Sampling of Newly-settled Snapper, *Pagrus auratus,* and Identification of Preferred Habitats in Port Phillip Bay - a Pilot Study

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OBJECTIVES:

1. Determine if newly-settled (10 - 30 mm) snapper can be quantitatively sampled in Port Phillip Bay.
2. Determine the habitat requirements of newly-settled snapper and assess whether such habitats are under threat of degradation.

NON TECHNICAL SUMMARY:

The ecology, including the distribution and preferred habitats of newly-settled snapper are largely unknown in Australian waters. Newly-settled snapper are fish of about 20-30 mm in length that have recently transformed from a larva living up in the water column to a bottom associated juvenile. This lack of information is primarily due to a lack of success in capturing snapper at this stage of their life-cycle. The settlement and early juvenile stage is often a critical phase in a fish's life cycle, and specific habitats are often required to provide food and/or protection from predators. Fluctuations in the abundance of older fish can often relate back to yearly variations in the abundance of these early life stages. The aims of this pilot study were to: 1) Determine if newly-settled snapper (10 - 30 mm) can be quantitatively sampled in Port Phillip Bay, Victoria, and 2) Determine the habitat requirements of newly-settled snapper and assess whether such habitats are under threat of degradation.

Studies in Japan and New Zealand suggest that newly-settled snapper can be found in the deeper soft sediment habitats of bays. For this study we designed a small beam trawl based on a design used to sample newly-settled snapper in Japan. The beam trawl was fished on the bottom and had mouth dimensions of approximately 2.5 m wide and 1.5 m deep when fishing. Floats and weights are used to open the net vertically and a 3m steel beam is used to open the net laterally.

Snapper spawn in Port Phillip Bay during summer and settlement of larvae to the bottom is predicted to occur in mid to late summer. Sampling was therefore conducted throughout Port Phillip Bay on a monthly basis from December 1996 through to April 1997. Previous studies in Port Phillip Bay have suggested that newly-settled snapper do not use shallow water habitats less than about 3 m deep, and that larval stages are most abundant in northern half of the bay. Consequently, sampling was restricted to depths of greater than 5 m and two sampling trips conducted in January and May 1997 concentrated on the northern end of the Bay. Sampling was conducted both in daylight and at night.

Overall, 110 sites were sampled in depths between 5 and 24 m. Over 3,500 fish comprising 61 species were captured. No newly-settled snapper were found, a small number of one year old snapper were captured. Given the large range of species captured, including one year old snapper, the net should have been able to capture newly- settled stages if they were present in the sampling area. A trawl survey conducted at the same time using a much larger winged trawl also failed to catch small young of the year snapper. Abundances of juvenile snapper are known

to show strong variability from year to year and we hypothesise that the failure to capture newly-settled snapper was due to very low or even failed recruitment of newly-settled snapper to the bay during the 1996-97 summer.

Without data on newly-settled snapper, we could not determine their habitat requirements and asses the threats to these habitats. Useful information on bottom habitats throughout the bay was obtained by conducting video surveys and we were able to investigate relationships between various habitat characteristics and a range of fish species. This information was also useful in describing habitats utilised by one year old snapper. One year old snapper were captured in depths from 8 to 24 m over soft bottom habitats with low or zero algal cover, but often with significant numbers of large sessile invertebrates such as cunjevoi (*Pyura stolonifera*). These habitats do not appear to be under any major threat of degradation.

Another habitat which has received limited investigation as a habitat for newly-settled snapper in Victoria is estuarine habitat. Concurrent with the beam trawl sampling we also conducted sampling with a beach seine net in four estuaries within Port Phillip Bay. During this sampling we captured 3,195 fish comprising 41 species. No newly-settled snapper were found. The absence of newly-settled snapper from estuarine habitats within Port Phillip Bay, however, may not mean that they do not use these habitats. Their absence may have also been due to low or failed recruitment. Estuaries within Port Phillip Bay were shown to provide nursery habitats for a range of commercially important species. However, the importance of estuarine habitats for newly-settled snapper requires further study in years of known high juvenile recruitment.

The beam trawl survey provided the first data on the baywide distribution of the introduced goby, *Amoya pflaumi*. Previous to this study this goby was only known from the Yarra Estuary. *Amoya pflaumi*, which is a native goby species of the south east Asian region, was one of the more abundant species captured by beam trawl and was distributed widely throughout the Bay.

Although this study failed to sample newly-settled snapper, we have developed a cost effective sampling method that will prove valuable for future studies of small bottom dwelling fishes. Future opportunistic sampling with this equipment in years and or other regions of known high settlement of snapper will be required to demonstrate the efficiency of the beam trawl for sampling these early juvenile stages.

Addendum (March 1998)

In early March 1998 a professional fisherman informed us that large numbers of newly-recruited 0+ age snapper were present in northern Port Phillip Bay. Based on these reports we conducted opportunistic sampling with the small beam trawl in northern Port Phillip Bay in early March and captured significant numbers of small, 3-7 cm in length, newly-recruited 0+ age snapper. This proves that the small beam trawl will sample newly-recruited snapper if they are present in the sampling area. This also supports our suggestion that failure to capture newly-settled recruits during summer 1996/97 was due to low or failed recruitment rather than major inefficiencies in the sampling technique. Unfortunately the time of sampling was likely to have been too late to capture newly-settled snapper. Anecdotal evidence from the professional fisherman suggests that very small, most likely recently or newly-settled snapper were abundant earlier in the year, around January and early February. Given the now proven ability of the small beam trawl to capture small 0+ recruits we have little doubt that it will also capture newly-settled recruits if they are present in the sampling areas.

KEYWORDS: Snapper, juvenile, settlement, habitat, sampling techniques

1. Non-technical Summary

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Studies in Japan and New Zealand suggest that newly-settled snapper can be found in the deeper soft sediment habitats of bays. For this study we designed a small beam trawl based on a design used to sample newly-settled snapper in Japan. The beam trawl was fished on the bottom and had mouth dimensions of approximately 2.5 m wide and 1.5 m deep when fishing. Floats and weights are used to open the net vertically and a 3m steel beam is used to open the net laterally.

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Overall, 110 sites were sampled in depths between 5 and 24 m. Over 3,500 fish comprising 61 species were captured. No newly-settled snapper were found, a small number of one year old snapper were captured. Given the large range of species captured, including one year old snapper, the net should have been able to capture newly-settled stages if they were present in the sampling area. A trawl survey conducted at the same time using a much larger winged trawl also failed to catch small young of the year snapper. Abundances of juvenile snapper are known to show strong variability from year to year and we hypothesise that the failure to capture newly-settled snapper was due to very low or even failed recruitment of newly-settled snapper during the 1996-97 summer.

Without data on newly-settled snapper, we could not determine their habitat requirements and asses the threats to these habitats. Useful information on bottom habitats throughout the bay was obtained by conducting video surveys and we were able to investigate relationships between various habitat characteristics and a range of fish species. This information was also useful in describing habitats utilised by one year old snapper. One year old

snapper were captured in depths from 8 to 24 m over soft bottom habitats with low or zero algal cover, but often with significant numbers of large sessile invertebrates such as cunjevoi (*Pyura stolonifera*). These habitats do not appear to be under any major threat of degradation.

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Although this study failed to sample newly-settled snapper, we have developed a cost effective sampling method that will prove valuable for future studies of small bottom dwelling fishes. Future opportunistic sampling with this equipment in years and or other regions of known high settlement of snapper will be required to demonstrate the efficiency of the beam trawl for sampling these early juvenile stages.

2. Background

Snapper, *Pagrus auratus*, form an important commercial fishery in all Australian states except Tasmania and the Northern Territory (Kailola et al. 1993). The annual Australian catch of snapper averages approximately 2000 tonnes (Kailola et al. 1993). Commercial snapper catches in Victoria and New South Wales have declined in recent years while fishing effort has increased. It is not known whether this decline is due to natural population fluctuations, overfishing, or environmental degradation. Apart from a peak in snapper catches during the late 1980's, the snapper fishery in Port Phillip Bay, which is the major fishery in Victoria, has seen a long term decline in catches over the past 20 years (Neira et al. 1997).

The early life history of snapper in Australia is very poorly known, particularly from the end of the larval stage to the end of the first year. Metamorphosis from the larva to the small juvenile occurs at approximately 10 mm length and at an age of about 20 to 40 days (Fukuhara 1985, Tanaka 1985, Foscarini 1988, Fukuhara 1991, Battaglene and Talbot 1992). Studies in Japan have shown that snapper begin to settle from the water column to the bottom at about 15 mm in total length (Azeta et al. 1980, Tanaka 1985). In Japan, small juveniles of approximately 10 to 20 mm length were collected in the deeper parts of a marine embayment by beam trawling (Azeta et al. 1980; Tanaka 1985). In New Zealand, the smallest juvenile recorded from intensive sampling was about 30 mm at an age of about 45 days, leading to the suggestion that the transition from pelagic to demersal existence is gradual (Francis et al. 1992). In this case, however, the 2 cm stretch mesh in the otter trawl used for sampling may have been too coarse for the efficient capture of smaller individuals. In Botany Bay, New South Wales, small recently settled recruits of 32 mm length were most abundant over unvegetated soft sediments in depths over 5 m (Anon 1981).

Port Phillip Bay is thought to be a major snapper spawning site (MacDonald 1982). Egg and larval stages have been collected in significant numbers in Port Phillip Bay from about November to April (Jenkins 1986) suggesting that spawning occurs predominantly during summer. The biology, including the habitat requirements of newly-settled juveniles, is poorly known in Port Phillip Bay. Small juveniles from approximately 40 mm length and upwards have been collected incidentally in trawls from deeper (>7m) areas of the bay in early Autumn (Marine and Freshwater Resources Institute (MAFRI), unpublished data). Studies in Port Phillip Bay have suggested that seagrass beds, reefs, and unvegetated sands at the shallow (< 5 m) margins of the Bay are not important habitats for newly settled snapper (Jenkins et al. 1993, Jenkins et al. 1994, Jenkins et al. 1996). This is consistent with studies in Japan (Azeta et al. 1980, Tanaka, 1985), New Zealand (Francis et al. 1992) and New South Wales (Anon 1981), where small juveniles were collected in the deeper parts of embayments.

3. Need

Snapper stocks are declining in areas such as Victoria and New South Wales for as yet unknown reasons. One possible factor is degradation of juvenile habitat. This may particularly be the case in an area like Port Phillip Bay, which is influenced by a large population living in its catchment. The settlement and early juvenile stages are often critical phases in a fish's life cycle, where specific habitats are required to provide food and/or protection from predators. In Australia, the habitat requirements of newly-settled snapper are unknown. We need to define the characteristics of preferred habitat at this stage so that it can be protected from degradation which could have a negative effect on snapper recruitment strength.

Long term trawl surveys in Port Phillip Bay (MAFRI, unpublished data) and studies in New Zealand (Francis 1993) and Japan (Azeta et al. 1980) have demonstrated that recruitment of juvenile snapper can show strong interannual variability. This variability could be important in explaining variability in the fishery. Successful sampling of newly-settled snapper could lead to the initiation of recruitment monitoring programs that may allow forecasts of recruitment strength to the fishery some years later. The ability to sample early juvenile stages would also enable more detailed investigations into factors influencing the recruitment of these early life stages.

This one year pilot study was undertaken to ascertain the potential for sampling newly-settled snapper. Development of a small scale, cost effective sampling technique would enable larger scale studies to be conducted, encompassing other important snapper recruitment areas in Australia.

4. Objectives

1) Determine if newly-settled (10 - 30 mm) snapper can be quantitatively sampled in Port Phillip Bay.

2) Determine the habitat requirements of newly-settled snapper and assess whether such habitats are under threat of degradation.

5. Methods

5.1 Sampling sites

Beam trawl survey of deeper water habitats within Port Phillip Bay

Sampling with a small purpose built beam trawl (described below) was conducted monthly throughout Port Phillip Bay from December 1996 to April 1997 (Fig. 1).

Anecdotal information from fishers along with information from annual trawl surveys (MAFRI, unpublished data) of the Bay, suggest that newly-settled snapper may be most likely to be found in the northern half of the Bay. Consequently, two sampling trips were conducted that concentrated only on the northern end of the Bay, and these trips were conducted in late January and in mid May, 1997. (Fig. 2).

For the purpose of allocating sampling positions, the Bay was divided into five zones (Fig. 1). The zones are similar to the environmental zones within Port Phillip Bay described in Anon (1973). Sites were chosen randomly within each zone, and one trawl sample was taken at each site. Monthly sampling trips consisted of 18 sites, nine sampled during daylight and nine sampled during night. Five day and five night sites were allocated to the central zone (zone 2), whereas one day and one night site were allocated to each of the other four zones. Day and night sampling trips were conducted on separate days, less than four days apart. The January sampling of the northern end of the bay consisted of six sites sampled during daylight and six sites sampled at night, all within a 10 hour period. The May sampling of the northern end of the Bay consisted of 12 sites that were all sampled at night.

As previous studies (Jenkins et al. 1996) have failed to find newly-settlement snapper on shallow reefs, seagrass and sand habitats less than 5 m deep in Port Phillip Bay, sampling was restricted to depths of 5 m and greater. The deepest samples were at 24 m depth. During the entire project 110 beam trawl samples were taken (Figs. 1 and 2).

Beach seine survey of estuarine habitats within Port Phillip Bay

Sampling with a small beach seine (described below) was conducted at four estuarine sites within Port Phillip Bay. These were the Patterson River estuary, Yarra River estuary, Werribee River estuary and the Grammar

School Lagoon at the mouth of Hovells Creek (Fig. 1). Sampling was conducted monthly between December 1996 and April 1997, and consisted of three or four non-overlapping net hauls, haphazardly placed around or inside the mouth of each estuary. The December sampling of the Yarra River estuary was conducted in Greenwich Bay (Fig. 1), however, later sampling was conducted directly in the mouth of the Yarra River. Estuarine sites were generally sampled on the same day except for February and April when sampling was spread over three and two days respectively. Tidal stage often varied between sampling trips and between estuaries. Net hauls were generally in water depths of less than 1.5 m irrespective of tidal stage.

