INVESTIGATION OF SCHOOL & GUMMY SHARK NURSERY AREAS IN SE TASMANIA

FINAL REPORT

PROJECT 91/23

CSIRO Division of Fisheries

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CONTENTS

A. INTRODUCTION

School sharks (*Galeorhinus galeus*) and gummy sharks (*Mustelus antarcticus*) are both medium sized houndsharks (Family Triakidae) attaining about 175 cm total length (TL). School sharks are widely distributed in temperate waters of the north east and south west Atlantic, eastern north and south Pacific, off South Africa, New Zealand and southern Australia. Locally, they have been recorded from Moreton Bay (Queensland) to Perth (Western Australia) including Lord Howe Island and Tasmania. They are mainly demersal on the continental and insular shelves and upper slopes from nearshore to 550 m depth. Gummy sharks are endemic to temperate Australian waters and have been recorded from at least as far north as Port Stephens (New South Wales) and Geraldton (Western Australia). They are demersal on the continental shelf from nearshore to about 80 m, but have been taken as deep as 350 m.

In Australia, school and gummy sharks are the main target species of the Southern Shark Fishery which has annual landings of about 4500 tonnes live weight worth about $15 million to fishermen in Victoria, Tasmania and South Australia. Sharks are taken by demersal gillnets and longlines; some are also caught commercially by trawlers. Stocks of both species are considered by scientists and many fishermen to be over-exploited and in 1988 a management plan was introduced which created a limited entry gillnet fishery and which imposed gillnet gear controls. Gummy (and limited numbers of school) shark are also caught commercially in Western Australia where fishing is controlled by a joint authority between Western Australia and the Commonwealth.

Research on school sharks was started in the 1940s (Olsen 1953, 1954, 1959) and on gummy sharks in the 1970s (Walker 1984, 1988). The biology and population dynamics of both species are now reasonably well known (Olsen 1984; Walker 1992). Both species are thought to consist of single stocks throughout their southern Australian range and both are ovoviviparous producing litters of up to 40 pups after a gestation of some 12 months. The young are born between November and January and are about 30 cm TL at birth. However, information on their first years of life are limited, particularly for gummy shark.

Olsen (1954) noted that the newborn school sharks were apparently restricted to nursery areas in sheltered inshore bays which were separate from the main adult population. Furthermore he considered that the nursery areas for the whole southern Australian stock were restricted to Tasmania and Victoria. Olsen (1954) chose a number of sites around Tasmania (Pittwater, Georges Bay and Port Sorell) and Victoria (Port Phillip Bay and Western Port Bay) where he was able to make high catch rates of juveniles by hook fishing. Based on tag-recaptures and information from fishermen Olsen (1954) proposed that pregnant school sharks move into shallow estuaries and bays around Tasmania and southern Victoria, give birth and then move out into deep water. The neonatal sharks stay in the nursery areas during summer and then move out into deeper inshore areas during winter. Juveniles return to the nursery areas during summer for up to two years after their birth. Different nursery areas appeared to have different age distributions of sharks; for example in Port Sorell only 0^+ and 1^+ year old fish were caught while in Georges Bay sharks ranged in age from 0^+ to 3^+ years. Using a standard fishing technique Olsen (1954) documented catch rates in two nursery areas over a 5 year period between 1948–1952; he noted an apparent decline in catch rate which he attributed to a decline in stock size resulting from heavy fishing pressure. Olsen (1984) commented that 'This work has not been repeated (since) and hence no recent data are available for comparison'.

Gummy shark are thought to utilise inshore bays throughout their southern Australian range as nursery areas, but no specific investigations into the distribution of neonatals and juveniles have been carried out. Inshore pupping is suggested on the basis that small juveniles are rarely caught by the offshore commercial fishery whereas they are taken as bycatch in various inshore operations targetting other species. However, these data are complicated by the effects of gear selectivity as the commercial shark fishery uses relatively large mesh and hook sizes and so is unlikely to catch these small fish. However, more limited research fishing using small mesh nets (50–102 mm stretched mesh) also indicates that small juveniles are rare offshore.

Both industry and scientists have identified as an issue of major importance the lack of information on the location and extent of shark nursery areas and the vulnerability of sharks within these areas to human-induced mortality. The Southern Shark Fishery Management Advisory Committee (SSFMAC) recomended in February 1990 that 'comprehensive information should be sought from fishermen and scientists on the location of pupping grounds in each State with a view to improved controls over such areas'. The report from the 5th Southern Shark Stock Assessment Workshop (SSSAW) stated that 'the vulnerability of juvenile sharks to capture by professional and recreational fishermen in Tasmanian inshore waters is of concern to the research group'. Because of the close stock-recruitment relationship in sharks, high mortality in the pupping and nursery areas as a result of fishing or habitat degradation will translate more directly into a reduction in adult stock size than in scale-fish fisheries. Increased recruitment through improved management of nursery areas would promote stock recovery and complement the current Commonwealth management plan aimed at stabilising catches by reducing effort in the fishery.

B. OBJECTIVES

(1) To test and refine a sampling strategy that will permit statistically robust estimates of the density of neonatal and juvenile school and gummy sharks in a study site in south eastern Tasmania.

(2) To use these estimates to establish whether pupping and nursery grounds for school and gummy sharks are confined to inshore sheltered habitats within the study site.

(3) To determine the distribution, size composition, duration time and movements of neonatal and juvenile sharks in the study site.

(4) To compare hook catch rates of school shark in Pittwater in 1992/93 with catch rates in the period 1947 to 1953

(5) To assess the impact of recreational and commercial fishing on neonatal and juvenile sharks in the study site.

with a view in the longer term to:

(5) Determining the location and extent of pupping and nursery grounds for school and gummy sharks in south eastern Australia.

(6) Assessing the contribution to recruitment of the different pupping and nursery areas.

(7) Examining fishing mortality in the more important pupping and nursery areas.

C. SUMMARY OF RESULTS

Catches of newborn (0^+) school sharks were essentially restricted to Pittwater, the majority being caught in upper Pittwater (Fig. 1) supporting the hypothesis that neonatals are restricted to inshore, sheltered embayments during summer. This was not the case for 0^+ gummy sharks which occurred throughout the study site but were most abundant in the catches from Frederick Henry and Storm Bay (Fig. 1).

The length distribution of sharks caught from all areas combined is shown in Fig. 5. School sharks ranged from 28.6–140.1 cm TL with the majority of the catch comprising 30–90 cm (0^+ to 3^+ year old) fish. Gummy shark ranged from 31.3–163.5 cm and comprised mainly 50–95 cm (1^+ to 4^+ year old) fish. Few fish of either species larger than 100 cm were caught (which is to be expected on the basis of mesh selectivity).

The length distribution of sharks caught in each bay is shown in Figs. 7 & 8. For school sharks, there is a trend for older fish to be caught in the deeper, more exposed bays. Pittwater contained newborn and 1 year old fish while Frederick Henry and Storm Bay contained mostly 1 and 2 year old sharks. Gummy shark length distributions varied by bay but no trend in the distribution of age classes with depth was apparent.

The catch per unit effort (cpue) for both species was generally higher in summer and lower in winter in all three bays (Fig. 4). Newborn school sharks were only caught in Storm Bay in winter, supporting the hypothesis that they move into deeper, warmer water during winter (Olsen 1954).

The cpue of school and gummy sharks in Frederick Henry and Storm Bay was generally much lower in the reef strata compared to the sand strata (Fig. 9). In the sand strata, the cpue of both species declined with increasing depth in Frederick Henry Bay while in Storm Bay the relationship between cpue and depth was less clear.

An index of abundance (mean cpue) was calculated for each species in each bay. Based on total catch, Frederick Henry Bay had the highest abundance of both school and gummy sharks (Fig. 10). When the catch is partioned by age class the highest abundance of 0^+ school sharks was in upper Pittwater, and of 1 and 2^+ school sharks was in Frederick Henry Bay (Fig. 10). The highest abundance of 0^+, 1^+ and 2^+ gummy sharks was in Frederick Henry Bay (Fig. 10).

An index of population size was calculated for each bay by multiplying the mean cpue of the bay by its area. Based on total catch, Frederick Henry Bay had the highest population index for school sharks and Storm Bay had the highest index for gummy sharks. (Fig. 11). When the catch is partitioned by age class the highest population index for 0^+, 1^+ and 2^+ school sharks was in Frederick Henry Bay (Fig. 11). The highest population index for 0^+, and 2^+ gummy sharks was in Storm Bay while the highest index for 1^+ fish was in Frederick Henry Bay (Fig. 11).

Of 195 school sharks and 782 gummy sharks tagged, since September 1991, 18 school (9.2%) and 60 gummy sharks (7.7%) have been returned to date. The majority of sharks were recaptured within the study site. The proportions of sharks moving different distances are summarised in Fig. 13.

A major decline in hook and line catch rates of juvenile school sharks from lower Pittwater was evident when the current data from 1991/92 were compared to the period 1947-53. Olsen (1954, 1984) was able to catch up to 80 juvenile school sharks a day on handlines off Woody Island in lower Pittwater. A total of seven days (22.5 hrs) handlining in the same position during 1991/92 resulted in a catch of 2 gummy sharks and no school sharks. Olsen (1954) also caught pregnant school sharks on longlines as they moved into Pittwater to give birth. Five longline sets with a total of 280 hooks were set in the same area where Olsen fished and resulted in a catch of 18 gummy sharks and no school sharks.

The diet of 0, 1 and 2^+ school sharks was examined. The importance of crustaceans in the diet declined with increasing age. In 0^+ sharks, fish, cephalopods and crustaceans were of similar importance, while in 2^+ sharks crustaceans were a negligable component of the diet. The cephalopod component in the diet also declined with increasing age class, but this was mainly a reflection of relatively high predation of 0^+ sharks on the inshore loliginid *Loliola noctiluca* in Pittwater. Of the identifiable teleost component in the diet, the most important species were school whiting *Sillago bassensis*, sand flathead *Platycephalus bassensis*, anchovy *Engraulis australis*, cod *Pseudophycis bachus* and (particularly in 0^+ sharks from Pittwater) bridled goby *Arenigobius bifrenatus.*

Monthly growth increments of 0 and 1^+ school sharks averaged about 2.3 cm TL and length at age estimates for 1, 2 and 3 year old sharks were 47, 64 and 80 cm respectively, similar to those obtained by Grant at al. (1979). While Olsen (1954) did not detect any seasonal variation in growth rates of tagged fish, we found that growth rates slowed during the colder months.

D. PRINCIPAL RECOMMENDATIONS FOR MANAGEMENT

Results of this 12 month study in Pittwater, Frederick Henry and Storm Bays indicate that newborn (0^+) school sharks are essentially restricted to the shallow protected environment of Pittwater, particularly to areas above the causeway, during the November to April period. Newborn gummy sharks were not restricted to shallow embayments within the study site. Gummy sharks of 1^+ to 4^+ years old are relatively abundant in Pittwater, particularly during November to April. Newborn sharks are vulnerable to 50 and 76 mm mesh gillnets and to hook fishing. The ban on the taking of school and gummy sharks and the use of gillnets (particularly with small meshes) in Pittwater should be maintained.

The shallow estuarine habitats of newborn school sharks and their possible association with sea grass beds would seem to make them particularly vulnerable to environmental degradation and pollution (such as agricultural run-off and sewage discharge).

Juvenile school and gummy sharks of 1^+ to 4^+ years old are relatively abundant in Frederick Henry Bay, particularly between November and April. Catch rates are highest in the shallow (0–10 m) depth strata over sand bottoms. Catch rates were low in the shallow (0–10 m) reef strata (the rocky areas around the perimeter of the bay). Current restrictions which permit fishing with 102 mm mesh recreational graball nets close to the shore, but prevent netting in deeper water, are adequate so long as effort is not targetted over sandy bottoms.

Gummy sharks of 1^+ to 4^+ years old are relatively abundant in Storm Bay, particularly between October and June, and in the 0–40 m depth range over sand bottoms; Storm Bay does not appear to be particularly important for juvenile school sharks.

Pregnant school sharks would appear to be very vulnerable to target fishing as they move into shallow water to give birth; this is especially true where they have to move through relatively narrow bays or channels to reach the pupping grounds.

E. DETAILED RESULTS

INTRODUCTION

Both industry and scientists have identified as an issue of major importance the lack of information on the location and extent of shark nursery areas and the vulnerability of sharks within these areas to human-induced mortality. The Southern Shark Fishery Management Advisory Committee (SSFMAC) recomended in February 1990 that 'comprehensive information should be sought from fishermen and scientists on the location of pupping grounds in each State with a view to improved controls over such areas'. The report from the 5th Southern Shark Stock Assessment Workshop (SSSAW) stated that 'the vulnerability of juvenile sharks to capture by professional and recreational fishermen in Tasmanian inshore waters is of concern to the research group'. Because of the close stock-recruitment relationship in sharks, high mortality in the pupping and nursery areas as a result of fishing or habitat degradation will translate more directly into a reduction in adult stock size than in scale-fish fisheries. Increased recruitment through improved management of nursery areas would promote stock recovery and complement the current Commonwealth management plan aimed at stabilising catches by reducing effort in the fishery. Improved management will have benefits for commercial shark fishermen and the Australian economy (the fishery is currently worth $15 million to fishermen in Victoria, Tasmania and South Australia).

As a result of Olsen's (1954) work a number of shark nursery areas were proclaimed; some of these areas were closed to gillnetting while in other areas bans were imposed on the taking of shark but not on the deployment of fishing gear. Recreational gillnetting, hook and line fishing and some commercial fishing for scale fish takes place in, and adjacent to, these regions and still results in some mortality of juvenile sharks. If Olsen's conclusions for school shark are correct, their restricted nursery sites makes them vulnerable to fishing pressure and environmental change. Anecdotal information suggests that both fishing and habitat degradation in these areas over the last four decades has dramatically reduced the numbers of neonatal and juvenile sharks found there. Habitat degradation has occurred through loss of sea grass beds, alteration of tidal flow (for example the causeway construction at Pittwater), high nutrient loadings caused by sewage, and toxins from agricultural runoff. The Tasmanian Government is committed to providing more effective protection to shark nursery areas but is hampered by the current lack of information. As an interim measure pending results of further research, new regulations restricting gillnetting in nursery areas were introduced from December 1990. These regulations banned recreational and commercial gillnetting in designated pupping grounds and restricted gillnets in designated juvenile grounds to shallow water (less than 200 m from shore).

MATERIALS AND METHODS

Choice of study site

The study site was chosen because of its proximity to Hobart, the fact that it included Pittwater which had been identified and studied as a school shark nursery area in the 1950s, and its structure. The site comprises a series of four interconnected bays which vary in depth, shelter and habitat availability from a shallow inshore estuary to a semi-exposed bay which opens to exposed waters of the continental shelf. The bays form a 'transect' which can be used to examine the distribution, size composition and abundance of juvenile sharks from 'inshore' to 'offshore' and to test the hypothesis that newborn sharks are confined to inshore, sheltered habitats.

