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Report prepared on behalf of
NSG Consulting
A division of NewSouth Global Pty Limited

Ecological issues in relation to BlueScope Steel SCP proposed salt water cooling

for

CH2M HILL Australia Pty Ltd

by

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August 2006
J069413

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EXECUTIVE SUMMARY:

BlueScope Steel Ltd has identified a need to modify aspects of the currently approved Illawarra Cogeneration Project (ICP), now known as the Steelworks Cogeneration Project (SCP). The project is located at the Port Kembla Steelworks. The approved ICP includes a closed circuit cooling water system using a cooling tower. However, the modification proposed by BlueScope Steel addressed in this report is a replacement of the re-circulated cooling system with a once-through salt water cooling system. Operation of the SCP would involve decommissioning of the No. 1 power house and cessation of the associated flows and temperature loads into Main Drain. It is proposed that saltwater used for cooling of the steam turbine generator condensers of the SCP would be drawn from Port Kembla Outer Harbour via the existing saltwater lift pump and channel, used as cooling water for the SCP and then returned back to Port Kembla Inner Harbour at a location in Allans Creek approximately 170m downstream of the existing No. 2 blower station drain. This return would occur by constructing an engineered device that would spread a thin thermal plume over the surface of the Inner Harbour rather than mixing through the entire water column, avoiding the possibility of a thermal plug. This could take a range of forms including a 'launder' that allows discharges to flow laterally into the surface layers of the receiving water body or a multi-port diffuser structure. Temperature dispersion modeling indicates that the heat-load discharge device is predicted to increase the rate of heat dissipation above that expected from alternative discharge options such as those that mix through the entire water column.

On the basis of recent modelling by Cardno Lawson Treloar Pty Ltd (CLT), the increase in average water temperature in the harbour is predicted to be less than 0.8ºC at most depths during average/typical heat-load conditions. Under such conditions, we predict that the SCP would cause no major loss of biota from marine communities within the already highly-modified ecosystem of the Harbour.

If, however, temperatures are elevated by more than 3°C as a result of operation of the SCP, then some ecologically important changes may occur. It should be noted that the effects of temperature are likely to be gradual and that the 3°C is not a threshold value, but rather one at which we would expect major effects to be

detectable. Ecological change associated with a 3°C or greater increase is most likely to occur in Inner Harbour near the mouth of Allans Creek, and may include:

- Ecologically important changes in the relative abundance of some temperate species
- The appearance of more warm water species (including exotic species)
- Increases in the toxicity and bioaccumulation of existing heavy metals and PAHs

The maintenance of a distinct thermal plume at the surface of Inner Harbour would be preferable on ecological grounds to temperature increases throughout the water column, because the cooler water beneath the plume would continue to provide alternative habitat for subtidal organisms less tolerant of higher temperatures.

Changes in water temperature in Allans Creek between the Main Drain and the heat-dissipation device under average/typical conditions of SCP operation seem unlikely to have a major effect on biota in the creek, including the movement of species up and down the creek. However, even if some changes in the biotic assemblage do occur, any return to a more natural temperature regime in the creek should nonetheless be seen as a positive step.

We conclude that operation of the proposed SCP under average/typical heat-load conditions is unlikely to cause major changes to marine communities within Port Kembla Harbour.

INTRODUCTION

BlueScope Steel Ltd has identified a need to modify aspects of the currently approved Illawarra Cogeneration Project (ICP), now known as the Steelworks Cogeneration Project (SCP). The project is located at the Port Kembla Steelworks. The approved ICP includes a closed circuit cooling water system using a cooling tower. However, the modification proposed by BlueScope Steel addressed in this report is a replacement of the re-circulated cooling system with a once-through salt water cooling system. Operation of the SCP would involve decommissioning of the No. 1 power house and cessation of the associated flows and temperature loads into Main Drain. It is proposed that saltwater used for cooling of the steam turbine generator condensers of the SCP would be drawn from Port Kembla Outer Harbour via the existing saltwater lift pump and channel, used as cooling water for the SCP and then returned back to Port Kembla Inner Harbour at a location in Allans Creek approximately 170m downstream of the existing No. 2 blower station drain. This return would occur by constructing an engineered device that would spread a thin thermal plume over the surface of the Inner Harbour rather than mixing through the entire water column, avoiding the possibility of a thermal plug. This could take a range of forms including a ‘launder’ that allows discharges to flow laterally into the surface layers of the receiving water body or a multi-port diffuser structure. Temperature dispersion modeling indicates that the heat-load discharge device is predicted to increase the rate of heat dissipation above that expected from alternative discharge options such as those that mix through the entire water column.

Port Kembla Harbour is a highly disturbed ecosystem, having been greatly modified by human activities. The Inner Harbour and the lower reaches of Allans Creek have been subjected to elevated water temperatures for decades due to the discharge to the creek of heated effluent from surrounding industries. Evidence of the effects of temperature and contaminants on aquatic biota has been documented in various environmental studies (He and Morrison 2001).

The Department of Environment and Conservation (DEC) require an assessment of the potential ecological effects of increases in water temperature associated with the commissioning of the SCP in order to satisfy the Protection of the Environment

Operations Act 1997. Dr Jan Carey (University of Melbourne) and Dr Emma Johnston (University of NSW) were contracted by CH2M HILL Pty Ltd to undertake a desk-top study to provide this assessment using currently available scientific information, including the numerical modelling of cooling water by Cardno Lawson Treloar (CLT 2006). This report describes the potential ecological effects of increased water temperatures in the Inner Harbour of Port Kembla and addresses specific ecological issues raised by the DEC (21/12/05) in relation to the BSL SCP project.

PREDICTED CHANGES IN TEMPERATURE

Water temperatures in the Inner Harbour typically range from 15.3 to 30.4°C at the present time, with a likely maximum of 32.4°C in summer under peak load conditions (Table 1). In comparison, long-term monthly mean sea surface temperatures for the Wollongong and Port Kembla region range from 17.7 to 23.5°C (METOC 2006). The difference in the temperature regimes of Inner Harbour and the coast in general, is a result of both the existing discharge of heated effluent to Allans Creek, and the sheltered and estuarine nature of the harbour (Roy et al. 2001).

Under the SCP proposal, average water temperatures in the Inner Harbour are expected to be within 0.8°C of existing conditions at most locations and water depths (Tables 2 and 3). Only in the bottom water layer of the innermost location 22,67 (near the Services Bridge over Allans Creek; Fig. 1) under maximum load conditions, is an increase in excess of 1°C predicted (Table 2). Decreases in average temperature up to 1°C are also predicted for location 22,67 at the surface and in the middle water layer (Tables 2 and 3).

Upper and lower bounds on predicted water temperatures presented in Table 1 have been calculated as the mean ± 1.96 standard deviations. The range of water temperatures between these bounds at any given site is predicted to be no more than 1°C greater under the SCP proposal than under existing conditions. Only at the site 300 m upstream of the No.2 Blower Station discharge is a greater increase of 1.13°C predicted. The upper bounds on predicted temperatures are no more than 1°C higher under the SCP proposal than under existing conditions.

The closure of the No.1 Power House will result in a substantial reduction in cooling water discharge from the main drain upstream of Allans Creek. This is expected to reduce the temperature between the Main Drain and the mouth of Allans Creek. Predicted changes in average temperatures at three sites in this part of Allans Creek range from a decrease of 0.7°C to an increase of 0.7°C (Tables 2 and 3).

Although the CLT modelling suggests that changes in average temperature due to the SCP are likely to be minimal (i.e. generally less than 0.8°C), we have taken a precautionary approach to assessing the potential ecological effects of the release of the SCP cooling water. Throughout this report we have considered possible effects of the modelled increase (i.e. <0.8°C) as well as the potential for a greater increase of 2-3°C in the harbour water. While the existing temperature regime in Inner Harbour is not a natural one, we have examined the potential consequences of a 2-3°C increase because it is defined as the threshold change from background temperature levels that should be avoided in order to maintain aquatic ecosystem health in the interim Water Quality Objectives for the Illawarra catchment (EPA 2000). It should be noted that the modelling undertaken by CLT indicates that even under extended peak-load conditions, the maximum increase in average temperature predicted is 2.44°C. Our approach thus makes some allowance for variation from average temperatures.

Table 1. Predicted temperature regime under existing conditions and the proposed SCP. Data were summarised from modelling studies (CLT 2006); maxima are from summer data and minima are from winter data, with peak load minima based on 3/4/2006 modelling .

Location	Predicted range of temperature through water column (mean ± 1.96 standard deviation; °C)			
	Existing under Average/Typical Load	SCP under Average/Typical Load	Existing under Peak Load	SCP under Peak Load
22,67 (Allans Creek)	17.00 - 30.40	16.39 - 30.66	16.50 - 32.40	16.75 - 31.58
45,68 (Inner Harbour)	15.49 - 25.85	15.74 - 26.34	16.07 - 26.88	16.22 - 27.66
60,62 (Inner Harbour)	15.47 - 25.12	15.72 - 25.65	15.98 - 25.95	16.12 - 26.83
77,46 (The Cut)	15.31 - 24.72	15.61 - 25.18	15.84 - 25.33	15.95 - 26.12
81,40 (Outer Harbour)	15.30 - 24.54	15.52 - 24.95	15.76 - 25.04	15.95 - 25.76
80,34 (Outer Harbour)	15.22 - 24.01	15.32 - 24.22	15.46 - 24.30	15.57 - 24.65
Sites in Allans Creek, upstream of No. 2 Blower Station discharge:				
100 m upstream	17.11 - 30.43	16.59 - 30.66		
300 m upstream	16.81 - 30.38	16.03 - 30.73		
500 m upstream	16.36 - 30.85	16.36 - 30.85		

Table 2: Estimated changes in average water temperature in Port Kembla Harbour in summer. Estimated existing and post-SCP temperatures are presented for three water layers and for the average/typical and peak heat-load conditions of the SCP. Locations in Allans Creek are measured upstream from the No. 2 Blower Station discharge.

Layer	Location	Existing	Post-SCP	Change in Temperaturec (°C)	Existing	Post-SCP	Change in Temperature (°C)
Surface		*Under average load*			*Under peak load*		
	22,67 (Services Bridge)	27.21	26.94	-0.27	28.62	27.58	-1.04
	45,68 (Inner Harbour)	24.42	24.93	0.51	25.08	25.92	0.84
	60,62 (Inner Harbour)	23.85	24.28	0.43	24.30	25.01	0.71
	77,46 (The Cut)	23.54	23.89	0.35	23.86	24.43	0.57
	81,40 (Outer Harbour)	23.38	23.68	0.30	23.63	24.13	0.50
	80,34 (Outer Harbour)	23.01	23.18	0.17	23.16	23.43	0.27
	Allans Creek 100 m	27.30	27.03	-0.27			
	Allans Creek 300 m	26.94	26.53	-0.41			
	Allans Creek 500 m	26.79	26.11	-0.68			
Middle							
	22,67 (Services Bridge)	28.20	28.17	-0.03	28.04	28.38	0.34
	45,68 (Inner Harbour)	23.32	23.55	0.23	23.38	23.68	0.30
	60,62 (Inner Harbour)	23.23	23.45	0.22	23.30	23.59	0.29
	77,46 (The Cut)	22.99	23.14	0.15	23.06	23.28	0.22
	81,40 (Outer Harbour)	22.83	22.92	0.09	22.89	23.02	0.13
	80,34 (Outer Harbour)	23.03	23.19	0.16	23.15	23.39	0.24
	Allans Creek 100 m	28.25	28.23	-0.02			
	Allans Creek 300 m	27.99	27.85	-0.14			
	Allans Creek 500 m	27.83	27.27	-0.56			
Bottom							
	22,67 (Services Bridge)	27.57	28.29	0.72	23.92	26.36	**2.44**
	45,68 (Inner Harbour)	22.92	23.02	0.10	22.94	23.08	0.14
	60,62 (Inner Harbour)	22.81	22.89	0.08	22.84	22.94	0.10
	77,46 (The Cut)	22.64	22.68	0.04	22.66	22.71	0.05
	81,40 (Outer Harbour)	22.67	22.72	0.05	22.70	22.77	0.07
	80,34 (Outer Harbour)	22.93	23.05	0.12	23.01	23.19	0.18
	Allans Creek 100 m	27.64	28.33	0.69			
	Allans Creek 300 m	27.56	28.15	0.59			
	Allans Creek 500 m	28.08	27.83	-0.25			

Table 3: Estimated changes in average water temperature in Port Kembla Harbour in winter. Estimated existing and post-SCP temperatures are presented for three water layers and for the average/typical conditions of the SCP. Locations in Allans Creek are measured upstream from the No. 2 Blower Station discharge.

Layer	Location	Existing	Post-SCP	Change in Temperature (°C)
Surface				
	22,67 (Services Bridge)	20.14	19.80	-0.34
	45,68 (Inner Harbour)	17.42	17.89	0.47
	60,62 (Inner Harbour)	16.84	17.29	0.45
	77,46 (The Cut)	16.51	16.91	0.40
	81,40 (Outer Harbour)	16.40	16.74	0.34
	80,34 (Outer Harbour)	16.14	16.32	0.18
	Allans Creek 100 m	20.32	19.96	-0.36
	Allans Creek 300 m	19.71	19.32	-0.39
	Allans Creek 500 m	19.36	18.81	-0.55
Middle				
	22,67 (Services Bridge)	21.08	21.06	-0.02
	45,68 (Inner Harbour)	16.44	16.76	0.32
	60,62 (Inner Harbour)	16.40	16.72	0.32
	77,46 (The Cut)	16.30	16.54	0.24
	81,40 (Outer Harbour)	16.26	16.41	0.15
	80,34 (Outer Harbour)	16.22	16.40	0.18
	Allans Creek 100 m	21.20	21.13	-0.07
	Allans Creek 300 m	20.77	20.75	-0.02
	Allans Creek 500 m	20.52	20.13	-0.39
Bottom				
	22,67 (Services Bridge)	21.05	21.70	0.65
	45,68 (Inner Harbour)	16.29	16.54	0.25
	60,62 (Inner Harbour)	16.25	16.46	0.21
	77,46 (The Cut)	16.21	16.35	0.14
	81,40 (Outer Harbour)	16.22	16.35	0.13
	80,34 (Outer Harbour)	16.21	16.36	0.15
	Allans Creek 100 m	21.14	21.76	0.62
	Allans Creek 300 m	21.02	21.54	0.52
	Allans Creek 500 m	21.30	21.16	-0.14

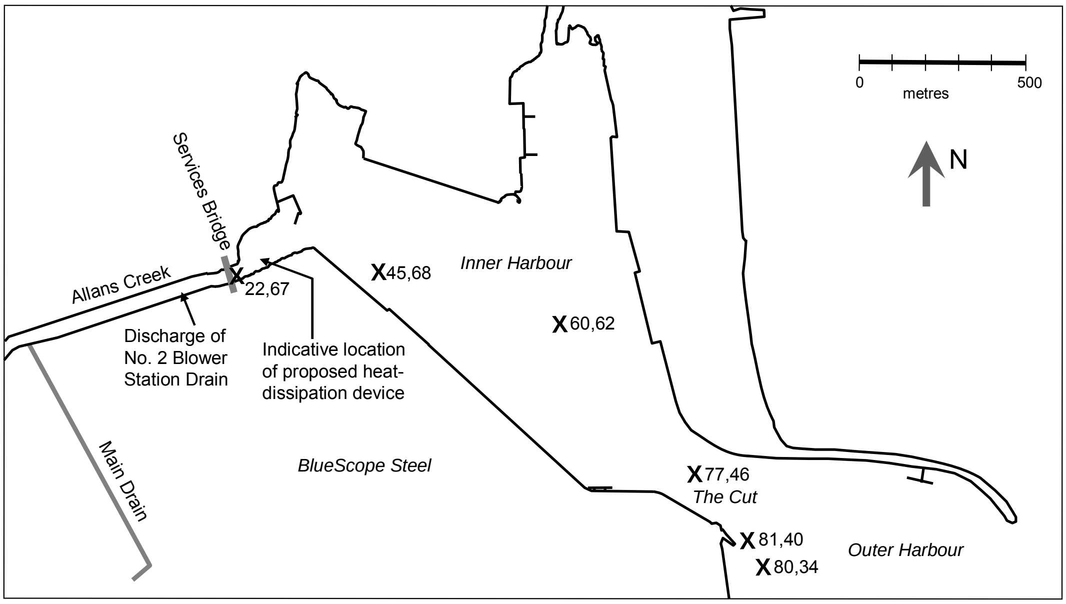

Figure 1. Map of Port Kembla Harbour showing proposed location of heat dissipation device and locations targeted in modelling data.