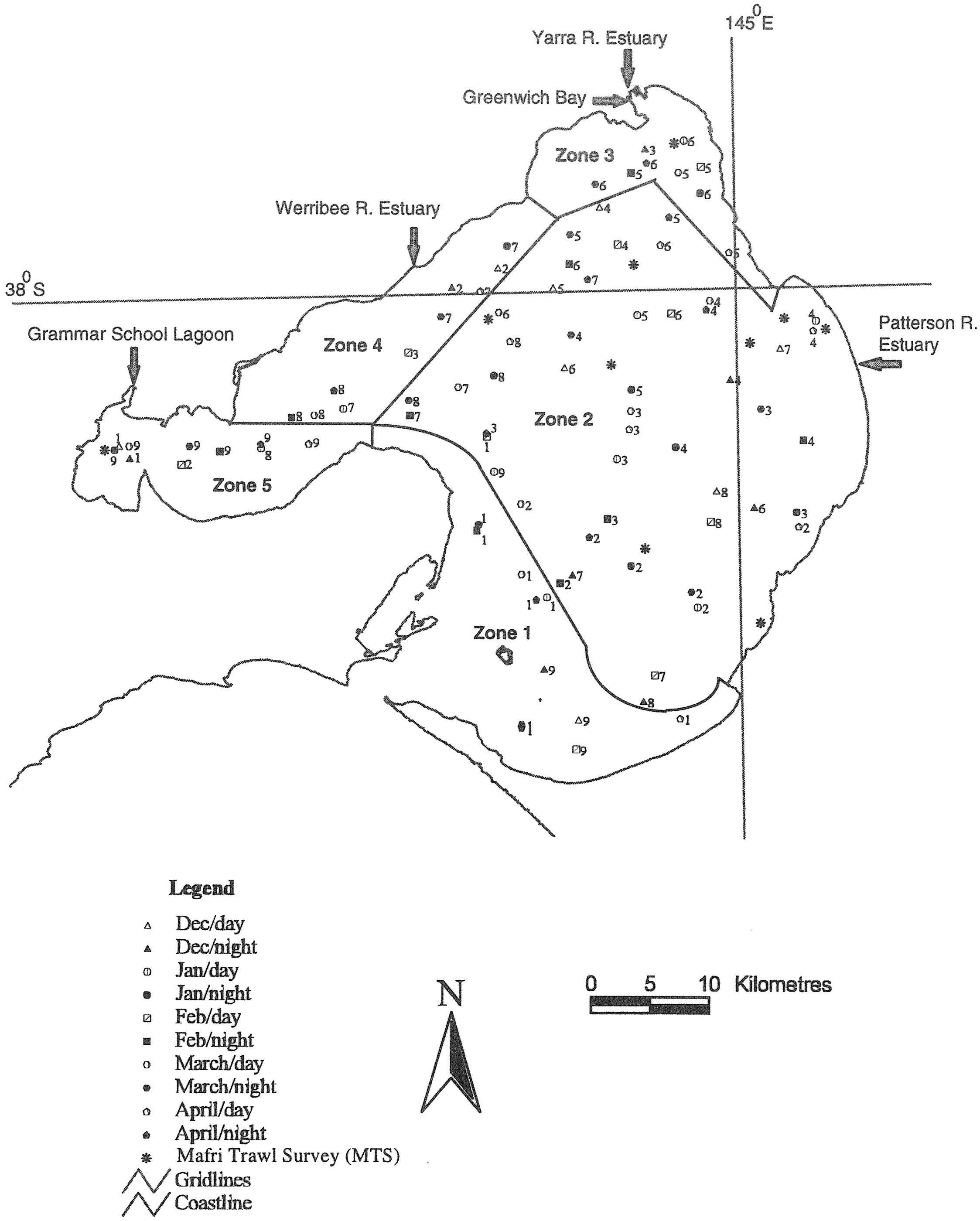

Figure 1. Positions of sites sampled by beam trawl, and locations of the estuarine sites sampled within Port Phillip Bay from December 1996 to April 1997.

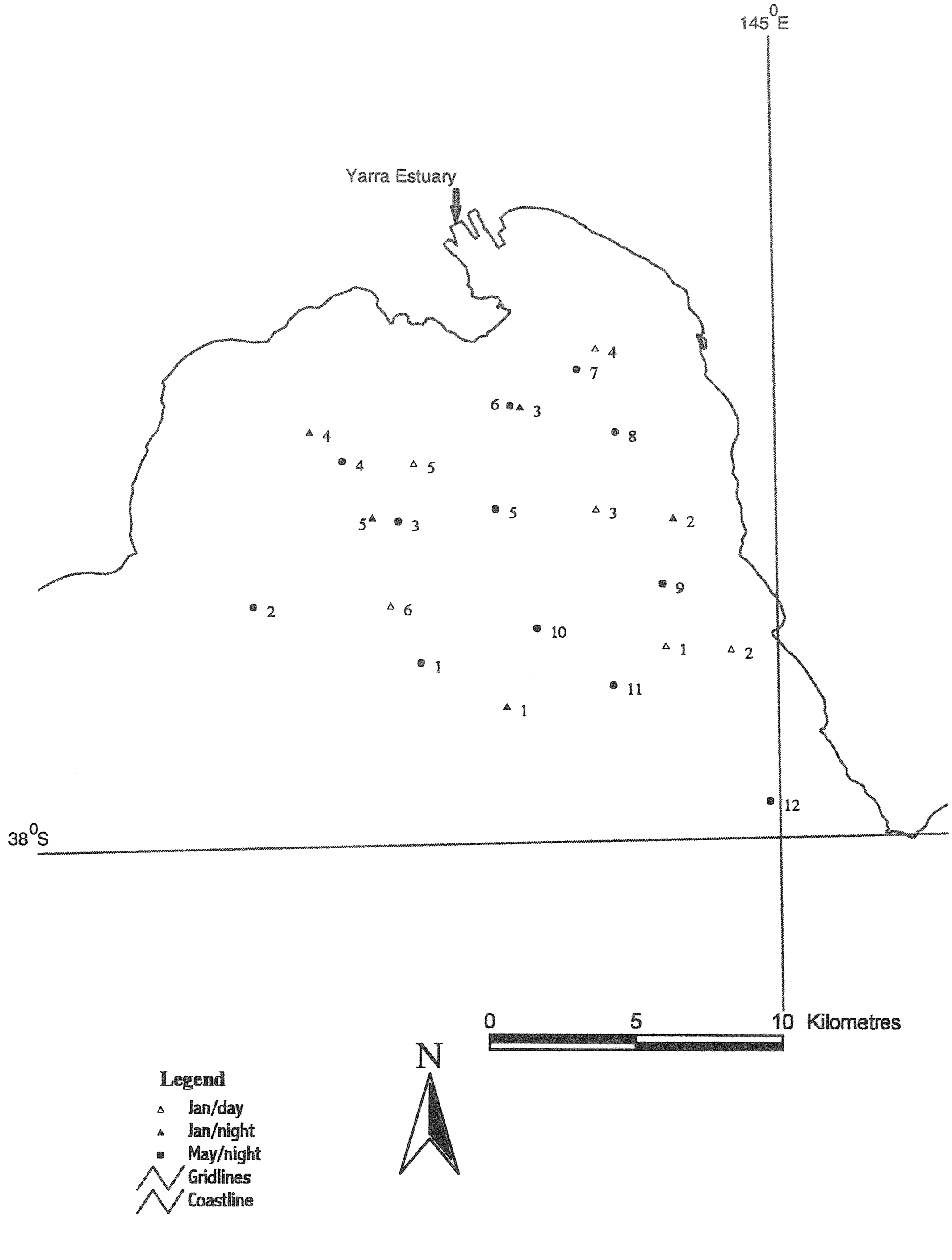

Figure 2. Positions of sites sampled by beam trawl during concentrated sampling in the northern end of Port Phillip Bay in January and May 1997.

5.2 Sampling equipment and methods

Beam trawl survey of deeper water habitats within Port Phillip Bay

A small beam trawl (Fig. 3) was designed specifically for sampling the early post-settlement stages of snapper and other small demersal fishes. The beam trawl design was based on a small beam or "plumb staff" beam trawl used by Gunderson and Ellis (1986) to sample benthic fish and a similar beam trawl used by Azeta et al. (1980) to sample newly-settlement snapper in a Japanese bay. The trawl was designed so it could be deployed from and towed behind a medium-sized high speed vessel. The trawl used floats and weights to open the net vertically and a steel beam to open the net laterally (Fig. 3). The net was towed behind a 7.32 m shark cat powered by twin 225 horsepower outboard motors. The tow rope ran through an A-frame at the back of the boat and a pot hauler was used to control the deployment and retrieval of the trawl. Triple braided polyester yachting rope of 12 mm diameter was used to haul the beam trawl.

The main body of the trawl net was constructed of 12 mm stretch, 4 mm^2 aperture, knotless mesh. The codend was constructed of 8 mm stretch, 3 mm^2 aperture, knotless mesh. The trawl was approximately 5 m in total length and the cod end bag was 1 m long. When fishing, the mouth is about 2.5 m wide and about 1.2 to 1.5 m deep. A tickler chain was attached to the net to mobilise fishes living on the sediment. The dimensions of the trawl and details of the bridle arrangement are displayed in detail in figure 3.

Initial trials of the net were conducted with a video camera attached to the beam that was hardwired to an on board television (described below). Using this system, we were able to observe the net fishing and trial different warp to depth ratios and towing speeds in various depths. From these trials we determined that, at a towing speed of 1.5 to 2 knots the warp to depth ratios required for good bottom contact were 3:1 for depths less than 10 m and 4:1 for depths of 10 m and greater. The bottom time of individual trawls was initially 10 minutes but was reduced to 5 minutes during the first sampling date due to excessive amounts of macroalgae in some areas of the Bay. Each 5 minute trawl sampled approximately 750 m^2 of bottom habitat.

All fish were removed from the net in the field and preserved in ethanol for later identification and enumeration in the laboratory. Larger specimens that could be identified in the field were measured and returned live to the water.

Figure 3

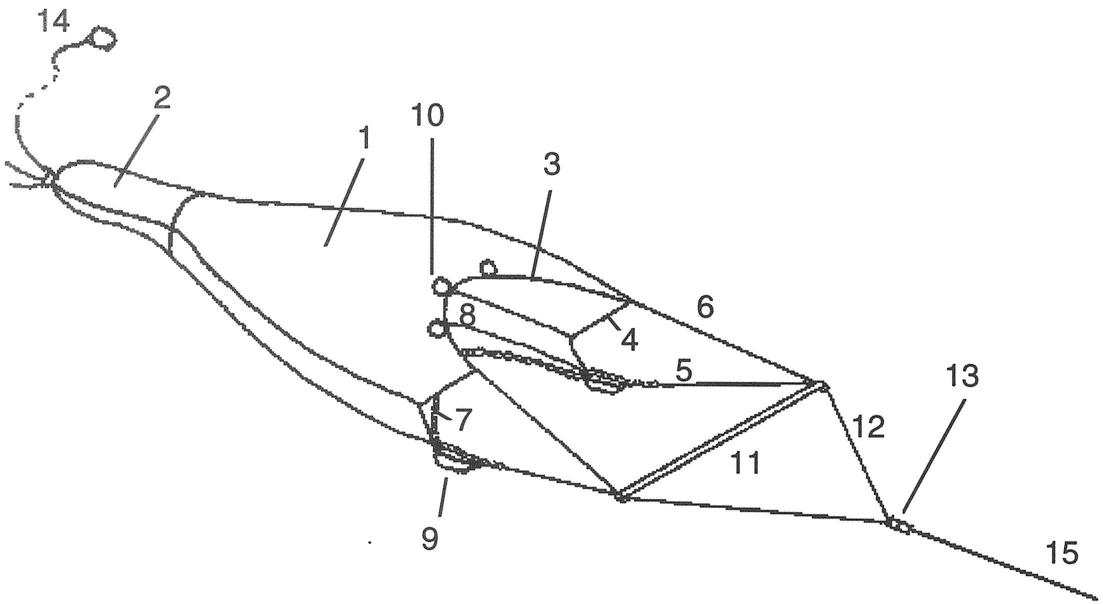

Figure 3. Diagram of beam trawl designed for sampling newly settled snapper (not to scale).

1. Main body of net, 4 m long, 12 mm stretch, 4 mm^2 aperture knotless mesh; 2. codend bag, 1 m long, 8 mm stretch, 3 mm^2 aperture knotless mesh; 3. 4.7 m headrope; 4. 2.2 m breastlines; 5. 1.7 m lower bridle, note the first metre of the lower bridle is 2 cm x 3 cm x 0.5 cm chain; 6. 1.8 m upper bridle rope; 7. 4.8 m tickler chain, same size chain as lower bridle chain; 8. 5.6 m footrope; 9. 6.3 kg detachable lead weights; 10. 9.5 cm diameter foam floats; 11. 3 m beam, 3 cm diameter steel pipe; 12. 4.1 m beam bridle rope; 13. heavy duty stainless steel swivel; 14. emergency retrieval line with fluorescent 9.5 cm foam float; 15. 1.2 cm diameter triple braided polyester tow rope.

Beach seine survey of estuarine habitats within Port Phillip Bay

A 20 m long X 2 m deep beach seine, constructed of 1 mm^2 mesh was used for the first sampling of estuarine sites in December. This net was set in a circle and retrieved by hand into a small boat. However, large amounts of drift algae at several sites, and steeply sloping banks at others made setting an retrieving this net difficult. As a result, we chose to use a smaller beach seine fitted with hauling ropes for the remainder of the estuarine sampling program. This small beach seine was 10 m in length X 2.5 m in depth, and was constructed of 1 mm^2 mesh. The net had 10 m ropes attached to each end to facilitate a constant 10 m haul. The net was deployed and hauled by hand into a fish bin. All fish were removed from the net in the field and preserved in ethanol for later identification and enumeration in the laboratory. Larger specimens that could be identified were measured and released live.

5.3 Laboratory methods

Fish were identified to genus and species using identification keys from Gomon et al. (1994). Total length of commercial species was measured using vernier callipers. Otoliths (earbones) of the snapper captured were aged by the central ageing facility (CAF) at the Marine and Freshwater Resources Institute (MAFRI), Queenscliff.

5.4 Video analysis of deeper water habitats within Port Phillip Bay

Video of habitats was taken from 19 to 21 of May, 1997, at the end of the sampling program. As net avoidance by fish was likely to have been greatest during daytime, we considered that the most reliable data on fish assemblages would be for sites sampled at night. Consequently, we decided to restrict video of habitats to the sites sampled at night by the beam trawl (see Fig. 1). As we only obtained data on the distribution of juvenile 1+ age snapper, we could only investigate the habitat requirements of these older juveniles. Video of habitats included all sites where juvenile (1+) snapper were captured during beam trawl sampling. To extend the investigation of the habitats of juvenile (1+) snapper, we also obtained video of habitat at 10 sites where large numbers of juvenile (1+) snapper were collected during the annual MAFRI trawl survey (MTS) of Port Phillip Bay conducted in March/April 1997 (Fig. 1).

