Report on the Southern Shark Fishery Pupping Workshop held at Queenscliff, August 1994

FRDC PROJECT NUMBER 93/063

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NON-TECHNICAL SUMMARY

PROJECT TITLE

The Development of Industry Based Strategies for Monitoring the Abundance of School and Gummy Shark Stocks. Part 1: Preparing a Scientific-Industry Workshop.

THE NEED

In recent years there has been considerable controversy over the status of the Southern Shark fishery and the stocks of gummy and school shark stocks it fishes. In particular there has been discussion about:

- The need for the fishery's managers to use the closure of areas to protect female school sharks while pupping inside shallow pupping grounds and,
- The potential for monitoring the abundance of pups to provide indices of stock abundance.

During these discussions it was identified that there is conflict between Industry and Scientific community as to the extent and location of pupping grounds. This conflict was preventing effective further discussions of proposals to use area closures to manage the fishery, and the development of monitoring techniques.

OBJECTIVES

The initial objectives of this project were to prepare material for a Scientific-Industry workshop and, to develop a proposal to hold a workshop to discuss the location of pupping grounds in the Southern Shark Fishery. The original scope of the project was to plan the workshop, prepare workshop discussion papers, identify workshop participants, and to prepare an application for funding to support the actual workshop.

INDUSTRY & MANAGEMENT CONSULTATION

This proposal arose out of the Industry-Research Workshop held in Melbourne in September 1992 and was developed in consultation and in conjunction with SHARKMAC and SIRLC.

PERFORMANCE INDICATORS

The success of this project is to be judged by the quality of the workshop prepared by this project.

REPORT

An outline for a workshop, and proposal to hold a workshop were prepared and submitted to the December 1993 FRDC funding round without success.

Despite this setback the workshop was held in Queenscliff, Tuesday 15 November 1994. There was strong support for the workshop, approximately 55 people attended and participated in discussions. There was good representation by industry, scientific community and fishery managers. Presentations reported on the research of CSIRO and VFRI, the industry survey by VFIF. Open forum discussion on key issues was facilitated.

The workshop was acknowledge as highly successful by attendees and SHARKMAC. The proceedings of the workshop have been documented. A final report of the proceedings accompanies this short report to FRDC and has been forwarded to SHARKMAC.

The workshop proceedings provides detailed documentation of the projects methods, content, findings and implications.

PROJECT FINDINGS & IMPLICATIONS

- Industry and the Scientific Community are agreed that gummy shark pupping is dispersed throughout the fishery with some concentration in shallow water, and that gummy shark pupping primarily occurs over summer.

- Industry and the Scientific Community disagree over the location and extent of school sharks pupping grounds. Many in industry believe some level of pupping is occurring in South Australia and south and western Tasmania. Scientific community claim it is restricted to Victoria and north and east coasts of Tasmania.

- The report documents and discusses the evidence supporting both sides of this argument. It is recommended that management should develop strategies to deter fishing targeted at adult school sharks, specifically the targeted gillnetting of pupping females in shallow pupping grounds. The application of the precautionary principle in this regard demands the assumption that pupping is occurring over the full range of areas reported by industry.

- Future research aimed at developing techniques for monitoring pup abundances should be aimed at statistically structured surveys to search for school shark pups in the areas nominated by industry.

CONCLUSIONS

This project has successfully achieved all of its original objectives.

A successful workshop was prepared and held as part of the 1994 Shark Conference in Queenscliff to discuss the location and distribution of pupping grounds in the Southern Shark Fishery. The proceedings of that workshop are reported in the attached workshop report. This report will provide the basis for SHARKMAC's and SSFAG's ongoing discussions about pupping areas, the monitoring of pup abundances and pupping area closures.

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1.0 Introduction

The school and gummy shark stocks of Southern Australia form the basis of one of Australia's oldest fisheries: the southern shark fishery, which is currently worth about $15 million annually to the fishers. Since levels of fishing effort reached historically high levels during the 1980s there has been intensive discussion about the best strategies for sustainable management of these stocks.

Targeted research on the fishery was begun by A.M. Olsen in 1946. Olsen studied the fishery biology of school sharks which were then the mainstay of the fishery. In his analysis of the fishery Olsen (1954) drew attention to the fact that sharks have a fundamentally different life cycle to bony fishes and invertebrates which makes them particularly vulnerable to over-fishing. Fish and invertebrates generally produce large numbers (up to millions) of small eggs or young many of which are subsequently lost to the process of natural mortality. In contrast sharks produce relatively few well formed eggs or pups, each of which has a much higher probability of surviving through to adulthood.

The consequence of this is that in bony fish and invertebrates, a relatively small number of breeding adults can still provide large amounts of recruitment to the fishery. In sharks the relationship between future recruitment and breeding adults is much more strongly defined. Olsen found that each school shark female produces approximately 30 live pups each pregnancy, and that near term pregnant female school sharks migrate into protected shallow waters to give birth to their pups.

It is now known that many species of sharks move away from the adult feeding grounds to lay eggs or to give birth to live young in pupping or nursery areas (Compagno 1990). It has been hypothesised that this behaviour has evolved to minimise the potential for cannibalism of pups and juveniles by highly predatory adults.

From his body of work Olsen (1954) concluded that "the most effective biological measures for the benefit of the fishery are the provision of protection for the two most vulnerable stages in the life cycle of the school shark; namely, the 2-month period prior to birth and the subsequent 3-4 yr of their inshore life." As a consequence of these findings some large inshore areas in south-east Tasmania were closed to fishing during the period of the inshore migration.

In the 1990s debate about the management of the southern Australian shark stocks has focussed on the need to maintain sufficient levels of breeding stocks and preventing targeted fishing of pregnant school sharks during their inshore migration. Victorian shark fishermen successfully lobbied their State Government to permanently close Victorian State waters (waters up to 3 miles offshore) to all commercial shark fishing. In 1993 & 1994 Commonwealth waters (waters beyond 3 miles) were closed to commercial shark fishing for 1 month over the period November to December. The possibility of monitoring the abundance of the shark stocks by surveying the abundance of pups within pupping grounds has also been raised. Discussions surrounding these issues and management initiatives has revealed differences in opinion between members of the scientific community and the fishing industry about the breeding biology of these species. These differences have at times caused dissension between groups seeking the same outcome of sustainability for the southern shark fishery.

1.1 This Report

In August, 1994, in conjunction with the Southern Shark Fishery Conference, a workshop was held involving fishers, managers and scientists to discuss the timing and location of school and gummy sharks pupping in south-eastern Australia. The aim of the workshop was to initiate structured dialogue on these issues between industry members and scientists and to document the perspective's of these two groups. The hope was that during this process the way towards resolution of these issues maybe opened up, and that future discussion, and research, will resolve the differences of opinion that currently exist. It is hoped that this resolution and development of consensus will promote the development of effective strategies for managing and monitoring the shark stocks of south-eastern Australia.

The purpose of this report is to document the proceedings of the workshop and to promote discussion of these topics. The author of this document has tried to accurately present the details of research results presented to the workshop and to represent the full range of opinions presented at the workshop. Apologies are offered in advance to the extent that this has not been achieved. However the author makes no apology for the general perspective from which this document proceeds and acknowledges that some will find aspects of this report opinionated and highly speculative. In structuring this report an attempt has been made to separate sections reporting research results and the opinions of others from the discussion and speculation for which the author takes full responsibility. As stated above, the hope of the author is that, in using a perspective which some will consider 'unscientific', discussion will be stimulated and eventual consensus on these topics reached.

1.2 Definitions

For clarification it is useful at this point to define what is meant by the terms 'pup' and 'juvenile' in this context. Both school and gummy sharks give birth to live young or pups. In the context of this report I am using the term '*pup*' to refer to school and gummy sharks in the first year of life. I am using the term '*juvenile*' to refer to sharks of 2-3 years of age, age classes that are too small to have fully recruited into the commercial fishery. Gummy sharks recruit into the commercial stocks at about 3-5 years of age, and school sharks 8-10 years of age. Some individuals of these species will begin maturing at around these ages but most will not mature until they are some years older. For ease of terminology I will refer to these maturing year classes as '*sub-adults*'.

2.0 Review of CSIRO Pupping & Nursery Area Research

The CSIRO Division of Fisheries has a long history of research into Australia's shark stocks. This overview of CSIRO's research into the pupping and nursery areas of school and gummy shark was presented to the workshop by Dr John Stevens of CSIRO, Hobart.

2.1 The Research of A.M. Olsen 1947-1952

Olsen (1954) conducted the first research program on the fisheries biology of the school shark in south eastern Australian waters. This included conducting a tagging program using hook and line fishing techniques.

Olsen initially interviewed fishers throughout Tasmania, Victoria and south-eastern South Australia about pupping in their areas. Olsen required detailed descriptions of pups with remnant (vestigial) external yolk sacks from the fishers before accepting that pupping was occurring in a locality (Olsen 1991 personal communication). He found evidence of widespread pupping in Tasmania and Victoria, but while suspecting that pupping might occur in the Coorong, South Australia, did not find the evidence sufficiently strong to support this conclusion.

Having defined to his satisfaction the approximate extent of school shark pupping Olsen selected Pittwater (Tasmania), George Bay (Tasmania), Port Sorell (Tasmania) and Port Phillip Bay (Victoria) for his intensive tagging project (Figure 2.1). These sites were selected because they were the areas in which he could capture the largest number of juveniles for tagging. Olsen released 4,755 school shark juveniles and pups into these inshore areas, of which approximately 200 were subsequently recaptured.

From his tagging studies Olsen (1954) concluded that;

> "During the late spring and early summer months the adult females move into, and give birth to their young in, the shallow waters of protected bays and certain estuaries of the south-eastern Australian coast. After the liberation of their young, they leave these "nursery" areas and begin active foraging to replenish food resources which were stored in the liver and depleted during the period of gestation. The young remain in these "nursery" areas until the late summer months, when they begin their leisurely seaward movement to deeper coastal waters where they stay over winter. In the following spring the majority return to their former "nurseries" whilst others move to adjacent estuaries and bays."

Olsen noted that there was some variability in the way school sharks used the different areas he studied (Figure 2.2). In Port Phillip Bay, Port Sorell and Pittwater he commonly captured pups (Length <45 cm) but in George Bay there were very few school sharks less than 1 year old. School sharks entered George Bay in their second year of life and remained in the system for two years taking advantage of its depth (20m) and sheltered, varied marine feeding grounds, but the Bay was not used for pupping. In contrast pups were common in Port Sorell but few juveniles were captured.

Olsen recorded a marked decline in the abundance of pups during his sampling program conducted in Pittwater and Port Sorell between 1947 and 1953 (Figure 2.3).

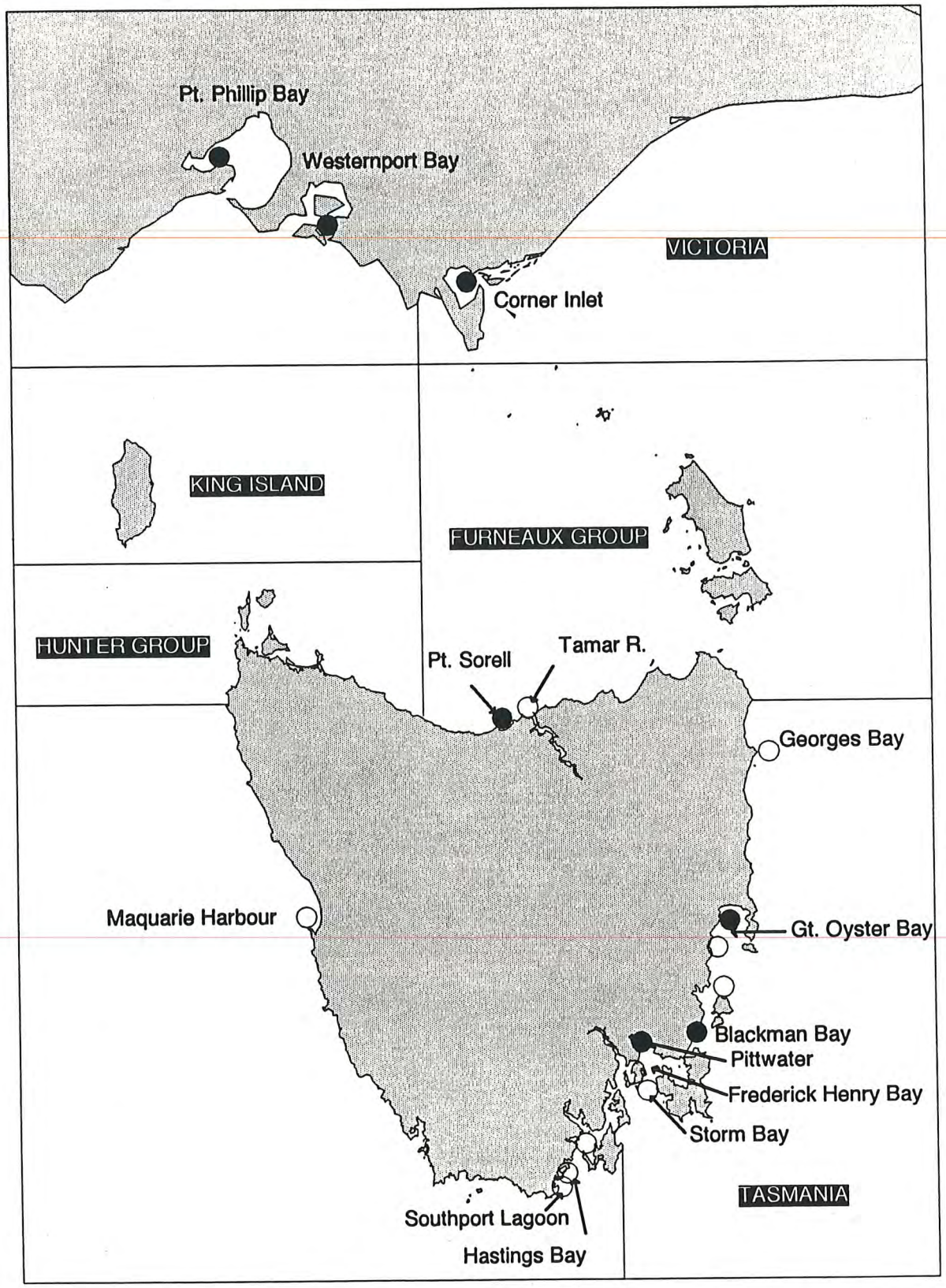

Figure 2.1 Map of Victorian and Tasmanian waters showing sites sampled for shark pups and juveniles by Olsen and Stevens of CSIRO and Walker of VFRI. Closed circles show locations at which school shark pups have been found by CSIRO, and open circles indicate locations at which school shark pups have not been found by CSIRO. Delineated regions are those used by Walker of VFRI for presentation of stock survey results (see Section 3).

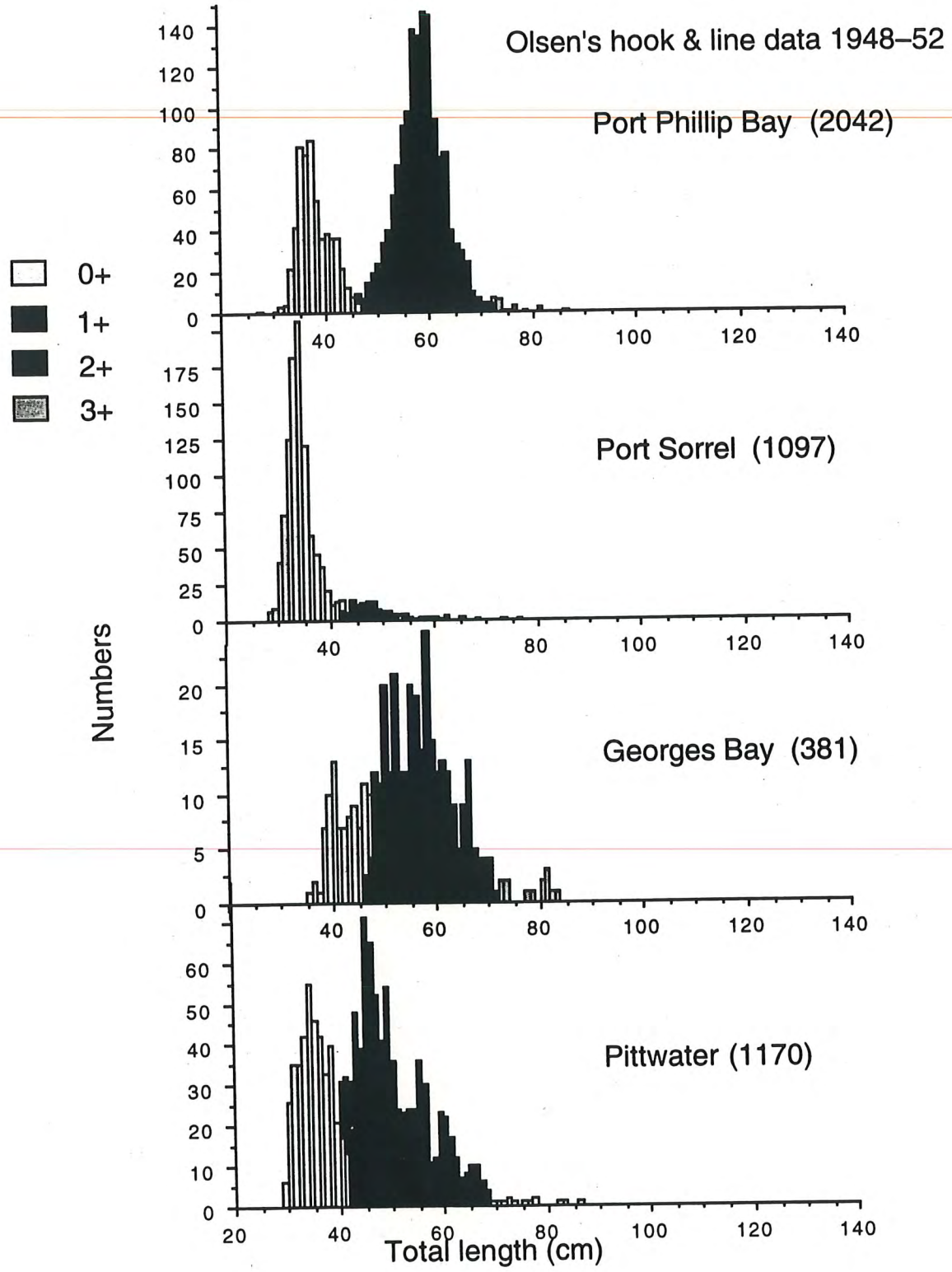

Figure 2.2 Size composition of school sharks captured by Olsen between 1948 and 1952 in Port Phillip Bay, Port Sorrel, Georges Bay, Pittwater. Courtesy J.Stevens CSIRO.

