried was 41. Figure 3 shows the relationship of number of full-term young to length of mother (33 females and 942 young).

4.3.2 Factors affecting reproduction

(i) Concentrated fishing pressures on gravid school sharks in channel approaches to recognized "nursery" areas.

(ii) Intensified fishing of narrow shelf areas adjacent to southeast coast of South Australia (613) in October and November each year as southward migrating schools containing gravid females make for Victorian and Tasmanian "nursery" areas.

(iii) High mortality rate (75%) of prematurely born full-term young during fishing operations (Olsen, 1954, p. 403)

(iv) Recreational and commercial fishermen's antipathy to small school sharks. Fishermen kill small sharks hooked when fishing for scale fish.

(v) Intensified gillnet fishing of adolescent school sharks in eastern Bass Strait since 1972.

4.4 Mortality and Morbidity

4.4.1 Mortality rates

- Fishing and natural mortality coefficients

Table IX

Fishing (F) and natural (M) mortality estimates for both sexes separately and combined (from Grand, Sandland and Olsen, 1979)

Total mortality	Total mortality Z	Standard error of Z	Correlation coefficient	Total mortality (Z) Fishing (F)	Natural (M)
Males	0.1056	0.0106	-0.904	0.0167	0.0889
Females	0.1246	0.0134	-0.889	0.0171	0.1075
All data	0.1184	0.0101	-0.929	0.0178	0.1006

Mortality estimates obtained indicated that there is negligible difference in instantaneous fishing mortality coefficients between the sexes, and the slight discrepancy between the sexes for the instantaneous natural mortality coefficient is not significant. (These conclusions are limited to results obtained from the combined sexes data.)

Variations in mortality: Beverton and Holt (1957) gave a method for finding fishing mortality for maximum yield in a constant recruitment fishery. This technique was used to indicate how different fishing regimes varied with respect to optimum yield per recruit.

Using rounded value of 21 500 g for parameter W_∞ and length/weight conversion equations (Section 4.1.3) four fishing regimes were analysed namely:

(i) legal minimum length of 91 cm, no upper limit (prior to 1972)

(ii) legal minimum length of 91 cm, upper limit of 104 cm (Victoria 1972)

(iii) legal minimum length of 71 cm, upper length limit of 112 cm (Victoria 1976)

(iv) legal minimum length of 71 cm, no upper limit (Tasmania, New South Wales, South Australia and proclaimed Commonwealth waters)

These analyses suggested that to achieve maximum yield per recruit, under all four regimes a substantial expansion of fishery was desireable. However, any analysis of this kind fails to take account of effect of fishing on breeding stock which is quite crucial to future of industry (Section 4.3.2).

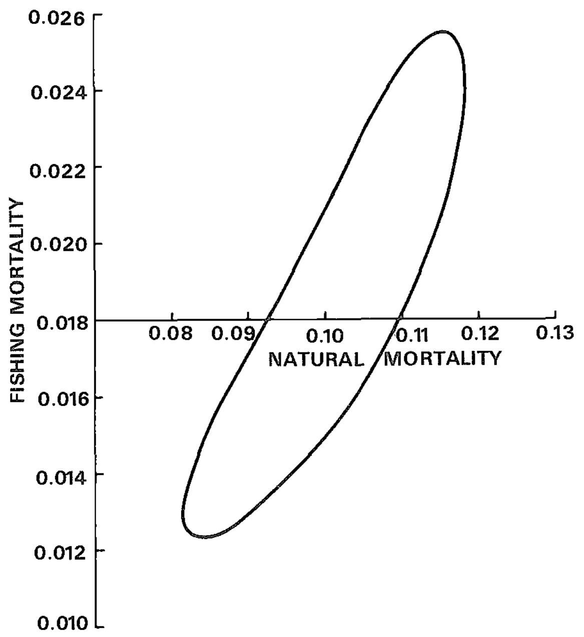

Figure 24 Joint confidence region for fishing and natural mortality of G. australis

The effect of changing fishing mortality (e.g., increasing fishing intensity twofold) on total breeding stock showed that estimates of fishing and natural mortality were highly correlated (Table X).

