APPENDIX H10

Entrainment assessments

Testimonial letter - Dr Miskiewicz

BN97813815 ICHTHYOLOGICAL INVESTIGATIONS ABN 78 517 024 838

15 October 2010

James Brook
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Adelaide SA 5001

Dear James

I have reviewed and provided comments on the four reports detailed below that have been prepared as part of the EIS for the proposed Point Lowly desalination plant in Upper Spencer Gulf:

- Appendix H10.1 - Survey of planktonic larvae near the proposed Port Lowly desalination plant.
- Olympic Dam Expansion Supplementary EIS Chapter 17- Marine Environment, Section 17.13 - Entrainment
- Appendix H10.2 – Entrainment threat assessment
- Appendix H7.2 - Spencer Gulf Modelling Assessments (280 ML/day desalination plant) Final Report, Section 8 Larval Entrainment

Based on my review of these four reports, the proponents have undertaken a very comprehensive study to assess the potential impacts of the desalination plant on the larval fish and invertebrate communities in the upper Spencer Gulf. These studies included field sampling of fish and invertebrate larvae over a one year period as well as detailed modeling to determine distributions of larvae based on the prevailing currents in the gulf. The conclusion from these field and modeling studies, as summarized in the entrainment threat assessment report, is that the desalination plant will have a minimal impact on the fish and invertebrate communities in the gulf due to intake of seawater.

On this basis, I consider the work to have been undertaken thoroughly, to a high technical level and in line with normal industry practice. I confirm that the work detailed in the three reports that I have reviewed is acceptable for its intended purpose.

Yours Faithfully

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Ichthyological Investigations
0407893292

APPENDIX H10.1

Survey of planktonic larvae near Point Lowly

BHP Billiton – Point Lowly Desalination Plant:

Survey of Planktonic Larvae Near the Proposed Point Lowly Desalination Plant.

14th October 2010

Cooe

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Executive Summary

BHP Billiton is investigating the potential environmental impacts associated with the construction of a desalination plant at Point Lowly to supply water for its proposed expansion of the Olympic Dam Mine.

This report summarises the results of four seasonal surveys targeting larval fish and crustaceans and juvenile cephalopods near Point Lowly between November 2008 and July 2009. The surveys were designed to generate ecological information to help in the evaluation of the potential entrainment of larval fish and invertebrates by the desalination plant seawater intake.

The study focused on marine species that as a part of their life cycle produce pelagic eggs and larvae, which are likely to be exposed to the desalination plant intake while drifting with local marine currents.

Larvae of crustaceans, cephalopods and fishes were collected with 300µm mesh plankton nets towed through the water profile behind a powered vessel by COOE marine biologists. Samples were collected from up to three, 500m-long transects at four sites around Point Lowly; southern and northern Fitzgerald Bay (sites 1 and 2, respectively), directly offshore from the Point Lowly Lighthouse (site 3) and Port Bonython (site 4).

The sampling was undertaken over a 24 hour period to cover all light and tide conditions. Samples comprising all planktonic organisms in the seawater column were sorted mainly for larval fishes as well as larvae of commercial invertebrates and identified down to the lowest possible taxonomic level with the available literature.

The overall findings of these surveys suggest that the larval fish assemblages in the Point Lowly area were typical in terms of richness and concentrations of southern Australian waters; anchovy concentrations were comparatively high. A strong seasonal pattern, as well as a night/day distinction typical of these marine species, was found.

The concentration of larval fish was an order of magnitude greater in summer than spring and two orders greater than autumn and winter. The highest number of larval fishes and species richness were observed during night surveys.

Site 2 yielded the highest overall concentration of larval fishes and crustaceans, followed by sites 1, 3 and 4 which could not be separated statistically. Based on summed standardised concentrations (i.e. number of larvae per 100 m^3 of water volume sampled), the larval fish assemblage in the Point Lowly area was dominated by grubfish (*Parapercis* spp.) and bluespot goby (*Pseudogobius olorum*) during spring (60% combined) and largely by anchovy (*Engraulis australis*) during summer and bluespot goby (73% and 19%, respectively). Larvae of other fishes, including some of commercial fish species, were caught in very small numbers.

Early juveniles of southern calamary (*Sepioteuthis australis*) were caught in small numbers; the highest numbers were caught in autumn. Larvae of penaeid prawns, including western king prawn (*Melicertus latisulcatus*), were identified in spring and summer but not in autumn or winter. Western king prawn larvae made up around 30% of the penaeid prawn larvae caught.

Statistical comparisons between sites based on species richness could not be made over the four seasons due to uneven sampling effort. There were different outcomes for comparisons between sites for the entire assemblage and for the most abundant six

species, making it difficult to draw conclusions about the suitability of site 1 with respect to other sites.

The main findings of this study are:

- The highest species richness and abundance occurs during spring and summer.
- More larvae were caught at night than during the day.
- Richness and concentration of larval fish was not strongly influenced by distance offshore.
- Anchovy accounted for 72.8% of the larvae caught in the summer survey and 69% of the total larval fish catch for the twelve month study.
- Larvae of commercially important fish species, excluding anchovy, accounted for just over 1% of all larval fishes caught.
- More larval crustaceans were caught during flood tides.
- The highest larval fish concentrations were recorded in site 2 in north Fitzgerald Bay.
- Overall larval fish concentrations in site 3 and 4 were not statistically separable from sites 1 and 2 in summer.

Based on the results of this study, it is concluded that the proposed intake (site 1) would be no more susceptible to larval entrainment than the three references sites. Furthermore, results during periods of peak concentration (in summer at night) showed that larval concentrations were significantly higher at site 2 than site 1. This pattern was strongly influenced by the two most abundant species, anchovy and blue spot goby and therefore could be subject to considerable variability.

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1 Introduction

BHP Billiton is currently preparing an Environmental Impact Statement (EIS) for the Olympic Dam Expansion Project. An important component of the project consists of a proposed desalination plant in the Point Lowly area which when fully operational will supply potable water to the Olympic Dam mine and the township of Roxby Downs.

Point Lowly is located approximately 34km northeast of Whyalla on the east coast of the Eyre Peninsula, in South Australia. The proposed seawater intake is to be located on the southern shore of Fitzgerald Bay, approximately 2km northwest of the Point Lowly lighthouse (Figure 1).

Numerous ecological and geophysical investigations are underway to help project designers minimise the impact on the environment in a cost effective manner. This study reports the findings of four seasonal surveys targeting fish and crustacean larvae and juvenile cephalopods undertaken during 2008-2009 in the vicinity of Point Lowly; from Port Bonython in the west to Backy Point at the north of Fitzgerald Bay.

The surveys focused on the likelihood of entrainment of larvae of commercially and ecologically sensitive invertebrates and fish species. A total of 312 plankton samples were collected over the study period, covering all seasons and times of day, the supporting data is presented in Appendix A.

This study evaluates to what extent the location of the planned intake pipe could influence entrainment of fish and invertebrate larvae. The information generated by these surveys will supplement ecological data and oceanographic modelling used to assess the impact of entrainment by the proposed Point Lowly desalination plant.

* Approximate transect lines are marked in red for each site

Figure 1. Location map of transect around Point Lowly.

2 Methodology

2.1 Study sites

Sampling sites were selected to represent waters around the proposed seawater intake and several sites for comparison. Plankton trawl transects were established around Point Lowly; site 1 (southern Fitzgerald Bay - the proposed intake area); site 2 (Point Backy); site 3 (Point lowly) and site 4 (Port Bonython) as shown in Figure 1.

The sites surveyed in each season were selected by the Olympic Dam Expansion EIS team based on their project requirements, the results of the previous season's survey data and in consultation with the plankton survey team on logistical considerations.

2.2 Sampling method

A pilot survey was conducted in September 2009 to explore the potential of sampling larvae post-intake from the pilot desalination plant at Point Lowly and to trial the proposed plankton towing techniques.

Sampling methodology and effort were based on the pilot survey conducted in September 2008 near the seawater intake of the pilot desalination plant along the Port Bonython jetty, and at the proposed intake area at site 1 (Figure 1).

Sampling through the pilot plant intake was unsuccessful due to extensive damage to the larval fishes by the pumps and was therefore discontinued. Towed sampling at site 1 in Fitzgerald Bay was retained and other sampling sites (sites 2-4) were added at various times for comparison with the proposed intake area, as shown in Table 1.

Table 1. Summary of seasonal plankton surveys undertaken during this study.

Survey Date	Spring 2008 12-14 Nov	Summer 2009 16-20 Feb	Autumn 2009 18-27 May	Winter 2009 20-23 Jul
Sites sampled	1	1, 2, 3, 4	1, 2, 4	1, 4
Samples per site	42	47, 24, 14, 14	48, 48, 24	12, 12
Samples analysed	42	99	120	24

2.3 Timing of surveys

The first plankton survey off Point Lowly was conducted in spring (November 2009) at site 1. Three transects were run at set distances from shore: transect (T1) was located over the preferred intake location 400m offshore, the second (T2) at around 100m offshore from T1 and the third (T3) 500m further offshore from T1. Only T1 and T3 were sampled after the spring survey because T2 showed no statistically significant differences from T1 and T3, in terms of species richness (i.e. composition) and concentrations of larval fishes.

Three additional sites (sites 2, 3 and 4) were surveyed in the summer of 2009 to explore spatial variation of larvae in the region. Site 2 comprised two transects parallel to the shore at 500m and 1,000m offshore while sites 3 and 4 comprised one transect each located 500m offshore (Figure 1). After the results of the summer survey were examined, sampling at site 3 was discontinued due to its similar abundances (during summer) to site 4. Site 2 was not surveyed in winter due to the statistical similarities to site 1 in autumn.

These modifications were in line with the main objective of assessing the potential of entrainment; while increasing the focus on spatial and temporal variability, the overall study design was not a statistically balanced design across all combinations of season, site, transect and time of day.

2.4 Sampling equipment and technique

Samples were collected using a standard PAIROVET bongo sampler, with two identical 0.25m diameter, 1.5m long nets (300µm mesh) with screw on PVC cod-ends. Each net was fitted with a General Oceanics flowmeter to quantify the volume of seawater filtered in each tow. The nets were fitted with a float attached to the frame between the two nets, to allow the depth of the net to be assessed rapidly during trawls (the float rope could be adjusted for the depth of each trawl).

Each tow was run parallel to the shore for 500m in a zig-zag pattern to maximise sampling effort and minimise sampling bias. Each tow lasted for approximately 10 minutes and covered the entire water column to the maximum possible depth of 25m.

The nets were slowly lowered to the maximum practicable depth by the 5 minute mark and then slowly retrieved until the nets surfaced at the 10 minute mark. Trawls were generally conducted in 8-18m of water (depth varied with time of tide cycle and location). Site 3 was located in deeper waters and reached around 25m below the surface during some sampling runs. The volume of water passing through the net during each tow was estimated using flowmeters attached at the mouth of each net.

The nets were washed with seawater and all contents of the cod-ends transferred into a 1L plastic container and fixed in a solution of 5-10% of formaldehyde in seawater. Field notes were collected during each tow recording date, time, site ID, transect, replicate number, flowmeter counts and general field observations. The same sampling equipment and methodology were used during each survey.

2.5 Sorting and treatment of samples

All plankton samples were rinsed with water to remove traces of formaldehyde and transferred to 70% ethanol for storage at the Museum of South Australia.

Larvae of all fishes and of commercial invertebrate species were removed under a dissecting microscope and transferred to 15mL plastic vials filled with 70% ethanol for taxonomic identification and counts.

Identification of larval fishes[1] and cephalopods was carried out by Dr. Francesco Neira to the lowest possible taxonomic level employing the identification atlas of Neira *et al*. (1998) and that of adult fishes of Gomon *et al.* (2007). The total number of larvae within a sample were standardised to numbers per 100m^3.

2.5.1 Crustacean larvae sorting procedure

Sub-samples were collected from selected samples and sorted for crustacean larvae. Most sub-samples came from the spring and summer seasons since this is the time of year in which the western king prawns are known to spawn in Spencer Gulf (Steer *et al*., 2006;

[1] Larva is described "as the developmental stage from hatching to the attainment of full external meristic characters (e.g. fin elements), and includes yolk sac through to postflexion stages" (Neira *et al.* 1998).

Dixon *et al*., 2009). Two samples from each of the autumn and winter surveys were also sorted for comparison.

Western king prawn larvae were sorted with the aid of a dissecting microscope to extract larvae. The number of larval prawns in 50mL were counted and returned to the main sample. This step was repeated three times and an average calculated. The average was extrapolated to give the total number of prawns in the whole sample. This value, together with flowmeter data, was used to calculate the concentration of prawn larvae per $100m^3$.