TEMPERATURE TOLERANCES AND PREFERENCES OF ORGANISMS CURRENTLY FOUND IN PORT KEMBLA HARBOUR

The April 2005 review by Carey listed 16 species commonly found in Port Kembla Harbour, together with their known geographic distributions. In the absence of specific information on the thermal tolerance of individual species, geographic distribution was used as a coarse surrogate for predicting possible gains or losses of species under the proposed temperature regime.

This report extends the April 2005 list to cover over 500 species recorded in the harbour (Annexure A). An extensive literature search (Annexure B) retrieved specific information on thermal tolerance for 9 of these species. Geographic distribution of species is again used as a surrogate for the thermal tolerance of other species where possible, and has now been explicitly linked to long-term average sea surface temperatures around the Australian coast (Annexure C).

Relevant information for each species is compiled in Annexure A, and our inferences based on that information are presented below. However, these inferences should be considered as ***only indicative*** of possible changes in species distributions. There is considerable uncertainty surrounding the prediction of such changes, because

- There are certainly many more species present in the harbour than have been recorded to date (as is typically the case with ecological sampling in marine habitats).
- Data on thermal tolerance for individual species is very limited.
- The known distribution of a species may be more a reflection of the incidence of observations of the species than of its true distribution.
- Stratification of the water column in the Inner Harbour not only offers alternative temperature regimes for organisms with a narrow range of preferred temperature, but also complicates the interpretation of geographic range as a surrogate for temperature.

Species which might be expected to respond to a changed temperature regime in the Inner Harbour could be broadly categorised as shown in the conceptual model in Figure 2.

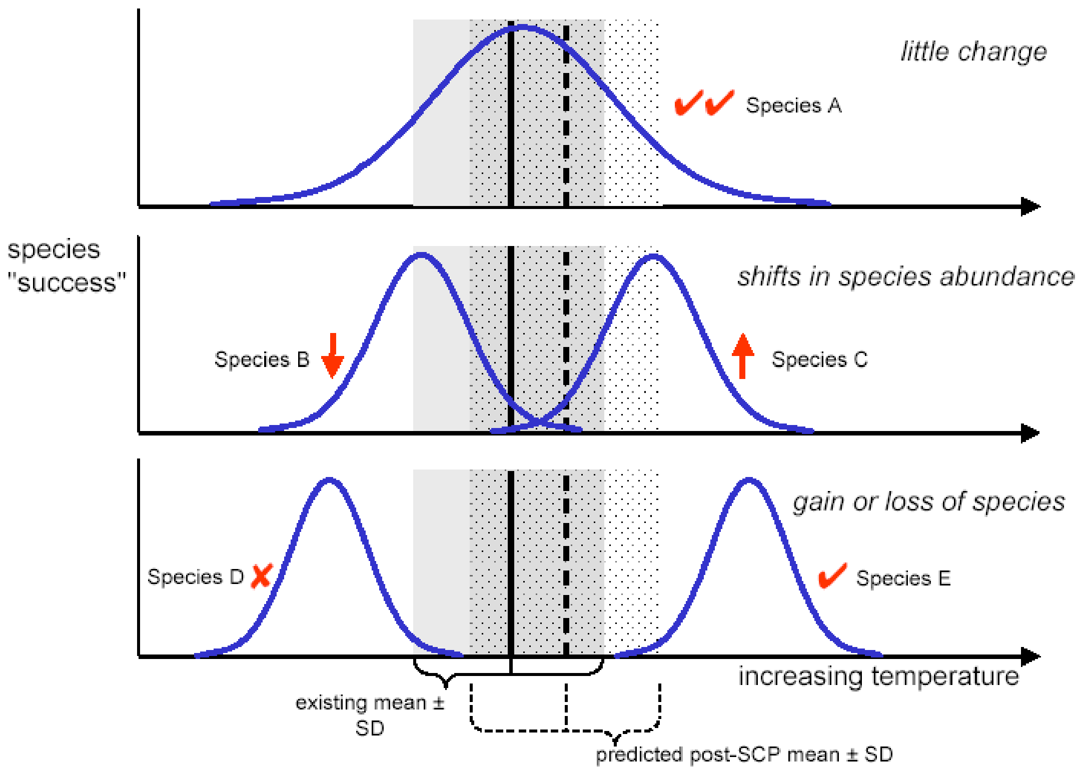

Figure 2. Conceptual model of effects of temperature change on species with different temperature tolerances.

Species already in the Inner Harbour and able to tolerate a relatively wide range of temperatures might be expected to show little change (Fig. 2, Species A). Species that are widely distributed through tropical and warm temperate waters in Australia might be expected to fall into this category. Candidate species, and the temperature ranges associated with their known geographic distribution (Annexure A), are:

- the barnacle *Balanus trigonus* (13 - 31°C)
- the ascidian *Herdmania momus* (13 - 30°C)
- the ascidian *Styela plicata* (13 - 31°C)

The abundance of moderately successful species under the current temperature regime may be reduced in parts of the Inner Harbour where predicted increases are highest (Fig 2, Species B). Candidate species for this category are

- the barnacle *Amphibalanus variegatus* (13 - 27°C)
- the barnacle *Chthamalus antennatus* (11 - 27°C)

Alternatively, species which are currently moderately successful under the existing temperature regime may become somewhat more abundant (Fig. 2, Species C). Candidate species currently near the southern limit of their ranges include

- the gastropod *Littoraria luteola* (15 - 31°C)
- the spider crab *Hyastenas elatus* (17 - 31°C)
- the blue swimmer crab *Portunus pelagicus* (15 - 31°C)
- the three-barred porcupinefish *Dicotylichthys punctulatus* (15 - 31°C)
- the big eye trevally *Caranx sexfasciatus* (down to 17°C)
- the silverbelly (fish) *Gerres subfasciatus* (17 - 31°C)
- the common toadfish *Tetractenos hamiltoni* (15 - 30°C)

Species presently found in the Inner Harbour at or near the northern limits of their distribution may be eliminated with any further increase in water temperature (Fig. 2, Species D).

- the peanut worm *Phascolosoma annulatum* (11 - 22°C)
- the gastropod *Clanculus plebejus* (13 - 24°C)
- the Tasmanian blenny (fish) *Parablennius tasmanianus* (11 - 23°C)

- the common weedfish *Heteroclinus perspicillatus* (11 - 22°C)
- the rosy wrasse (fish) *Pseudolabrus psittaculus* (11 - 24°C)

Warmer-water species may appear in the Inner Harbour with an increase in temperature (Fig. 2, Species E). Some may be exotic species introduced via shipping vectors such as ballast water or hull fouling (see Introduced Species section below).

- the Asian green mussel (*Perna viridis*)
- the black-striped mussel (*Mytilopsis sallei*)
- the golden mussel (*Limnoperna fortunei*)
- the Japanese shore crab (*Hemigrapsus sanguineus*)

Species existing in the upper water column, close to their upper limits of thermal tolerance, may have alternatives other than reduced abundances or elimination from the Inner Harbour. One possibility for species not dependent on tidal movement is withdrawal from the upper warmer water layer in the Inner Harbour to the cooler water beneath the thermal plume. In this regard, the continuing presence of a distinct thermal plume at the surface under the SCP proposal presents a better ecological alternative than a more uniform temperature regime through the water column. There is clear evidence that such partitioning of habitat occurred in the Inner Harbour in the past. Motile species such as fish are able to relocate to regions of preferred water temperature (e.g. Tsuchida 2005), and the fish kills for which the harbour was known in the 1970s and earlier could not have occurred had there been no fish living beneath the then-highly-polluted thermal plume. Relocation horizontally to cooler parts of the Inner Harbour is another possible strategy to avoid warmer water.

As the relative abundances of species within the harbour change in direct response to increased temperatures, secondary effects are also to be expected. Some species may gain a competitive edge over others as a result of changed interactions among species. For example, a decrease in predator numbers or reduced competition for space may allow a species to increase in abundance. Such indirect effects are well documented in the marine environment and are acknowledged as an important influence on marine community structure (Menge 1995). However, they may be difficult to predict, particularly in the absence of an obvious keystone species or ecosystem engineer. Of the species listed above, the barnacles and ascidians are perhaps the most likely candidates to generate secondary effects in the Inner Harbour because they both occupy space and provide structure within the hard substrate assemblage. However, prediction of the net effect is still problematic. For example, a reduction in the abundance of one barnacle species may be counteracted by an increase of another (Hawkins et al. 2003), resulting in minimal net change to the physical structure of the habitat.

Changes in water temperature in Allans Creek between the Main Drain and the launder under typical conditions of SCP operation (Tables 1,2 and 3) seem unlikely to have a major effect on biota in the creek. However, should there be a return to a more natural temperature regime in this part of the creek, the area may be less attractive to species such as the small fish with tropical affinities that have been reported there in the past (Carey 2005). Of the four mollusc, three crab and 17 fish species recorded in Allans Creek during the 2002 fish study (MSE 2002 and Annexure A), only two fish species (*Caranx sexfasciatus* and *Gerres subfasciatus*) and one crab (the mud crab *Scylla serrata*) would seem to be at risk from reduced temperatures on the basis of their known geographic distribution. However, both fish species are active swimmers so may well be able to move to warmer water within the harbour, while the crab is known to occur in estuaries, suggesting it is likely to tolerate higher temperatures than suggested by its geographic range alone. Irrespective of possible changes to the biotic assemblage, any return to a more natural regime in Allans Creek should be seen as a positive step.

In summary, as previously indicated in the April 2005 report, no major losses of biota from the Inner Harbour are anticipated as a result of the proposed temperature increases given that:

- The predicted changes to water temperatures are less than 0.8ºC across most of Inner Harbour, and
- Species currently residing in the Inner Harbour have been shown to survive temperatures higher than would be expected at the latitude of Port Kembla.

However, some changes to the composition of the assemblages may be expected to occur, particularly at the innermost locations near the mouth of Allans Creek where the predicted changes in water temperatures are greatest.

GENERAL TEMPERATURE EFFECTS ON MAJOR BIOCHEMICAL PROCESSES

- The major biochemical processes of photosynthesis, respiration and methanogenesis are strongly temperature sensitive. The marine nitrogen cycle including bacterially mediated nitrogen fixation, and denitrification are similarly temperature sensitive. Considered in isolation, an increase in temperature will generally cause an increase to the rate of any one of these processes. However, many other factors also influence the rate of biochemical processes. Predicting impacts on the interaction of these complex systems will be difficult. General case studies for denitrification and photosynthesis are provided below.
- Factors that influence denitrification in estuaries include temperature, the supply of nitrate and organic matter, and oxygen concentration (Seitzinger 1988, Nowicki 1994). Denitrification occurs only under low oxygen or anaerobic conditions. Oxygen needs to be <0.2 mgL^{-1} for denitrification (in water or sediments). Since the dissolved oxygen concentration of water is predicted to decrease with increasing temperature, denitrification rates may be expected to increase, however this will be limited by the supply of nitrate and organic carbon.
- Temperature is likely to increase the rate of photosynthesis of algae (Kirk 1983) up until the temperature exceeds the optimum for each species. The alga *Ulva lactuca*, for example, has a temperature optimum at approximately 25 $^{\circ}$C (Kirk 1983). Hence, for this species any increase in temperature due to the SCP during the cooler months may lead to an increase in its rate of photosynthesis. During the summer months, however, increases above 25°C are likely to lead to a decrease in its rate of photosynthesis. Photosynthetic rates do not translate directly to growth rates (primary production) which depend on a multitude of other factors related to respiration and nutrient availability. The majority of macroscopic algal populations within Port Kembla Harbour (and one seagrass species *Halophila ovalis;* Annexure A) are restricted to sections of the Outer Harbour. The expected temperature change in this area is highly unlikely to cause significant changes to the abundance or density of these algal populations. Further

increases in temperatures within the Inner Harbour may continue to restrict algal populations from establishing in these areas, however, other environmental factors (such as increased turbidity) may also be restricting macroalgal populations within the Inner Harbour.

SPECIES EXPECTED IN A SLIGHTLY TO MODERATELY DISTURBED ESTUARINE SYSTEM

Port Kembla Harbour is currently considered a highly disturbed estuary (DEC 21/12/05). Pristine estuaries have a high proportion of natural vegetation cover in the catchment and minimal changes to the hydrology, tidal regime, or ecology of the system. Such estuaries experience minimal disturbance from catchment land use, low impact human use and minimal impacts from pests or weeds (National Land and Water Resources Audit 2001). Port Kembla does not currently fulfill any of the requirements of a pristine estuary and can be considered 'severely modified' (National Land and Water Resources Audit 2001). Highly disturbed estuaries are defined as "measurably degraded ecosystems of lower ecological value" (ANZECC 2000). There are no specific water quality or biological integrity values associated with this categorisation system however highly disturbed estuaries may be considered to be substantially impacted by human activities.

The Protection of the Environment Operations Amendment Act 2005 and DEC's objectives require practical measures be taken to restore or maintain the environmental values of the environment. Thus, a significant improvement in all disturbed systems ranging from 'slightly to moderately disturbed' to 'highly' disturbed is required. The ANZECC water quality guidelines define "slightly to moderately disturbed" marine systems as those that retain largely intact habitats and associated biological communities. Following an extensive search of published literature, lists of organisms that inhabit such marine environments are not currently available. The NSW Government have specified interim Water Quality Objectives for the Illawarra catchment area (EPA 2000). Objectives relevant to Port Kembla Harbour include the maintenance or rehabilitation of estuarine processes and habitats. However, there are no specific requirements for the species composition of any category (disturbed or otherwise) of marine community (EPA 2000). In the absence of agreed species lists or biotic indices of marine harbour health, it is necessary to attempt to compare available information on species composition of Port Kembla Harbour with that from surrounding harbours that are considered slightly to moderately disturbed (e.g. DEC recommendations to compare assemblages with those in Wollongong Harbour).

Port and estuarine environments have been subject to anthropogenic change for the benefit of industry and urbanisation (Kennish 2002). Many ports now carry increased sediment and pollutant loads and suffer ongoing disturbance to their natural hydrological regimes. Many of the hard-substrate species found in Port Kembla's Outer Harbour are also found in other port environments that may be considered to be moderately to slightly disturbed such as Wollongong Harbour (Moran and Grant 1989), Sydney Harbour (Glasby 1998), Botany Bay (Clark and Johnston 2005) and Port Phillip Bay (Johnston and Keough 2005). These assemblages tend to have a wide variety of species including solitary and colonial ascidians (sea squirts), sponges, encrusting and arborescent bryozoans, barnacles, hydroids, bivalves and serpulid polychaete worms.