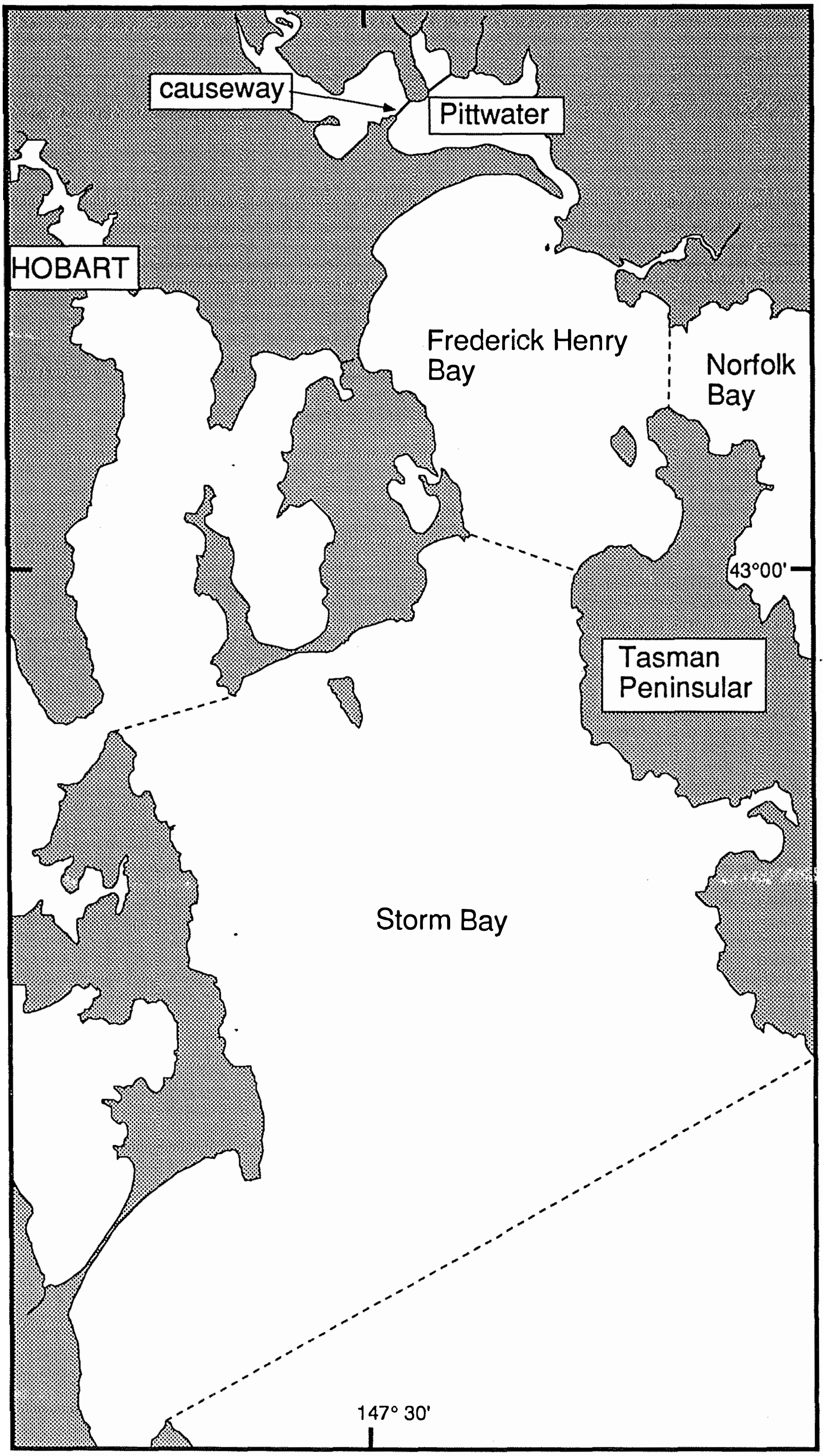


Figure. 1 The study site of Pittwater, Frederick Henry Bay and Storm Bay.

Description of study site

The four bays, upper Pittwater, lower Pittwater, Frederick Henry Bay and Storm Bay, are shown in Fig. 1. Pittwater is a shallow estuarine embayment divided, apart from a narrow channel, by a road causeway into an upper section, which includes the Coal River estuary, and a lower section which opens into the adjacent Frederick Henry Bay by a narrow channel. Pittwater consists of a series of flats, some exposed at low tide, and deeper channels and basins. Maximum depths are about 7.5 m in upper Pittwater and 11.0 m in lower Pittwater, and the bottom type is predominantly muddy sand throughout. The area of upper and lower Pittwater which we were able to sample was 7.7 km^2 and 12.6 km^2, respectively. Frederick Henry Bay has a maximum depth of 42 m, an area of 255 km^2 and the bottom type varies mainly from sand to muddy sand although there are areas of reef, mainly around the perimeter of the bay. Storm Bay has an area of 734 km^2 and a maximum depth of 73 m; the bottom type varies from reef to sand and muddy sand.

Fishing gear

The bottom-set monofilament gillnets were 75 m in length comprising 25 m panels of 50, 76 and 102 mm stretched mesh. The monofilament diameter was 0.40–0.45 mm and the 50, 76, and 102 mm mesh panels were 50, 34 and 25 meshes deep, respectively. The sequence of the different mesh panels was randomised between nets. These mesh sizes were required to adequately sample the 0^+ to 4^+ year old fish (Kirkwood and Walker 1986). All nets had hanging ratios of 0.5, hanging coefficients of 0.87 and a depth of 2.2 m. The headline was made of 6 mm diameter blue polypropylene rope, with 1 Y3 float (40 g upthrust) per 80 cm giving 94 floats per net (3 kg upthrust). The leadline was made of 6 mm diameter blue polypropylene rope, with 50 g leads every 40 cm giving 188 leads per net (9.4 kg). The nets were anchored with 5 kg weights at either end.

Longline gear comprised 235 m of 7 mm lead-core mainline with 57 number 8318 Mustad 10/0 hooks. Hooks were tied to 1 m snoods of 3 mm diameter braided polypropylene which were attached to the mainline with a 100 mm sharkclip and swivel. Snoods were attached at 4 m intervals along the mainline.The longline was anchored on the bottom by a number 4 Danforth anchor at each end of the mainline. The bait was fresh or frozen fish, either mullet (*Aldrichetta forsteri*) or Australian salmon (*Arripis trutta*). Longlines were set overnight either with all or most hooks on the bottom.

Handlining was carried out with barbless hooks (Mustad size 1) on monofilament handlines or on rod and reel. Fresh fish or frozen squid was used as bait.

Table 1a. Number of fishing stations per month in each strata of Pittwater and Frederick Henry Bay.

Area	**Strata**						
	Channels	Flats	0–10 reef	0–10 sand	10–20 sand	20–30 sand	>30 sand
Upper Pittwater	1-7	2-5					
Lower Pittwater	2–4	3–10					
Frederick Henry			1	7–8	6–8	3	1

Table 1b. Number of fishing stations per month in each strata of Storm Bay.

Strata				
0–10 reef	0–10 sand	10–20 sand	20–40 sand	40–80 sand
1	4–8	5–9	5–9	5–9

Sampling design

A random statified sampling design was used for the gillnet survey. Stations were stratified by depth and bottom type (reef or sand) for each of the four bays. A chart-recording echo sounder (Solo model SM 180) was used to record depth and a benthic scissor grab was used to take a sediment sample at each station to confirm the bottom type. The number of stations assigned to each strata depended on the area of the strata. The location of stations was chosen using a random number generator. Each bay was sampled once a month. The number of strata and the stations assigned to each strata for the different areas are shown in Tables 1a & b. The nets were set around dusk and hauled as soon after dawn as possible. Within the limitations of the sampling logistics we attempted to standardise fishing time of individual nets. The average fishing time was about 17 hrs. Fishing time was recorded as the time from the end of the set to the end of the haul. Monthly sampling was carried out around the period of full moon. Stations were located by means of a JRC Global Positioning System (GPS).

The mean cpue for a bay was calculated from the equation:

$$\overline{X} = \sum_{i=1}^{n} A_i \overline{X}_i \Big/ \sum_{i=1}^{n} A_i$$

where $\overline{X}_i$ = mean cpue for stratum i, and A_i = area of stratum i.

The variance of the mean was calculated from:

$$\text{var}\,\overline{X} = \sum_{i=1}^{n} A_i^2 \text{var}\overline{X}_i \Big/ \left(\Sigma A_i\right)^2$$

Because of the skewed distribution of the catch data, with the most common catches being zero, then one (Fig. 2), the square root of the catches were used. An adjustment was made to make the back transformed values of stratum mean and variance unbiassed (Haskard, *pers. comm*)

Treatment of catch

The number, length (fork length for teleosts; total length for elasmobranchs) and sex (for elasmobranchs) of each species in the catch was recorded by mesh size. Live school and gummy sharks (and a number of other shark species) in a suitable condition were tagged and released (see next section). School and gummy sharks which were dead in the net had their stomachs removed for subsequent dietary analysis. Stomachs were removed by cutting anteriorly at the junction of the oesophagus and posteriorly at the junction with the spiral valve, and fixed in 10% formalin.

Diet of sharks

In the laboratory each stomach was opened lengthways and the contents washed into a petri dish. Individual prey items, or portions of prey, were sorted, counted, given a digestion stage, blotted dry and weighed to 0.01 g. Any remaining stomach content debris was washed through a 1 mm sieve and the retained portion blotted dry and weighed. Stomachs that contained only general debris such as isolated vertebrae, otoliths or fragments of muscle or crustacean exoskeleton (but which were not weighable to 0.01 g) were classed as empty. Prey items were identified to the lowest possible taxon. Identifications were based on both intact items and remaining hard parts such as cephalopod beaks. Results were expressed in terms of the number of stomachs containing a particular prey item among those stomachs that contained food, the number of individuals of a particular prey item, and the total weight of individuals of a particular prey item.

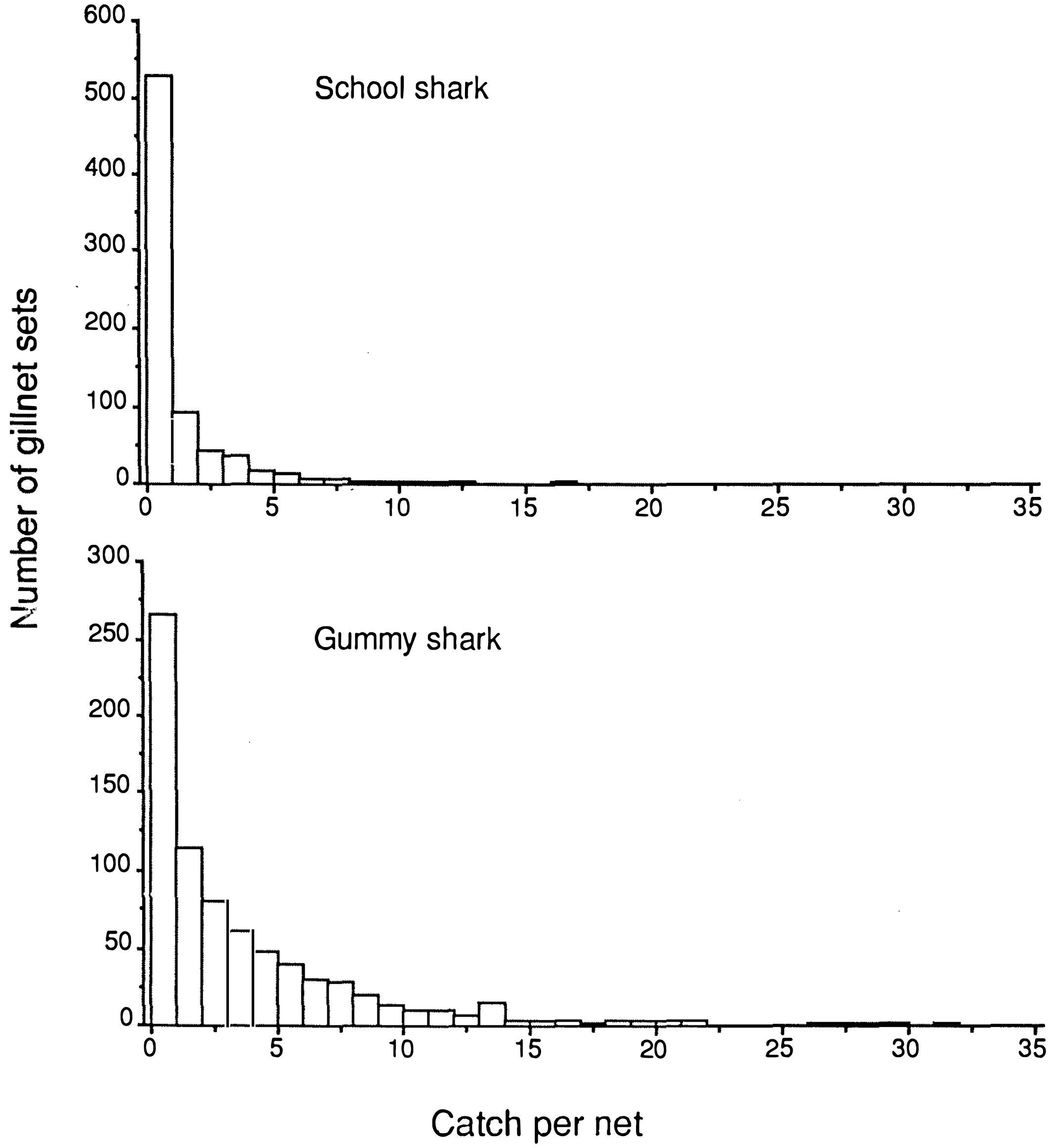


Figure 2. Frequency distribution of the gillnet catches of school and gummy shark.

Tagging

Initially, trials were carried out with an internal tag with an external streamer (Hallprint, Holden Hill, S.A.) but aquarium tests suggested a high mortality rate and so these tags were not used during the field program. Instead, sharks less than about 60 cm TL were tagged with 90 mm long plastic headed dart tags (HallPrint); the tag was applied below the first dorsal fin with a stainless steel tagging needle. Larger sharks were tagged in the first dorsal fin with plastic Rototags (Daltons, Henley-on-Thames, England) as described in Stevens (1976, 1990). Sharks were injected with oxytetracycline hydrochloride (mixed with seawater) at a dose rate of 25 mg/kg body weight, for age validation studies currently being undertaken by the Marine Science Laboratories, Queenscliff, Victoria.

Growth rate of sharks

Lenth-frequency distributions of school sharks were analysed using the Macdonald and Green (1988) MIX modal-analysis computer program. Monthly length-frequency data were grouped by 2 cm length interval for analysis. The gummy shark length data were not analysed as modes could not easily be detected in the monthly length-frequency data. MIX provides the option of fitting normal, lognormal, exponential or gamma distributions to a data set using maximum-likelihood estimation for grouped data; we assumed normal distributions for analysing the school shark data. Initial parameters for the distributions were estimated by selecting modes in the length frequency data by eye, and from von Bertalanffy predicted lengths-at-age for school shark (Grant, Sandland and Olsen 1979).

RESULTS

Catch rates and length composition

Gillnet fishing

The average set duration was about 17 hrs with 77% of sets ranging from 14–20 hrs and over 99% ranging from 9–26 hrs. Within this range of fishing time there was little correlation between catch and duration for either species when the data for all areas were combined (Fig. 3). The relationship between catch and set duration may be affected by a number of variables such as area, depth and season, and it is possible that a multivariate analysis would identify a relationship between catch and fishing time. However, for the purposes of this report we ignored fishing time and used catch per net as the unit of cpue.

