

Baywide Egg and Larval Surveys Sub-Program

Milestone Report No. 2
(Nov. 2007–Jan. 2008)

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April 2009

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Silvana Acevedo and Greg Jenkins

April 2009

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Executive Summary

A recently completed three-year study (2004–07) investigated the relative abundance of snapper (*Pagrus auratus*) larvae within Port Phillip Bay (PPB), compared with the entrance and the open coast. Anchovy (*Engraulis australis*) eggs and larvae were also collected but not analysed. In 2007-08, sampling of fish eggs and larvae was conducted within PPB (Region 1: Hobsons Bay, Carrum, Mordialloc, Frankston, Central Bay and Point Wilson) and in Port Phillip Heads (Region 2). For this milestone report, anchovy eggs and larvae were sorted from historical samples and the results compared with those sampled in 2007-08.

A total of 13 267 anchovy eggs and 106 729 anchovy larvae were collected over four years of sampling from 2004-05 to 2007-08. Total anchovy egg concentrations were highest in 2007-08 (Period 4) and lowest in 2004-05 (Period 1). Total larval concentrations were highest in 2007-08 (Period 4) and lowest in 2006-07 (Period 3). Over all four periods combined, the highest concentrations of anchovy eggs and larvae were recorded in the eastern area of the Bay (Carrum, Frankston and Mordialloc). Anchovy egg concentrations were lower in the northern area of the Bay (Hobsons Bay). In 2007-08 (Period 4),

unlike the previous periods, high concentrations of anchovy eggs and larvae were also recorded in the western area of the Bay (Point Wilson). No anchovy eggs were recorded in Port Phillip Heads in 2004-05 and 2007-08. Anchovy larval concentrations were lower in Port Phillip Heads in all periods compared to other areas.

Conclusions

Current results, together with historical data, suggest that PPB is a key spawning area for anchovy. In summary, the key conclusions are:

- Anchovy eggs and larvae were collected throughout the Bay, but were recorded in low concentrations in Port Phillip Heads
- Within PPB, the highest abundances of anchovy eggs and larvae were in the eastern area of the Bay (Carrum, Frankston and Mordialloc)
- Interannual variation in anchovy 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).

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Introduction

The Egg and Larval Surveys Sub-Program of the Channel Deepening Baywide Monitoring Programs (CDBMP) tracks trends in fish egg and larval abundance in Port Phillip Bay (PPB), with a focus on anchovy (*Engraulis australis*) and snapper (*Pagrus auratus*).

This sub-program is described in CDBMP Sub-Program 2a Egg and Larval Surveys Detailed Design - CDP_ENV_MD_015 Rev 1.1 (PoMC 2008).

The objective of this subprogram is to detect interannual changes in the abundance of snapper and anchovy eggs and larvae outside of expected variability.

Purpose of this report

This milestone report summarises results of the sub-program with respect to:

- Comparison of anchovy egg and larval abundances from the 2007–08 CDBMP field sampling event with historical anchovy egg and larval data, and incorporates findings of Progress Report #2 (Acevedo *et al.* 2009a).

Materials and Methods

Materials and methods for this sub-program are described in PoMC (2008) and Acevedo *et al.* (2009a,b). Additional data analysis methods not otherwise described by PoMC (2008) are summarised in Appendix 1.

Samples were collected from two regions in PPB: Region 1, which consisted of six sampling areas within the Bay, and Region 2, which consisted of a transect immediately inside Port Phillip Heads (Figure 1). Samples were collected during daylight hours, from 23 November 2007 to 4 January 2008. Historical data was provided by Hamer and Jenkins (2007) (see also Acevedo *et al.* 2009a and Appendix 1 for details). No historical data is available for the Central area of PPB (Region 1).

QA/QC

There were no significant field events observed or other QA/QC issues recorded during this reporting period.