Many species found in Port Kembla's Outer Harbour, however, are not found in the Inner Harbour (Johnston and Clark 2004). Hard-substrate assemblages (e.g. rocky reef communities) of the Inner harbour tend to have more unoccupied space, and are dominated by small serpulid polychaete worms, arborescent bryozoans and barnacles (Johnston and Clark 2004). In hard substrate communities, space availability provides an indication of the time since the last disturbance and the intensity of competition (Karlson 1978, Sousa 2001). Communities with more space have generally been more recently disturbed, which removes the strong competitors (e.g. ascidians and sponges) and allows colonisers (e.g. barnacles and serpulids) to recruit (Connell and Keough 1985). Inner harbour assemblages of Port Kembla Harbour are indicative of a stressful environment subject to frequent disturbances in which only the early colonizing species have an opportunity to live very short lives (Johnston and Keough 2002, 2003).

If the Inner Harbour sessile invertebrate assemblages were to match those of a "slightly to moderately disturbed" system, we would expect to see greater abundances of sponges, and ascidians. For example, we would expect to find the colonial ascidian *Botrylloides magniocoecum*, and a sponge of the genus *Haliclona sp*. within a healthy functioning assemblage of the Inner Harbour. We would also expect to see rapid colonisation and competition for available space. There are multiple potential causes of this biological paucity within the Inner Harbour that have yet to be differentiated. These include, changes to the hydrology, turbidity, salinity, temperature and toxicant load of this area (He and Morrison, 2001).

Fish assemblages appear to be similar to many other NSW estuaries (MSE 2002). Moreover, there are several species that are more often associated with tropical waters that seem to survive for long periods (and maybe even over the entire year) within the Inner Harbour; possibly due to the warm coolant water.

ASPECTS OF CURRENT ENVIRONMENT THAT MAY BE EXCLUDING SPECIES

Port Kembla Harbour is an industrialised harbour with a history of heavy-metal pollution (He and Morrison 2001). It is subject to frequent shipping activities and its surrounds include steelworks, coal and grain exporting terminals, and an acid plant. The port is divided into an Inner and Outer Harbour connected via a narrow shipping channel (the Cut). Water quality in the Inner Harbour is poor, and heavy-metal concentrations in both the water and sediment frequently exceed Australian guidelines (He and Morrison 2001, ANZECC 2000). The Outer Harbour is considered less polluted (He and Morrison 2001), with better flushing and fewer pollution point sources. There is also some evidence of increased temperature and turbidity in the Inner Harbour (BSL Water Quality data). These environmental conditions may be excluding many species (such as sponges and ascidians) from areas within the Inner Harbour.

Differences between the assemblages of species in the Inner and Outer Harbours may be due to differences in water quality, but may also be due to intrinsic changes in the distribution of species among estuaries. Manipulative field experiments, comparative surveys amongst estuaries and laboratory bioassays would be required to distinguish the causal factors explaining the distribution of species within Port Kembla. It is possible that remediation of the chemical environment may be a prerequisite for biological remediation and this will not be achievable without massive intervention (e.g. removal of contaminated sediments from the Harbour).

The concentrations of contaminants in the water in Port Kembla Harbour have been reduced dramatically since the 1970s and this improvement in water quality has correlated with an increase in the diversity and abundance of invertebrates and fish in Port Kembla Harbour (He and Morrison 2001). In the 1970s, for example, zinc, copper, lead and cadmium were often several to tens of times greater than the current ANZECC guidelines; while cyanide was over 140 times greater than the guidelines in some locations within the Inner Harbour. In 2005, zinc, copper and lead were still found in concentrations greater than that in the guidelines, however, this occurred infrequently and was usually no greater than twice the prescribed concentrations in the guidelines (BSL Water Quality Data); while cyanide was only rarely detected and at concentrations much lower than the guidelines. It is highly likely that continuing to improve the water quality (similar to that found in appropriate reference estuaries) will result in the biological diversity (diversity and abundance of organisms; e.g. algae, invertebrates and fish) of the harbour becoming relatively similar to that found in similar estuaries.

A REVIEW OF THE INFLUENCES OF TEMPERATURE ON TOXICITY AND BIOACCUMULATION OF CONTAMINANTS ON MARINE AND ESTUARINE ORGANISMS

HEAVY METALS

Numerous studies have investigated the interactive effects of temperature and contaminants such as heavy metals. Several excellent reviews provide a basis from which to discuss the effects of temperature on the toxicity of heavy metals on marine/estuarine organisms. Some of these reviews are recent (Heugens et al. 2001), while others are a little older (Sprague et al. 1984, McLusky et al. 1986) but have not currently been superseded (as supported by our literature searches – see Annexure B).

Laboratory studies show that increases in temperature are related to increases in the toxicity of heavy metals. This pattern has been observed for a wide range of marine organisms (i.e. algae, invertebrates and fish) at various life history stages (i.e. fertilisation, larval development, juvenile and adult mortality) and for a wide range of metals and organic compounds (McLusky et al. 1981, Heugens et al. 2001). Generally, however, the temperatures and the ranges over which experiments have been conducted are quite different to those that may possibly occur due to the release of cooling water from the SCP. Most studies involve ambient temperatures of less than 20°C and/or compare differences in temperature that are greater than 5°C. A few studies have, however, evaluated the effects of increases in temperature over a range that is only slightly greater than the maximum temperature change that may occur in Port Kembla Harbour (i.e. 2.44°C) and the results of these studies support the general finding that an increase in temperature leads to increased toxicity heavy metals (e.g. cadmium, zinc and copper) on a range of algae, invertebrates and fish. None of these studies have, however, used species that occur in Port Kembla Harbour (McLusky et al. 1981, Heugens et al. 2001, Annexure A).

A specific example of the temperature effect on the toxicity of heavy metals is from the data of Axiak and Schembri (1982). In this study, the mortality of an intertidal gastropod (*Monodonta turbinata*) was measured after being exposed to water contaminated with mercury across a temperature range relevant to this study. At 25°C, 2 mgL^{-1} of mercury killed approximately 10 % of the snails; while the same concentration at 30°C killed 30% of the snails (a tripling in the mortality rate; Figure 3 below). At slightly higher mercury concentrations (i.e. 8 mgL^{-1}) the effects were even greater, in absolute terms, with 35% of the snails being killed at 25°C compared to 82 % at 35°C (more than doubling the mortality rate). Consistent increases in the mortality rate were also observed for intermediate concentrations. *Monodonta turbinata* does not occur in Australia, but several species from the same family (i.e. Trochidae; *Turbo torquatus*, *Austrocochlea porcata*, *Austrocochlea constricta*) occur in estuaries along the NSW coast and *Austrocochlea constricta* has been observed alive in Allans Creek (MSE 2002). We were unable to find any estimates of the mercury concentration in the waters of Port Kembla as it is not measured in

BlueScope Water Quality Surveys and it was not mentioned in He and Morrison (2001).

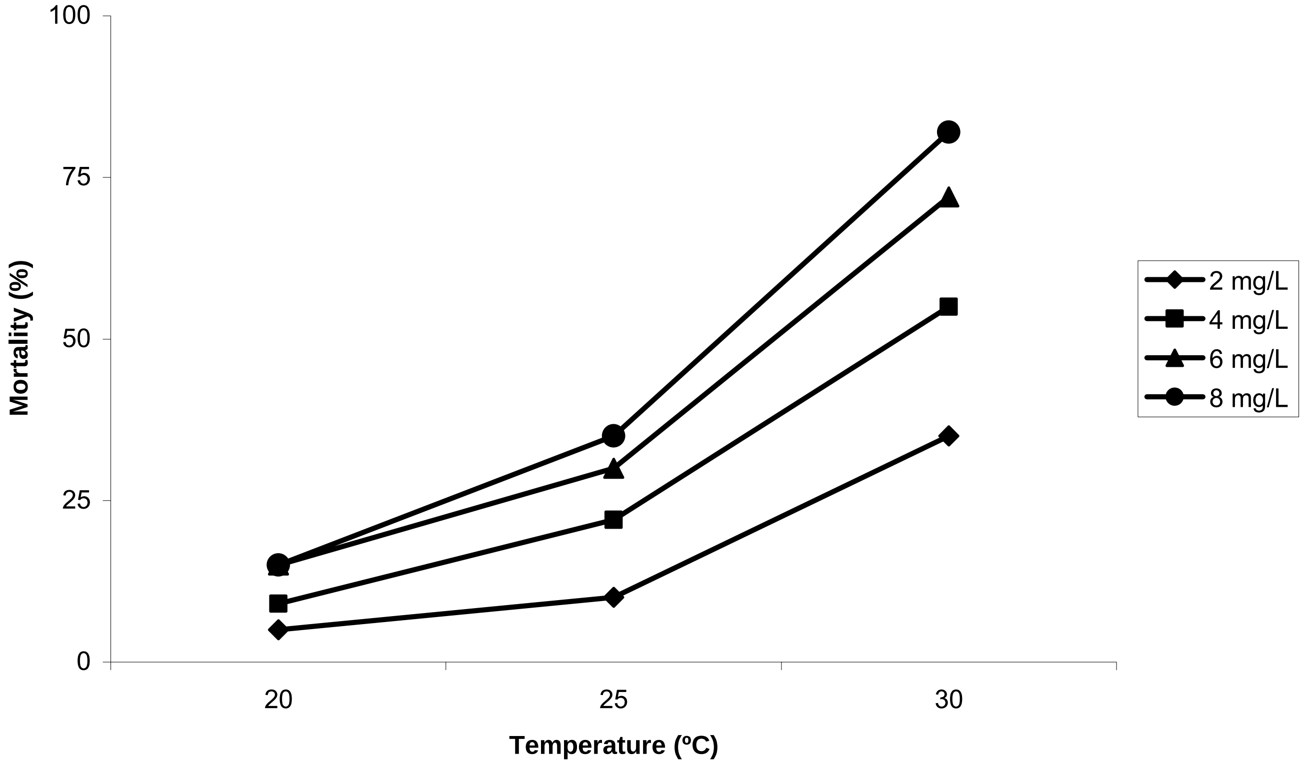

Figure 3: A general example of the influence of temperature on the toxicity of heavy metals, reproduced from Axiak and Schembri (1982). The mortality of an intertidal gastropod exposed to water contaminated with mercury across a temperature range relevant to that which could occur in the Inner Harbour of Port Kembla if temperature changes due to the proposed SCP exceed the modelling predictions.

Bioaccumulation of metals in marine organisms has also been found to increase with increases in temperature (Denton and Burdon-Jones 1981, Watkins and Simkiss 1988, Munda and Hudnik 1988, Regoli et al. 1991). Significant increases have been observed with zinc in the mussel *Mytilus edulis* (10-25°C; Watkins and Simkiss 1988) and in the macroalga *Fucus vesiculosus* (Munda and Hudnik 1988); with copper in the bivalve *Donacilla cornea* (18-25°C; Regoli et al. 1991); and with cadmium and mercury in the oyster *Saccostrea echinata* (20-30°C; Denton and Burdon-Jones 1981). None of these species occur in Port Kembla Harbour (Annexure A), although several closely related species have been found within the Harbour (e.g. the mussel *Mytilus galloprovincilis* and the oyster *Saccostrea glomerata*), as have functionally similar species (e.g. the foliose algae, *Ecklonia radiata* and the bivalve *Fulvia tenuicostata*).

The increased toxicity and bioaccumulation of heavy metals and organic contaminants associated with temperature increases are generally related to increases in the metabolism of the organisms (McLusky et al. 1981, Heugens et al. 2001). Increases in metabolism can lead to greater uptake of the contaminants through food consumption and greater effects due to competition between ions for binding sites on enzymes related to respiration and to reduced oxygen transfer across the membranes of gills (McLusky et al. 1981, Heugens et al. 2001).

Ecological effects of heavy metals at various temperatures do not appear to have been investigated or at least published in the scientific literature (not detected in any of the literature searches conducted for this review – see Annexure B). Although, there have been numerous ecological studies that have shown that heavy metals can have very strong effects (Morrisey et al. 1996, Stark 1998, Kelaher et al. 2003, Johnston and Keough 2005), none have simultaneously investigated the influence of elevated temperature. This makes it difficult to assess whether the effects of temperature predicted from laboratory toxicity tests and bioaccumulation studies would actually occur in the field (Kimball and Levin 1985). Furthermore, many organisms exposed to pollution are not just exposed to one contaminant, but rather to a myriad of contaminants. Predicting the effects of combinations of contaminants is virtually impossible from single contaminant toxicity tests. Hence, as argued in the ANZECC guidelines (2000), efforts should be made to evaluate the effects of contaminants and changes to the environmental conditions in the field itself and with the organisms themselves (i.e. site-specific tests).

POLYCYCLIC AROMATIC HYDROCARBONS

There has been a reasonable amount of research on the effects of polycyclic aromatic hydrocarbons, enough for several reviews to have been written (Malins and Hodgins 1981, Law and Klungsoeyr 2000). There is, however, little research on the influence of temperature on the effects of polycyclic aromatic hydrocarbons (PAHs; Annexure II). The only study (Korn et al. 1979) involved experiments on fish and shrimp and evaluated the effects of toluene, naphthalene and the soluble fraction of crude oil. None of these species are found in Port Kembla Harbour, although several prawn species have been found with the Harbour (Annexure A, MSE 1991).

Bioaccumulation of PAHs varies greatly among organisms (Law and Klungsoeyr 2000). Fish are able to metabolise PAHs rapidly, while invertebrates are relatively slow to metabolise these contaminants (Malins and Hodgins 1981, Law and Klungsoeyr 2000). There appears to be no published literature, however, on the effects of temperature on the bioaccumulation of PAHs.

POTENTIAL INFLUENCE OF TEMPERATURE INCREASES ON THE TOXICITY AND BIOACCUMULATION IN PORT KEMBLA HARBOUR

The chemistry and biochemistry involved in the interactions between temperature and contaminants are complex and are likely to be influenced by several physico-chemical factors and hence they are difficult to accurately predict. Similarly, the translation of any physiological effects (such as toxicity and bioaccumulation) into ecological effects (i.e. actual differences in mortality or the distribution and abundance of species) is also complex and likely to be influenced by many factors such as the life-history or reproductive stage of the organisms, their behaviour or their condition (i.e. energy reserves).

Hence, it is unclear whether detectable increases in toxicity would be likely to occur following the commissioning of the SCP. It would, however, appear unlikely that a general increase of less than 0.8°C (i.e. modelling by CLT, Table 2 above) would cause a large (e.g. >50%) increase in the effects (toxic or bioaccumulation) of the heavy metals or PAHs at the entrance to Allans Creek or the Inner Harbour. This prediction is based on the general relationship that temperature generally increases the toxicity of heavy metals but that this tends to be linear and not exponential relationship (i.e. a small change would be unlikely to create a disproportionately large effect). If, however, the increase in temperature goes above the maximum predicted temperature change (e.g. > 3°C), then it is possible that there may be significant increases in toxicity or bioaccumulation due to the temperature change but only for some organisms and some toxicants (see review above). The ANZECC guidelines

(ANZECC and ARMCANZ 2000) suggest that site-specific values or effects should be assessed, and toxicity testing conducted, to evaluate the potential impacts on the ecology of marine and estuarine environments. In order to more accurately predict the interactive effects of toxicant exposure and temperature elevation, toxicity tests could be conducted in the laboratory over relevant temperature and toxicity ranges (0-5°C temperature elevations and toxicant ranges based on BSL water quality data). Ideal candidate organisms for such tests would be the endemic barnacle *Amphibalanus variegatus* and the endemic bryozoan *Beania magellanica* both of which currently occur broadly throughout the Inner harbour (Johnston and Clark 2005). Also, evaluating whether the predicted temperature changes are exceeded and whether any actual ecological effects occur in the Inner Harbour due to the commissioning of the SCP should be done (outlined in the section "Design of an ecological monitoring program for pelagic and/or benthic communities" below).