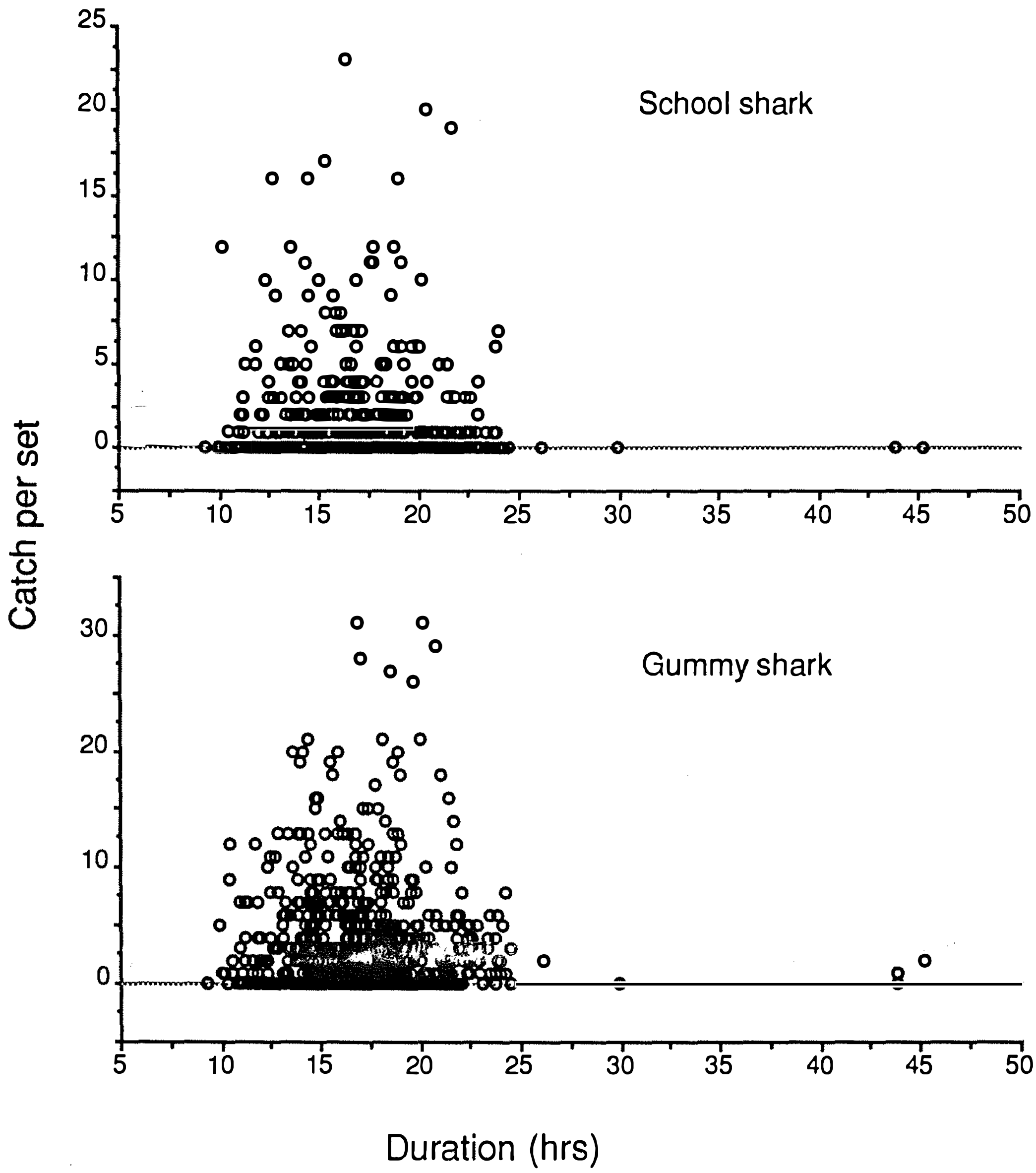


Figure 3. Relationship between shark catch and gillnet set duration.

Table 2. Number of school and gummy sharks caught, and number of gillnet sets by area and month.

	Upper Pittwater			Lower Pittwater			Frederick Henry Bay			Storm Bay		
	School	Gummy	Sets	School	Gummy	Sets	School	Gummy	Sets	School	Gummy	Sets
OCTOBER	0	9	4	0	49	10	55	125	20	8	59	19
NOVEMBER	12	9	4	7	44	10	103	119	20	2	93	31
DECEMBER	25	24	5	6	78	8	75	93	18	2	183	36
JANUARY	22	33	10	4	61	14	106	94	20	9	157	35
FEBRUARY	11	7	10	3	67	10	94	163	21	7	106	33
MARCH	6	11	6	3	28	8	53	129	18	15	85	27
APRIL	7	15	8	2	22	7	51	88	18	31	80	30
MAY	3	14	6	1	10	7	34	67	18	29	70	30
JUNE	1	0	6	0	3	7	8	38	18	18	74	30
JULY	0	2	6	0	5	6	0	18	18	9	23	30
AUGUST	0	0	8	0	9	8	0	39	18	2	49	30
SEPTEMBER	0	3	8	0	7	8	12	56	18	5	47	30
TOTAL	**87**	**127**	**81**	**26**	**383**	**103**	**591**	**1029**	**226**	**137**	**1026**	**361**

The total number of school and gummy sharks caught, the effort expended, and the cpue in upper and lower Pittwater, Frederick Henry Bay and Storm Bay (Fig. 1) are shown by month in Tables 2 & 3. Cpue for both species was generally higher in summer and lower in winter in all three bays (Table 3 and Fig. 4). Cpue for both species was highest in Frederick Henry Bay (Table 3).

The length distribution of sharks caught from all areas combined is shown in Fig. 5. School sharks ranged from 28.6–140.1 cm TL with the majority of the catch comprising 30–90 cm (0^+ to 3^+ year old) fish. Gummy sharks ranged from 31.3–163.5 cm and comprised mainly 50–95 cm (1^+ to 4^+ year old) fish. Few fish of either species larger than 100 cm were caught which is to be expected on the basis of mesh selectivity.

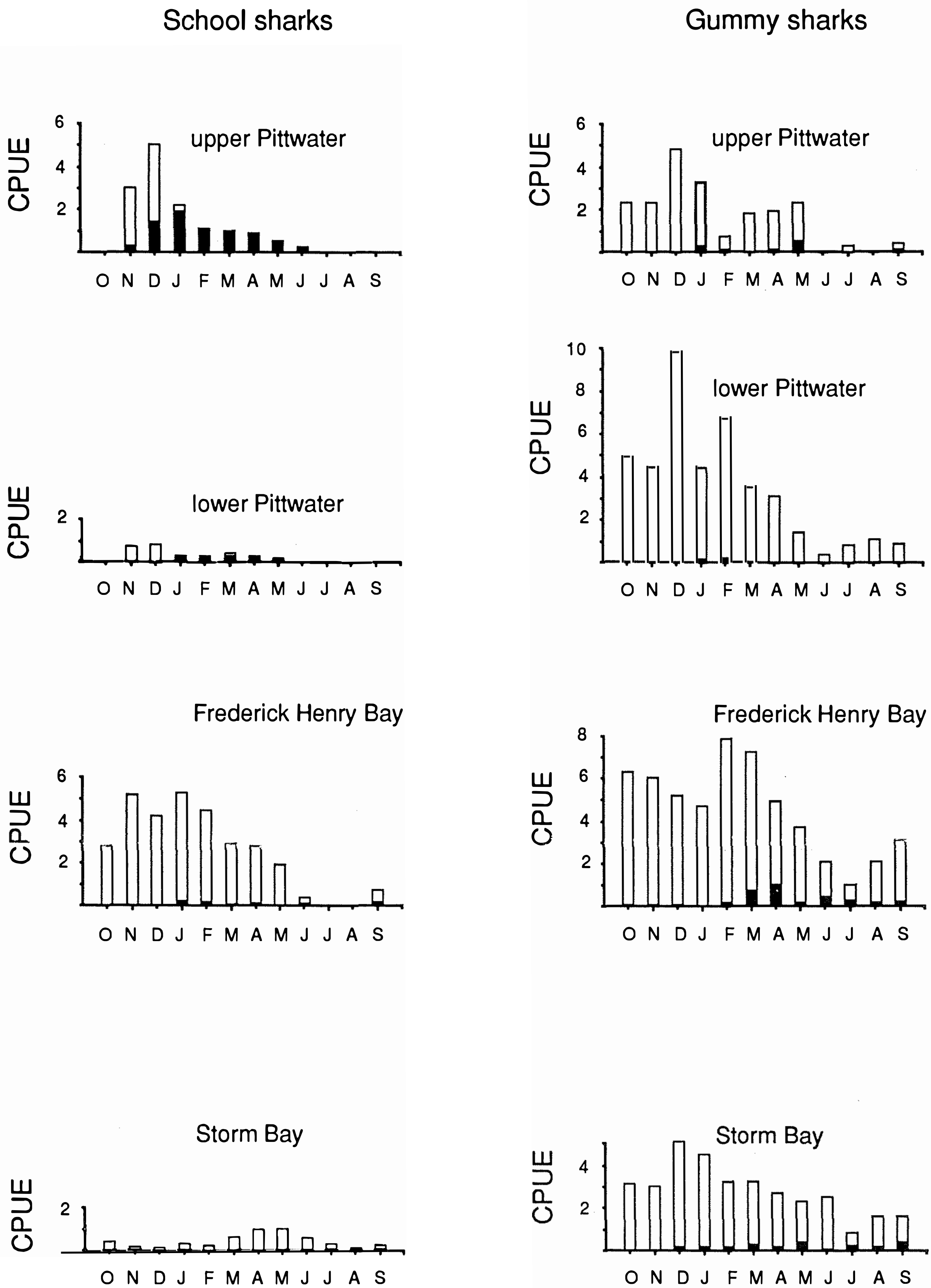
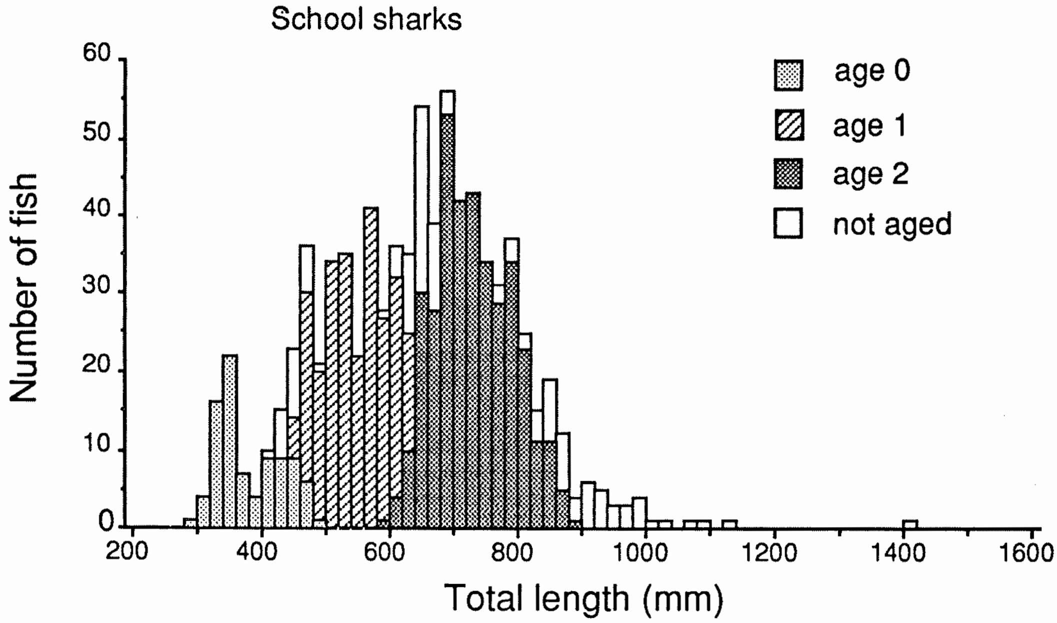


Figure 4. CPUE (average catch per net) for school and gummy sharks over the 12 month study period, for each of the four areas. Unfilled columns represent the total catch, those filled with black represent the catch of fish aged up to 1 year old.



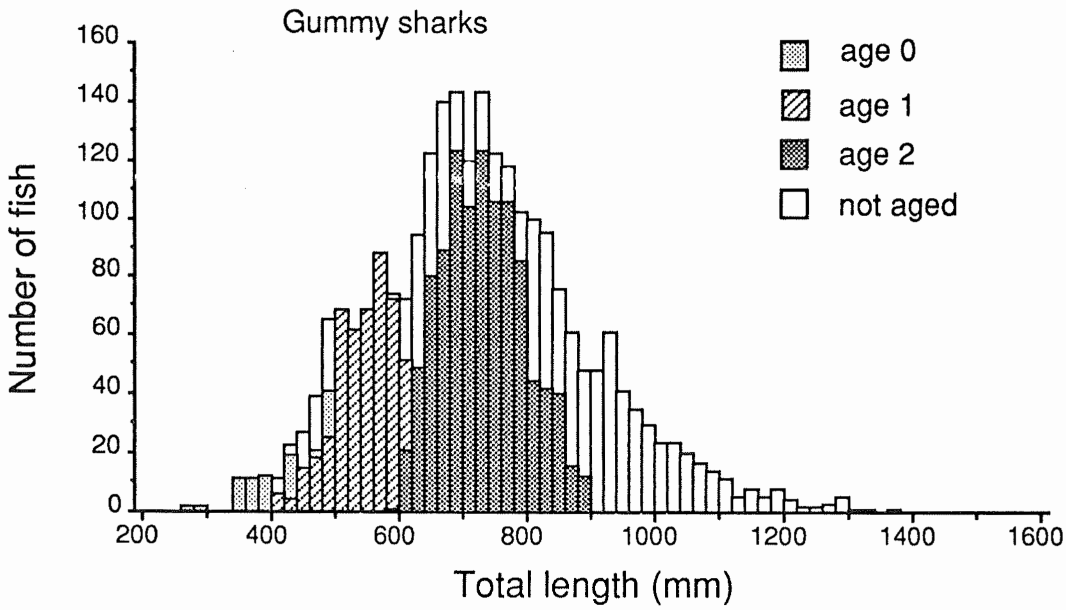


Figure 5. Size distribution of school and gummy sharks caught by gill-net

Table 3. Catch per unit effort (catch per set) of school and gummy sharks by area and month.

	Upper Pittwater		Lower Pittwater		Frederick Henry Bay		Storm Bay	
	School	Gummy	School	Gummy	School	Gummy	School	Gummy
OCTOBER	0	2.3	0	4.9	2.8	6.3	0.4	3.1
NOVEMBER	3.0	2.3	0.7	4.4	5.2	6.0	0.1	3.0
DECEMBER	5.0	4.8	0.8	9.8	4.2	5.2	0.1	5.1
JANUARY	2.2	3.3	0.3	4.4	5.3	4.7	0.3	4.5
FEBRUARY	1.1	0.7	0.3	6.7	4.5	7.8	0.2	3.2
MARCH	1.0	1.8	0.4	3.5	2.9	7.2	0.6	3.2
APRIL	0.9	1.9	0.3	3.1	2.8	4.9	1.0	2.7
MAY	0.5	2.3	0.1	1.4	1.9	3.7	1.0	2.3
JUNE	0.2	0	0	0.4	0.4	2.1	0.6	2.5
JULY	0	0.3	0	0.8	0	1.0	0.3	0.8
AUGUST	0	0	0	1.1	0	2.1	0.1	1.6
SEPTEMBER	0	0.4	0	0.9	0.7	3.1	0.2	1.6
TOTAL	**1.1**	**1.6**	**0.3**	**3.7**	**2.6**	**4.6**	**0.4**	**2.8**

Kirkwood and Walker (1986) estimated that the peak selectivity for a gummy shark in a 100 mm mesh is about 75 cm TL, which is somewhat larger than suggested by our data (Fig. 6). At a length of about 115 cm a 100 mm net would catch only about 11% of the available population (Kirkwood and Walker 1986). School sharks have a more pointed snout than gummy sharks and it might be expected that the length at peak selectivity for a given mesh size would be greater for school shark. However, we caught fewer school sharks over 100 cm than gummy sharks.