The life cycles of crustacean species have more larval stages than fish and are therefore more complicated to identify to species level. In this study, we were able to identify penaeid prawns and refine the taxonomy to identify western king prawn (*Melicertus latisulcatus*) larvae based on photographs provided by a South Australian western king prawn hatchery.

3 Results and discussion

3.1 Larval fish and juvenile cephalopod community near Point Lowly

The results from the field surveys were evaluated at the seasonal, site and transect level. On a seasonal level the data from all sites and all transects were pooled, this provided an understanding of larval fish and cephalopod assemblages at various times of the year.

At site level, the pooled transect data provided an understanding of the spatial distribution of larval fish and juvenile cephalopods around Point Lowly. This spatial evaluation was refined by analysing the transect data to determine if distance offshore effected the distribution of larval fishes.

The results of the larval fish assemblages in this study are summarised below:

- Over the monitoring period, larvae of 31 taxa (fish species) from 21 families were recorded in the study area. The greatest species richness occurred in spring (22 taxa) and summer (21 taxa), while lower richness was recorded in autumn (13 taxa) and winter (4 taxa).
- The greatest concentration of larval fishes occurred during summer, followed by spring, autumn and winter having the lowest concentration, Table 2.
- Anchovy (*Engraulis australis*) was the most abundant species in summer, also occurring in spring and autumn but in lower concentrations, Table 3.
- The second most abundant species was the bluespot goby (*Pseudogobius olorum*), which was also abundant in spring, summer and autumn and absent in winter.
- Soldierfish (*Gymnapistes marmoratus*) was the only species to be caught in all seasons.
- Besides anchovy, larvae of other species of commercial importance were identified in this study, these included yellowfin whiting (*Sillago schomburgkii*), mackerel (*Trachurus sp*), skipjack trevally (*Pseudocaranx wrighti*), garfish (*Hyporhamphus melanochir*) and flathead (*Platycephalus sp*.). However, each species was represented by a small number of larvae.
- Sixteen small juveniles of southern calamary (*Sepioteuthis australis*) were caught during this study, 12 in autumn (all sites) and 2 in winter (site 1 only) and 2 in summer (site 1 only).
- The family Syngnathidae (pipefish and seahorses) were found sporadically at each site and generally in low numbers. The Spotted pipefish (*Stigmatopora argus*) was the most common Syngnathidae, with larvae occurring in all seasons except summer.
- No snapper (*Chrysophrys auratus*) larvae or cuttlefish (*Sepia apama*) hatchlings were caught during this study.
- Assemblages are typical of protected bays and estuaries across temperate Australia with seagrass beds and sandy or rocky bottoms
- The number of families recorded was consistent with a previous study near Whyalla and some locations in temperate Australia, but lower than other locations (Table 5).

Table 2. Total number of larval fishes caught in each season.

	Spring Nov 08	Summer Feb 09	Autumn May 09	Winter Jul 09	**Totals**
Number of samples	42	99	120	24	**285**
Total larval fish caught per survey	955	21,116	276	45	**22,392**
Total number of taxa	22	21	13	4	**31**
Total number of families	16	15	10	4	**21**

The percentage contribution[2] each taxon made to the larval fish assemblages in each season around Point Lowly is presented Table 3. The total number of larvae caught over the whole study period, shown in the last column provides a picture of the relative abundance of individual species.

Table 3. Seasonal contribution of individual taxa to larval fish assemblages at Point Lowy.

Family	**Taxa**	**Common name**	**Spring** %	**Summer** %	**Autumn** %	**Winter** %	**Total caught**
Engraulidae	*Engraulis australis*	Anchovy	14	72.8	7.3		15,364
Gobiidae	*Pseudogobius olorum*	Bluespot goby	23.7	18.6	20.5		4,205
	Nesogobius sp. 1	Goby	1.8	1		48	271
	Nesogobius sp. 2	Goby			24		66
	Favonigobius lateralis	Southern longfin goby	0.9	0.5	0.7		129
Pinguipedidae	*Parapercis spp.*	Grubfish	36.7	2.8			948
Terapontidae	*Pelates octolineatus*	Western striped grunter	1.3	2.7			708
Tetrarogidae	*Gymnapistes marmoratus*	Soldierfish	0.4	0.9	0.3	4	204
Clinidae	Clinids	Weedfishes	0.6		18	33.9	70
	Heteroclinus sp.	Weedfish	0.5				4
	Ophioclinus antarcticus	Weedfish	0.2				
Blenniidae	*Parablennius tasmanianus*	Tasmanian blenny	0.9	<0.1	13.4		19
	Ommobranchus anolius	Oyster blenny	0.5	0.1			
Paralichthyidae	*Pseudorhombus arsius*	Largetooth flounder	5.8	0.1			75
Callionymidae	Callionymid	Stinkfish	1.1	0.2	3.2		59
Monacanthidae	Monacanthid	Leatherjacket	3.2	<0.1	8.1		53
Sillaginidae	*Sillago schomburgkii*	Yellowfin whiting	0.7	0.2			53
Syngnathidae	*Stigmatopora argus*	Spotted pipefish	0.6		2.5	14.1	18
	Hippocampus sp.	Seahorse	0.3	<0.1			4
	Campichthys sp.	Short pipefish		<0.1	0.3		2
	Filicampus tigris	Tiger pipefish		<0.1			4
Odacidae	*Haletta semifasciata*	Blue weed whiting	2.6				25
Gobiesocidae	Gobiesocid	Clingfishes	2.1				19
Tetraodontidae	Tetraodontid	Pufferfishes	2				18
Apogonidae	*Siphamia cephalotes*	Wood's siphonfish		<0.1			5
Carangidae	*Trachurus* sp.	Mackerel		<0.1			3
	Pseudocaranx wrighti	Skipjack trevally		<0.1			2
Hemiramphidae	*Hyporhamphus melanochir*	Sea garfish		<0.1	1		4
Platycephalidae	*Platycephalus* sp.	Flathead	0.2				2
Triglidae	*Lepidotrigla* sp.	Gurnard			0.7		1
Serranidae	*Caesioperca* sp.	Perch		<0.1			1

[2] Percentage contribution is based on standardised numbers, which is the number of larvae caught divided by the volume of water passing through the plankton net.

The mean concentration[3] and standard deviation found in each season is shown in Table 4. This table provides a quantitative description of the relative abundance of individual species in each season and provides a measure of variability. It should be noted that these means pool concentrations of larval fishes from all sites and are presented here to describe typical larval fishes assemblages in different seasons around Point Lowly.

Table 4. Mean concentrations of larval fish found in four seasons around Point Lowly.

	Spring		Summer		Autumn		Winter	
Standardised	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Total larvae	43.95	27.05	786.59	648.48	3.68	5.87	2.76	2.84
Engraulis australis	6.14	5.76	572.49	416.12	0.27	0.64		
Pseudogobius olorum	10.42	8.31	146.70	288.80	0.76	2.34		
Nesogobius sp. *1*	0.81	1.81	7.75	8.45			1.32	2.37
Nesogobius sp. *2*					0.88	2.92		
Favonigobius lateralis	0.39	0.95	3.90	6.84	0.02	0.19		
Parapercis	16.14	11.51	22.41	20.87				
Pelates octolineatus	0.56	1.31	20.86	31.89				
Gymnapistes marmoratus	0.17	0.54	7.40	8.98	0.01	0.13	0.39	0.69
Clinid	0.24	0.95			0.66	1.39	0.94	1.94
Heteroclinus sp.	0.22	1.16						
Ophioclinus antarcticus	0.10	0.47						
Parablennius tasmanianus	0.39	1.01	0.25	1.08	0.49	1.68		
Ommobranchus anolius	0.23	0.65	0.43	1.33				
Pseudorhombus arsius	2.57	6.90	0.95	2.16				
Callionymid	0.47	1.00	1.33	2.34	0.12	0.41		
Monacanthid	1.39	1.66	0.04	0.36	0.30	0.87		
Sillago schomburgkii	0.29	0.89	1.36	2.62				
Stigmatopora argus	0.25	0.84			0.09	0.37	0.11	0.37
Hippocampus sp.	0.13	0.47	0.04	0.36				
Campichthys sp.			0.04	0.43	0.01	0.14		
Filicampus tigris			0.20	0.89				
Haletta semifasciata	1.15	2.03						
Gobiesocid	0.93	3.42						
Tetraodontid	0.88	1.63						
Siphamia cephalotes			0.19	1.16				
Trachurus sp.			0.14	1.01				
Pseudocaranx wrighti			0.06	0.49				
Hyporhamphus melanochir			0.02	0.25	0.04	0.23		
Platycephalus sp.	0.07	0.32						
Lepidotrigla sp.					0.03	0.20		
Caesioperca sp.			0.04	0.36				
Sepioteuthis australis					0.16	0.52	0.14	0.47

* mean = sum of concentration of larvae in that season from all sites, transects and replicates collected, divided by the number of samples, SD = standard deviation.

3.1.1 Comparison to other fish larvae studies

In this study anchovy were by far the most dominant species, mostly due to the large number of larvae caught during the summer survey. The mean concentration of anchovy in summer was 572 larvae per $100m^3$, higher than that recorded within Port Phillip Bay

[3] Concentration (or density in some literature) is the total number of larvae divided by the volume of water passing through the nets times 100.

during peak spawning period (343 larvae per 100 m^3) reported by Neira and Sporcic (2002) and 383 larvae per 100 m^3 reported by Dimmlich *et. al.* (2004) in SA Gulf waters.

Dimmlich *et al.* (2004) reported that the maximum egg density in northern gulf waters of 13,942 eggs 100 m^3 was among the higher egg densities recorded in other populations of Australian anchovy where nets of 300µm mesh or less was used. In this study, a considerable number of anchovy eggs were also found in each sample during spring and summer. This suggests that Upper Spencer Gulf is an important breeding area for anchovy.

The number of families recorded in this survey was consistent with a previous study near Whyalla (Bruce and Short 1992) and some locations in temperate Australia, but lower than other locations, Table 5.

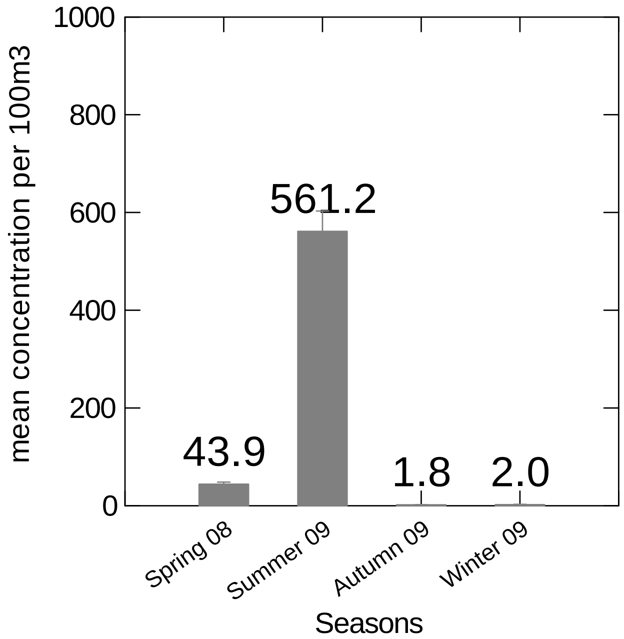
Table 5. Comparison with other larval fish studies.

System	State	Estuary (E) Enclosed Bay (EB)	Number families	Sampling duration	References
Upper Spencer Gulf	SA	EB	21	12 months	(this study)
Upper Spencer Gulf	SA	EB	23	5 months	Bruce and Short (1992)
Lake Macquarie	NSW	E	41	2 tidal cycles	Trnski (2001)
Tamar Estuary	Tas	E	44	14 months	Lara-Lopez (2006)
Port Phillip Bay	Vic	EB	32	1 year	Neira and Sporcic (2002)
Hopkins River	Vic	E	9	20 months	Newton (1996)
Swan Estuary	WA	E	37	1 year	Neira *et al.* (1992)
Nornalup-Walpole	WA	E	23	1 year	Neira and Potter (1994)
Wilson Inlet	WA	E	17	19 months	Neira and Potter (1992)

Source: adapted from Lara-Lopez (2006).
Note: there were differences in oceanographic conditions, degree of exposure and the extent of habitats such as seagrass, soft substrates and rocky reefs between these studies.

3.2 Seasonal effects on larval fishes

This study found that larval fish concentrations have a distinct seasonal cycle. Larvae of most pelagic fish species caught in this study start increasing in spring, reaching a peak in summer before markedly declining through to winter, Figure 2.



* error bar = standard error of mean.

Figure 2. Seasonal variation in larval fish concentrations at site 1.