TEMPERATURE EFFECTS ON THE TOXICITY OF CLAMTROL

Clamtrol is a biocide used to inhibit the growth of sessile marine organisms and thereby prevent fouling of pipework associated with cooling water infrastructure. There appear to be no data on the effects of temperature on the toxicity of Clamtrol (see Annexure B – literature searches) or even its toxicity generally to marine or estuarine organisms. There is, however, an enormous amount of data on its toxicity to freshwater organisms (see Clamtrol MSDS; PAN Pesticides Database - Chemical Toxicity Studies on Aquatic Organisms). These data indicate that Clamtrol is highly toxic to freshwater organism (i.e. fish and bivalves which have been tested).

The general lack of data on the toxicity of Clamtrol to marine organisms and the influence of temperature on its toxicity make it impossible to provide a reasonable estimation of the effects of the release of this biocide at elevated temperatures into Port Kembla Harbour. Appropriate manipulative experiments (as above) are, therefore, necessary to evaluate such effects - especially considering the increase in toxicity and bioaccumulation that general occurs with increases in temperature and the high level of toxicity of Clamtrol.

INFLUENCE OF TEMPERATURE CHANGE ON THE POTENTIAL FOR INTRODUCTIONS OF EXOTIC SPECIES INTO PORT KEMBLA HARBOUR

Over the past 10 years, information has been collected on introduced species in Australian marine and estuarine environments. One aspect of this National Priority Pests project has been the identification of species already established in Australia, which give rise to the greatest concern (Hayes et al. 2005). These domestic target species are those which can be transported via shipping (including hull fouling and ballast waters), and have demonstrated impacts on the environment, the economy or human health. Potential target species not yet present in Australia are identified as international target species. Table 4 provides predictions as to the likely effect of the commissioning of the SCP for high and medium international and domestic priority target pest species.

The temperature of warm water flowing from the SCP into the Inner Harbour (CLT 2006) is unlikely to significantly increase ambient temperatures. If, however, temperatures are elevated by ~3°C then ecologically significant changes may occur. Such increases are likely to influence the potential of the introduction of warm water exotic species by creating a warm water refuge throughout the year.

Most of the species that have been identified as potential invaders (i.e. within other parts of Australia and from outside Australia) (Hayes et al. 2005) tend to inhabit a wide range of water temperatures (e.g. from temperate to tropical waters). Changes in temperature are unlikely to influence the potential for invasion of a large number of these exotic species into Port Kembla Harbour. However, the changed temperature regime may heighten the likelihood of establishment of some exotic species including: *Perna viridis*, *Mytilopsis sallei*, *Limnoperna fortunei*, and the crab *Hemigrapsus sanguineus*. There are currently no available estimates of absolute invasion risk for priority pest species. It is therefore not possible to predict the extent to which the invasion risk will be heightened by any temperature increase. These species are known to be introduced by shipping vectors and tend to occur in warm water areas. If successfully translocated, they may be able to colonise the area surrounding the cooling water outfall similarly to the tropical fish assemblage identified in MSE (MSE 2002).

Establishment of these pest species may have striking effects on the composition and biological diversity of Port Kembla Harbour (Mack et al. 2000). More problematic, however, would be the establishment of a source population which may then facilitate recruitment into neighbouring habitats and other ports and estuaries (stepping-stone effect). Biological invasions are notoriously difficult, expensive, and sometimes even impossible to reverse (Hooper et al. 2005). The introduction of new marine pests may result in the port being quarantined and/or the restriction on subsequent movement of ships that do visit the port.

Management options currently exist for reducing the risk of marine introductions and these include ocean ballast exchange and antifouling paints. With the predicted small increase in temperature in Port Kembla Harbour there is an even greater imperative for pro-active prevention of marine pest incursions.

Table 4. The current distributions and likelihood of an effect of the change in water temperature on the establishment or invasion of the high to medium priority species identified in Hayes et al. (2005) to be potential threats to invasion from A) within Australia to other parts of Australia or B) from outside of Australia to Australia. Evaluation of the likelihood of establishment was based on whether the species was more likely to establish in the Inner Harbour due to a 3°C increase in water temperature.

A) Potential domestic target species

1. High priority:	Common name	Distribution	Temperature range	Source	Establishment interpretation
Gymnodinium catenatum	Dinoflagellate	Temperate	Not available		No likely effect from possible temperature increase
Alexandrium minutum	Dinoflagellate	Temperate	Not available		No likely effect from possible temperature increase

2. Medium-high priority:	Common name	Region of distribution	Temperature range	Source	Establishment interpretation
Caulerpa taxifolia	Green Alga	Temperate-Tropical	11.2 – 32 °C	Wright 2005	No likely effect from possible temperature increase
Sabella spallanzanii	Fan worm	Temperate	Not available		No likely effect from possible temperature increase
Asterias amurensis	Northern Pacific seastar	Temperate	0 – 25 ºC. For Tasmanian larvae, optimum range is <8.0 - 16.5 ºC, with abnormal development over 20 ºC.	NIMPIS 2002. Sutton and Bruce 1996.	No likely effect from possible temperature increase
Crassostrea gigas	Pacific oyster	Temperate	Spawn at water temps of 18.5 to 24 ºC (15-30 C for larval development) with maximum growth attained at 30 C. Can tolerate temperature as high as 35. Live and grow in water with temperatures of 4-24, high growth rates at 15-19.	NIMPIS 2002	No likely effect from possible temperature increase
*Bugula neritina**	Bryozoan	Temperate-Tropical	Not available		No likely effect from possible temperature increase
*Ciona intestinalis**	Sea-squirt	Temperate	Not available		No likely effect from possible temperature increase
*Schizoporella errata**	Bryozoan	Temperate	Not available		No likely effect from possible temperature increase
Codium fragile tomentosoides	Brocolli weed	Temperate	Not available		No likely effect from possible temperature increase
Polysiphonia brodiaei	Red alga	Temperate	Not available		No likely effect from possible temperature increase
Hydroides ezoensis	Polychaete worm	Temperate	Not available		No likely effect from possible temperature increase
*Watersipora arcuata**	Bryozoan	Temperate	Not available		No likely effect from possible temperature increase
Undaria pinnatifida	Japanese kelp	Temperate	Not available		No likely effect from possible temperature increase
Styela clava	Sea-squirt	Temperate	Not available		No likely effect from possible temperature increase
Musculista senhousia	Bag mussel	Temperate-Tropical	0.8 - 31.1 ºC	NIMPIS 2002	No likely effect from possible temperature increase
Carcinus maenas	European shore crab	Temperate	Can tolerate temperatures from 0-33 ºC	NIMPIS 2002	No likely effect from possible temperature increase

* Already present within the Port Kembla Harbour

Table 4 continued.

B) International potential target species

1. High priority:	Common name	Distribution	Temperature range	Source	Establishment interpretation
Perna viridis	Asian green mussel	Tropical			**Potential effect from possible temperature increase**

2. Medium priority:	Common name	Distribution	Temperature range	Source	Establishment interpretation
Mytilopsis sallei	Black striped mussel	Tropical			**Potential effect from possible temperature increase**
Limnoperna fortunei	Golden mussel	Tropical-temperate			**Potential effect from possible temperature increase**
Hemigrapsus sanguineus	Japanese shore crab	Tropical-temperate			**Potential effect from possible temperature increase**
Charybdis japonica	Lady crab	Temperate-tropical			No likely effect from possible temperature increase
Pseudodiaptomus marinus	Calanoid copepod	Temperate-tropical			No likely effect from possible temperature increase
Balanus eburneus	Ivory barnacle	Temperate-tropical			No likely effect from possible temperature increase
Tridentiger bifasciatus	Shimofuri goby	Temperate-tropical			No likely effect from possible temperature increase
Eriocheir sinensis	Chinese mitten crab	Temperate-tropical			No likely effect from possible temperature increase
Neogobius melanostomus	Round goby	Temperate-tropical			No likely effect from possible temperature increase
Potamocorbula amurensis	Brackish-water corbula	Temperate-tropical			No likely effect from possible temperature increase

DESIGN OF AN ECOLOGICAL MONITORING PROGRAM FOR PELAGIC AND/OR BENTHIC COMMUNITIES.

Macroinvertebrates, aquatic plants and fish are the key indicators of water quality for aquatic ecosystems listed in the interim environmental objectives relevant to Port Kembla Harbour (EPA 2000). The ecological monitoring program suggested below has focused on the macroinvertebrates because:

- the distribution of macroalgae and seagrass is limited in Port Kembla Harbour, and
- the mobility of fish means that they may not be continuously exposed to the predicted changes in temperature. It also means that they may be more difficult to sample with confidence.

Among the macroinvertebrates, sessile species are particularly suitable for monitoring purposes because they must endure the environmental conditions of the location in which they settle. They are also amenable to sampling through the use of settlement plates.

In keeping with the general thrust of DEC requirements (DEC letter of 21/12/2005), the suggested monitoring program is consistent with the ANZECC water quality guidelines (ANZECC and ARMCANZ 2000). For formal hypothesis testing of univariate measures such as species abundance, the MBACI design (Keough and Mapstone 1995, 1997) is the preferred option among the conventional statistical procedures considered in the Guidelines. In addition, a multivariate approach would be particularly useful for assessing possible changes in the species composition of a harbour assemblage. While not necessarily applying a formal test of statistical significance, such an approach may be inferentially quite powerful (ANZECC and ARMCANZ 2000).

A) MBACI DESIGN FOR UNIVARIATE MEASURES

The MBACI design incorporates multiple sampling locations and times, the “M” denoting multiple locations designed to better assess natural variation against which the change of interest must be detected. Importantly, it focuses effort on the one or two spatial and temporal scales most relevant in a management context.

The test of main interest in an MBACI analysis is the *BA* x *CI* interaction, which compares the change from Before the environmental change to After at the Impact location, with the corresponding change at the Control locations. The structure of this hypothesis test is such that the statistical power of the test is dependent on the total number of locations sampled. (Power in this context is the confidence with which an effect of a specified magnitude may be detected.) In this case, there is a single Impact location, Inner Harbour. A region of Outer Harbour remote from the Cut and not subject to the increased temperatures would be suitable as one of the control locations. Wollongong Harbour may serve as another. While it is far from being a “natural” location, it is an enclosed body of water subject to some maritime traffic, and is remote from the proposed changes in water temperature. Additional control locations would boost the power of the hypothesis test, but may not be readily available.

Our suggested sampling design is as follows:

- Single Impact location - the inner section of Inner Harbour
- Multiple Control locations (minimum of 2) - Outer Harbour, Wollongong Harbour
- 3 randomly-selected replicate sites within each location (for confidence in location estimates)
- Multiple sampling times Before and After commissioning of the SCP (necessary for inferential confidence that changes in water temperature and in the dependent variable were not simply coincidence. Annual sampling would minimize seasonal effects.)

SELECTION OF DEPENDENT VARIABLE (INDICATOR)

In the context of a change in temperature regime, possible dependent variables for univariate analysis include basic measures of abundance of individual species or higher taxa (counts of individuals or percentage cover of modular species), measures of process such as growth rate or respiration, or assemblage-based measures such as species richness or diversity indices. We do not recommend the assemblage-based measures for univariate analysis, at least not in isolation. While species richness is a measure of biodiversity and is generally well-behaved in a statistical sense, it tends to be less responsive to environmental changes than taxon-based measures such as abundance. Species that are lost in response to an environmental disturbance tend to be replaced by others that are more tolerant, so the overall species richness may not show marked change even when an assemblage is substantially modified.

Abundance or growth rates of individual taxa are our preferred choice for univariate analyses in the present context. Desirable characteristics of a taxon (or taxa) for such analysis are:

- it is currently present in parts of the Inner Harbour that are predicted to experience a substantial change in temperature.
- it is likely to be responsive to the predicted changes in temperature.
- it is not highly mobile, and is thus continuously exposed to the changed temperature regime.
- it is reasonably easy to sample, identify, and measure or count.
- it has previously been the subject of quantitative study, thus an estimate of variance would be available for *a priori* power calculations.

One likely candidate species for monitoring is the barnacle *Amphibalanus variegatus*. Its natural distribution extends to northern NSW, where long-term average sea surface temperatures range from 21 – 27°C (Annexure C). Below, the abundance of this species is used in an *a priori* calculation of statistical power for the *BA* x *CI* interaction.

ESTIMATED POWER OF THE TEST

The choice of an ecologically-sensible effect size is not a simple matter (Fairweather 1991), and often becomes a matter of subjective assessment on the part of the monitoring program designer. Based on our collective experience with hard substrate assemblages and with Port Kembla Harbour, we estimate that a 40% change in abundance (relative to the Before/Impact mean, and after adjustment for natural variation) could be ecologically important. However, anticipating that acceptable power may be difficult to achieve, a 50% change has been chosen as the target effect size.

Previous experience with this species (Johnston and Clarke 2004) suggests that a log transformation of the raw data will be needed to meet the assumptions of the analysis. A 50% change in raw abundance in a simulated data set based on the data of Johnston and Clarke (2004) translated to 34% change in the log-transformed data.

Conditions for the *a priori* power calculation were as follows:

- 2 times sampled Before and 2 times After
- 1 Impact location and 2 Control locations, 3 random replicate sites within each
- Total sample size = 36 (4 times x 3 locations x 3 replicates)
- Type I error rate = 0.05 (the conventional value)
- estimated error variance = 0.08 (the upper value obtained over a small number of trials with our simulated data set)

The power of *BA* x *CI* test to detect a change of 34% in the log-transformed abundance would be 0.14. Such a low figure means that a test result of “no change” could not be interpreted in any meaningful way.

By relaxing the Type I error rate to 0.10 to focus on minimising Type II errors, power is increased somewhat to 0.28. However, the principal way to increase the power of this test to detect the change of interest is to increase the number of Control locations sampled. The trade-off between the monitoring effort expended and the confidence gained in detecting the change of interest is illustrated in Table 5. Sampling at 5 Control locations could be expected to result in over 80% confidence in detection.

Table 5. Power of the BA x CI test to detect a change of 34% with α = 0.10. (Calculations performed with GPower, Faul and Erdfelder 1992)

No. of Control Locations	Total Sample Size	F-ratio	Power
2	36	$F_{1,1}$	0.28
3	48	$F_{1,2}$	0.54
4	60	$F_{1,3}$	0.73
5	72	$F_{1,4}$	0.84

B) MULTIVARIATE APPROACH TO ASSESSING CHANGES IN SPECIES COMPOSITION

Multidimensional scaling (MDS; Kruskal and Wish 1978, Clarke 1993) is a multivariate approach that has been widely used to identify ecological changes as a result of environmental disturbances (Clarke and Warwick 2001). Complex calculations involving multiple variables of interest result in a simple plot of sampling units in space which represent the presumed ecological relationships among those units. The strength of the inference relies on the sensible selection of the sampling units. In the Port Kembla Harbour case, the sampling design adopted for the MBACI analysis would provide a suitable inferential basis for MDS. The variables of interest would be the abundances or percentage cover scores of species present in the samples.

SUMMARY

On the basis of recent modelling by Cardno Lawson Treloar Pty Ltd (CLT), the increase in average water temperature in the harbour is predicted to be less than 0.8ºC at most depths during average/typical heat-load conditions. Under such conditions, we predict that the SCP would cause no major loss of biota from marine communities within the already highly-modified ecosystem of the Harbour.