The length distribution of sharks caught in each bay is shown in Figs. 7 & 8. For school sharks, there is a trend for longer and older fish to be caught in the deeper, more exposed bays. Pittwater contained newborn and 1 year old fish while Frederick Henry and Storm Bay contained mostly 1 and 2 year old sharks. Of the 88 newborn (0^+) school sharks caught during this project, 66 were caught in Pittwater, 55 of them in upper Pittwater.

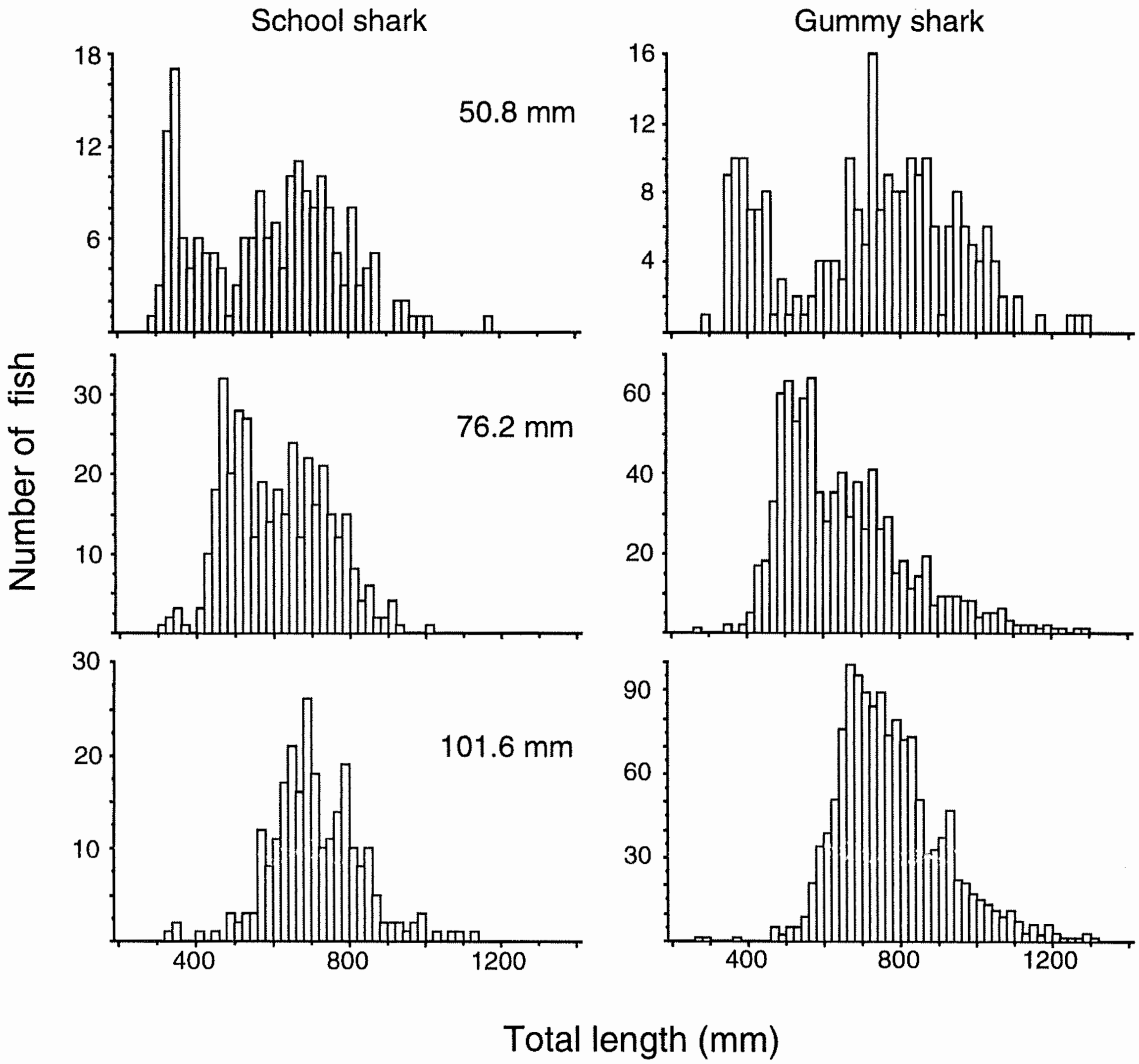


Figure 6. Length-frequency distributions of school and gummy sharks caught in 50.8, 76.2 and 101.6 mm stretched mesh gillnets.

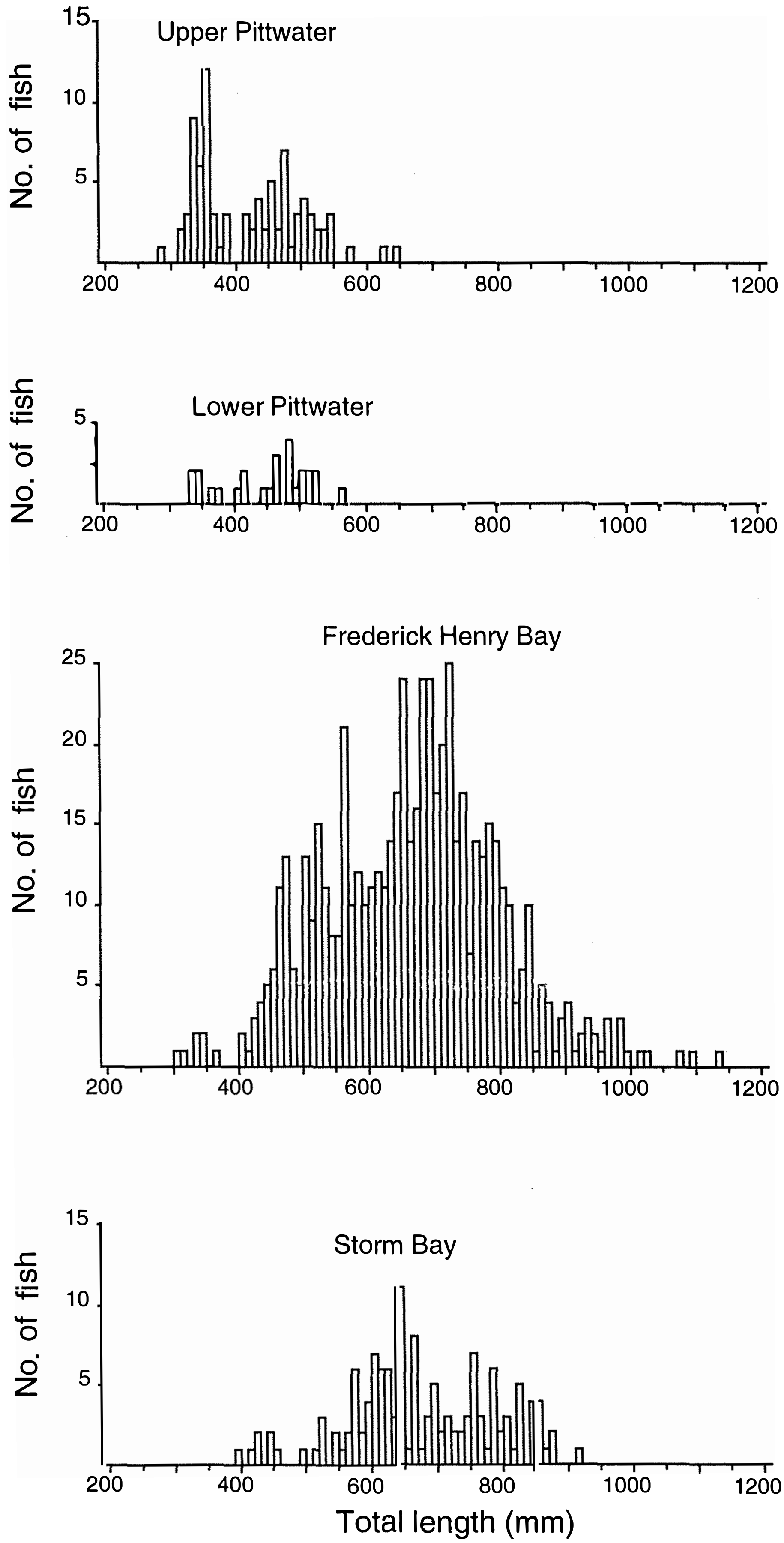


Figure 7. Length-frequency distribution of school sharks caught in experimental gillnets in Pittwater, Frederick Henry Bay and Storm Bay

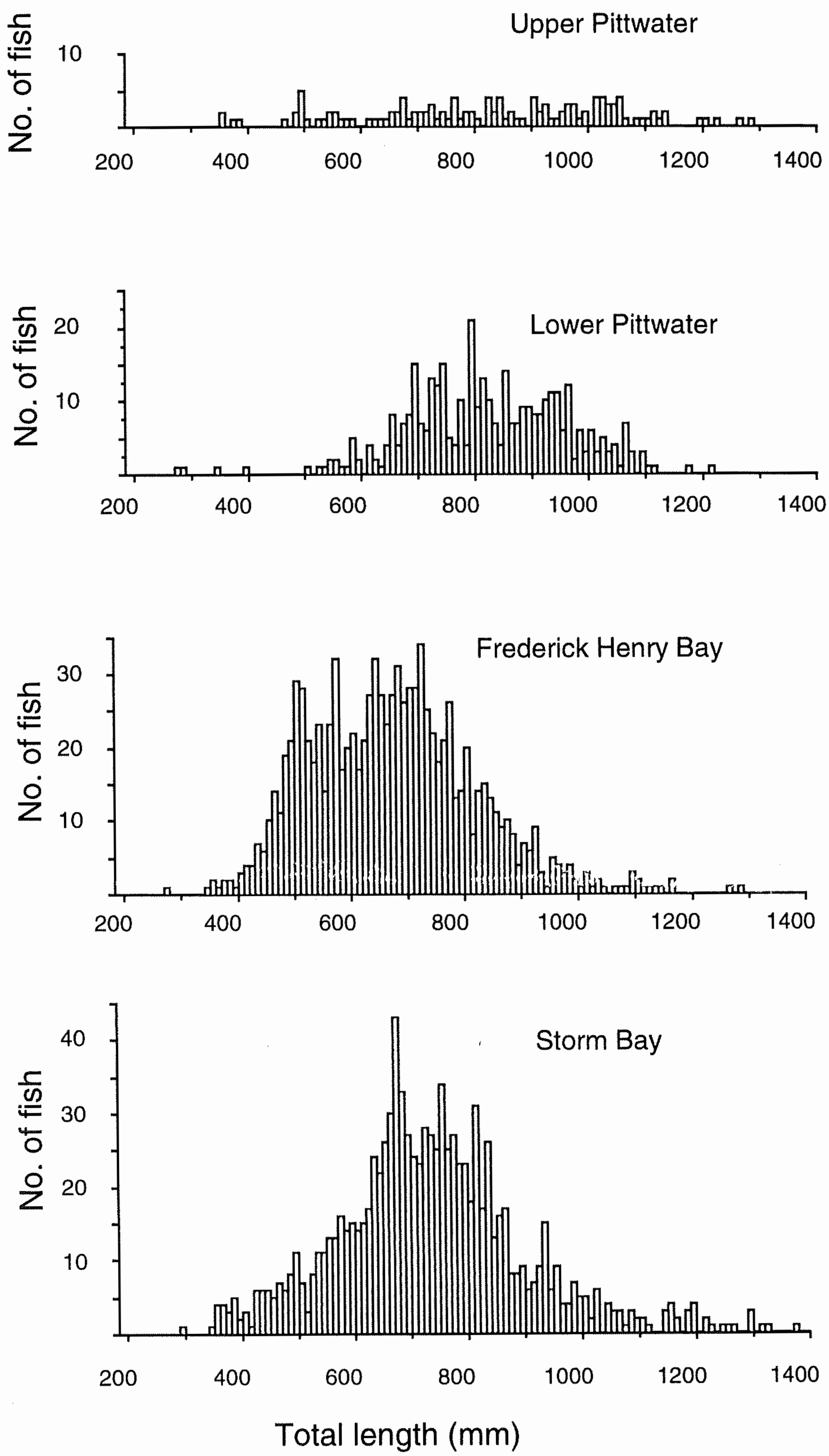


Figure 8. Length-frequency distribution of gummy sharks caught in experimental gillnets in Pittwater, Frederick Henry Bay, and Storm Bay

The catches show (Fig. 4, Tables 2 & 3) that newborn school sharks first appear in the Pittwater catch in November and that few are caught there after May. There appears to be a general movement of juvenile school sharks from shallow water in summer to deeper water in winter. The only newborn school sharks caught in Storm Bay were taken in the colder months from June to September. Only ten newborn school sharks (11%) were caught in Frederick Henry Bay during the warmer months between January and April, and most of these were caught off Seven Mile Beach close to the channel into Pittwater. Gummy shark length distributions varied by bay but no trend was apparent (Fig. 8). Newborn gummy sharks were taken in all four bays although 117 (91%) of the 128 caught were from Frederick Henry and Storm Bay, of which 96 were taken between April and September.

In Frederick Henry and Storm Bay, the cpue for school and gummy sharks was generally much higher in the sand strata compared to the reef strata (Fig. 9). The cpue for both species declined with increasing depth in the sand strata of Frederick Henry Bay. In Storm Bay, catch rates in the sand strata were highest between 10 and 40 m for school sharks and between 0 and 40 m for gummy shark.(Fig. 9). The depth range in Pittwater was insufficient to determine any trend in catch rate with depth.

An index of abundance (mean cpue) based on the random, stratified sampling design was calculated for each species in each bay. Based on total catch, Frederick Henry Bay had the highest cpue for both school and gummy sharks (Fig. 10). When the catch is partioned by age class the highest cpue for 0^+ school sharks was in upper Pittwater while the highest cpue for 1^+ and 2^+ sharks was in Frederick Henry Bay. The highest cpue for 0^+, 1^+ and 2^+ gummy sharks was in Frederick Henry Bay (Fig. 10) .

An index of population size was calculated for each bay by multiplying the mean cpue of a bay by its area. Based on total catch, Frederick Henry Bay had the highest population index for school sharks and Storm Bay had the highest index for gummy sharks (Fig. 11). When the catch is partioned by age class the highest population index for 0^+, 1^+ and 2^+ school sharks was in Frederick Henry Bay (Fig. 11). The highest population index for 0^+, and 2^+ gummy sharks was in Storm Bay, while the highest index for 1^+ fish was in Frederick Henry Bay (Fig. 11).