Table X

Percentage of breeding stock available relative to that stock which would be available at zero fishing mortality

Confidence region area	F values corresponding	% breeding stock
Low M = 0.08	0	100.00
	0.013	77.78
	0.026 (double)	61.71
Intermediate M = 0.10	0	100.00
	0.021	70.25
	0.042 (double)	50.88
High M = 0.12	0	100.00
	0.025	68.20
	0.050 (double)	47.94

Table X shows that doubling fishing effort (F = 0.050) would reduce total breeding stock ratio to below 0.50 towards right-hand extremity of confidence region (Grant, Sandland and Olsen, 1979).

This analysis of yield per recruit indicates that theoretical maximum yield is far in excess of present yield. The theoretical maximum yield represents a tenfold increase but this is only true if recruitment is independent of stock size. However, recruitment in school sharks is highly dependent on stock size.

In Author's opinion, mortality due to fishing is greater than shown by these estimates from 1949-56 tag return data. For the reasons set out below the above analysis, although best available, must be considered provisional.

(i) Data for only about half of the recaptured school sharks have been recorded due to:

- deliberate suppression of information by some fishermen;
- internal tags accidentally lost overboard during gutting and cleaning operations at sea.

(ii) The effect of intensified fishing effort on immature school sharks in eastern Bass Strait waters since 1972 and decline of stocks of juveniles in "nursery" areas. Thus juveniles have not been recruited into stock at a constant rate.

(iii) Beverton and Holt's (1957) formula for determining fishing mortality for maximum yield assumes a constant recruitment fishery. This is not the case in the school shark fishery (Section 4.2.2). The data used in analysis came from only a short period of tagging (1949-56).

4.4.2 Factors causing or affecting mortality

Effects of fishing: For the initial phase of development of this fishery there was a seasonal fishery on gravid females coming inshore to release their young. Subsequently, there was a demand for both liver and flesh of school sharks from 1940 through 1949. As a consequence, all inshore stocks of school sharks were heavily fished. Because of decline in abundance of inshore populations, shark fishermen began moving to offshore waters in 1946-47 and longline offshore fishery reached its peak of development by 1964. In that year eastern Victorian fishermen reintroduced large mesh nets into offshore fishery and within a decade longline fishing has been virtually phased out in all areas of southeastern Australia.

In 1972, Victorian authorities imposed a ban on taking of school sharks above a certain maximum total length (104 cm). Four years later legal maximum total length was raised to 112 cm for all school sharks landed in Victoria. This legislative decree for a legal minimum (71 cm) and a legal maximum length (112 cm) for school sharks has resulted in an intensification of fishing effort on immature sharks.

Fishermen in Tasmanian and South Australian waters were forced to curtail their fishing effort on school sharks because sharks in their waters, as a general rule, exceeded legal maximum length of school sharks which may be sold in Victoria. The legislative requirements for a legal minimum and maximum length for school sharks in Victoria were imposed because natural accumulation of mercury in the muscle tissues of adult school sharks exceeded legal permissible level of 0.5 mg/kg hg wet weight.

Indirect effects: High mortality (75%) of full-term embryos released prematurely from captured gravid females caught on longlines and in mesh nets (Olsen, personal observation).

4.4.3 Dynamics of population as a whole

Estimation of parameters:

Von Bertalanffy parameters - c.f. Tables V and IX.

(i) $\frac{\text{Natural mortality}}{\text{Growth}} = \frac{M}{K} = \frac{0.1006}{0.1639} = 0.614$

(ii) $\frac{\text{Length at entry to fishery}}{\text{Calc. max. length}} = \frac{lc}{l_\infty}$

$= \frac{71}{160.04} = 0.443$

(iii) Exploitation rate $= \frac{F}{F\&M} = \frac{0.0178}{0.1184}$

$= 0.150$

Readers are referred to Grant, Sandland and Olsen (1979, pp. 634-5) for further information about a stock assessment of the school shark fishery.