Bottom habitats were surveyed using a closed circuit underwater video camera attached to a 1 m high, four legged stainless steel frame. The legs of the frame were 1 m apart at their bases, and when the frame was positioned on the bottom, the camera captured an area of bottom of approximately 0.8 m^2 . The camera was hard wired to a television on deck. This enabled real time viewing of the habitat, and aided in the placement of the frame when taking habitat quadrats. A differential global positioning system (DGPS) was used to locate sites where trawls were conducted. Data on latitude and longitude obtained from the DGPS, along with water depth, time and date, were overlayed onto the image by an onboard computer. The image along with the overlayed information was recorded on video tape by an onboard video recorder. The video equipment was powered by a generator on deck.

At each site the camera frame was towed as close as possible along the path taken by the beam trawl, and dropped to the bottom at haphazard intervals to obtain 10 habitat quadrats. Habitat quadrats were analysed in the laboratory for percent cover of macroalgae, and percent cover of larger sessile organisms that projected above the substrate (ie. cunjevoi, oysters etc). There was no attempt to discriminate between species of macroalgae. Sediment type for individual sites was given a number rating from one (coarser) to four (finer), based on data from Beasley (1966) (1=sand, sandy gravel, gravelly sand; 2=silty sand, clayey sand; 3=sand-silt-clay, silty clay, sand-clay-silt, clayey silt, sandy silt; 4=clay).

5.5 Data analysis

Beam trawl survey of deeper water habitats within Port Phillip Bay

Analysis of variance was used to investigate for effects of zone, month and day/night on total abundance and number of species collected by the beam trawl during sampling throughout the Bay. Zone, month and day/night were treated as fixed factors. Assumptions of the analysis were examined using box and residual plots. Monthly data on total abundance and species number was average across sites for day and night sampling in zone two. To achieve acceptable homogeneity of variances and distribution of residuals, the total abundance and species number data were transformed to log(x+1). Tukey's test was used for post-hoc comparisons of fish abundances between zones after analysis of variance. Data obtained during concentrated sampling of the northern end of the bay was not subject to statistical analysis.

Beach seine survey of estuarine habitats within Port Phillip Bay

Analysis of variance was used to investigate for effects of estuary and month on total abundances and number of species collected by the beach seine. Data from sampling in December 1996 was excluded from the analysis due to the different net used, and the different site sampled at the Yarra River mouth. Estuary and month were treated as fixed factors. Total abundance data was transformed to log(x+1) to achieve suitable distribution of residuals and homogeneity of variances. Tukey's test was used for post-hoc comparison of species numbers between estuarine sites after analysis of variance.

Video analysis of deeper water habitats within Port Phillip Bay

For each site, habitat variables (ie. algal cover, cover of sessiles) were averaged across the 10 quadrats, and the average values were used in correlations. Spearman's rank correlation was used to analyse for association between habitat variables, total abundance of fish, number of species and abundance of several of the more abundant fish species captured during beam trawling.

6. Results

6.1 Beam trawl survey of deeper water habitats within Port Phillip Bay

Snapper

Newly-settled snapper were not collected in any of the beam trawl samples, however, 10 older juvenile snapper were collected. Based on analysis of otolith yearly increments, these fish were all 1+ age (just over one year of age) except for an individual captured in December, which was a 0+ age fish that was almost one year old. Therefore these fish were spawned the previous summer. These fish ranged from 111 mm to 170 mm in total length (TL) and were all taken at night (Fig. 4). Except for one specimen taken in the southern half of the Bay, all juvenile snapper were taken in the northern end of the Bay. The beam trawl was not designed for sampling these larger juveniles, and their absence from daytime trawls suggest they were capable of avoiding the net. The capture of larger juveniles suggests that the net should have been able to capture newly-settled snapper if they were present in the sampling areas.

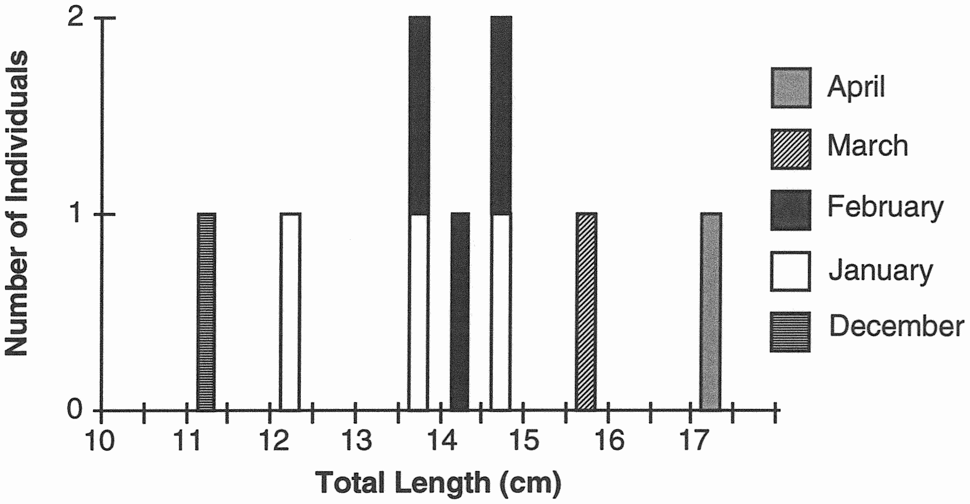

Figure 4. Size distribution of juvenile snapper, *Pagrus auratus,* captured with the beam trawl in Port Phillip Bay from December 1996 to April 1997.

Other species

A total of 3,049 fish, comprising 58 species, were collected with the beam trawl during sampling throughout the Bay (Table 1). A further 500 fish comprised of 32 species were collected by the beam trawl during sampling in the northern end of the Bay (Table 2). Overall 61 species were collected during the beam trawl survey.

Except for zone 1, generally more fish were captured during night time beam trawls than daytime trawls (Fig. 5). Zone 5 had the highest catches of fish both in day and night. Analysis of variance revealed significant effects of day/night and zone on the logged abundance of fish collected by the beam trawl (Table 3). There were no significant interactions between zone, day/night and month (Table 3). Tukey's post-hoc comparisons revealed that significantly more fish were captured in zone 5 than the remaining four zones (Tukey's test, p=0.010), which were not significantly different from each other.

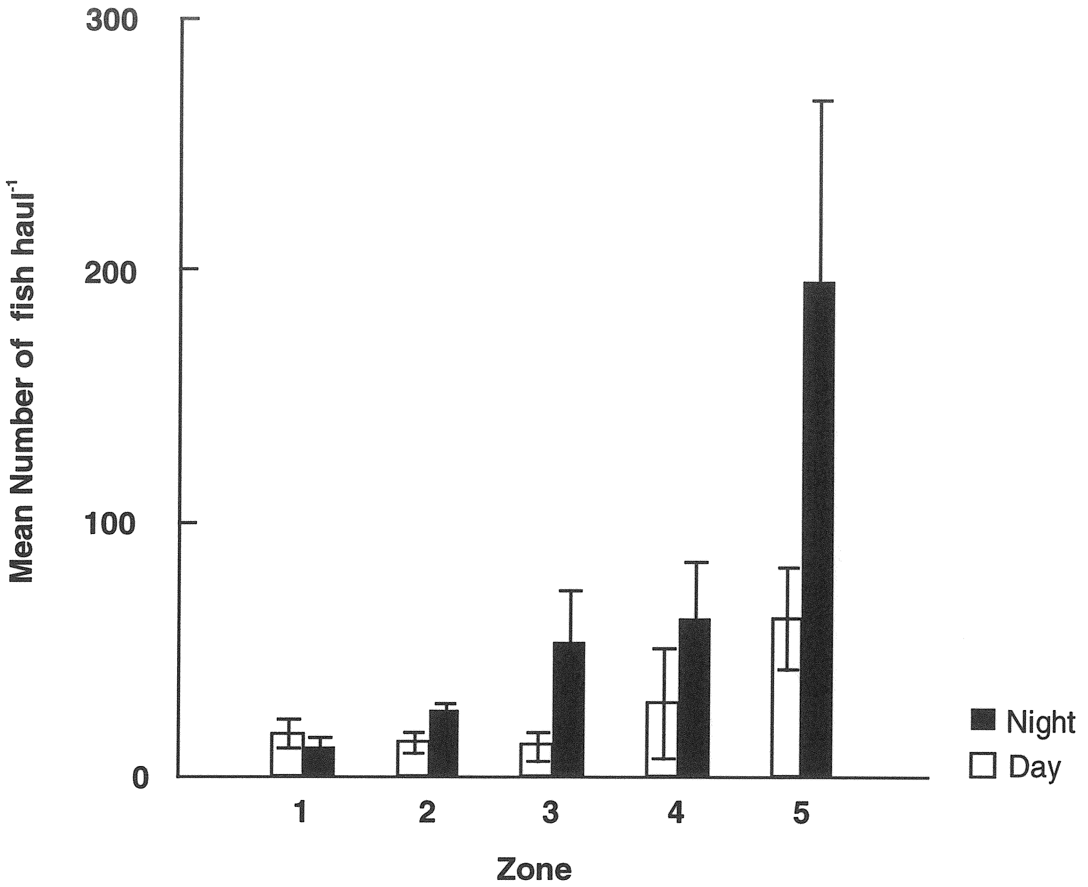

Figure 5. Comparisons of mean number of fish captured per beam trawl, between zones and day and night. Error bars are one standard error.

Table 1. Analysis of variance of beam trawl data investigating effects of zone and day/night on log(x+1) transformed fish abundance.

Source	DF	MS	F	P
Zone	4	5.319	4.316	0.016
Month	4	2.133	1.731	0.196
Day/Night	1	10.091	8.189	0.012
Zone*Month	16	0.641	0.520	0.897
Zone*Day/Night	4	2.118	1.718	0.198
Month*Day/Night	4	0.476	0.379	0.820
Error	15	1.232		

Overall, 30 species were captured in zone 1, 32 in zone 2, 21 in zone 3, 30 in zone 4 and 28 in zone 5. A total of 53 species were captured at night compared with 40 species during the day (Table 1). However, analysis of variance revealed no significant effects of day/night or zone on the number of species captured by the beam trawl (Fig. 6, Table 4).

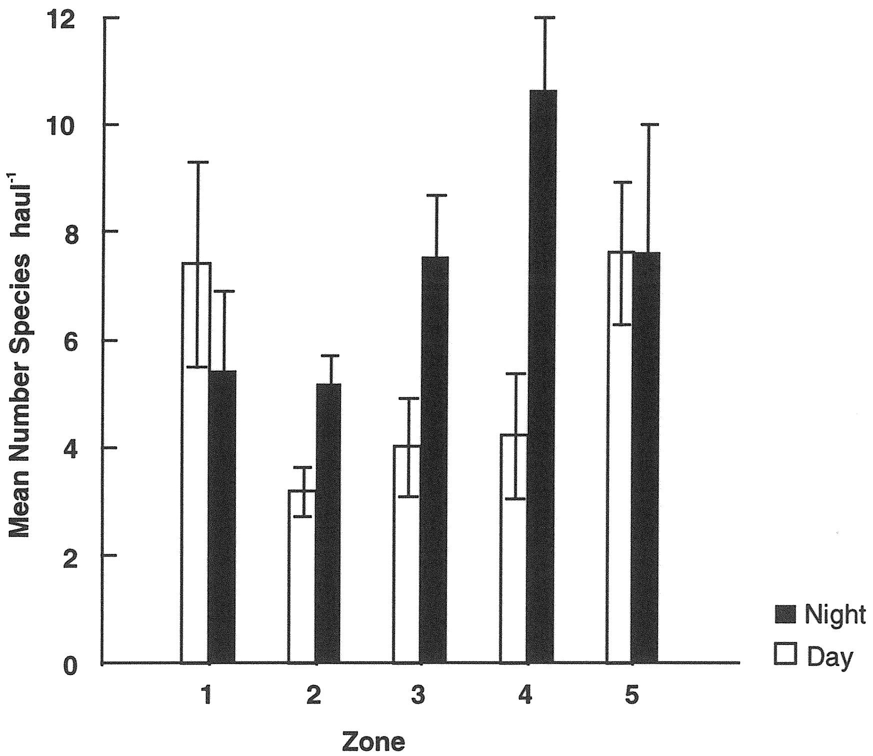

Figure 6. Comparisons of mean number of species captured per beam trawl, between zones and day and night. Error bars are one standard error.

Table 2. Analysis of variance of beam trawl data investigating effects of zone and day/night on log(x+1) transformed number of species.

Source	DF	MS	F	P
Zone	4	0.411	1.018	0.429
Month	4	0.194	0.480	0.750
Day/Night	1	1.494	3.699	0.074
Zone*Month	16	0.297	0.736	0.726
Zone*Day/Night	4	0.897	2.221	0.116
Month*Day/Night	4	0.227	0.561	0.694
Error	15	0.404		

The five most abundant species captured during sampling throughout the bay were orange spotted goby, *Nesogobius hinsbyi*, followed by Wood's siphon fish, *Siphaemia cephalotes*, sand flathead, *Platycephalus bassensis*, little rock whiting, *Neoodax balteatus*, and bridled leatherjacket, *Acanthaluteres spilomelanurus* (Table 3). The five most abundant species captured in the northern end of the Bay were *N. hinsbyi*, followed by *P. bassensis*, threadfin sand goby *Nesogobius* sp. 2, the introduced gobiid, *Amoya pflaumi*, and southern cardinalfish, *Vincentia conspersa* (Table 4).

Table 3. List of species and mean catch rates of fish collected in during beam trawl sampling in Port Phillip Bay, from December 1996 to April 1997.