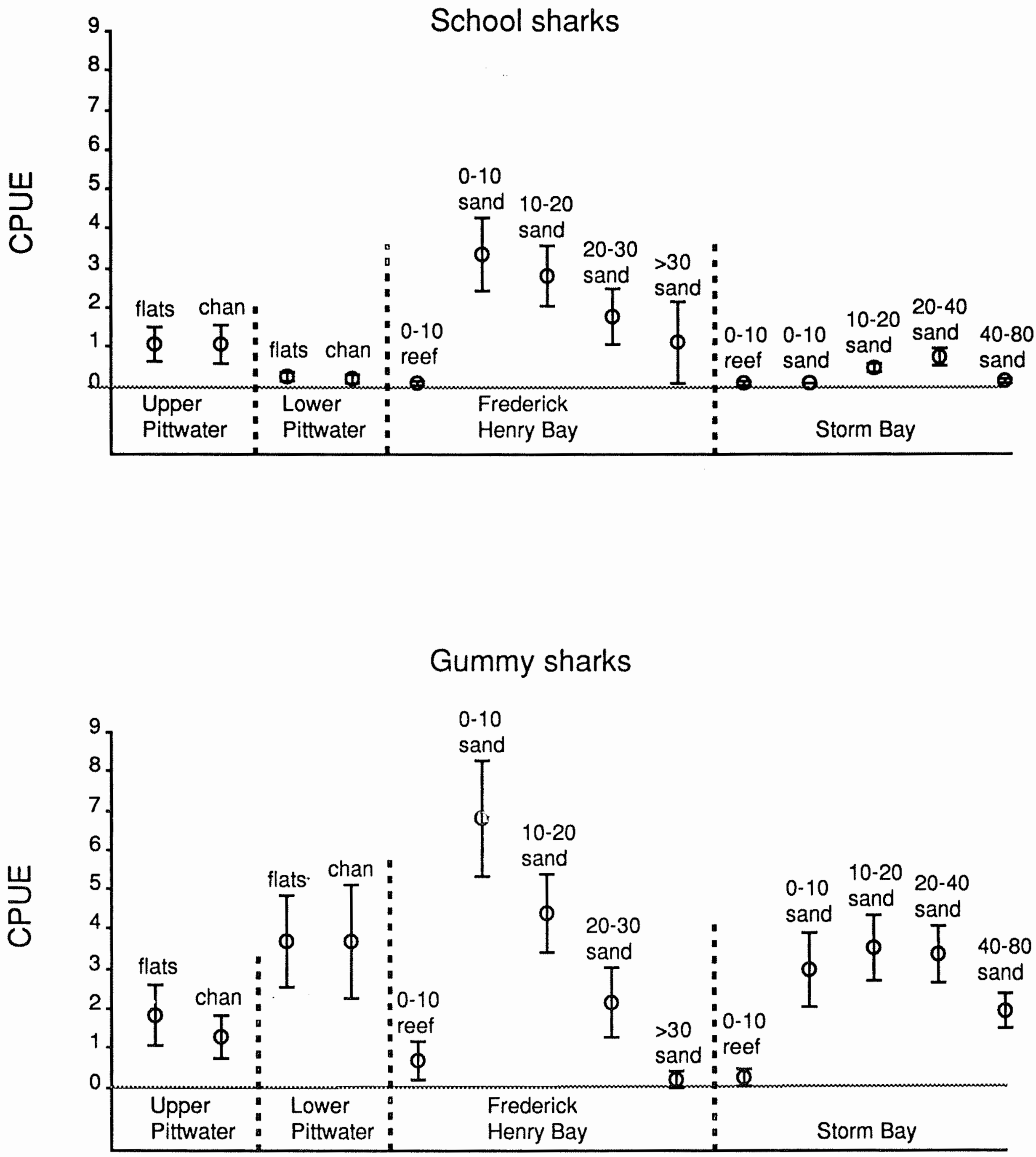


Figure 9. Average catch per net of school and gummy sharks by strata, for each of the bays in the study site. Circles represent the mean, and bars are 2 s.e. of the mean.

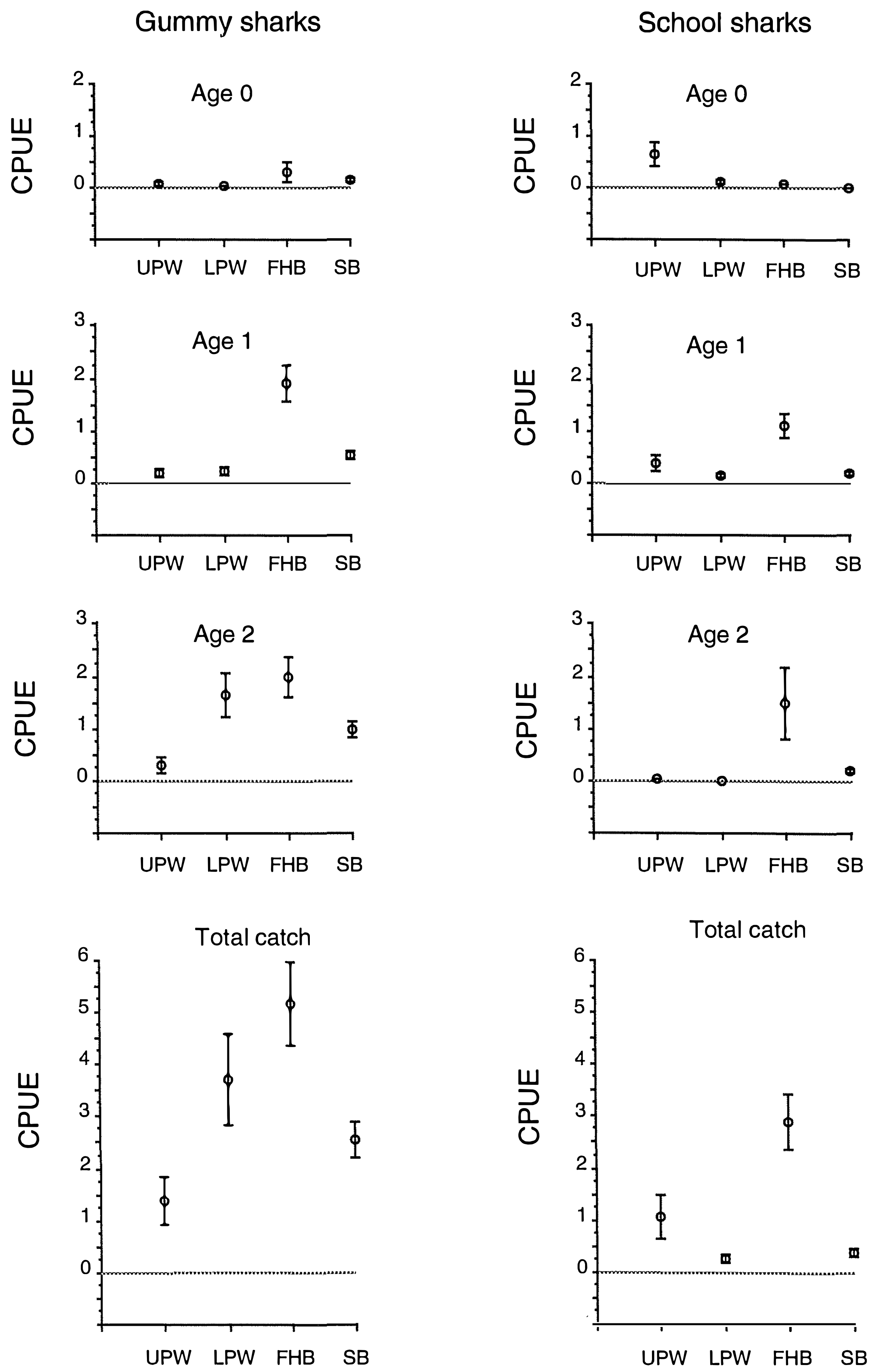


Figure 10. Average catch per net of school and gummy sharks by age group and area. Circles represent the means, and error bars are 2 s.e. of the mean. UPW=upper Pittwater, LPW=lower Pittwater, FHB=Frederick Henry Bay, SB=Storm Bay

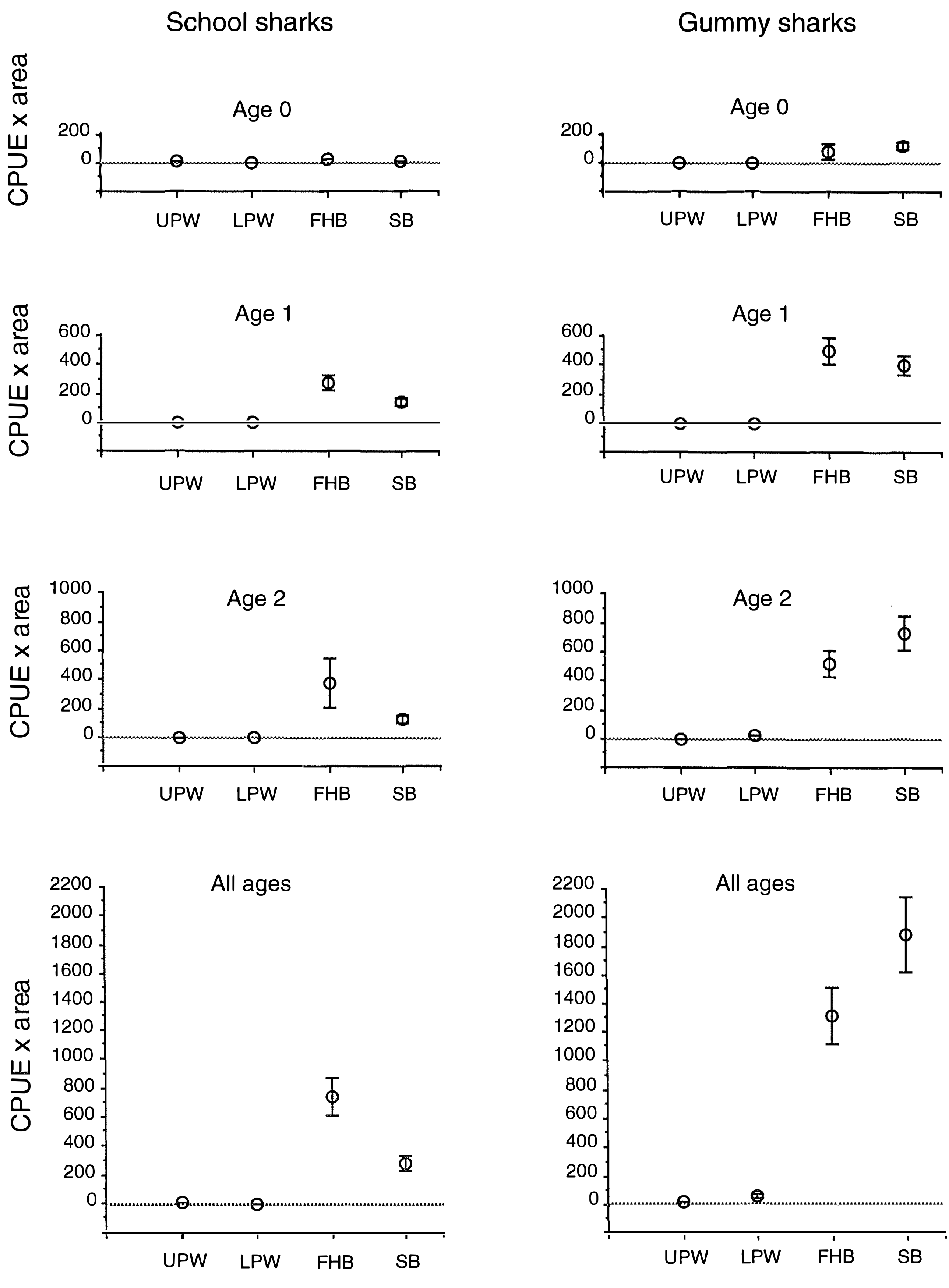


Figure 11. Index of population size (CPUE x area of bay) for school and gummy sharks. UPW=upper Pittwater, LPW=lower Pittwater, FHB=Frederick Henry Bay, SB=Storm Bay.

Hook fishing

Between 1947 and 1953 Olsen (1984) was able to catch up to 80 juvenile school sharks a day on handlines off Woody Island in lower Pittwater. A total of seven days (22.5 hrs) handlining in the same position during 1991/92 resulted in a catch of 2 gummy sharks and

Table 4. Daily catches of school sharks caught between October and February by handline off Woody Island, lower Pittwater (1947–1953 data from A.M. Olsen, 11 Orchard Grove, Newton, S.A. 5074 personal communication).

Year	**Numbers caught per day**			**Number of days fished**
	Minimum	Maximum	Mean	
1947/48	19	81	51	3
1948/49	21	51	33	6
1949/50	3	56	17	10
1950/51	1	41	13	11
1951/52	3	27	11	11
1952/53	1	21	8	3
1991/92	**0**	**0**	**0**	**7**

no school sharks.The comparison with Olsen's data are shown in Table 4. Olsen (1954) also caught pregnant school sharks on longlines as they moved into Pittwater to give birth. Five longline sets with a total of 280 hooks were set in the same area which Olsen fished and resulted in a catch of 18 gummy sharks and no school sharks.

Shark tagging

195 school sharks were tagged (146 with dart tags and 49 with rototags) of which 18 have been returned to date (9.2%); 782 gummy sharks were tagged (427 with dart tags and 355 with rototags) of which 60 have been returned so far (7.7%). The length distribution of the sharks tagged is shown in Fig. 12. The majority of sharks were recaptured within the study site. The proportions of sharks moving different distances are summarised in Fig. 13. Of the longer distance returns, four gummy sharks travelled to Bass Strait (minimum straight