4.5 The Population in the Community and the Ecosystem

The early stages of the life cycle of the school shark are passed in an inshore environment, particularly in low energy coast regimes, before the juvenile school sharks move out into the open waters of the continental shelf of southeastern Australia.

5. EXPLOITATION

5.1 Fishing Equipment

5.1.1 Present gear (summarized from Hughes, 1971, 1981)

- Mesh nets

The gillnet is bottom set as a stationary net, anchored and buoyed at each end.

Material: Mostly monofilament, sometimes of 210/15- or 210/18-ply multifilament nylon with the fibre having a breaking strain of 300-400 N.

Length: 400-600 m and/or 30 m and multiples of these lengths.

Depth: 10-15 meshes "drop".

Headline: 6-10 mm diam sisal or polypropylene rope.

Leadline: 6 mm diam polyethylene rope.

Floats: 80-120 g upthrust for attaching at intervals of 5-10 m along the headline.

Weights: 7 x 60 g lead weights/float.

Hanging coefficient: Between 0.5 and 0.7 (i.e., half or more slack).

Minimum mesh size (legal): South Australia 15 cm, Tasmania 15 cm, Proclaimed waters 15 cm, and Victoria 15 cm.

- Hauling gear - stern mounted drum winch for nets

Mostly hydraulically driven, which allows the net to be set over the stern. The net is hauled over a forward mounted roller with vertical guide rollers and then lead back to the drum winch for hauling and storage (Hughes, 1981).

Number of nets used:

(a) up to 10 nets may be used at any one time (400-600 m units);

(b) 30-m long mesh nets - 45 nets may be used.

- Longlines - fibre or rope

Ground line: Made up into units of 6-8 m diam sisal, manila or synthetic rope (polypropylene) 400 or more metres in total length.

Snoods: 60-96 thread, hard laid cotton seine twine (according to individual preference) or equivalent in sisal, manila or synthetic twine (5-6 mm braided propylene) 1-2 m in length are fastened to a 15-20 cm long 14 gauge galvanized wire trace, to which is secured the hook. The snoods are spaced 4-8 m apart and are either fixed permanently or attached temporarily by means of a clip to the ground line.

Hooks: Sizes Nos. 9/0, 10/0, 11/0 or 12/0, according to area, are used, sometimes offset shanks are preferred or alternatively long shank hooks are used in place of wire traces.

Buoy line: 6-8 mm diam sisal or synthetic rope. Length depending on depths fished and tide strengths.

Anchor line: Similar to buoy line though in some circumstances a small diameter line to the anchor may be used on rocky bottom.

Anchors: Individual preference but usually a Danforth anchor is used.

Buoys: Two or three 30-40 cm diam buoys fastened to a flag marker are attached to the buoy line. A stray line, with smaller diameter buoy for grappling, may be secured to flag marker buoys.

Box or set of hooks: Each ground line consists of approximately 100 hooks or some such preferred number convenient for storage and baiting.

Fishing operation: A number of boxes or sets of 100 hooks are joined together according to personal preference or circumstances. As many as 2 500-3 000 hooks joined into one longline may be set on the bottom in one operation.

Bait: In southeastern Australian waters fresh bait is preferred.

Common bait:
- Barracouta (snoek) - *Leionura atun*
- Australian salmon - *Arripis trutta*
- Yellow-eye mullet - *Aldrichetta forsteri*

Hauling gear: Longlines are fed over a rail-mounted roller to a waist-high horizontally mounted double-disc hauler driven either separately by a hydraulic or electric motor connected by belts to a drive from the main engine.

- Longline - wire

Ground line: 3-mm diam galvanized, flexible 6/19 steel wire of approximately 500 kg breaking strain made up in units of 200 m. Each 200-m unit has eyes spliced into the end for link clips. Wire ground line is treated with wire rope lubricant as necessary.

Buoy line: 4-mm diam galvanized flexible 6/19 steel wire of approximately 760-kg breaking strain. Wire rope lubricant treatment as necessary. Lengths varying from 20, 40, 100 to 200 m each end are attached to link clips.