Species	Zone 1		Zone 2		Zone 3		Zone 4		Zone 5	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
	mean haul^{-1}		mean haul^{-1}		mean haul^{-1}		mean haul^{-1}		mean haul^{-1}	
Urolophidae										
Urolophus paucimaculatus	2.40	0.20	0.24	0.09	0.75	0	0	0	0.20	0
Trygonoptera mucosa	0	0	0.12	0.04	0	0	0	0	0	0
Ophichthidae										
Muraenichthys breviceps	0	0	0	0.13	0	0	0	0	0	0
Clupeidae										
Hyperlophus vittatus	0	0	0	0.74	0	0.80	0	0	0	0
Engraulididae										
Engraulis australis	0	0	0	1.39	0	1.80	0	6.60	0.40	49.60
Moridae										
Pseudophycis bachus	0	0	0	0.17	0	0	0	0.20	0	0
Ophidiidae										
Genypterus tigerimus	0	0	0	0	0	0	0	0.20	0	0
Atherinidae unidentified	0	0	0	0	0	0	0	0.40	0	0
Hemiramphidae										
Hyporhamphus melanochir	0	0	0	0.17	0	0	0	0	0	0.20

Table 3. continued

Species	Zone 1 Day	Zone 1 Night	Zone 2 Day	Zone 2 Night	Zone 3 Day	Zone 3 Night	Zone 4 Day	Zone 4 Night	Zone 5 Day	Zone 5 Night
	mean haul^{-1}		mean haul^{-1}		mean haul^{-1}		mean haul^{-1}		mean haul^{-1}	
Zeidae unidentified	0.20	0	0	0	0	0	0	0	0	0
Syngnathidae										
Mitotichthys mollisoni	0.20	0	0	0	0	0	0	0	0	0
Stigmatopora argus	0	0.40	0.08	0	0	0	0.20	0.20	0	0.20
Vanacampus phillipi	0	0	0	0	0	0	0	0	0	0.20
Vanacampus margaritifer	0	0.20	0	0	0	0	0	0	0	0
Stigmatopora nigra	0.20	0	0	0	0	0	0	0	0	0
Hippocampus breviceps	0	0.20	0	0	0	0	0	0	0	0
Scorpaenidae										
Maxillicosta scabriceps	0.60	0.40	0	0.04	0	0.40	0	0.20	0	0
Gymnapistes marmoratus	0.20	0	0.20	0.22	0.25	0	0	0.20	1.00	1.00
Nesosebastes scorpaenoides	0	0	0.04	0.04	0	0.40	0	0.60	0	0
Triglidae										
Lepidotrigla papilio	1.00	0.20	0.60	0.91	0	0.40	0	0.40	0	0
Lepidotrigla vanessa	0	0	0	0.04	0	0	0	0	0	0
Platycephalidae										
Platycephalus bassensis	3.80	0.80	3.60	7.87	3.00	6.60	0	1.20	1.80	1.00

Table 3. continued

Species	Zone 1 Day	Zone 1 Night	Zone 2 Day	Zone 2 Night	Zone 3 Day	Zone 3 Night	Zone 4 Day	Zone 4 Night	Zone 5 Day	Zone 5 Night
	mean haul^{-1}		mean haul^{-1}		mean haul^{-1}		mean haul^{-1}		mean haul^{-1}	
Platycephalus speculator	0	0.20	0	0.04	0.25	0	0.20	0.20	0.20	0.20
Apogonidae										
Siphaemia cephalotes	0	0	0.08	0.22	0.50	3.40	22.00	13.20	2.80	36.40
Vincentia conspersa	0	0	0.04	0	0	2.20	0.60	1.80	1.20	1.00
Sillaginidae										
Sillaginodes punctata	0	0	0	0	0	0	0	0.40	0	0.20
Sparidae										
Pagrus auratus	0	0	0	0.09	0	1.00	0	0	0	0
Mullidae										
Upeneichthys vlamingii	0	0.20	0.04	0.04	0	0	0.60	0.20	0	0
Odacidae										
Neoodax balteatus	0	0	0.08	0.13	0.25	0.60	2.40	5.40	31.40	27.80
Percophidae										
Enigmapercis reducta	0	0.60	0	0	0	0	0	0	0	0
Creediidae										
Creedia haswelli	0	1.60	0	0	0	0	0	0	0	0

Table 3. continued

Species	Zone 1 Day	Zone 1 Night	Zone 2 Day	Zone 2 Night	Zone 3 Day	Zone 3 Night	Zone 4 Day	Zone 4 Night	Zone 5 Day	Zone 5 Night
	mean haul^{-1}		mean haul^{-1}		mean haul^{-1}		mean haul^{-1}		mean haul^{-1}	
Leptoscopidae										
Crapatalus munroi	0.20	0.40	0	0	0	0	0	0	0	0
Uranoscopidae										
Kathetostoma laeve	0.20	0	0	0	0	0	0	0	0	0
Clinidae										
Cristiceps australis	0.80	0.20	0.08	0.30	0	0	0.40	2.60	0.20	0.20
Heteroclinus sp.1	0.40	0	0	0	0	0	0	0	0	0
Heteroclinus adelaide	0	0	0	0	0	0	0	0.20	0.60	0.40
Callionymidae										
Eocallionymus papilio	0	0	0	0.04	0	0	0.20	0.60	0	0
Gobiidae										
Arenigobius bifrenatus	0	0	0	0	0	0	0	0	0	18.40
Arenigobius frenatus	0	0	0	0	0	0	0	0	0.20	0
Callogobius mucosus	0.20	0	0	0.13	0	0	0	0.20	1.40	0
Nesogobius.sp.2.	3.20	0.20	0.40	2.39	0.50	6.80	0.40	12.40	0	2.00
Nesogobius sp.5	0	2.20	0	0	0	0	0	0	0	0
Nesogobius sp.6	0	0	0	0	0	0	0	0.40	0	0
Nesogobius sp.7	0.40	0.40	0	0	0.25	0.20	0	2.80	0	0.20

Table 3. continued

Species	Zone 1		Zone 2		Zone 3		Zone 4		Zone 5	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
	mean haul^{-1}		mean haul^{-1}		mean haul^{-1}		mean haul^{-1}		mean haul^{-1}	
Nesogobius hinsbyi	0.80	0.60	6.96	8.52	0.25	20.20	0	1.40	0.20	0.20
Amoya pflaumi	0	0	0.28	1.26	0.25	2.40	0.20	4.20	5.40	4.60
Bothidae										
Arnoglossus bassensis	0.60	0	0	0	0	0	0	0	0	0
Pleuronectidae										
Ammotretis rostratus	0.80	0.20	0	0	0.25	0	0	0	0.40	0
Rhombosolea tapirina	0	0	0.04	0	0	0.40	0.20	0.20	0.20	0.20
Monacanthidae										
Brachaluteres jacksonianus	0	0	0	0	0	0.20	0.40	1.20	0	0.20
Acanthaluteres spilomelanurus	0	0	0	0	0	0	0.40	3.40	14.00	51.00
Acanthaluteres vittiger	0	0.80	0.04	0	0	0	0.20	0.20	0	0
Monacanthidae larvae unidentified	0	1.00	0	0.04	0	0	0	0	0	0
Scobinichthys granulatus	0	0	0	0	0	0	0	0	0.20	0.20
Meuschenia australis	0.20	0	0	0.04	0	0	0	0	0	0
Meuschenia scaber	0	0	0	0.09	0	0	0	0	0	0
Tetraodontidae										
Tetractenos glaber	0	0.40	0	0	0	0	0	0	0.20	0

Table 3. continued

Species	Zone 1		Zone 2		Zone 3		Zone 4		Zone 5	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
	mean haul^{-1}		mean haul^{-1}		mean haul^{-1}		mean haul^{-1}		mean haul^{-1}	
Diodontidae										
Diodon nicthemerus	0	0	0.08	0.04	0	0.20	0.20	0.20	0.20	0
Mean abundance (No. per haul)	16.40	11.40	13.00	25.26	6.50	48.00	28.60	61.40	62.20	195.40
Total number of species	19	21	18	28	11	17	15	30	20	22

Table 4. List of species and mean catch rates of fish collected during beam trawl sampling concentrated in the northern end of Port Phillip Bay in January and May 1997.

Species	January		May
	Day	Night	Night
	mean haul^{-1}		
Urolophidae			
Urolophus paucimaculatus	0.33	0	0
Ophichthidae			
Muraenichthys breviceps	0	0.4	0
Clupeidae			
Hyperlophus vittatus	0	0	0.5
Engraulis australis	0	0	0.33
Moridae			
Pseudophycis bachus	0	0.2	0
Ophidiidae			
Genypterus tigerimus	0	0.2	0
Hemiramphidae			
Hyporhamphus melanochir	0	0	0.08
Syngnathidae			
Stigmatopora argus	0.17	0	0
Scorpaenidae			
Gymnapistes marmoratus	0	0	0.08
Neosebastes scorpaenoides	0	0.4	0
Triglidae			
Lepidotrigla papilio	0.33	0.2	0.42
Platycephalidae			
Platycephalus bassensis	3	5.8	5
Apogonidae			
Siphaemia cephalotes	0	0	0.33
Vincentia conspersa	0.17	1.4	0.33
Sillaginidae			
Sillago flindersi	0	0	0.08
Carangidae			
Trachurus declivis	0	0	0.08
Sparidae			
Pagrus auratus	0	0.6	0

Table 4. continued

Species	January Day	January Night	May Night
	mean haul^{-1}		
Odacidae			
Neoodax balteatus	0.17	1.6	0
Clinidae			
Cristiceps australis	0	0.8	0
Callionymidae			
Eocallionymus papilio	0	0.2	0
Gobiidae			
Callogobius mucosus	0	0.2	0
Nesobobius sp. 2	3.50	3	1.67
Nesogobius sp.6	0	0	0.75
Nesogobius sp.7	0.17	0.2	0
Nesogobius hinsbyi	18.50	17.8	1.58
Amoya pflaumi	0	0.2	2.58
Pleuronectidae			
Ammotretis rostratus	0	0	0.08
Rhombosolea tapirina	0.17	0	0
Monacanthidae			
Brachaluteres jacksonianus	0	0	0.08
Scobinichthys granulatus	0	0	0.08
Diodontidae			
Diodon nicthemerus	0.17	0	0.25
Contusus richei	0	0	0.17
Mean abundance (No. per haul)	26.67	33.2	14.5
Total number of species	11	16	19

Introduced species

One introduced species was captured in significant numbers. The introduced gobiid, *Amoya pflaumi*, was the eighth most abundant species captured throughout the Bay. Prior to this study, *A. pflaumi* had only been recorded from the Yarra River estuary (M. Gomon, pers. comm.). This study revealed that it was distributed widely throughout the bay, occurring in all zones except zone 1 (Table 1). *A. pflaumi* was most abundant in zone 5 (the Geelong Arm/Corio Bay). Sizes of *A. pflaumi* ranged from 10 to 70 mm TL. The largest *A. pflaumi* were

Geelong Arm/Corio Bay). Sizes of *A. pflaumi* ranged from 10 to 70 mm TL. The largest *A. pflaumi* were captured in the central part of the Bay (zone 2), smaller fish predominated in the eastern side of the Bay and into the Geelong Arm (zones 4 and 5). The smallest fish of 10-15 mm TL were captured in zone 4 in February (Fig. 7).

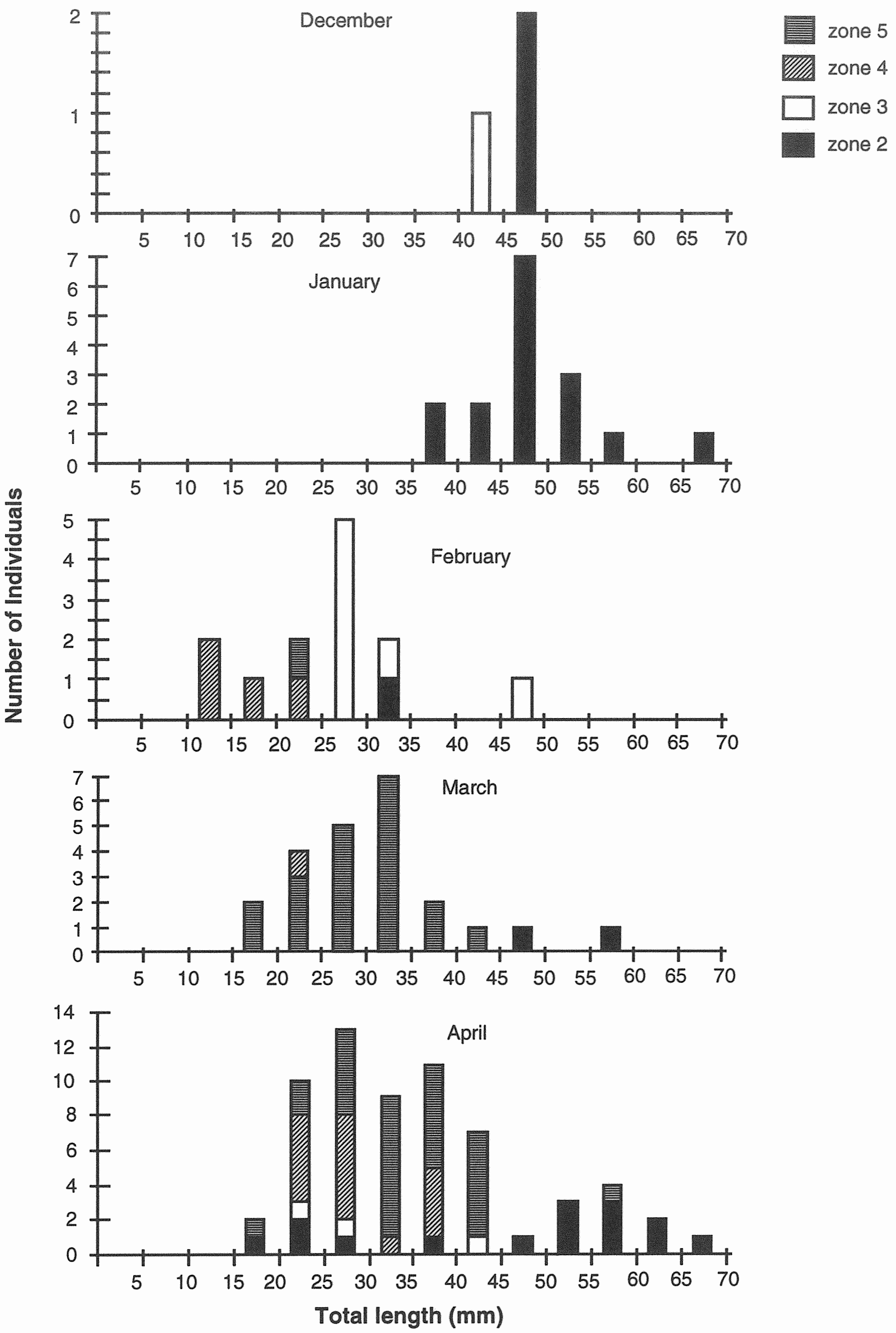

Figure 7. Size distributions of *Amoya pflaumi* captured with the beam trawl in Port Phillip Bay from December 1996 to April 1997.

The only commercial species captured in significant numbers were sand flathead, *Platycephalus bassensis*, and Australian anchovy, *Engraulis australis*. Other commercial species that were caught in small numbers were greenback, *Rhombosolea tapirina* and long snout flounder, *Ammotretis rostratus*, Yank flathead, *Platycephalus speculator,* sandy sprat, *Hyperlophus vittatus*, and King George whiting, *Sillaginodes punctata*.

Sand flathead, *Platycephalus bassensis*

Sand flathead were common in all zones, but were most abundant in zones 2 and 3 (Table 1). The sizes of sand flathead captured ranged from 3 to 35 cm TL (Fig. 8). The size distribution of sand flathead showed three main groups of fish. Based on size at age data from Brown (1977), the size groups would have corresponded to newly recruited 0+ age fish (3-7 cm TL in December), fish of 1+ age (12-17 cm TL in December) and fish of mixed ages greater than 2 years (> 18 cm TL). Newly recruited juveniles of 3 to 10 cm TL were taken predominantly in the central and southern parts of the bay (zones 1 and 2), and predominantly from December through to February (Fig. 8). Between December and April, recruits had grown from about 5 cm TL to about 11 cm TL. Larger fish were taken in all zones and the majority of fish captured were between 20 and 30 cm TL (Fig. 8).

