

Baywide Egg and Larval Surveys Sub-Program

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Executive Summary

Fish eggs and larvae are the stages of the fish life cycle that are most vulnerable to environmental perturbations. A recently completed three year study investigated the relative abundance of snapper (*Pagrus auratus*) larvae within Port Phillip Bay, compared with the entrance and the open coast. This study confirmed that juvenile snapper in Port Phillip Bay are derived predominantly from spawning within the Bay, rather than from coastal waters. Fish eggs and larvae of other fish species, such as anchovy (*Engraulis australis*), were also collected but not analysed. This study provides a background dataset on fish eggs and larvae in the Bay.

Over the snapper spawning period of 2007-08, which overlaps the spawning period of anchovy, intensive sampling of fish eggs and larvae was conducted as part of the present study within Port Phillip Bay (Hobsons Bay, Carrum, Mordialloc, Frankston, Central Bay and Point Wilson) and across the entrance of Port Phillip Heads. Each area was sampled in two rounds (Round 1: late November/early December, and Round 2: mid December/early January). The aim was to track trends in the abundance of eggs and larvae of snapper, anchovy and other fish species for comparison between different areas and sampling periods.

A total of 76,552 fish eggs were collected from the samples in 2007-08. Total fish eggs showed considerable variability, with significant differences among areas within Port Phillip Bay. The highest concentration of fish eggs was recorded in the north-western area of the Bay.

A total of 48,194 fish larvae were collected during 2007-08, 74.52% of which were anchovy larvae and 0.64% snapper larvae. Concentrations of total fish larvae were significantly different between areas within Port Phillip Bay. These differences were not consistent between sampling rounds. The result for anchovy larvae reflected that for total larvae.

The highest concentrations of total fish larvae were recorded in Period 1 (2004-05) and Period 4 (2007-08), and the lowest in Period 3 (2006-07). In Period 1, larval concentrations were highest at Carrum, while in Periods 2-4 they were highest at Mordialloc. Snapper larvae, ranging between 1.5 mm (newly hatched) and 11.0 mm (settlement stage) (standard length), were also most abundant in periods 1 and 4.

The 2007-08 sampling event of the CDBMP program provides the fourth year of data, collectively forming the baseline for ongoing monitoring of interannual changes in abundance of fish eggs and larvae, including snapper and anchovies, in PPB.

Current results, together with historical data, suggest that Port Phillip Bay is a key spawning area for important species such as snapper and anchovy. In summary, the key conclusions to date are:

- Anchovy eggs were collected throughout the Bay, but none were recorded in Port Phillip Heads.
- Snapper larvae were collected throughout Port Phillip Bay, with highest abundance in the north east (Carrum, Frankston and Mordialloc), and lowest abundances in Port Phillip Heads.

Interannual variation in eggs and larvae is high, and the concentrations recorded in the first year (2007-08) of the CDBMP program (Period 4) were within the range of natural variability recorded over the previous three years (Periods 1-3). High interannual variability is likely to be linked to environmental fluctuations that affect plankton productivity and, in turn, influence the survival of young larvae.

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Introduction

Several regions of Port Phillip Bay (PPB) are important to fish as feeding, spawning and nursery grounds. Eggs and larvae are the fish life cycle stages most vulnerable to environmental perturbations (Jenkins and McKinnon 2006).

A recent study confirmed juvenile snapper in Port Phillip Bay are derived predominantly from spawning within the Bay rather than from coastal waters (Hamer and Jenkins 2007), and provided information on the abundance of snapper and other larvae across the Bay.

The objective of the Egg and Larval Survey Sub-program of the Channel Deepening Baywide Monitoring Programs (CDBMP) in PPB is to detect interannual changes in the abundance of total fish eggs and larvae, anchovy eggs and larvae, and snapper larvae outside of expected variability. To achieve this objective, the sub-program will track trends in fish egg and larval abundance, egg and larval abundance of anchovies and abundances of snapper larvae in PPB.

This sub-program is described in the Port of Melbourne Corporation CDBMP Sub-Program 2a Detailed Design - CDP_ENV_MD_015 Rev 0 (PoMC 2007).

Purpose of this report

This milestone report incorporates results from the first field sampling event (November 2007-January 2008), including findings of Progress Report #1 (Acevedo *et al.* 2008) with respect to:

- Snapper larvae and total larvae abundance in relation to sampling areas and sampling rounds, and also in relation to years (periods)
- Anchovy egg and larval abundance in relation to sampling areas and sampling rounds (2007–08 only)
- Size frequency distributions of snapper larvae amongst periods
- Discussion of any trends or peculiarities observed in data, along with comparisons against historical data where possible, and environmental conditions, where appropriate
- Discussion of any QA/QC issues along with any associated implications for the collected data
- Raw data for the sampling event (Appendix 1).

This report also considers the results of other relevant monitoring programs.

Materials and Methods

Field Methods

Ichthyoplankton sampling methods were based on the recently completed three year sampling program for snapper larvae in PPB (Hamer and Jenkins 2007). Samples were collected from two regions within the Bay (Figure 1):

- Region 1: consisted of six defined geographical areas of approximately 44 km² (Hobsons Bay, Carrum, Mordialloc, Frankston, Central Bay and Point Wilson)
- Region 2: consisted of six sampling points between Queenscliff Pier and the Quarantine Station near Portsea at Port Phillip Heads (at the entrance of PPB).

The areas within the Bay correspond to areas where adult snapper (*Pagrus auratus*) are known to aggregate during the spawning season (Hamer and Jenkins 2007) and overlap with known anchovy spawning areas (Jenkins 1986).

Samples were collected during daylight from 23 November 2007 to 4 January 2008, using a 500 µm mesh plankton net with a circular mouth of 0.8 m diameter. The sampler was towed for 20 minutes at a speed of 1.5 knots using stepped oblique tows. Each tow consisted of a series of 1.5 minute pauses at each of five depths as the net was lowered and again as it was retrieved. The five depths included: just below the surface, 1/4, 1/2, 3/4 of total depth below the surface and approximately 1m above the bottom. The net depth was set on the basis of warp length and angle, verified periodically using a submersible pressure gauge. The plankton net was washed with seawater after completion of each tow. The contents of the cod-end were filtered through a 500 µm sieve and immediately preserved in 95% ethanol. A calibrated General Oceanics flow-meter (attached to the opening of the net) was used to calculate the volume of water filtered on each deployment. Volume filtered for each tow averaged approximately 400 m³.

Each region was sampled on two occasions (Round 1, late November/early December and Round 2, mid December/early January) during the spawning season. Five randomly placed plankton tows were conducted in each Round, within each area of Region 1. In Region 2 the same six sampling points were sampled in each Round. Significant tidal currents in the Port

Phillip Heads area meant sampling was restricted to flood tide for consistency.

Laboratory Methods

All fish eggs, anchovy (*Engraulis australis*) eggs and fish larvae were extracted from the samples and counted. Snapper eggs cannot be distinguished reliably from eggs of other fish species and therefore were not counted separately. Anchovy and snapper larvae were then identified, based on the descriptions in Neira *et al.* (1998), and counted. The standard length (SL, tip of snout to the posterior extremity of the notochord) of all undamaged snapper larvae was measured under a dissecting microscope using an ocular micrometer. Some samples contained a large number of fish eggs and/or anchovy larvae. For these samples, the anchovy eggs and other fish larvae were extracted and a plankton splitter was then used to divide the sample into either 1/2, 1/4, 1/8 or 1/16 sub-samples, depending on the amount of material. Fish eggs and larval concentrations (per 1000 m³) in each sample were calculated using the equation: $D = ((N/S)/V) * 1000$, where N is the total of eggs/larvae in each sample, S is the fraction of the sample that was split and V is the volume of water sampled (m³). The volume of water sampled was calculated by multiplying the distance towed by the opening area of the net.