Hooks: Sizes 10/0, 11/0 and 12/0.

Snoods: 96 thread cotton with 15-20 cm 14 gaude galvanized wire trace is fastened to hooks of required size. The cotton twine is fastened to safety clip.

Ball stops: Moulded directly to the wire ground line by a split-hinged mould and swaged tight where necessary. Spacing approximately 1 m apart.

Reels: Ground and buoy lines are hauled directly on to reels each of which hold 1 000 m and weigh approximately 45 kg. Ground and buoy lines are unclipped and wound on the same reels. The snoods are unclipped from the ground line as it is hauled. Reels are fabricated from 76-mm diam mild steel pipe and 19-mm thick marine ply. The mild steel pipe forms a hollow central spindle, and mild steel flanges 15-cm diam are welded 25 mm from ends of pipe. These flanges have bolted to them the marine ply to complete the reel. Each reel is engaged in lugs on the winch shaft and secured by a flange-headed bolt screwed into the shaft. The reels are therefore easily detachable from the winch.

Setting of longline: Buoy and ground lines are paid out over a fairlead, preferably on stern of vessels, from reels attached to the winch. Baited hooks, stowed in a 3-compartmented galvanized iron trough are clipped sequentially to the appropriate ball stop as the line comes off the reel and passes through the fairlead (Cowper and Downie, 1957).

- Changes in fishing methods and area during development of fishery

Period	Fishing method	Fishing area
1927-40	Longlines and large mesh gillnets	Bay waters
1940-45	Longlines	Inshore waters (36-55 m)
1945-50	Longlines	Offshore waters (to 110 m)

Period	Fishing method	Fishing area
1950-64	Longlines (rope and wire)	Offshore waters (to 165-180 m)
1964-74	Longlines and large mesh gillnets	Offshore waters (to 180 m)
1974-	Large mesh gillnets (except on edge of continental shelf)	Offshore waters (to 270 m)

5.1.2 Changes in types of boats and types of gear and mean distances travelled per trip during development of fishery

See Table XI.

5.2 Fishing Areas

5.2.1 General geographic distribution

- Southeastern Australia

South Australia	613	Western limit-longitude 130°E
Victoria	614	Western limit-longitude 141°E
Tasmania	617	Eastern limit-longitude 149°E Southern limit-latitude 45°S
New South Wales	615	Northern limit-latitude 35°S
New Zealand North and South Islands	630	Continental shelf trawl grounds

5.2.2 Geographic range

Figure 2 shows limits of existing fishery in Australian waters.

5.2.3 Depth ranges

Continental shelf to 600 m (Cowper and Downie, 1957; Smith, 1980).

5.3 Fishing Seasons

5.3.1 General pattern of season(s)

In general, the fishery operates all the year round but it is controlled by weather, hence more intensified in summer and autumn when calmer sea conditions prevail.

5.3.2 Dates of beginning, peak and end of season(s)

See Table XII.

5.4 Fishing Operations and Results

5.4.1 Effort and intensity

Inadequate records of effort and species differentiation at beginning of fishery and confusion in recording effort data during 1941-45 precluded any uniform unit of effort being used throughout the fishery (see Olsen, 1959, pp. 150-1)(see Tables XIII, XIV and XV).

5.4.2 Selectivity

- Selective properties of gear

Juveniles: Refer Olsen, 1954, p. 379.

Fishermen have transferred to 15-20 cm mesh nets for fishing school and gummy sharks because they considered this technique more efficient and giving a higher economic return per unit of effort than longline gear (Tables XIII, XIV, XV).

5.4.3 Catches - southeastern Australia[1/] (Victoria, Tasmania and South Australia)

The total landings of school shark have, in the main, been separated from catches of other shark species. During examination of all catch records of landings in southeastern Australia from 1927 to 1956, Olsen (1959)(Table XVI) found and corrected many errors of interpretation and transposition; consequently his figures of total carcase landings of school shark will be at variance with published official reports.