Exceptions

Exception Report ER2008#6 (Vers. 2), according to the Detailed Design (PoMC 2008), still applies in part for the study period November 2007–January 2008 (see also Acevedo *et al.* (2009a,b)), and specifically relates to:

- Five instead of six plankton tows conducted within each sampling area.

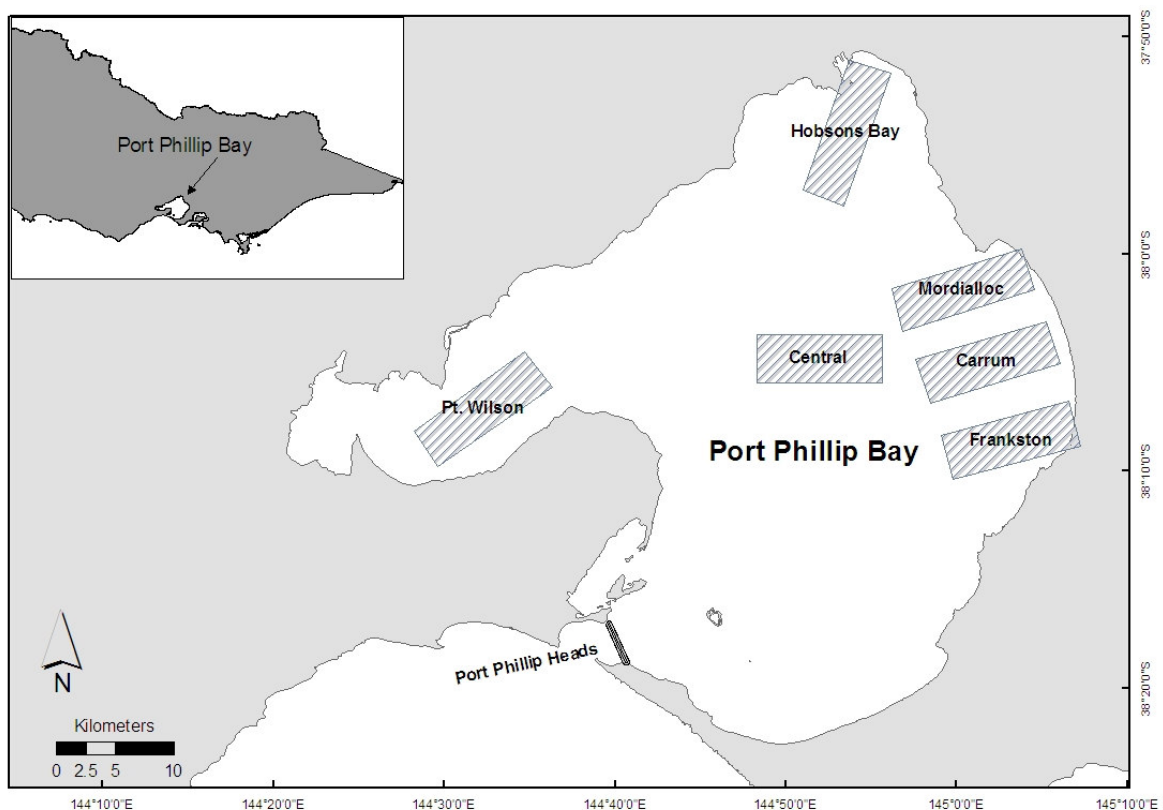


Figure 1. Map showing locations of plankton sampling areas (shaded boxes) within PPB (Region 1) and the sampling transect immediately inside Port Phillip Heads (Region 2).

Results

The results for anchovy eggs and larval abundances from this sub-program have been previously reported by Acevedo *et al.* (2009a,b), and are provided in Appendix 2 and summarised below.

A total of 13 267 anchovy eggs and 106 729 anchovy larvae were collected over all four periods (Period 1: 2004-05, Period 2: 2005-06, Period 3: 2006-07 and Period 4: 2007-08).