Data Analysis

Abundances for anchovy eggs, anchovy larvae and total fish eggs and larvae for 2007–08 (Period 4) were graphed. Analysis of variance (ANOVA) was conducted to assess the variation in abundance of total fish and anchovy eggs and total larvae, anchovy and snapper larvae in relation to sampling areas and rounds for Region 1, and sampling rounds for Region 2. Prior to ANOVA analysis, egg and larvae concentrations (number per 1000m³) were log₁₀ (x+1) transformed to improve data normality and reduce heterogeneity of variances. Sampling areas and rounds were treated as fixed factors. Where necessary, Post-hoc Tukey's tests were conducted to determine if there were significant differences among areas.

Abundance of snapper larvae and total fish larvae (all species) was graphically compared between historical data (Period 1: 2004–05, Period 2: 2005–06 and Period 3: 2006–07) collected by

Hamer and Jenkins (2007), and the present study (Period 4). ANOVA was conducted on total larvae in relation to Period and Area. The sampling window used by Hamer and Jenkins (2007) was initially from early December to late January in 2004–05, but was subsequently modified (late November to early January in 2006–07) as knowledge of snapper spawning increased. For comparability with the present study, a “window” of historical data ranging from late November to early January only has been analysed. The Central area was excluded from the historical comparison as it was not sampled in Period 1 and sampled in a very limited way in Period 2. For this historical analysis ‘Round’ was not included because some Round 2 samples fell outside the sampling window.

Snapper larvae were not analysed by ANOVA in the historical comparison because the large number of zeros in the data set meant that the data did not conform to the assumptions of analysis (normality and homogeneity of variances)(CSIRO/Emphron 2008).

Length-frequency histograms for snapper larvae were constructed and compared with the historical data. Distributions were statistically compared by Kolmogorov-Smirnov (K-S) test. No adjustments to measured SL were made to account for shrinkage of stored specimens, although this would be expected to be minimal in 95% ethanol (Theilacker 1980).

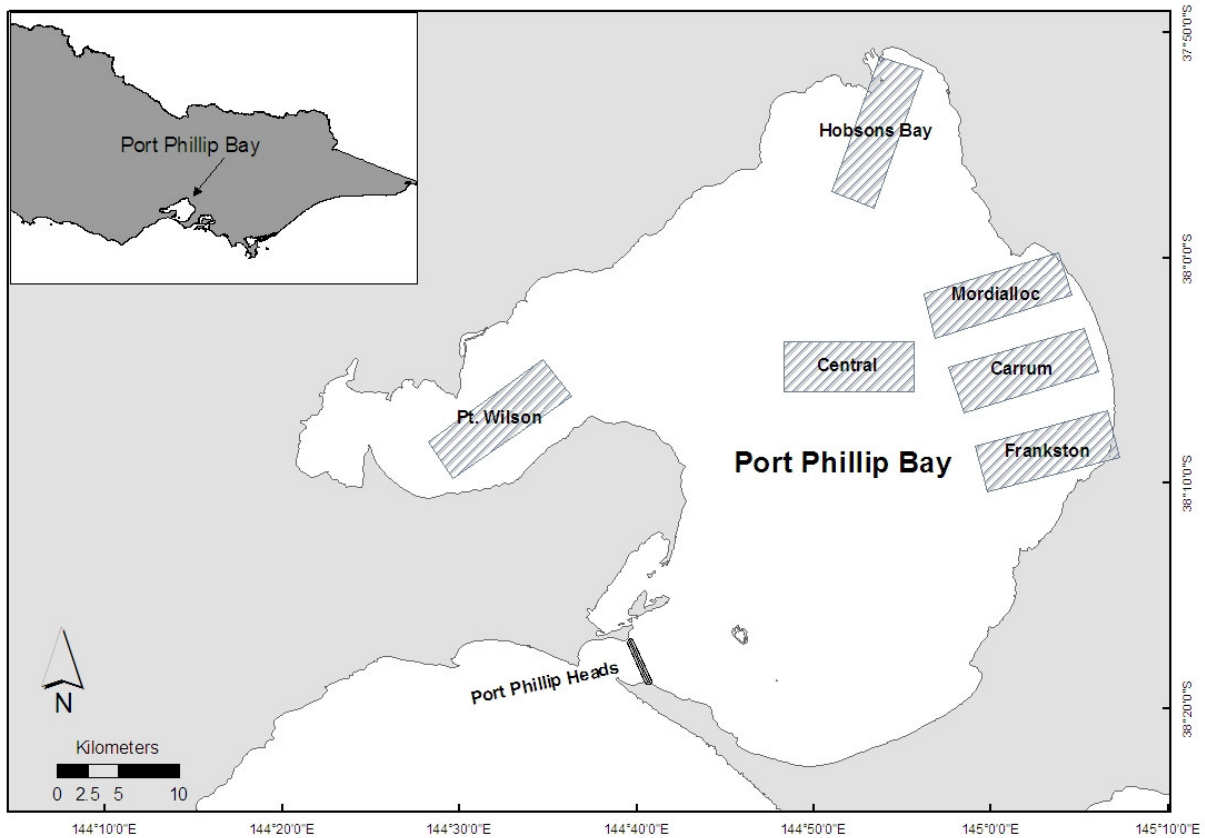


Figure 1. Map showing locations of plankton sampling regions and areas (shaded boxes).

Data Management

QA/QC

Quality Assurance and Quality Control procedures employed in this study are detailed in Appendix 2.

Exceptions

Exceptions to the Detailed Design (PoMC 2007) for the reporting period are documented in Exception Reports ER2008#6 (see also Acevedo *et al.* 2008) and ER2008 #15 and are summarised as follows:

- ER2008#6 & #15: Delayed submission of reports
- ER2008#6: Five replicate samples per site/round instead of 6
- ER2008#6: Sampling areas 44 km² not 4.5 km²
- ER2008 #15: Snapper larvae not analysed with ANOVA for the historical comparison
- ER2008 #15 "Rounds" not analysed for comparison with historical data (nb. terminology change to "Rounds" from "Months").

Results

A total of 76,552 fish eggs (Table 1) and 48,194 (Table 2) fish larvae were collected during the present (2007-08) study period (Period 4).

Fish eggs

Total fish egg concentrations showed considerable variability, with significant differences among areas and rounds within Port Phillip Bay (Table 3a). Concentrations of fish eggs (mean \pm 1 standard error eggs per 1000 m³) in the Point Wilson area (24,049.0 \pm 4,005.5) were significantly higher than in the Hobsons Bay (3,831.3 \pm 1,741.7), Central (2,262.4 \pm 134.2) and Mordialloc (3,780.4 \pm 931.4) areas (Tukey's test < 0.05) (Figure 2a; Table 1). Significant differences were recorded among rounds, with the highest concentration of fish eggs recorded in Round 1 (8,340.6 \pm 1,772.2) (Figure 3a). In Port Phillip Heads, fish egg abundances showed significant differences among rounds (Table 3b). In contrast to Port Phillip Bay, abundances of fish eggs were significantly higher in Round 2 (Figure 3b).