If, however, temperatures are elevated by more than 3°C as a result of operation of the SCP, then some ecologically important changes may occur. It should be noted that the effects of temperature are likely to be gradual and that the 3°C is not a threshold value, but rather one at which we would expect major effects to be detectable. Ecological change associated with a 3°C or greater increase is most likely to occur in Inner Harbour near the mouth of Allans Creek, and may include:

- Ecologically important changes in the relative abundance of some temperate species
- The appearance of more warm water species (including exotic species)
- Increases in the toxicity and bioaccumulation of existing heavy metals and PAHs

The maintenance of a distinct thermal plume at the surface of Inner Harbour would be preferable on ecological grounds to temperature increases throughout the water column, because the cooler water beneath the plume would continue to provide alternative habitat for subtidal organisms less tolerant of higher temperatures.

Changes in water temperature in Allans Creek between the Main Drain and the heat-dissipation device under average/typical conditions of SCP operation seem unlikely to have a major effect on biota in the creek or on the passage of fish within the creek. However, even if some changes in the biotic assemblage do occur, any return to a more natural temperature regime in the creek should nonetheless be seen as a positive step.

We conclude that operation of the proposed SCP under average/typical heat-load conditions is unlikely to cause major changes to marine communities within Port Kembla Harbour

REFERENCES

ANZECC, and ARMCANZ. 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council, Canberra.

Axiak, V., and J. L. Schembri. 1982. Effects of Temperature on the Toxicity of Mercury and Cadmium to the Littoral Gastropod *Monodonta turbinata*. *Marine Pollution Bulletin* **13**:383-386.

Carey, J.M. 2005. Review of the likely ecological effects of increased water temperatures in Allans Creek and Port Kembla Harbour. Report to BlueScope Steel (AIS) Pty Ltd. School of Botany, University of Melbourne, Vic.

Clark, G. F., and E. L. Johnston. 2005. Manipulating larval supply in the field: a controlled study of marine invasibility. *Marine Ecology Progress Series* **298**:9–19.

Clarke, K.R. and R.M. Warwick. 2001. *Change in Marine Communities: An Approach to Statistical Analysis and Interpretation*. (2nd Ed.) PRIMER-E, Plymouth, UK.

Clarke, K.R. 1993. Non-parametric multivariate analyses of change in community structure. Australian *Journal of Ecology* **18**: 117-143.

CLT. 2006. BlueScope Steel Limited Steelworks Co-generation Plant (SCP), Proposed Salt Water Cooling, Numerical Cooling Water Studies. Report LJ2504/R2257 prepared for BlueScope Steel. July 2006. Cardno Lawson Treloar Pty Ltd, Gordon, NSW.

Connell, J. H., and M. J. Keough. 1985. Disturbance and patch dynamics of subtidal marine animals on hard substrata. Pages 125-151 in S. T. A. Pickett and P. S. White, editors. *The ecology of natural disturbance and patch dynamics*. Academic Press, New York.

DEC letter of 21/12/2005 to Technology and Environment Department, BlueScope Steel (Alan O'Brien) from Trevor Jones, DEC ref 282151A7:WOF18617:PW.

Denton, G., and C. Burdon-Jones. 1981. Influence of Temperature and Salinity on the Uptake, Distribution and Depuration of Mercury, Cadmium and Lead by the Black-Lip Oyster Saccostrea echinata. *Marine biology* **64**:317.

EPA. 2000. Water Quality and River Flow Interim Environmental Objectives - Illawarra. Environment Protection Authority, NSW Department of Environment and Conservation, Sydney South, NSW. <http://www.epa.nsw.gov.au/ieo/LakeIllawarra/index.htm>, accessed 13/3/2006.

Fairweather, P.G. 1991. Statistical power and design requirements for environmental monitoring. *Australian Journal of Marine and Freshwater Research*. **42**: 555-567.

Faul, F. and E Erdfelder. 1992. GPOWER: a priori, post-hoc and compromise power analyses for MS-DOS. (Version 2.0) Bonn University, Department of Psychology, Bonn, FRG.

Glasby, T. 1998. Estimating spatial variability in developing assemblages of epibiota on subtidal hard substrata. *Marine and Freshwater Research* **49**:429-437.

Hawkins, S.J., A.J. Southward, and M.J.Genner, 2003. Detection of environmental change in a marine system - evidence from the western English Channel. *The Science of the Total Environment* **310**: 245-256.

Hayes, K., C. S.Sliwa, F. Migus, McEnnulty, and P. K. Dunstan. 2005. National priority pests. Part II, ranking of Australian marine pests. Australian Government Department of the Environment and Heritage, Parkes.

He, Z. and R.J. Morrison. 2001. Changes in the marine environment of Port Kembla Harbour, NSW, Australia, 1975-1995: a review. *Marine Pollution Bulletin* **42**: 193-201.

Heugens, E., A. Hendriks, T. Dekker, N. van Straalen, and W. Admiraal. 2001. A Review of the Effects of Multiple Stressors on Aquatic Organisms and Analysis of Uncertainty Factors for Use in Risk Assessment. *Critical Reviews in Toxicology* **31**:247.

Johnston, E.L. and G.F. Clark. 2004. No effect of dredging on hard-substrate invertebrates in Port Kembla harbour. Report for Port Kembla Port Corporation PKH#0204. School of Biological, Earth and Environmental Science, University of New South Wales, Sydney, NSW.

Johnston, E. L., and M. J. Keough. 2002. Direct and indirect effects of repeated pollution events on marine hard-substrate assemblages. *Ecological Applications* **12**:1212-1228.

Johnston, E. L., and M. J. Keough. 2003. Competition modifies the response of organisms to a toxicant. *Marine Ecology Progress Series* **251**:15-26.

Johnston, E. L., and M. J. Keough. 2005. Reduction of pollution impacts through the control of toxicant release rate must be site- and season-specific. *Journal of Experimental Marine Biology and Ecology* **320:**9-33.

Karlson, R. H. 1978. Predation and space utilisation in a marine epifaunal community. *Journal of Experimental Marine Biology and Ecology* **31**:225-239.

Kennish, M. J. 2002. Environmental threats and environmental future of estuaries. *Environmental Conservation* **29**:78-107.

Keough, M.J. and B.D. Mapstone. 1995. Protocols for designing marine ecological monitoring programs associated with BEK mills. National Pulp Mills Research Program, Technical Report No. 11. CSIRO, Canberra.

Keough, M.J. and B.D. Mapstone. 1997. Designing environmental monitoring for pulp mills in Australia. *Water Science and Technology* **35**(2-3): 397-404.

Kimball, K. D., and S. A. Levin. 1985. Limitations of laboratory bioassays: The need for more ecosystem level testing. *BioScience* **35**:165-171.

Kirk, J. T. 1983. Light and photosynthesis in aquatic ecosystems. Cambridge Univesity Press, Cambridge.

Korn, S., D. A. Moles, and S. D. Rice. 1979. Effects of Temperature on the Median Tolerance Limit of Pink Salmon and Shrimp Exposed to Toluene, Naphthalene, and Cook Inlet Crude-Oil. *Bulletin of Environmental Contamination and Toxicology* **21**:521-525.

Kruskal, J.B and M Wish. 1978. *Multidimensional Scaling*. Sage University Paper series on Quantitative Applications in the Social Sciences, Number 07-011. Sage Publications, London, UK.

Law, R., and J. Klungsoeyr. 2000. The analysis of polycyclic aromatic hydrocarbons in marine samples. *International Journal of Environment and Pollution* **13**:262.

Malins, D., and H. Hodgins. 1981. Petroleum and Marine Fishes: A Review of Uptake, Disposition, and Effects. *Environmental Science and Technology* **15**:1272.

McLusky, D. S., V. Bryant, and R. Campbell. 1986. The Effects of Temperature and Salinity on the Toxicity of Heavy-Metals to Marine and Estuarine Invertebrates. *Oceanography and Marine Biology* **24**:481-520.

METOC. 2006. *Coastal Sea Surface Temperatures*. Royal Australian Navy's Directorate of Oceanography and Meteorology, Garden Island, Sydney, NSW. <http://www.metoc.gov.au/products/data/aussst.html>, accessed 7/3/2006.

Moran, P.J. and T.R. Grant. 1989. The effects of industrial pollution on the development and succession of marine fouling communities. I. Analysis of species richness and frequency data. *Marine Ecology*. **10**:231-246.

MSE. 2002 *Allans Creek Fish Study*. Report to BHP Steel Ltd. Marine Science and Ecology Pty Ltd, Essendon, Vic.

Munda, I., and V. Hudnik. 1988. The effects of Zn, Mn, and Co accumulation on growth and chemical composition of *Fucus vesiculosus* L. under different temperature and salinity conditions. *Pubblicazioni della Stazione zoologica di Napoli I: Marine ecology* **9**:213.

NIMPIS. 2002 *National Introduced Marine Pest Information System*. Eds: Hewitt C.L., Martin R.B., Sliwa C., McEnnulty, F.R., Murphy, N.E., Jones T. and Cooper, S. Web publication <http://crimp.marine.csiro.au/nimpis>, accessed 29/4/2005 - 22/3/2006.

Nowicki, B. L. 1994. The Effect of Temperature, Oxygen, Salinity, and Nutrient Enrichment on Estuarine Denitrification Rates Measured with a Modified Nitrogen Gas Flux Technique. *Estuarine and Coastal Marine Science* **38**:137-156.

Regoli, F., E. Orlando, M. Mauri, M. Nigro, and G. Cognetti. 1991. Heavy metal accumulation and calcium content in the bivalve *Donacilla cornea*. *Marine Ecology Progress Series* **74**:219.

Roy, P. S., R. J. Williams, A. R. Jones, I. Yassini, P. J. Gibb, B. Coates, R. J. West, P. R. Scanes, J. P. Hudson, and S. Nicholi. 2001. Structure and Function of South-east Australian Estuaries. *Estuarine, Coastal and Shelf Science* **53**: 351–384.

Seitzinger, S. P. 1988. Denitrification in freshwater and coastal marine ecosystems: ecological and geochemical significance. *Limnology and Oceanography* **33**:702-724.

Sousa, W. P. 2001. Natural Disturbances and the dynamics of marine benthic communities. Pages 85-130 *in* M. D. Bertness, S. Gaines, and M. E. Hay, editors. Marine Community Ecology. Sinauer Associates, Sunderland, Massachusetts.

Sprague, J. B. 1970. Measurement of Pollutant Toxicity to Fish .2. Utilizing and Applying Bioassay Results. *Water Research* **4**:3-32.

Sprague, J. 1985. Factors that modify toxicity. Pages 124-163 *in* G. Rand and S. Petrocelli, editors. Fundamentals of aquatic toxicology - Methods and applications. Hemisphere Publishing Corporation, Washington.

Sutton, C.A. and B.D. Bruce. 1996. *Temperature and salinity tolerances of the larvaeof the northern Pacific seastar, Asterias amurensis*. Technical Report No. 6, Centre for Research on Introduced Marine Pests, CSIRO Division of Fisheries, Hobart, Tas.

Tsuchida, S. 2005. The relationship between upper temperature tolerance and final preferendum of Japanese marine fish. *Thermal Biology* **20**:35-41.

Watkins, B., and K. Simkiss. 1988. The Effect of Oscillating Temperatures on the Metal-Ion Metabolism of *Mytilus edulis*. *Journal of the Marine Biological Association of the United Kingdom* **68**:93-100

APPENDIX A

AQUATIC SPECIES RECORDED FROM PORT KEMBLA HARBOUR

Annexure A. Aquatic species recorded from Port Kembla Harbour

Notes:
1) Many organimsm listed below are incompletely identified; for such records, no distributional information was sought. Records identified at family level or higher have not been included (e.g. 7 species of polyclad recorded in Pollard & Pethebridge (2002).
2) Distributions are given anti-clockwise around Australia, unless stated otherwise.
3) Distributions are accurately known for only a few groups of organisms (Edgar 2000). In general, only more recent sources have been used for species distributions. (e.g. Hale 1927-1929 was not consulted for current crustacean distributions)
4) For distributions that end in the southern half of NSW (thus suggesting that the species might be near the limits of its preferred temperature regime), minimum and maximum monthly mean sea surface temperatures (METOC 2006) corresponding with the distribution are given in the right hand column.
5) Temperatures corresponding with geographic distributions have been rounded to integers; mimima have been rounded down, and maxima rounded up. This was done because i) the correspondence between temperature and distribution is at a coarse scale, and ii) monthly mean sea surface temperatures given by METOC can vary by 0.1 to 1.5°C (METOC 2006).
6) OH = Outer Harbour
7) Sources are listed below the table.

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
Cyanophyta (blue-green algae)						
	Oscillatoria sp.		MSE 2002; Pollard & Pethebridge 2002			
	Spirulina sp.		MSE 2002			
Bacilliariophyta (diatoms)						
	Achnanthes sp.	OH only	Pollard & Pethebridge 2002			
	Amphora sp.		Pollard & Pethebridge 2002			
	Ardissonea crystallina		Pollard & Pethebridge 2002			
	Bacillaria paxillifera		Pollard & Pethebridge 2002			
	Bacteriastrum sp.		Pollard & Pethebridge 2002			
	Campylodiscus sp.		Pollard & Pethebridge 2002			
	Cerataulina pelagica		Pollard & Pethebridge 2002			
	Chaetoceros sp.		MSE & CEC 1992; Pollard & Pethebridge 2002			
	Cocconeis sp.		Pollard & Pethebridge 2002			
	Coscinodiscus sp.		MSE & CEC 1992			
	Coscinodiscus spp.	OH only	Pollard & Pethebridge 2002			

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Cylindrotheca closterium		Pollard & Pethebridge 2002			
	Cymbella sp.		Pollard & Pethebridge 2002			
	Dactyliosolen antarcticus		Pollard & Pethebridge 2002			
	Dactyliosolen fragilissimus	OH only	Pollard & Pethebridge 2002			
	Detonula sp.		Pollard & Pethebridge 2002			
	Entomoneis sp.		Pollard & Pethebridge 2002			
	Guinardia deliculata	OH only	Pollard & Pethebridge 2002			
	Guinardia flaccida		Pollard & Pethebridge 2002			
	Guinardia striata		Pollard & Pethebridge 2002			
	Helicotheca tamesis		Pollard & Pethebridge 2002			
	Hemiaulus sp.		Pollard & Pethebridge 2002			
	Leptocylindrus danicus		Pollard & Pethebridge 2002			
	Licmorphora sp.	OH only	Pollard & Pethebridge 2002			
	Melosira sp.		Pollard & Pethebridge 2002			
	Minidiscus trioculatus		Pollard & Pethebridge 2002			
	Nitzchia longissima		Pollard & Pethebridge 2002			
	Nitzchia sigmoidea		Pollard & Pethebridge 2002			
	Nitzchia spp.		Pollard & Pethebridge 2002			
	Paralia sulcata		Pollard & Pethebridge 2002			
	Pleurosigma sp.		Pollard & Pethebridge 2002			
	Proboscia alata	OH only	Pollard & Pethebridge 2002			
	Pseudo-nitzchia pseudodelicatissima	OH only	Pollard & Pethebridge 2002			
	Pseudo-nitzchia pungens/multiseries		Pollard & Pethebridge 2002			
	Pseudo-nitzchia spp.		Pollard & Pethebridge 2002			
	Rhizosolenia spp.		Pollard & Pethebridge 2002			
	Skeletonema costatum		Pollard & Pethebridge 2002			
	Surirella sp.		Pollard & Pethebridge 2002			
	Thalassionema sp.		Pollard & Pethebridge 2002			
	Thalassiosira sp.		Pollard & Pethebridge 2002			
Chlorophyta (microscopic forms only here)						
	Staurastrum sp.		Pollard & Pethebridge 2002			
Chrysophyta						
	Apedinella spinifera		Pollard & Pethebridge 2002			