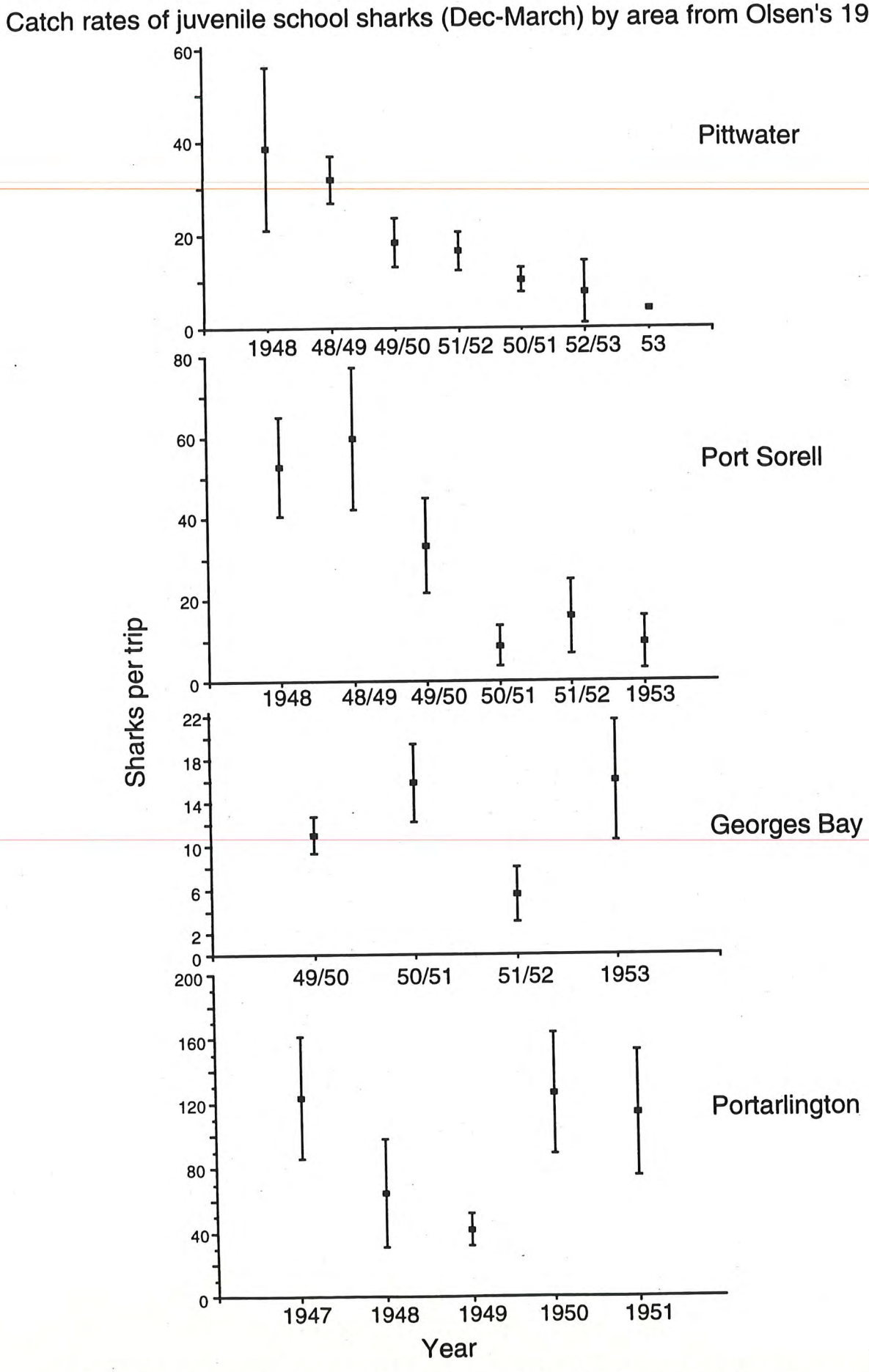

Figure 2.3 Olsen's catch rates of juvenile school sharks in Port Phillip Bay, Port Sorrel, Georges Bay, Pittwater between 1948 and 1952. Courtesy J.Stevens CSIRO.

George Bay and Portarlington showed no clear pattern in the number of small school sharks caught per trip, but Olsen (1954) noted that he changed his sampling locations and techniques to maintain his catch rates in these areas.

2.2 Investigation of School and Gummy Shark Nursery Areas in South East Australia 1991-94

Since 1991 John Steven's group at CSIRO has been conducting an investigation of School and Gummy Shark Nursery Areas in South East Australia funded by the Fisheries Research and Development Corporation (FRDC).

In 1991 CSIRO undertook a 12 month study of the distribution of gummy and school shark pups and juveniles within Pittwater, Frederick Henry Bay and Storm Bay (Figure 2.4) to test the hypothesis that school and gummy shark pups are most prevalent in protected inshore environments. Small gillnets (75 m length with 3 x 25 m panels, mesh sizes 50, 76 & 102 mm) and some longline sets were used to sample the area.

The earlier findings of Olsen for school shark were confirmed by this phase of the study. New born school shark pups were only found over the summer months in Pittwater, principally in upper Pittwater above the causeway (Figure 2.5). During the winter following their birth older pups were found in the deeper water of Frederick Henry Bay and Storm Bay, where one and two year old juveniles were found throughout the study.

In contrast gummy shark pups and juveniles were principally found in the deeper water of Frederick Henry Bay and Storm Bay (Figure 2.6).

During subsequent years of the project selected bays and estuaries along the east and north coasts of Tasmania (Figure 2.1) were sampled with the same small gillnets to test for the presence or absence of school and gummy shark pups and juveniles.

In Tasmania school shark pups were found in Port Sorell, Great Oyster Bay, Blackman Bay, Marion Bay, Norfolk Bay, Upper and Lower Pittwater and Frederick Henry Bay. Juveniles in their second and third years of life were also captured in Storm Bay, and Isthmus Bay. In the areas previously sampled by Olsen the size composition of sharks using those areas were found to be similar to the compositions measured by Olsen.

In contrast gummy shark pups and juveniles were more widespread. In addition to the sites listed above they were also captured in the Tamar River, Ralphs Bay, Great Bay, Great Taylor Bay, Huon River, Large Taylor Bay and Southport Lagoon. Small numbers of gummy shark pups were taken in almost all areas in which juveniles were captured.

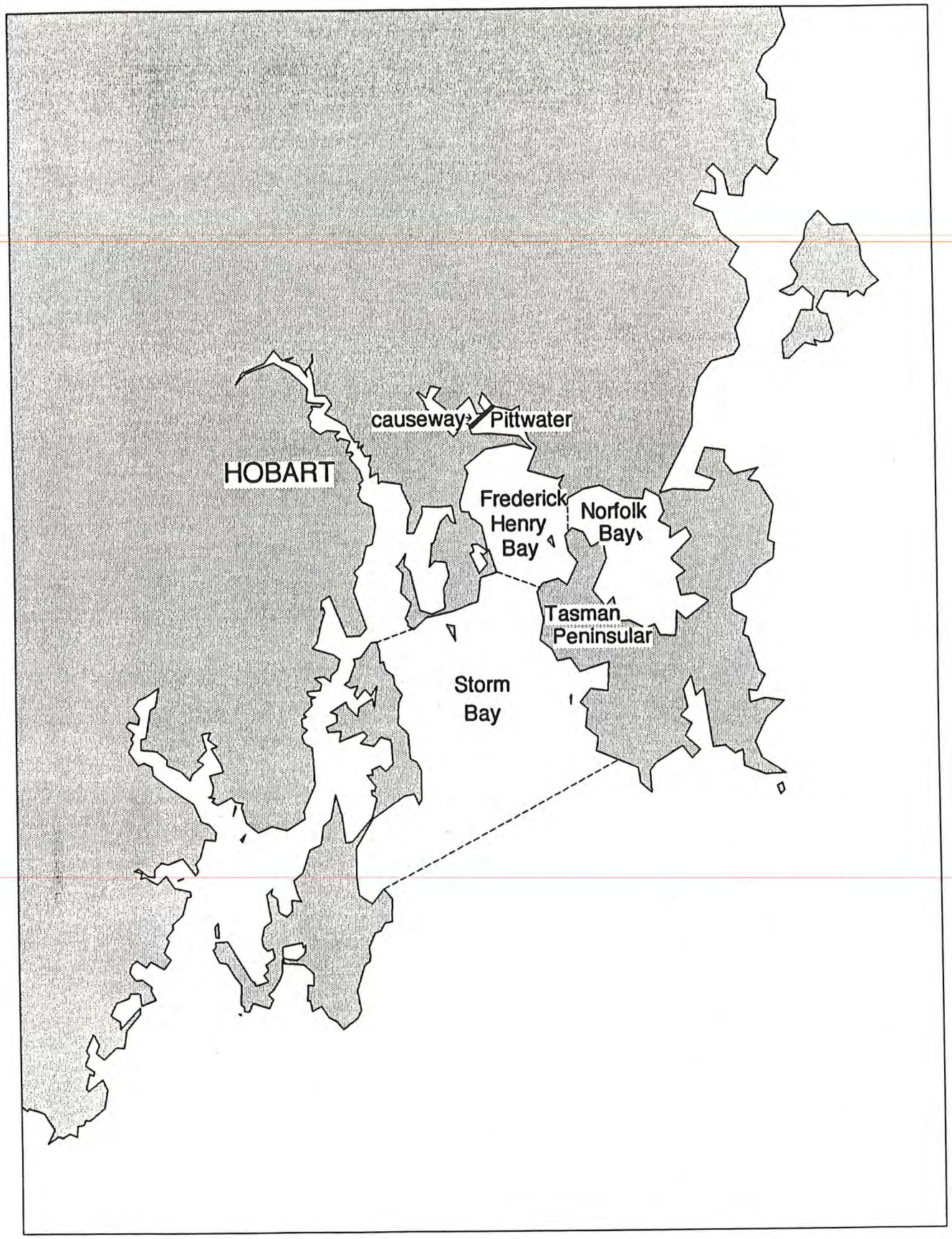

Figure 2.4 Map of south-eastern Tasmania showing Pittwater, Frederick Henry Bay and Storm Bay site of CSIRO sampling during 1991. Source Biospherics Pty Ltd.

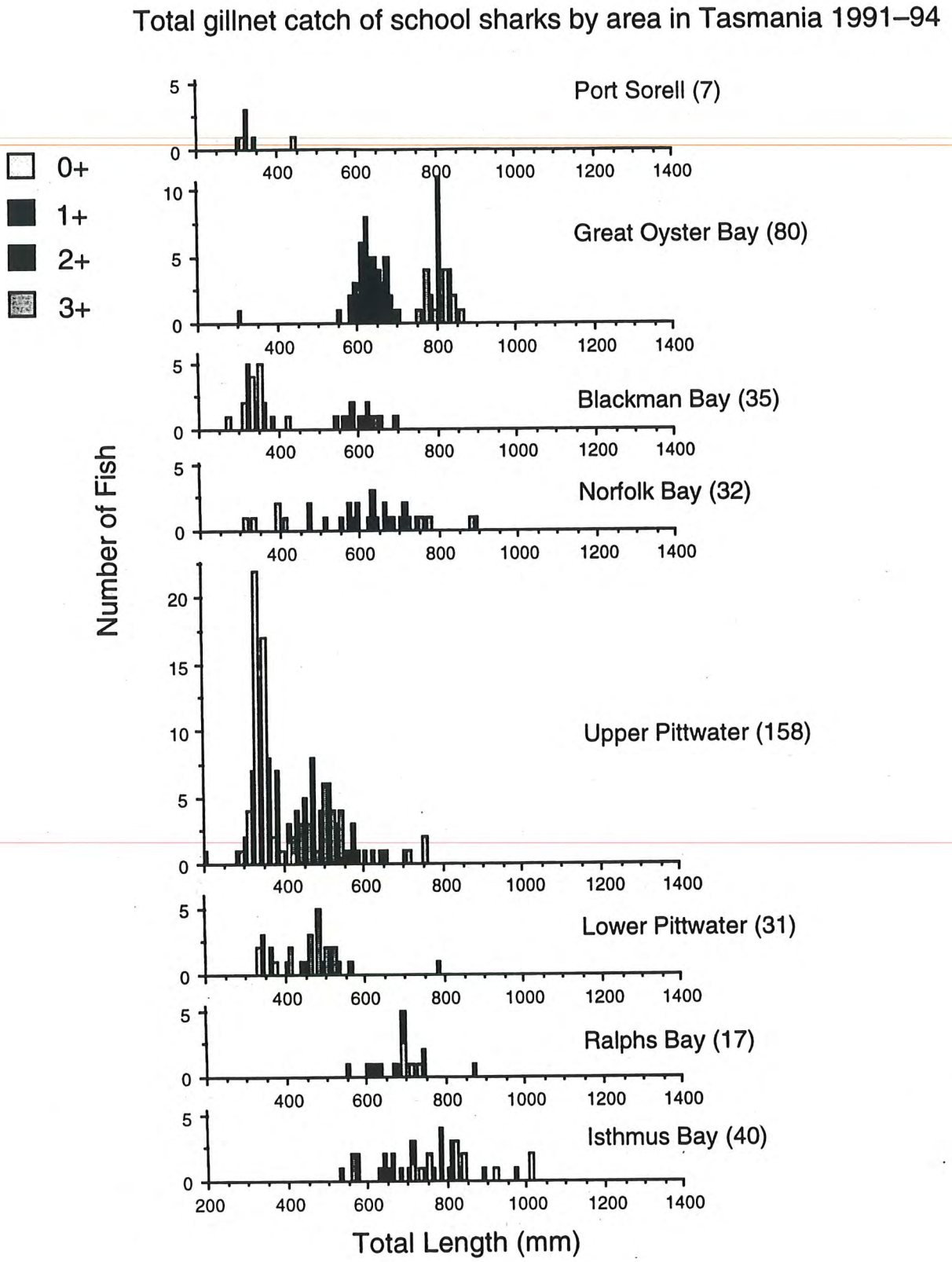

Figure 2.5 Size composition by area of school sharks captured during CSIRO's surveys 1991-94. Courtesy J.Stevens CSIRO.

Total gillnet catch of school sharks by area in Tasmania 1991–94

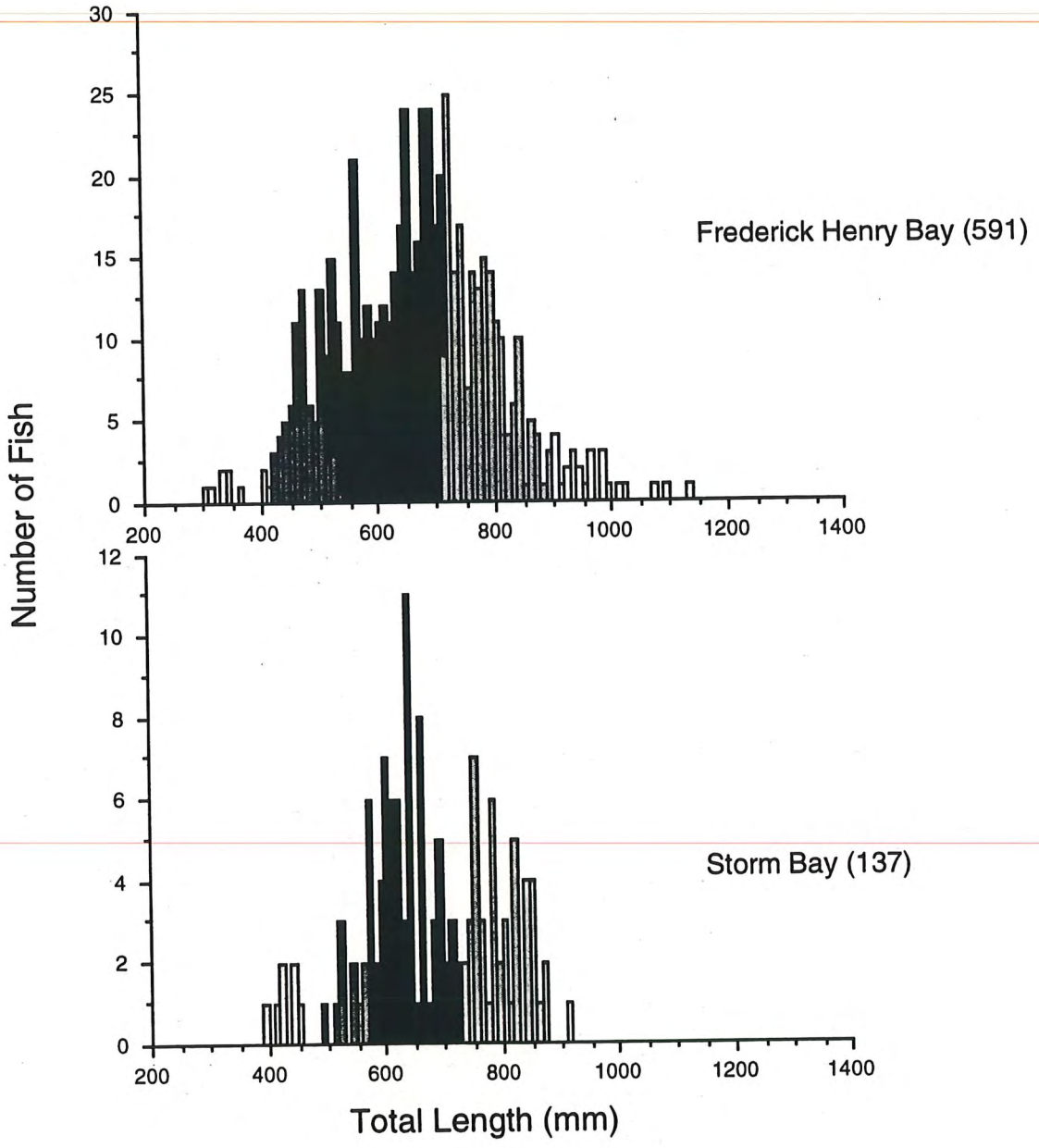

Figure 2.5 ...continued.