Anchovy eggs in Period 4 (2007-08) comprised 9.13% of the total fish eggs recorded across all samples (mean concentration of 261.6 \pm 54.2 eggs per 1000 m³) (Table 1; Figure 2a). Anchovy egg abundances showed variability, with significant differences among areas but not sampling rounds within Port Phillip Bay (Table 3a; Figure 2a). Concentrations of anchovy eggs were highest in the Frankston area (851.4 \pm 300). By contrast, the lowest concentrations of anchovy eggs were recorded in the Hobsons Bay area (67.9 \pm 31.8) (Table 1; Figure 2a). This difference was statistically significant (Tukey's test, p < 0.05). Concentrations of anchovy eggs were similar between the Point Wilson (274.5 \pm 77.8) and Mordialloc (267.5 \pm 64.8) areas (Table 1; Figure 2a). No anchovy eggs were recorded at Port Phillip Heads.

Fish larvae

A total of 48,194 fish larvae were collected during Period 4 (Table 4). Concentrations of fish larvae (mean \pm 1 standard error larvae per 1000 m³) showed a significant interaction between area and rounds within Region 1 (Table 3a; Figure 4a), indicating that there were significant differences amongst areas, but these were not consistent between sampling rounds. In Round 1 (late November/ early December), the highest concentration of fish larvae was recorded in the Mordialloc area (5,400.6 \pm 2,772.8) and the

lowest was recorded in the Frankston area (595.7 \pm 167.6) (Figure 4a). In Round 2 (mid-December to early January), the highest concentration of fish larvae was in the Frankston area (3,600.6 \pm 1,982.8) and the lowest concentration was recorded in the Central area (625.0 \pm 137.4) (Figure 4a). In Region 2 there was no significant difference between rounds in the concentration of total larvae (Table 3b).

Anchovy larvae comprised 74.52% of the total fish larvae recorded (mean concentration of 1,338.2 \pm 303.1 larvae per 1000 m³) in Period 4 (Table 2; Figure 2b). The result for anchovy larvae reflected that for total larvae in that there was a significant interaction between area and rounds (Table 3a; Figure 4b). In Round 1, the highest concentration of anchovy larvae was recorded in the Mordialloc area (3,741.3 \pm 1,894.7) and the lowest in the Frankston area (364.3 \pm 1481.0) (Figure 4b). In Round 2, the highest concentration of anchovy larvae was in Frankston (3,196.7 \pm 1,837.4) and the lowest was recorded in the Carrum area (493.9 \pm 144.3) (Figure 4b). At Port Phillip Heads, variation in anchovy abundance between rounds was significant (Table 3b). The highest abundances were recorded in Round 2 (53 \pm 23.5).

A total of 114,902 fish larvae were collected over all four periods (Table 4). Total fish larvae concentration in Region 1 differed significantly between periods and areas (Table 5a). Total fish larval concentrations were highest in Periods 1 and 4 (Table 4; Figure 5). Total fish larval concentrations were higher in the Mordialloc area and lower in the Point Wilson area over all periods combined (Figure 6). There was also a significant interaction between periods and areas (Table 5a) (Figure 7a). This interaction was due to different patterns of larval concentration between areas across periods. For example, concentrations were high in Period 1 for all areas except Point Wilson, and unlike other areas, concentrations in the Mordialloc area were highest in Period 2. In Region 2, there were no significant differences in the concentration of total fish larvae between periods (Table 5b). In Region 2, total fish larvae abundance was highest in Period 1 (Table 4). Over all four periods, total fish larvae concentrations across the two regions were highest in Period 1 (2,044.4 \pm 333.6) and lowest in Period 3 (477.1 \pm 92.7) (Table 4; Figure 5).

Of the total fish larvae recorded in all four periods, snapper larvae made up 0.87% and were only collected in Region 2 during Period 1 (Table 4). Within Port Phillip Bay, snapper larvae concentration was highest in Period 1 (35.7 ± 10.5 ; 1.8% of total fish larvae recorded) (Table 4; Figure 5). A second peak was also recorded in Period 4 (11.9 ± 3.3 ; 0.64% of total fish larvae recorded) (Figure 5). In both Periods (1 and 4), snapper larvae were most abundant in north-eastern Port Phillip Bay (Carrum, Frankston and Mordialloc) (Table 4; Figure 7b). In Period 2, snapper larvae were collected in low concentrations in the Frankston area only (5.7 ± 3.1) (Table 4). Abundance of snapper larvae was also low in Period 3 with the highest concentration recorded again in the Frankston area (10.78 ± 3.23) (Table 4).

Abundance of snapper larvae in Period 4 showed considerable variability, with significant differences between areas (Table 3a). Highest abundances were recorded in the Carrum and Mordialloc areas (Table 4). The interaction between areas and rounds was also significant (Table 3a). Abundances were highest in the

Carrum and Mordialloc areas in Round 1, but were highest in the Frankston area in Round 2 (Figure 8).

Size distributions – *Pagrus auratus*

Snapper larvae collected in Region 1 over the four periods ranged between 1.5 mm (newly hatched) and 11.0 mm (settlement stage) (Figure 9). The smallest snapper larvae (SL 1.5-1.9 mm) were recorded only in Period 4, from the Carrum, Hobsons Bay and Frankston areas. Almost 57% of all snapper larvae measured in all four periods ranged between 3.0 and 4.4 mm (SL) (Figure 9). Only two snapper larvae greater than 11 mm (SL) were collected from all four periods. These were recorded in Period 1 from the Carrum and Frankston areas. No larvae greater than 5.4 mm (SL) were found in Period 2. Overall, there was no significant difference between periods and between size distributions of snapper larvae in Region 1 (K-S; $p > 0.05$, Appendix 3). Snapper larvae in Region 2 only occurred in Period 1 and ranged between 2.0 and 5.4 mm (Figure 9).

Table 1. Total number and mean concentration (\pm standard error) of fish eggs and anchovy eggs collected in Period 4 (2007-08).

Area	Total fish eggs	Mean concentration fish eggs (eggs per 1000m ³)	Total anchovy eggs	Mean concentration anchovy eggs (eggs per 1000m ³)
Carrum	5,634	6,263.9 \pm 1,506.7	1,160	312.8 \pm 98.9
Central	9,732	2,262.4 \pm 134.2	462	108.9 \pm 31.1
Frankston	11,576	7,423.9 \pm 2,740.6	3,165	851.4 \pm 300
Hobsons Bay	14,736	3,831.3 \pm 1,741.7	274	67.9 \pm 31.8
Mordialloc	5,627	3,780.4 \pm 931.4	841	267.5 \pm 64.8
Point Wilson	20,700	24,049.0 \pm 4,005.5	1,089	274.5 \pm 77.8
Port Phillip Heads	8,547	3,153.0 \pm 722.8	0	0
All Areas	76,552	7,138.1\pm1,107	6,991	261.6\pm54.2

Table 2. Total number and mean concentration (\pm standard error) of fish larvae and anchovy (*Engraulis australis*) larvae collected in Period 4 (2007-08).

Area	Total fish larvae	Mean concentration fish larvae (larvae per 1000m ³)	Total anchovy larvae	Mean concentration anchovy larvae (larvae per 1000m ³)
Carrum	10,308	3061.8 \pm 1,617.8	8,537	2,554.6 \pm 1,455.5
Central	3,872	916.1 \pm 215.1	2,391	571.7 \pm 157.0
Frankston	7,921	2,098.2 \pm 1063.4	6,711	1,780.5 \pm 988.9
Hobsons Bay	5,964	1,506.1 \pm 270	4,801	1,215.5 \pm 198.2
Mordialloc	11,245	3,124.1 \pm 1,514.2	8,073	2,231.2 \pm 1,029.2
Point Wilson	7,733	1,898.8 \pm 625.5	5,255	1,249.2 \pm 652.9
Port Phillip Heads	1,151	215.7 \pm 30.7	147	26.7 \pm 13.7
All Areas	48,194*	1,787.2\pm360.1	35,915	1,338.2\pm303.1

Note: snapper eggs could not be distinguished reliably from eggs of other fish species;* Slight variation from Progress Report 1 after some samples re-sorted.