Australian anchovy, *Engraulis australis*

Australian anchovy where captured in all zones except zone 1. The size distribution of the anchovies was distinctly bimodal. Large numbers of recruits from 2.5 to 6 cm TL were captured in February and in April on the eastern side of the Bay. Adult fish of 8.5 to 12 cm TL were captured throughout the sampling period (Fig. 9).

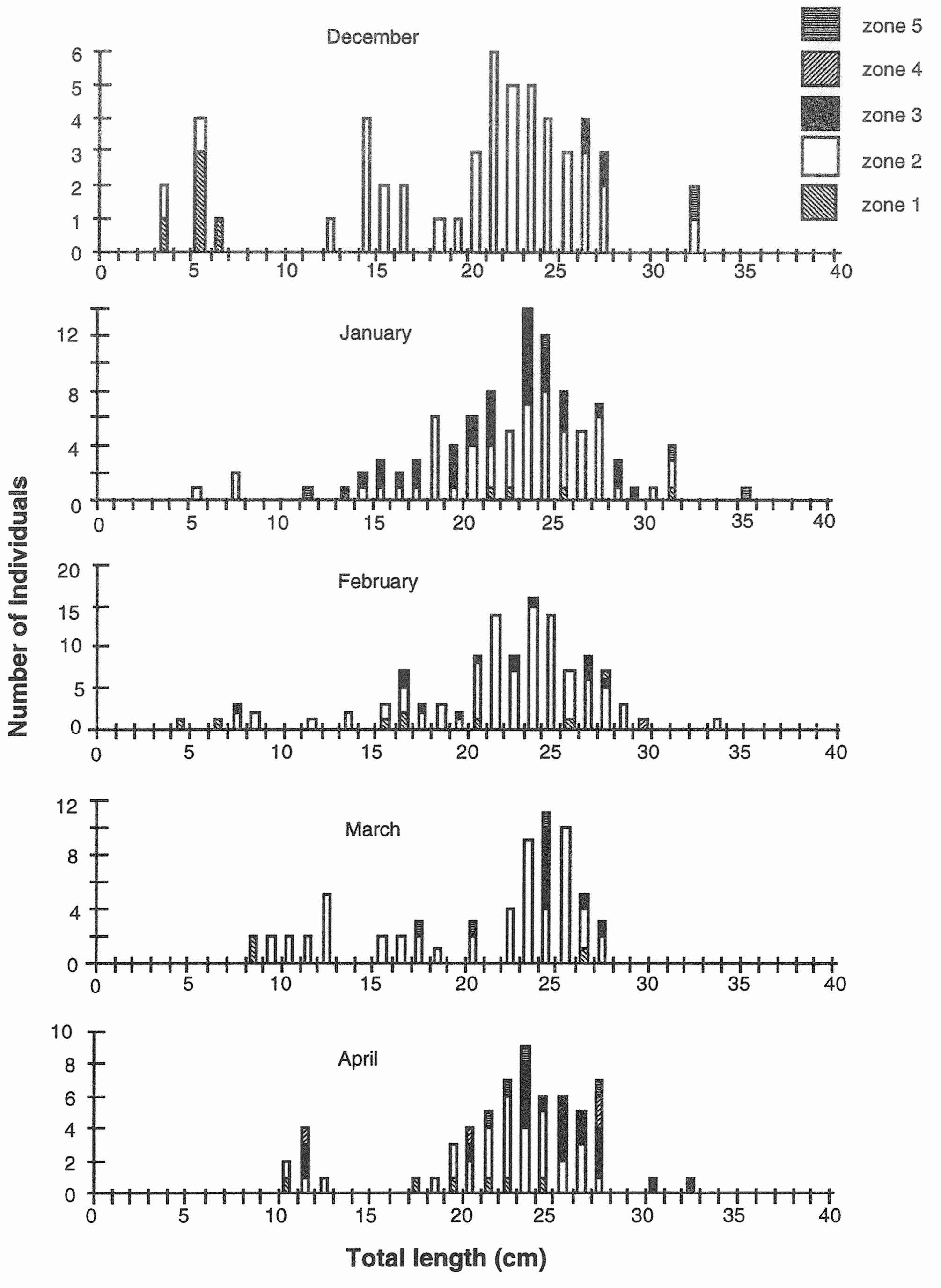

Figure 8. Size distribution of sand flathead, *Platycephalus bassensis*, captured by the beam trawl in Port Phillip Bay from December 1996 to April 1997.

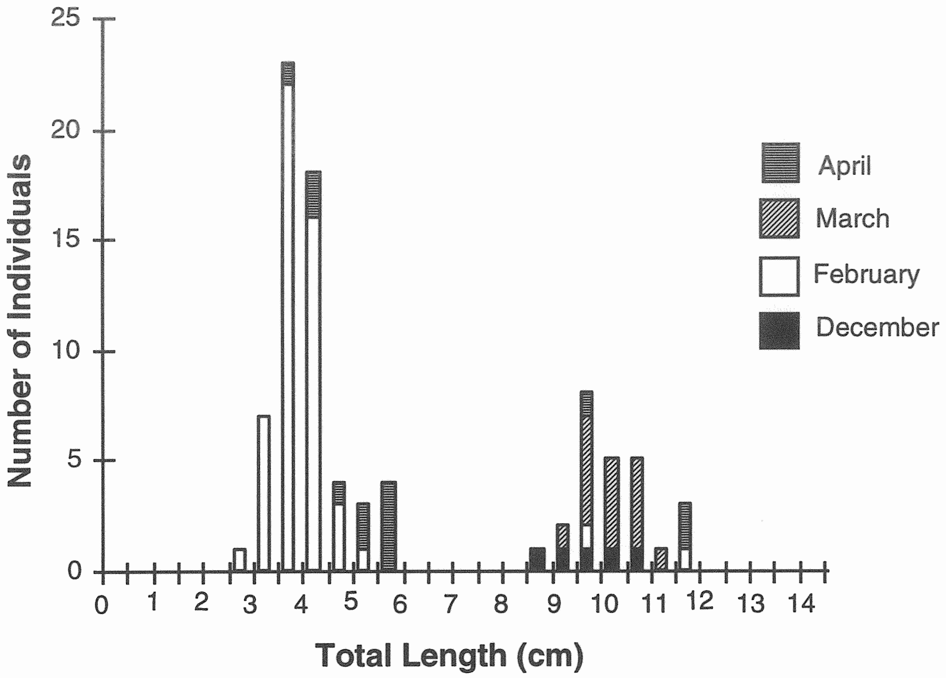

Figure 9. Size distribution of Australian anchovy, *Engraulis australis*, captured by the beam trawl in Port Phillip Bay from December 1996 to April 1997.

6.2 Beach seine survey of estuarine habitats within Port Phillip Bay

A total of 3,195 fish, comprising approximately 40 species, were collected during sampling of estuarine sites within the Bay (Table 5). No recently settled snapper were collected at any of the estuarine sites.

Analysis of variance (December data excluded) revealed no significant effect of estuary or month on logged total abundance of fish (Table. 6, Fig. 10). There was, however, a significant effect of estuary on the number of species collected (Table. 7) . Tukey's post-hoc comparisons revealed that samples from the Grammer School Lagoon had significantly (Tukey's test $p<=0.003$) higher species abundance than all the other estuarine sites, which were not significantly different from each other (Fig. 11). However, with December data included, a total of 27 species were collected from the Yarra River estuary, including Greenwich Bay, 26 species from the Werribee River estuary, 25 species from the Grammar School Lagoon and 16 species from the Patterson River estuary (Table 5).

The five most abundant species found at each of the estuarine sites were as follows: Patterson River estuary- yellow-eye mullet, *Aldrichetta forsteri*, followed by common galaxias, *Galaxias maculatus*, Tamar River goby, *Favonogobius tamarensis*, longfin goby, *Favonogobius lateralis*, and West Australian salmon, *Arripis truttacea* ; Yarra River estuary- glass goby, *Gobiopterus semivestitus*, followed by hardyheads, Atherinid species, bridled goby, *Arenogobius frenatus*, sandy sprat, *Hyperlophus vittatus*, and smooth toadfish, *Tetractenos glaber*;

vittatus, King George whiting, *Sillaginodes punctata*, and bluespot goby, *Pseudogobius olorum*; Grammar School Lagoon-*Sillaginodes punctata,* followed by, *Neoodax balteatus,* atherinid species,bridled goby *Arenogobius frenatus,* and spotshoulder weedfish, *Heteroclinus perspiculatus* (Table 5).

Table 5. List of species and mean catch rates of fish collected during monthly sampling of estuaries around Port Phillip Bay from December 1996 to April 1997 (note data for Yarra includes December samples from Greenwich Bay)

	Estuary			
Species	Patterson	Yarra	Werribee	Grammar School
	mean haul^{-1}			
Urolophidae				
Trygonoptera mucosa	0	0	0.06	0
Clupeidae				
Hyperlophus vittatus	0	3.39	12.88	0
Engraulididae				
Sprattus novaehollandiae	0	0.11	0	0
Galaxiidae				
Galaxias maculatus	19.67	0	0	0
Atherinidae				
Atherinosoma microstoma	0.61	0.06	0.81	1.75
Kestratherina esox	0	0	0	0.19
Leptatherina presbyteroides	0.50	0	0.06	0.19
Unidentified Atherinidae	0.45	15.05	0.19	0.13
Syngnathidae				
Stigmatopora argus	0.06	0.67	0.19	1.13
Stigmatopora nigra	0	2.06	15.06	0.13
Urocampus carinirostris	0	0	0	0.19
Vanacampus phillipi	0	0	0	0.81
Platycephalidae				
Platycephalus laevigatus	0	0	0	0.19
Platycephalus speculator	0.22	0	0	0.31
Unididentified Platycephalidae	0	0.06	0	0

Table 5. continued

Species	Patterson	Yarra	Werribee	Grammar School
	Estuary			
	mean haul^{-1}			
Apogonidae				
Siphaemia cephalotes	0	0.11	0	0
Sillaginidae				
Sillaginodes punctata	0	0.56	2.69	4.06
Arripidae				
Arippis truttacea	1.56	0	0.06	0
Sparidae				
Acanthopagrus butcheri	0	0.22	0.19	0
Mugilidae				
Aldrichetta forsteri	22.22	1.56	20.94	0.06
Odacidae				
Neoodax balteatus	0.11	1.28	0.13	2.31
Blenniidae				
Parablennius tasmanianus	0	0	0.06	0
Clinidae				
Cristiceps australis	0	0.06	0.06	0.38
Heteroclinus adelaide	0	0	0.06	0.31
Heteroclinus perspicillatus	0	0	0	1.25
Gobiidae				
Acanthogobius flavimanus	0	0.78	0.06	0
Arenigobius bifrenatus	0	0.28	0.06	0.88
Arenigobius frenatus	0	3.94	0	1.75
Favonigobius lateralis	1.72	0.11	0.50	0.75
Favonigobius tamarensis	1.94	1.11	0.75	0
Gobiopterus semivestitus	0	19.22	1.31	0
Nesogobius sp.1	0.61	0.17	0	0
Nesogobius sp.3	0	0	0	0.31
Pseudogobius olorum	0	0.56	1.81	0.06
Redigobius macrostma	0	0.56	0	0
Tasmanogobius lasti	0	0.89	0.88	0

Table 5. continued

Species	Patterson	Yarra	Werribee	Grammar School
	Estuary			
	mean haul^{-1}			
Pleuronectidae				
Rhombosolae tapirina	0.94	0.17	0.56	0.13
Ammotretis rostratus	0.61	0	0	0
Monacanthidae				
Meuschenia freycineti	0	0.06	0	0.06
Tetraodontidae				
Contusus unidentified juveniles	0	0	0.13	1.19
Tetractenos glaber	1.00	2.72	0.06	0.19
Unidentified	0	0	0.06	0
Mean abundance (No. per haul)	52.22	55.72	59.63	18.69
Total number of species	16	27	26	25

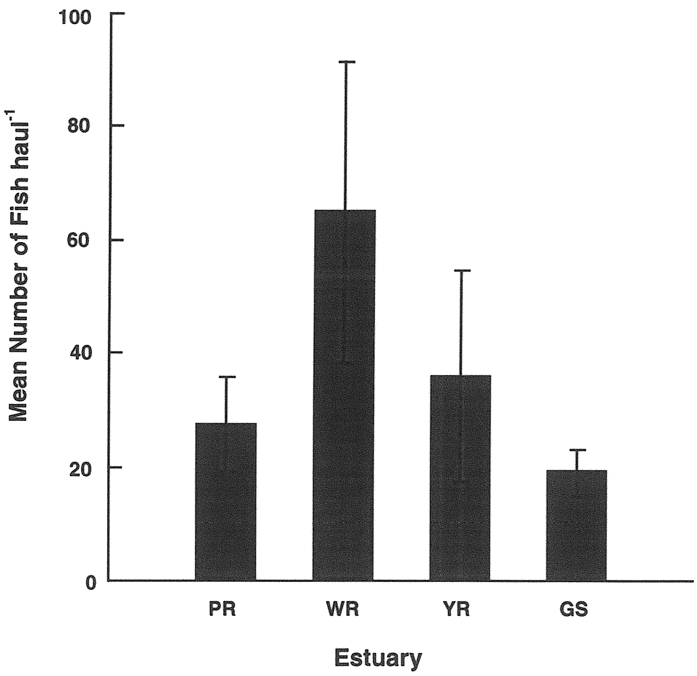

Figure 10. Comparisons of mean number of fish captured per beach seine net haul, between estuaries within Port Phillip Bay from January to April 1997. Error bars are one standard error. PR=Patterson River estuary, WR=Werribee River estuary, YR=Yarra River estuary, GS=Grammar School Lagoon

Table 6. Analysis of variance investigating effects of month and estuary on log(x+1) transformed abundance of fish sampled by beach seine net in estuaries around Port Phillip Bay from January to April 1997.