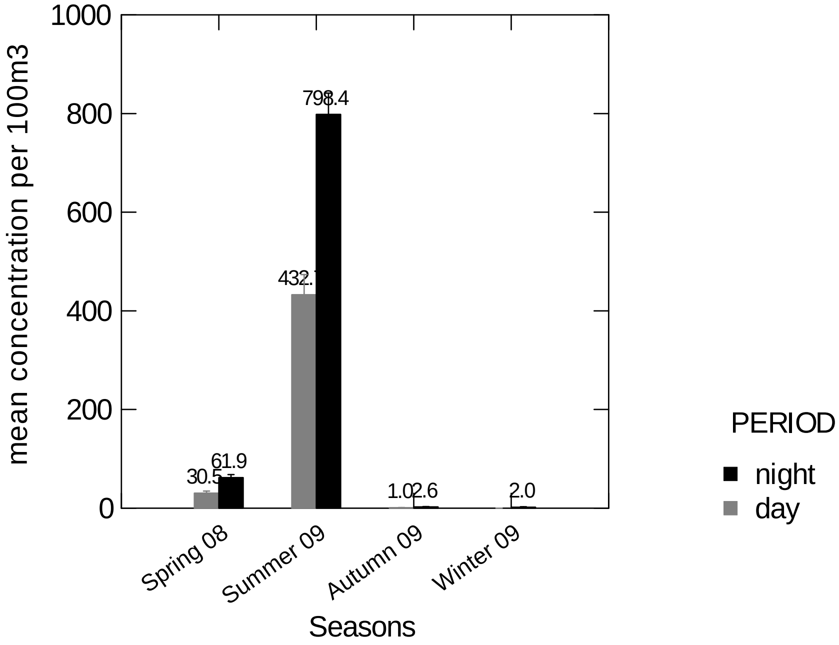
The spawning season of anchovy starts in spring and peaks in summer as water temperatures increase in South Australian waters (Dimmlich *et al*. 2004). The seasonality of anchovy spawning is typical of enclosed bays and estuaries across temperate Australia (Neira *et al*. 1998).

The second most abundant taxa caught in the Port Bonython area was bluespot goby followed by grubfish and the western striped grunter, Table 3 and Table 4. The remaining 28 taxa occurred in comparatively lower numbers, representing 5.2% of the total fish larvae catch for the year.

In addition to anchovy, larvae of other commercially important taxa included yellowfin whiting, mackerel, skipjack trevally, garfish, flathead and flounder. Larvae of four species found are listed as marine species under the 1999 EPBC Act; these were the Syngnathids tiger pipefish (*Filicampus tigris*), seahorse (*Hippocampus* sp.), spotted pipefish (*Stigmatopora argus*) and pipefish (*Campichthys* sp.).

3.3 Day and night effects on larval concentrations

Significantly more larvae were caught at night than during the day, Figure 3. Around twice as many larval fishes were caught during the night at site 1 than during the day in spring summer and autumn, no day time sampling was undertaken in winter due to weather conditions.



* error bar = standard error of mean.

Figure 3. Seasonal and diurnal variations in larval fish concentrations at site 1.

3.4 Invertebrates

Southern calamary was most abundant during autumn (12 juveniles). The breeding behaviour of southern calamary complicates the interpretation of plankton tow data, because of the ongoing cycle of adults entering the inshore spawning grounds throughout the year (Steer *et al*., 2006). It is also known that southern calamary have offshore nursery and inshore spawning grounds (Sauer, 1995) which may explain why very few juvenile southern calamary were caught.

Western king prawn (*Melicertus latisulcatus*) is the main target of trawl fisheries in Spencer Gulf, with by-product species mainly slipper lobsters (*Ibacus* spp.) and southern calamary. Blue swimmer crab (*Portunus armatus*[4]) is the second most important commercial crustacean species in Spencer Gulf; larvae of this species proved more difficult to identify.

Table 6 shows the number of penaeid prawns obtained in selected samples taken from the Port Bonython area during this study. The level of confidence in identifying crustacean larvae to family level (Penaeidae) was estimated at 90%, due to around 10% of specimens being in nauplii stage and hence difficult to separate from other crustaceans using standard methods. Random sampling of these penaeid prawns resulted in around 30% being western king prawns in a zoeal stage (an early free swimming larval stage).

[4] Formerly *P. pelagicus*

Table 6. Concentrations of penaeid prawn larvae caught in this study.

SEASON	SITE	TIME	Concentrations (numbers per 100m^3)
Spring	1	20:00	38
Spring	1	2:00	89.4
Spring	1	20:00	89.8
Summer	1	21:30	173.3
Summer	1	5:40	202.7
Summer	1	3:11	206.3
Summer	1	0:37	314.6
Summer	1	19:48	682
Summer	2	1:33	275.5
Summer	2	19:36	380.5
Summer	2	21:35	1318.8
Summer	4	23:21	118.4
Summer	4	20:09	445.3
Summer	4	19:40	522.6

Values highlighted in tan come from samples taken during dodge tides, yellow cells during outgoing tides and green cells during flood tides.

Larvae of penaeid prawns were present in all spring and summer samples but none were present in autumn or winter, consistent with the main spawning period (November to February) of these invertebrates in South Australian waters (Dixon *et al*., 2009).

Concentrations of penaeid prawn larvae were lower in spring than summer. Larval prawn concentrations appear to correspond to tidal movement rather than time of day or location. The lowest concentrations of larval prawns were obtained during a dodge tide, whereas intermediate and highest concentrations were recorded during outgoing (ebb) and flood tides, respectively.

Crabs were found predominantly in the zoeal stage and specimens were difficult to identify with the methods employed beyond the infra-order of brachyuran, which includes the blue swimmer crab (*Portunus pelagicus*).

3.5 Considerations in predicting number of larval fishes

Several commercial and non-commercial invertebrate and fish species are found on seagrass meadows, sandy seabed, and rocky reef in the Spencer Gulf. However, apart from anchovies, larvae of very few species of commercial importance were found during this survey. For example, no larvae of snapper (*Chrysophrys auratus*) were caught, even though this commercial species is known to spawn repeatedly between late October and early March in South Australian waters. Bruce and Short (1992) also found no larval snapper in their survey during January and March covering the whole of Spencer Gulf and out to the continental shelf. This may be the result of the sporadic spawning of this species but may also be the result of spawning occurring further offshore.

The location of sampling sites over potentially important habitat is also a significant consideration. For example, the highest abundance of larval fishes was obtained at site 2 which was located over large and well developed seagrass beds (see Figure 1) known as important early nursery areas for several fish species.

These plankton tows provide a snap shot of what is passing through the area at the time of sampling; therefore data from these surveys can only be used with caution for calculations of potential larval concentrations within the survey area. These calculations need to take many biotic and abiotic factors into account to generate meaningful predictions of larval concentrations, including the inter-seasonal fluctuations in nutrient levels, the abundance of local adult fish populations and the spawning pattern of individual species.

4 Entrainment of larvae and location of intake pipe

Entrainment is the process whereby fish and other biota are pulled into a seawater intake system of a power plant or, as in this case, a desalination plant. It is generally only of significance to the early life stages of marine fauna, as the individuals are small enough to pass through the intake screens.

Pelagic eggs, larvae and juveniles of several marine species[5] may theoretically be entrained by the desalination plant intake. This is less likely for juveniles and later stages of larval fish that are active swimmers and have the appropriate avoidance behaviour.

It is assumed that for eggs, larvae and juveniles of marine species to be entrained they must:

1. Be drifting over the intake structure as a component of the plankton assemblage; that is drifting at the same depth and geographical position of the intake.
2. Be unable to avoid being pulled in with the seawater, that is overcome the suction force of the intake.

The proposed intake will draw water from 2 to 5m above the seabed (BHP Billiton, 2009); this may avoid larval aggregations on the surface or seabed, but depth stratified sampling would be required to confirm this.

4.1 Optimal location for the seawater intake

The four geographical locations selected for this study represent the various current energies experienced in the Port Bonython area. Site 3 directly offshore from Point Lowly experiences the fastest currents, followed by sites 4, 1 and 2 in approximately decreasing order.

Species richness appeared to be related to sampling effort within each season (Table 7). Due to uneven sampling, no conclusions could be drawn about the relative species richness at different locations.

Table 7. Seasonal distribution of larval fish taxa in the Point Lowly area.

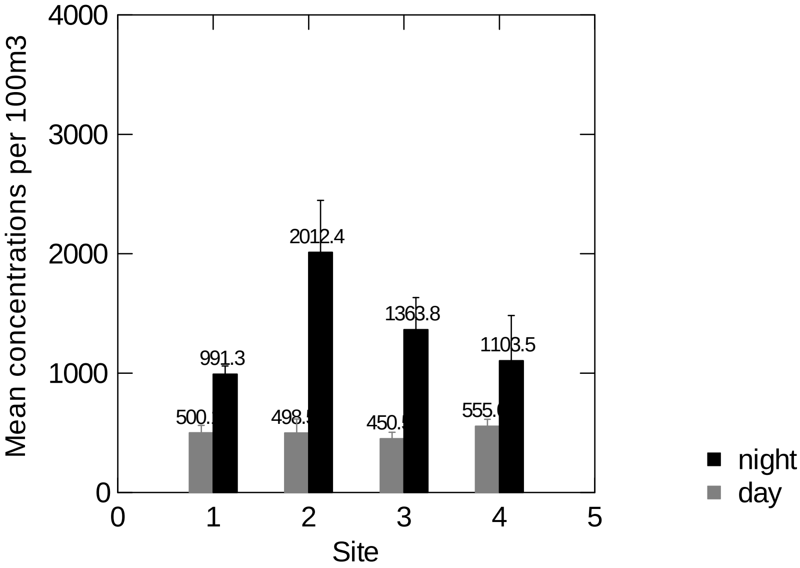
	Summer				Autumn			Winter	
Site	**1**	**2**	**3**	**4**	**1**	**2**	**4**	**1**	**4**
Samples	**47**	**24**	**14**	**14**	**48**	**48**	**24**	**12**	**12**
Total taxa	**19**	**14**	**14**	**11**	**12**	**11**	**8**	**3**	**4**

* Spring survey only sampled at site 1.

Site 1 also had a higher intensity of sampling during summer compared to the other three sites, which may have significantly influenced the higher number of taxa caught. When the same number of samples was collected in autumn, similar numbers of taxa were found at sites 1 and 2. Site 4 had the lowest number of taxa in summer and autumn but again the lower sampling intensity may have contributed to this.

Assuming similar composition of larval fish taxa throughout the sampling area, the main concern with respect to entrainment is larval fish concentrations. Figure 4 shows the day and night distribution of larval fishes at for sites during summer.

[5] Larvae and juveniles in the plankton may come from benthic eggs, pelagic eggs or live bearing species.



* error bar = standard error of mean.

Figure 4. Inter-site and diurnal variations in larval fish concentrations during the summer 2009 survey.

One-way analysis of variance (ANOVA) was conducted to test statistical differences between the mean concentrations of larval fish at each site during the summer survey. The analysis was initially conducted on the pooled taxa for day and night surveys, followed by individual species concentrations for the six numerically dominant taxa.

Table 8 presents the probability of statistically significant outcomes from the ANOVA on log transformed concentrations. Significant results were analysed further using Bonferroni adjustment methods to separate differences between sites. Graphs of the least mean squares (LMS) to visually represent differences between sites are presented in Appendix B.

No significant differences in total larval fish concentrations were found between sites during the day. Site 1 had significantly lower concentrations of larval fishes than site 2 at night during summer, but was not significantly different to sites 3 and 4. Larval fish concentrations at site 2 were not statistically different to sites 3 and 4, neither was site 3 to site 4.

The statistical interpretation of the combined larval fishes is strongly influenced by the dominance of anchovy as indicated by the similar statistical outcomes in Table 8.

At night, anchovy and bluespot goby concentrations were significantly lower at site 1 than site 2, but grubfish concentrations were higher at site 1 than 2. Site 3 had significantly higher concentrations of soldier fish than site 2. Both sites 1 and 2 had significantly higher concentrations of blue spot gobies than sites 3 and 4.

During the day, site 1 had significantly higher concentrations of bluespot gobies than site 4 and site 1 also had significantly higher concentrations of soldierfish than site 2. No other significant differences between sites were observed for the six most numerous species during the summer survey.

Table 8. Statistical differences between sampling sites during the summer 2009 survey.