From its beginning in 1927 the school shark fishery had a steady rise in total landings to a minor peak of 1 862 t in 1949 (Figure 25).

During the following decade annual production fell, due to a reduced demand for livers for high potency Vitamin A liver oil.

1/ Exclusive of New South Wales trawl catches of school shark. The NSW shark catch is approximately 800 t annually and only 3-7% is composed of school sharks. In Western Australia school sharks form a very minor component of the shark catches and is not listed as a separate species in landings

Table XI

Changes in types of boats and kinds of gear used during development of fishery

Period	Boats Av.length	Crew No.	Engine		Hauling gear	Fishing gear			Distance travelled per trip (km)	Improvements in fishing technology
			Power hp	Propulsion		Nets	Longlines			
							Av.No.of hooks	No.of times used/trip		
1927-40	15-30 ft 4.5-9 m	1-2	5-20	Petrol	Hand hauled	10-15 cm	100-200	1	3-10	-
1940-45	23-52 ft 6.7-15.8 m	2-3	20-60	Petrol: a few diesels only	Hand hauled. Prototype mechanical hauler being tried	Used occasionally in-shore areas	200-1200	1	8-23	Diesel engines fitted into 1 or 2 vessels. Prototype mechanical line haulers introduced. Ship to shore HF radio-telephone introduced. Refrigeration units installed on 1 or 2 vessels.
1945-50	36-60 ft 10.9-18.3 m	3-4	60 & over	Mostly diesel	Mechanical longline disc hauler	-	1500-2500	1-2	90-112	Diesel engines replacing petrol motors. Automatic line haulers introduced. Echosounders introduced. Refrigeration units and ice boxes installed.
1950-64	40 ft & over 12-24 m	3-4	60 & over	Diesel	Mechanical longline disc hauler	-	1500-2500	1-4	90-112	More powerful diesel engines replacing smaller diesels. Vessels leaving home ports, unloading in another port and fishing on return voyage. Longer periods at sea. Automatic pilot and remote steering controls. Radar and sonar fish finders installed. Direction finders installed.
1964-74	40 ft & over 12-24 m	3-4	100 & over	Diesel	Mechanical net hauler introduced	10-20 cm mesh gillnets reintroduced	longlines being phased out	1-4	90-112	Progressive introduction of stern mounted net drum winches - redesign of vessel superstructure in some areas. Lights on dahn buoys for night fishing with nets.
1974-	40 ft & over 12-24 m	3-4	100 & over	Diesel	Mechanical net hauler	12-20 cm gillnets	-	-	90-112	Almost complete phasing out of longlines except along edge of continental shelf. Radio transmitter buoy on deep water longlines.

Table XII

Approximate dates of fishing intensities in different areas

Land area code	Area			Beginning	Peak	End
613	South Australia	West coast		Jun.	Aug.-Oct.	Nov.
		Southeast coast	(i)	Apr.-May	Jun.-Jul.	Aug.
			(ii)	Sep.	Oct.-Nov.	Dec.
1.6.3	Western Bass Strait			Oct.	Nov.-May	Jul.
4.9.3	Eastern Bass Strait			Oct.	Nov.-May	Jul.
617	Tasmania	(a) Continental shelf		Nov.	Dec.-May	Jul.
		(b) Continental slope		Apr.-May	Jun.-Jul.	Aug.

Table XIII

Longlining fishing catch and effort in inshore (1944) and offshore (1956) Victorian waters (Olsen, 1959)

Year	No. of vessels	No. of sharks caught	No. of hooks used	Wt. of shark landed ('000 lb)	Mean No. of months worked	Shark mean wt. (lb)	No. of hooks/ shark	lbs/ hook	Catch/ boat month (lb)	Hooks/ boat month
1944	20	66 097	482 690	973	10.2	14.7	7.3	2.01	4 765	2 366
1956	26	57 096	788 925	786	6.5	13.7	13.6	0.99	4 643	4 668

Catch records for early period of shark fishing at Stanley, Tasmania[a]