Source	DF	MS	F	P
Month	3	0.255	0.131	0.941
Estuary	3	2.569	1.325	0.279
Month*Estuary	9	1.506	0.776	0.639
Error	41	1.940		

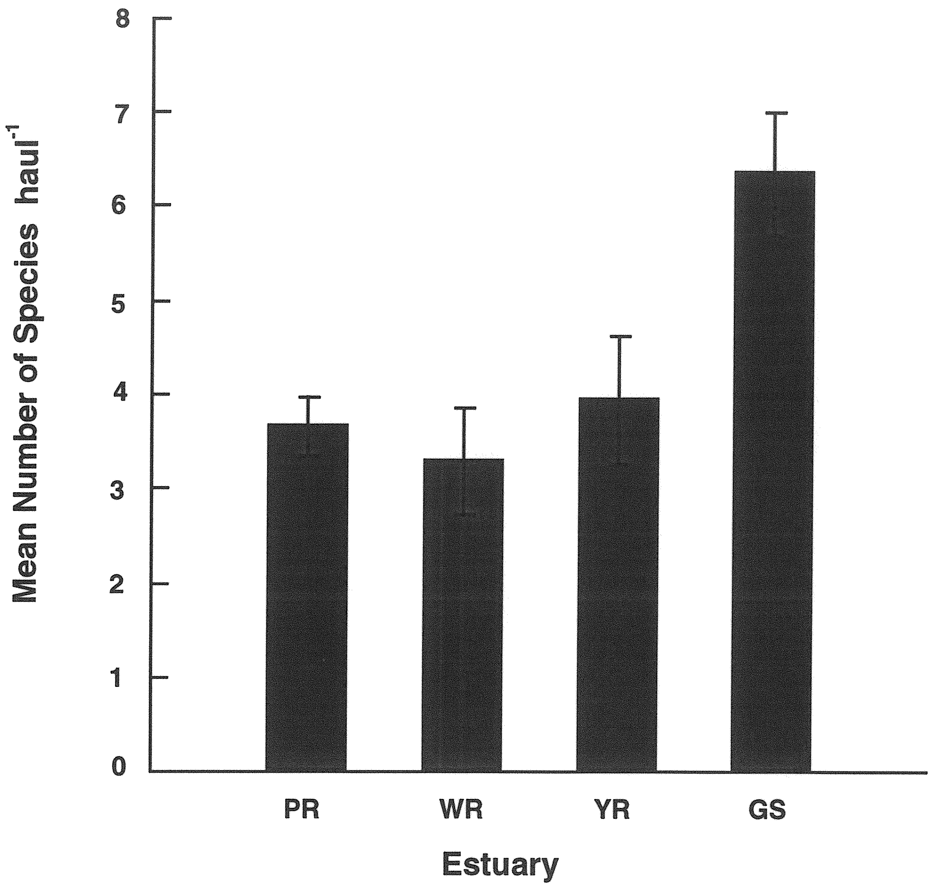

Figure 11. Comparison of mean number of species captured per beach seine net haul, between estuaries within Port Phillip Bay from January to April 1997. Error bars are one standard error. PR=Patterson River estuary, WR=Werribee River estuary, YR=Yarra River estuary, GS=Grammar School Lagoon

Table 7. Analysis of variance investigating effects of month and estuary on number of species captured by beach seine net in estuaries around Port Phillip Bay from January to April 1997.

Source	DF	MS	F	P
Month	3	2.850	0.652	0.587
Estuary	3	34.001	7.773	0.000
Month*Estuary	9	4.783	1.094	0.389
Error	41	4.374		

Introduced species

One introduced species, the yellowfin goby, *Acanthogobius flavimanus*, was captured from estuarine sites. This species was found in the Yarra and Werribee River estuaries.

Commercial species

Commercial species captured in significant numbers in estuaries included, *Sillaginodes punctata*, *Aldrichetta forsteri*, *Arripis truttacea*, and *Hyperlophus vittatus*. Other commercial species captured in small numbers were flathead, Platycephalus spp, green back flounder, *Rhombosolea tapirina*, and black bream, *Acanthopagrus butcheri* .

King George whiting, *Sillaginodes punctata*

King George whiting were most abundant in the Grammar School Lagoon, followed by the Werribee River estuary, and the Yarra River estuary (Table. 5). No *S. punctata* were captured in the Patterson River estuary. The size distribution of *S. punctata* shows a group of new recruits that were 3 to 5.5 cm TL in December, which grew to 14 cm TL by March (Fig. 12). A small number of fish of 9.5 to 13 cm TL were present during December, and a group of fish of 16-20 cm TL was present in February (Fig. 12).

Yellow-eye mullet, *Aldrichetta forsteri*

Yellow-eye mullet were common at all estuarine sites, but were captured in greatest numbers in the Patterson and Werribee River estuaries (Table 5). The size range of fish was 1.5 to 15 cm TL (Fig. 13). In December, most fish were from the Patterson River and the size distribution showed two clear modes of fish, a group of new recruits from 1.5 to 4.5 cm TL and a group of fish that were 4-8 cm TL. In the later months, new recruits increased in size to 3.5-5 cm TL. In January and February fish from 7-11 cm TL were abundant. Few fish were captured in March, and in April and new recruits of 4-6 cm TL dominated samples (Fig. 13).

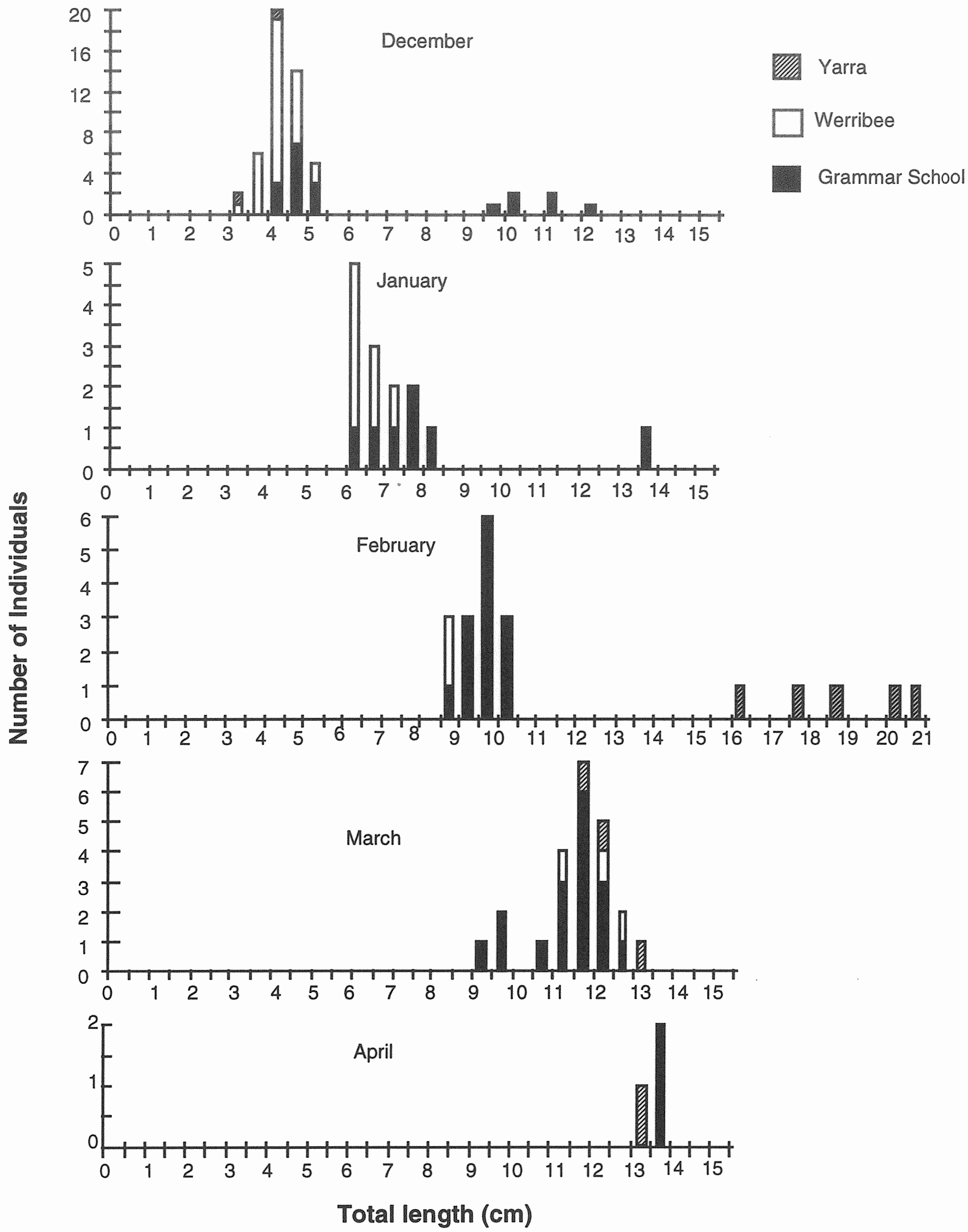

Figure 12. Monthly size distributions of King George whiting, *Sillaginodes punctata,* captured with the beach seine net from estuaries within Port Phillip Bay from December 1996 to April 1997.

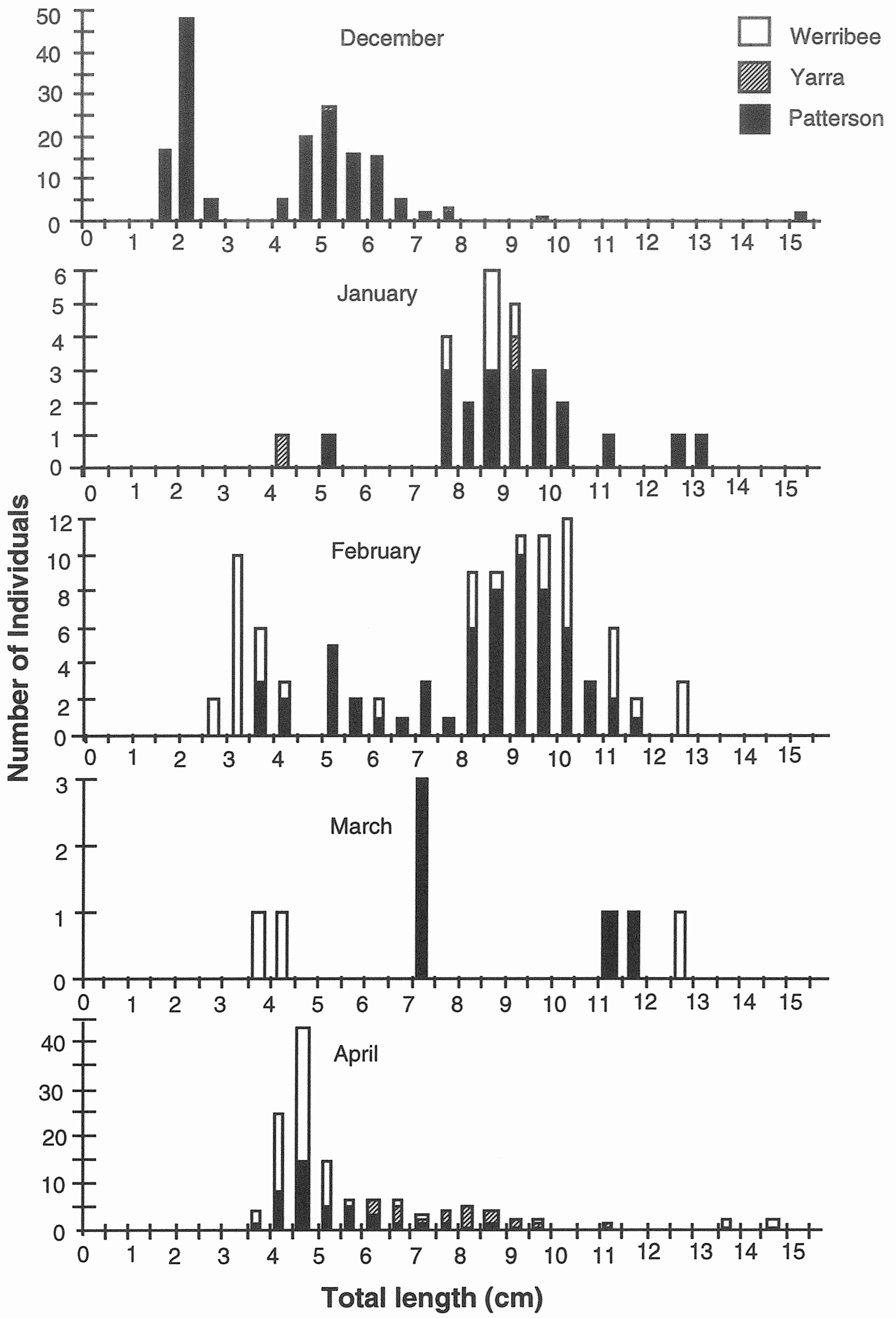

Figure 13. Monthly size distributions of yellow-eye mullet, *Aldrichetta forsteri,* captured with the beach seine net from estuaries within Port Phillip Bay from December 1996 to April 1997.

West Australian salmon, *Arripis truttacea*

West Australian salmon were only captured in significant numbers in the Patterson River estuary during December (Fig. 5). The fish captured were small juveniles ranging in size from 6.5 to 9 cm TL.

Sandy sprat, *Hyperlophus vittatus*

Sandy sprat were captured in greatest numbers in the Werribee and Yarra River estuaries (Table 5). The majority of fish were small juveniles of 3.2 to 4 cm TL, with a few larger fish up to 10 cm TL.

Greenback flounder, *Rhombosolea tapirina*

Greenback flounder were captured in small numbers in all estuaries, but were most abundant in the Patterson River estuary (Table 5). In all estuaries fish were small juveniles ranging in size from 3.5 to 13 cm TL.

Flathead, *Platycephalus* spp.

Juvenile rock flathead, *P. laevigatus*, were captured in the Grammar School Lagoon while juvenile yank flathead, *P. speculator* were captured in the Grammar School Lagoon and the Yarra and Patterson River estuaries (Table 5). The size of rock flathead ranged from 7-7.5 cm TL, and yank flathead from 4-6 cm TL.

Black bream, *Acanthopagrus butcheri*

A small number of black bream were captured in the Yarra and Werribee River estuaries (Table 5). These fish ranged in size from 5.5 to 10.5 cm TL.

6.3 Video analysis of deeper water habitats within Port Phillip Bay

Video transects were conducted at 55 sites throughout the bay, ranging in depth from approximately 5 to 25 m. All the sites were over soft-bottom. The main habitat variables investigated were macroalgal cover, cover of large sessile organisms and sediment type.

Macroalgae was absent from sites deeper than about 15 m. Greatest cover of macroalgae was along the eastern side of the bay and into the Geelong Arm (zone 5) (Fig. 14). Cover of sessiles was greatest in depths less than about 15 m. Sessiles were most abundant in the northern half of the Bay (Fig. 15). The predominant sessile organism was cunjevoi, *Pyura stolonifera*, while mussels, oysters and the fan worm , *Sabella spallanzanii*, were also common.