Taxa	Day		Night	
	Probability/ conclusions	Site [mean concentrations]	Probability/ conclusions	Site [mean concentrations]
All larvae	*Not sig*		*P=0.032* **1 < 2** 1~3~4 2~3~4 3~4	1 = [991.32] 2 = [2012.35] 3 = [1363.79] 4 = [1103.45]
Engraulis australis (Anchovy)	*Not sig*		*P=0.017* **1 < 2** 1~3~4 2~3~4 3~4	1 = [673.24] 2 = [1204.20] 3 = [1199.91] 4 =[967.03]
Pseudogobius olorum (Bluespot goby)	*P=0.049* 1~2~3 **1 > 4** 2~3~4 3~4	1 = [56.85] 2 = [57.18] 3 = [33.42] 4 = [26.98]	*<0.0001* **1 < 2** **1 > 3,4** **2 > 3,4** 3~4	1 = [219.01] 2 = [741.64] 3 = [45.36] 4 =[37.59]
Parapercis spp. (Grubfish)	*Not sig*		*P=0.047* **1>2** 1~3~4 2~3~4 3~4	1 = [3.64] 2 = [2.32] 3 = [3.77] 4 = [3.35]
Pelates octolineatus (Western stripped grunter)	*Not sig*		*Not sig*	
Gymnapistes marmoratus (Soldierfish)	*P=0.008* **1>2** 1~3~4 2~3~4 3~4	1 = [8.76] 2 = [1.09] 3 = [3.07] 4 = [8.31]	*P=0.039* 1~2~3~4 **2<3** 2~4 3~4	21 = [11.16] 2 = [2.13] 3 = [28.05] 4 = [8.46]
Nesogobius sp. 1 (Goby)	*Not sig*		*Not sig*	

These results suggest that while the two most abundant species (anchovies and bluespot gobies) were found in greater concentrations at site 2 than site 1, there is no consistent order of sites from least to greatest concentrations for the six dominant species investigated.

4.2 Optimal distance offshore for the seawater intake

To examine the optimal distance for the seawater intake the three transects surveyed at site 1 during the spring survey were evaluated for differences in mean larval fish concentrations. The first transect over the proposed intake area is around 400m offshore the second transect is around 500m and a third at 900m offshore. While larval concentrations tended to increase with distance offshore during the spring survey, the differences were not statistically significant (Table 9).

Table 9. Larval fish concentrations with distance offshore at site 1.

Period	Day			Night		
Transect **m offshore**	**T1** 400	**T2** 500	**T3** 900	**T1** 400	**T2** 500	**T3** 900
Spring 2008 Larvae /100m^3	23.6 (10.7)	31.9 (13.3)	35.9 (29.7)	61.1 (21.7)	61.4 (17.2)	63.2 (37.8)
Summer 2009 Larvae /100m^3	392.3 (156.4)		579.2 (373.1)	937.4 (247.1)		1063.2 (373.7)
Autumn 2009 Larvae /100m^3	1.3 (1.5)		0.8 (1.0)	2.3 (2.2)		2.9 (2.3)

* Standard deviation in brackets Transect 2 was eliminated after the spring survey. Only 1 transect surveyed in winter.

Based on the data from three transects at site 1 during the spring of 2009 it is concluded that distance from shore does not overly influence larval fish concentrations at this site.

4.3 Quantifying Larvae to be entrained

In order to estimate the total number of larval fishes that would potentially be entrained during the operational stage of the desalination plant, the summary data presented in Section 3.1 can be used with caution. Such an estimate would rely on several assumptions:

- An estimate of the concentration of larval fishes around the intake located 2 - 5m above the seabed (i.e. not through the water column as in this survey);
- An estimate of the variable concentration of larval fishes throughout the season. Each species has a different spawning pattern and seasonal variations trigger different spawning densities.
- An estimate of the percentage of the larvae that are in the preflexion stage; that is the numbers that would be passively entrained.
- An estimate of the percentage of the postflexion larvae that would never the less be entrained.

It is recommended that estimates be done on the basis of individual taxa. The data collected during this study has not been used to predict the potential impact that entrainment of spawning products may have on local adult fish populations, because of the complexity of the ecosystem, the adaptive capacity of individual species and the importance relative to natural mortality.

5 Conclusion

This study focuses on marine species that as a part of their life cycle produce pelagic eggs and larvae that, as a part of plankton assemblages, drift with local water currents and are likely to be exposed to the desalination plant intake structure.

The main findings of this study are:

- The highest species richness and abundance occurs during spring and summer.
- More larvae were caught at night than during the day.
- Richness and concentration of larval fish was not strongly influenced by distance offshore.
- Anchovy accounted for 72.8% of the larvae caught in the summer survey and 69% of the total larval fish catch for the twelve month study.
- Larvae of commercially important fish species, excluding anchovy, accounted for just over 1% of all larval fishes caught.
- More larval crustaceans were caught during flood tides.
- The highest larval fish concentrations were recorded at site 2 in northern Fitzgerald Bay.
- Overall larval fish concentrations in site 3 and 4 were not statistically separable from sites 1 and 2 in summer.

Besides anchovy, larvae of other commercially important fish species during the study period accounted for a very small percentage of the overall larval catches.

Based on the results of this study, it is concluded that the proposed intake (site 1) would be no more susceptible to larval entrainment than the three references sites. Furthermore, results during periods of peak concentration (in summer at night) showed that larval concentrations were significantly higher at site 2 than site 1. This pattern was strongly influenced by the two most abundant species, anchovy and blue spot goby and therefore could be subject to considerable variability.

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The South Australian Museum provided the use of their laboratory for sample sorting and sample storage facilities and have added the larval fish specimens to their collection.

APPENDIX A – LARVAL FISH - RAW DATA

Date	Site	Period	Transect	Replicate	Volume m^3	Anchovy eggs	Total larvae	*Engraulis australis*	*Pseudogobius olorum*	*Parapercis*	*marmoratus*	*Platycephalus*	Monacanthid	*Pseudorhombus arsius*	*Heteroclinus*	*Sillago schomburgkii*	*Nesogobius sp. 1*	Callionymid	*Hippocampus*	*Favonigobius lateralis*	Gobiesocid	*anolius*	*Pelates octolineatus*	*antarcticus*	Clinid	*Stigmatopora argus*	Tetraodontid	*tasmanianus*	*Haletta semifasciata*	*Pseudocarnax wrighti*	*Filicampus tigris*	*Siphamia cephalotes*	*Trachurus*	Serranid	*melanochir*	*Campichthys*	Nesogobius sp. 2	*Lepidotrigla*	*Sepioteuthis australis*
12/11/08	1	1	1	1	80.01	Y	12	3	1	6	1	1																											
12/11/08	1	1	1	2	51.72	Y	16	2	4	4			1	1		1	1	1									1												
12/11/08	1	1	2	1	64.90	Y	13	2	4	5			1	1																									
12/11/08	1	1	2	2	79.98	Y	12	1	3	6						1			1																				
12/11/08	1	1	3	1	68.78	Y	14		3	7								1		3																			
12/11/08	1	1	3	2	70.01	Y	6	1	2	3																													
12/11/08	1	1	1	1	41.06	Y	5						1		3									1															
12/11/08	1	1	1	2	46.07	Y	20		9												9				2														
12/11/08	1	1	2	1	73.55	Y	20	1	7	5				1			2					1	3																
12/11/08	1	1	2	2	58.10	Y	13	1	2	6				2			1						1																
12/11/08	1	1	3	1	48.00	Y	7		4	2										1																			
12/11/08	1	1	3	2	56.06	Y	13	2	2	7				1				1																					
12/11/08	1	2	1	1	44.55	Y	28	4	9	8			1			2		2								1	1												
12/11/08	1	2	1	2	48.71	Y	25	1	15	2			1							1	4							1											
12/11/08	1	2	2	1	51.23	Y	21	4	4	5							2				4						1		1										
12/11/08	1	2	2	2	53.62	Y	29	6	8	11			1						1			1					1												
12/11/08	1	2	3	1	65.41	Y	59	12	20	19			1	1							1							2	3										
12/11/08	1	2	3	2	55.26	Y	25	6	11	6								1											1										
13/11/08	1	2	1	1	51.88	Y	12	2	3	2			1	2	1									1															
13/11/08	1	2	1	2	44.52	Y	37	5	11	15	1			1				1									2	1											
13/11/08	1	2	2	1	55.94	Y	34	13	6	7			1	1			3												3										
13/11/08	1	2	2	2	59.06	Y	29	7	7	10				1												1	1		2										
13/11/08	1	2	3	1	45.58	Y	11	2	1	5			1				1										1												
13/11/08	1	2	3	2	61.21	Y	13	3	2	8																													
13/11/08	1	1	1	1	52.66	Y	9	3	2	1										1			2																
13/11/08	1	1	1	2	60.34	Y	13	1	2	8													1						1										
13/11/08	1	1	2	1	53.39	Y	16	2	1	9				1									3																
13/11/08	1	1	2	2	49.58	Y	22	4	2	12				1						1		1	1																
13/11/08	1	1	3	1	58.58	Y	28	6	4	13	1		1	1			1	1																					
13/11/08	1	1	3	2	45.96	Y	37	4	4	7			2	20																									
13/11/08	1	2	1	1	56.75	Y	39	3	9	18			1	2		1				1		1					1		2										

Date	Site	Period	Transect	Replicate	Volume m^3	Anchovy eggs	Total larvae	*Engraulis australis*	*Pseudogobius olorum*	*Parapercis*	*marmoratus*	*Platycephalus*	Monacanthid	*Pseudorhombus arsius*	*Heteroclinus*	*Sillago schomburgkii*	*Nesogobius* sp. 1	Callionymid	*Hippocampus*	*Favonigobius lateralis*	Gobiesocid	*anolius*	*Pelates octolineatus*	*antarcticus*	Clinid	*Stigmatopora argus*	Tetraodontid	*tasmanianus*	*Haletta semifasciata*	*Pseudocarnax wrighti*	*Filicampus tigris*	*Siphamia cephalotes*	*Trachurus*	Serranid	*melanochir*	*Campichthys*	Nesogobius sp. 2	*Lepidotrigla*	*Sepioteuthis australis*
13/11/08	1	2	1	2	59.29	Y	46	3	14	19		1	1	1			1								1		2	2	1										
13/11/08	1	2	2	1	45.67	Y	39	7	10	16			2	1															3										
13/11/08	1	2	2	2	42.26	Y	33	2	9	14			2	3													2		1										
13/11/08	1	2	3	1	46.10	Y	41	3	4	18			1	1			4		1	1						2	3		3										
13/11/08	1	2	3	2	47.51	Y	52	10	5	17			3	6							1		1		2	1	2	1	3										
14/11/08	1	1	1	1	47.79	Y	15		7	5			1				2																						
14/11/08	1	1	1	2	40.92	Y	7	2	2	2			1																										
14/11/08	1	1	2	1	38.16	Y	18	1	2	10			2									1	1						1										
14/11/08	1	1	2	2	36.53	Y	18	1	6	9				1		1																							
14/11/08	1	1	3	1	53.98	Y	43	7	7	21	1		1	3				1										2											
14/11/08	1	1	3	2	39.05	Y	5			4								1																					
16/02/09	1	1	1	A	80.40	Y	354	318	6	3	8					2				6		2	7					2											
16/02/09	1	1	1	B	67.09	Y	446	390	29	3	5					1	8	2		2		1	5																
16/02/09	1	1	1	C	77.61	Y	193	142	8	1	3					4	6			2		1	26																
16/02/09	1	1	2	A	75.55	Y	257	166	72							3	2						14																
16/02/09	1	1	2	B	61.63	Y	233	187	37	2	1							2		2			2																
16/02/09	1	1	2	C	63.16	Y	117	73	22	8	3					4	1	3					3																
16/02/09	2	1	1	A	67.07	Y	71	21	10	1						1	6			3		2	26							1									
16/02/09	2	1	1	B	54.57		425	205	61							2	14			11			130					2											
16/02/09	2	1	1	C	49.89	Y	429	236	91							1	7			6		1	87																
16/02/09	1	1	1	A	43.18		94	56	12	7	2					1	3	1					12																
16/02/09	1	1	1	B	35.51		132	85	24	12	4					2	1	1		1		1	1																
16/02/09	1	1	1	C	38.71		221	103	45	25						3	13	2				1	29																
16/02/09	1	1	2	A	37.00		74	38	20	6	3						5						2																
16/02/09	1	1	2	B	29.76		134	85	27	3	4					1	2						12																
16/02/09	1	1	2	C	39.88		121	91	11	4	3							1					11																
16/02/09	2	2	1	A	44.72	Y	1602	690	871	21	1						15	1		3																			
16/02/09	2	2	1	C	30.33	Y	893	532	334	11				1			7			4			1									3							
16/02/09	2	2	2	B	36.86		224	159	51	7	1						2	1		1			2																
16/02/09	2	2	2	C	37.61		242	180	48	5				2			2	1		2			2																
17/02/09	1	1	1	A	40.05		137	88	35	8	4												2																
17/02/09	1	1	1	B	52.59		92	56	20	4	6					1	3			2																			
17/02/09	1	1	1	C	36.07		204	144	39	8	3					1	1	2		3			3																
17/02/09	1	1	2	A	42.50		82	63	11	4	3												1																