Total gillnet catch of gummy shark by area in Tasmania 1991–94

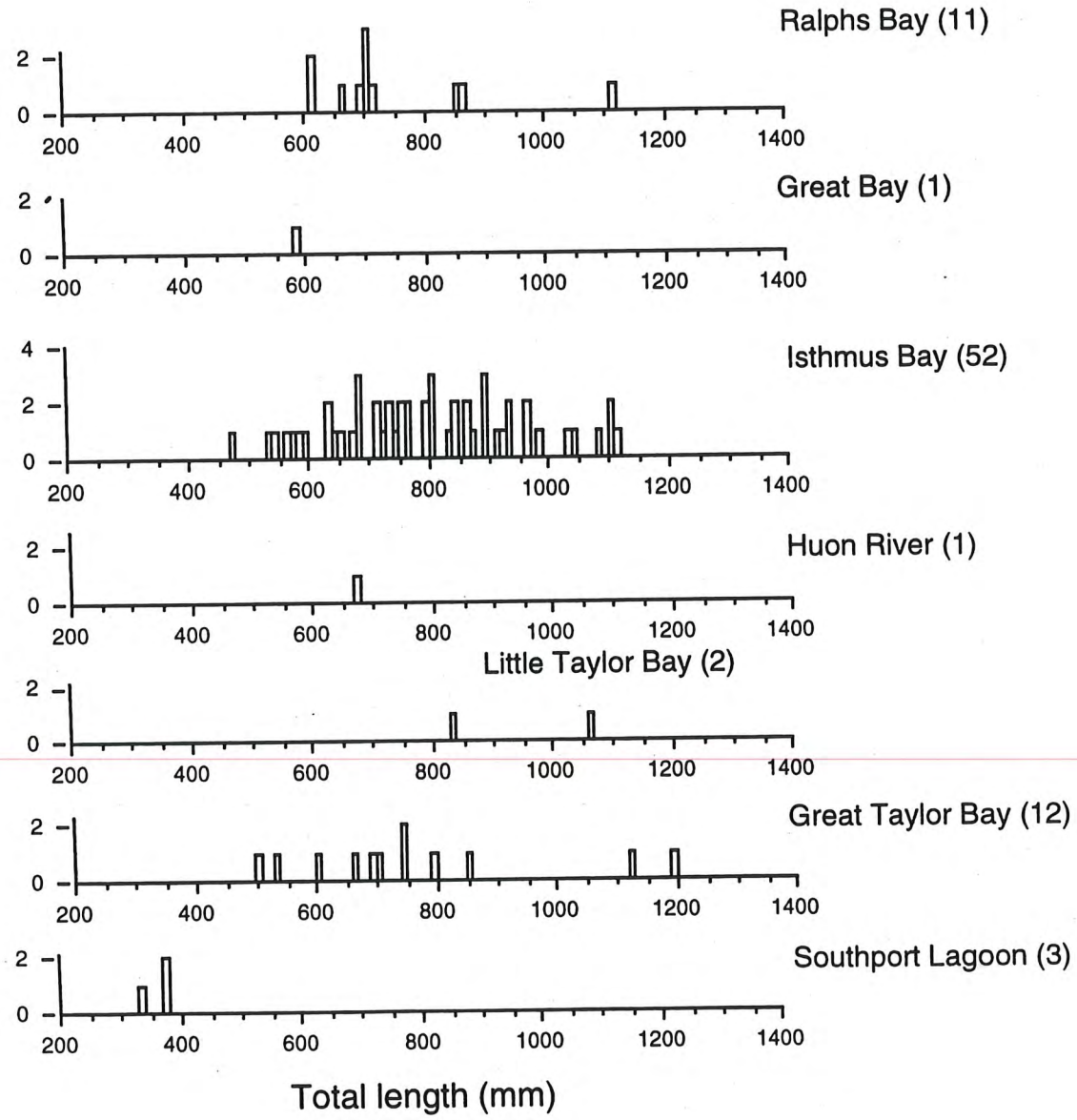

Figure 2.6 Size composition by area of gummy sharks captured around Tasmania during CSIRO's surveys 1991-94. Courtesy J.Stevens CSIRO.

Total gillnet catch of gummy shark by area in Tasmania 1991–94

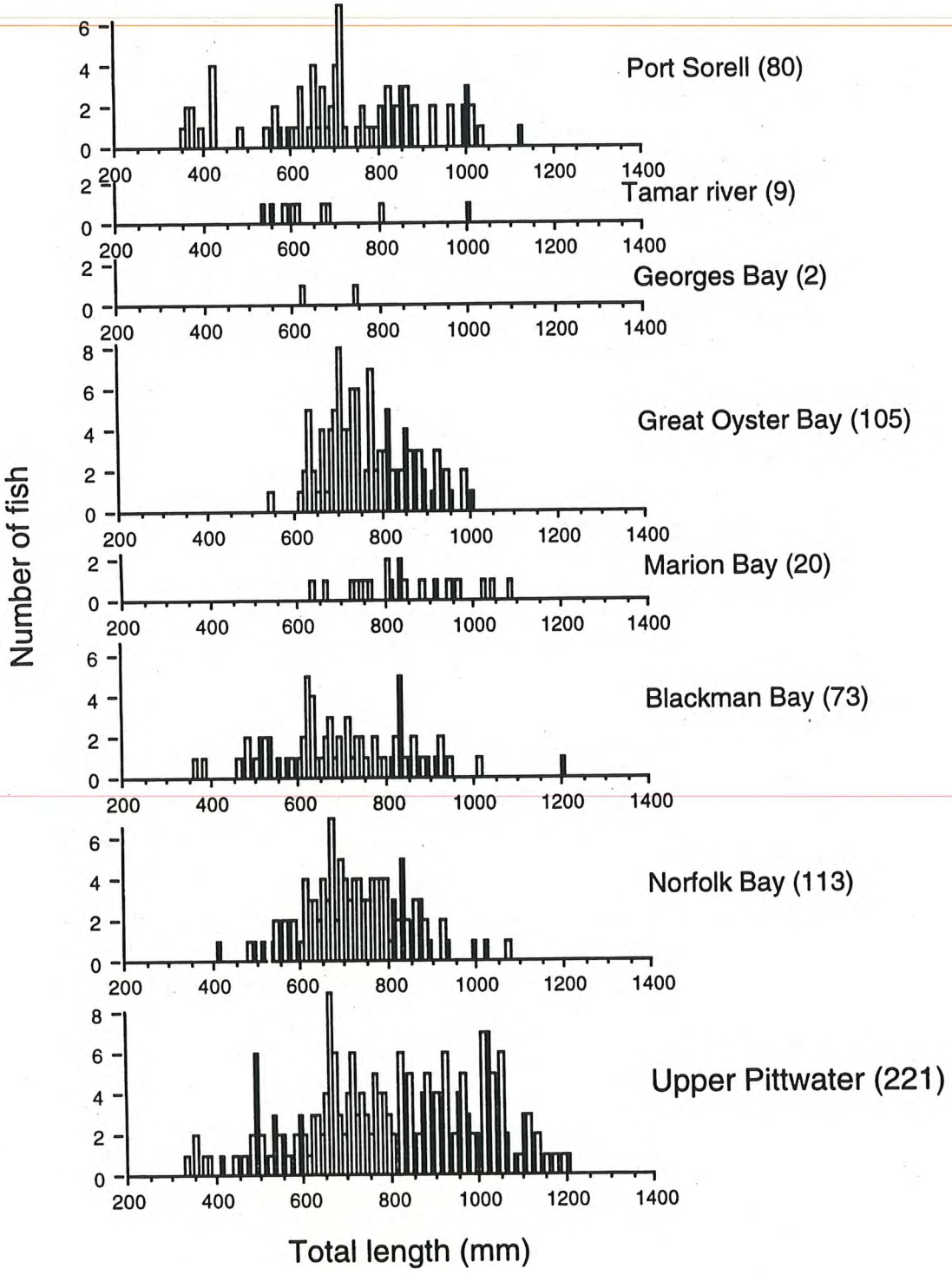

Figure 2.6 ...continued.

Total gillnet catch of gummy shark by area in Tasmania 1991–94

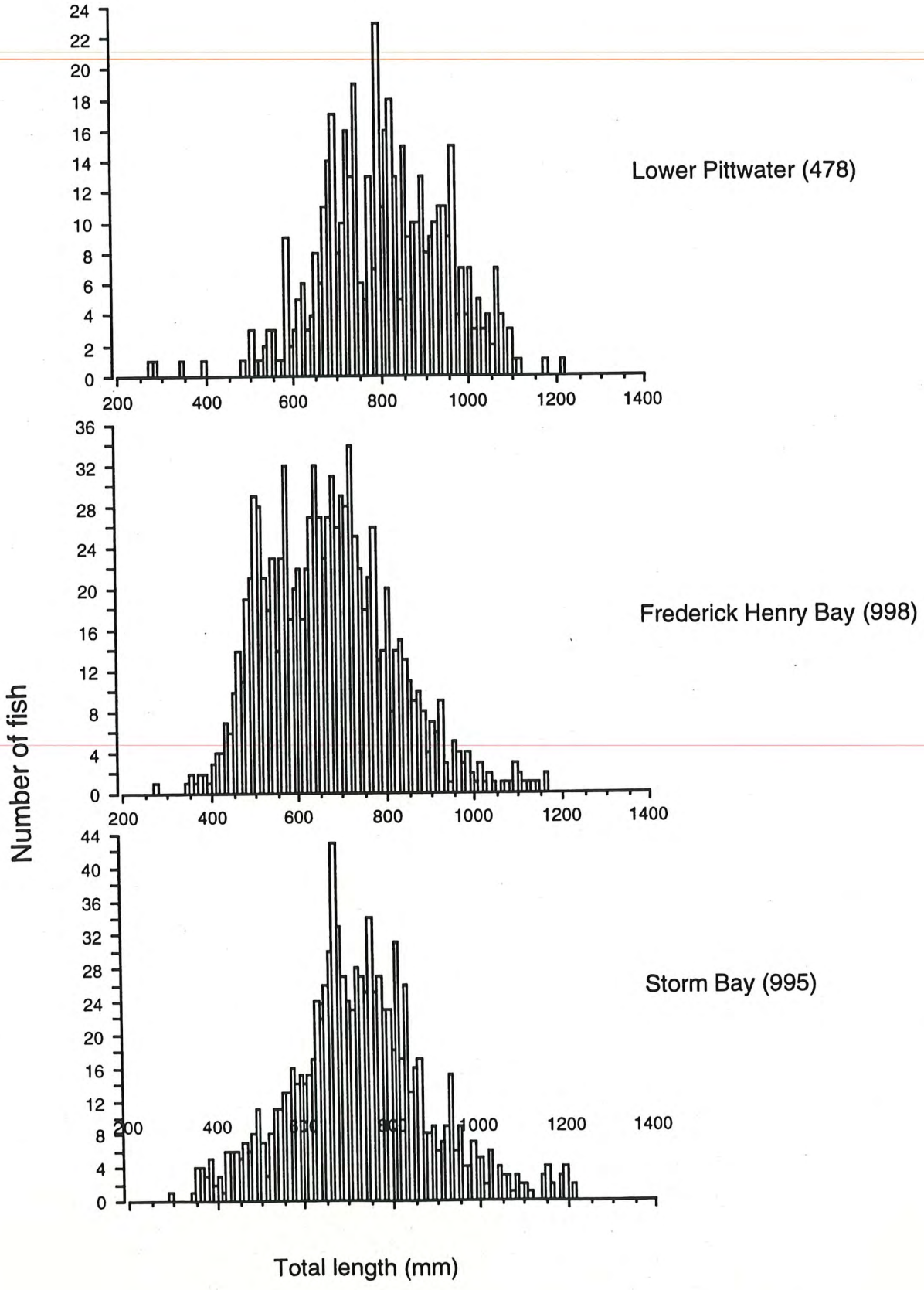

Figure 2.6 ...continued.

2.3 Comparison of School Shark Pup Abundance over Time

During the 1991-1994 study John Stevens attempted to derive information about the comparative abundance of school shark pups between the time of Olsen's study (1948-1953) and recent times.

In Portarlington, Port Sorell and Pittwater, Olsen was able to catch with handlines up to 80-100 sharks per day whereas during the recent study in Pittwater catch rates were 1.2 school shark pups per 75 m net and 3.9 per 50 hooks. Because Olsen used handlines to sample school shark pups it is not possible to directly compare his results with those of the more recent study using gillnets and longlines (Figure 2.7). To provide a direct comparison with Olsen's catch rates 7 days (22.5 hours) handlining were conducted in Pittwater during the recent study. No school shark pups were captured with this technique which may suggest that in these areas the decline documented initially by Olsen has continued to the present day.

However Olsen notes that this comparison may also not be strictly correct as differing areas of Pittwater were sampled during the two studies (Olsen 1996 personal communication). None of his sampling sites were above the causeway in Upper Pittwater where the recent study caught all of its school shark pups, during his study Olsen only fished the deep channels in Lower Pittwater where he believed the density of pups to be greatest.

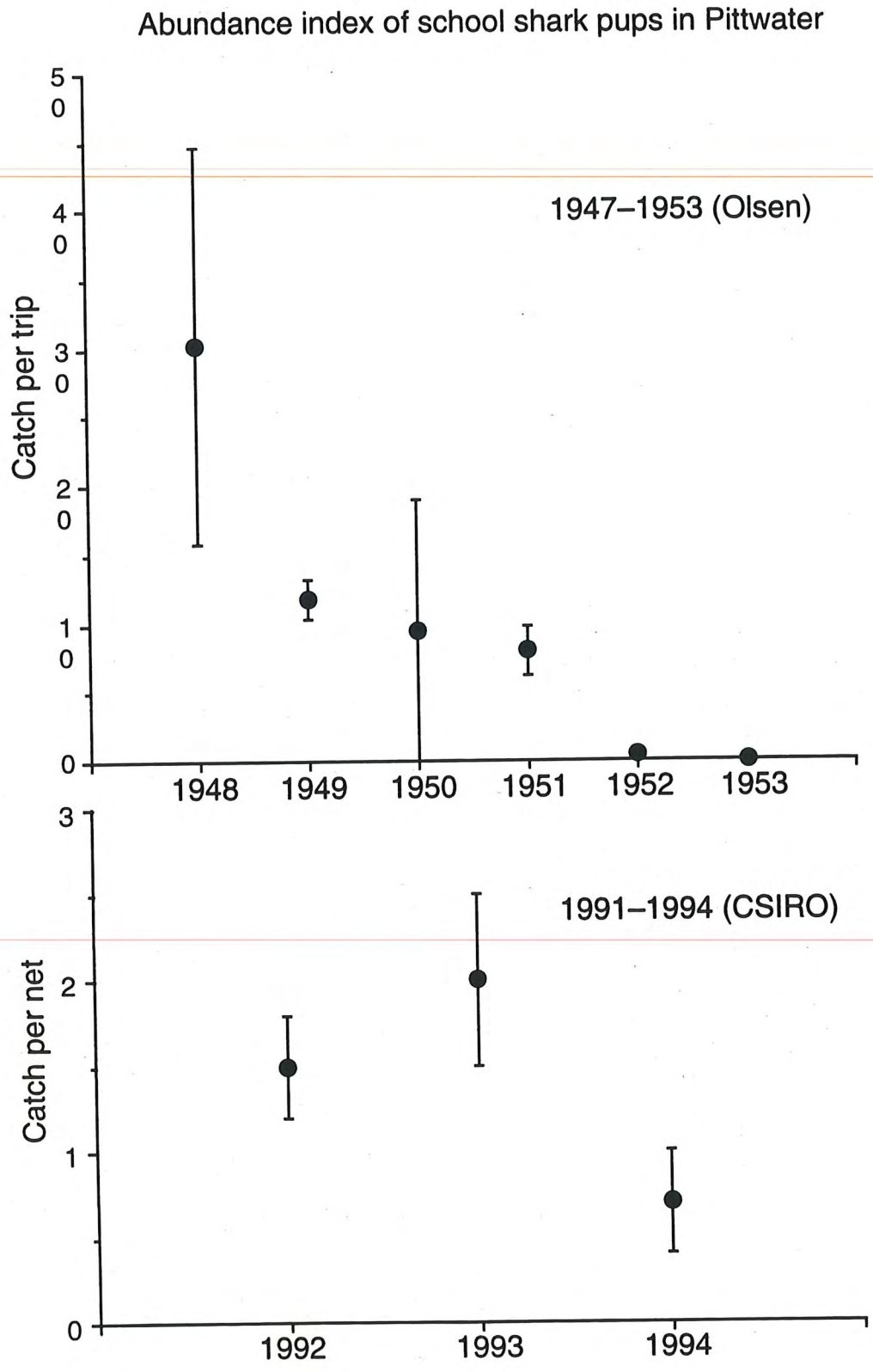

Figure 2.7 Catch rates for school shark pups in Pittwater during Olsen's study 1948-1953 and Steven's study 1992-1994. Courtesy J.Stevens CSIRO.

3.0 Victorian Research into the Southern Shark Fishery

In addition to the CSIRO Division of Fisheries the other main institution involved in research into the southern shark fishery has been the Victorian Fisheries Research Institute (VFRI) at Queenscliff, Victoria. Terry Walker the principal VFRI shark researcher provided the workshop with an overview of their research into the pupping and nursery areas of school and gummy sharks of Victoria.

The Southern Shark Research Group within VFRI have been conducting research into the southern shark fishery since the early 1970s. Until recently this research was focussed on the age classes of sharks being fished by the fishery. Their research has measured gillnet selectivity on sharks of different sizes, and described rates of growth and movement through tagging, stock assessment related surveys of the commercial fishing grounds have also been conducted. Most of this body of work has little direct relevance to the topic of this workshop.

3.1 Stock Assessment Surveys

During 1973-1976 and 1986-1987 VFRI conducted two surveys of the commercial shark fishing grounds off Victoria, Tasmania and South Australia. Composite gillnets made up of a wide range of mesh sizes (2-9 inches during 1973-1976 and 5-8 inches during 1986-1987) were used for the surveys. The inshore bay and estuarine environments (which the CSIRO work has shown contains the school shark pupping grounds) were not systematically surveyed. The surveys results presented here are based on catches made with 2, 3 and 4-inch mesh nets (Table 3.1 to 3.3). Walker defined six localities for his surveys and these are used for the presentation of these results in this report. He designated waters off South Australia as one locality and subdivided the areas he sampled off Tasmania and Victoria into five localities; Victoria (east of Wilson's Promontory and north of the Furneaux Group), Tasmania (east coast), King Island, Hunter Group and the Furneaux Group. Figure 2.1 shows the Victorian and Tasmanian localities as defined by Walker.