Table 3. Results of ANOVA comparing variation in abundances of anchovy eggs/larvae (*Engraulis australis*), total fish eggs/larvae and snapper (*Pagrus auratus*) larvae amongst areas and rounds in a) Region 1 (Port Phillip Bay) and b) Region 2 (Port Phillip Heads) during Period 4 (2007–08). NB: Results in bold are those significant at $p < 0.05$.

a) REGION 1		Total fish eggs		Anchovy eggs		Total fish larvae		Anchovy larvae		Snapper larvae	
Source	df	MS	p	MS	p	MS	p	MS	p	MS	p
Area	5	1.795	0.001	2.260	0.001	0.143	0.461	0.261	0.341	1.391	0.000
Round	1	1.631	0.038	0.953	0.140	0.129	0.360	0.032	0.706	0.159	0.394
Area x Round	5	0.175	0.782	0.774	0.124	0.637	0.003	0.746	0.012	1.289	0.000
Error	48	0.357	-	0.423	-	0.151	-	0.225	-	0.215	-

b) REGION 2		Total fish eggs		Anchovy eggs		Total fish larvae		Anchovy larvae		Snapper larvae	
Source	df	MS	p	MS	p	MS	p	MS	p	MS	p
Round	1	0.565	0.035	NR	NR	0.051	0.280	4.322	0.007	NR	NR
Error	10	0.095	-	NR	NR	0.039	-	0.381	-	NR	NR

Legend: NR none recorded

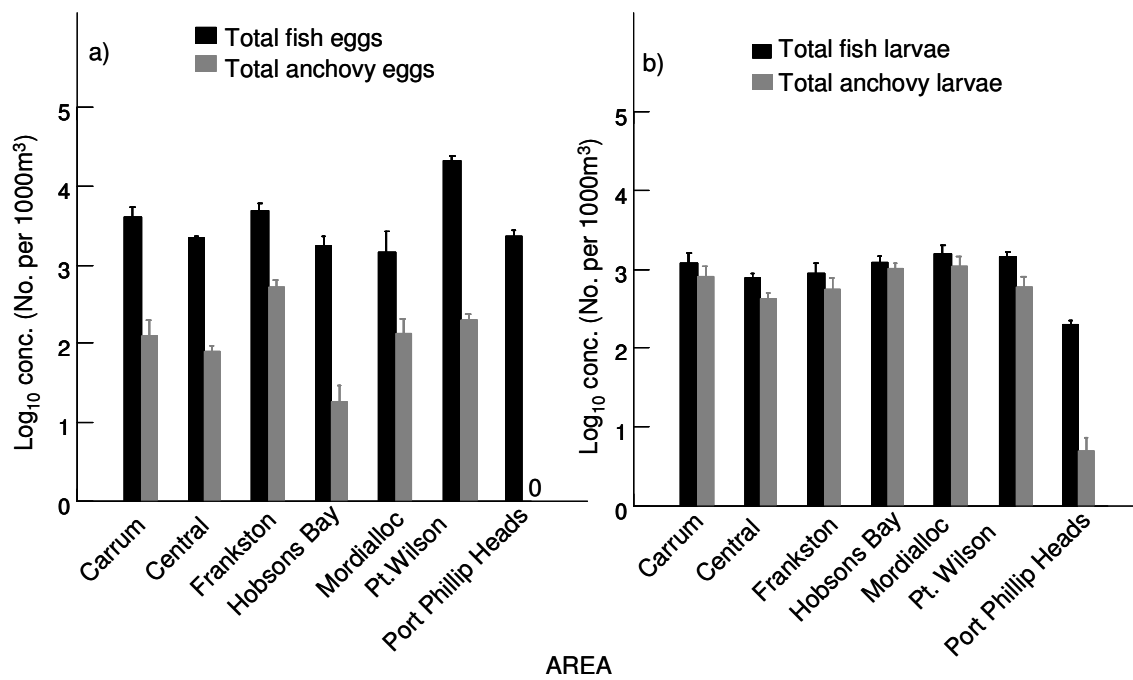


Figure 2. Mean concentration (± 1 standard error) of a) total fish eggs and anchovy (*Engraulis australis*) eggs, and b) total fish larvae and anchovy larvae, from samples taken in each area/region during Period 4 (2007-08).

Table 4. Total number and mean concentration (\pm standard error) of fish larvae and snapper (*Pagrus auratus*) larvae collected in all areas/regions during all four periods.

Period	Area	Total fish larvae	Mean concentration fish larvae (larvae per 1000m ³)	Total snapper larvae	Mean concentration snapper larvae (larvae per 1000m ³)
1	Carrum	5,598	3,153.9 \pm 1090.1	134	71.8 \pm 21.1
	Frankston	8,978	3,477.1 \pm 929.2	198	74.9 \pm 37.3
	Hobsons Bay	2,427	1,612.5 \pm 547.5	4	2.6 \pm 2.6
	Mordialloc	10,374	3,166.5 \pm 785.6	183	57.9 \pm 9.1
	Point Wilson	1,396	3,295.0 \pm 54.0	2	0.6 \pm 0.4
	Port Phillip Heads	2,735	557.9 \pm 183.1	63	0.2 \pm 0.1
	All Areas	31,508	2,044.4\pm333.6	584	35.7\pm10.5
2	Carrum	5,851	1,207.3 \pm 558.4	0	0
	Frankston	6,382	1,397.3 \pm 449.6	24	5.7 \pm 3.1
	Hobsons Bay	553	225.7 \pm 47.3	0	0
	Mordialloc	9,010	3,017.4 \pm 1481.0	0	0
	Point Wilson	986	400.4 \pm 101.7	0	0
	Port Phillip Heads	1,613	291.7 \pm 52.3	0	0
	All Areas	24,395	1,073.5\pm264.3	24	1.2\pm0.7
3	Carrum	1,049	268.0 \pm 146.5	5	1.3 \pm 0.6
	Frankston	2,452	489.8 \pm 113.9	51	10.8 \pm 3.2
	Hobsons Bay	485	316.9 \pm 8.8	2	1.2 \pm 1.2
	Mordialloc	2,844	793.7 \pm 432.4	19	5.3 \pm 2.9
	Point Wilson	3,022	676.5 \pm 214.3	15	3.5 \pm 1.9
	Port Phillip Heads	953	224.8 \pm 29.9	0	0
	All Areas	10,805	477.1\pm92.7	92	4.1\pm1.0
4	Carrum	10,308	3,061.8 \pm 1,617.8	91	28.0 \pm 16.1
	Central	3,872	916.1 \pm 215.6	15	3.60 \pm 1.2
	Frankston	7,921	2,098.2 \pm 1063.4	53	13.7 \pm 8.3
	Hobsons Bay	5,964	1,506.1 \pm 270.0	33	8.1 \pm 6.9
	Mordialloc	11,245	3,124.1 \pm 1514.2	110	30.8 \pm 11.4
	Point Wilson	7,733	1,898.8 \pm 625.5	5	1.2 \pm 0.6
	Port Phillip Heads	1,151	215.7 \pm 30.7	0	0
All Areas	48,194	1,787.2\pm360.1	307	11.9\pm3.3	

Table 5. Results of ANOVA comparing variation in concentrations of total fish larvae in a) Region 1 (within Port Phillip Bay) and b) Region 2 (Port Phillip Heads) during all four Periods. NB: Results in bold are those significant at $p < 0.05$.