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Calycomonas spp.		Pollard & Pethebridge 2002			
	Leucocryptos marina		Pollard & Pethebridge 2002			
	Plagioselmis prolonga		Pollard & Pethebridge 2002			
	Rhodomonas salina		Pollard & Pethebridge 2002			
Ciliophora						
	Tintinopsis sp.	OH only	MSE & CEC 1992			
Dinophyta (dinoflagellates)						
	Alexandrium ostenfeldii/peruvianum		Pollard & Pethebridge 2002			
	Alexandrium sp. (catenella type)		Pollard & Pethebridge 2002			
	Cachonina niei		Pollard & Pethebridge 2002			
	Ceratium arietinium	OH only	Pollard & Pethebridge 2002			Range of mean annual surface water temp: 5 - 30°C (Dodge & Marshal 1994)
	Ceratium furca		Pollard & Pethebridge 2002			Range of mean annual surface water temp: 5 - 30°C (Dodge & Marshal 1994)
	Ceratium fusus	OH only	Pollard & Pethebridge 2002			Range of mean annual surface water temp: 5 - 30°C (Dodge & Marshal 1994)
	Ceratium gibberum	OH only	Pollard & Pethebridge 2002			Range of mean annual surface water temp: 10 - 30°C (Dodge & Marshal
	Ceratium horridum/tenue		Pollard & Pethebridge 2002			
	Ceratium lineatum	OH only	Pollard & Pethebridge 2002			Range of mean annual surface water temp: 3 - 20°C (Dodge & Marshal 1994)
	Ceratium macroceros	OH only	Pollard & Pethebridge 2002			
	Ceratium sp.	OH only	Pollard & Pethebridge 2002			

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Ceratium teres	OH only	Pollard & Pethebridge 2002			Range of mean annual surface water temp: 14 - 30°C (Dodge & Marshal
	Ceratium tripos		Pollard & Pethebridge 2002			Range of mean annual surface water temp: 5 - 30°C (Dodge & Marshal 1994)
	Chrysochromulina spp.		Pollard & Pethebridge 2002			
	Dinophysis acuminata		Pollard & Pethebridge 2002			
	Dinophysis caudata	OH only	Pollard & Pethebridge 2002			
	Dinophysis tripos	OH only	Pollard & Pethebridge 2002			
	Diplopelta bomba		Pollard & Pethebridge 2002			
	Gonyaulax sp.		Pollard & Pethebridge 2002			
	Gonyaulax spinifera		Pollard & Pethebridge 2002			
	Gymnodinioid spp.		Pollard & Pethebridge 2002			
	Gymnodinium sanguineum	OH only	Pollard & Pethebridge 2002			
	Gymnodinium spp.		Pollard & Pethebridge 2002			
	Heterocapsa rotundata		Pollard & Pethebridge 2002			
	Oblea rotunda	OH only	Pollard & Pethebridge 2002			
	Ornithocerus magnificus	OH only	Pollard & Pethebridge 2002			
	Paleophalachroma unicincta	OH only	Pollard & Pethebridge 2002			
	Peridinium quincecorne		Pollard & Pethebridge 2002			
	Phalachroma rotundatum		Pollard & Pethebridge 2002			
	Preperidinium meuneri		Pollard & Pethebridge 2002			
	Prorocentrum compressum	OH only	Pollard & Pethebridge 2002			
	Prorocentrum gracile	OH only	Pollard & Pethebridge 2002			
	Prorocentrum micans		Pollard & Pethebridge 2002			
	Prorocentrum triestinum	OH only	Pollard & Pethebridge 2002			
	Protoceratium reticulatum		Pollard & Pethebridge 2002			
	Protoperidinium bipes	OH only	Pollard & Pethebridge 2002			
	Protoperidinium brevipes	OH only	Pollard & Pethebridge 2002			
	Protoperidinium c.f. calidicans	OH only	Pollard & Pethebridge 2002			

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Protoperidinium claudicans		Pollard & Pethebridge 2002			
	Protoperidinium conicum		Pollard & Pethebridge 2002			
	Protoperidinium depressum		Pollard & Pethebridge 2002			
	Protoperidinium leonis		Pollard & Pethebridge 2002			
	Protoperidinium minutum		Pollard & Pethebridge 2002			
	Protoperidinium nudum		Pollard & Pethebridge 2002			
	Protoperidinium oblongum	OH only	Pollard & Pethebridge 2002			
	Protoperidinium pallidum/pellucidum		Pollard & Pethebridge 2002			
	Protoperidinium pentagonum		Pollard & Pethebridge 2002			
	Protoperidinium sp. (round brown)		Pollard & Pethebridge 2002			
	Protoperidinium spp.		Pollard & Pethebridge 2002			
	Protoperidinium subinerme		Pollard & Pethebridge 2002			
	Scrippsiella spp.		Pollard & Pethebridge 2002			
Euglenophyta						
	Eutreptiella sp.	OH only	Pollard & Pethebridge 2002			
Prasinophyta						
	Micromonas pusilla		Pollard & Pethebridge 2002			
	Nephroselmis sp.		Pollard & Pethebridge 2002			
	Pyramimonas spp.		Pollard & Pethebridge 2002			
	Tetraselmis sp.		Pollard & Pethebridge 2002			
Prymnesiophyta						
	Chrysochromulina spp.		Pollard & Pethebridge 2002			
	Emiliania huxleyi		Pollard & Pethebridge 2002			Change in growth rate with temp varies between warm water and cold water strains. (Conte et al. 1998)
Chlorophyta (green algae - macroscopic forms)						

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Codium harveyi		Pollard & Pethebridge 2002	Shark Bay WA to Lake Macquarie NSW, and around Tas.	Edgar 2000	
	Derbesia sp.	OH only	Pollard & Pethebridge 2002			
	Enteromorpha sp.		MSE 2002			
Phaeophyta (brown algae)						
	Dictyopteris acrostichoides	OH only	Pollard & Pethebridge 2002			
	Dictyota alternifida		Pollard & Pethebridge 2002			
	Dictyota dichotoma	OH only for P & P 2002	MSE & CEC 1992; Pollard & Pethebridge 2002	Around Australia & widespread overseas	Edgar 2000	
	Dilophus marginatus	OH only	Pollard & Pethebridge 2002	Port Stanvac SA to Noosa Qld, and northern Tas.	Edgar 2000	
	Ecklonia radiata		Pollard & Pethebridge 2002	Kalbarri WA to Caloundra Qld, and around Tas.	Edgar 2000	
	Halopteris paniculata		Pollard & Pethebridge 2002	Port Willunga SA to Newcastle NSW, and around Tas.	Edgar 2000	
	Halopteris sp.		Pollard & Pethebridge 2002			
	Lobophora variegata		Pollard & Pethebridge 2002	Around Australia & widespread overseas	Edgar 2000	
	Phyllospora comosa	OH only	Pollard & Pethebridge 2002	Robe SA to Port Macquarie NSW, and around Tas.	Edgar 2000	
	Sargassum sp.		Pollard & Pethebridge 2002			
	Spatoglossum sp.	OH only	Pollard & Pethebridge 2002			
	Sphacelaria sp.	OH only	Pollard & Pethebridge 2002			
	Zonaria diesingiana	OH only	Pollard & Pethebridge 2002	Green Cape to Coffs Harbour NSW.	Edgar 2000	15 to 26
Rhodophyta (red algae)						
	Acrosorium venulosum	OH only	Pollard & Pethebridge 2002			
	Amphiroa anceps		Pollard & Pethebridge 2002	Around Aust mainland and northern Tas.	Edgar 2000	

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Antithamnion amphigeneum		Pollard & Pethebridge 2002			
	Apoglossum unguiculescens		Pollard & Pethebridge 2002			
	Callithamniella pacifica	OH only	Pollard & Pethebridge 2002			
	Callithamnion korfense	OH only	Pollard & Pethebridge 2002			
	Ceramium macilentum		Pollard & Pethebridge 2002			
	Ceramium rubrum		Pollard & Pethebridge 2002			
	Champia parvula	OH only	Pollard & Pethebridge 2002	Widely reported from most temperate waters, but many records need verification.	Womersley 1996	
	Crustose coralline	OH only	Pollard & Pethebridge 2002			
	Gelidium sp.	OH only	Pollard & Pethebridge 2002			
	Haliptilon roseum		Pollard & Pethebridge 2002	Shark Bay WA to Bowen Qld, and around Tas.	Edgar 2000	
	Heterosiphonia australis	OH only	Pollard & Pethebridge 2002			
	Laurencia obtusa		Pollard & Pethebridge 2002	Different subspecies (varieties?) of *L. obtusata* synonomised with different *Laurencia* species, so distribution is unclear.	Womersley 2003	
	Phycodrys australasica	OH only	Pollard & Pethebridge 2002	Hamelin Bay WA, Port Noralunga SA, Port Phillip Bay & Western Port Vic, NSW, Norfolk Is, Lord Howe Is.	Womersley 2003	
	Polysiphonia constricta	OH only	Pollard & Pethebridge 2002	Coffin Bay SA to Crawfish Rock Vic. NSW?	Womersley 2003	
	Polysiphonia scopulorum		Pollard & Pethebridge 2002	Dampier Archipelago WA to Barwon Heads Vic, NSW & southern Qld.	Womersley 2003	

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Polysiphonia sp.	OH only	Pollard & Pethebridge 2002			
	Polysiphonia sp. x	OH only	Pollard & Pethebridge 2002			
	Rhipidothamnion secundum	OH only	Pollard & Pethebridge 2002			
	Rhodymenia australis	OH only	Pollard & Pethebridge 2002	Rottnest Is WA (and prob. further north) to Gabo Is Vic, and around Tas.	Womersley 1996	
Hydrocharitales (seagrass)						
	Halophila ovalis	OH only	Pollard & Pethebridge 2002	Dongara WA to Sydney NSW, and around Tas.	Edgar 2000	11 to 24
Porifera (sponges)						
	Callyspongia sp.		Pollard & Pethebridge 2002			
	Chelonaplysilla violacea		Pollard & Pethebridge 2002			
	Coelospharea verrucosa	OH only	Pollard & Pethebridge 2002			
	Dactylia palmata		Pollard & Pethebridge 2002			
	Dysidea sp.		Pollard & Pethebridge 2002			
	Dysidea sp. 1		Pollard & Pethebridge 2002			
	Halichondria panicea		Pollard & Pethebridge 2002			
	Halichondria sp.		Pollard & Pethebridge 2002			
	Haliclona sp.		Pollard & Pethebridge 2002			
	Haliclona sp. 1		Pollard & Pethebridge 2002			
	Haliclona sp. 2		Pollard & Pethebridge 2002			
	Haliclona sp. 3		Pollard & Pethebridge 2002			
	Halisarca sp.		Moran & Grant 1989			
	Hymeniacidon perleye		Pollard & Pethebridge 2002			
	Ircinia rubra		Pollard & Pethebridge 2002			
	Ircinia sp.		Pollard & Pethebridge 2002			
	Leuconia spp.		Moran & Grant 1989			
	Leucosolenia spp.		Moran & Grant 1989			
	Raspailia sp.		Pollard & Pethebridge 2002			
	Suberites sp.		Pollard & Pethebridge 2002			

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Sycon gelatinosum		Pollard & Pethebridge 2002			
	Sycon sp.		Moran & Grant 1989; Pollard & Pethebridge 2002			
	Sycon sp. 1	OH only	Pollard & Pethebridge 2002			
	Sycon sp. 2	OH only	Pollard & Pethebridge 2002			
	Tedania sp.		Pollard & Pethebridge 2002			
	Tethya pellis		Pollard & Pethebridge 2002			
	Tethya sp.		Pollard & Pethebridge 2002			
Cnidaria						
Anthozoa						
	Culicea c.f. tenella		Pollard & Pethebridge 2002	*C. tenella* found from Perth WA to Solitary Is NSW, and around Tas.	Edgar 2000	
Hydrozoa						
	Aequorea phillipensis		Pollard & Pethebridge 2002			
	Bimeria sp.		Moran & Grant 1989			
	Bougainvillia macloviana		Pollard & Pethebridge 2002			
	Clytia hemisphaerica		Pollard & Pethebridge 2002	Cosmopolitan species abundant in Aust coastal waters.	Pollard & Pethebridge 2002	
	Clytia serrulata		Pollard & Pethebridge 2002			
	Clytia sp. 1		Pollard & Pethebridge 2002			
	Clytia stolonifera		Pollard & Pethebridge 2002			
	Eirene sp.		Pollard & Pethebridge 2002			
	Gymnangium longirostrum	OH only	Pollard & Pethebridge 2002			
	Halecium delicatulum		Pollard & Pethebridge 2002			
	Halecium vasiforme		Pollard & Pethebridge 2002			
	Kirchenpaueria sp.		MSE 1996			
	Obelia australis	both sessile & medusa stages	MSE & CEC 1992: MSE 1996			
	Obelia spp.		Moran & Grant 1989			

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Phialella quadrata	medusa only; OH only	MSE & CEC 1992			
	Proboscidactyla ornata	limnomedusa	MSE & CEC 1992			
	Sarsia eximia		MSE 2002; Pollard & Pethebridge 2002	Cosmopolitan species common in coastal waters of southern Aust.	Pollard & Pethebridge 2002	
	Staurocladia haswelli		Pollard & Pethebridge 2002			
	Stereotheca elongata	OH only	Pollard & Pethebridge 2002			
	Syncorne sp.		Moran & Grant 1989			
	Tubiclava sp.		Pollard & Pethebridge 2002			
	Tubularia ralphi		Moran & Grant 1989	Fremantle WA to Brisbane Qld.	Watson 1982	
	Tubularia sp.		Moran 1981			
Sipunculida (peanut worms)						
	Phascolosoma annulatum		Pollard & Pethebridge 2002	Ceduna SA to Vic, and Tas (also NZ).	Edmonds 1982	11 to 22
	Themiste sp.		Pollard & Pethebridge 2002			
Mollusca (shellfish)						
Bivalvia						
	Anomia trigonopsis		Moran & Grant 1989 (as *A. descripta*); Pollard & Pethebridge 2002	Southern WA to NSW, and northern Tas. (Edgar); NSW to Qld. (L & H)	Edgar 2000; Lamprell & Healy 1998	
	Arthritica semen		MSE 1996			
	Barbatia pistachia		Pollard & Pethebridge 2002	Kimberley WA to Qld, and around Tas.	Edgar 2000	
	Barbatia sp.		Moran & Grant 1989			
	Cardita excavata	OH only	Pollard & Pethebridge 2002			
	Codakia rugifera	shell only	Pollard & Pethebridge 2002			

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Fulvia tenuicostata	shell only; OH only	Pollard & Pethebridge 2002	Fremantle WA to northern NSW, and around Tas.	Edgar 2000	
	Hiatella australis		Pollard & Pethebridge 2002	All Aust states.	Lamprell & Healy 1998	
	Irus crenatus		Pollard & Pethebridge 2002			
	Kellia sp.		Pollard & Pethebridge 2002			
	Laternula creccina		MSE 1996	Southern WA, SA, Tas, Vic & NSW.	Lamprell & Healy 1998	
	Lima lima vulgaris	shell only	Pollard & Pethebridge 2002	*L. lima* found around Aust, including Tas.	Edgar 2000	
	Limatula strangei	shell only	Pollard & Pethebridge 2002	Southern WA to southern Qld, and around Tas.	Edgar 2000	
	Monia zelandica		Pollard & Pethebridge 2002	Southern WA, SA, Tas, Vic & NSW.	Lamprell & Healy 1998	
	Musculus cumingianus		Pollard & Pethebridge 2002	Vic, NSW to northern Qld.	Lamprell & Healy 1998	
	Musculus sp. 1		Pollard & Pethebridge 2002			
	Myadora sp.	shell only	Pollard & Pethebridge 2002			
	Mytilus galloprovincialis	Confusion over name of blue mussel common in Aust. (Lamprell & Healy 1998)	Pollard & Pethebridge 2002	*M. edulis*: Perth WA to NSW, and around Tas.	Edgar 2000	Incipient lethal temp = 28.2°C for *M. edulis* from eastern Aust acclimated to 25°C (Wallis 1975)
	Ostrea angasi		MSE & CEC 1992; Pollard & Pethebridge 2002	Fremantle WA, around southern Australia, to NSW.	Edgar 2000	
	Pholas australasiae	shell only; OH only	Pollard & Pethebridge 2002	All Aust states.	Lamprell & Healy 1998	