Overall, few pups (<450 mm length) of either species were found; 8 gummy sharks and 52 school sharks (Table 3.2 & 3.3). However, despite the low numbers of pups caught and the fact that sampling was conducted outside school shark pupping depths, the results of these stock surveys are generally consistent with the findings of CSIRO. School shark pups (<450 mm) were principally caught between November and March in depths of 10-29 m. Only 1 pup was caught in depths < 10 m. School shark pups were only captured around Hunter Island, the Furneaux Group and eastern Tasmania. Juvenile school sharks (450-799 mm) were caught over the full depth range sampled (<10 - 79 m) in all areas sampled.

Catches of school shark pups and juveniles were highly clumped. Of the 190 pups and juveniles captured two thirds (127) came from just 5 sampling categories (Table 3.2). Almost half (84) were captured in the single sampling category of: November - March, 10-19m in Tasmania. In contrast, gummy shark pups and juveniles were captured more uniformly over the sampling categories (Table 3.3). This is consistent with CSIRO's finding that gummy shark pupping areas are less clearly defined than those of school sharks.

Number of shots of 2, 3 and 4-inch gill-nets

Depth	Locality																					Total		
	SA			Victoria			King I			Hunter Gp			Furneau Gp			Tasmania								
	Ap-Oc		Nv-Mr	Ap-Oc		Nv-Mr	Ap-Oc		Nv-Mr	Ap-Oc		Nv-Mr	Ap-Oc		Nv-Mr	Ap-Oc		Nv-Mr	Ap-Oc		Nv-Mr	Ap-Oc		
	Oc	Tl	Mr	Oc	Tl	Mr	Oc	Tl	Mr	Oc	Tl	Mr	Oc	Tl	Mr	Oc	Tl	Mr	Oc	Tl	Mr	Oc	Tl	
10-19 m	2	2	4	.	4	.	.	.	3	.	3	3	1	4	4	.	4	14	3	17				
20-29 m	5	5	6	1	7	.	2	2	4	.	4	2	4	6	5	.	5	17	12	29				
30-39 m	4	4	1	.	1	3	.	3	2	1	3	.	2	2	.	.	.	6	7	13				
40-49 m	3	3	6	1	7	1	7	8	.	.	.	.	4	4	4	3	7	11	18	29				
50-59 m	1	1	2	3	5	.	2	2	.	.	.	.	3	3	.	1	1	2	10	12				
60-69 m	.	.	2	1	3	1	2	3	.	.	.	1	1	2	.	.	.	4	4	8				
70-79 m	.	.	.	2	2	.	.	.	.	.	.	1	1	2	.	1	1	1	4	5				
Total	15	15	21	8	29	5	13	18	9	1	10	7	16	23	13	5	18	55	58	113				

Table 3.1 Distribution of VFRI survey effort with 2,3 and 4-inch mesh 1986-1987. See text in section 3.1 and figure 2.1 for definition of localities. Courtesy T.Walker VFRI.

Table 3.2 Number of school sharks caught during VFRI small mesh surveys 1986-1987 by area, depth, time of sampling and size of shark. Courtesy T.Walker VFRI.

School shark		Number of sharks caught with 2, 3 and 4-inch mesh-size																			
		SA		Victoria			King I			Hunter		Furneau Gp			Tasmania			Total		
		Ap-Oc	Tl	Nv-Mr	Ap-Oc	Tl	Nv-Mr	Ap-Oc	Tl	Nv-Mr	Tl	Nv-Mr	Ap-Oc	Tl	Nv-Mr	Ap-Oc	Tl	Nv-Mr	Ap-Oc	Tl
		N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Length (mm)	Depth (m)																				
<450	<10 m	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	1	.	1
	10-19 m	.	.	.	.	.	.	.	.	1	1	11	.	11	28	.	28	40	1	41
	20-29 m	.	.	.	.	.	.	.	.	8	8	.	.	.	2	.	2	10	.	10
	Total			.	.	.	.	.	.	10	10	11	.	11	30	.	30	51	1	52
450-599																					
	10-19 m	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	4	4	.	4
	20-29 m	.	.	.	.	.	.	.	.	3	3	.	1	1	10	.	10	13	1	14
	30-39 m	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	3	2	1	3
	40-49 m	.	.	1	.	1	.	.	.	.	.	.	.	.	1	.	1	2	.	2
	50-59 m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	21	21	.	21	21
	60-69 m	.	.	.	.	.	.	1	1	1	1	.	.	.	4	3	7	5	4	9
	70-79 m	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	1	.	1
	Total	.	.	1	.	1	.	1	1	4	4	1	1	2	21	25	46	27	27	54
600-799																					
	10-19 m	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	1	.	1
	20-29 m	.	.	.	.	.	.	.	.	3	3	.	.	.	46	.	46	49	.	49
	30-39 m	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	2	2	.	2
	40-49 m	2	2	3	.	3	.	.	.	.	.	.	.	.	1	.	1	4	2	6
	50-59 m	.	.	1	.	1	.	.	.	.	.	.	.	.	.	1	1	1	1	2
	60-69 m	.	.	3	.	3	.	5	5	1	1	.	.	.	11	.	11	15	5	20
	70-79 m	.	.	.	.	.	.	.	.	.	.	.	4	4	.	.	.	.	4	4
	Total	2	2	7	.	7	.	5	5	4	4	.	4	4	61	1	62	72	12	84
>800																					
	20-29 m	.	.	.	.	.	.	.	.	4	4	.	.	.	1	.	1	5	.	5
	40-49 m	17	17	1	.	1	.	2	2	.	.	.	.	.	.	.	.	1	19	20
	50-59 m	.	.	2	.	2	.	.	.	.	.	.	.	.	.	.	.	2	.	2
	60-69 m	6	6	5	.	5	1	4	5	.	.	.	.	.	2	.	2	8	10	18
	70-79 m	.	.	.	1	1	.	.	.	.	.	1	1	2	.	.	.	1	2	3
	Total	23	23	8	1	9	1	6	7	4	4	1	1	2	3	.	3	17	31	48
Total																					
	<10 m	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	1	.	1
	10-19 m	.	.	.	.	.	.	.	.	1	1	9	.	9	33	.	33	43	.	43
	20-29 m	.	.	.	.	.	.	.	.	18	18	.	1	1	59	.	59	77	1	78
	30-39 m	.	.	.	.	.	.	.	.	.	.	.	.	.	4	1	5	4	1	5
	40-49 m	19	19	5	.	5	.	2	2	.	.	.	.	.	2	.	2	7	21	28
	50-59 m	.	.	3	.	3	.	.	.	.	.	.	.	.	.	22	22	3	22	25
	60-69 m	6	6	8	.	8	1	10	11	2	2	2	.	2	17	3	20	29	20	49
	70-79 m	.	.	.	1	1	.	.	.	.	.	2	5	7	.	.	.	2	6	8
	Total	25	25	16	1	17	1	12	13	?	22	13	6	19	115	26	141	167	70	237

Table 3.3 Numbers of gummy sharks caught during VFRI small mesh surveys 1986-1987 by area, depth, time of sampling and size of shark. Courtesy T.Walker VFRI.

School shark		Number of sharks caught with 2, 3 and 4-inch mesh-size																	Total		
		SA		Victoria			King I			Hunter		Furneau Gp			Tasmania					
		Ap-Oc	Tl	Nv-Mr	Ap-Oc	Tl	Nv-Mr	Ap-Oc	Tl	Nv-Mr	Tl	Nv-Mr	Ap-Oc	Tl	Nv-Mr	Ap-Oc	Tl	Nv-Mr	Ap-Oc	Tl
		N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Length (mm)	Depth (m)																			
<450	<10 m	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	1	.	1
	10-19 m	.	.	.	.	.	.	.	.	1	1	11	.	11	28	.	28	40	1	41
	20-29 m	.	.	.	.	.	.	.	.	8	8	.	.	.	2	.	2	10	.	10
	Total	.	.	.	.	.	.	.	.	10	10	11	.	11	30	.	30	51	1	52
450-599	10-19 m	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	4	4	.	4
	20-29 m	.	.	.	.	.	.	.	.	3	3	.	1	1	10	.	10	13	1	14
	30-39 m	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	3	2	1	3
	40-49 m	.	.	1	.	1	.	.	.	.	.	.	.	.	1	.	1	2	.	2
	50-59 m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	21	21	.	21	21
	60-69 m	.	.	.	.	.	.	1	1	1	1	.	.	.	4	3	7	5	4	9
	70-79 m	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	1	.	1
	Total	.	.	1	.	1	.	1	1	4	4	1	1	2	21	25	46	27	27	54
600-799	10-19 m	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	1	.	1
	20-29 m	.	.	.	.	.	.	.	.	3	3	.	.	.	46	.	46	49	.	49
	30-39 m	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	2	2	.	2
	40-49 m	2	2	3	.	3	.	.	.	.	.	.	.	.	1	.	1	4	2	6
	50-59 m	.	.	1	.	1	.	.	.	.	.	.	.	.	.	1	1	1	1	2
	60-69 m	.	.	3	.	3	.	5	5	1	1	.	.	.	11	.	11	15	5	20
	70-79 m	.	.	.	.	.	.	.	.	.	.	.	4	4	.	.	.	.	4	4
	Total	2	2	7	.	7	.	5	5	4	4	.	4	4	61	1	62	72	12	84
>800	20-29 m	.	.	.	.	.	.	.	.	4	4	.	.	.	1	.	1	5	.	5
	40-49 m	17	17	1	.	1	.	2	2	.	.	.	.	.	.	.	.	1	19	20
	50-59 m	.	.	2	.	2	.	.	.	.	.	.	.	.	.	.	.	2	.	2
	60-69 m	6	6	5	.	5	1	4	5	.	.	.	.	.	2	.	2	8	10	18
	70-79 m	.	.	.	1	1	.	.	.	.	.	1	1	2	.	.	.	1	2	3
	Total	23	23	8	1	9	1	6	7	4	4	1	1	2	3	.	3	17	31	48
Total	<10 m	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	1	.	1
	10-19 m	.	.	.	.	.	.	.	.	1	1	9	.	9	33	.	33	43	.	43
	20-29 m	.	.	.	.	.	.	.	.	18	18	.	1	1	59	.	59	77	1	78
	30-39 m	.	.	.	.	.	.	.	.	.	.	.	.	.	4	1	5	4	1	5
	40-49 m	19	19	5	.	5	.	2	2	.	.	.	.	.	2	.	2	7	21	28
	50-59 m	.	.	3	.	3	.	.	.	.	.	.	.	.	.	22	22	3	22	25
	60-69 m	6	6	8	.	8	1	10	11	2	2	2	.	2	17	3	20	29	20	49
	70-79 m	.	.	.	1	1	.	.	.	.	.	2	5	7	.	.	.	2	6	8
	Total	25	25	16	1	17	1	12	13	[illegible]	22	13	6	19	115	26	141	167	70	237

Terry Walker of VFRI also argues that this is evidence of a concentration or 'hot spot' of school shark pups and juveniles in Frederick Henry Bay, south-east Tasmania which is consistent with the view that school shark pupping grounds are principally restricted to Bass Strait and eastern Tasmania.

However in evaluating the trends described by Walker it is important to consider the structure of the surveys; where and when surveys were and were not conducted, and the clumping of the catch statistics. Even if school shark pupping were occurring in other areas these stock assessment surveys would have been unlikely to detect them.

The catches of school shark pups and juveniles that did occur were highly clumped, almost half the sampled animals came from the small area of Frederick Henry Bay, while 100% of the pups, and approximately 80% of pups and juveniles combined, were taken between November and March.

Away from Tasmania and the Bass Strait Islands the main commercial shark fishing grounds are some distance offshore from reported pupping grounds. Surveys of commercial fishing grounds in these areas should not be expected to detect inshore concentrations of juveniles and pups. Additionally no surveying with small mesh gillnets occurred in South Australia during November to March (Table 3.1) when, on the basis of survey results, pups and juveniles would be most likely to be caught. Thus the probability of the surveys detecting pups and juveniles would have differed between areas. This prevents equal comparison being made between the areas. Because the chance of detection differs between the regions, in this case the absence of evidence cannot be used as evidence for absence.

Consequently while the data from these stock assessment surveys may be used to support arguments that school shark pupping is occurring in Bass Strait and eastern Tasmania because pups and juveniles were captured there, the results cannot be used to exclude the possibility of pupping in areas outside of the detected 'hotspots'.

3.2 VFRI Study of School and Gummy Sharks Pupping in Victoria

It was only in 1993/94 that VFRI commenced an FRDC funded study of school and gummy shark pupping in Victoria.

Up until the time of this workshop this work had involved using longlines and small mesh gillnets to capture and tag pups in Port Phillip Bay, Western Port Bay and Corner Inlet. Pups of both species were found in each of these areas although only one school shark pup was caught in Corner Inlet. The length frequency data from this work (Figure 3.1) show that a broader size range of gummy sharks are caught in these areas than school shark. This suggests that these areas are only used by school sharks as pupping and early nursery grounds, while gummy sharks are using these areas more extensively.

A comparison of the catch rates of the VFRI (Table 3.4) in Port Phillip Bay using longline sets of 200 hooks and those of Olsen using handlines at Port Arlington (Figure 2.3) supports John Stevens conclusion that the number of school shark pups in the pupping areas identified by Olsen is now extremely low compared to the 1940s and 1950s.

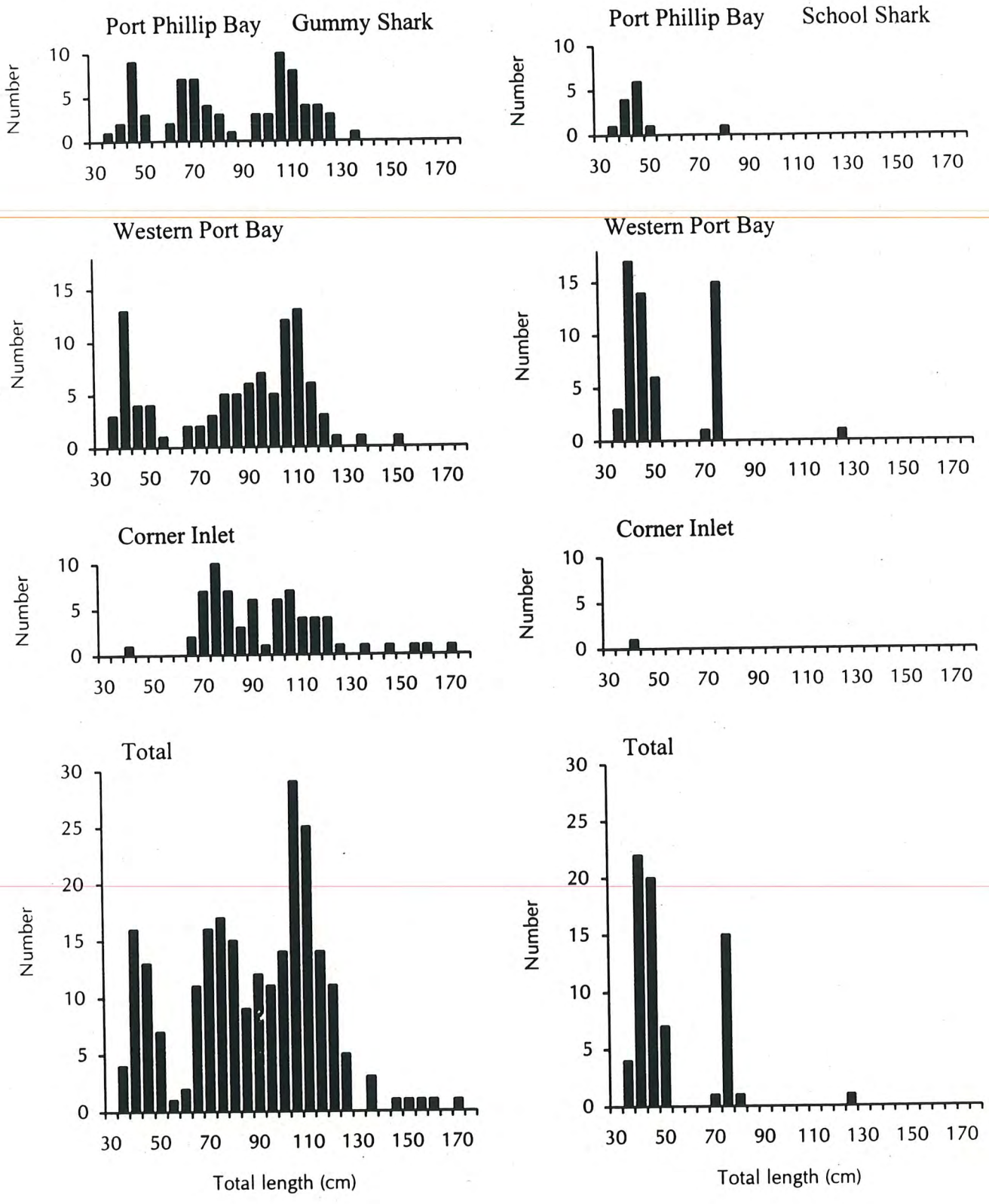

Figure 3.1 Length frequency histograms showing the size of school and gummy sharks caught during VFRI sampling in Port Phillip Bay, Western Port Bay and Corner Inlet using hooks and 2, 3 and 4-inch mesh gillnets. Courtesy T.Walker VFRI.

4.0 Industry Survey on Pupping & Nursery Area

During 1994 Karen Clifton of the Victorian Fishing Industry Federation circulated a questionnaire around commercial shark fishermen operating out of Victoria, Tasmania and South Australia requesting information about pupping and nursery areas.

There were 32 respondents, 19 from Victoria, 9 from South Australia and 4 from Tasmania. This is a relatively low number of respondents and the number from each area shows that the eastern part of the fishery is strongly represented and the western part of the fishery poorly represented. In this situation it should be expected that the responses will more accurately report the situation in Bass Strait and eastern Tasmania and poorly report the situation in South Australia and western Tasmania.

In addition the survey did not clearly define which species respondents were primarily targeting or the size of mesh respondents were using. Both these factors will effect the quality of knowledge respondents have about each species and the inshore occurrence of pups in their areas.

As a part of the survey fishermen were asked to nominate areas and depths in which they believe gummy and school sharks are pupping, the observed timing of pupping, and the evidence on which they base these beliefs.

The evidence cited included;

- the predictable capture of near term pregnant females in shallow water in early summer (PF).