a) REGION 1		Total fish larvae	
Source	df	MS	p
Period	3	5.843	0.000
Area	4	0.685	0.035
Period x Area	12	1.029	0.000
Error	153	0.257	-

b) REGION 2		Total fish larvae	
Source	df	MS	p
Periods	3	0.085	0.449
Error	41	0.094	-

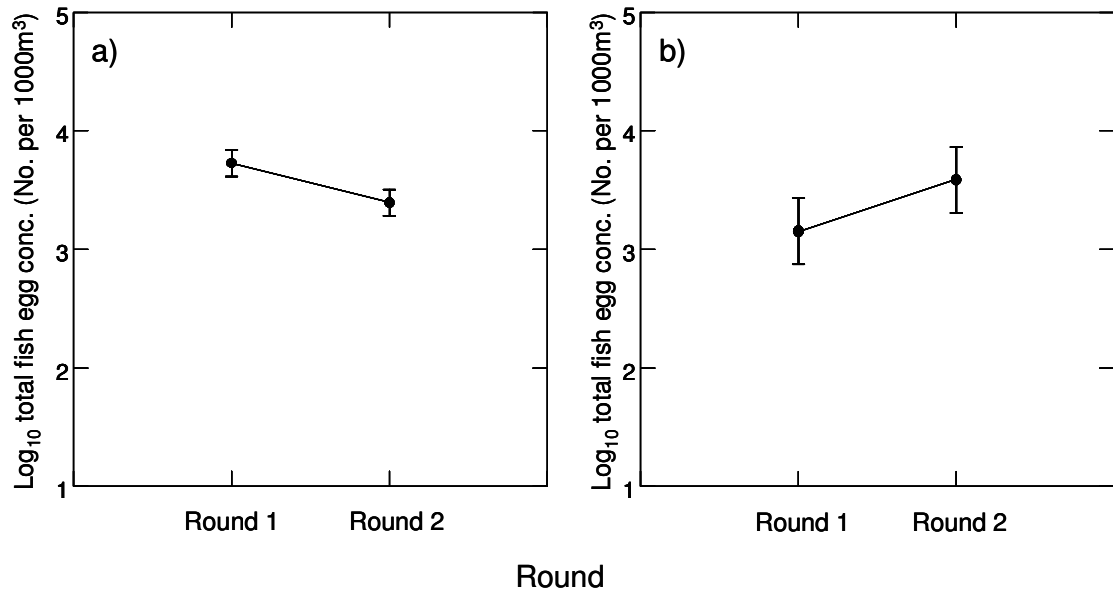


Figure 3. Mean concentration (± 1 standard error) of total fish eggs from samples taken in a) Region 1 and b) Region 2 during sampling Rounds 1 & 2, Period 4 (2007-08).

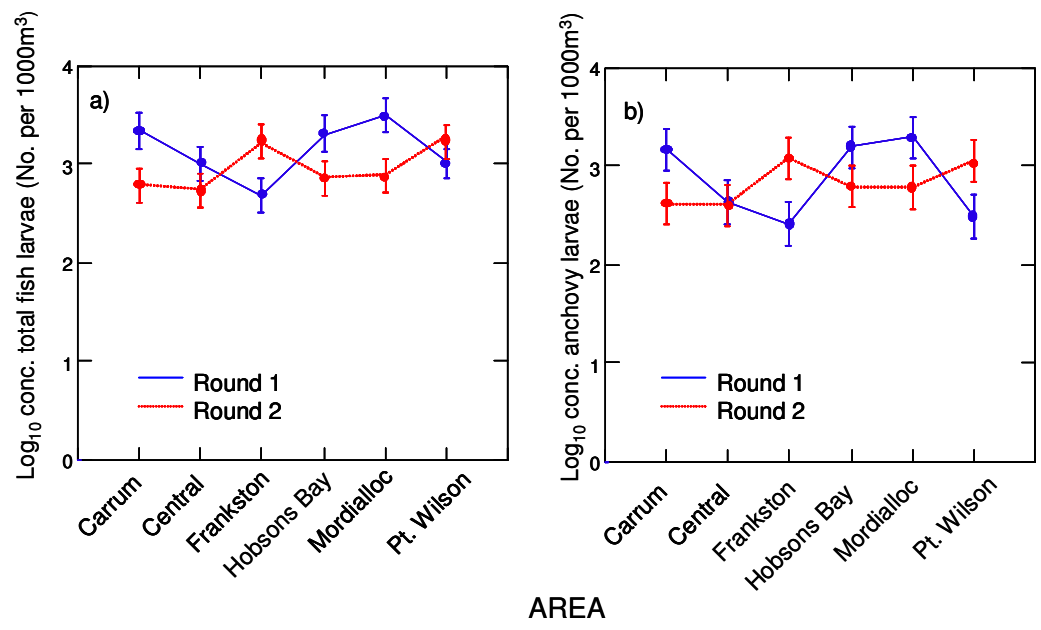


Figure 4. Mean concentration (± 1 standard error) of a) total fish larvae and b) anchovy (*Engraulis australis*) larvae from samples taken in Region 1 during sampling Round 1 & 2, Period 4 (2007-08).

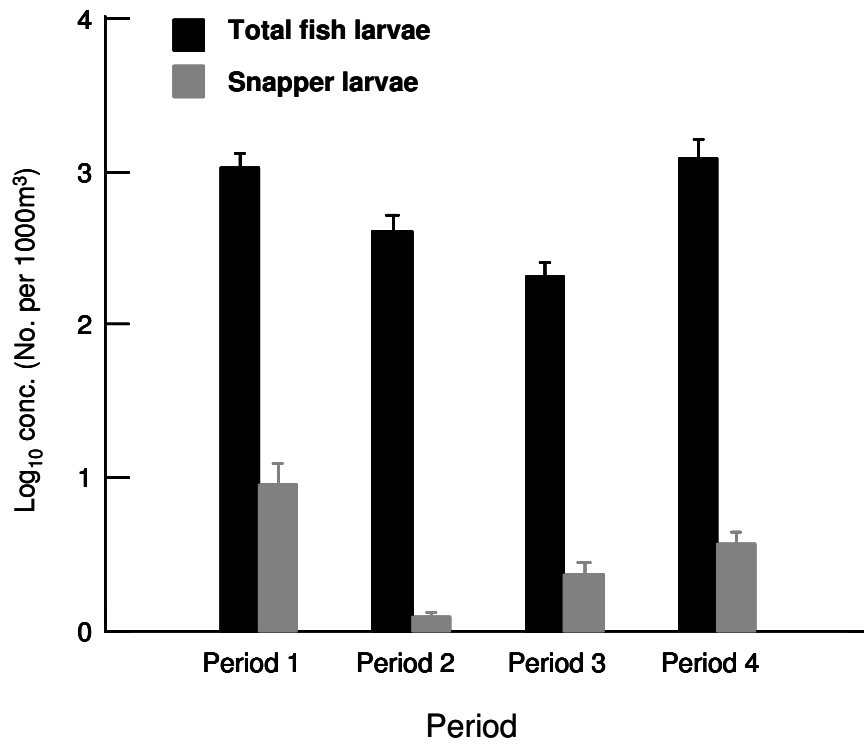


Figure 5. Mean concentration (± 1 standard error) of total fish larvae and snapper (*Pagrus auratus*) larvae from samples taken in Region 1 during each period.