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Saccostrea glomerata		Moran & Grant 1989 (as *Saccostrea commercialis*); MSE & CEC 1992 (as *Crassostrea commercialis*); Pollard & Pethebridge 2002	Port Phillip Bay, Vic, to southern Qld.	Edgar 2000	
	Spisula trigonella	shell only for P & P 2002	MSE 1996 (as *Notospisula trigonella*); Pollard & Pethebridge 2002	Around Aust including Tas.	Edgar 2000	
	Tellina deltoidalis	shell only	Pollard & Pethebridge 2002	Fremantle WA to southern Qld, and around Tas.	Edgar 2000	
	Tellina sp.		MSE 1996			
	Theora fragilis		MSE 1996			
	Trichomusculus barbatus		Pollard & Pethebridge 2002	Tas, Vic & NSW.	Lamprell & Healy	
	Trichomya hirsuta		Pollard & Pethebridge 2002	Great Aust Bight SA to southern Qld, and Flinders Is Tas.	Edgar 2000	Incipient lethal temp = 35.2°C for *T. hirsuta* acclimated to 25°C (Wallis 1977)
	Venerupis anomala	OH only	Pollard & Pethebridge 2002	SA to southern Qld, and around Tas.	Edgar 2000	
Gastropoda						
	Agnewia tritoniformis	OH only	Pollard & Pethebridge 2002	Port Fairy Vic to central NSW, and around Tas.	Edgar 2000	11 to 25
	Antisabia foliacea	shell only; OH only	Pollard & Pethebridge 2002	Geraldton WA to NSW.	Wilson et al. 1993	
	Austrocochlea constricta		MSE 2002	Albany WA to Coffs Harbour NSW, and around Tas.	Edgar 2000	
	Austrocochlea porcata	shell only; OH only	Pollard & Pethebridge 2002	Geraldton WA to Townsville Qld, and northern and eastern Tas.	Edgar 2000	

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Austrodrilla c.f. angasi	shell only; OH only	Pollard & Pethebridge 2002	For A. angasi, Bass Strait Vic to NSW.	Wilson et al. 1994	
	Austroginella muscaria	shell only; OH only	Pollard & Pethebridge 2002	South-eastern Aust.	Wilson et al. 1994	
	Bankivia fasciata	shell only; OH only	Pollard & Pethebridge 2002	SA to NSW.	Wilson et al. 1993	
	Bedeva hanleyi	OH only	Pollard & Pethebridge 2002	Shark Bay WA to southern Qld.	Wilson et al. 1994	
	Bembicium auratum		MSE 2002; Pollard & Pethebridge 2002	Southern WA to southern Qld, and around Tas.	Edgar 2000	
	Cabestana spengleri	OH only	Pollard & Pethebridge 2002	SA to southern Qld, and around Tas.	Edgar 2000	
	Clanculus plebejus		Pollard & Pethebridge 2002	Cape Naturaliste WA to Sydney NSW.	Wilson et al. 1993	13 to 24
	Conuber conicum	shell only; OH only	Pollard & Pethebridge 2002			
	Crepidula aculeata	shell only; OH only	Pollard & Pethebridge 2002	Shark Bay WA, north around Aust to eastern Vic.	Wilson et al. 1993	
	Cupidoliva nympha	shell only; OH only	Pollard & Pethebridge 2002	SA to NSW, and possibly Fremantle to Dampier Archipelago in WA.	Wilson et al. 1994	
	Cymatium parthenopeum	OH only	Pollard & Pethebridge 2002	Lancelin WA to northern NSW, and northern Tas.	Edgar 2000	
	Dicathais orbita	OH only	Pollard & Pethebridge 2002	Barrow Is WA to southern Qld, and around Tas.	Edgar 2000	
	Eurytrochus strangei	shell only; OH only	Pollard & Pethebridge 2002	NSW to southern Qld.	Wilson et al. 1993	
	Haliotis coccoradiata		Pollard & Pethebridge 2002	Mallacoota Vic to northern NSW.	Edgar 2000	15 to 27

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Haliotis rubra	shell only	Pollard & Pethebridge 2002	Fremantle WA to nothern NSW, and around Tas.	Edgar 2000	
	Herpetopoma aspersa		Pollard & Pethebridge 2002	Shark Bay WA to NSW.	Wilson et al. 1993	
	Leiopyrga lineolaris	shell only; OH only	Pollard & Pethebridge 2002	Eastern Vic to NSW.	Wilson et al. 1993	
	Littoraria luteola		MSE 2002	Merimbula NSW to Torres Strait Qld.	Edgar 2000	15 to 31
	Mesoginella translucida	shell only; OH only	Pollard & Pethebridge 2002			
	Mitrella australis	shell only; OH only	Pollard & Pethebridge 2002	NSW.	Wilson et al. 1994	
	Mitrella c.f. semiconvexa	shell only; OH only	Pollard & Pethebridge 2002	For *M. semiconvexa*: Cape Naturaliste WA to NSW.	Wilson et al. 1994	
	Mitrella c.f. tayloriana	shell only; OH only	Pollard & Pethebridge 2002	For *M. tayloriana*: NSW.	Wilson et al. 1994	
	Mitrella sp.	shell only; OH only	Pollard & Pethebridge 2002			
	Nassarius burchardi	shell only	Pollard & Pethebridge 2002	Fremantle WA to Townsville Qld.	Wilson et al. 1994	
	Nassarius jonasii		MSE & CEC 1992; Pollard & Pethebridge 2002	SA to southern Qld, but not Tas.	Wilson et al. 1994	
	Nassarius nigellus	shell only; OH only	Pollard & Pethebridge 2002	Fremantle WA to Cairns Qld, and south to Tas.	Wilson et al. 1994	
	Nassarius particeps	shell only	Pollard & Pethebridge 2002	Ningaloo Marine Park WA to southern Qld.	Wilson et al. 1994	
	Nassarius sp.	shell only & OH only for P & P 2002	MSE 1996; Pollard & Pethebridge 2002			
	Notogibbula bicarinata		Pollard & Pethebridge 2002	SA to Moreton Bay Qld.	Wilson et al. 1993	

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Notomella candida	shell only; OH only	Pollard & Pethebridge 2002			
	Ophicardelus ornatus	shell only	Pollard & Pethebridge 2002			
	Patelloida mimula		MSE 2002	Tropical Aust south to Lakes Entrance Vic.	Edgar 2000	
	Scutellastra chapmani	shell only	Pollard & Pethebridge 2002			
	Stomatella impertusa		Pollard & Pethebridge 2002	Southern WA to NSW, and around Tas.	Edgar 2000	
	Tugali parmophoidea	OH only	Pollard & Pethebridge 2002	SA to NSW	Edgar 2000	
	Turbo torquatus	shell only	Pollard & Pethebridge 2002	Port Gregory WA to eastern SA and NSW.	Edgar 2000	
Polychaeta (bristleworms)						
Nereidae						
	Neanthes cricognatha		MSE 1996			
Serpulidae						
	Filograna implexa		Moran & Grant 1989	WA to NSW, and around Tas.	Edgar 2000	
	Galeolaria caespitosa	OH only for MSE record	Moran & Grant 1989; MSE & CEC 1992	Perth WA to Hervey Bay Qld, and around Tas.	Edgar 2000	
	Galeolaria hystrix		Moran & Grant 1989; Johnston & Clark 2004			
	Hydroides brachyacantha		Moran & Grant 1989			
	Hydroides dirampha		Pollard & Pethebridge 2002			
	Hydroides elegans		Moran & Grant 1989; Johnston & Clark 2004	Central WA, south around Australian mainland, to Qld	NIMPIS 2002	
	Hydroides ezoensis		Pollard & Pethebridge 2002			
	Hydroides norvegica		Moran 1981			
	Hydroides sp.		MSE & CEC 1992			
	Janua steuri		Moran & Grant 1989			
	Pileolaria lateralis		Moran & Grant 1989			
	Pomatoceros sp.		Moran & Grant 1989			

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Pomatostegus sp.		Moran & Grant 1989			
	Salmacina sp.		Johnston & Clark 2004			
	Serpula vermicularis		Moran 1981			
	Spirobranchus sp.		Moran & Grant 1989			
Spionidae						
	Boccardia chilensis		Pollard & Pethebridge 2002			
	Boccardia proboscidea		Pollard & Pethebridge 2002			
Spirorbidae						
	Spirorbis sp.		Moran 1981			
Crustacea						
Amphipoda (beach hoppers etc)						
	Belmos ephippium		Pollard & Pethebridge 2002			
	Corophium acutum		Pollard & Pethebridge 2002; ELA 2004			
	Corophium sp.		MSE 1996			
	Cymadusa setosa	OH only	Pollard & Pethebridge 2002			
	Cyproidea ornata	OH only	Pollard & Pethebridge 2002			
	Dulichiella australis		Pollard & Pethebridge 2002			
	Elasmopus rapax		Pollard & Pethebridge 2002			
	Ericthonius sp.		Pollard & Pethebridge 2002			
	Iphimedia sp.		Pollard & Pethebridge 2002			
	Leucothoe brevidigitata		Pollard & Pethebridge 2002			
	Leucothoe commensalis	OH only	Pollard & Pethebridge 2002	Widespread on continental shelf and bays of eastern Aust.	MV 1996	
	Liljeborgia c.f. dellavallei		Pollard & Pethebridge 2002			
	Maera sp.		Pollard & Pethebridge 2002			
	Melita matilda		Pollard & Pethebridge 2002			
	Paradexamine pacifica	OH only	Pollard & Pethebridge 2002			
	Stenothoe valida	OH only	Pollard & Pethebridge 2002			
Brachyura (true crabs)						
	Charybdis feriatus		Pollard & Pethebridge 2002			

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	Charybdis hellerii		MSE & CEC 1992			
	Charybdis sp.	OH only	Pollard & Pethebridge 2002			
	Elamenopsis octagonalis	OH only	Pollard & Pethebridge 2002			
	Halicarcinus ovatus		Pollard & Pethebridge 2002	Geraldton WA to Port Stephens NSW, and around Tas.	Edgar 2000	
	Hyastenas elatus		Pollard & Pethebridge 2002	Tropical Aust, south to Fremantle WA and Botany Bay NSW.	Edgar 2000	17 to 31
	Paragrapsus laevis		MSE & CEC 1992 , MSE 1996 (both as *P. labus*); MSE 2002	Warrnambool Vic to Moreton Bay Qld, and south to Marion Bay Tas.	Edgar 2000	
	Parasesarma erythodactyla		MSE 1996, MSE 2002 (both as *Sesarma erythrodactyla*)	Western Port Vic to Qld.	Edgar 2000	
	Pilumneopeus serratifrons		Pollard & Pethebridge 2002	Southern Aust from Swan River WA to southern Qld.	Jones & Morgan 1994	
	Pilumnus fissifrons		Pollard & Pethebridge 2002			
	Portunus pelagicus		MSE & CEC 1992	Tropical Aust, south to Cape Naturaliste WA, and Eden NSW.	Edgar 2000	15 to 31
	Scylla serrata		MSE & CEC 1992; MSE 1996; MSE 2002	Exmouth WA, north around Australia, to northern NSW.	Jones & Morgan 1994	
	Thalamita crenata		MSE & CEC 1992; MSE	WA, NT, Qld, NSW.	Poore 2004	
	Thalamita sp.		Pollard & Pethebridge 2002			
	Xanthias elegans	OH only	Pollard & Pethebridge 2002			
Caridea (shrimps)						
	Alpheus euphrosyne		Pollard & Pethebridge 2002	Around mainland Aust and Tas.	Edgar 2000	
	Alpheus socialis	OH only	Pollard & Pethebridge 2002			
	Biffarius arenosus		Pollard & Pethebridge 2002	Tas to southern Qld.	MV 1996	

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Macrobrachium intermedium		Pollard & Pethebridge 2002	Perth WA to Port Molle Qld, and around Tas.	Edgar 2000	
	Macrobrachium novaehollandiae		Pollard & Pethebridge 2002			
	Rhynchocinetes serratus	OH only	Pollard & Pethebridge 2002	Central Vic to northern NSW, and northeastern Tas.	Edgar 2000	
Cirrepedia (barnacles)						
	Austrobalanus imperator		Pollard & Pethebridge 2002	NSW and Qld.	Edgar 2000	
	Balanus amphitrite		Moran 1981; Moran & Grant 1989; Pollard & Pethebridge 2002; Johnston & Clark data			
	Balanus trigonus		Moran & Grant 1989; MSE & CEC 1992; Pollard & Pethebridge 2002; Johnston & Clark 2004	Tropical Australia, south to Rockingham WA, and Vic.	Edgar 2000	13 to 31
	Amphibalanus variegatus		Moran 1981; Moran & Grant 1989; MSE & CEC 1992; MSE 1996; Pollard & Pethebridge 2002; Johnston & Clark 2004 (all as *Balanus variegatus*)	Carnarvon WA, south around Australia (mainland only?), to northern NSW.	Edgar 2000	13 to 27
	Chamaesipho tasmanica		MSE 1996 (as *Chaemosipho columna*)	Port Sinclair SA, around southern Australia, to Byron Bay NSW.	Edgar 2000	11 to 27
	Chthamalus antennatus		Pollard & Pethebridge 2002	Discovery Bay Vic to northern NSW, and around Tas.	Edgar 2000	11 to 27
	Megabalanus rosa		Pollard & Pethebridge 2002			
	Megabalanus tintinnabulum		Pollard & Pethebridge 2002			
	Megabalanus zebra		Pollard & Pethebridge 2002			
	Tesseropera rosea		Johnston & Clark 2004	Fremantle WA, and Inverloch Vic to southern Qld.	Edgar 2000	
Cladocera						

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	Evadne sp.	OH only	MSE & CEC 1992; MSE 1996			
Copepoda						
	Acartia sp.		MSE & CEC 1992; MSE 1996			
	Calanus finmarchicus		MSE & CEC 1992			Development of life-cycle stages varied with temp regime for Norwegian nauplii (Pedersen & Tande 1992)
	Caligus sp.	OH only	MSE & CEC 1992			
	Coryceus sp.		MSE 1996			
	Oncaea sp.		MSE & CEC 1992			
	Temora sp.	OH only	MSE & CEC 1992			
Isopoda (pill bugs etc)						
	Cirolana australiense		Pollard & Pethebridge 2002			
	Cirolana harfordi	OH only	Pollard & Pethebridge 2002			
	Cymodoce coronata	OH only	Pollard & Pethebridge 2002			
	Mesanthura sp.		MSE 1996			
	Seriolina eugeniae	OH only	Pollard & Pethebridge 2002			
	Sphaeroma walkeri		Pollard & Pethebridge 2002	Wide range; better conditions 15 - 25°C.	NIMPIS 2002	
Mysidacea (opossum shrimps)						
	Heteromysis abrucei	OH only	Pollard & Pethebridge 2002			
Penaeoidae (peneid prawns)						
	Leucifer hanseni		MSE & CEC 1992	SE Australian waters, incl. Melbourne Harbour, SE Tasmania & Derwent Estuary. Indian Ocean & South China Sea.	Ritz et al. 2003	
	Leucifer sp.		MSE 1996			