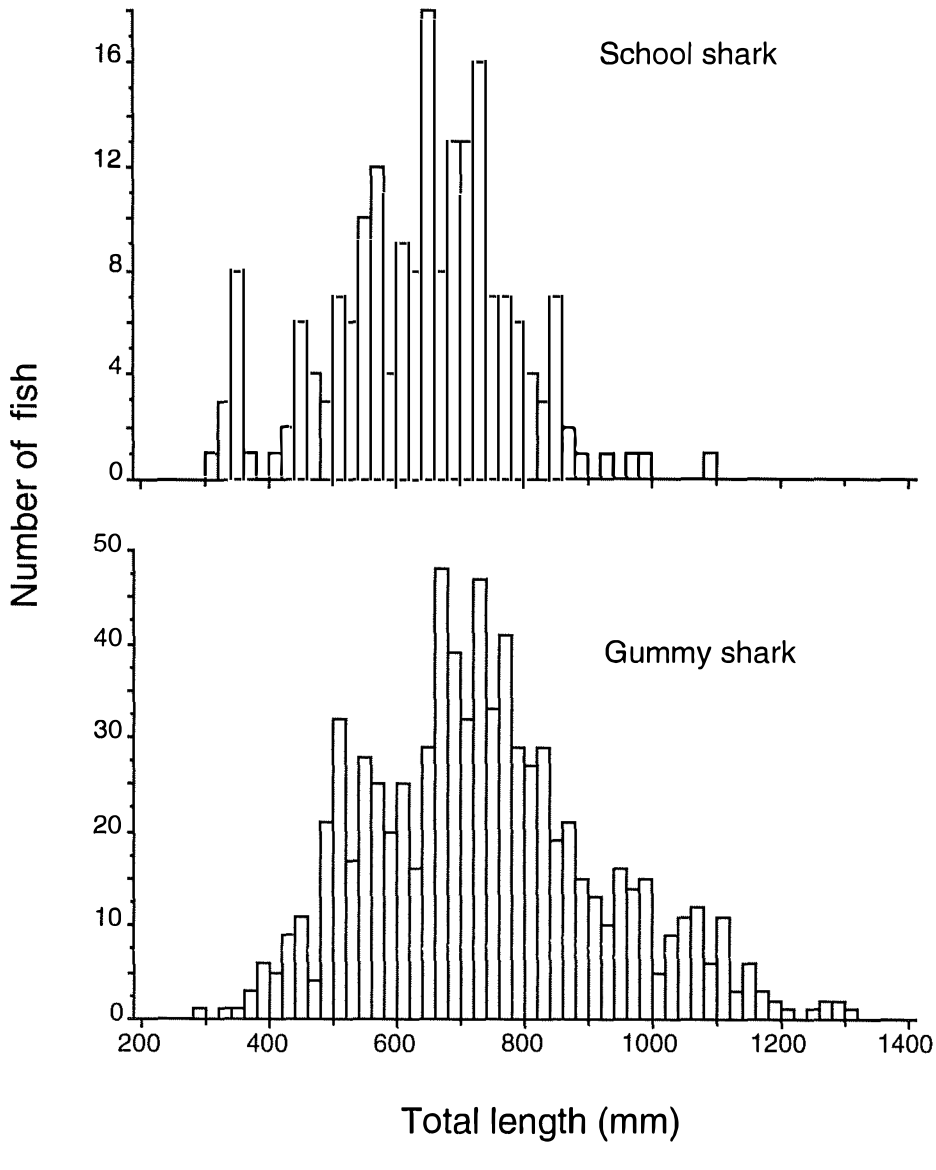


Figure 12. Length-frequency distributions of tagged school and gummy sharks

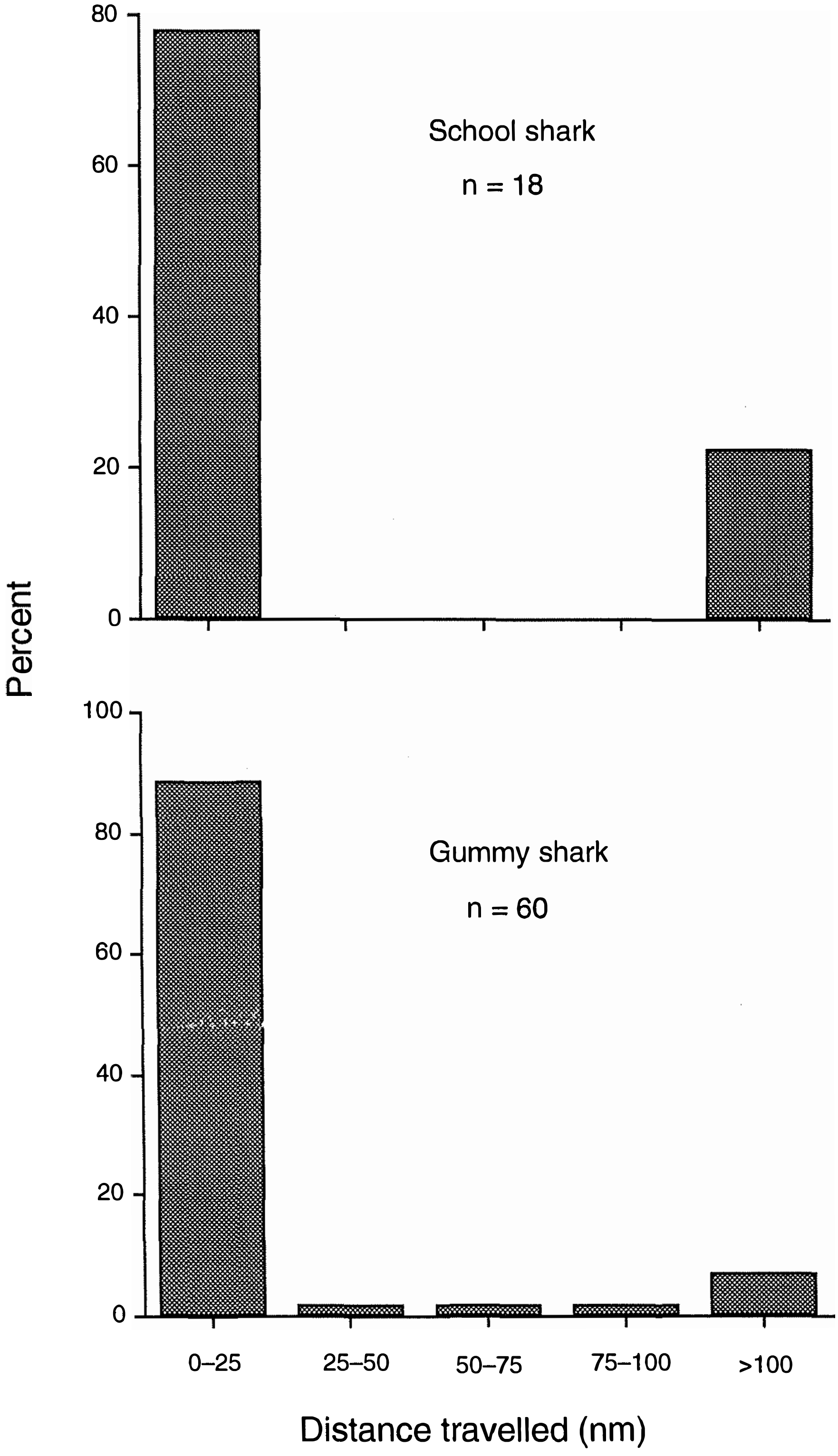


Figure 13. Distance travelled (nm) by tagged school and gummy sharks.

line distances of between 210 and 442 nm), two school sharks travelled to Bass Strait (285 and 300 nm) and one school shark moved 600 nm to South Australian waters.

Shark diets

The stomach contents of 432 school sharks ranging in length from 28.6–140.1 cm were examined; these included 28 0^+ fish (61% of which were from upper Pittwater), 180 1^+ fish (66% from Frederick Henry Bay) and 195 2^+ year old fish (88% from Frederick Henry Bay) (Table 5). Of the 0^+ fish, 3.6% had empty stomachs, while 20.6% and 22.6% of the 1^+ and 2^+ fish had empty stomachs, respectively. The percentage occurrence, number and weight of prey items recorded are shown in Tables 6, 7 & 8 for the first three

Table. 5. Length range of school sharks analysed for stomach contents.

Age class	Sex	Sample size	Mean TL (mm)	TL range (mm)
0^+	Male	18	378	286–490
	Female	9	381	312–444
	Total	28	378	286–490
1^+	Male	90	538	422–692
	Female	89	560	442–694
	Total	180	549	422–694
2^+	Male	108	724	554–890
	Female	81	734	620–865
	Total	195	729	554–890

age classes. The contribution to the diet of the major prey categories are shown in Fig. 14. In 0^+ sharks, fish, cephalopods and crustaceans were of similar importance in the diet while in older sharks crustaceans were less important. The cephalopod component in the diet also declined with increasing age class but this was mainly a reflection of relatively high predation of 0^+ sharks on the inshore loliginid *Loliola noctiluca* in Pittwater. Of the identifiable teleost prey, the most important species were school whiting *Sillago bassensis*, sand flathead *Platycephalus bassensis*, anchovy *Engraulis australis*, cod *Pseudophycis bachus* and (particularly in 0^+ sharks from Pittwater) bridled goby *Arenigobius bifrenatus*.

Table 6. Stomach contents of age 0^{+} school sharks.

Prey item	% frequency occurence per stomach	%frequency occurence by weight	% frequency occurence by number
Unidentified teleosts	46.4	14.6	17.0
Loliolus noctiluca	35.7	0.1	20.2
Unidentified crustacea	25.0	0.7	9.6
Unidentified crab	25.0	1.4	8.5
Unidentified shrimp	17.9	1.2	7.4
Sepiolid sp	17.9	0.2	19.1
Arenigobius bifrenatus	10.7	2.9	3.2
Sillago bassensis	7.1	21.4	3.2
Platycephalid spp	7.1	17.8	2.1
Engraulis australis	7.1	7.6	3.2
Sepia spp.	7.1	0.0	3.2
Pleuronectid spp.	3.6	0.9	1.1
Octopus berrima	3.6	0.0	1.1
Alpheid shrimp	3.6	0.1	1.1

Table 7. Stomach contents of age 1^{+} school sharks.

Prey item	% frequency occurence per stomach	% frequency occurence by weight	% frequency occurence by number
Unidentified teleost	51.1	31.5	34.6
Loliolus noctiluca	19.5	2.7	16.6
Notodarus gouldi	7.8	1.9	5.4
Sepia spp	6.7	0.1	6.9
Octopus berrima	6.1	3.0	4.5
Sillago bassensis	5.6	14.3	4.2
Arenigobius bifrenatus	5.0	2.4	9.0
Sepiolid sp	3.9	0.0	2.7
Pleuronectid spp	3.3	1.1	1.8
unidentified crustacea	3.3	0.1	1.8
unidentified crab	3.3	0.2	2.4
Atherinid spp	1.7	0.2	1.5
Platycephalid spp	1.1	3.1	0.6
Thyristes atun	1.1	3.0	0.6
Sepioteuthis australis	1.1	2.2	0.9
Alpheid shrimp	1.1	0.0	0.6
Amphipod spp	1.1	0.0	1.2
Trachurus declivis	0.6	5.1	0.3
Hyporhamphus melanochir	0.6	0.0	0.3
Latridopsis forsteri	0.6	0.3	0.3
Unidentified chondrichthyan	0.6	0.1	0.3
Unidentified cephalopod	0.6	0.3	0.3
Ebalia intermedia	0.6	0.1	0.6
Mysid shrimp	0.6	0.0	0.3
Euphausid shrimp	0.6	0.0	1.2
Engraulis australis	0.6	0.4	0.3
Contusus richei	0.6	1.8	0.6

Shark growth rates

Information on growth of juvenile school sharks obtained from modal analysis of length frequency data suggest that, following birth at about 30 cm TL, school sharks attain 47 cm at age 1, 64 cm at age 2 and about 80 cm at age 3. The average monthly growth increment for 0^+ fish between January and May was 2.7 cm and for 1^+ fish between November and June was 2.0 cm TL. Growth was distinctly seasonal with most of the years growth being achieved by May (Fig. 15).

Table 8. Stomach contents of age 2^+ school sharks.

Prey item	% frequency occurence per stomach	% frequency occurence by weight	% frequency occurence by number
Unidentified teleosts	52.3	33.6	56.1
Unidentified cephalopod	6.7	5.3	6.1
Sillago bassensis	6.2	15.5	6.1
Notodarus gouldi	5.6	1.6	5.2
Octopus berrima	4.1	1.0	4.2
Pleuronectid spp	3.6	3.2	3.8
Loliolus noctiluca	2.6	0.0	2.4
Pseudophycis bachus	2.1	9.6	1.9
Sepiolid sp	2.1	2.1	1.9
Platycephalid spp	1.5	3.0	1.4
Sepioteuthis australis	1.5	1.0	1.4
Engraulis australis	1.0	0.4	2.8
Arenigobius bifrenatus	0.5	0.1	0.5
Contusus richei	0.5	2.8	0.5
Thyristes atun	0.5	2.4	0.5
Notalabrius tetricus	0.5	3.6	0.5
Callorhynchus milii	0.5	0.3	0.5
Acanthopegasus lancifer	0.5	0.1	0.5
Lepidotriga mulhalli	0.5	1.0	0.9
Pterygotrigla polymmata	0.5	0.1	0.5
Unidentified chondrichthyan	0.5	0.0	0.5
Sepia spp	0.5	0.0	0.5
Unidentified crustacea	0.5	0.0	0.5
Philyra laevis	0.5	0.0	0.5
Unidentified amphipod	0.5	0.0	0.5

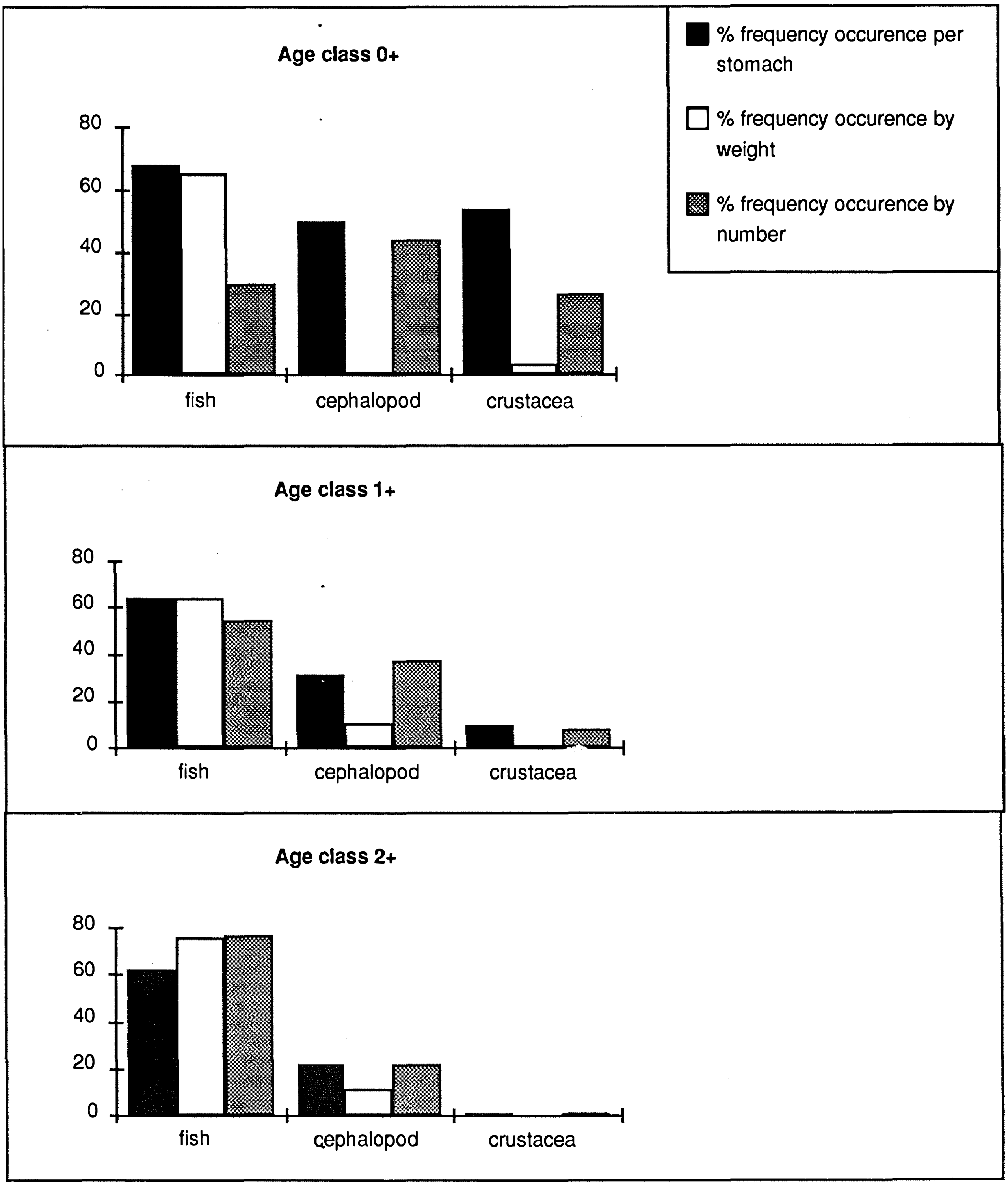


Figure 14. Stomach contents of juvenile school sharks

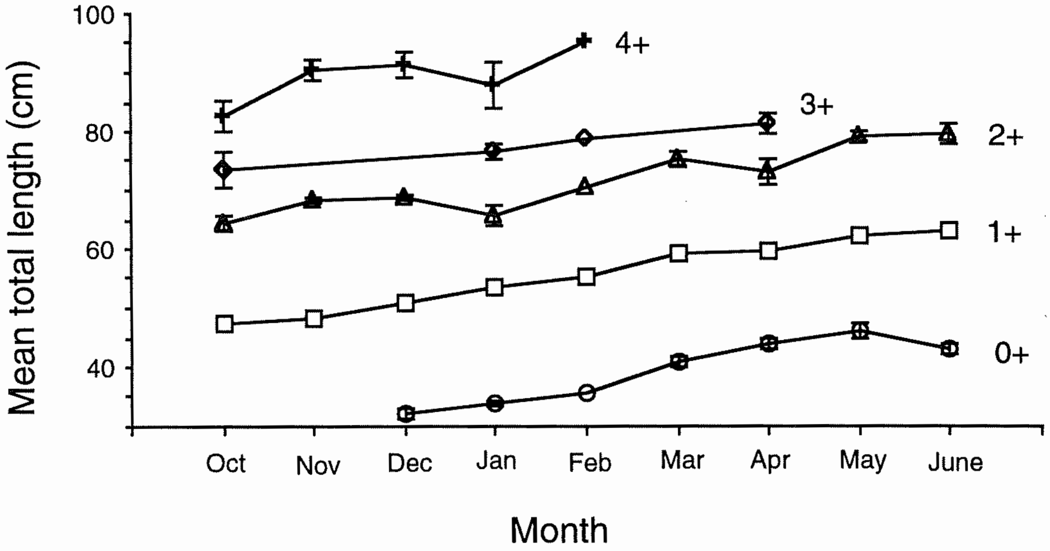


Figure 15. Growth rate of 0+ to 4+ age group school sharks derived from length-frequency analysis

DISCUSSION

Catch results from this study support Olsen's (1954, 1984) hypothesis that newborn (0^+ age class) school sharks are restricted to shallow, protected embayments during summer. It appears that birth occurs within these areas as opposed to the pups moving in from deeper water after birth. Olsen (1954) caught numerous pregnant females inside Pittwater and, although we caught none during this study, we subsequently (January 1993) caught a large female in upper Pittwater which had recently given birth. Olsen (1954) noted that the birth period varied from year to year, with December being the main month in Tasmanian waters. He found (1954 and personal communication) that the newborn pups were most abundant in lower Pittwater where they congregated at the top of the main channel near Woody Island. Our catch data confirm that during the 1991/92 summer, December was the main birth month, although in 1992/93 (subsequent to this study) the peak birth period ocurred one month later in January. However, we caught very few newborn pups in lower Pittwater compared to upper Pittwater. Whether this reflects a change in the school shark's behaviour or is a result of Olsen's lower sampling effort in upper Pittwater and his greater reliance on hook fishing rather than net fishing is unclear.