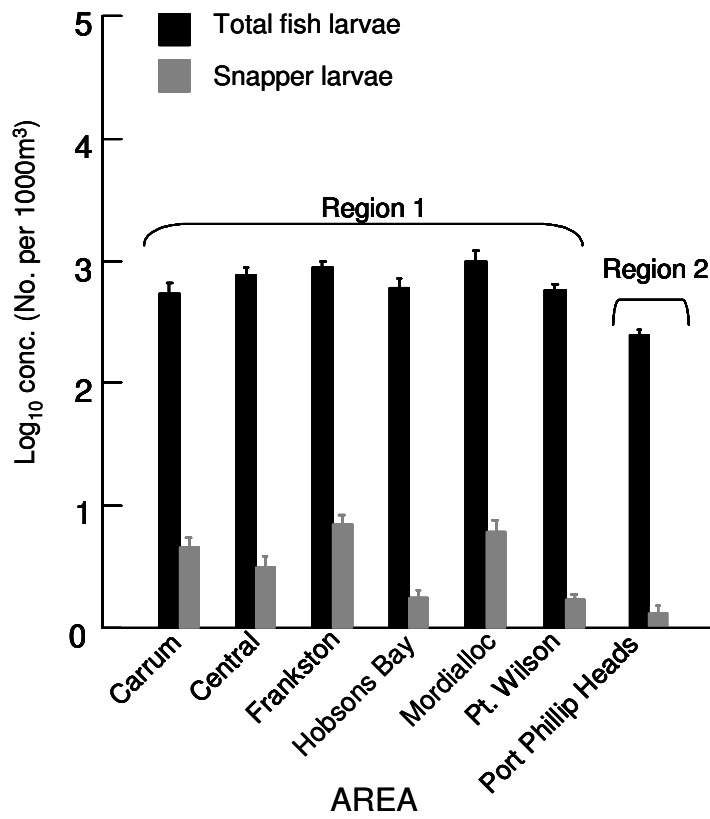


Figure 6. Mean concentration (± 1 standard error) of total fish larvae and snapper (*Pagrus auratus*) larvae taken in each area/region during Periods 1 - 4.

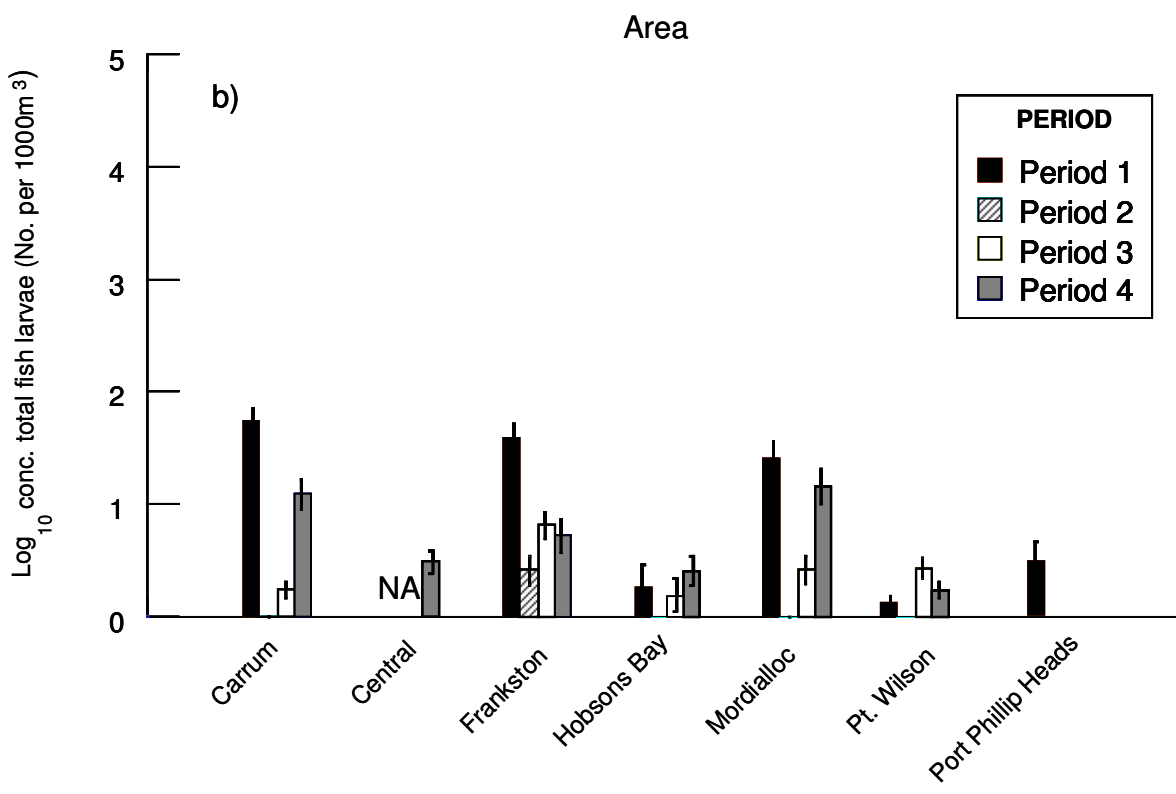
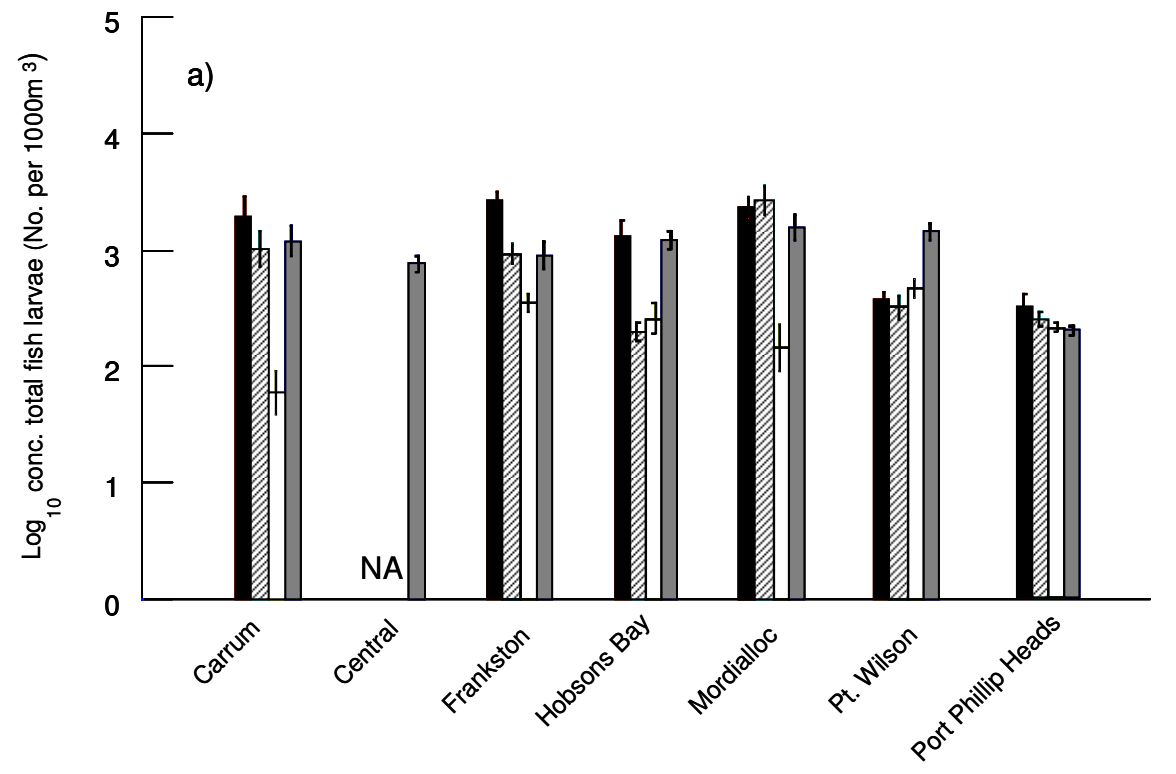


Figure 7. Mean concentration (± 1 standard error) of a) total fish larvae and b) snapper (*Pagrus auratus*) larvae taken in each area/region during all four periods.