Anchovy egg and larval concentrations varied between years. Total anchovy egg concentrations were lowest in 2004-05 (Period 1) and highest in 2007-08 (Period 4). Total anchovy

larval concentrations were lowest in 2006-07 (Period 3) and highest in 2007-08 (Period 4). Over all four years combined within Region 1, anchovy eggs and larvae were most concentrated in eastern PPB (Carrum, Frankston and Mordialloc areas). By contrast, the lowest concentrations of anchovy eggs were recorded in northern PPB (Hobsons Bay). Low concentrations of anchovy eggs, recorded only in 2005-06 (Period 2) and 2006-07 (Period 3), and anchovy larvae were recorded in Port Phillip Heads (Region 2).

Discussion

The importance of anchovy to the ecology and fisheries of PPB has been reported by Jenkins (1986), Jenkins and McKinnon (2006) and (Parry and Stokie 2009). Anchovy spawning in Victorian bays occurs between August and April, with a peak in summer (Blackburn 1950; Arnott and McKinnon 1985; Jenkins 1986; Hoedt and Dimmlich 1995; Hoedt *et al.* 1995; Neira *et al.* 2000; Neira and Sporcic 2002).

Anchovy egg concentrations over the four sampling periods suggest significant anchovy spawning within PPB. This is consistent with studies by Jenkins (1986) and Neira and Sporcic (2002). An increasing trend from 2004-05 (Period 1) to 2007-08 (Period 4) was recorded for anchovy eggs. This trend could be related to an increasing spawning biomass and/or output by anchovy over the four year period from 2004-05. Another explanation would be that the distribution of anchovy spawning, or the transport of anchovy eggs (which are positively buoyant) by wind driven currents, changed in relation to the sampling areas over the same four year period.

In contrast to the increasing trend for anchovy eggs, anchovy larval concentrations were more variable, declining from 2004-05 (period 1) to 2006-07 (Period 3) but increasing again in 2007-08 (Period 4). This pattern is likely to be related to patterns of dispersal and/or mortality of larvae, possibly in relation to production of planktonic food. The trend in abundance of anchovy larvae reflected that of total fish larvae (Acevedo *et al.* 2009a,b), which is not surprising given anchovy larvae are a dominant species in PPB (Jenkins 1986; Parry and Stokie 2009). Like anchovy larvae, snapper larvae were most abundant in 2004-05 (Period 1) and 2007-08 (Period 4), but unlike anchovy larvae, were least abundant in 2005-06 (Period 2) (Acevedo *et al.* 2009a,b).

Anchovy eggs over all four sampling periods were relatively abundant in the eastern areas of PPB (Carrum, Frankston and Mordialloc). This is partially consistent with the study of Neira and Sporcic (2002), where anchovy eggs were most abundant off Frankston in 1996. In 2007-08

(Period 4), high concentrations of anchovy eggs were also recorded at Point Wilson, in contrast to relatively low abundances at this site in previous years (Period 1-3), but consistent with findings of Neira and Sporcic (2002) during summer 1995-96. Abundances of anchovy eggs in the Hobsons Bay area in 2007-08 were lower than elsewhere, but this has not always been the case. Neira and Sporcic (2002) reported lower concentrations, and Jenkins (1986) reported higher concentrations of anchovy eggs off St Kilda near Hobsons Bay.

Anchovy egg abundance was very low in the Port Phillip Heads area, with no eggs at all recorded in 2004-05 (Period 1) or 2007-08 (Period 4). Jenkins (1986) also reported that the eggs of anchovy were widespread throughout the Bay, with the exception of the Port Phillip Heads area.

Anchovy larvae over the four sampling periods occurred in high concentrations in eastern areas of the Bay (Carrum, Frankston and Mordialloc). These findings agree with those of Jenkins (1986) and Neira and Sporcic (2002). Hobsons Bay appeared to be as important as the eastern area of the Bay when concentrations were log-transformed, reducing the influence of a few, very large samples. Low concentrations of anchovy larvae in Port Phillip Heads suggest that those occurring within PPB are the result of localised spawning.