  Shark fishers gut, head and fin sharks soon after capture and it is common practice for fishers to examine sex, gonadal status and stomach contacts as the catch is being cleaned. This information is used by fishers to discern the sharks behaviour (feeding, mating, pupping, travelling etc.) and to better predict where the nets should be set in the future.

  Many fishers infer where pupping is occurring on the basis of being able to predictably target near term pregnant females in certain locations.

- the capture of new born pups (P).

  Shark fishers observe carefully the items other than commercial catch that is brought to the surface in their nets. Pieces of sponge and coralline rubble, other species etc. are all used to indicate the type of environment the net has been in and the type of biological activity occurring on the sea floor. While their nets are too large (6-8" meshes) to efficiently capture pups and juvenile sharks, a few small sharks are occasionally entangled in the net.

  Many fishers infer where pupping is occurring on the basis of regularly entangling shark pups around those areas.

- the presence of membranous sacks in the nets which fishermen call 'after births' (AB).

  While gutting sharks fishers observe that near term school shark pups are surrounded by individual membranous sacks, possibly the egg case in which the pup has developed. Sometimes when target fishing for near term pregnant school sharks these membranous sacks are observed tangled in the net.

Normally when this occurs the fishing is unsuccessful. Fishers interpret this as an indication that pupping has already occurred and that the pregnant sharks have left the pupping grounds.

Many fishers infer where pupping is occurring on the basis of these experiences and observations.

• the general experience of the fisher (GE).
Experienced fishers have well defined theories on the behaviour of the species they target. These theories of behaviour provide the basis for an individual fishers fishing pattern and are in turn based upon the general experience of the fisher built up over time. Fishers are not always overly verbal in their communication and may find it difficult to explain exactly why they believe they know certain things. They attribute these beliefs to their 'general experience.'

4.1 Industry Survey Results

Obviously a survey of this type cannot be exhaustive or entirely accurate however some clearly consistent trends emerge.

Firstly, the reported pupping of gummy sharks is more widespread than for school sharks, both in space and time (Tables 4.1 & 4.2). More locations were nominated for gummy sharks and those locations nominated were often broad areas. Fewer areas were nominated for school sharks and the locations given were more often specific than general. In South Australia the Eucla Bluff and Coorong were nominated as being school shark pupping areas.

A wider range of depths (0-40 fathom or 0-80 m) were nominated for gummy shark than for school shark (0-30 fathom, mostly less than 15 fathoms).

Almost all times of the year are nominated for gummy shark but only spring and summer months are nominated for school shark.

4.2 Answers to Specific Questions

Many of the answers to survey questions were somewhat confused because the survey was not specific about the species being asked about. However several survey questions produced instructive answers.

From your Knowledge, have these always been Pupping Areas or have they Changed over Time?

No, they have always been the same	16
Yes, Frederick Henry Bay & Pittwater are too polluted now virtually no pupping.	1
Yes, More pupping offshore. Less adults inshore.	1
Yes, Less adults now due to fishing pressure.	1
Number of Respondents	**19**

These answers indicate that gummy and school sharks pup predictably in the same areas over time but that in some places fishermen have observed declining levels of pupping which were variously explained by increased pollution and declining stock levels.

Also of interest are the reasons proffered by fishermen to explain the characteristics of pupping areas that make them suitable for pupping.

Suggested Reasons for Location of Pupping Grounds

Sandy Bottom	1
Sheltered Area	9
Suitable small prey for pups	7
Nearby Reef Areas	5
Traditional Area	3
Warm Shallow Water	4
Lack of Predators	3
Estuarine Influence (comment about school sharks)	1

The sheltered nature of the areas, abundance of small prey species and presence of protecting reefs are the most commonly mentioned reasons for an area being suitable for pupping. The warmth of sheltered inshore waters, lack of major predators, and stable long term use of areas were also cited as reasons for areas being used for pupping.

Table 4.1 List of Gummy Shark Pupping & Nursery Areas nominated by respondents to the industry survey.

Location	Timing	Depth	Evidence	Reports
Victoria				
Wilson's Prom.-Cape Howe	Sept.-Feb.	0-30f	PF P	1
Wilson's Prom.-Oil Rigs	April-Oct.	3-30f	PF	1
Ninety Mile Beach	Around December	0-8f	PF	1
Corner Inlet	Around December	0-10f	PF P GE	3
Port Philip Bay	December	5-10f	PF GE	2
Split Point Northward	March/April	25-40f	P	1
Westernport Bay	December, Spring/Autumn	5-15f	PF P GE	4
Discovery Bay SW	Spring	0-20f	PF	2
Bridgewater Bay SW	Spring	0-12f	PF	2
South Australia				
Inshore along SE of Kingston	All Year		PF P	1
Wrights Bay Godfey Is.-Cape Jaffa	May-Aug.	0-10f	PF P	1
Coorong Victor Hb - Kingston	All Year	0-20f	PF P	2
Spencer Gulf	All Year	5-40m	P PF	2
Spencer Gulf	Oct-Nov.	5-20f	PF	1
Spencer Gulf - Corny Pt	Sept-Oct.	0-24m	PF P	1
St Vincent Gulf	Oct-Nov.	5-20f	PF	1
Eucla Bluff	June & Dec.	4-14f	PF	1
Reef Head West Coast	All Year	5-40m	PF P	1
Ceduna	All Year	5-40m	PF P	1
Venus Bay West Coast	Jan-Feb.	2-4m	P	1
Tasmania				
Ringarooma Bay	Nov.-Dec.	1-16f	GE	1
Sandy Cape-Eddystone Pt.	All Year	0-15f	PF	1
Eddystone Pt.-Swan Is.	July-Sept.	8-18f	PF	1
Mercury Bay	Spring/Autumn	10-40f	GE	1
Frederick Henry Bay	Winter/Spring	5-20m	GE	1
Storm Bay	Winter/Spring	5-20m	GE	1
Furneaux Group				
Northern End of Flinders - Deal Is.	Aug.-Oct.	25-30f	PF	1
Armstrong Channel	Nov.-Dec.	1-16f	GE	1
Franklin Sound	Nov.-Dec.	1-16f	GE	2
Flinders Is. & Cape Barren Is.	All Year	0-15f	PF	2
Foo Chow-Babel Is.	Sept.-Feb.	0-7f	PF	1
King Island				
Phoques Bay NW	Spring	0-20f	PF	2
Stokes Pt - Bold Hd	July-Sept.	8-24f	PF	1
General				
All Inshore waters-Bays & Estuaries			GE	3
All Inshore waters-Bays & Estuaries	All Year		GE P PF	3
All Estuaries, Ocean Beaches, Bays	Sept.-Jan.		PF P	2
All Inshore waters-Bays & Estuaries	March-April		GE	1
All Areas	All Year		PF P	1

Table 4.2 List of School Shark Pupping & Nursery Areas nominated by respondents to the industry survey.

Location	Timing	Depth	Evidence	Reports
Victoria				
Wilson's Prom.-Cape Howe	Sept.-Feb.	0-30f	PF P	1
Discovery Bay SW	Spring	0-20f	PF	2
Bridgewater Bay SW	Spring	0-12f	PF	2
Westernport Bay	Summer/Autumn	5-15f	PF P	4
Port Philip Bay	Summer	5-10f	1	
South Australia				
Coorong		Inshore		1
Eucla Bluff	Dec.	4-14f	PF	1
Tasmania				
Ringarooma Bay	Nov.-Dec.	1-16f	GE	1
Sandy Cape-Edison Pt.	Sept.-Feb.	0-15f	PF	1
Swan River	Dec.-Jan.	0-10f	PF P	1
Little Swanport River	Dec.-Jan.	0-15f	PF P	1
Cape Sorell - S.E. Cape	Dec.-Jan.	5-30f	PF P	1
Furneaux Group				
Armstrong Channel	Nov.-Dec.	1-16f	GE	1
Franklin Sound	Nov.-Dec.	1-16f	GE	2
Foo Chow	Sept.-Feb.	0-14f	PF P AB	2
Flinders Is. & Babel Is.	Sept.-Feb.	0-15f	PF	2
King Island				
Phoques Bay NW	Spring	0-20f	PF	2
General				
Inshore Waters, Bays & Estuaries	Summer	PF P GE	6	
All Ocean Beaches, Bays	Sept.-Jan.	PF P	1	
All Areas	All Year	1		

5.0 Synthesis of Industry and Scientific Perspectives

Many commercial shark fishers do not support facets of the information contained in the scientific literature, or views expounded by some of the scientific community about the biology of gummy and school sharks. The purpose of this section is to define the points on which the scientific community and shark fishermen agree and diverge. The aim is to clearly present the opinions advanced by each of these groups.

During this segment of the workshop participants were confronted with a series of points concerning the pupping of each species (reported in bold) and invited to comment. Where possible participants were divided into industry and biologists with each group being invited to contribute in turn.

5.1 Gummy Sharks

1. Pupping is widespread throughout the fishery, occurs in all states and can occur in all depths, but is concentrated in the shallow, sheltered inshore waters.

The fishermen and biologists present at the workshop agreed that gummy sharks can pup in all depths and in all regions of the fishery. It was also agreed by both groups that in relatively unfished areas the greatest concentrations of pregnant gummy sharks and gummy shark pups occur in shallow water.

The fishermen based these opinions on the regular capture of pregnant females and newborn pups in depths as great as 35-40 fathoms (and even greater on rarer occasions). Some Victorian fishermen also noted that prior to the closure of Victorian State waters there were extremely low numbers of pupping females and pups in inshore areas but nevertheless the catch from the offshore fishery for young gummy sharks had remained stable. From this they deduce that the offshore fishery was not dependent on inshore pupping.

John Stevens of CSIRO supported the belief that gummy sharks are not obligated to pup in inshore areas by noting that tropical gummy sharks occur in deep water along the shelf edge off Queensland. These are extremely similar to the southern gummy shark although they may constitute a different species. The tropical gummy sharks do not enter shallow water in Queensland because they cannot tolerate the high temperatures of shallow water. Unless it is assumed that these northern animals are the same species and migrate to southern waters to pup it must be assumed that these populations are sustaining themselves by pupping in deep water.

2. Pupping can occur in any season but is concentrated in summer.

Based on catches of pregnant gummy sharks and pups, the fishermen reported that the timing of gummy shark pupping varies between areas. In Victoria pupping is primarily thought to occur between September and March, although one Victorian fisher observed that he had found full term pregnant females in May. In South Australia fishers claimed pupping occurs between September and May, with two peaks of pupping activity in November and May.

Fishers stressed the importance of temperature in determining both the timing and location of gummy shark pupping. In colder areas pupping is observed to be more

restricted in the time of the year it occurs. Sheltered inshore areas are also warmer and this is thought to be the reason why pupping is concentrated in those areas.

Based on research in Victoria, Tasmania and Western Australia the biologists present at the workshop stated their belief that pupping only takes place between October and January.

4. Pupping and Nursery Areas.

The fishermen and biologists both believe that gummy shark pups and juveniles occur widely through the area of the fishery in the same areas as the adults occur. Consequently the concept of pupping and nursery areas distinct from adult feeding and breeding grounds has little use for this species.

5.2 School Sharks

1. Pupping restricted to summer.

The fishermen stated their belief that the exact timing of school shark pupping varies between years and is determined by rising water temperature during spring. Fishermen from the various states nominated the months over which pupping occurs in each state as:

Victoria	- October to February
South Australia	- August to January
Tasmania	- September to January

The biologists attending the workshop stated their belief school shark pupping only occurs between November and January.

2. Pupping restricted to specific long term/traditional pupping areas.

The fishermen stated their belief that there are traditional pupping grounds where pregnant females invariably pup each year. However some also believe that in other areas lower levels of pupping occur, and the use of these areas is more variable between years.

The fishermen at the meeting stated their belief that females do not necessarily home to the same pupping areas each years, rather they use pupping areas opportunistically, moving into areas adjacent to the feeding grounds they have been using prior to pupping.

The biologists at the meeting agreed with the hypothesis that there are 'hotspots' or concentrations of pupping in inshore areas but that some lower level of pupping may occur outside these core areas.

3. School shark pupping grounds are characteristically: sheltered inshore areas or oceanic beaches with some estuarine influence, and are often protected by a sheltering reef or headland.

Fishermen at the meeting were in broad agreement with this statement.

Comments proffered by the fishermen emphasised the importance of sheltering features such as reefs and headlands, and the fact that the geomorphology of pupping grounds invariably offers protection from the prevailing summer winds.

The importance of some freshwater influence was also noted, this influence may be from riverine flow or groundwater. This characteristic is often linked to the presence of seagrass beds in many school shark pupping grounds. Pupping grounds along ocean beach areas are not always characterised by the presence of seagrass, but some fishers noted that at the time of pupping, floating racks or attached growths of seaweed, commonly occurred in these areas. The fishers believe the seagrass and seaweed is an important characteristic of the pupping grounds, offering shelter and feeding opportunities for newborn pups.

The fishermen base the above claims on catches of pregnant females with full term pups, catches of new born pups, catches of 'after birth' and direct observation. Fishermen at the meeting recounted observing the characteristic behaviour of near term pregnant female school sharks within pupping grounds. Near term females are relatively docile, moving leisurely and repeatedly backwards and forwards along the beaches, sand banks, reefs and channels of the pupping grounds. It was noted that pupping females are so docile they tend to mesh poorly, consequently when hauling a gillnet set in a pupping ground fishermen need to be watchful or sharks fall out of the net as it is pulled.

4. Some pupping areas in every state.

Most but not all of the fishermen agreed with this statement. The basic belief of fishermen expressed at the meeting was that where ever the conditions described above existed, school sharks would use them for pupping at some time.

Some of the Victorian fishermen did not believe that pupping was occurring in South Australia because of the lack of physical evidence. Shark fishermen from South Australia at the meeting were certain that school shark pupping did occur in specific areas in their State and made the comment that fishermen should only talk authoritatively about their own areas.

Despite the dissenting views a broad body of fishers maintain that school shark pupping grounds exist, or have existed, in (Figure 5.1):

NSW	- estuaries and shorelines of southern NSW,
Victoria	- eastern and central Victoria,
Tasmania	- the Furneaux Group,
	- King Island
	- southern, western and northern Tasmania, and
South Aust.	- around Beachport and Robe
	- the Coorong,
	- south coast of Kangaroo Island,
	- south coast of Yorke Peninsula
	- south-western Eyre Peninsula, and
	- the Head of the Bight.

The biologists present at the meeting could not agree with the proposition that pupping was occurring in South Australian waters. Terry Walker of VFRI stated that he could only accept the capture of newly born pups as evidence of pupping. In his view this standard of evidence only indicates school shark pupping around Victoria, and northern and eastern shorelines of Tasmania, specifically:

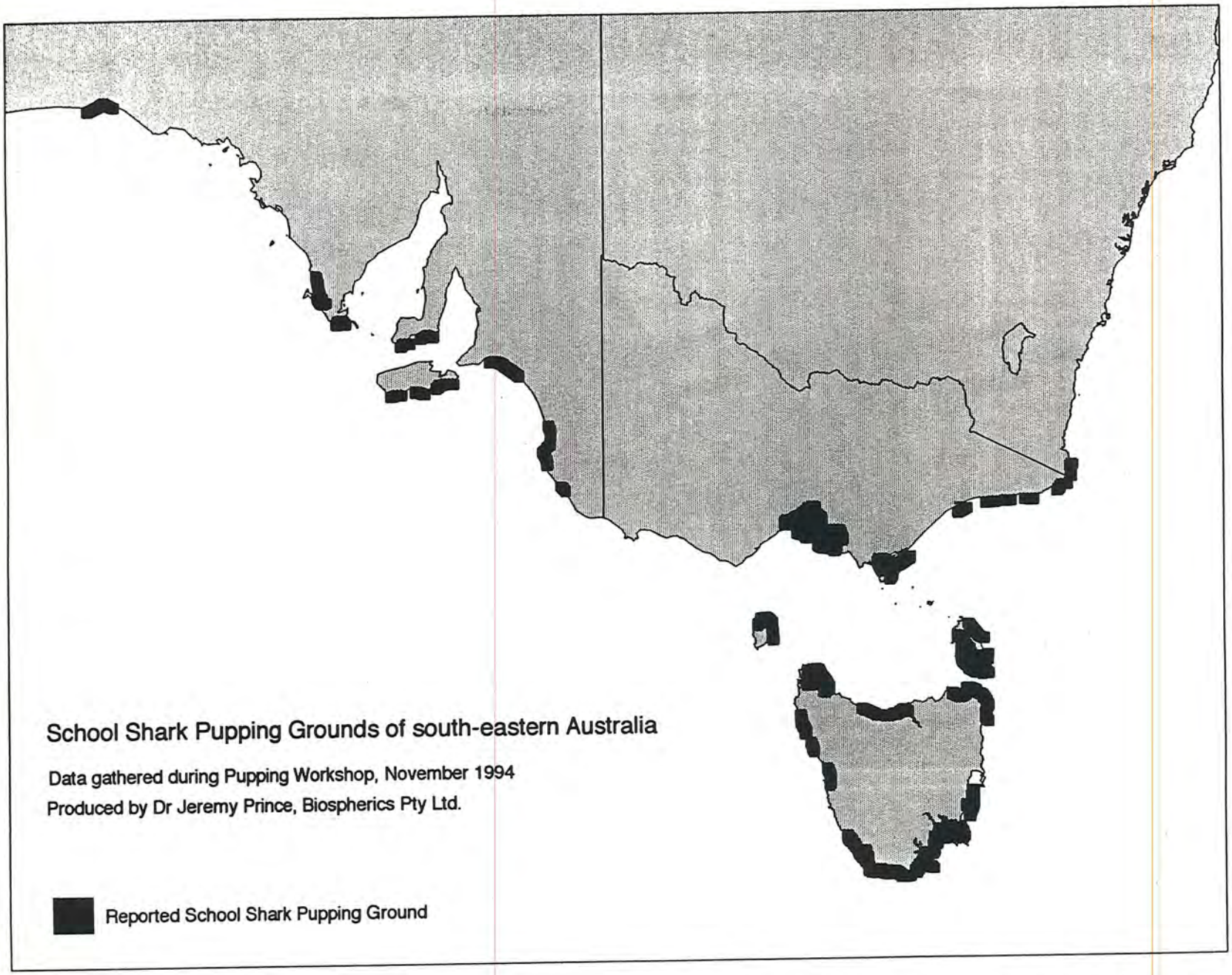

Figure 5.1 Map of areas reported by fishers as being potential pupping grounds for school sharks in south eastern Australia.