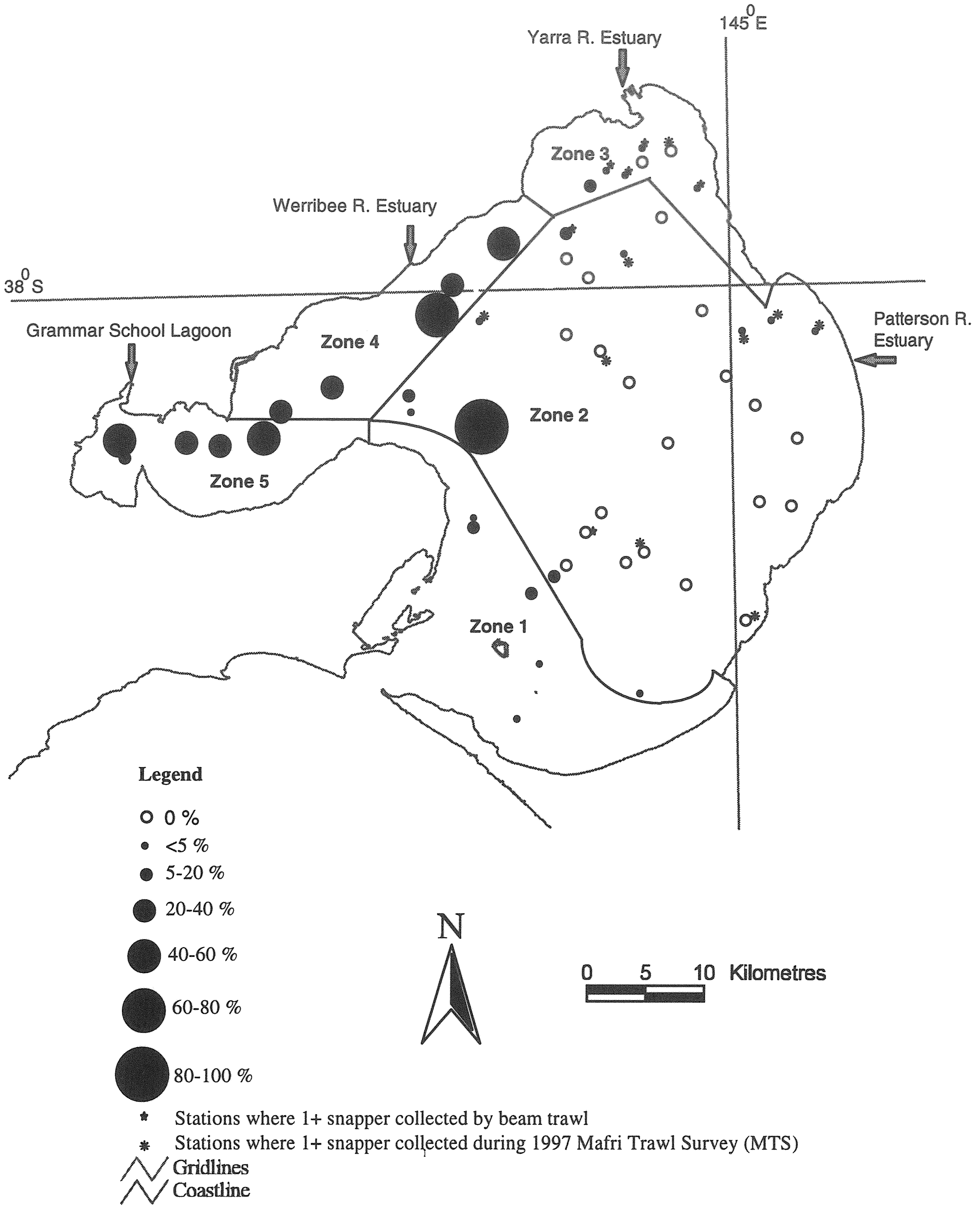

Figure 14. Map of Port Phillip Bay showing distribution and approximate percentage cover of macroalgae determined during video surveys in May 1997. Sites where one year old snapper were sampled are also shown.

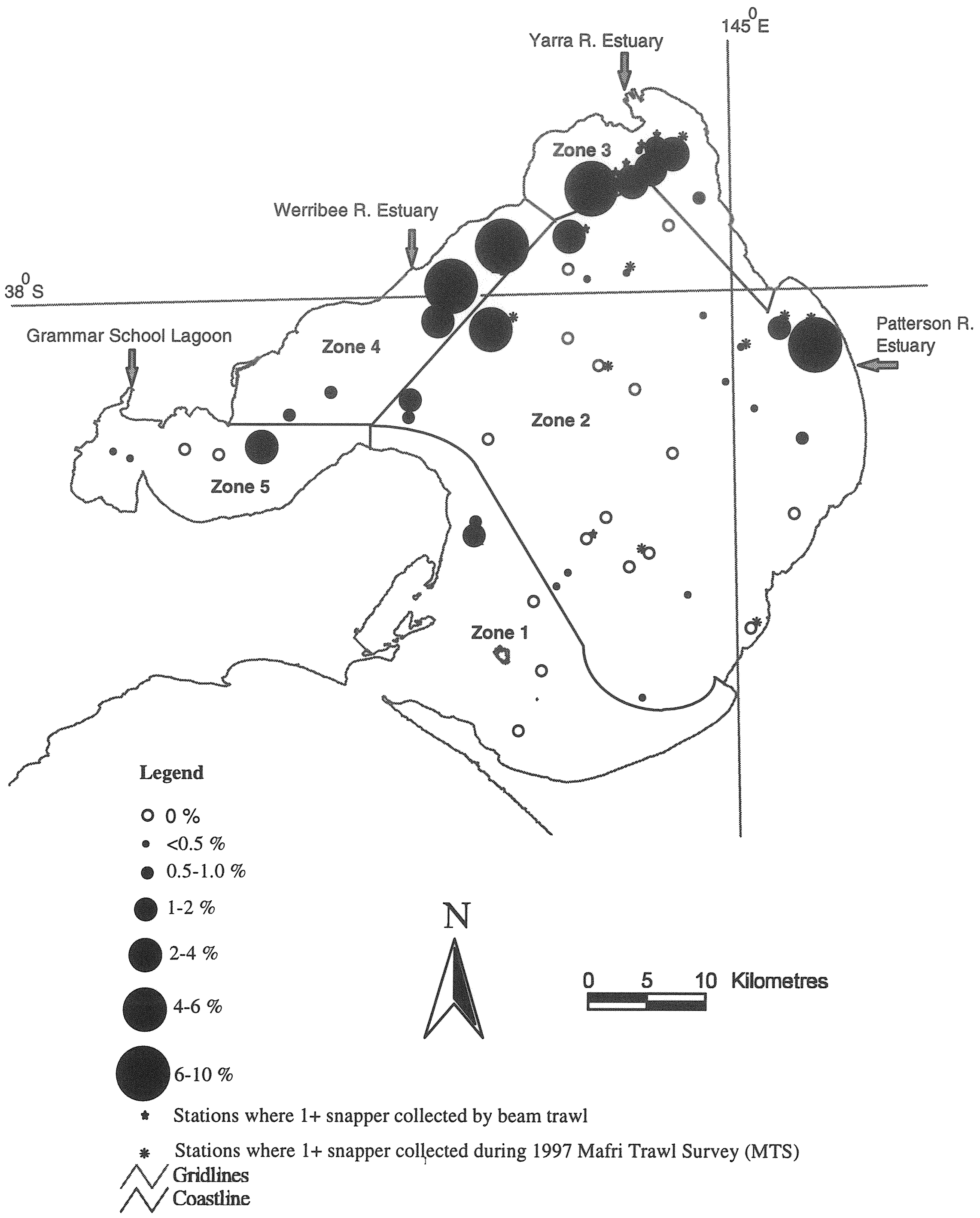

Figure 15. Map of Port Phillip Bay showing distribution and approximate percentage cover of sessiles determined during video surveys in May 1997. Sites where one year old snapper were sampled are also shown.

Habitats of 1+ snapper

Correlations between snapper abundances and habitat variables were not possible due to the small sample size. Snapper of 1+ age class were captured during this study over bottom with zero or very low cover of macroalgae, and with sessile organisms, predominantly, *Pyura stolonifera,* present at all but one site in the centre of the bay (Fig. 14, 15). Snapper were captured over all the major soft sediment types present in the bay.

Large numbers of 1+ snapper were captured during the MTS, Feb-April 1997. The habitats where these fish were captured were typically low in macroalgal cover. Larger sessile organisms such as *Pyura stolonifera* and oysters were present in some but not all areas. Significant numbers were captured over all sediment types, however, largest numbers were taken over silty and clayey sand. In both studies, snapper of 1+ age class were captured in a range of depths from 8 to 22 m.

Correlations between habitat variables and fish distribution

Species number and fish abundance:

Species number was significantly positively correlated with percentage cover of macroalgae (Spearman's r (r_S)=0.335, $0.02<p<0.05$) and percentage cover of sessiles (r_S=0.366, $0.02<p<0.01$). Total abundance of fish was significantly positively correlated with percentage cover of sessiles (r_S=0.319, $0.02<p<0.05$) but was not with percentage cover of algae. Sediment type was not significantly correlated with either species number or total abundance.

Correlations between abundance of individual fish species and habitat variables

Percentage cover of macroalgae:

Eight species were collected in significantly large numbers to perform correlations with habitat variables. Species that had significant positive correlations with percentage cover of macroalgae included; little rock whiting, *Neoodax balteatus* (r_S=0.632, $p<0.001$); bridled leatherjacket, *Acanthaluteres spilomelanuru* (r_S=0.497, $p<0.001$); Wood's siphon fish, *Siphaemia cephalotes* (r_S=0.547, $p<0.001$); and the threadfin sandgoby, *Nesogobius* sp. 2 (r_S=0.440, $0.002<p<0.005$). Species that had significant negative correlations included sand flathead, *Platycephalus bassensis* (r_S=-0.400, $0.005<p<0.01$) and the orangespotted goby, *Nesogobius hinsbyi*, (r_S=-0.447, $0.002<p<0.005$).

Percentage cover of sessiles:

Species that had significant positive correlations with % cover of sessiles included *Neoodax balteatus* (r_S=0.398, $0.005<p<0.01$), *Nesogobius* sp.2 (r_S=0.481, $0.001<p<0.002$) and *Vincentia conspersa* (r_S=0.425, $0.002<p<0.005$).

Sediment grade:

Sediment grade was significantly positively correlated with *Platycephalus bassensis* abundance, suggesting greater abundances on finer sediments (r_S=0.411, $0.001<p<0.002$).

Introduced species

Abundance of *Amoya pflaumi* showed no correlation with any of the habitat variables.

7. Discussion

This project failed to achieve the primary objective of collecting newly-settled snapper. This failure could be attributed to several factors. For example, the sampling equipment may have been inefficient in capturing newly-settled snapper or the spatial coverage of the sampling program may not have been extensive enough to ensure coverage of discrete habitats or areas where newly-settled snapper may have congregated. However, we believe that the most likely reason for our failure to collect newly settled snapper was very low or even failed recruitment during the study period.

7.1 Beam trawl survey of deeper water habitats within Port Philip Bay

Snapper

The beam trawl was efficient in capturing a large range of species with varying swimming abilities, behavioural characteristics, habitat usage and sizes. Species such as sand flathead and several species of gobiids that live directly on the bottom were captured in large numbers, as were species such as little rock whiting, bridled leatherjacket and anchovies that inhabit the water column above the bottom. One year old snapper, which would be assumed to have greater avoidance capabilities than newly-settled snapper, were also captured, albeit only at night. The mesh sizes used also retained fish below the size of newly-settled snapper. In light of these facts, and given the success of similar sampling equipment in Japan (Azeta et al. 1980), we do not believe that the beam trawl was incapable of sampling newly settled snapper if they were present in the sampling areas. However, given that significantly more fish were captured at night, and that juvenile snapper were only captured at night, future sampling for newly-settled snapper with this equipment would be likely to be most successful at night.

A large number of sites were sampled, spread widely throughout the Bay in depths ranging from 5 to 24 m. These sites encompassed a range of habitat types from unvegetated sediment to areas of high macroalgae cover and abundant sessile organisms such as *Pyura stolonifera*. The only major habitat types not sampled were rocky reef and shallow water sand and seagrass habitats. Rocky reef habitat could not be sampled by beam trawling.

Previous studies conducted in subtidal reef habitats of 1 to 6 m deep around Port Phillip Bay from November 1992 to April 1993 failed to find any newly settled snapper (Jenkins et al. 1996). Sampling of shallow (<3 m deep) sandy unvegetated and seagrass habitats during the same period also failed to capture newly settled snapper (Jenkins et al. 1996). The absence of newly-settled snapper from these habitats during the above study was unlikely to have been due to recruitment failure as significant numbers of newly recruited O+ age snapper were captured in deeper soft sediment habitats during the same period by the annual MTS (MAFRI, unpublished data). Given the large spatial coverage of the deeper parts of the Bay in the present study, it is unlikely that failure to catch newly settled snapper was due to failure to sample a particular deeper water habitat type, or region where snapper may have congregated.

It is possible that newly-settled snapper where very sparsely distributed or highly aggregated and that the area sampled by individual trawls was insufficient to collect them. Studies in Japan suggest that newly settled snapper aggregate near the bottom during the day and separate into solitary individuals at night (Azeta et al. 1980). Whilst the scale of individual beam trawls was relatively small (approx 750 m^2), the large number of samples and large spatial coverage of the Bay, should have been sufficient to capture at least some newly-settled snapper even if they were distributed sparsely or highly aggregated Although previous studies (Jenkins 1986, MAFRI, unpublished) suggest that the northern end of the bay is an area were newly-settled snapper may congregate, we also failed to capture newly-settled snapper in this region of the Bay. Sampling during the annual MTS using a large winged trawl that had successfully captured recently settled recruits in previous years also failed to capture any newly settled recruits during the same period as this study (MAFRI, unpublished).

The most likely reason for the failure to collect newly-settled snapper by beam trawling was that limited spawning and or low egg and larval survivorship resulted in very low or even complete failure in recruitment of newly-settled snapper to Port Phillip Bay during the summer of 1996-97. This scenario is supported by data collected by annual MTS that also suggests that the 1996-1997 summer was particularly poor for recruitment of 0+ age snapper to the Bay (MAFRI, unpublished data). Data from these annual trawl surveys suggests that significant recruitment of O+ age snapper to the Bay has only occurred in four of the last 7 years (MAFRI, unpublished). This suggests strong interannual variability in recruitment of 0+ age snapper to the Bay. Strong interannual variability in recruitment of 1+ snapper has been observed in New Zealand, and it has been shown that recruitment of 1+ snapper is strongly positively correlated with water temperatures during the 0+ year (Francis 1993). Strong interannual variability in abundance of newly-settled snapper has also been noted in Japan (Azeta et al. 1980). The factors influencing recruitment variability in Port Phillip Bay are currently unknown and in need of further study.