Abundances of older stages of anchovy collected by Parry and Stokie (2009) 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. A lack of young-of-the-year anchovy was reported by Parry and Stokie (2009) in PPB for 2008. One of the possible explanations provided was that a recruitment failure may have occurred, despite Acevedo *et al.* (2009a, b) recording high concentrations of anchovy eggs and larvae about six months prior to the sampling reported by Parry and Stokie (2009). The reasons for the apparent absence of young-of-the-year anchovy in PPB during 2008 require further consideration.

Conclusions

Current results, together with historical data, suggest that PPB is a key spawning area for anchovy. The key conclusions to date are:

- Anchovy eggs and larvae were collected throughout the Bay, but were recorded in low concentrations in Port Phillip Heads
- Within PPB, the highest abundances of anchovy eggs and larvae were in the eastern area of the Bay (Carrum, Frankston and Mordialloc)
- Interannual variation in anchovy 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).

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Appendix 1 Materials and Methods

Laboratory Methods

For this report, anchovy (*Engraulis australis*) eggs and larvae were sorted and counted from the historical samples (Hamer and Jenkins 2007). Anchovy larvae were identified based on the descriptions in Neira *et al.* (1998). Anchovy egg 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), consistent with Acevedo *et al.* (2009 a,b).

Data Analysis

Concentrations of anchovy eggs and anchovy larvae were tabulated and 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 recent CDBMP sampling (Period 4: 2007–08). Results are presented for both raw concentrations and log-transformed concentrations. Log-transformation was used to reduce the influence of individual samples with exceptionally high concentrations on the mean values.

Analysis of variance (ANOVA) was conducted to assess the variation in abundance of anchovy eggs and larvae in relation to sampling areas and sampling periods for Region 1, and sampling periods for Region 2 (adjacent to Port Phillip Heads). Prior to ANOVA analysis, anchovy egg and larval concentrations (number per 1000 m³) were $\log_{10}(x+1)$ transformed to improve data normality and reduce heterogeneity of variances. Sampling areas were treated as fixed factors.

Appendix 2 Results

Results for the 2007–08 field sampling event only have been previously reported by Acevedo *et al.* (2009a,b). A total of 13 267 anchovy eggs and 106 729 anchovy larvae were collected over all four periods (Table 1).

Anchovy Eggs

Total anchovy egg concentrations were lowest in 2004-05 (Period 1) and highest in 2007-08 (Period 4) (Table 1). Over all years combined for Region 1, anchovy eggs were most abundant in eastern PPB (Carrum, Frankston and Mordialloc areas), with the highest concentration being in the Frankston area (Table 2).

ANOVA of log-transformed data showed that there were significant differences between years and areas within PPB (Region 1) (Table 3a). For the log-transformed data, there was an increasing trend from 2004-05 (Period 1) to 2007-08 (Period 4) (Figure 2). For the log-transformed data over all years, the highest concentration of anchovy eggs within PPB (Region 1) was in Carrum, and the lowest concentrations were recorded in northern PPB (Hobsons Bay and Point Wilson) (Figure 3).

ANOVA of log-transformed data showed a significant interaction between years and areas within PPB (Region 1) (Table 3a). Anchovy egg abundances in 2004-05 (Periods 1), 2005-06 (Period 2) and 2007-08 (Period 4), showed significant differences amongst areas (Table 4). The primary reason for this interaction was that in the earlier years, anchovy egg concentrations were low in areas such as Hobsons Bay, Point Wilson and to a lesser extent Frankston, but in later years eggs were widespread though the Bay (Figure 4a).

In the Port Phillip Heads area (Region 2), there was no significant difference in the concentration of anchovy eggs between periods (Table 3b). Anchovy eggs were only collected in

this Region in 2005-06 and 2006-07 (Periods 2 and 3), and only in low concentrations (< 3 eggs per 1000 m³) (Table 1; Figure 4a).