Victoria
- Port Phillip Bay
- Western Port Bay
- Corner Inlet
- Ninety Mile Beach
- Gippsland Lakes (near Metang in a drought year when salinity was high)

Tasmania
- Coastal waters / oceanic north-west. coast Tasmania
- Port Sorell
- The mouth of the Tamar River
- Ringarooma Bay
- Maria Island

He noted that he personally has not caught any pups in his sampling along the Ninety Mile Beach but he has talked with fisherman who have. He also noted that despite having sampled around King Island he failed to capture pups there and that CSIRO has sampled along the west coast of Tasmania in summer and failed to detect pups.

It was noted that the prevailing scientific view is that pregnant females captured or observed inshore during summer in South Australian waters are travelling towards Victorian and Tasmanian pupping areas to give birth.

6.0 General Workshop Discussions

This section documents and supplements a number of recurrent themes that arose during general workshop discussions. The following section has been devoted to debate about whether or not school sharks pup in South Australia.

6.1 Gummy Sharks

By all accounts gummy sharks pup over a wider area and a broader season than school sharks.

Large pupping females are commonly caught along sheltered marine coastlines, but they can also be taken on deeper fishing grounds. Newly born gummy shark pups are also found throughout the commercial fishing grounds as well as in inshore areas.

All agree that pupping tends to be concentrated over the warmer months but that gummy sharks can be found carrying near term pups almost all year round. Based on their research in Victoria and Tasmania the biologists present at the workshop believed that gummy shark pupping only takes place between the months October and January. In contrast the fishers noted that the timing of gummy shark pupping varies between areas. In Victoria pupping is primarily thought to occur between September and March. In South Australia fishers claimed pupping occurs between September and May, with two peaks; November and May.

Fishers stressed the importance of temperature in determining both the timing and location of gummy shark pupping. In colder areas pupping is observed to be more restricted in the time of the year that it occurs. Sheltered inshore areas are also warmer and this is thought to be the reason why pupping is concentrated in those areas.

Orthodox theory postulates that the evolution of pupping grounds distinct from adult feeding grounds was driven by the biological imperative of minimising the potential for adults to cannibalise pups and juveniles. This theory also postulates that the most carnivorous sharks will have the most distinct pupping grounds. Gummy sharks are less active predators than school sharks, eating benthic invertebrates in adult life. Adult school sharks prey on fast moving pelagic prey such as jack mackerel and squid. Consequently school shark adults would be expected to most prone to eating their own young if given the opportunity. Thus the observation that school shark pupping grounds are more distinct from adult feeding grounds than is the case for gummy shark is satisfyingly consistent with orthodox theory.

6.2 School Sharks

6.2.1 Location of Pupping Grounds

It is widely agreed that school sharks pup over early summer in identifiable shallow low energy marine environments. These pupping grounds are used relatively predictably on an annual basis and have been for many years, although in some areas the level of use has apparently declined.

There is disagreement between scientists and industry on the extent of school shark pupping grounds across south-eastern Australia. The scientists argue that school shark pupping grounds are restricted to central and eastern Victorian, and northern and eastern Tasmania. In contrast many in industry believe that pupping also occurs along low

energy coastlines of southern and western Tasmania, the Furneaux Group and King Island, and South Australia and NSW.

No structured scientific surveying has been conducted to rigorously determine presence or absence of pupping because few resources have been allocated to this priority. However the biologists present at the meeting could not agree with the proposition that school shark pupping was occurring in all these outlying areas, because they have no evidence of it.

Industry argues that school shark can, and do, use a wide range of semi-sheltered shorelines throughout most of the school sharks range. These potentially include almost any relatively sheltered area, with some estuarine influence or ground water influence.

School shark fishermen have informed opinions about the pupping grounds of school shark because the targeting fishing of pupping females was for some years a lucrative fishing practice in each region of the fishery. This practice is now much less common in the industry probably because pupping aggregations are now much smaller in size. Much of the knowledge is now held by retired fishermen living in the original school shark ports. Today's gummy shark fishermen often know relatively little first hand but can often identify retired school shark fishermen with this knowledge.

6.2.2 Vulnerability

Female school sharks move into and out of the pupping grounds within a very short period of time (days). But like sea turtles homing to natal beaches the adult female school sharks are extraordinarily vulnerable to capture and interference during that short period of time. Many in industry believe that water temperature and moon cycle determines the exact timing each year of the movement of near term pregnant school sharks out of deep water into the shallows. But for a few weeks to days prior to giving birth in spring and early summer each year the females accumulate adjacent to the pupping grounds, characteristically swimming slowly backwards and forwards along beaches, reefs sandbanks and channels of the ground.

Fishermen are by nature observant, and school shark fishermen in each area eventually learnt the locations of these pupping grounds and the time of year when they are used. Because of the predicability of their location and timing, and the shallowness of the water these aggregations of large slow moving sharks in shallow water were easily exploited with gill nets. Commercial shark gill-nets are usually about 2 m high and this cuts off a large part of the water column in only 2-5 m of water. The rest of the school sharks life is spent moving widely over broad areas of the shelf edge, feeding pelagically as well as benthically in 100-200 m of waters where the same gill-nets pose a far less significant threat.

6.2.3 Migration Back to Pupping Grounds

The prevailing scientific view is that during gestation pregnant female school sharks migrate to the warmer waters at the northern ends of their range of the Great Australian Bight and the NSW coast. Females that will pup in any year migrate to the south or south-east during the spring to the pupping grounds in Bass Strait and eastern Tasmania.

Since Olsen's study emphasis has been increasingly placed on the movement of school sharks between South Australia and Bass Strait. However Olsen (1954) also

emphasised movements between Bass Strait and southern NSW waters as he recovered tags from as far north as Ulladulla.

Fishers provide anecdotal accounts of tracking 'runs' of school sharks along the continental shelf. However in relation to migration to pupping grounds industry members emphasise the movement of sharks inshore from the deeper shelf waters rather than north-south movements. Fishers talk about school sharks approaching inshore pupping grounds through canyons that cut into the edge of the shelf, and observe that the exact timing of inshore movement is determined by moon cycle and temperature. Fishers believe that because water temperatures are higher in the north school shark enter more northerly pupping grounds earlier than southerly grounds. They also note variability between years in timing and location of pupping which they associate with inter-annual variability in water temperatures.

Olsen (1984) also found temperature to be critically important in determining the timing of pupping with pregnant females only entered pupping grounds to give birth when the bottom water temperatures inside nursery areas exceeded 14°C. He observed that pupping began 1 month earlier in Port Sorell than at Pittwater.

Fishers also discuss the existence of resident and migratory school sharks noting the way that fishing can deplete small areas of the fishery for a time independently of other areas close by and from this infer some degree of residency. Olsen also stresses that not all school sharks participate in migratory movements and that significant resident populations may exist in any given area. From the mixed colouration of individuals captured from a single school and the differing fate of sharks tagged from the same school he infers that schools of sharks may travel further and persist for longer than the participation of individual sharks within the school. Viewed in this way moving schools of sharks are not so much aggregations of sharks travelling together as lose mauls of resident sharks attracted for a time to a phenomena travelling through their territory.

6.2.4 Dispersed vs Aggregated Pupping Grounds

Many shark fishermen argue that small breeding populations dispersed over wide areas contribute significant levels of pups to the south-eastern school shark stocks.

For example it is known that along the Ninety Mile Beach fishers there are a string of small pupping grounds, each around the mouth of a small river, or inside a sheltering reef. Throughout the fisheries range, local fishers in each area tell of similar strings of small pupping grounds. The argument is about the relative size and number of aggregations, and their distribution through the fishery. Many in industry argue that in total these small dispersed pupping grounds amount to a significant level of pup production. This is a view point supported by Olsen (1996 personal communication).

From industry's perspective the scientific community, since Olsen's study, has focused too heavily on a few prominent pupping grounds; Port Phillip Bay and Western Port Bay in Victoria, and Frederick Henry Bay and Pittwater in south eastern Tasmania. And that until recently the scientific community has failed to appreciate the broader distribution and importance of smaller pupping grounds outside these major grounds.

Industry agrees that Port Phillip Bay, Western Port Bay and south eastern Tasmania were historically areas used by large populations of pupping school sharks. Industry also generally concurs with Olsen's description of the decline in these grounds during the 1940s and 1950s. However since that decline the school shark fishery west of

Tasmania and Port Lincoln, has developed and continues into the 1990s. Industry's experience is that in the western half of the fishery the stocks were not impacted by the decline observed in the 1940s and 1950s. Their belief is that since the decline of the eastern grounds during the 1940s and 1950s the fishery in the west has been sustained by many smaller pupping grounds scattered across the west of the fishery.

In their defence the scientific community points out the difficulty and expense of research to prove or disprove the existence of these small pupping grounds and the shortage of research funding. However much of the frustration expressed by fishers in this debate is not aimed at the lack of resources available for research but the scientifically sophisticated perspective which dismisses accumulated years of fisher experience for the want of a single observation by a scientist.

6.2.5 The Importance of Port Phillip Bay, Westernport Bay, Pittwater & Frederick Henry Bay?

From the shark industry's perspective it is tempting to suggest that Olsen's early focus on the Port Phillip Bay in Victoria and Frederick Henry Bay - Pittwater in south eastern Tasmania has lead to the scientific focus on these areas that continues to the present time. Olsen himself was surprised at how narrowly school shark pupping grounds were being defined when he re-entered the shark debate in the early 1990s (Olsen 1991 personal communication). He emphasised that his original work was concentrated in those areas for the simple logistical reason that in the 1940s and 1950s it was easy for him to catch and tag school shark pups and juveniles in those areas.

At the beginning of Olsen's study (1946) the school shark fishery was a longline fishery centred in Bass Strait. The fishery was just developing in South Australia. Olsen (1959) documented a 90% decline in the annual catch of adult sharks from eastern Bass Strait and eastern Tasmania, this coincided with similar declines in his capture rates of pups and juveniles, and a similar decline in a commercial fishery for juveniles in Port Phillip Bay. Olsen's professional and published assessment (1959) was that the inshore school shark stocks in Port Phillip Bay collapsed during the 1940s and early 1950s. School shark catches have never recovered in these areas and CSIRO and VFRI's recent studies suggest that there has been no recovery in pup abundances in Pittwater.

So what was the importance of Pittwater, Port Phillip Bay and the other large pupping grounds identified by Olsen, and what is their continuing importance to the modern fishery?

Prior to the collapse of the 1940s and 1950s around 120,000 lb of school shark pups and juveniles were taken annually from Port Phillip Bay. Olsen estimated that this catch represented the annual capture of 50,000 - 60,000 juveniles. Each pregnant female school shark produces an average of 29.7 pups so this catch represented the production of some 1,700 - 2,000 female school sharks annually. Assuming the fishery for pups was catching about 25 - 50% of the pups in the Bay this could mean that something in the order of magnitude of 4,000 - 8,000 females were pupping in the Bay each year at that time.

Crudely making a judgement on the productivity of the coastal systems of south eastern Australia and their areal extent; the Port Phillip Bay breeding population of school sharks numbering in thousands of individuals, must originally have been one of the largest in Australia. Westernport Bay would probably have held a similar but smaller population and the original breeding population in south-eastern Tasmania (Great Oyster

Bay - Frederick Henry Bay - D'Entrecasteaux Channel - Recherche Bay) was probably somewhat larger, perhaps 2-3 times.

Adding together these core areas with these sort of populations figures we could estimate that prior to the collapse documented by Olsen, these areas may have annually been used by around 20,000 - 40,000 female sharks. Factoring in a subsequent 90% decline in abundances with no recovery would lead us to estimate the breeding population annually using these areas now may only be a few thousand sharks in total.

However the school shark fishery has continued to land school sharks since the collapse documented by Olsen. Walker (1995) estimates that 108,000 female school sharks are landed annually, of which he estimates 10% are actively breeding. If we multiply this up to include males we can assume that the fishery continues to catch more than 200,000 individuals each year. Taking into account the age of the catch (assume 8-10 y.o.) and reasonable mortality rates, this annual catch must be generated by the annual production of some 1-2 million pups annually by some 33,500 - 67,000 pupping females.

These ball park figure suggests that even prior to the collapse of the eastern areas documented by Olsen, the core pupping grounds would barely have been capable of supporting the modern fishery by themselves. Now, given that their 90% collapse has apparently never been reversed, it seems even less likely that current pup production can be coming from those grounds.

In the workshop John Stevens of CSIRO backed this judgement saying that he found it hard to believe that the school shark stocks are being sustained from the Bays he was sampling. He conceded that "perhaps the recruits are coming from somewhere else". Terry Walker of VFRI also supports this view (personal communication). So the question remains: where does this continuing catch come from?

'Where are the pupping grounds that produce the 1-2 million pups that sustain today's fishery?'

6.2.6 Do breeders home or mix between pupping grounds?

In fact within the context of assessing the status of the Australian school shark resource and developing sustainable harvest policies the most crucial issue is not where school shark pups are coming from, but whether or not pupping school sharks home to their own natal pupping grounds or use other pupping grounds opportunistically?

Whether or not school sharks home to their exact natal grounds or simply find the closest suitable habitat for pupping is crucially important to determining how the stocks should be managed. Stocks of a certain species may migrate long distances, mingle on adult feeding grounds and exchange genetic material in large mating aggregations, but if they faithfully home to natal pupping grounds the stock in each breeding ground will require individual management consideration. If school sharks home to natal pupping grounds individual pupping grounds can be pushed to extinction by targeted fishing and/or environmental degradation, while nearby pupping grounds remain unaffected. In this case the potential will exist for the impact of fishing on the stocks to be sequential, rather than uniform across the stocks. This sequential depletion of small areas of stock within the fishery could occur despite the proven ability of the sharks to move long distances.

The fishermen at the meeting stated their belief that female school sharks do not necessarily home to the same pupping areas each years, rather they use pupping areas opportunistically moving into areas adjacent to the feeding grounds they have been using prior to pupping.

However many migratory marine species do return faithfully to their exact natal grounds from distant adult feeding grounds. Moreover it has been found that many of these species are homing by using distinctive traces within the freshwater of their natal grounds. It is therefore of potential importance that many people who are knowledgeable about school shark pupping areas note the correlation between pupping grounds and freshwater influences.

There is even less evidence to scientifically support homing to natal pupping grounds in school shark than there is to argue that pupping occurs in South Australia. But because the implication of homing behaviour is so serious for the management of the species the precautionary principle of management suggests that this possibility should receive some serious consideration.

7.0 Do School Sharks Pup in South Australian Waters?

Industry and scientists are in broad agreement about the pupping habits of the gummy shark and most of those involved in the assessment of the southern shark fishery believe that the gummy shark fishery is currently sustainable. The discussions of the workshop identified the distribution of school shark pupping grounds as the primary point of contention between large sections of industry and the scientific community. Consequently this section focuses on the issue of whether or not school sharks pup in South Australian waters.

The contention of many within industry is that outside the main pupping grounds identified by the scientific process many smaller pockets of pupping exist distributed widely through the school sharks range. In South Australia fishers commonly suggest that pupping does or has occurred around Beachport, the Coorong area, the southern shoreline of Kangaroo Island, and the south-eastern tip of Eyre Peninsula. There are even some suggestion of the southern shoreline of York Peninsula and the Head of the Bight (Figure 5.1).

Within the workshop these claims attracted much debate. This debate revolved around what evidence exists to substantiate these wide held opinions and the counter claim that pupping is restricted to Victoria, Bass Strait and south-eastern Tasmania.

7.1 The Evidence

7.1.1 Scientific Surveys.

There has never been any scientifically rigorous, statistically structured survey of all potential school shark pupping areas in Australia. Figure 2.1 shows the extent to which areas have been sampled. To be scientifically rigorous sampling should be statistically structured so that all potential areas are a sampled with comparable and sufficient intensity to ensure the chance of finding a pup is at least equal to the chance of not finding pups.

During the 1940s and 1950s Olsen systematically visited the full range of the fishery which at that stage stretched from eastern and northern Tasmania to the western extremity of the Eyre Peninsula. He did not have the resources to search all areas for pups so instead he interviewed fishermen about pupping. Olsen's purpose was to select sites for capturing pups for tagging, it was not his purpose to exhaustively determine the full extent of school shark pupping grounds.

The standard of proof that he required was for fishermen to give him accounts of having caught free swimming school shark pups with the vestigial yolk sac still visible externally on its lower ventral surface. These he reasoned would have been caught within 1-2 weeks of being pupped. He discounted second hand accounts or stories of spontaneous abortion; when a near term female aborts apparently fully viable pups while being caught. Where ever possible he also sampled to test the anecdotal accounts he had been given.

In this way he proved a number of pupping areas in Tasmania and Victoria, and from these proven areas he selected a few sites to work with intensively, these included Pittwater and Port Phillip Bay. These were chosen because within his resources he

wanted to be able to capture and tag as many pups as possible (Olsen 1991 personal communication). Olsen expected to find that the Coorong was a pupping area, but the evidence he accumulated was not conclusive by his high standard of proof.

However school shark fishing with longlines had only recently developed around Port Lincoln and the Coorong when he interviewed South Australian fishermen. The fishers' knowledge of, and experience with, the stocks in South Australia was probably not as detailed as it then was around eastern Bass Strait and eastern Tasmania. Today the anecdotes of industry suggest that most of the pupping grounds in South Australia were only discovered and fished when gillnets were introduced to the fishery in the late 1960s and early 1970s. A considerable time after Olsen's research.

Olsen's personal view is that pupping can be dispersed over wide areas and he assumed that he did know the full extent of the pupping grounds (Olsen 1991 &1996 personal communication).

No new pupping grounds have been identified by the scientific community since Olsen's work. But due to lack of research resources no statistically powerful scientific censuses of the full extent of potential pupping areas has ever been conducted. Recent work has done little more than confirm that school sharks are still pupping in some of the areas identified by Olsen. It needs to be noted again, that in this context the absence of evidence is not the same as evidence of an absence. The limited surveys conducted to date provide no rigorous evidence, one way or the other, about whether or not pupping occurs in South Australia, or for that matter in western and southern Tasmania, King Island, the Furneaux Group or southern NSW because no rigorous sampling has occurred in those locations.

Moreover we must remember that in many areas school sharks stocks are thought to be relatively low compared to historic levels. It would be extremely easy not to find pups where they might in fact exist, or have existed, in low numbers. With depleted levels of pupping it could become (for logistical reasons) statistically impossible to prove that an area has traditionally been a pupping ground.