Legend: NA none available.

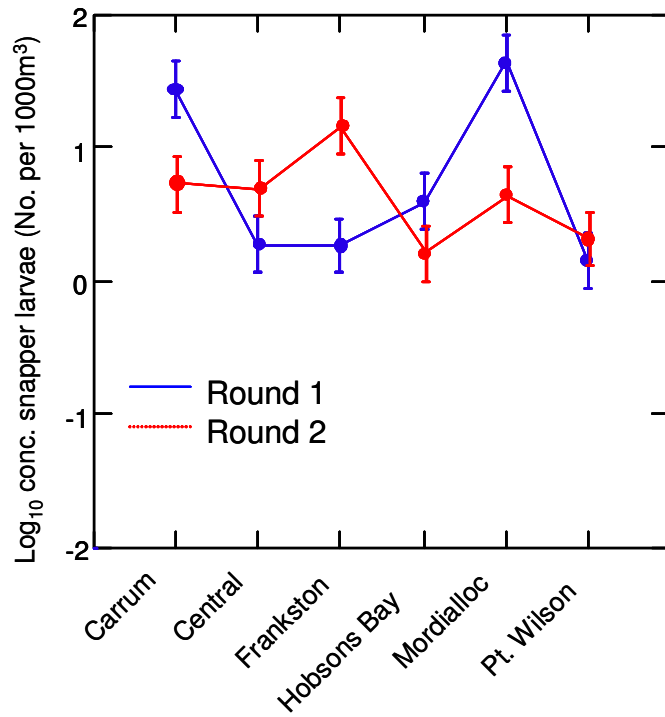


Figure 8. Mean concentration (± 1 standard error) of snapper (*Pagrus auratus*) larvae from samples taken in all areas, Region 1, during sampling Round 1& 2, Period 4 (2007-08).

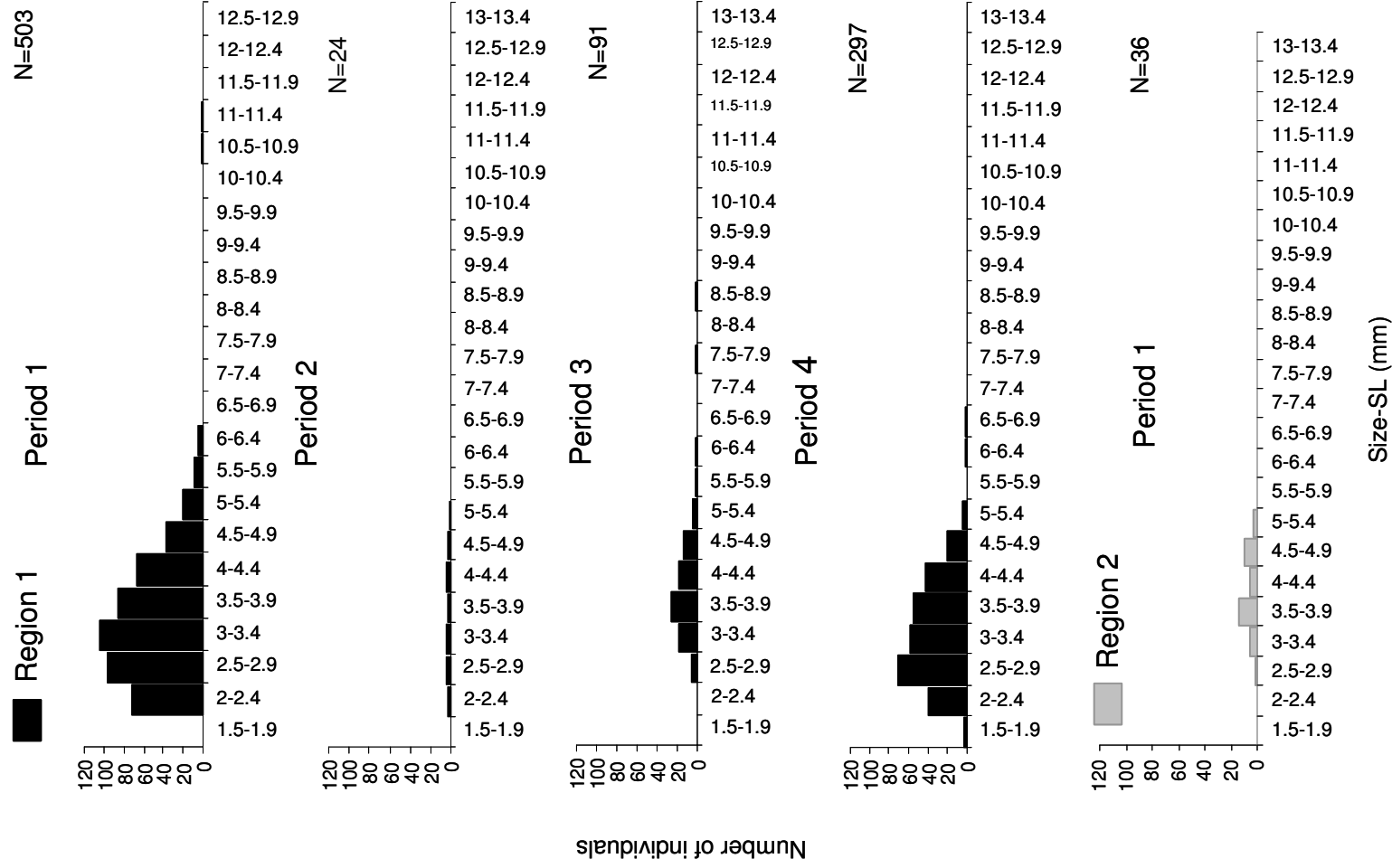


Figure 9. Size-frequency distribution of snapper (*Pagrus auratus*) larvae collected in Region 1, compared over all four periods, and Region 2 for Period 1.

Legend: N= number of undamaged snapper measured.

Discussion

Port Phillip Bay is a large, semi-enclosed embayment. It supports significant commercial and recreational fisheries, as well as providing suitable spawning and nursery areas for several fish species (Neira *et al.* 1998).

Snapper is an important commercial and recreational fishing species within the bay. Snapper migrate into Port Phillip Bay for spawning in spring/summer. Although snapper can potentially spawn in Port Phillip Bay from November to late February, most spawning appears to occur during late November and December (Jenkins 1986; Coutin *et al.* 2003; Hamer and Jenkins 2007).

Anchovy are a very important forage (food) species for fish and seabirds in PPB, and also provide the basis for a small commercial fishery (catch of 84 Tonnes in financial year 2005/06). Anchovy spawning in Victorian bays occurs between August and April, with a peak in summer (Arnott and McKinnon 1985; Jenkins 1986; Blackburn 1950; Hoedt and Dimmlich 1995; Neira *et al.* 2000; Neira and Sporcic 2002).

The results of the present investigation suggest significant anchovy spawning within Port Phillip Bay. Consistent with the present study, Jenkins (1986) recorded highest abundances of anchovy eggs in Port Phillip Bay in December. In contrast, Neira and Sporcic (2002) found anchovy eggs to be most abundant in January and March, although overall abundances were lower than other studies.