Anchovy Larvae

Total anchovy larval concentrations were highest in 2007-08 (Period 4) and lowest in 2006-07 (Period 3) (Table 1). For all years combined in Region 1, anchovy larvae were most abundant in eastern PPB (Carrum, Frankston and Mordialloc) (Table 2).

ANOVA of log-transformed data showed that total anchovy larval concentration within PPB (Region 1) differed significantly amongst years and areas (Table 3a). For the log-transformed data, the highest concentration was in 2004-05 (Period 1) and the lowest in 2006-07 (Period 3) (Figure 2). For all years combined, high concentrations were recorded in Mordialloc, Frankston and Hobsons Bay (Figure 3).

ANOVA of log-transformed data also showed a significant interaction between years and areas within PPB (Region 1) (Table 3a). This interaction was due to the different pattern of anchovy larval concentration between areas for each year. For example, there was a significant difference amongst areas in 2004-05 (Periods 1), 2005-06 (Period 2) and 2006-07 (Period 3) (Table 4). Concentrations of anchovy larvae were high in Carrum and Mordialloc, except in 2006-07 (Period 3) (Figure 4b). In 2004-05 (Period 1) and 2007-08 (Period 4), anchovy larvae concentrations were high in Hobsons Bay (Figure 4b).

In the entrance to PPB (Region 2), concentrations of anchovy larvae were significantly different between periods (Table 3). In general there was a decline in anchovy larval concentration over the four years in this region (Figure 4b), with the exception of an increase in 2006-07 (Period 3).

Table 1. Total number and mean concentration (\pm standard error) of anchovy eggs and larvae collected in all areas/regions of PPB during all four periods from 2004-05 to 2007-08.

Period	Area	Total anchovy eggs	Mean concentration anchovy eggs (eggs per 1000 m ³)	Total Anchovy larvae	Mean concentration anchovy larvae (larvae per 1000 m ³)
1 (2004-05)	Carrum	148	73.9 \pm 31.6	4343	2477.3 \pm 853.3
	Frankston	34	11.7 \pm 5.9	7369	2799.5 \pm 822.9
	Hobsons Bay	2	1.2 \pm 0.7	2263	1504.5 \pm 544.7
	Mordialloc	705	161.8 \pm 111.4	8851	2639.1 \pm 756.3
	Point Wilson	0	0	1104	327.8 \pm 47.1
	Port Phillip Heads	0	0	1368	287.2 \pm 122.7
	All Areas	889	43.7 \pm 23.1	25 298	1637.5 \pm 290.1
2 (2005-06)	Carrum	800	185.2 \pm 85.2	9203	1942.4 \pm 702.4
	Frankston	115	26.6 \pm 13.6	5344	11 83.2 \pm 439.0
	Hobsons Bay	1	0.4 \pm 0.4	370	151.7 \pm 44.7
	Mordialloc	169	54.3 \pm 25.7	11 751	3861.7 \pm 1,565.2
	Point Wilson	6	2.5 \pm 0.9	278	114.9 \pm 52.0
	Port Phillip Heads	17	2.9 \pm 1.8	322	57.9 \pm 33.8
	All Areas	1108	49.6 \pm 18.9	27 268	1187.8 \pm 309.0
3 (2006-07)	Carrum	340	80.4 \pm 29.1	670	171.4 \pm 115.3
	Frankston	2345	714.9 \pm 599.3	1 501	306.1 \pm 75.5
	Hobsons Bay	342	202.6 \pm 124.7	378	248.9 \pm 97.1
	Mordialloc	1017	233.6 \pm 170.6	2304	646.9 \pm 384.3
	Point Wilson	233	50.5 \pm 26.0	1440	304.3 \pm 47.0
	Port Phillip Heads	2	0.4 \pm 0.3	194	44.1 \pm 12.1
All Areas	4279	225.7 \pm 128.2	6487	287.7 \pm 73.2	
4 (2007-08)	Carrum	1,160	312.8 \pm 98.9	8537	2554.6 \pm 1,455.5
	Central	462	108.9 \pm 31.1	2391	571.7 \pm 157.0
	Frankston	3,165	851.4 \pm 300	6711	1780.5 \pm 988.9
	Hobsons Bay	274	67.9 \pm 31.8	4801	1215.5 \pm 198.2
	Mordialloc	841	267.5 \pm 64.8	11 839	3351.4 \pm 1,468.7
	Point Wilson	1,089	274.5 \pm 77.8	13 250	3335.1 \pm 2,200.6
	Port Phillip Heads	0	0	147	26.7 \pm 13.7
All Areas	6991	261.6 \pm 54.2	47 676	1783.4 \pm 447.6	
All Periods		13 267	160.1 \pm 37.7	106 729	1237.6 \pm 173.1