Year	No. of sharks caught	No. of hooks used	Shark mean wt. (lb)	No. of hooks/ shark	lbs/ hook	Average distance trav. from base to fishing area	No. of hook miles/ shark
1942	292	600		2.0		3.0	6
1944	1 688	8 000		4.7		6.3	29
1946	861	4 400		5.1		18.0	91
1947	687	6 100		8.9		10.6	94
1948	470	3 000		6.4		24.0	153

a/ Data extracted from log of commercial fisherman

Table XIV

Comparison of longline production and fishing effort for four shark species for years 1970, 1978, and 1979 for eastern and western Victorian waters (Walker and Caton, 1980)

Year	Production (t)[a/]				Fishing effort		
	Shark species						
	School	Gummy	Saw	Elephant	Boats (1 t +)	Boat days	1 000-hook lifts
				Eastern Victoria			
1970	828	257	2	0	39	2 688	3 971
1978	20	2	0	0	2	48	37
1979	9	18	0	0	2	54	93
				Western Victoria			
1970	247	64	0	0	25	776	907
1978	1	2	0	0	1	33	50
1979	1	1	0	0	2	23	9

a/ Carcase weight (beheaded and gutted)

Table XV

Shark production of four species by mesh netting and fishing effort for the years 1970, 1978 and 1979 for Eastern and Western Victoria (Walker and Caton, 1980)

Year	Production (t)				Fishing effort				Ton /100 km net-lift			
	Shark species								Shark species			
	School	Gummy	Saw	Elephant	Boats (1 t)	Boat days	Net 10^3 km-lifts	Hooks 10^3-lift	School	Gummy	Saw	Elephant
						Eastern Victoria						
1970	60	257	42	12	21	1 274	3.6	-	16.5	71.5	11.6	3.5
1978	219	830	285	79	48	2 847	17.6	-	12.4	47.0	16.2	4.5
1979	321	560	263	107	48	2 567	17.5	-	18.3	32.0	14.9	6.1
						Western Victoria						
1970	248	82	12	1	20	2 001	2.5	-	100.2	33.2	4.7	0.3
1978	43	140	47	3	25	871	2.7	-	15.8	51.0	17.0	1.1
1979	89	110	52	4	25	816	2.9	-	30.7	37.8	18.0	1.2
						Total Victoria						
1970	1 385	702	75	14	124	9 526	21.2	-				
1978	288	1 021	368	99	87	3 920	21.7	-				
1979	432	750	353	122	96	3 679	22.4	-				

Table XVI

School shark production[a/] - southeastern Australia 1956-57/1980-81
Landed weight in t (carcase)

Year	South Australia	Victoria	Tasmania	Southeastern Australia
1956-57	508	602	433	1 543
1957-58	353	688	335	1 356
1958-59	330	635	144	1 109
1959-60	328	529	586	1 443
1960-61	303	367	252	992
1961-62	285	866	180	1 331
1962-63	473	879	151	1 503
1963-64	430	954	197	1 581
1964-65	348	1 003	136	1 487
1965-66	371	959	265	1 595
1966-67	678	1 075	208	1 961
1967-68	587	1 003	349	1 939
1968-69	487	1 130	393	2 010
1969-70	533	1 403	279	2 215
1970-71	526	1 385	228	2 139
1971-72	591	1 260	298	2 149
1972-73	246	842	276	1 364
1973-74	463	159	111	733
1974-75	183	234	152	569
1975-76	617	570	195	1 382
1976-77	480	541	355	1 376
1977-78	421	388	375	1 184
1978-79	415	288	631	1 334
1979-80	708	432	480	1 620
1980-81	958	-	540	1 498[b/]
1981-82	1 065	-	-	
1982-83				