In the present study, anchovy eggs were relatively abundant in the north-eastern and Pt. Wilson areas, but abundances were lower in the Hobsons Bay area. This is consistent with the study of Neira and Sporcic (2002), where anchovy eggs were most abundant off Werribee (December and January) and Frankston (March). Blackburn (1950) recorded the highest concentrations of anchovy eggs in the northern area of the bay. Jenkins (1986) reported the eggs of anchovy to be widespread throughout the bay with the exception of the entrance area. The lack of anchovy eggs in the entrance area is consistent with the findings of the present study.

Anchovy larvae during Period 4 occurred in high concentrations over the sampling period from late November to early January, and were mainly recorded in the eastern area of the Bay

(Mordialloc and Carrum, mean concentrations > 3000 larvae per 1000 m³). The study by Jenkins (1986) also recorded highest concentrations of anchovy larvae in December. In contrast, Neira and Sporcic (2002) found few anchovy larvae in December, with highest concentrations being recorded in January and March (Neira and Sporcic 2002). These two peaks resulted from higher abundances in north-western (Geelong Arm and Werribee) and south-eastern (Frankston and south of Frankston) areas of the bay, although overall abundances were low compared to other studies (Neira and Sporcic 2002).

Abundances of older stages of anchovy collected in the CDBMP Sub-Program 2b Anchovy Study during June-July 2008 were highest in the south-eastern and deep central areas of the Bay, with few anchovy collected in the north-west region of the Bay (Parry 2008).

Variation in concentrations and distribution of anchovy eggs and larvae in the present study, when compared with the studies by Neira and Sporcic (2002) and Jenkins (1986), may be due to several factors, including natural interannual variability, sampling timing and intensity and differences in plankton sampling gear (e.g. mesh size used). Sampling by Neira and Sporcic (2002) specifically differed from the present study in that they conducted night sampling to investigate the ichthyoplankton community of Port Phillip Bay.

Total larval and snapper larval concentrations over the four sampling periods recorded in this milestone report displayed high interannual variability in Port Phillip Bay, possibly due to natural variation in plankton production and associated survival of larval stages within the Bay. Other environmental factors affecting larval transport such as wind and currents, and predators, may also have contributed to such variability (Hamer and Jenkins 2004, 2007). Period 1 had the highest average concentration, and Period 4 had the second highest average concentration of both total larvae and snapper larvae. Jenkins (1986) recorded a peak in average larval concentration in December of approximately 3000 larvae per 1000 m³. Neira and Sporcic (2002) recorded a peak in average larval concentration in January of approximately 1800 larvae per 1000 m³. These values are similar

to the present study although comparisons are difficult because of differing sampling gears and sites sampled.

Total larvae concentrations were generally higher in the north-eastern area of the Bay (Mordialloc, Frankston, Carrum) over the four years of sampling. This pattern was reflected in the distribution of snapper larvae, suggesting that the preferred spawning area was relatively stable over that period. The pattern of snapper larval dominance in north-eastern Port Phillip Bay was also recorded by Jenkins (1986) in 1983-84.

No anchovy eggs and few anchovy larvae were collected from Port Phillip Heads. This suggests that the majority of anchovy spawning was occurring inside Port Phillip Bay during the reporting period. Snapper larvae were also only collected on one occasion from Port Phillip Heads; a result supported by Jenkins (1986) where no snapper larvae were collected in Port Phillip Heads. Again, this indicates that snapper spawning is mainly occurring within Port Phillip Bay (Hamer and Jenkins 2007).

Modelling studies suggest that for spawning in Port Phillip Bay, with typical egg and larval durations of species such as snapper and anchovy, few eggs and larvae would be transported to the entrance area due to the long residence time of water within the Bay (Jenkins and Hatton 2007).

Length-frequency distributions of snapper showed that almost 41% of snapper larvae recorded were newly hatched larvae (<3.0 mm SL; approx. 4 days age). This further supports the contention that spawning is occurring within the Bay, particularly in the north-eastern area. This coincides with the aggregation of adults with ripe ovaries within this part of PPB during Spring/Summer (Coutin *et al.* 2003).

Conclusions

Current results, together historical data, suggest that Port Phillip Bay is a key spawning area for important species such as snapper and anchovy. In summary, the key conclusions to date are:

- Anchovy eggs were collected throughout the Bay, but none were recorded in Port Phillip Heads.
- Snapper larvae were collected throughout Port Phillip Bay, with highest abundance in the north east (Carrum, Frankston and Mordialloc), and lowest abundances in Port Phillip Heads.

Interannual variation in eggs and larvae is high, and the concentrations recorded in the first year (2007-08) of the CDBMP program (Period 4) were within the range of natural variability recorded over the previous three years (Periods 1-3). High interannual variability is likely to be linked to environmental fluctuations that affect plankton productivity and, in turn, influence the survival of larvae.

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Appendix 1

Data files

Electronic data file is as follows:

- Period 4 Fish Eggs Larvae Data Metadata Storage.xls

Appendix 2

QA/QC Procedure

Field Methods

The equipment used (plankton net, flow-meter and hand-held multi-meter) in the 2007-08 sampling program was the same as the recently completed three year sampling program for snapper larvae conducted in Port Phillip Bay (Hamer and Jenkins 2007). Functionality has therefore been previously proven and tested prior to the present program.

Laboratory Methods

After all the samples were sorted for all fish eggs and fish larvae, random samples from each area were re-examined (10% of the total).

A workshop, aimed at training staff in the identification of fish larvae, was hosted by Dr. Anthony Miskiewickz during the 14th-19th of January 2008. Dr. Miskiewickz, an expert larval fish taxonomist, has been working on the identification and ecology of fish larvae in southern Australian waters since 1981. A second workshop was later held on the 14th and the 15th of April 2008. During this time, Dr. Miskiewickz randomly re-examined 15% of the total fish larvae samples to verify identification. The results were compared to all original identifications and were confirmed as correct. As part of established QA/QC procedure, historical samples were re-sorted for snapper larvae and total larvae to confirm the accuracy of the original data.

Data Analysis

In re-analysing historical samples, it was established that six samples were missing. Three of the six missing samples came from outside the defined sampling window for historical analysis (Point Wilson 17/1/05). The three remaining missing samples came from sites where more than sufficient samples for analysis are available. At least four samples are required from an area/period for analysis; one missing sample came from Frankston in 05-06 but 11 were already sorted. A second missing sample came from Mordialloc in 04-05, but nine were already sorted. The third missing sample came from Port Phillip Heads in 04-05, but ten analysed samples were already available. In summary, relatively large sample sizes for these sites/periods were available and the statistical integrity of the data was not affected.

Data Management

Data was entered into an Excel software package worksheet by the person who conducted the laboratory analyses. Data included: site, tow number, type of sampling, maximum depth, wind direction, wind speed, start/end latitude, start/end longitude, total eggs/larvae, total snapper larvae and total anchovy eggs/larvae. The data was then re-checked by a second person. A discussion between both people then decided where corrections were necessary. All data was saved to hard drive and DPI server.

Appendix 3

Kolmogorov-Smirnov two sample test results: for comparison of snapper larval sizes between periods

Maximum Differences for Pairs of Groups

	Period 1	Period 2	Period 3	Period 4
Period 1	0.00			
Period 2	0.33	0.00		
Period 3	0.25	0.21	0.00	
Period 4	0.17	0.25	0.21	0.00

Two-Sided Probabilities

	Period 1	Period 2	Period 3	Period 4
Period 1	1.00			
Period 2	0.11	1.00		
Period 3	0.38	0.60	1.00	
Period 4	0.84	0.38	0.60	1.00