Table 2. Total number and mean concentration (\pm standard error) of anchovy eggs and larvae collected in each area[#]/region of PPB over all four periods (from 2004-05 to 2007-08) combined.

Area (all periods combined)	Total anchovy eggs	Mean concentration anchovy eggs (eggs per 1000 m ³)	Total anchovy larvae	Mean concentration anchovy larvae (larvae per 1000 m ³)
Carrum	2,448	172.9 \pm 39.6	22,753	1,709.6 \pm 482.2
Frankston	5,659	416.5 \pm 189.1	20,925	1,421.1 \pm 334.5
Hobsons Bay	619	62.3 \pm 26.7	7,812	836.6 \pm 163.1
Mordialloc	2,732	190.2 \pm 57.3	34,745	2,521.3 \pm 567.8
Point Wilson	1,328	94.7 \pm 30.2	16,072	1,143.1 \pm 650.6
Port Phillip Heads	19	0.9 \pm 0.5	2,031	97.2 \pm 31.9

Central area of PPB (Region 1) not included due to lack of historical data

Table 3. Results of ANOVA comparing variation in concentrations ($\log_{10}(x+1)$ transformed) of anchovy eggs/larvae within a) PPB (Region 1), and b) in Port Phillip Heads (Region 2) n.b. results in bold are those significant at $p < 0.05$.

a) Region 1	df	Anchovy eggs		Anchovy larvae	
		MS	p	MS	p
Area	4	3.381	0.002	1.472	0.004
Period	3	18.293	0.000	9.121	0.000
Area x Period	12	1.479	0.036	1.791	0.000
Error	153	0.769	-	0.366	-
b) Region 2					
Period	3	0.172	0.086	6.742	0.000
Error		0.073	-	0.323	-

Table 4. Results of ANOVA comparing variation in concentrations ($\log_{10}(x+1)$ transformed) of anchovy (eggs/larvae amongst areas in PPB (Region 1) n.b. results in bold are those significant at $p < 0.05$.

Region 1		Anchovy eggs		Anchovy larvae	
Period 1	df	MS	p	MS	p
Area	4	2.237	0.023	0.956	0.038
Error	153	0.769	-	0.366	-
Period 2					
Area	4	2.117	0.030	2.720	0.000
Error	153	0.769	-	0.366	-
Period 3					
Area	4	1.440	0.118	2.583	0.000
Error	153	0.769	-	0.366	-
Period 4					
Area	5	2.261	0.022	0.330	0.464
Error	153	0.769	-	0.366	-