Date	Site	Period	Transect	Replicate	Volume m^3	Anchovy eggs	Total larvae	*Engraulis australis*	*Pseudogobius olorum*	*Parapercis*	*marmoratus*	*Platycephalus*	Monacanthid	*Pseudorhombus arsius*	*Heteroclinus*	*Sillago schomburgkii*	*Nesogobius* sp. 1	Callionymid	*Hippocampus*	*Favonigobius lateralis*	Gobiesocid	*anolius*	*Pelates octolineatus*	*antarcticus*	Clinid	*Stigmatopora argus*	Tetraodontid	*tasmanianus*	*Haletta semifasciata*	*Pseudocarnax wrighti*	*Filicampus tigris*	*Siphamia cephalotes*	*Trachurus*	Serranid	*melanochir*	*Campichthys*	Nesogobius sp. 2	*Lepidotrigla*	*Sepioteuthis australis*
17/02/09	1	1	2	B	38.29		225	182	26	6	4					1	2	1		1			2																
17/02/09	1	1	2	C	37.11		254	190	31	16	4					2	4						7																
17/02/09	2	1	1	A	30.26		124	75	26	4	1					1	8	2		4			3																
17/02/09	2	1	1	B	32.27		38	30	3		1						1			1			2																
17/02/09	2	1	1	C	40.16		53	25	8	1										9			10																
17/02/09	1	1	1	A	29.66		117	95	13		3									4			2																
17/02/09	1	1	1	B	32.44		105	86	12	2										2			3																
17/02/09	1	1	2	A	22.69		208	184	11	3	7						2						1																
17/02/09	1	1	2	B	24.36		261	215	29	6	8						1			1			1																
17/02/09	1	1	2	C	28.86		162	135	13	7	4							1					2																
17/02/09	2	1	1	A	31.75		88	62	11		1					1	4						9																
17/02/09	2	1	1	B	32.11		310	295	8		1						2	1		2			1																
17/02/09	2	1	1	C	38.43		204	176	11	1				1			4			3			8																
18/02/09	1	2	1	A	22.37		218	149	50	4	4					1	3						7																
18/02/09	1	2	1	B	19.03		230	162	50	7				2			3	2					4																
18/02/09	1	2	1	C	29.08		317	231	63	7	1					3	2	1					8									1							
18/02/09	1	2	2	A	25.10		270	217	35	6	1			1						2			8																
18/02/09	1	2	2	B	29.75		278	238	25	6							3						6																
18/02/09	1	2	2	C	25.47		313	268	30	4	1					3	2			1			4																
18/02/09	2	2	1	A	15.73		529	292	227	2	1						4			1			2																
18/02/09	2	2	1	B	13.97		140	101	31											1			7																
18/02/09	2	2	1	C	14.07		198	169	19	1				1			1			1		1	5																
18/02/09	2	2	2	A	11.02		344	196	140					1						5			2																
18/02/09	2	2	2	B	12.78		184	137	37	4	1						1			1			2					1											
18/02/09	1	2	1	A	27.96		225	160	44	10							2	1	1				7																
18/02/09	1	2	1	B	22.74		202	117	57	12	5						4						5										2						
18/02/09	1	2	1	C	29.84		244	163	51	16	6						3	1					4																
18/02/09	1	1	2	A	28.01		433	400	21	6	2												3											1					
18/02/09	1	1	2	B	40.74		245	226	9	3	1			1			2						2												1				
18/02/09	1	1	2	C	33.61		225	200	14	5				2			2						1								1								
18/02/09	2	1	1	A	30.16		52	46	2	2								1					1																
18/02/09	2	1	1	B	28.25		112	70	22	13				1				1		1			3					1											
18/02/09	2	1	1	C	27.81		109	90	8	8				1								1	1																
18/02/09	1	2	1	A	20.11		148	52	69	9	3			1		1	4	2		1			5								1								

Date	Site	Period	Transect	Replicate	Volume m^3	Anchovy eggs	Total larvae	*Engraulis australis*	*Pseudogobius olorum*	*Parapercis*	*marmoratus*	*Platycephalus*	Monacanthid	*Pseudorhombus arsius*	*Heteroclinus*	*Sillago schomburgkii*	*Nesogobius* sp. 1	Callionymid	*Hippocampus*	*Favonigobius lateralis*	Gobiesocid	*anolius*	*Pelates octolineatus*	*antarcticus*	Clinid	*Stigmatopora argus*	Tetraodontid	*tasmanianus*	*Haletta semifasciata*	*Pseudocarnax wrighti*	*Filicampus tigris*	*Siphamia cephalotes*	*Trachurus*	Serranid	*melanochir*	*Campichthys*	Nesogobius sp. 2	*Lepidotrigla*	*Sepioteuthis australis*
18/02/09	1	2	1	B	24.03		122	70	23	8	4						1	2		1			12					1											
18/02/09	1	2	1	C	21.16		202	123	52	12	3						3						9																
18/02/09	1	2	2	A	25.53		151	91	38	13	2						5						2																
18/02/09	1	2	2	B	20.08		331	236	58	22	5						6			1			3																
18/02/09	1	2	2	C	20.18		145	102	16	17	1						6			1			1										1						
18/02/09	3	1	1	A	17.56	Y	67	50	13	1						1	1					1																	
18/02/09	3	1	1	B	13.42	Y	60	52	1	3	2						1	1																					
18/02/09	3	1	1	C	24.97	Y	45	24	11	2							5			1			1								1								
18/02/09	4	1	1	A	17.86	Y	64	47	9		3					1	2			1			1																
18/02/09	4	1	1	B	18.26	Y	77	62	5	1	5									1			3																
18/02/09	4	1	1	C	17.30	Y	55	36	5	1						2						1	10																
19/02/09	1	2	1	A	19.76		266	177	65	9	7			1						1			5									1							
19/02/09	1	2	1	B	19.03		234	141	73	9	1			1			1	1		1			6																
19/02/09	1	2	1	C	23.31		161	105	49	4	1						1	1																					
19/02/09	1	2	2	A	21.73		350	243	81	14	2			1			4						5																
19/02/09	1	2	2	B	23.12		227	139	64	11	5						5	1					1													1			
19/02/09	1	2	2	C	26.72		207	134	54	8	1						6			2			2																
18/02/09	3	2	1	A	21.42	Y	379	337	8	17	8			1			1	1					5							1									
18/02/09	3	2	1	B	27.62	Y	318	286	6	11	3		1				1			1			8								1								
18/02/09	3	2	1	C	19.48	Y	228	193	15	5	7					1	2			1			4																
18/02/09	4	2	1	A	30.98		187	160	10	5													12																
18/02/09	4	2	1	B	23.41		260	226	8	8	2						2						14																
18/02/09	4	2	1	C	23.74		379	337	11	10	4						3						14																
19/02/09	3	1	1	A	10.86		87	79	5		1												2																
19/02/09	3	1	1	B	23.34		89	79	2	4	1					1	1						1																
19/02/09	4	1	1	A	16.84		74	71	1							1							1																
19/02/09	4	1	1	C	19.76		120	106	4	5	2											1	2																
19/02/09	2	1	1	A	30.76		108	62	27	2							3			11			2					1											
19/02/09	2	1	1	B	21.61		378	344	28	5													1																
19/02/09	2	1	1	C	27.16		65	53	4	3	1						1	1		1			1																
20/02/09	3	1	1	A	15.78		56	45	5	2							1						3																
20/02/09	3	1	1	B	23.44		158	140	11	6													1																
20/02/09	3	1	1	C	23.29		82	74	3	2							1						2																
20/02/09	4	1	1	A	35.54		320	290	3	18	5						1	1					2																

Date	Site	Period	Transect	Replicate	Volume m^3	Anchovy eggs	Total larvae	*Engraulis australis*	*Pseudogobius olorum*	*Parapercis*	*Platycephalus marmoratus*	Monacanthid	*Pseudorhombus arsius*	*Heteroclinus*	*Sillago schomburgkii*	*Nesogobius* sp. 1	Callionymid	*Hippocampus*	*Favonigobius lateralis*	Gobiesocid	*anolius*	*Pelates octolineatus*	*antarcticus*	Clinid	*Stigmatopora argus*	Tetradontid	*tasmanianus*	*Haletta semifasciata*	*Pseudocarnax wrighti*	*Filicampus tigris*	*Siphamia cephalotes*	*Trachurus*	Serranid	*melanochir*	*Campichthys*	Nesogobius sp. 2	*Lepidotrigla*	*Sepioteuthis australis*
20/02/09	4	1	1	B	31.96		129	106	12	7						2						2																
20/02/09	4	1	1	C	26.19		156	128	14	9	2					2			1																			
20/02/09	3	1	1	A	18.51		101	92	5	1	1								1			1																
20/02/09	3	1	1	B	19.74		95	78	10	3			1			1			1			1																
20/02/09	3	1	1	C	27.24		97	87	5	1						1						3																
20/02/09	4	1	1	A	26.82		168	140	5	10	2		1									10																
20/02/09	4	1	1	B	25.19		180	162	6	5	2								1			4																
20/02/09	4	1	1	C	27.23		196	158	6	8			1						1			22																
18/05/09	1	1	1	A	74.48		1												1																			
18/05/09	1	1	1	B	102.9		1					1																										
18/05/09	1	1	1	C	72.18		0																															
18/05/09	1	1	2	A	81.28		0																															
18/05/09	1	1	2	B	77.67		0																															
18/05/09	1	1	2	C	85.88		1					1																										
18/05/09	2	1	1	A	93.11		1	1																														
18/05/09	2	1	1	B	76.18		0																															
18/05/09	2	1	1	C	63.64		1																													1		
18/05/09	2	1	2	A	75.49		1										1																					
18/05/09	2	1	2	B	81.23		1					1																										
18/05/09	2	1	2	C	72.03		0																															
18/05/09	1	1	1	A	75.22		0																															
18/05/09	1	1	1	B	74.60		0																															
18/05/09	1	1	1	C	69.27		0																															
18/05/09	1	1	2	A	66.27		0																															
18/05/09	1	1	2	B	71.53		2		1			1																										
18/05/09	1	1	2	C	71.64		0																															
18/05/09	2	1	2	A	65.51		0																															
18/05/09	2	1	2	B	67.02		2										1										1											
18/05/09	2	1	2	C	67.41		3					1					1										1											
18/05/09	2	1	1	A	67.81		4					3												1														
18/05/09	2	1	1	B	63.67		2												1																	1		
18/05/09	2	1	1	C	64.22		0																															
19/05/09	1	1	1	A	69.08		2					1															1											
19/05/09	1	1	1	B	65.29		1																		1													

Date	Site	Period	Transect	Replicate	Volume m^3	Anchovy eggs	Total larvae	*Engraulis australis*	*Pseudogobius olorum*	*Parapercis*	*marmoratus*	*Platycephalus*	Monacanthid	*Pseudorhombus arsius*	*Heteroclinus*	*Sillago schomburgkii*	*Nesogobius* sp. 1	Callionymid	*Hippocampus*	*Favonigobius lateralis*	Gobiesocid	*anolius*	*Pelates octolineatus*	*antarcticus*	Clinid	*Stigmatopora argus*	Tetraodontid	*tasmanianus*	*Haletta semifasciata*	*Pseudocarnax wrighti*	*Filicampus tigris*	*Siphamia cephalotes*	*Trachurus*	Serranid	*melanochir*	*Campichthys*	Nesogobius sp. 2	*Lepidotrigla*	*Sepioteuthis australis*
19/05/09	1	1	1	C	69.46		2																			1											1		
19/05/09	1	1	2	A	67.99		0																																
19/05/09	1	1	2	B	65.08		0																																
19/05/09	1	1	2	C	71.21		0																																
19/05/09	2	1	2	A	64.92		0																																
19/05/09	2	1	2	B	65.56		1																			1													
19/05/09	2	1	2	C	62.18		1																		1														1
19/05/09	2	1	1	A	64.72		1																														1		
19/05/09	2	1	1	B	64.23		0																																
19/05/09	2	1	1	C	61.63		3	2										1																					
19/05/09	2	1	2	A	61.38		2																														2		
19/05/09	2	1	2	B	68.74		0																																
19/05/09	2	1	2	C	60.43		0																																
19/05/09	2	1	1	A	71.15		1						1																										
19/05/09	2	1	1	B	63.90		0																																
19/05/09	2	1	1	C	63.66		0																																
19/05/09	1	1	1	A	65.08		3											1																			2		
19/05/09	1	1	1	B	54.57		1		1																														
19/05/09	1	1	1	C	62.40		0																																
19/05/09	1	1	2	A	65.31		1																															1	
19/05/09	1	1	2	B	56.21		1	1																															
19/05/09	1	1	2	C	55.82		1		1																														
21/05/09	1	2	1	A	76.61		0																																
21/05/09	1	2	1	B	61.41		0																																1
21/05/09	1	2	1	C	62.33		0																																
21/05/09	1	2	2	A	61.65		0																																
21/05/09	1	2	2	B	60.98		2	1	1																														
21/05/09	1	2	2	C	51.69		0																																
21/05/09	2	2	1	A	72.16		10		1																4												5		
21/05/09	2	2	1	B	66.92		3																		1												2		
21/05/09	2	2	1	C	63.85		3																		1	1											1		
21/05/09	2	2	2	A	65.57		2																														2		
21/05/09	2	2	2	B	59.80		1																		1														
21/05/09	2	2	2	C	75.63		4		1																2												1		