a/ Production figures 1927-56 see Olsen, 1959 b/ Incomplete

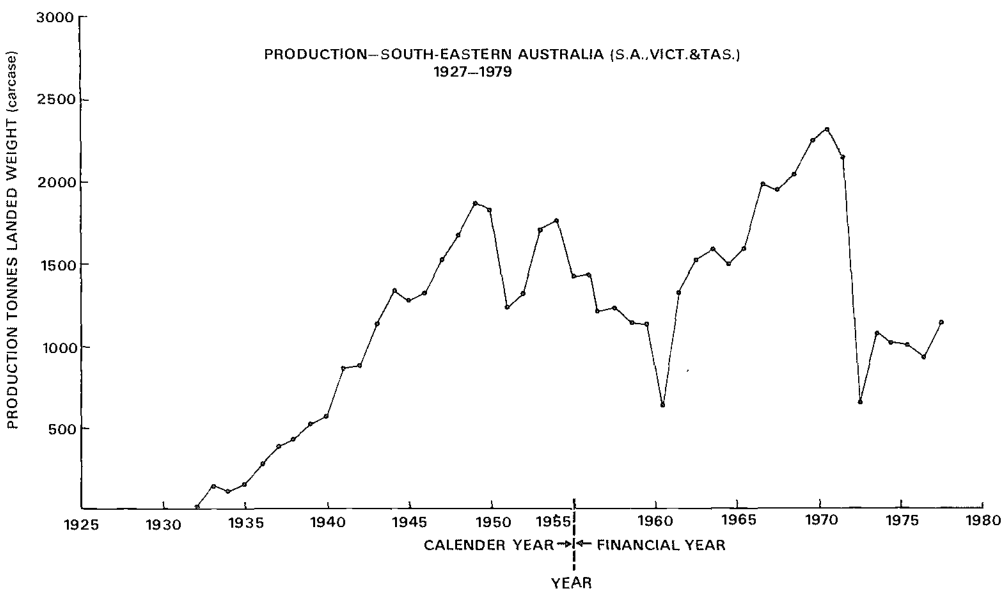

Figure 25 School shark production - southeastern Australia

A low of 992 t in 1960-61 was reached, only to rise again with the introduction of mesh netting (Table XI) to a maximum yield of 2 215 t in 1969-70. The subsequent dramatic decline beginning in 1972-73 was the result of introduction of a legal maximum concentration content of total mercury (0.5 mg/kg wet weight) in flesh of school sharks. This action stopped the sale of large mature sharks and so prevented fishermen from landing these larger sharks.

The legislation resulted in increased fishing pressure on immature sharks in eastern Bass Strait and elsewhere, and there has been a rise from a low yield of 569 t in 1974-75 to reach more than 1 600 t in 1979-80. The impact of increased fishing pressure on immature school sharks since 1975 is causing concern for the future of this long-lived shark species.

New Zealand: School sharks have traditionally been a by-catch in the trawl fisheries of both islands (Watkinson and Smith, 1972) with some small target line fisheries, usually seasonal, in some regions. Reported production to 1979 was some 300-600 t annually, with higher but unrecorded catches during the Vitamin A/liver oil fishery of the late 1940s and early 1950s. From 1980 there has been greatly increased effort in target line and net fisheries, bringing the annual catch to 2 000-3 000 t." (Paul, personal communication).

6. PRODUCTION AND MANAGEMENT

6.1 Regulatory (Legislative) Measures

6.1.1 Limitation or reduction of total catch

Various management tools are used to limit fishing effort, i.e., mesh size regulations (see Table XVII).

- Limitations on number of fishing units - fishermen

Victoria has limited entry provisions. South Australia has restricted the use of mesh nets for sharks to certain categories of fishermen.

6.1.2 Protection of portions of populations of school sharks

See Table XVIII.

Table XVII

Mesh nets - regulations on use

Mesh nets	Victoria	Tasmania	South Australia	New South Wales	Proclaimed waters[a] adjacent to 3 States
Minimum mesh size	15 cm	15 cm	15 cm	4 in (10 cm) monofilament gillnetting controlled by permit	15 cm
Net length	-	-	Maximum 550 m each - 2 or more may be joined	-	-
Number of nets to be carried or used	-	-	Vessel may not carry or use more than 5 nets (max. = 2 750 m)	-	-
Restrictions on operations	-	-	Nets must not be left set for more than 4 h, or left unattended	Bottom set nets banned in oceanic waters (except by special permit)	Bottom set nets banned in proclaimed waters off NSW (except by special permit)

a/ See Australian Government Gazette S144, Fisheries Notice No. 65, proclaimed 17 August 1976 - for definition of proclaimed waters off Victoria, Tasmania and South Australia