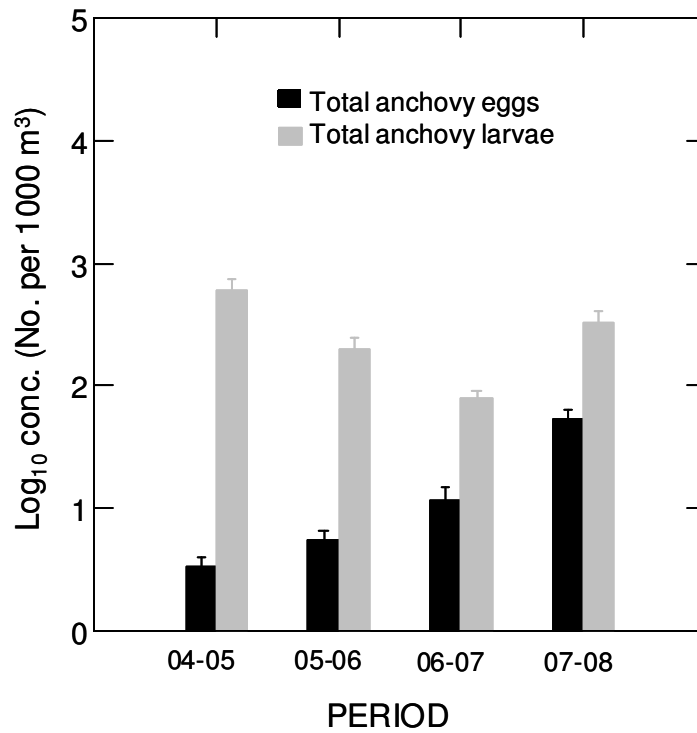


Figure 2. Mean of the log-transformed concentration (± 1 standard error) of anchovy eggs and larvae collected during each period (all areas combined).

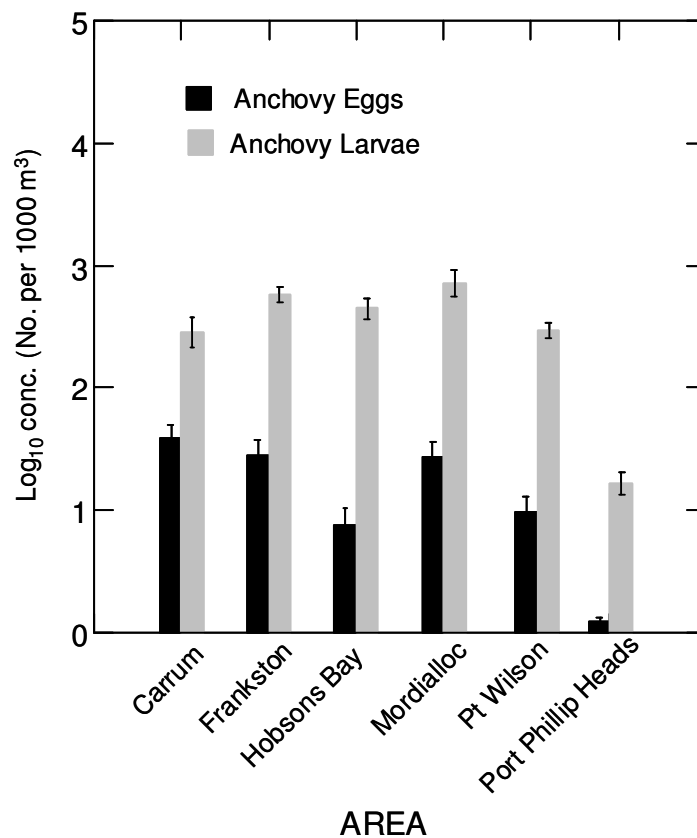


Figure 3. Mean of the log-transformed concentration (± 1 standard error) of anchovy eggs/larvae from samples taken in each area over all four periods combined (from 2004-05 to 2007-08).