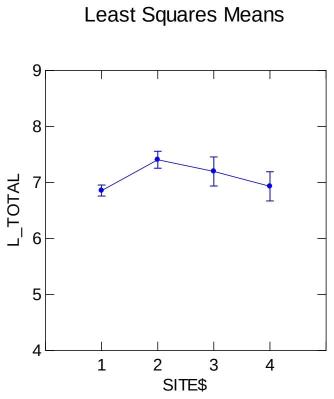
Date	Site	Period	Transect	Replicate	Volume m^3	Anchovy eggs	Total larvae	*Engraulis australis*	*Pseudogobius olorum*	*Parapercis*	*Platycephalus marmoratus*	Monacanthid	*Pseudorhombus arsius*	*Heteroclinus*	*Sillago schomburgkii*	*Nesogobius* sp. 1	Callionymid	*Hippocampus*	*Favonigobius lateralis*	Gobiesocid	*anolius*	*Pelates octolineatus*	*antarcticus*	Clinid	*Stigmatopora argus*	Tetraodontid	*tasmanianus*	*Haletta semifasciata*	*Pseudocarnax wrighti*	*Filicampus tigris*	*Siphamia cephalotes*	*Trachurus*	Serranid	*melanochir*	*Campichthys*	Nesogobius sp. 2	*Lepidotrigla*	*Sepioteuthis australis*
22/05/09	2	2	1	A	61.55		4		1															2												1		
22/05/09	2	2	1	B	65.78		1		1																													
22/05/09	2	2	1	C	58.74		4																	3	1													
22/05/09	2	2	2	A	64.57		1																	1														
22/05/09	2	2	2	B	62.32		1	1																														1
22/05/09	2	2	2	C	65.61		2																												1	1		
22/05/09	1	2	2	A	72.64		4		1		1						1							1														
22/05/09	1	2	2	B	49.84		3										1							2														
22/05/09	1	2	2	C	63.12		3		1			1												1														1
22/05/09	1	2	1	A	62.34		1	1																														
22/05/09	1	2	1	B	60.43		1	1																														
22/05/09	1	2	1	C	63.40		3					2													1													
22/05/09	2	2	1	A	57.22		5		1															1												3		
22/05/09	2	2	1	B	58.75		5	1																4														
22/05/09	2	2	1	C	56.16		0																															
22/05/09	2	2	2	A	66.38		0																															
22/05/09	2	2	2	B	59.76		1		1																													
22/05/09	2	2	2	C	57.97		1																													1		
22/05/09	1	2	2	A	60.93		1										1																					
22/05/09	1	2	2	B	58.12		1		1																													
22/05/09	1	2	2	C	66.68		1																				1											
22/05/09	1	2	1	A	68.89		1		1																													
22/05/09	1	2	1	B	62.76		2		1															1														
22/05/09	1	2	1	C	64.39		0																															
23/05/09	1	2	2	A	62.96		1																											1				
23/05/09	1	2	2	B	60.98		4	1	2			1																										
23/05/09	1	2	2	C	59.13		1	1																														1
23/05/09	1	2	1	A	58.74		3																	2			1											1
23/05/09	1	2	1	B	52.92		3	1																1			1											
23/05/09	1	2	1	C	51.88		2		2																													
23/05/09	2	2	1	A	64.52		3																	3														
23/05/09	2	2	1	B	55.46		2																	1												1		
23/05/09	2	2	1	C	55.12		2																	2														
23/05/09	2	2	2	A	64.02		2	1	1																													

Date	Site	Period	Transect	Replicate	Volume m^3	Anchovy eggs	Total larvae	*Engraulis australis*	*Pseudogobius olorum*	*Parapercis*	*marmoratus*	*Platycephalus*	Monacanthid	*Pseudorhombus arsius*	*Heteroclinus*	*Sillago schomburgkii*	*Nesogobius* sp. 1	Callionymid	*Hippocampus*	*Favonigobius lateralis*	Gobiesocid	*anolius*	*Pelates octolineatus*	*antarcticus*	Clinid	*Stigmatopora argus*	Tetraodontid	*tasmanianus*	*Haletta semifasciata*	*Pseudocarnax wrighti*	*Filicampus tigris*	*Siphamia cephalotes*	*Trachurus*	Serranid	*melanochir*	*Campichthys*	Nesogobius sp. 2	*Lepidotrigla*	*Sepioteuthis australis*
23/05/09	2	2	2	B	66.05		3	1																		1									1				
23/05/09	2	2	2	C	72.85		5	1																	1										1		2		1
25/05/09	4	2	1	A	63.24		6		3																3														
25/05/09	4	2	1	B	66.01		12		7				3															2											1
25/05/09	4	2	1	C	56.17		17		10				2												2			3											
26/05/09	4	2	1	A	69.22		11		6				2					1							1			1											1
26/05/09	4	2	1	B	62.04		5		3																			1										1	2
26/05/09	4	2	1	C	59.09		8		6																2														1
26/05/09	4	1	1	A	60.29		1		1																														
26/05/09	4	1	1	B	61.79		0																																
26/05/09	4	1	1	C	63.46		0																																
26/05/09	4	1	1	A	63.24		1	1																															
26/05/09	4	1	1	B	54.63		0																																
26/05/09	4	1	1	C	66.61		0																																
26/05/09	4	2	1	A	61.04		13	1																	2			4									6		
26/05/09	4	2	1	B	55.68		8	1																				5									2		
26/05/09	4	2	1	C	55.59		3																		1												2		
27/05/09	4	2	1	A	62.44		21																					6									15		
27/05/09	4	2	1	B	62.87		12	1					2												1			5									3		
27/05/09	4	2	1	C	58.40		14	1					1															3									9		
27/05/09	4	1	1	A	57.18		0																																
27/05/09	4	1	1	B	50.66		1																														1		
27/05/09	4	1	1	C	55.85		0																																
27/05/09	4	1	1	A	45.76		0																																
27/05/09	4	1	1	B	53.24		0																																
27/05/09	4	1	1	C	60.61		0																																
20/07/09	1	2	1	A	66.68		0																																1
20/07/09	1	2	1	B	71.17		3				1														2														
20/07/09	1	2	1	C	78.58		7																		7														
20/07/09	4	2	1	A	81.86		2										1									1													
20/07/09	4	2	1	B	68.37		1										1																						
20/07/09	4	2	1	C	71.06		1																			1													
21/07/09	1	2	1	A	66.34		1																		1														
21/07/09	1	2	1	B	69.95		0																																

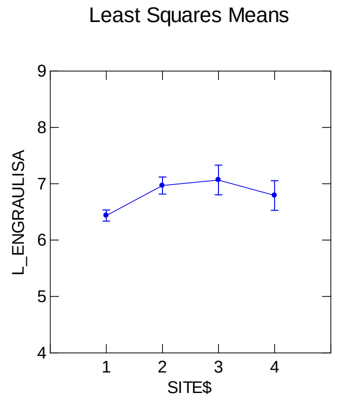
Date	Site	Period	Transect	Replicate	Volume m^3	Anchovy eggs	Total larvae	*Engraulis australis*	*Pseudogobius olorum*	*Parapercis*	*Platycephalus marmoratus*	Monacanthid	*Pseudorhombus arsius*	*Heteroclinus*	*Sillago schomburgkii*	*Nesogobius* sp. 1	Callionymid	*Hippocampus*	*Favonigobius lateralis*	Gobiesocid	*anolius*	*Pelates octolineatus*	Clinid *antarcticus*	*Stigmatopora argus*	Tetraodontid	*tasmanianus*	*Haletta semifasciata*	*Pseudocarnax wrighti*	*Filicampus tigris*	*Siphamia cephalotes*	*Trachurus*	Serranid	*Campichthys melanochir*	Nesogobius sp. 2	*Lepidotrigla*	*Sepioteuthis australis*
22/07/09	1	2	1	C	69.60		2																2													
23/07/09	4	2	1	A	61.66		1									1																				
24/07/09	4	2	1	B	69.15		5									5																				
25/07/09	4	2	1	C	68.78		7									6							1													
22/07/09	1	2	1	A	75.92		1				1																									
22/07/09	1	2	1	B	75.76		0																													
23/07/09	1	2	1	C	61.75		1				1																									
24/07/09	4	2	1	A	69.38		1									1																				
25/07/09	4	2	1	B	66.65		2									1							1													
26/07/09	4	2	1	C	58.97		3									3																				
23/07/09	1	2	1	A	49.54		0																													
23/07/09	1	2	1	B	62.07		2				1					1																				
24/07/09	1	2	1	C	55.87		0																													1
25/07/09	4	2	1	A	54.32		3				1					1							1													
26/07/09	4	2	1	B	43.77		0																													
27/07/09	4	2	1	C	64.11		2				1												1													

APPENDIX B - STATISTICAL OUTPUT - ONE-WAY ANOVA LEAST MEAN SQUARES

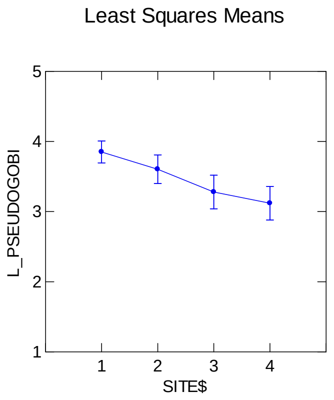
The following graphs show the least square means to support the statistical conclusions on the output from the analysis of variance and separation of means using Bonferroni adjustments.



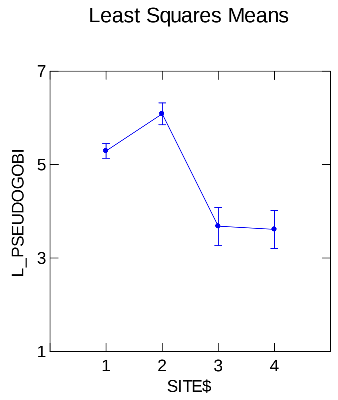
Log-transformed total taxa: Night period Bonferroni adjustment 2 > 1 no separation between 1, 3 and 4 and between 2, 3 and 4



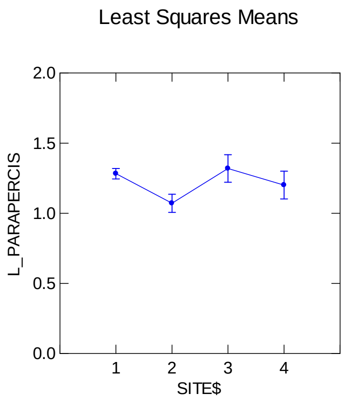
Log-transformed *Engraulis australis:* Night period Bonferroni adjustment 2 > 1 no separation between 1, 3 and 4 and between 2, 3 and 4



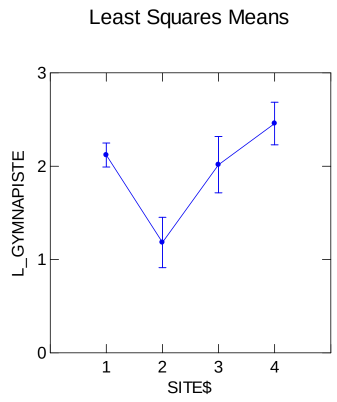
Log-transformed *Pseudogobius olorum*: Day period Bonferroni adjustment 1 > 4 no separation between 1, 2 and 3 and between 2, 3 and 4



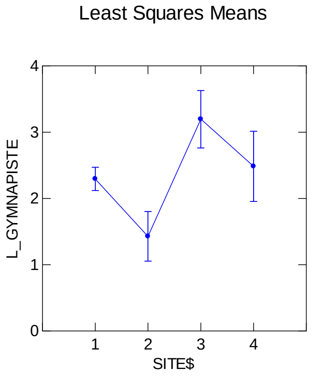
Log-transformed *Pseudogobius olorum*: Night period Bonferroni adjustment 2 > 1, 3 and 4, 1 > 3 and 4 and no separation between 3 and 4.