7.1.2 Tagging

The first tagging study of school shark in south eastern Australia was initiated by Olsen in the 1940s and his tags are still being recovered. Terry Walker of VFRI also tagged some school shark during the 1973-1976 tagging project directed at gummy shark . More recently a second, joint program by Terry Walker and John Stevens of CSIRO has been initiated targeting both species.

Long distance movements of tagged individuals along the continental shelf are common; between NSW and Tasmania and, between Tasmania and South Australia. Tagged individuals can move large distances (1000 km) within weeks (Olsen 1954). Recently tagged school sharks have been reported moving between New Zealand and south eastern Australia (Coutin 1991 personal communication).

However many tagged sharks are also recaptured close to their original release sites, even after many years. Of course with these animals it is impossible to know how far they may have wandered between release and recapture. Likewise we have no way of knowing if the sharks recaptured after long movements would have returned to their original capture sites. Interpretation of tagging results are further complicated by the concentration of historic tagging and fishing effort in Bass Strait and eastern Tasmania and the fact that animals may be moving large distances to feed rather than to breed.

Schools sharks take their name from the schooling behaviour they display as they track mobile aggregations of jack mackerel, squid, pilchards and other pelagic prey. The abundance and distribution of these prey species in south-eastern Australian waters is determined by the Sub-tropical Convergence Zones. Off the eastern coast of Australia this zone is formed by the mixing of the Eastern Australian Current with colder, nutrient rich southern water. Off the southern coast by the mixing of the Leeuwin Current with the same colder, nutrient rich southern water. Where the warm northern waters mix with the nutrient rich southern water phytoplankton blooms enhancing a food chain which culminates in jack mackerel, squid, pilchards and school sharks.

The enriched waters of the Sub-tropical Convergence Zones oscillate annually along the coastline of south-eastern Australia in response to the ebbing and flowing of its component water masses. In summer the convergence zone reaches its southernmost extent, enriching the shelf of eastern and north-western Tasmania, in winter it reaches its most northerly extent, off the shelf of the Great Australian Bight and southern NSW.

Fishers working on the edge of the continental shelf report that many 'runs' of commercial species, including school shark, coincide with the seasonal movement of the Sub-tropical Convergence Zones - north in winter, south in summer.

Regardless of natal pupping sites school sharks of all ages can be expected to track convergence zones as they cycle north during winter, and south during spring, because they are the major source of food in their environment. Tagging results to date prove little more than the fact that school sharks are moving long distances coincidentally with the movement of the Sub-tropical Convergence Zone.

At present the tagging data provide no information about the extent of pupping grounds . The proposed employment of expensive 'smart tags' which when recaptured can be interrogated to provide a path travelled, may in time provide more definitive information about these issues. But unless school sharks from every pupping ground are tagged and recovered archival tags will not help determine the full extent of school shark pupping grounds in Australia.

7.1.3 Trends in the Fishery

The school shark fishery of south eastern Australia has had four periods of expansion and contraction.

1930s-1940s. Bass Strait and Eastern Tasmania
The original school shark fishery developed in Bass Strait and off eastern Tasmania in the 1930s - 1940s. Olsen (1959) described this phase of the fishery and documented a 90% decline in catches through this area of the fishery during the 1940s and 1950s.

1950s-1960s. South Australia, Beachport to Port Lincoln
Olsen (1959) documented the movement of fishers westwards during the 1950s and 1960s, away from the eastern part of the fishery where shark stocks were declining. During this period fishing intensified between north-west Tasmania and Port Lincoln. The fishery moved because those areas were remote from the market in Melbourne and large adults with valuable livers could still be caught in this region. As the fishery expanded westwards Olsen noted that the pattern of fishery dynamics he had observed in the east was repeating itself in western areas. Fishing effort and catches in each area initially increased rapidly but then declined forcing the fishers to move further west and further offshore.

1970s. The Introduction of Gillnets
The introduction of gillnets and the abandonment of hooks in the late 1960s and early 1970s for a few years made school shark fishing profitable again in all areas being fished. Landings quickly declined. This is the only expansion of the school shark fishery which occurred without an expansion of the geographical extent of the fishery. This short lived expansion was powered by the increased fishing power gained by using gillnets.

1980s. Western Tasmania and Great Australian Bight
The fourth and most recent expansion and decline of school shark catches occurred during the 1980s in western Tasmania and to the west of Port Lincoln in the Great Australian Bight, areas where previous fishing pressure had been relatively light. Catch rates and catches in these areas are now declining.

Because school sharks reproduce and grow slowly we know their stocks are incapable of recovering rapidly from being fished down. So the successive expansions of the school shark fishery have not been fuelled by recoveries in overall stock levels. All the expansion of catches (with the exception of that made possible by the introduction of gillnets) have occurred because the industry has expanded into new areas of stock that were previously relatively unfished.

However this pattern of repeated expansion and decline, would not have been possible if all pregnant females in south eastern Australia return to a few pupping grounds around Bass Strait and eastern Tasmania.

If this were the case, the entire stock of school sharks would have been heavily impacted when the fishery in Bass Strait and eastern Tasmania declined in the 1940s and 1950s. The fishery could not have continued to catch school sharks in the quantities it has if the entire female population and production of pups had been reduced by 90% in the 1940s and 1950s. The pattern of fishery dynamics, with sequential development, contraction and redevelopment, is the strongest existing evidence that significant sources of pups must exist outside the main pupping grounds positively identified by Olsen.

7.1.4 Reproductive Status

Terry Walker of VFRI claims that scientific observations of breeding status provides evidence for a migration of ovulating school sharks to the Great Australian Bight and of pregnant school sharks back to pupping grounds in Bass Strait and south-eastern Tasmania.

According to Walker, no fisherman in Bass Strait ever finds school sharks with eggs larger then 1.5 inches (approx. 35 cm) or pregnant school sharks during winter. The mean diameter of the three largest ova that he observed during his 1973-76 surveys was 30 mm in a school shark caught near southern King Island (November 1975), all other ova were less than 20 mm. Outside Bass Strait and in the Great Australian Bight in particular, unfertilised eggs are much bigger. Olsen (1954) apparently records female school shark with large ova up to 50 mm off Tasmania. While Walker, himself, observed mean ova diameters ranging 41-47 mm to the west of Port Lincoln during June 1975, 31-56 mm in the Great Australian Bight during May 1987, and 40-50 mm during November 1995. Lauren Brown of VFRI has observed 40+ mm ova off north-east Tasmania in February, 1995.

In addition Walker also notes that during his surveys he has never found a pregnant female in Bass Straight during the winter months.

Taken together he interprets these observations as implying that females developing eggs move out of Bass Strait to northern areas of their range and that mating and fertilisation occurs in South Australia, northern Victoria and NSW before the females return to Bass Strait and eastern Tasmania to pup.

It is difficult to know what importance to place on these observations. It should be noted that these observations and the inferences that Walker draws from them have never been drawn together and published so they have yet to be subject to any peer group scrutiny. Nor were these observations derived from a sampling regime that was rigorously designed to study these reproductive trends and thus the recorded observations may be heavily influenced by the timing of sampling in different areas and differing age structures due to various regimes of fishing mortality.

School shark fishers provide anecdotal accounts of mating aggregations occurring off Flinders Island, Kangaroo Island and western Tasmania. These aggregations occur during July and August each year and fishermen recognise them because the females have extremely fresh teeth marks on their backs (mating scars), and the claspers (shark sex organ) of the males are knotted and twisted. Fishers notice catches from these aggregations because while the catch is cleaned the semen of the males flows freely and it smells extremely strongly of ammonia irritating the fishers' eyes. Fishermen off Strahan in Tasmania recount regularly finding the mating aggregation in their location.

As Olsen (1954) noted these observations suggest that mating and fertilization of eggs is occurring in the south of the school shark range as well as in the north. This apparently contradicts the pattern of reproductively linked movement hypothesised by Walker above (Olsen 1996 personal communication).

Within the workshop Walker noted that it is difficult to judge whether or not mating is occurring on the evidence described by the fishers; freely running semen, fresh mating scars, or raw and enlarge claspers. This stance contrasts with Olsen's who was prepared to use these observations as evidence of mating behaviour (Olsen 1954 & 1996 personal communication).

7.1.5 Fishery Experience

There are a large number of South Australian shark fishers that believe school shark pupping grounds exist in South Australia. These opinions have been formed on the basis of their own observations and experiences, and on the shared observations, experiences and opinions of their colleagues.

These observations and experiences include;-

Catches of near term females in shallow water over summer.

South Australian shark fishers who fished during the 1970's, when gillnets were first introduced to the areas, recount being able to seasonally target inshore aggregations of school sharks displaying characteristic pupping behaviour; slow, swimming backwards and forwards along beaches, banks of reef and sand, channels. These large summer catches were not sustained for many years, nor were the catches of whiskery sharks that were also found through these inshore grounds when gillnets were first introduced.

These fishers, most of whom are now retired, believe they were targeting pupping aggregations of school shark and are somewhat bemused if told that scientists do not believe school sharks can pup in these areas. They recount stripping near term pups from the females as they cleaned the catch and, of placing strongly swimming pups in wet-wells where the pups would remain alive for up to a week.

Scientists who were at the workshop argued that the inshore aggregations of pregnant females were probably aggregations of females travelling inshore on their way to their pupping grounds in Bass Strait and eastern Tasmania. They also argued that aborted pups can swim quite strongly for some time prior to birth and that this observation does not necessarily imply pupping was about to take place. But this response irritates the fishers concerned because it denies the characteristic pre-pupping behaviour of the pregnant sharks they fished. The observed behaviour of the sharks and the predictability of the catches contradicts the idea that the sharks were simply intercepted in transit to more distant pupping grounds.

After Birth or Birth Sacks

Fishers also argue that the tangling of 'birth sacks' or 'after birth' in the meshes of their gillnets is further evidence of pupping occurring in these areas. When fishing for pregnant school sharks in supposed pupping grounds fishers sometimes make a shot which catches few if any school sharks but instead catches the membranous bags that they observe encasing school shark pups within their mother. Fishermen infer from this that they have fished the area a fraction too late and that school sharks have been in the area, given birth and dispersed prior to the nets being set, leaving just the empty egg cases or 'birth sacks' to be entangled in the nets. In these cases fishers believe they have missed the pupping event by a day or less.

It was argued by some scientists at the workshop however, that this could be attributed to pregnant females migrating to Bass Strait and eastern Tasmanian pupping grounds becoming entangled and aborting before escaping, or that the fishermen cannot be sure that the empty egg cases come from school sharks rather than gummy sharks. The fact that the fishers fish these areas to target predictable aggregations of pregnant school sharks in these areas would seem to discredit both of these arguments.

The Capture of Pups

It was argued by the biologists involved in the workshop that the absolute proof that pupping is occurring in any area is the capture of pups from that area. Pups being recognised by their small size (<45 cm) and vestigial yolk sacs. In the 1950s soon after fishing with hooks had commenced in South Australia Olsen failed to find fishers in South Australia who could describe the capture of pups, likewise during 1973-76 Walker failed to find industry members claiming to have captured pups in South Australia.

South Australian fishers at the workshop claimed that very young school shark are in fact occasionally captured in South Australia. Peter Riseley of Robe is one prominent fishermen who has observed the capture of pups in the Coorong area.

Within the workshop these observations were devalued attacked because no fisher has ever sent a school shark pup to the scientists at VFRI or CSIRO for examination. However it needs to be noted that no campaign has ever been mounted to inform industry that they should forward incidentally caught school shark pups to these scientists. It should also be noted that fishermen closely guard information about school

shark pupping grounds and their collaboration within the scientific process in this regard tends to be patchy. Moreover the closure to fishing of school pupping grounds in south-eastern Tasmania has made some in the fishing industry reluctant to draw attention to what they believe is happening in other areas.

It was also argued within the workshop that not enough pups are reported from South Australia to substantiate the claims that there are pupping grounds in these areas. The accidental capture of pups is apparently more common in eastern Bass Strait and Tasmania. The South Australian shark fishers countered however with the argument that in their area the fishery has historically used 7" and 8" meshes in their nets and have only more recently changed to using smaller 6 1/2" mesh, and that these larger mesh nets are less effective at entangling the small pups than the 6" mesh commonly used through Bass Strait by fishers. In turn this argument was countered with the observation that the mullet fishery of the Coorong involves a large amount of estuarine fishing with 2" mesh nets but there are no substantiated reports from that fishery of school shark pups being captured. However fishers from the Robe - Coorong area rejected this comment because the Coorong is very gently sloping and a large distance separates areas inside the estuary where people fish for mullet and the inshore areas outside the estuary where fishers would target pupping school sharks.

Even the inference that the location of pupping can be deduced by the capture of pups was then called into question by the claim that pups observed in the Coorong could have been born in Bass Strait pupping grounds and moved rapidly to South Australia as tagged 1-2 year old juvenile school sharks have been observed to make these types of rapid movement. It was also claimed that any pups caught in these area may have been aborted by female school sharks in transit to pupping grounds in Bass Strait. It being presumed that a pregnant female school shark had struggled with the net, aborted its young, and then escaped.

By this point of the workshop the circularity of some these arguments was beginning to frustrate the fishers who felt that their experience and credibility was being devalued by the process.

7.2 Conflicting views within industry: individual experience, perspective & vested interests?

During workshop discussions it was obvious that not all the industry members present agreed about whether or not school sharks pup in South Australia. Most of those disagreeing with the proposition were Victorian fishermen who believe that there are dispersed pupping grounds but that these are only spread through Victorian and Tasmanian waters.

One of the South Australian fishermen noted this fact and made the public point that; "Each fisherman can only talk about their own area" because their knowledge is not first hand for areas in which they are inexperienced.

However even within the South Australian fishing industry divided opinions can readily be found. Fishers form their opinions on the basis of their own observations and experiences as well as the shared observations, experiences and opinions of their colleagues. Where their own first hand experience is limited they will rely heavily on the views around them. But publicly stated opinions can also be heavily influenced by vested interest.

In considering how opinion is formed amongst fishers it should be remembered that there are many fishers who do not wish their knowledge about pupping grounds to be made public. Knowledge about the location and timing of school shark pupping is extremely valuable information to a school shark fisherman. Knowledge about the times and spots to fish are the trade secrets of the fishing industry. To a fisher who is the only one, or one of a few, these intellectual assets can be worth thousands of dollars of assured income . This type of valuable secret information is not shared freely and within fishing societies it is socially acceptable to lie publicly about these issues.

In the modern management context, fishers who still rely on the targeting of pregnant school sharks are feeling threatened by the rapidly encroaching management regime. State fishing entitlement holders are scared of losing access to inshore waters and are reluctant to speak openly on these topics. In interviewing people I (Jeremy Prince) have had it stressed to me, that if I want accurate information I must speak to people now retired from the shark fishery, because they no longer have a vested interest to protect. In one situation, an ex-shark fisher who is now a successful fishermen in another sector, gave me detailed descriptions of his experiences while shark fishing in South Australia with his father. He assured me that his father has detailed knowledge of school shark pupping grounds in South Australia and arranged a meeting with his father so that I could benefit from his father's extensive experience. However the father is still actively fishing inshore areas under a state entitlement, and when I met him he actively denied all knowledge of the issue. I also know that he has told Terry Walker of VFRI that no school shark pupping occurs in South Australia.

Areas of reserved information are common throughout the fishing industry. Without a depth of relationship on which to judge the depth of personal experience and level of vested interest it is impossible to gauge the quality of information being offered by different industry representatives (Johannes & Lewis 1993).

The closest one can come to positive proof in these matters is to find a first hand source who you judge to provide quality information, and then under independent circumstances have the same information corroborated by a second source of high quality information. One unsolicited case of this occurred between sessions at the workshop. John Stevens, a CSIRO colleague and myself were standing in front of a map of Ninety Mile Beach, Victoria discussing the reported location of pupping areas. Where many fishermen had indicated the Ninety Mile Beach area as being important generally for school shark pupping, a retired school shark fisherman from Lakes Entrance had marked on the map a number specific spots along Ninety Mile Beach, each in front of small river or inside a small reef. Wyn Hobson a fishermen of many years in that area, strode up to join the discussion no doubt intent on putting the scientists straight. Seeing the map, but without noticing the small yellow high lights, he pointing at the map and said he would show us the exact pupping spots. Halfway through his sentence he noted that every spot he pointed to already had a little yellow mark in place. He was at first puzzled at how we scientists could have known those locations and began demanding an explanation. But then caught himself and changed his question to ask which old time school shark fishermen had told us about these spots?

In South Australia I personally have only been able to sustain this level of proof for the Coorong and the southern coast of Kangaroo Island. Given the time lapse since pupping females were actively targeted in these areas, the unfunded nature of this type of research and, the difficulty in locating retired fishermen scattered through outlying ports who can provide high quality information, these independent corroborations are not easily attained. The other areas reported in South Australia and indicated in Figure

5.1 are not corroborated at this level, they have been reported by a single high quality source and/or by 3-4 lower quality (second or third hand) sources.

7.3 Biological Logic

As a biologist I find myself judging the issue of whether or not school sharks are likely to be pupping in South Australia by applying what I think of as biological logic.

One principle of biological logic uses comparisons between similar species, or populations of the same species in closely related circumstances, to predict what the species or population under consideration may do.

In the context of this argument;

School sharks occur in New Zealand and are genetically extremely similar to the Australian stocks (Ward 1996 personal communication). Tagged school sharks have been recorded moving between Australia and New Zealand. In New Zealand the National Institute of Water and Atmospheric research (formerly the Research Division of the Ministry of Agriculture and Fisheries) has systematically sampled most inshore areas in New Zealand with small mesh gillnets, systematics trawl surveys have also be conducted over a number of years to monitor gummy shark stocks. School shark pups (<35 cm) have been found over summer along most of the low energy beaches sampled in New Zealand (Francis & Paul 1996 personal communication). From this research pupping is inferred to occur around the North Island at Great Exhibition Bay in the extreme north-east, Hauraki Gulf, Kaipura Harbour and Manukua Harbour near Auckland, and inside Kapita Island near Otaki in the south-west. Around the South Island pups have been captured in Golden Bay, Tasman Bay and the Marlborough Sounds in the north and, in Pegasus Bay and Port Lyttelton near Christchurch. Insufficient inshore sampling has occurred to the south of these areas to draw any conclusions but fishers in those areas report targeting adults inshore over summer and believe pupping is occurring in the south.

The conclusion of Francis and Paul, New Zealand's shark experts is that school sharks pup throughout their range in New Zealand, taking advantage of all available low energy, shallow marine environments.