Table XVIII

Summary of regulations on taking of school shark

		Victoria	Tasmania	South Australia	New South Wales	Proclaimed waters adjacent to 3 States
Closed areas		Bays and inlets closed to mono-filament gill-nets	Prohibition of taking school shark in certain waters	-	-	-
Closed seasons		-	-	-	-	-
Legal minimum length	Measured from fifth gillslit to base of tail.	Min. 40 cm (partial length)	Min. 40 cm (partial length)	Min. 40 cm (partial length)		Min. 40 cm (partial length)
	Equiv. total length	71 cm	71 cm	71 cm	36 in (91 cm)	71 cm
Legal maximum length	Measured from fifth gillslit to base of tail.	63 cm (partial length)	-	-	-	-
	Equiv. total length	112 cm				
Mercury concentration	milligrams/kilogram flesh wet weight	0.5	0.5	1.0	0.5	0.5
Restrictions on use of shark	Carcase form for landing	Must be landed dressed, but head attached	-	-	-	-

7. MISCELLANEOUS

7.1 Metallic Element Concentrations

Walker (1976) showed that total mercury concentrations varied exponentially with shark length, and male school sharks had significantly higher levels of mercury than females.

A large female school shark, 156 cm in length and at an estimated age of 21 years at release, recaptured after 25 years of freedom, had a total mercury concentration of 4.50 mg/kg (60% moisture), the equivalent of 3.40 mg/kg at 80% moisture (Olsen, 1983)(Table XIX).

Maximum concentrations of total mercury and cadmium (from different sharks) exceed the maximum permissible concentrations for these metallic elements in Australia. The inorganic arsenic concentration of the shark with a total arsenic concentration of 23 mg/kg is not known (Glover, 1979).

All other metallic element concentrations are less than the legal maximum permissible concentrations in Australia.

7.2 Vitamin A Potency of School Shark Liver Oil (International Units/gm Oil)

Livers of school sharks were sought after in Australia as a replacement of cod-liver oil (Olsen, 1959). Liver weights increased with increase in cleaned weight, non-gravid females having heaviest livers (Olsen, 1954).

The Vitamin A potency (I.U./gm liver oil) varies widely:

Year	Annual bulk potency (I.U./gm)
1941	20 000
1948-49	18 000
1952	14 000
1953	12 900

Table XIX

Maximum concentration of metallic elements found in muscle tissue of school sharks

Element	Hg	Cu	Zn	As	Se	Cd	Mn
Maximum concentration (mg/kg wet weight)	3.40	0.6	4.0	23	0.8	0.6	0.6
Element	**Co**	**Cr**	**Pb**	**Mo**	**Ni**		
Below limit of detection (mg/kg wet weight)	0.3	0.5	0.1	0.2	0.2		

Maximum individual liver oil potencies (from selected livers)

Sex	Total length	Liver colour	Liver weight	% oil	Vitamin A I.U./gm oil
Male	155 cm	dark	1.361 kg	45	122 000
Female	158.7 cm	-	0.755 kg	16.4	156 000

(The female was carrying full-term embryos when caught.)

Seasonal variation: Highest - 16-24 000 I.U. (average) - February, July-August
Lowest - 11 000 I.U. (average) - April

Area variation: Highest - western Bass Strait and South Australian waters
Lowest - eastern Bass Strait

Variation between sexes: Males - 24-30 000 Vitamin A I.U./gm oil
(selection by liver size) Females - 6-9 000 Vitamin A I.U./gm oil

At birth, the Vitamin A content of school shark liver oil is negligible but gradually increases in potency with length of sharks (Olsen, unpublished data).

Hypervitaminosis symptoms from eating cooked school shark livers have been reported (Lonie, 1950).

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ISBN 92-5-102085-X