Log-transformed *Parapercis* sp: Night period Bonferroni adjustment 2 < 1 no separation between 1, 3 and 4 and between 2, 3 and 4



Log-transformed *Gymnapistes marmoratus*: Day period Bonferroni adjustment 1 > 2 no separation between 1, 3 and 4 and between 2, 3 and 4



Log-transformed *Gymnapistes marmoratus*: Night period Bonferroni adjustment 2 < 3, 2, 3 and 4 are not different to 1, 2 is not different to 4 and 3 is not different to 4.

APPENDIX H10.2

Entrainment threat assessment

H10.2 ENTRAINMENT THREAT ASSESSMENT

H10.2.1 INTRODUCTION

This appendix provides supporting material for Section 17.13 of the Supplementary EIS. It uses information from local field surveys (see Appendix H10.1 of the Supplementary EIS) and published literature to determine whether adult fish and invertebrate populations in Upper Spencer Gulf could credibly be exposed to a threat from entrainment (i.e. being taken up into the desalination plant) due to a reduction in recruitment success. It is noted that other tools (e.g. hydrodynamic modelling – see Appendix H7.2 of the Supplementary EIS) also contribute to the overall impact assessment of entrainment.

The intake of large volumes of seawater will result in (mainly) small marine organisms, including larvae and para-larvae of fish and invertebrates, being entrained and therefore removed from the Spencer Gulf ecosystem (refer Section 16.6.10 of the Draft EIS).

Reductions in larvae, however, do not generally translate into an equivalent reduction in the adult population because of the high spatial and temporal variability of larvae populations and the episodic nature of successful replenishment events, the large size of larvae populations relative to adult populations, and the fact that few larvae naturally survive to adulthood (CEE 2008; Steinbeck et al. 2007).

In particular, species known to have a broad spatial distribution of spawning activity within Upper Spencer Gulf, or known to have high levels of natural mortality between larval and adult stages, are considered unlikely to be impacted by entrainment.

The methodology adopted to assess whether there is a credible threat to adult populations is essentially a two-step process: the first considers whether there are significant natural larval abundances near the intake; and, if so, the second considers whether any associated threat to adult populations can be dismissed due to a wide distribution of spawners within Upper Spencer Gulf, or a high level of natural mortality (i.e. a high proportion of the eggs/larvae would not otherwise have developed into adults).

Species

This credible threat assessment includes species:

- recorded in moderate or high abundances during larval surveys at Point Lowly (see abundance categories below)
- species identified by Bryars (2003) as potentially having larvae in Upper Spencer Gulf (see Appendix H9.5 of the Supplementary EIS)
- otherwise of significance to fisheries
- of conservation significance.

The exclusion of species with few or no larvae recorded at Point Lowly during seasonal larval surveys (see Appendix H10.1 of the Supplementary EIS) from this assessment is consistent with the two-step methodology. Inclusion of species of socio-economic (fisheries) or conservation importance despite few or no larvae being recorded allows additional information to be considered that will increase confidence in the assessment.

Expected local abundance of larvae

Data from local seasonal surveys (see Appendix H10.1 of the Supplementary EIS) or existing literature (Bruce and Short 1992; Dimmlich et al. 2004) was used to classify the natural density of larvae near Point Lowly for each species assessed. The classification was conservative in that the highest seasonal abundance was used when data for multiple seasons was available.
The following categories were adopted:

- Low (<10 larvae/100 m^3, or no larvae recorded)
- Moderate (10–100 larvae/100 m^3)
- High (>100 larvae/100 m^3)
- Unknown.

Spawning distribution/natural mortality criteria

The following criteria are used to assess the threat of entrainment to adult populations:

- distribution of the spawning population, using distribution records summarised in Appendix H1 of the Supplementary EIS, and published information about distributions or habitat affinities (in conjunction with habitat maps)
- natural mortality of larvae, based on published literature.

Credible threat from entrainment

The expected local abundance categories, and the spawning distribution/natural mortality criteria were applied for each species to determine whether entrainment presents a credible threat to (and measurable effect on) adult populations, using the matrix provided in Table H10.2.1.

Table H10.2.1 Assessment of credible threat to adult populations

Spawning distribution/Natural mortality criteria	Abundance of larvae likely to be entrained		
	High/Unknown	Moderate	Low
Localised spawning population and low to moderate or unknown natural mortality	yes	yes	no
Wide distribution of spawning population or high natural mortality	no	no	no

H10.2.2 OUTCOMES AND CONCLUSIONS

The outcomes of the assessment are presented in Table 10.2.2. Entrainment was not considered to be a credible threat to the adult population of any species assessed.

Table H10.2.2: Credible threat assessment for larval entrainment in Upper Spencer Gulf. The final three columns relate to Table H10.2.1

Species	Spawning details	Characteristics of eggs and larvae	Abundance of larvae likely to be entrained	Spawning distribution/natural mortality criteria	Credible threat to adult populations?
Fish					
Australian Anchovy *Engraulis australis*	Oviparous, batch spawner. Spawns throughout the year in estuaries, bays and coastal waters, with peak spawning spring to autumn (Neira et al. 1998; Neira & Sporcic, 2002).	Eggs pelagic (Robertson 1975). Larvae pelagic (Neira et al. 1998). Post-flexion larvae capable of vertical migration within highly flushed estuaries; preflexion and flexion behave like passive particles (Lara-Lopez 2006, Lara-Lopez et al. 2010). Larval duration is 30 days (CEE 2008, citing Hoedt and Dimmlich 1995, Hobday 1992), as for a congener (Cotano et al. 2008). Otolith measurements support a 30–day duration, with some outliers of 80 days (Bruce & Bradford 2002).	High-mean concentrations recorded near Point Lowly were >500 larvae/100 m^3 in summer 2008–2009, with a large number of newly hatched larvae (see Appendix H10.1 of the Supplementary EIS).	Anchovy spawn throughout shelf, bay and gulf waters in southern Australia. The highest densities occur in Spencer Gulf and, in particular, Gulf St Vincent (with peak concentrations more than twice those of Spencer Gulf). Due to competitive interactions with Sardines Sardinops sagax throughout much of this range, Spencer Gulf, north of Wallaroo, and Gulf St Vincent, provide critical habitat for Australian Anchovy (Dimmlich et al. 2004). The area of this critical habitat is nevertheless large.	No
Bluespot Goby *Pseudogobius olorum*	Oviparous. Spawns in upper reaches of estuaries, usually among thick vegetation (Gill et al. 1996). Swan Estuary population spawns biannually in spring and autumn (Gill et al. 1996). Larvae occur in Swan and Nornalup-Walpole estuaries and in Wilson Inlet (WA) in most months; peak abundances November to January (Neira & Potter 1992, 1994; Neira et al. 1992).	Benthic eggs – with filamentous attachments; attach eggs to substrates; eggs tended by adults. Larvae pelagic (Neira et al. 1998). Larvae of various species in Tamar estuary, including Bluespot Goby, behave similarly to anchovy (Lara-Lopez 2006; Lara-Lopez et al. 2010). Larval duration 3–20 days for gobies (Hoese 1998).	High-mean concentrations recorded near Point Lowly were approximately 150 larvae/100 m^3 in summer 2008–2009 (see Appendix H10.1 of the Supplementary EIS).	Adults have extensive habitat throughout Upper Spencer Gulf, including the eastern side of the gulf, where they have been recorded near Port Pirie (see Appendix H1 of the Supplementary EIS).	No
Grubfish *Parapercis* spp.	Oviparous. Spawns in estuaries, enclosed bays and inshore waters (Neira et al. 1992, 1998). P. haackei larvae in Swan Estuary (WA) November to April, peak in Jan (Neira et al. 1992).	Eggs pelagic (Robertson 1975). Larvae pelagic (Neira et al. 1998). Larval duration and behaviour unknown.	Moderate-mean concentrations near Point Lowly approximately 20 larvae/100 m^3 in spring/summer 2008–2009 (see Appendix H10.1 of the Supplementary EIS. Note that Pinguipedid larvae (listed under former name Mugiloididae) were recorded in January and March 1988 (Bruce & Short 1992).	Adults have extensive habitat and have been widely recorded in Upper Spencer Gulf, including Red Cliff Point and 10 km south of Port Augusta (see Appendix H1 of the Supplementary EIS) and Spencer Gulf (Currie et al. 2009).	No

Table H10.2.2: Credible threat assessment for larval entrainment in Upper Spencer Gulf. The final three columns relate to Table H10.2.1 (cont'd)

Species	Spawning details	Characteristics of eggs and larvae	Abundance of larvae likely to be entrained	Spawning distribution/natural mortality criteria	Credible threat to adult populations?
Western Striped Grunter *Pelates octolineatus*	Oviparous. Spawns in estuaries and inshore waters (Neira et al. 1998). Larvae recorded in two WA estuaries from November to April, and SA gulfs from January to March (Neira et al. 1998).	Eggs undescribed. Larvae pelagic (Neira et al. 1998).	Moderate-mean concentrations near Point Lowly approximately 20 larvae/100 m³ in summer 2008–2009 (see Appendix H10.1 of the Supplementary EIS). An unknown number of Terapontid larvae were found in Upper Spencer Gulf in January 1988 (Bruce & Short 1992).	Adults have extensive habitat and have been widely recorded in Upper Spencer Gulf, including at Port Pirie, Red Cliff Point and False Bay (see Appendix H1 of the Supplementary EIS) and Spencer Gulf (Currie et al. 2009).	No
Soldierfish *Gymnapistes marmoratus*	Oviparous. Spawning occurs in late winter and early spring (Grant 1972), with larvae (in Victoria) present from July to October (Jenkins 1986; Ramm 1986), peaking in July and August (Neira et al. 1992).	Eggs unknown but presumed pelagic. Larvae pelagic (Neira et al. 1998; Neira 1989). Larval duration and behaviour unknown.	Low-mean concentrations near Point Lowly approximately eight larvae/100 m³ in summer 2008–2009 (see Appendix H10.1 of the Supplementary EIS An unknown number of Scorpaenid larvae were found in Upper Spencer Gulf in March and May 1988 (Bruce & Short 1992).	Adults have extensive habitat and have been widely recorded in Upper Spencer Gulf, including at Port Pirie, Red Cliff Point and False Bay (see Appendix H1 of the Supplementary EIS), and Spencer Gulf (Currie et al. 2009).	No
Flathead *Platycephalus* spp.	Oviparous. Spawning of P. bassensis is regionally variable but can extend from spring to autumn (Bruce & Bradford 2002).	Eggs pelagic; described in Hyndes and others (1992). Larvae pelagic (Hyndes et al. 1992, Neira et al. 1998). Larval duration 30–90 days (Jordan 2001).	Low – only two larvae recorded during seasonal surveys in 2008–2009 (see Appendix H10.1 of the Supplementary EIS).	Distributed widely in Upper Spencer Gulf (see Appendix H1 of the Supplementary EIS; McDonald 2008; McDonald, B, PhD student, pers. comm., 30 October 2007).	No
Southern Sea Garfish *Hyporhamphus melanochir*	Oviparous. Spawning occurs over seagrass and macroalgae, from October to March, with peaks in October-November and March (Noell & Ye 2008).	Eggs are benthic, large and have 8 mm filaments that help them attach to seagrass (Noell & Ye 2008). Larvae are pelagic (Noell 2003, Neira et al. 1998), and are well developed on hatching (Jones & Noell 2005). Soon after hatching, larvae swim to the surface and remain there until the juvenile stage (Noell & Ye 2008).	Low – an unknown number of garfish larvae were found in Upper Spencer Gulf in January 1988 (Bruce & Short 1992), but only two larvae were recorded during seasonal surveys in 2008–2009 (see Appendix H10.1 of the Supplementary EIS).	Extensive spawning habitat in Upper Spencer Gulf (refer Figure 16.5 of the Draft EIS).	No
Yellowfin Whiting *Sillago schomburgkii*	Oviparous. Spawns from October to January, with peak in November-December in Upper Spencer Gulf (Ferguson 2000), over unvegetated soft bottom, sheltered beaches and tidal flats.	Eggs are pelagic. Larval duration 23–28 days (Ferguson 2000).	Low – an unknown number of Yellowfin Whiting larvae were found in Upper Spencer Gulf in January 1988 (Bruce & Short 1992), but concentrations of less than two larvae/100 m³ were recorded during seasonal surveys in 2008–2009 (see Appendix H10.1 of the Supplementary EIS).	Distributed widely in Upper Spencer Gulf (see Appendix H1 of the Supplementary EIS; Ferguson 2000).	No

Table H10.2.2: Credible threat assessment for larval entrainment in Upper Spencer Gulf. The final three columns relate to Table H10.2.1 (cont'd)