A second important principle of biological logic is the maxim that a species will generally follow the path of least resistance. If conditions are sufficient to sustain the entire life cycle of a species in any area, over evolutionary time the species will adapt to fully utilise the habitat by completing its life cycle within that area. For example in the Great Lakes of North America landlocked runs of salmon have evolved which complete their life cycle within lakes and rivers without the need to return to the sea.

Thus school sharks in Australia should not be expected to swim further than they need to feed and breed to satisfaction. Given the fact that school shark of all ages can be found in all areas of their Australian range, conditions evidently exist in most areas of the fishery suitable to sustain the life-cycle of school sharks. The question I ask myself is this; what adaptive advantage can South Australian school sharks derive from an obligated migration to Tasmania for pupping? If there is no specific benefit why would this behaviour have evolved? If it is occurring some specific adaptive advantage must exist for school sharks to swim past apparently suitable pupping grounds in South Australia to reach Tasmania.

The only obvious potential adaptive advantage is that the sub-tropical convergence is at its southern extreme during summer (Ridgway & Godfrey in press) and because of this feeding would be good for school sharks around Tasmania in summer. But upwellings are also common along the South Australian coastline in summer and these enrich the summer environment of school sharks off South Australia as well (see Lewis 1981 & Griffin *et al.* in press). Moreover it should also be remembered that school sharks are highly mobile and could as easily migrate from feeding grounds around southern Tasmania to South Australia for pupping, as they could migrate from South Australia to Tasmania. Why evolve exclusive homing to Bass Strait and eastern Tasmania if all the resources required exist closer to home?

Even if the pupping grounds of Bass Strait are the prime pupping environments in southern Australia, as they may well have been, we should expect that prior to human exploitation the shark stock would have expanded over evolutionary time to fill even the most marginal environments as well as the best areas. Prior to the impact of the fishery the school shark stocks should be expected to have filled to capacity all potentially useful habitat.

Without identifying any key adaptive advantage that school sharks gain by limiting their pupping grounds to Bass Strait and eastern Tasmania, and without rigorous proof to the contrary; the logical a priori position for a biologist to assume is that pupping grounds will occur throughout the range of school sharks, where ever suitable habitat allows.

The opinions of credible fishermen consistently support this view. The areas suggested by fishermen for schools shark pupping are remarkably consistent and fit a sensible broad ecological pattern.

Each reported pupping ground has the following characteristics:

- Freshwater influences, run-off or groundwater.
- Geomorphological features which provide shelter from prevailing summer winds.
- Co-incidental 'runs' of juvenile school sharks are reported to the seaward of the area.
- Adjacent to each reported pupping ground there is enhanced oceanic productivity, associated with localised seasonal upwellings which could be expected to enhance the food chain for school sharks both inshore and offshore.
- Despite being close to upwelling features and thus cold oceanic temperatures the reported pupping grounds characteristically trap pockets of warm water, enhancing the environment of the pups.

All these features are significant to a biologist attempting to understand school shark biology as each is likely to be of adaptive advantage to the school shark stocks. But the importance of these features is often poorly appreciated by the individuals who have provided the information about individual locations. Because of the localised focus of the individuals providing these reports I consider it most unlikely that such a sensible biological 'big picture' would be created erroneously from so many individual reports of geographically far-flung locations.

In the face of so much other arguable evidence I find this biologically logical 'big picture' compelling evidence in itself that school shark probably do pup throughout most of their Australian range.

8.0 Implications for Management

Reflecting the current focus of discussions about management of the Southern Shark Fishery this section focuses on the management implications for the school shark stocks of the material presented in this report.

8.1 Principles for Management of the School Shark Fishery

School sharks are relatively long lived, individuals tagged as young adults by Olsen have been recaptured after more than 40 years at liberty (Olsen 1991). There is also known to be a close relationship between the number of adults in the stock (breeding biomass) and the number of pups produced each year (Olsen 1954).

Thus managing the school shark fishery for optimal levels of sustainable harvest requires balancing harvests with the necessity of maintaining sufficient breeding stock to sustain the on-going supply of young animals (recruitment) to the stock and the fishery.

The following simplistic analysis uses estimates of school shark growth and mortality rates to compare the likely impact of differing harvest strategies on the potential of the adult school shark stocks to produce pups. This type of static analysis is commonly called a 'yield-per-recruit' model although the yield we are interested in here is the relative number of pups each individual will produce on average during its life. Consequently we will call this analysis a 'pup-per-recruit analysis'. This analysis is simplistic and ignores the fact that to some extent as a stock is fished down survival of young individuals should increase to some extent due to density dependence factors. But never the less it provides a simple and useful means of examining the relative extent to which alternative harvest strategies will impact the reproductive potential of each year class of sharks growing through the fishery.

The estimates of growth used in this analysis are the estimates derived by Grant *et al.* (1979) for both sexes combined. The mortality estimates used are 30% per annum for the 0^+ and 1^+ age classes, 20% per annum for 2^+-4^+ and 10% per annum for the age classes 5^+ and older. The relative number of pups produced is assumed to be proportional to the biomass of individuals older than 15 years of age.

Figure 8.1 depicts the expected age structure of an unfished school shark stock in terms of weight, or biomass. It can be seen that within the unfished stock each year class would be expected to reach its maximum biomass at around 10-15 years of age, about the time they mature and begin breeding. Figure 8.1 also depicts the way a single age class of school sharks will change biomass as they grow through the stock. Initially each year class is composed of numerous, small sharks which are growing rapidly and the process of growth is more rapid than the effect of natural mortality so the year class increases in biomass. Around 10-15 years of age growth slows down and the effect of natural mortality becomes more influential so the biomass of each year class reaches its maximum and then begins declining.

From Figure 8.1 it can be seen that fishing school sharks too young (<6-8 years of age) risks capturing the sharks before each class fulfils their full potential for growth. Capturing fish before they have finished building their full biomass is called growth overfishing.

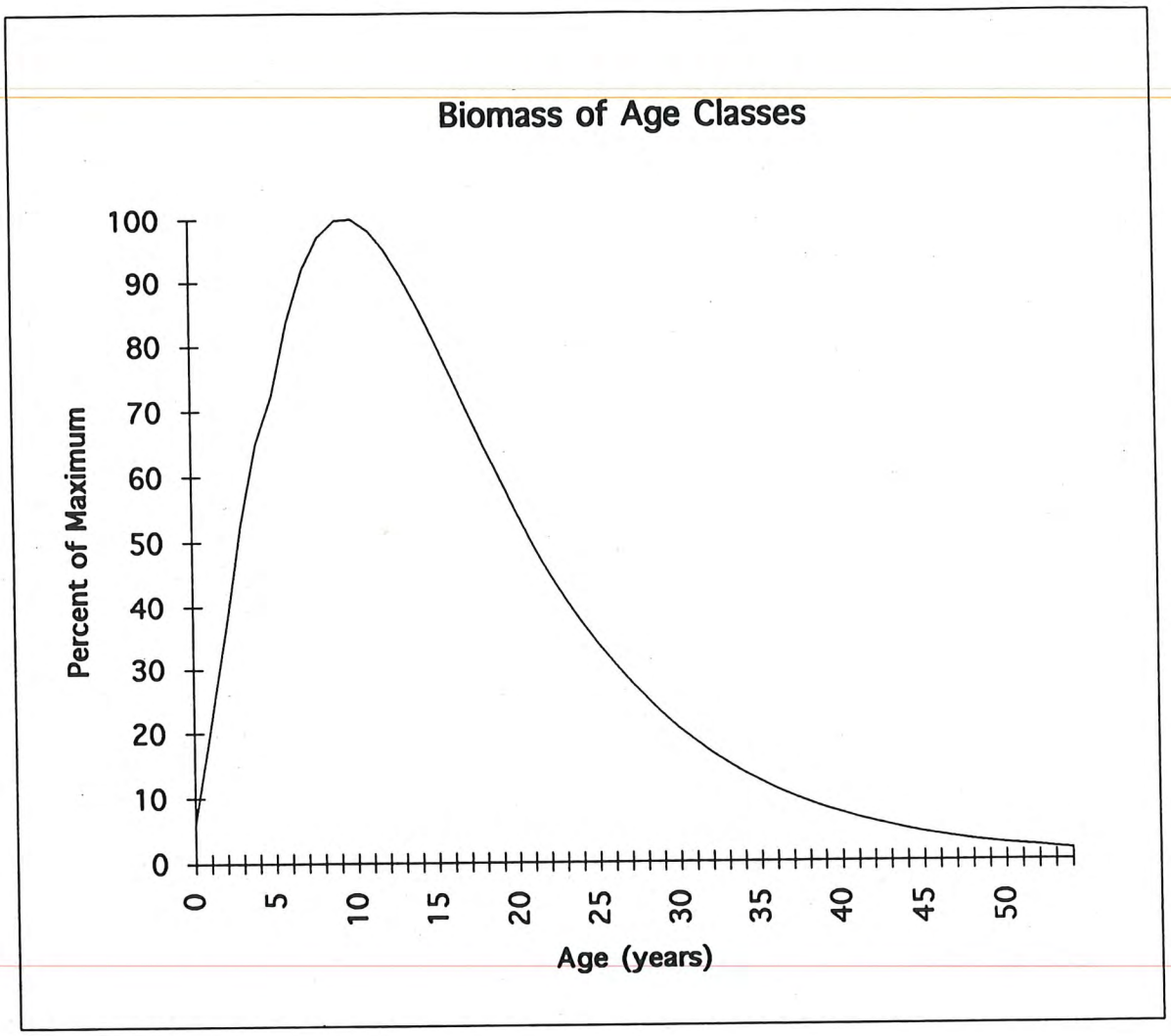

Figure 8.1 The expected age structure of an unfished school shark stock in terms of biomass (weight). Modelled using published growth and mortality rates of school shark (see text). Source Biospherics Pty Ltd.

Given that school sharks begin breeding around 16 years of age, it can also be seen from Figure 8.1 that the breeding portion of an unfished stock will be comprised of many age classes of adults. In other words on average each adult would be expected to breed many times during its life time. This feature makes it relatively easy for a fishery to overfish the breeding stock and risk depriving itself of a continuing supply of young sharks.

The solid line in Figure 8.2 shows the impact that varying levels of fishing pressure (10-40% probability of capture in each year) are predicted to have on the stock's potential to produce pups if the fishery is allowed to target all age classes older than 7 years old. In this figure the age structure of the unfished stock shown in Figure 8.1 is taken as the benchmark whereby the stock fulfils 100% of its breeding potential. From Figure 8.2 it can be seen that if the fishery targets all age classes above 7 years of age and each shark has a 10% chance of being captured in a year, each year classes' potential for pup production is reduced to just 19% of the level expected in an unfished stock. If the chance of capture each year is raised to 20% each year classes' potential for pup production is reduced to just 4% of the level expected in an unfished stock

This large impact on the potential of school sharks predicted at low levels of fishing on the school shark breeding stock is the result of the longevity of the school shark. Because the life strategy of school sharks involves the adults breeding at low levels for many years the addition of even a low level of mortality by fishing has a large impact on stocks potential to continue producing pups.

To sustainably manage a school shark fishery which is allowed to target adult school sharks, it will be necessary to strictly constrain overall harvest rates at an extremely low level (probably under 5% per annum). Given the overlap between fishing for gummy and school shark in the Southern Shark Fishery, and the existing management framework it is highly unlikely that such a management objective can be reliably achieved.

A more robust management strategy would be to deter targeted fishing on the adult stock altogether and only allow targeted fishing for a few age classes of sub-adults. This type of fishery has been called a 'gauntlet' fishery, because the fishery is like a short gauntlet which each year class has to run through before being protected. In Figure 8.2 the broken line shows the estimated impact of varying levels of fishing pressure on the potential pup production by each year class if the fishery is restricted to targeting 8-14 year old school sharks.

Even with a gauntlet strategy there is still an overall need to control fishing pressure or the supply of sub-adults to the breeding stock is cut off and the level of breeding stock will decline. However under this strategy fishing pressure does not need to be so tightly controlled at low levels. It is estimated that an annual harvest rate of 10% will maintain the pup production of each year class at around 49% of its unfished potential, while a harvest rate of 20% will reduce pup production to 22%. Given the existing configuration of the Southern Shark Fishery these levels of fishing pressure are probably a more achievable management goal.

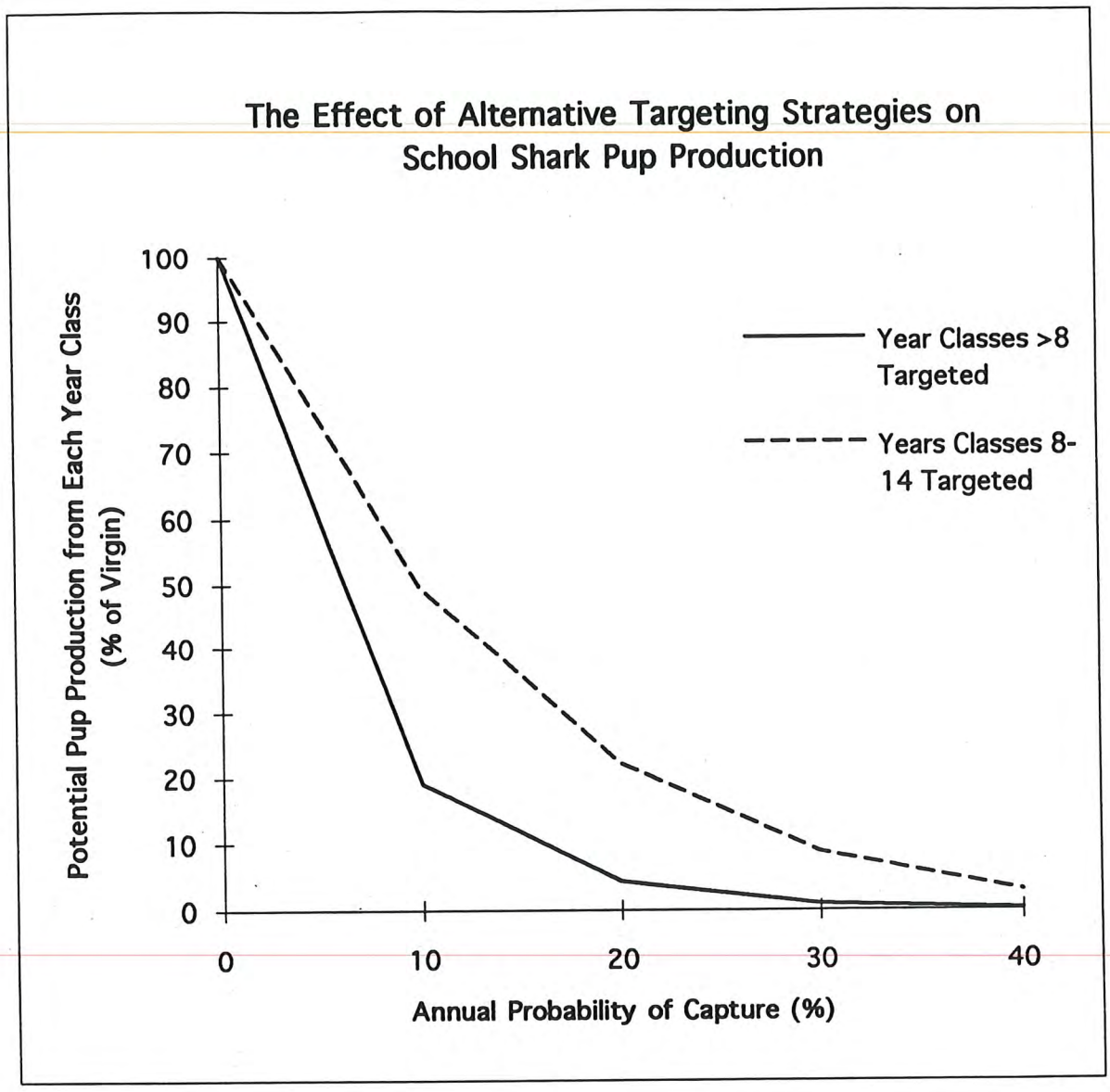

Figure 8.2 The modelled impact of varying levels of fishing mortality (0.1 - 0.4) on potential pup production. Pup production expressed as a percentage of the production expected in an unfished stock. Solid line indicates all year classes >8 targeted by fishing pressure. Dashed line indicates 'gauntlet fishery' with year classes 8-14 subject to fishing mortality. Source Biospherics Pty Ltd.

From the above analysis it can be concluded that a management strategy that optimises sustainability and long term production in the school shark fishery will:

- target effort at sub-adult age classes after they have attained most of their adult weight, and
- deter targeting of long lived adults so as to maintain breeding stocks stable at levels which optimise annual pup births.

8.2 Implications for Management

The immediate objective of management in the school shark fishery should be to stabilise levels of breeding stock by discouraging targeted fishing for adult school sharks.

This can be achieved by:

- the imposition of small mesh nets and,
- using strategic closures to cover times and places when adult school sharks are particularly vulnerable to capture, specifically during summer in shallow water.

Adult school sharks spend most of their time in deep water (100-800m) near the edge of the continental shelf. Most of their prey are pelagic species which the sharks presumably pursue throughout the water column. The fishing power of a gillnet in this environment is relatively low. In contrast, during their short time in and around pupping grounds the female school shark is extremely vulnerable to skilfully targeted fishing. The females re-use the same locations at about the same time each year and fishermen anticipating this can cut off a large part of the shallow water column with skilfully placed nets.

Management strategies should be designed to prevent targeted fishing for pregnant school sharks in and around all pupping grounds. Accepting this management strategy for school sharks leads directly to the central issue identified by the workshop: Where are the school shark pupping grounds in south-eastern Australia?

8.3 Application of the Pre-cautionary Principle

There is no rigorous scientific proof as to the actual extent of school shark pupping grounds prior to human impact, and it is probable that proof rigorous enough to convince the most sceptical minds will never exist.

The managers of this fishery must devise their management strategies in the face of this uncertainty.

The Precautionary Principle of Management has been devised for this type of situation. The principle is that faced with uncertainty managers should manage cautiously making assumptions which err on the side of increased protection for the managed stock. Applying this principle to this issue managers should manage on the basis that pupping areas are as widespread as industry believes, not on the basis that pupping grounds are restricted to the areas proved to scientific satisfaction. In this case the onus of proof should be reversed and placed upon the scientific community to prove case by case that pupping is not occurring within areas being nominated by fishers.

For management to continue managing on the basis of the scientific advice that pupping grounds are restricted to Bass Strait and eastern Tasmania is directly contrary to the application of the precautionary principle.

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