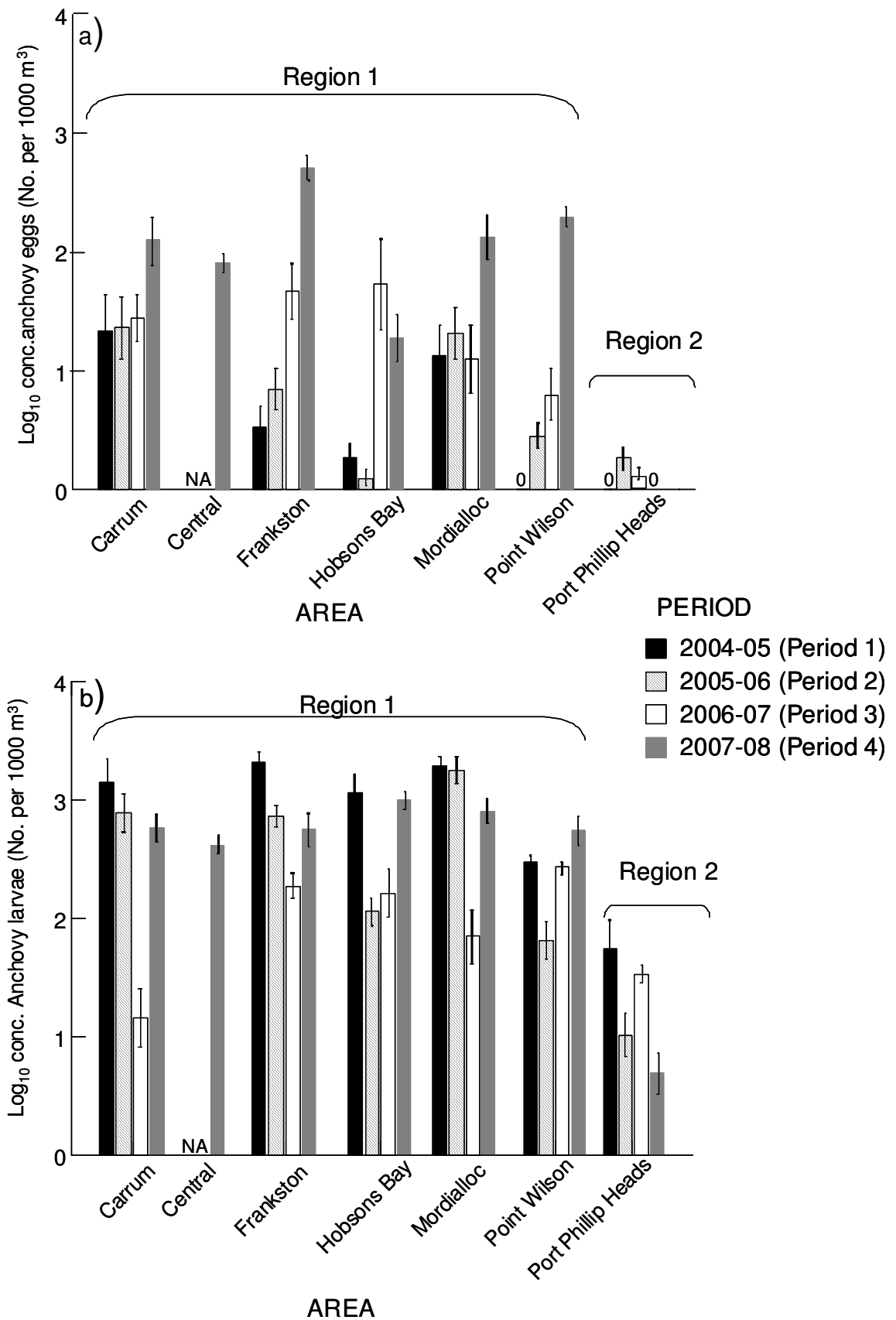


Figure 4. Mean of the log-transformed concentration (± 1 standard error) of a) anchovy eggs and b) anchovy larvae taken in each area/region during all four periods (from 2004-05 to 2007-08).

Appendix 3 Data

Data Files

All data and metadata for the first period (2007-08) of the CDBMP sub-program is provided in the following electronic data file:

- PPB_Anchovy eggs larvae_snapper larvae_Period 4.xls