Species	Spawning details	Characteristics of eggs and larvae	Abundance of larvae likely to be entrained	Spawning distribution/natural mortality criteria	Credible threat to adult populations?
Yellowtail Kingfish *Seriola lalandi*	Oviparous. Spawning occurs from November to January (Neira et al. 1998). Hatchery spawning occurs from August to December (Fowler et al. 2003).	Eggs, larvae pelagic; described in Moser (1996).	Low – Yellowtail Kingfish larvae were not recorded during seasonal surveys in 2008–2009 (see Appendix H10.1 of the Supplementary EIS) and are not known to have been recorded in Upper Spencer Gulf. Undifferentiated Carangid larvae were reported in False Bay in January 1988 (Bruce & Short 1992), but these may have been Pseudocaranx wrighti (see below). Hatchery larvae are raised at salinities less than 38 g/L, suggesting that Kingfish larvae may be beyond their salinity tolerance in Upper Spencer Gulf.	Recorded at a few locations in Upper Spencer Gulf (see Appendix H1 of the Supplementary EIS) but its distribution in open water habitats of Upper Spencer Gulf is largely un-documented.	No
Large-tooth Flounder *Pseudorhombus arsius*	Oviparous, spawning details unknown.	Eggs and larvae pelagic. Larvae described for several genera – (from Family Pleuronectidae/Bothidae) Leis & Carson-Ewart (2000).	Low – an unknown number of Larvae from order Pleuronectiformes were recorded north of Point Lowly in late May 1988 (Bruce & Short 1992), but concentrations of less than three larvae/100 m^3 were recorded during seasonal surveys in 2008–2009 (see Appendix H10.1 of the Supplementary EIS).	Distribution in Upper Spencer Gulf is unknown but its preferred sand or mud habitat (Froese & Pauly 2010) is extensive.	No
King George Whiting *Sillaginodes punctata*	Oviparous. Spawns from March to May in the south of the SA gulfs (McGarvey et al. 2005).	Eggs and larvae pelagic. Larvae described in Neira et al. (1998). Larval duration 80–120 days (McGarvey et al. 2005).	Low/unknown – an unknown number of King George Whiting larvae were recorded in Upper Spencer Gulf in May 1988 (Bruce & Short 1992), but none were recorded during seasonal surveys in 2008–2009 (see Appendix H10.1 of the Supplementary EIS).	Distributed widely in Upper Spencer Gulf (see Appendix H1 of the Supplementary EIS), which has extensive soft-bottom habitat.	No
Snapper *Chrysophrys auratus*	Oviparous. Spawns from late November to early February, with peak spawning in December (Saunders 2009).	Eggs and larvae pelagic. Larval duration 20–30 days (Fowler et al. 2010).	Low – no Sparid larvae were found in Upper Spencer Gulf by Bruce and Short (1992), and no Snapper larvae were recorded during seasonal surveys in 2008–2009 (see Appendix H10.1 of the Supplementary EIS).	Spawning is likely to occur at distinct hotspots in Upper Spencer Gulf (Fowler et al. 2010), e.g. artificial reefs south of Whyalla and near Port Broughton (Saunders 2009).	No
Trevally *Pseudocaranx* spp.	Oviparous. Spawning could occur from spring to summer (Neira et al. 1998; Bruce & Bradford 2002).	Eggs planktonic, described. Larvae described in Neira and others (1998).	Low – an unknown number of Carangid larvae were found in Upper Spencer Gulf in January 1988 (Bruce & Short 1992), but only two Trevally larvae were recorded during seasonal surveys in 2008–2009 (see Appendix H10.1 of the Supplementary EIS).	Distributed widely in Upper Spencer Gulf (see Appendix H1 of the Supplementary EIS).	No

Table H10.2.2: Credible threat assessment for larval entrainment in Upper Spencer Gulf. The final three columns relate to Table H10.2.1 (cont'd)

Species	Spawning details	Characteristics of eggs and larvae	Abundance of larvae likely to be entrained	Spawning distribution/natural mortality criteria	Credible threat to adult populations?
Jack Mackerel *Trachurus* sp.	Oviparous. Spawning occurs in summer and autumn, but may be more protracted (Bruce & Bradford 2002; Neira et al. 1998).	Eggs, larvae pelagic (Robertson 1975; Neira et al. 1998).	Low – an unknown number of Carangid larvae were found in Upper Spencer Gulf in January 1988 (Bruce & Short 1992), but only two Jack Mackerel larvae were recorded during seasonal surveys in 2008–2009 (see Appendix H10.1 of the Supplementary EIS).	Recorded at a few locations in Upper Spencer Gulf (see Appendix H1 of the Supplementary EIS) but its distribution in open water habitats of Upper Spencer Gulf is largely un-documented.	No
Seahorse *Hippocampus* spp.	Ovoviviparous – pouch brooders. Habitat for various species includes sheltered seagrass and reef.	Hatching takes place inside male's pouch; larvae are pelagic, like miniature adults (Neira et al. 1998).	Low – an unknown number of Syngnathid larvae were found in Upper Spencer Gulf in January, March and May 1988 (Bruce & Short 1992), but only four seahorse larvae were recorded during seasonal surveys in 2008–2009 (see Appendix H10.1 of the Supplementary EIS).	Widely distributed through Upper and Mid Spencer Gulf (Currie et al. 2009).	No
Spotted Pipefish *Stigmatopora argus*	Ovoviviparous – pouch brooders. Adults prefer seagrass to sand/silt (McDonald 2008).	Hatching takes place inside male's pouch; larvae are pelagic, like miniature adults (Neira et al. 1998).	Low – an unknown number of Syngnathid larvae were found in Upper Spencer Gulf in January, March and May 1988 (Bruce & Short 1992), but only 18 Spotted Pipefish larvae were recorded during seasonal surveys in 2008–2009 (see Appendix H10.1 of the Supplementary EIS)	The preferred habitat for this species is seagrass rather than sand/silt, and it was the most abundant species recorded during beam trawls in False Bay (McDonald 2008).	No
Pipefish *Campichthys* sp.	Ovoviviparous – pouch brooders. Adult C. galei inhabit shallow sub-tidal rubble substrates and adjacent seagrass beds to 18 m (Inshore Fish Group 2010a).	Hatching takes place inside male's pouch; larvae are pelagic, like miniature adults (Neira et al. 1998).	Low – an unknown number of Syngnathid larvae were found in Upper Spencer Gulf in January, March and May 1988 (Bruce & Short 1992), but only two species from this genus were recorded during seasonal surveys in 2008–2009 (see Appendix H10.1 of the Supplementary EIS).	Gales Pipefish C. galei is the only species from this genus recorded in Spencer Gulf, in the lower and mid gulf (Baker 2010). It inhabits reef, rubble, sand and sparse Posidonia seagrass (Baker 2010; Inshore Fish Group 2010a).	No
Tiger Pipefish *Filicampus tigris*	Ovoviviparous – pouch brooders. Adults inhabit sandy/muddy substrates, adjacent to channels (Edgar 2008; Inshore Fish Group 2010b).	Hatching takes place inside male's pouch; larvae are pelagic, like miniature adults (Neira et al. 1998).	Low – an unknown number of Syngnathid larvae were found in Upper Spencer Gulf in January, March and May 1988 (Bruce & Short 1992), but only four Tiger Pipefish larvae were recorded during seasonal surveys in 2008–2009 (see Appendix H10.1 of the Supplementary EIS).	Widely distributed over sand/silt habitat in mid and Upper Spencer Gulf (see Section 17.9 of the Supplementary EIS).	No

Table H10.2.2: Credible threat assessment for larval entrainment in Upper Spencer Gulf. The final three columns relate to Table H10.2.1 (cont'd)

Species	Spawning details	Characteristics of eggs and larvae	Abundance of larvae likely to be entrained	Spawning distribution/natural mortality criteria	Credible threat to adult populations?
Invertebrates					
Blue Swimmer Crab *Portunus armatus*[1]	Ovigerous. Spawning habitat includes seagrass, unvegetated soft bottom, sheltered beach, tidal flats (Bryars 2003). Spawning occurs from January to April (Bryars 1997, Currie & Hooper 2006).	Larvae pelagic. Larval duration 20+ days (Currie & Hooper 2006, Bryars & Adams 1999), up to 45 days under typical South Australian conditions (Bryars 1997).	Unknown – the broad-scale distribution of Blue Swimmer Crab larvae in South Australia is largely unknown (Svane & Bryars 2005), although Bryars (1997) did find larvae throughout Gulf St Vincent. Crabs were found during seasonal surveys in 2008–2009, but specimens were difficult to identify even in regard to family (see Appendix H10.1 of the Supplementary EIS).	Regionally, the distribution of juveniles in Spencer Gulf appears skewed towards sites on the eastern coastline and in particular to sites between Port Pirie and Port Broughton (McDonald et al. 2005). Larval mortality has been estimated as 98–99% (Ingles & Braum 1989; Bryars 1997). In comparison (based on volumetric proportions), the desalination plant would remove approximately 0.21% of Blue Swimmer Crab larvae from Upper Spencer Gulf over the same period.	No
Purple Urchin *Heliocidaris erythrogramma*	Oviparous. Spawning occurs from late summer to early autumn (Dix 1977, Williams & Anderson 1975, Laegdsgaard et al. 1991). Adults exclusively inhabit reef habitat near Point Lowly.	Eggs and larvae pelagic. Larval duration five days (Huggett et al. 2006; Williams & Anderson 1975).	Unknown.	Largely restricted to reef east of Black Point, Fitzgerald Bay and Backy Point, but have been recorded further north near Red Cliff Point. Natural mortality of urchin larvae has been estimated at 6–27% per day (McEdward & Miner 2001), equating to 30–85% during the larval duration.	No
Razorfish *Pinna bicolor*	Oviparous. Adults inhabit seagrass, unvegetated soft bottom, tidal flats and tidal creeks. Spawning occurs from November to January, peaking in December (Butler 1987).	Eggs and larvae pelagic (undescribed). Larval duration three to four weeks, based on typical planktotrophic bivalves (Butler 1987).	Unknown.	Widely distributed in sand/silt habitats within the South Australian gulfs (see Appendix H1 of the Supplementary EIS; Butler 1987).	No

Table H10.2.2: Credible threat assessment for larval entrainment in Upper Spencer Gulf. The final three columns relate to Table H10.2.1 (cont'd)

Species	Spawning details	Characteristics of eggs and larvae	Abundance of larvae likely to be entrained	Spawning distribution/natural mortality criteria	Credible threat to adult populations?
Western King Prawn *Melicertus latisulcatus*	Spawning occurs over unvegetated soft bottom in deep water (>10 m) between October and April, with the main spawning period between November and February (Dixon et al. 2009).	Eggs and larvae pelagic. Larval duration 15–34 days, depending on temperature (Dixon et al. 2009).	High – mid to late stage larvae were recorded at a mean concentration of 500 larvae/100 m^3 during the spawning season. Peak concentrations of 1800 larvae/100 m^3 recorded during flood tides are consistent with mean concentrations provided by Carrick (2003) for the Point Lowly region.	Carrick (2003) estimated a natural mortality of 5% per week in Spencer Gulf nurseries during winter. Based on volumetric proportions, the desalination plant would remove 0.03% of prawn larvae from Upper Spencer Gulf per week during the previous summer/autumn spawning period. Furthermore, there is evidence of density-dependent mortality in nursery grounds (Kangas 1999), implying that additional mortality of larvae may have no impact on nursery populations.	No
Australian Giant Cuttlefish *Sepia apama*	Spawning occurs from May to September (refer Appendix O5 of the Draft EIS) over reef habitat.	Eggs adhere to underside of rock crevices. Hatchlings can swim, and shelter near substrate (Hall & Fowler 2003).	Low – due to swimming capability and benthic affinity (avoiding intake at 2–5 m depth).	The reef habitat near the intake supports less than 4% of the breeding population in the Point Lowly/Fitzgerald Bay region (and generally <0.5% over the past decade) (see Appendix H9.3 of the Supplementary EIS).	No
Southern Calamary *Sepioteuthis australis*	Spawning occurs over reef and seagrass, at varying times across regions.	Eggs adhere to substrate or benthos in clutches. Hatchlings can swim and initially swim to the surface, then return to the benthos at an early age, and are believed to migrate from inshore spawning grounds to offshore nursery grounds (Steer et al. 2007).	Low – due to swimming capability, and surface and benthic affinities (avoiding intake at 2–5 m depth).	Abundant in Upper Spencer Gulf, contributing one quarter of the state-wide catch (Steer et al. 2007). Extensive spawning habitat in Upper Spencer Gulf (refer Figure 16.5 of the Draft EIS).	No

[1] Formerly *P. pelagicus*

H10.2.3 REFERENCES

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