To further assess the usefulness of this sampling technique for studies of snapper settlement, sampling will need to be conducted in years and or in regions where snapper settlement is significant.

Other species

Overall, significantly more fish were captured at night and in the Geelong Arm (zone 5). The capture of greater numbers of fish at night suggests that net avoidance by fish was significant during daylight. The greater abundances of fish in the Geelong Arm was due to large catches of bridled leatherjackets, little rock whiting and Wood's siphonfish. These species were associated with macroalgae which was abundant in the Geelong Arm. Of the 61 species captured, the most abundant species were gobies, although commercial species such as sand flathead, and to a lesser extent, anchovies, were captured in significant numbers.

Sand flathead were one of the more abundant species captured in all zones by the beam trawl. Significant numbers of small recruits were only captured in zones 1 and 2, suggesting that the southern and central regions of the bay are the most important for recruitment of 0+ flathead. These new recruits were probably derived from spawning in spring (Brown 1977). Large flathead were captured in all zones but were most abundant in zones 2 and 3. This is consistent with previous studies showing greater abundance of sand flathead in the deeper regions of the Bay (Anon, 1973; Parry et al. 1995).

Anchovies were captured in all regions except the southern end of the Bay. New recruits were abundant in February, a finding which is consistent with studies by Blackburn (1950) and Jenkins (1986) that show spawning of anchovies in summer. The greatest catches of anchovy recruits occurred in the entrance to the Geelong Arm in February. Adults anchovies were most common in northern (zone 3) and eastern (zone 4) parts of the Bay.

New recruits of species such as King George whiting and flounder that are abundant in shallow habitats around the Bay (Jenkins et al. 1996, Jenkins and Wheatley in press) were not captured in the deeper parts of the Bay. This suggests that deeper parts of the Bay are not important nursery habitats for small juveniles of these species.

Another species of interest that was captured in significant numbers during beam trawling was the introduced goby, *Amoya pflaumi*. This species was one of the more abundant species, occurring in all areas except the southern end of the Bay (zone 1). This species is a native of the south east Asian region (Fowler 1972) and has previously only been recorded in Australia from the Yarra River Estuary (M. Gomon, pers. comm.). Transport in ships ballast water is thought to be the most likely mechanism of introduction. Previous to this study, the presence and distribution of the species throughout the Bay was unknown. The ecological impacts of this species are unknown, but given its wide distribution and high abundance throughout the Bay, the potential to compete with native species is significant.

In summary, the ease of deployment from a relatively small, fast research vessel makes this style of beam trawl an ideal, cost effective sampling tool for investigations of small benthic fishes in non reef habitats. There have been no previous surveys of the small benthic fishes of Port Phillip Bay using this type of equipment, and the data obtained during this study will provide valuable baseline data for comparison with future studies.

7.2 Beach seine survey of estuarine habitats within Port Phillip Bay

Snapper

As with the beam trawl, the failure to capture newly-settled snapper from estuaries was unlikely to have been due to inefficiencies in the sampling technique. Beach seines of smaller dimensions to the one used in this study have been used successfully to capture newly settled snapper in Japan (Tsukamoto et al. 1989). The beach seine captured a large range of species including fast swimming fish such as yellow -eye mullet, and bottom dwelling species such as flounder and gobies. The seine net also captured small numbers of a similar sparid species, black bream, *Acanthopagrus butcheri*.

Sampling in estuaries was haphazard with respect to habitat, however, the various habitat types present in the estuaries were sampled over the course of the project. These included seagrass, macroalgae and bare sediment. The absence of newly-settled snapper from shallow water estuarine habitats in Port Phillip Bay is consistent with earlier studies of the same habitats outside of estuaries (Jenkins et al. 1996, Jenkins et al. 1997, Jenkins and Wheatley in press). However, small juveniles of 35 mm in length have been found over seagrass in a large estuarine system in eastern Victoria, the Gippsland Lakes (Rigby 1984). This system is similar to the estuarine system studied by Neira and Potter (1992) in south Western Australia where snapper enter estuaries from coastal waters as late stage larvae of 7 to 11 mm length . In these systems the supply of larval stages appears to be from spawning in coastal waters rather than within the estuary. Recruitment process in these estuarine systems are likely to be very different from those in large bays, such as Port Phillip Bay, were spawning is believed to occur within the embayment (Jenkins 1986).

The failure to capture newly settled snapper from estuaries within the Bay, however, cannot be directly attributed to them not using these habitats. Absence of newly settled snapper may have been due to low or failed recruitment of newly-settled snapper. Further studies in years of known high recruitment are required before definitive statements can be made regarding the importance of estuaries to newly-settled snapper in Victoria.

Other species

Abundance of fish did not vary significantly between estuarine sites. However, samples from the Grammar School Lagoon had significantly higher species numbers than in the other estuaries. Higher species abundance in the Grammar School Lagoon may be related the greater amount of seagrass habitat in this area relative to the other estuaries. Studies in Port Phillip Bay have shown that seagrass harbours greater numbers of species than unvegetated sediments (Jenkins et al. 1996, Jenkins et al. 1997, Jenkins and Wheatley in press).

Of the 40 species captured during sampling in estuaries juveniles of yellow-eye mullet, *Aldrichetta forsteri* and King George whiting, *Sillaginodes punctata,* were the most abundant commercial species. Juveniles of a range of other commercial species including West Australian salmon, *Arripis truttacea*, sandy sprat, *Hyperlophus vittatus,* flathead, *Platycephalus* spp., green back flounder, *Rhombosolea tapirina*, and black bream, *Acanthopagrus butcheri*, were also captured.

Yellow-eye mullet, *Aldrichetta forsteri*, were the most abundant species overall, and were found in all estuaries. Newly recruited *A. forsteri* were captured throughout the sampling period, with the smallest recruits being caught in December. This is consistent with previous studies that suggest *A. forsteri* recruit to estuaries at a length of about 3 cm from mid to late summer until late winter/early spring (Ramm 1986, Jenkins et al. 1993, Jenkins et al. 1996).

Small juveniles (0+ age) of King George whiting, *Sillaginodes punctata,* were most abundant in the Grammar School Lagoon and Werribee River estuary, and were absent from the Patterson River estuary. These fish would have recruited to shallow water habitats in Port Phillip Bay in spring at a size of about 2 cm (Jenkins and May 1994). The absence of recruits from the Patterson River estuary may have been due to the absence of suitable juvenile habitat, seagrass and reef/algae (Jenkins et al. 1996, Jenkins and Wheatley in press).

Individuals of all the commercial species captured during the estuary survey were small juveniles. While this may be partly due to the ability of larger fish to avoid the seine net, it demonstrates that estuarine habitats within Port Phillip Bay provide important nursery areas for a range of commercially important fish species.

7.3 Video analysis of deeper water habitats within Port Phillip Bay

Snapper

The lack of data on the distribution of newly-settled snapper made it impossible to investigate the habitat requirements of these life stages. However, we were able to make some descriptions of habitats used by 1+ age snapper. Juveniles of 1+ age, which are generally about 12-19 cm TL, were most abundant over soft bottom habitats in depths from 8 to 24 m , with low or zero macroalgal cover and often with significant numbers of large sessile invertebrates such as cunjevoi, *Pyura stolonifera*. These soft bottom habitats do not appear to be under any major threat of degradation. Reef habitats were not investigated during this study and the importance of these habitats was not assessed. While, anecdotal information and personal observation suggest that larger juvenile snapper can be found on subtidal reefs, Jenkins et al. (1996) suggested this habitat to be of limited importance to small newly recruited juveniles.

Other species

Correlation analysis suggests that areas with greater cover of macroalgae and large sessile invertebrates may harbour a greater diversity and abundance of fish. Studies in shallow water within Port Phillip Bay have demonstrated that structured habitats such as reef-algae and seagrass have greater numbers of species and abundance of fishes than bare sediments (Jenkins and Wheatley in press). However, as macroalgae and the dominant large sessile, *Pyura stolonifera,* were most abundant in water less than 15 m deep, it is possible that the observed patterns may in some way be related to water depth. Future studies comparing structured with bare habitats in the same depths in deeper parts of the Bay would be required to determine the relative importance of structured and bare habitats to deeper water fish assemblages.

The habitat data was also used to investigate the habitat associations of a range of species that were caught in significant numbers during the beam trawl survey. Several species were associated with structured habitats characterised by abundant macroalgae and large sessile invertebrates such as *Pyura stolonifera*. Sand flathead, *Platycephalus bassensis,* were most abundant in deeper water habitats characterised by finer sediments and little or no cover of macroalgae. Pervious studies have also demonstrated greater abundance of *P. bassensis* in deeper the deeper parts of Port Phillip Bay (Anon, 1973; Parry et al. 1995). The introduced goby, *Amoya pflaumi,* showed no strong associations with any habitat variables and appears to be capable of exploiting the full range of deeper water habitats present in the Bay.

8. Benefits

The benefits of this research lie primarily in the development of the small beam trawl and protocols for its use. This beam trawl is a cost effective method for sampling small benthic fishes. However, further investigations of the efficiency of this sampling technique for collecting newly-settled snapper are required. These tests can only be successful if newly-settled recruits are known to be abundant.

Further benefits lie in the information obtained on deeper water habitats throughout Port Phillip Bay. Descriptions of deeper water habitats used by 1+ snapper and a range of other commercial and non-commercial fish species were obtained. The extensive video footage provides a useful archive of bottom habitats for comparison with future studies.

Benefits also lie in the greater understanding of the deeper water fish assemblages in the bay, in particular smaller benthic species such as gobiids which are not retained by larger sampling equipment. The data obtained on the exotic goby, *Amoya pflaumi*, is the first information on its distribution throughout the bay and may provide valuable data for comparison with future studies of this species.

The information on fish assemblages in the bays estuaries is also valuable for comparison with future studies and demonstrates the role of estuarine habitats as nurseries for a range of important commercial and recreational fish species.

9. Further Development

The development of the beam trawl will enable opportunistic sampling to be conducted in future years to further investigate the usefulness of this sampling method as a tool for monitoring of settlement/recruitment of snapper and other commercial and non-commercial species. It is also possible that this sampling method could be trialed in other areas where numbers of newly-settled snapper are likely to be higher than in Port Phillip Bay.

If the small beam trawl proves to be an efficient sampler of newly-settled snapper when recruitment is known to be significant, long term monitoring could be initiated. The sampling technique could also be used in studies of factors influencing snapper recruitment both in Victoria and in other regions.

To fully understand the habitat requirements of newly-settled snapper, sampling of different habitats needs to be conducted in years of high recruitment. Given the apparent high level of recruitment variability of this species, any study of habitat requirements will need to be conducted over a number of years to ensure at least one year of high recruitment. Alternatively, long term monitoring could be initiated whereby a limited number of sampling trips are conducted early in the settlement season to gauge the magnitude of recruitment. If significant numbers of newly-settled snapper were captured early in the season, then sampling of discrete habitat types could be undertaken using previously developed sampling protocols.

If the absence of newly settled snapper was due to very low or failed recruitment this may become evident as an absence of the 1996-97 year class in future studies of snapper population age structure within Port Phillip Bay.

10. Conclusion

The objective of this project was to develop a small scale, cost effective technique for sampling newly-settled snapper and to determine the habitat requirements of newly-settled snapper.

A small beam trawl suitable for deployment from a small research vessel was successfully designed and protocols for its use were developed. Monthly sampling throughout Port Phillip Bay conducted both during day and night from December 1996 to April 1997. Sampling of the northern end of the bay in January and May also failed to capture any newly-settled snapper. A small number of one year old snapper were captured at night. The reason(s) for the absence of newly-settled snapper are unclear. Overall, 110 sites were sampled with the beam trawl and over 3,500 fish comprising 61 species were taken. It is unlikely that the net was incapable of capturing newly-settled snapper given its ability to capture such a large range of species, including one year old snapper that would have greater avoidance capabilities than newly-settled snapper. We hypothesise that the absence of newly-settled snapper was due to extremely poor or even failed recruitment of newly-settled snapper during the study period.

Sampling of estuarine habitats within Port Phillip Bay using a small beach seine also failed to find newly-settled snapper. Estuaries were demonstrated to provide nursery habitat for a range of other commercially important species. The failure to find newly settled snapper elsewhere in the Bay made it impossible to make any definite statements as to the relative importance of estuarine and deeper water bay habitats as habitat for newly-settled snapper. Their absence from estuaries may have been due to low or failed recruitment rather than avoidance of this habitat.

The lack of data on newly-settled snapper made it impossible to determine the habitat requirements of these life stages. Video of 55 sites throughout the Bay showed that habitats used by one year old snapper were typically low or lacking in macroalgae, and often had significant amounts of large sessile organisms such as cunjevoi, *Pyura stolonifera.* One year old snapper were found over all the major sediment types in the bay, and in the full range of depths sampled from 8 to 24 m.

In conclusion, while the main objectives of this study were not fulfilled, the sampling equipment developed during the project will be valuable in future studies of small demersal fishes, and may still prove suitable for investigating recruitment and habitat requirements of newly-settled snapper in future years.

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12. Appendix 1: Intellectual Property

The major intellectual property is in the development of the small beam trawl and protocols for its use.

13. Appendix 2: Staff

Mr. Paul Hamer

Dr. Gregory Jenkins

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Addendum (March 1998)

In late February 1998 we were contacted by a local professional fisherman who had been capturing considerable numbers of small snapper less than about 5 cm in length whilst purse seining for bait fish in northern Port Phillip Bay. This fisherman was also on the lookout for small newly-recruited snapper, during and after our sampling was completed last year. Like our study and the trawl surveys conducted by Marine and Freshwater Resources Institute at the same time, he also failed to report any small newly- recruited 0+ age snapper. Based on this fisherman's reports we recently (11/3/98) conducted some opportunistic sampling with the small beam trawl in northern Port Phillip Bay and captured significant numbers of small newly recruited snapper ranging in size from about 3-7 cm in length. This supports the conclusion that failure to capture newly-recruited 0+ snapper with the small beam trawl during the 1996/97 study was due to low or failed recruitment rather than major inefficiencies in the sampling technique. Unfortunately the time of sampling was likely to have been too late to capture newly-settled snapper. Anecdotal evidence from the professional fisherman suggests that very small, most likely recently or newly-settled snapper were abundant earlier in the year, around January and early February. Given the now proven ability of the small beam trawl to capture small 0+ recruits we have little doubt that it will also capture newly-settled recruits if they are present in the sampling areas.

We plan to conduct at least two more sampling trips in March 1998 to further test the efficiency of the small beam trawl during day and night and to collect 0+ snapper recruits for daily ageing and determination of spawning times.