The size distribution of sharks caught in Pittwater in our study was similar to that caught by Olsen (1954) comprising mainly 0 and 1 year olds. In Frederick Henry and Storm Bay, we caught mostly 1 and 2 year old sharks during summer, supporting Olsen's (1954) findings that older juveniles are found in deeper, more exposed bays. Olsen (1954) suggested that newborn pups and small juveniles remained in the shallow nursery areas during summer, moving into deeper water during the colder months. Our catch data supports this seasonal movement of juveniles into deeper water during winter. However, our catch rates of newborn pups in upper Pittwater also declined during the summer from December (the birth period) to February. This may reflect mortality of the pups, or some movement out of the area. Of the new born pups tagged in upper Pittwater, one tagged in December was recaught in lower Pittwater in January and another tagged in January was recaught in February in the channel joining upper and lower Pittwater, confirming that some sharks move out of upper Pittwater during summer.

The mesh sizes used in this study were chosen to maximise the capture of juvenile sharks. As expected from the selectivity characteristics of these nets, very few sharks over 100 cm were caught. Consequently, our results do not reflect the the status of adult shark stocks in the study site – to do this would require using larger mesh nets or relatively non-selective gear such as hooks.

Our catch data for gummy shark do not support the hypothesis that newborn fish are restricted to shallow, protected embayments during summer. We caught newborn fish in all four bays, but over 90% of the captures were from Frederick Henry and Storm Bay, most during the April to September period. Within these two bays, there was a tendancy for the 0^+ fish to be more abundant in the shallower sand strata. The size composition of gummy sharks caught varied between bays but no trend was apparent which could be related to exposure of the bay. Frederick Henry generally had a smaller size distribution of fish than the other bays. As for school sharks, catch rates generally declined during the colder months suggesting a movement of fish into deeper water.

In Frederick Henry Bay, the shallow reef strata had very low catch rates of both species but in the sand strata the abundance of school and gummy sharks decreased with increasing depth. Current regulations in this area restrict recreational gillnetting to waters less than 200 m from shore on the basis that fishermen are targetting scale fish on reef areas. These regulations are adequate for protecting juvenile sharks providing effort is not targetted over sandy bottoms. In Storm Bay, the shallow reef strata also had low catch rates of both species but in the sand strata gummy shark catch rates were similar (and relatively high) between 0 and 40 m, only declining in the deepest strata. School shark showed a similar pattern with depth, but catch rates were generally low in all strata of Storm Bay.

Within the study area, the bay having the highest abundance index of 0^+ school sharks was upper Pittwater, reflecting its importance as a pupping ground. However, the bay with the highest population index for 0^+ fish was Frederick Henry (20.0) which was considerably higher than the index for upper and lower Pittwater combined (6.5) (Fig. 11). If Pittwater was the only source of pups for the study area, this might seem an unlikely result. However, a number of factors could be involved. Both indexes are averaged over 12 months and do not take proper account of seasonal effects due to the movement of pups out of Pittwater during winter. The 0^+ fish are present over a nine month period in Frederick Henry Bay but for a maximum of eight months in Pittwater, with peak abundance occurring over about five months. The majority of the 0^+ fish caught in Frederick Henry Bay were also older than those caught in Pittwater as they were caught during the cooler months after they had moved out of Pittwater. These older fish may be more mobile and have a higher catchability. It is also possible that some 0^+ fish were pupped in other shallow water areas such as the Derwent, D'Entrecasteaux Channel and Norfolk Bay and then moved into the connected waters of Frederick Henry Bay during the cooler months.

A major decline in hook and line catch rates for juvenile school sharks from lower Pittwater was evident when the current data from 1991–92 were compared to the period 1947–53 (Olsen 1954, 1984). This is most probably due to a combination of overfishing and environmental changes in Pittwater, although it is also possible that the sharks may have changed their behaviour. As noted above, we caught more 0 and 1^+ fish in nets in upper Pittwater than in lower Pittwater. The total number of 0^+ fish caught was low (88), equivalent to the litters from only 2–3 females. If this reflects a low number of 0^+ fish in the population it is cause for concern; however, other factors may be involved. Catchability may be very low, although this seems unlikely given the amount of sampling effort in the relatively small area of Pittwater, and the range of mesh sizes used which should cover peak selectivity for the newborn fish. The sharks may have changed their behaviour and be utilising other embayments with similar characteristics to Pittwater. If so, sampling in other areas subsequent to this study has so far failed to locate them. The hypothesis of specific nursery areas may be wrong and relatively low numbers of pups may be present over a much wider range than previously thought. However, this is not supported by the distribution of pups in the present study area where they were restricted to Pittwater.

Olsen (1954) reported a recapture rate of 4.2% from 4755 juvenile school sharks tagged by hook fishing in Tasmania and Victoria between 1947 and 1952. To date (March 1993) we have had 9.2% of our tagged juvenile school sharks returned, presumably reflecting the greater fishing pressure on school shark stocks at this time. Commercial fishing accounted for 37.5% of tag returns, research fishing for 31.3% and recreational fishing for 25.0% of school shark tag returns. About 80% of tagged school sharks were recaptured within 25 nm of where they were tagged; four fish moved distances of between 285 and 600 nm, three fish travelling to Bass Strait and one to South Australian waters. These movements are consistent with the results of Olsen (1954) and show that even juvenile school sharks are capable of mixing accross south eastern Australian waters.

Our current return rate of 7.7% for gummy sharks is somewhat lower than the return rate of 9.2% for school sharks. Commercial fishing accounted for 62.5% of tag returns, research fishing for 30.4% and recreational fishing for only 7.1% of gummy shark tag returns. About 90% of the recaptures have been made within 25 nm of the tagging site with only 7% (four fish) travelling distances in excess of 100 nm. Previous tagging studies of gummy shark (T. I. Walker, Marine Science Laboratories, Victoria, personal communication) have also shown that the majority of fish show relatively limited movement.

Olsen (1954) noted that the fish and cephalopod component was lower in the diet of 3–4 year old juvenile school sharks (88%) than in adults (98%), and that juveniles supplemented their diet with annelids, molluscs, and crustaceans. The diet of small sharks which he examined in Pittwater included sandworms, crabs, shrimps, small fish, and cephalopds. Walker (In Press) reported smaller quantities of cephalopods (notably *Octopus* spp) and fish (notably *Thyrsites atun*) in small sharks (less than 90 cm TL) than in larger sharks. In this study, the most notable difference in the diet of the first three age classes was the decline in importance of crustaceans with increasing age. In 0^+ sharks, fish, cephalopods and crustaceans were of similar importance while in 2^+ sharks crustaceans were a negligable component of the diet. The cephalopod component in the diet also declined with increasing age class but this was mainly a reflection of relatively high predation of 0^+ sharks on the inshore loliginid *Loliola noctiluca* in Pittwater.

Olsen's (1954) monthly sampling of juveniles from Pittwater, Port Sorell and Portarlington showed an increase in modal length of the population of about 1.0 cm per month. From analysis of length frequency distributions and growth data from tagging he estimated modal lengths for ages 1, 2 and 3 at 45, 58 and 70 cm TL. Grant et al. (1979) used the von Bertalanffy growth model to predict a length at age from tagging data of 49.7, 66.4 and 79.5 cm TL for ages 1, 2 and 3, respectively. Monthly growth increments of 0 and 1^+ sharks in our study averaged about 2.3 cm TL and length at age estimates for 1, 2 and 3 year old sharks were 47, 64 and 80 cm respectively, similar to those obtained by Grant et al. (1979). While Olsen (1954) did not detect any seasonal variation in growth rates of tagged fish, we found that growth rates slowed during the colder months.

ACKNOWLEDGEMENTS

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F. APPENDIX

Details of original grant application.

FISHING INDUSTRY RESEARCH AND DEVELOPMENT TRUST FUND
APPLICATION FOR A NEW GRANT 1991/92

SECTION 1 **Project Title**

Investigation of school and gummy shark nursery areas in south eastern Tasmania.

SECTION 2 **Keywords**
Shark; nursery; identification; protection.

SECTION 3 **Objective(s)**

The objectives of the study are:

To test and refine a sampling strategy that will permit statistically robust estimates of the density of neonatal and juvenile school and gummy sharks in a study site in south eastern Tasmania.

To use these estimates to establish whether pupping and nursery grounds for school and gummy sharks are confined to inshore sheltered habitats within the study site.

To determine the distribution, size composition, duration time and movements of neonatal and juvenile sharks in the study site.

To assess the impact of recreational and commercial fishing on neonatal and juvenile sharks in the study site.

with a view in the longer term to:

Determining the location and extent of pupping and nursery grounds for school and gummy sharks in south eastern Australia.

Assessing the contribution to recruitment of the different pupping and nursery areas.

Examining fishing mortality in the more important pupping and nursery areas.

SECTION 4 **Justification**

Fishery background

The southern shark fishery is currently worth $20 million to fishermen in Victoria, Tasmania and South Australia with annual landings exceeding 5000 tonnes live weight. The stocks of both school (*Galeorhinus galeus*) and gummy (*Mustelus antarcticus*) shark are considered by scientists and many fishermen to be over-exploited (Walker 1988). Catch per unit effort in Bass Strait (both species combined) declined from about 14 kg/km hr in 1973 to about 6 kg/km hr in 1987. The fishery is currently managed by the Commonweath through a system of licence limitation and gear restrictions.

School and gummy shark are each thought to consist of a single stock throughout their range in southern Australian waters. School shark produce live young and the neonatals and small juveniles apparently occur in well defined nursery areas in shallow, inshore bays and estuaries separate from the main adult population. Gummy shark also produce live young but their nursery areas are thought to be less specific than those of school shark.

Importance of nursery area research

Both industry and scientists have identified as an issue of major importance the lack of information on the location and extent of shark nursery areas and the vulnerability of sharks within these areas to human-induced mortality. The Southern Shark Fishery Management Advisory Committee (SSFMAC) recomended in February 1990 that 'comprehensive information should be sought from fishermen and scientists on the location of pupping grounds in each State with a view to improved controls over such areas'. The report from the 5th Southern Shark Stock Assessment Workshop (SSSAW) stated that 'the vulnerability of juvenile sharks to capture by professional and recreational fishermen in Tasmanian inshore waters is of concern to the research group'. Because of the close stock-recruitment relationship in sharks, high mortality in the pupping and nursery areas as a result of fishing or habitat degradation will translate more directly into a reduction in adult stock size than in scale-fish fisheries. Increased recruitment through improved management of nursery areas would promote stock recovery and complement the current Commonwealth management plan aimed at stabilising catches by reducing effort in the fishery. Improved management will have benefits for commercial shark fishermen and the Australian economy (the fishery is currently worth $20 million to fishermen in Victoria, Tasmania and South Australia).

Previous research

Work carried out by CSIRO in the late 1940s and early 1950s suggested that nursery areas for the whole southern Australian stock of school shark were restricted to inshore bays and estuaries in Tasmania and southern Victoria. High catch rates of small juveniles were only made at Pittwater, Georges Bay and Port Sorell in Tasmania, and Port Phillip Bay and Westernport Bay in Victoria, despite relatively extensive fishing around the coast (Olsen 1954). Based on tag-recaptures and information from fishermen Olsen (1954) proposed that pregnant school sharks move into shallow estuaries and bays around Tasmania and southern Victoria, give birth and then move out into deep water. The neonatal sharks stay in the nursery areas during summer and then move out into deeper inshore areas during winter. Juveniles return to the nursery areas during summer for up to two years after their birth. Different nursery areas appeared to have different age distributions of sharks; for example in Port Sorell only 0^+ and 1^+ fish were caught while in Georges Bay sharks ranged in age from 0^+ to 3^+. Using a standard fishing technique Olsen (1954) documented catch rates in two nursery areas over a 5 year period between 1948–1952; he noted an apparent decline in catch rate which he attributed to a decline in stock size resulting from heavy fishing pressure. Olsen (1984) commented that 'This work has not been repeated (since) and hence no recent data are available for comparison'.

Gummy shark are thought to utilise inshore bays throughout their southern Australian range as nursery areas, but no specific investigations into the distribution of neonatals and juveniles have been carried out. Inshore pupping is suggested on the basis that small juveniles are rarely caught by the offshore commercial fishery whereas they are taken as bycatch in various inshore operations targetting other species. However, these data are complicated by the effects of gear selectivity as the commercial shark fishery uses relatively large mesh and hook sizes and so is unlikely to catch these small fish. However, more limited research fishing using small mesh nets (2-4 inch stretched mesh) also indicates that small juveniles are rare offshore.

Current legislation on nursery areas

As a result of Olsen's (1954) work a number of shark nursery areas were proclaimed; a few of these areas were closed to gillnetting while in other areas bans were imposed on the taking of shark but not on the deployment of fishing gear. Recreational gillnetting, hook and line fishing and some commercial fishing for scale fish takes place in, and adjacent to, these regions and the protective regulations have been largely ineffective in reducing the mortality on juvenile sharks. If Olsen's conclusions for school shark are correct, the restricted size and number of nursery sites makes them vulnerable to fishing pressure and environmental change. Anecdotal information suggests that both fishing and habitat degradation in these areas over the last four decades has dramatically reduced the numbers of neonatal and juvenile sharks found there. Habitat degradation has occurred through loss of sea grass beds, alteration of tidal flow (for example the causeway construction at Pittwater), high nutrient loadings caused by sewage, and toxins from agricultural runoff. The Tasmanian Government is committed to providing more effective protection to shark nursery areas but is hampered by the current lack of information. As an interim measure pending results of further research, new regulations restricting gillnetting in nursery areas have been introduced and will take effect from December 1990.

General proposal

We propose a study of shark nursery areas to be carried out in two phases, a one year feasibility study to be followed, if successful, by a more extensive two year study.

The initial 1 year project will test and refine a sampling strategy to compare distributions and densities of neonatal (0-1 years) and pre-recruit juveniles (1–4 years) in a study site of south-eastern Tasmania. The study site comprises a series of three interconnected bays which vary in depth, shelter and habitat availability from a shallow inshore estuary to a semi-exposed bay which opens to exposed continental shelf waters. The bays form a 'transect' which can be used to examine the distribution, size composition and densities of juvenile sharks from 'inshore' to 'offshore'. The ability to estimate densities of juvenile sharks in different areas is vital in assessing the contribution of these areas to recruitment and thus in assessing the impact of any fishing mortality. For example, a large area with a relatively low density of sharks may contribute just as much to recruitment as a small area with a high density of sharks. Without careful attention to sampling design it will not be possible to tell whether differences in catch rates between sites are related to shark population size or to the concentrating effects of the topography (i.e. restriction of sharks to channels in shallow sites at certain tidal states). The shark by-catch of various inshore commercial fisheries operating in the study area will be investigated as will recreational fishing mortality on juvenile sharks. Neonatal and juvenile sharks will be tagged to determine their movements and residence time in the study area.

If the one year study is successful (that is, it allows us to make statistically meaningful comparisons of juvenile density and distribution between areas) we would propose as the second phase a more extensive study to locate and examine the extent of pupping and nursery areas around Tasmania, Victoria, and possibly South and Western Australia to give coverage over the entire stock range. The relative contribution to recruitment of the various nursery areas could then be assessed. This would allow studies of recreational and commercial fishing mortality to be concentrated in the more important regions. If pilot work is encouraging, the use of microprobe analysis of shark vertebrae would be further evaluated as a possible means of identifying the nursery areas from which the adult sharks have originated.

SECTION 5 **Proposal in detail**

a) Plan of operation

(1) Method of Procedure

Sampling design for experimental fishing

A random stratified sampling design will be used to survey the study site to determine the distribution and abundance of juvenile sharks in each of three interconnected bays. Pittwater (41 km2) is a shallow protected estuary which was identified by Olsen (1954) as a school shark nursery area. Pittwater connects with the semi-protected Frederick Henry Bay (177 km2) which in turn connects with the semi-exposed Storm Bay (826 km2) which opens onto the continental shelf. Random stations will be selected within strata of substrate–type and depth. Substrate–type taken initially from charts will be checked from core samples taken at each station. The direction of net set will be randomised at each station. Between–bay comparisons within a given stratum will be limited because the same strata are not common to all sites due to the different depth profiles of the bays. Preliminary data on juvenile shark distribution by stratum–type will be used to assign the number of stations within strata. More stations will be fished in strata with expected higher densities of sharks; on average about five stations will be chosen within each stratum. Based on current information on the pupping season and seasonal movements of the juveniles, sampling will be carried out once a month between April and October, twice a month in November, December, February and March and three times a month in January. A new set of random stations will be chosen each sampling period. The objective will be to derive a statistically meaningful mean catch per unit effort (CPUE) value for each stratum by reducing the variance as much as possible. A mean index of abundance (which it is assumed can be related to shark density) for each bay will be calculated by weighting the mean stratum CPUE by the proportion of that stratum present.

Fishing gear

School and gummy sharks are born at about 30 cm total length and are about 80 cm long at 4 years of age. Because of gill-net mesh selectivity nets of 2, 3 and 4 inch stretched mesh must be used to adequately sample the 30–80 cm fish (Kirkwood and Walker 1986). Each net will be 75 m long and comprised of equal lengths of 2, 3 and 4 inch mesh. The sequence of the different mesh panels will be randomised between nets. A standard set time will be chosen to minimise mortality and maximise capture of live sharks for tagging.

Tagging to determine residence time and movements in nursery areas

Juvenile sharks caught in the nursery areas will be tagged using an internal tag with an external streamer to determine seasonal residence time in, and movement between nursery sites within the study area. In the follow up study, tagging would provide information on interannual residence time, movement between different nursey areas and time to recruitment to the fishery. Tagged fish will be injected with a marker (oxytetracycline or strontium chloride) to aid in validation of ageing work currently being undertaken by T. I. Walker at the Marine Science Laboartories, Queenscliff, Victoria..

Substrate type

Core samples will be taken at each station to confirm that the station is within the designated bottom-strata type; the samples will be retained and analysed for particle size. In the event that we encounter high shark CPUE variance in some of our designated strata, particle size analysis would provide greater refinement of substrate type and may help explain the variability. Turbidity will be measured at each station.

Diet of sharks

The diet of any captured sharks which it is not possible to release alive will be examined through stomach content analysis (mass, number and percentage occurrence of prey items).

Impact of Recreational Fishing in nursery areas

A study initiated by Department of Sea Fisheries is examining recreational gill-net catches of sharks in Frederick Henry Bay (part of the study area in this proposal) and the adjacent Norfolk Bay and will be continued through 1991. The study is, and will continue to be funded by Sea Fisheries with some personnel assistance from CSIRO. The bays were initially surveyed to determine the distribution of recreational nets. Standard recreational nets (50 m long, 4 inch stretched mesh) are deployed over a three day period every month. Six stations are sampled in each bay. Each station comprises two nets; one set close to reef and one further offshore over flat ground. A day set and an overnight set are made at each station. To quantify the amount of recreational effort in each bay a number of surveys will be made at different times and counts made of the number of deployed nets.

Impact of Commercial fishing in nursery areas

The impact of commercial fishing operations (Danish seining, flounder fishing and gillnetting) within the study site will be examined by monitoring these fishing activites.

Catch index for neonatal sharks

Olsen (1954) used a standard hook and line fishing technique to document catch rates in two nursery areas, one of which was Pittwater, over a 5 year period between 1948–1952; he noted an apparent decline in catch rate which he attributed to a decline in stock size resulting from heavy fishing pressure. Olsen's sampling technique will be repeated at the same site in Pittwater to document any changes after 40 years of commercial fishing.

If, in the longer term, major nursery areas are identified and shown to be limited in number (most likely for school shark) it may be possible to develop a catch index for neonatal sharks which could provide an independent check on relative adult stock size.

Microprobe analysis to determine nursery areas.

This method is based on the changing ratios of elements incorporated into fish hardparts (such as otoliths or vertebrae) during their development. These ratios are sensitive to environmental conditions such as water temperature, and so may constitute an 'environmental fingerprint'. This technique could provide a means of assessing the contribution of different nursery areas to the adult stock. For example, it may be possible to describe the 'fingerprint' of the south eastern Tasmanian, northern Tasmanian and southern Victorian nursery areas from the vertebrae of neonatal sharks caught there and then to identify the proportion of sharks taken from anywhere in southern Australia with these nursery 'fingerprints'.

Extensive microprobe work is not proposed during the 1 year study. However, it is proposed to collect a sample of vertebrae from the sharks of both species (0^+ to 2^+ year classes) from the study area and from a site in northern Tasmania during March 1992. A sample from the southern Tasmanian site will also be collected in March 1991 during the current Sea Fisheries project. Microprobe analysis of these samples would give some idea of the amount of interannual variation to be expected from the same site and will also allow comparison of two widely separated sites. If results are encouraging more extensive work would be carried out in a subsequent proposal.

Annual cycles of element deposition may provide a more accurate means of ageing fish than techniques in current use. Independent estimates of age would be a useful spin-off from the microprobe work, particularly as there are real problems with ageing school shark using current vertebral staining techniques. Microbrobe analysis of recaptured sharks at liberty for over 30 years (Moulton et al. 1989) would provide important information as standard staining methods reveal no more than 11 'annual' rings on these vertebrae.

Investigation of inshore pupping migration.

Biological sampling aboard commercial shark vessels will be carried out to determine the presence of near-term pregnant females off the Tasmanian coast. Commercial effort data will be analysed to detect any seasonal shifts in fishing location which might indicate targetting on aggregations of pregnant fish. Seasonal data from market sampling will be examined to detect any shifts to larger size classes in the population which may indicate increases in catches of pregnant fish.

(2) Facilities available

Office and Laboratory Space The project would be a joint study between CSIRO Fisheries, Hobart and the Department of Sea Fisheries, Taroona. Facilities available include separate office space for the Senior Research Scientist and the two Experimental Scientists at CSIRO and for the two Scientific Officers (and 2 Technical Officers) at Sea Fisheries, Taroona. Laboratories, administrative support, library facilities and computing power (Mainframe and Macintosh personal computers) are available at both organisations.

Research Vessels and vehicles CSIRO 5.5 m Shark Cat 'Ophelia', trailer and towing vehicle and 12 m twin diesel powered launch 'Scottsman'. Department of Sea Fisheries 6 m Broadbill, trailer and towing vehicle.

Fishing Gear 12 standard recreational 50 m long 10 cm stretched mesh monofilament gill-nets.

(b) Supporting data

(i) Previous work in this or related fields

Dr J. Stevens (CSIRO), the project supervisor, has fifteen years of shark research (10 in Australia) resulting in 35 publications (bibliography attached). This work included the FIRTA funded Northern Pelagic Program (FIRTA 83/49) and Analysis of Taiwanese Catch Data (FIRTA 87/19). Dr Stevens has been asssociated with the southern Australian shark fishery and research program through the Southern Shark Research Group (SSRG), Southern Shark Stock Assessment Workshops (SSSAW) and Southern Shark Fishery Management Advisory Commitee (SSFMAC) meetings since 1979.

Ms S. Davenport (CSIRO) has been involved with shark research for 9 years including working on FIRTA projects 87/19 and 83/49 noted above. Ms Davenport was senior author on a paper on shark ageing.

Mr G. West (CSIRO) has worked in the shark program for 18 months; his work has concentrated on the analysis of tagging data.

Dr H. Williams and Mr A. Schapp (Department of Sea Fisheries) are (or have been) members of the SSRG and SSFMAC for 3 and 2 years respectively and have been involved with the industry through liaison with the Tasmanian Fishing Industry Council (TFIC). They have been instrumental in designing and implementing the pilot study to assess recreational fishing mortality in two inshore bays in Tasmania.

Mr R. Green and Mr C. Waterworth (Department of Sea Fisheries) have worked for the Department for 13 and 10 years respectively and have been involved with a wide range of fisheries; they have extensive experience in the field with a variety of fishing methods and fishing gear.

SECTION 6 **Research Priority**

This proposal is a tactical research project of a fishery resource assessment nature, that has been identified by industry, fisheries managers and research groups as requiring urgent attention.

SECTION 7 **Transfer of Results to Industry**

Progress reports will be tabled directly at the SSFMAC (which are attended by industry representatives) or at SSRG meetings or the annual SSSAW which report to the SSFMAC. Since a study of shark nursery areas was in part raised by industry and since the program intends to take advantage of industry offers to assist with the project (through sampling on commercial vessel) there will be close contact with industry during the course of the project. Results will also be made available to a wider industry audience through articles in Australian Fisheries.

SECTION 8 **Predicted Commencement and Completion Dates**

Commencement Date	1 July 1991
Completion Date	30 June 1992
Final report to FIRDC	31 December 1992

SECTION 9 **Requested Budget**

Item	**Requested 91/92**
Salaries & wages	$14727
Operating expenses	$40610
Travel expenses	$8202
Capital items	$21780
TOTAL	**$ 85319**

SECTION 10 **Funds Sought From Other Sources**

Funds are not being sought from any other sources

SECTION 11 **Financial Contribution Of Applicant**

The main financial contribution to the project by the applicant would be the salaries of the personnel engaged on the study (see below) and by way of the facilities and services listed under section 5.

The Department of Sea Fisheries is funding (and will continue to fund through 1991) the component of the study addressing recreational fishing mortality on juvenile sharks in Frederick Henry and Norfolk Bay. Equipment (vessels, towing vehicles and fishing gear) for this work is provided by Sea Fisheries, with some assistance from CSIRO.

CSIRO contributory component

Salaries

Staff	Classification	% time on project		Salary component	
		90/91	91/92	90/91	91/92
Stevens	CSOF6	3	80	1600	42409
Davenport	CSOF5	5	90	1900	36816
West	CSOF5	5	90	1900	36816
Admin overheads				4320	92833
Total contributory				**$9720**	**$208874**

Sea Fisheries contributory component

Item	1990/91	1991/92
Total salaries *	21300	63009
Admin overhead	17040	50407
Vessel operating costs	3600	3600
Fishing gear	1800	-
Vehicle costs	2700	2700
Travel	1000	1400
Total contributory	**$47440**	**$121116**

* Details of salary component

Staff	Classification	% time on project		Salary component	
		90/91	91/92	90/91	91/92
Williams		20	10	9000	4500
Schapp		10	5	4500	2250
Green		20	5	5200	1300
Waterworth		10	5	2600	1300
T.B.A.	Research Scientist	-	80	-	28702
T.B.A.	Technical Officer	-	100	-	24957
Total contributory				**$21,300**	**$63,009**

SECTION 12 **Detailed Budget**

Budget Item			91/92
Salaries			$
	Name	T. B. A.	
	Position	CSOF2 (2 month casual position)	
	Salary		4849
	On-costs		610
	Overtime		1968
	Name	Bruce Barker *	
	Position	CSOF3	
	Salary		(contributory)
	On-costs		-
	Overtime		7300
	Total salaries		**14727**
Travelling costs			
	Fares		–
	Allowances (marine survey) *72 person days @ aprox $42	3000	
	Accommodation (camping)	5202	
	Vehicle costs		-
	Other		-
	Total travel		**8202**
Operating costs			
	Ophelia	54 days @ $250/day	13500
	Scottsman*	36 days @ $600/day	21600
	Rough weather allowance (10% boat costs to allow for delays due to bad weather)		3510
	Boat maintenance		1000
	Microprobe analysis		1000
	Total operating		**40610**
Capital costs			
	Nets, ropes,buoys, danpoles,	8000	
	Tags and applicators		1500
	Net drum for Scottsman, rollers for both vessels	5000	
	GPS*		6000
	Protective clothing		1080
	Laboratory equipment (thermometers, sample bags etc)	200	
	Total capital		**21780**
Total proposed expenditure			**$85319**

Notes on detailed budget

* Coxswain of the 'Scottsman'
* Award restructuring proposals currently being discussed may increase this to approx. $11000
'* Scottsman' is required for offshore sampling in Storm Bay and the relatively high operating costs and the overtime component for the coxswain contribute 34 % of the cost of this study. Extensive offshore sampling would not be required in future studies significantly reducing costs.
* Some of the capital cost could be redeemed by sale at the end of the study

Date of compilation of financial data: November 1990

SECTION 13 **Organisation**

CSIRO Marine Laboratories, Division of Fisheries
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GPO Box 1538, Hobart, Tasmania 7001
Telephone (002) 206222; Telex AA 57182; Fax (002) 240530

Chief of Fisheries Division: Dr Peter Young

SECTION14 **Project Supervisor**

Dr J. D. Stevens
Senior Research Scientist
CSIRO Marine Laboratories, Fisheries Division
GPO Box 1538, Hobart, Tas 7001

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SECTION 15 **STAFF**

CSIRO
Dr J. D. Stevens Senior Research Scientist BSc(Hons), PhD Project Leader
Ms S. Davenport Experimental Scientist BSc
Mr G. West Experimental Scientist BSc(Hons)

Sea Fisheries
Dr H. Williams Scientific Officer BSc(Hons), PhD
Mr A. Schapp Scientific Officer BSc(Hons)
Mr R. Green Technical Officer
Mr C. Waterworth Technical Officer

SECTION 16 **Administrative Contact**

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