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	Metapenaeus macleayi		MSE & CEC 1992	Eastern Vic to Hervey Bay Qld.	Edgar 2000	
	Penaeus sp.	OH only	MSE & CEC 1992; Pollard & Pethebridge 2002			
Pycnogonida (sea spiders)						
	Achelia assimilis	OH only	Pollard & Pethebridge 2002	Perth WA to Heron Is Qld, and Tas.	Staples 1997	
	Achelia sp.		MSE 1996			
Bryozoa						
	Amathia sp.	OH only	Pollard & Pethebridge 2002			
	Arachnopusia unicornis		Pollard & Pethebridge 2002	Common and widely distributed in southern Aust and NZ.	Bock 1982	
	Arthropodaria sp.		Moran 1981; Moran & Grant 1989			
	Beania magellanica		Johnston & Clark 2004	Widely distributed in southern hemisphere.	Bock 1982	
	Beania quadricornuta		Pollard & Pethebridge 2002			
	Bowerbankia imbracata		Johnston & Clark 2004			
	Bowerbankia sp.		Moran 1981; Moran & Grant 1989; Pollard & Pethebridge 2002			
	Bugula avicularia		Moran 1981; Moran & Grant 1989			
	Bugula flabellata		MSE & CEC 1992; Pollard & Pethebridge 2002; Johnston & Clark 2004	Southern WA, south around Australia, to central Qld.	NIMPIS 2002	
	Bugula neritina		Moran 1981; Moran & Grant 1989; MSE & CEC 1992; Pollard & Pethebridge 2002; Johnston & Clark 2004	WA, SA, Vic, Tas, NSW, Qld, NT.	NIMPIS 2002	

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Bugula stolonifera		Pollard & Pethebridge 2002; Johnston & Clark 2004			
	Calyptotheca sp.		Pollard & Pethebridge 2002			
	Celleporaria fusca	OH only	Pollard & Pethebridge 2002	May be widely distributed in southwest Pacific and Indian Oceans, but not all records reliable.	Bock 1982	
	Celleporaria sp.		Pollard & Pethebridge 2002; Johnston & Clark 2004			
	Cryptosula pallasiana	OH only for P & P 2002	Moran & Grant 1989; Pollard & Pethebridge 2002			
	Fenestrulina sp.		Johnston & Clark data			
	Hopitella armata	OH only	Pollard & Pethebridge 2002			
	Membranipora sp.		Johnston & Clark data			
	Microporella sp.		Johnston & Clark 2004			
	Pleurocodonellina signata		Pollard & Pethebridge 2002			
	Schizoporella errata	OH only for P & P 2002	Pollard & Pethebridge 2002; Johnston & Clark 2004			
	Schizoporella sp. A	OH only	Pollard & Pethebridge 2002			
	Schizoporella sp. B	OH only	Pollard & Pethebridge 2002			
	Schizoporella sp. C		Pollard & Pethebridge 2002			
	Schizoporella unicornis	OH only	Pollard & Pethebridge 2002			
	Tricellaria inopinata		Johnston & Clark 2004			
	Tricellaria occidentalis	OH only	Pollard & Pethebridge 2002			
	Tryphyllozoon sp.		Pollard & Pethebridge 2002			
	Tubulipora sp.	OH only	Pollard & Pethebridge 2002			
	Watersipora arcuata		Pollard & Pethebridge 2002; Johnston & Clark data	Recorded mainly from Pacific Ocean.	Bock 1982	
	Watersipora subovoidea		Moran 1981; Moran & Grant 1989			
	Watersipora subtorquata		Pollard & Pethebridge 2002; Johnston & Clark 2004			
	Zoobotryon verticellatum		MSE & CEC 1992			

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
Chaetognatha (arrow worms)						
	Krohnita sp.	OH only	MSE & CEC 1992			
Ascidiacea (sea squirts)						
	Ascidia sp.		Moran & Grant 1989; Pollard & Pethebridge 2002			
	Botrylloides leachi		Johnston & Clark 2004	Dampier Archipelago WA to Cape Flattery Qld, and around Tas.	Edgar 2000	
	Botrylloides magnicoecum	OH only	Pollard & Pethebridge 2002	Shark Bay WA to Gladstone Qld, and around Tas.	Edgar 2000	
	Botrylloides schlosseri		Moran 1981; Johnston & Clark 2004			
	Botryllus schlosseri		Moran & Grant 1989			
	Ciona intestinalis		Moran 1981; Moran & Grant 1989; MSE & CEC 1992; Pollard & Pethebridge 2002	Southern WA, around southern Australia, to Qld. (Noted as being in decline in Australia & New England)	NIMPIS 2002	Above 21°C, filtration rate in laboratory declined rapidly with increasing temp (Petersen & Riisgard 1992)
	Cnemidocarpa areolata		Pollard & Pethebridge 2002			
	Cnemidocarpa oligocarpa?	OH only	Pollard & Pethebridge 2002			
	Cnemidocarpa sp. 1		Pollard & Pethebridge 2002			
	Cnemidocarpa stolonifera?		Pollard & Pethebridge 2002			
	Diplosoma sp.		Moran & Grant 1989; Johnston & Clark 2004			
	Herdmania momus		Pollard & Pethebridge 2002); Johnston & Clark 2004	Broome WA, around southern Australia, to Lizard Is. Qld.	Edgar 2000	13 to 30
	Microcosmus squamiger		Pollard & Pethebridge 2002			

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Molgula ficus		Pollard & Pethebridge 2002			
	Molgula sp.		Moran & Grant 1989			
	Polyandrocarpa australiensis	OH only	Pollard & Pethebridge 2002			
	Pyura elongata		Pollard & Pethebridge 2002			
	Pyura irregularis		Pollard & Pethebridge 2002			
	Pyura spinosa	OH only	Pollard & Pethebridge 2002			
	Pyura stolonifera		Pollard & Pethebridge 2002	Shark Bay WA to Noosa Qld, and around Tas.	Edgar 2000	
	Styela canopus		Pollard & Pethebridge 2002			
	Styela plicata		Moran & Grant 1989; MSE & CEC 1992; Pollard & Pethebridge 2002; Johnston & Clark 2004	Tropical to warm temperate seas. WA, south around Australian mainland, to Qld.	NIMPIS 2002	13 to 31
Larvacea						
	Oikopleura sp.		MSE & CEC 1992; MSE 1996			
Chondrichthyes (cartilaginous fish)						
	Dasyatis fluviorum		MSE & CEC 1992			
Osteichthyes (bony fish)						
	Acanthogobius flavimanus		MSE & CEC 1992			
	Acanthopagrus australis	OH only for P & P 2002	MSE & CEC 1992; MSE 1996; MSE 2002; Pollard & Pethebridge 2002	Lakes Entrance Vic to Townsville Qld.	Edgar 2000	
	Acanthurus nigrofuscus	OH only	Pollard & Pethebridge 2002			
	Acanthurus triostegus		MSE & CEC 1992			
	Acentrogobius pflaumi		Pollard & Pethebridge 2002			
	Achoerodus viridis	OH only	MSE & CEC 1992	Wilsons Promontory Vic to Hervey Bay Qld.	Edgar 2000	
	Ambassis jacksoniensis		Pollard & Pethebridge 2002			
	Ambassis marianus		MSE & CEC 1992; MSE 1996; MSE 2002			

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Amphichaetodon howensis		MSE & CEC 1992	Merimbula NSW to southern Qld.	Edgar 2000	15 to 27
	Anguilla australis		MSE & CEC 1992	Bremer R SA to Brisbane R Qld, and around Tas.	Edgar 2000	
	Anguilla reinhardtii		MSE & CEC 1992	Melbourne Vic to Cape York Qld, and northern and eastern Tas.	Edgar 2000	
	Anoplocapros inermis		MSE & CEC 1992	Western Port Vic to southern Qld.	Edgar 2000	
	Apogon limenus		MSE & CEC 1992	Merimbula NSW to Yeppoon Qld.	Edgar 2000	15 to 28
	Arenigobius bifrenatus		MSE & CEC 1992; MSE 1996; Pollard & Pethebridge 2002	Fremantle WA to Moreton Bay Qld, and around Tas.	Edgar 2000	
	Argyrosomus hololepidotus		MSE & CEC 1992	Exmouth Gulf WA to Brisbane Qld.	Edgar 2000; Kuiter 1993	
	Arothron firmamentum		MSE & CEC 1992			
	Arothron hispidus		MSE & CEC 1992			
	Arrhamphus sclerolepis		MSE & CEC 1992			
	Arripis trutta		MSE 1996; MSE 2002	Port Phillip Bay Vic to Brisbane Qld, and around Tas.	Edgar 2000	
	Atherinosoma presbyteroides		MSE & CEC 1992			
	Atypichthys strigatus	OH only for P & P 2002	MSE & CEC 1992; Pollard & Pethebridge 2002	Apollo Bay Vic to Noosa Head Qld, and south to Tasman Peninsula.	Edgar 2000	
	Austrolabrus maculatus	OH only	MSE & CEC 1992	Shark Bay WA to Victor Harbour SA. Montague Is to Byron Bay NSW.	Edgar 2000	14 to 27
	Bathygobius fuscus		MSE & CEC 1992			

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Bathygobius kreffti	OH only	Pollard & Pethebridge 2002	Spencer Gulf SA, and southern NSW to northern Qld.	Edgar 2000	15 to 31
	Caesioperca lepidoptera		MSE & CEC 1992	Albany WA to Byron Bay NSW, and around Tas.	Edgar 2000	11 to 27
	Callogobius depressus	OH only	Pollard & Pethebridge 2002			
	Caranx sexfasciatus		MSE 2002	Widespread tropical Indo-Pacific; south to Sydney on east coast	Kuiter 1993	Down to 17
	Caranx sp.		MSE & CEC 1992; MSE 1996			
	Centropogon australis	OH only for P & P 2002	MSE & CEC 1992; Pollard & Pethebridge 2002	Lakes Entrance Vic to Hervey Bay Qld.	Edgar 2000	
	Chaetodon auriga	OH only for P & P 2002	MSE & CEC 1992; Pollard & Pethebridge 2002			
	Chaetodon guentheri		MSE & CEC 1992	Merimbula NSW to Capricorn Group Qld.	Edgar 2000	15 to 28
	Chaetodon plebeius	OH only	Pollard & Pethebridge 2002			
	Chaetodontoplus conspicillatus	OH only	MSE & CEC 1992			
	Chaetodontoplus meredithi		MSE & CEC 1992			
	Cheilodactylus fuscus	OH only for P & P 2002	MSE & CEC 1992; Pollard & Pethebridge 2002	Eastern Bass Strait Vic to Hervey Bay Qld.	Edgar 2000	
	Cheilodactylus spectabilis		MSE & CEC 1992	Robe SA to Seal Rocks NSW, and around Tas.	Edgar 2000	
	Chrysophrys auratus		MSE & CEC 1992	Barrow Is WA to Hinchinbrook Is Qld, and northern Tas.	Edgar 2000	
	Cnidoglanis macrocephalus		Pollard & Pethebridge 2002	Houtman Abrolhos WA to southern Qld, and northern Tas.	Edgar 2000	

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Conger wilsoni		MSE & CEC 1992	Geraldton WA to Kangaroo Is SA, and Bermagui NSW to southern Qld.	Edgar 2000	16 to 27
	Contusus richei		MSE & CEC 1992			
	Crinodus lophodon	OH only	MSE & CEC 1992	Mallacoota Vic to Byron Bay NSW.	Edgar 2000	15 to 27
	Dicotylichthys punctulatus		MSE & CEC 1992	Southern NSW to Qld, and Flinders Is Tas.	Edgar 2000	15 to 31
	Dinolestes lewini	OH only	MSE & CEC 1992	Rottnest Is WA to Port Macquarie NSW, and around Tas.	Edgar 2000	
	Diodon nichthemerus		MSE & CEC 1992	Dongara WA to Seal Rocks NSW, and around Tas.	Edgar 2000	
	Engraulis australis		MSE & CEC 1992			
	Enoplosus armatus		MSE & CEC 1992; Pollard & Pethebridge 2002	Kalbarri WA to Noosa Head Qld, and northern Tas.	Edgar 2000	
	Eocallionymus papilio		MSE & CEC 1992	Kalbarri WA to Port Stephens NSW, and northern Tas.	Edgar 2000	
	Favonigobius lateralis		MSE & CEC 1992; MSE 1996; Pollard & Pethebridge 2002	Shark Bay WA to central Qld, and around Tas.	Edgar 2000	
	Favonigobius tamarensis		MSE & CEC 1992; MSE 1996			
	Gambusia affinis		MSE & CEC 1992	All Australian states in freshwater rivers and streams.	Scott et al. 1974	
	Gerres subfasciatus		MSE & CEC 1992; MSE 1996; MSE 2002; Pollard & Pethebridge 2002	Tropical Aust south to Albany WA and Wollongong NSW.	Edgar 2000	17 to 31

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Girella tricuspidata	OH only for P & P 2002	MSE & CEC 1992; MSE 1996; MSE 2002; Pollard & Pethebridge 2002	Adelaide SA to Hervey Bay Qld, and northern Tas.	Edgar 2000	
	Gymnothorax prasinus		MSE & CEC 1992	Shark Bay WA to southern Qld, and south to Maria Is Tas.	Edgar 2000	
	Heteroclinus perspicillatus		MSE & CEC 1992	Port Lincoln SA to Merimbula NSW, and around Tas.	Edgar 2000	11 to 22
	Hippocampus abdominalis	OH only	MSE & CEC 1992	Kangaroo Is SA to Sydney NSW, and around Tas.	Edgar 2000	11 to 24
	Hyperlophus vittatus		MSE & CEC 1992; Pollard & Pethebridge 2002	Kalbarri WA to Moreton Bay Qld.	Edgar 2000	
	Hypoplectrodes maccullochi	OH only	MSE & CEC 1992	Wilsons Promontory Vic to Byron Bay NSW, and south to Bicheno Tas.	Edgar 2000	11 to 27
	Hyporhamphus regularis		MSE & CEC 1992			
	Istigobius hoesei		Pollard & Pethebridge 2002			
	Leseurena platycephala	OH only	Pollard & Pethebridge 2002			
	Marilyna pleurosticta		MSE & CEC 1992			
	Meuschenia freycineti		MSE & CEC 1992	Jurien Bay WA to Broughton Is NSW, and around Tas.	Edgar 2000	
	Meuschenia trachylepis		MSE & CEC 1992			
	Microcanthus strigatus		MSE & CEC 1992	Exmouth Gulf to Cape Leeuwin WA, and Merimbula NSW to Capricorn Group Qld.	Edgar 2000	15 to 28
	Monodactylus argenteus		MSE & CEC 1992; MSE 2002			
	Mugil cephalus		MSE & CEC 1992; MSE 1996; MSE 2002	Around Aust mainland and Tas.	Edgar 2000	

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Myxus elongatus		MSE & CEC 1992; MSE 1996; MSE 2002; Pollard & Pethebridge 2002			
	Neopomacentrus azysron		MSE & CEC 1992			
	Nesogobius sp.		Pollard & Pethebridge 2002			
	Norfolkia clarkei	OH only	Pollard & Pethebridge 2002	Rottnest Is WA to Coffs Harbour NSW, and around Tas.	Edgar 2000	
	Odax cyanomelas	OH only	Pollard & Pethebridge 2002	Kalbarri WA to Coffs Harbour NSW, and south to Tasman Peninsula Tas.	Edgar 2000	
	Omobranchus anolius		MSE & CEC 1992			
	Opthalmolepis lineolatus	OH only	MSE & CEC 1992	Houtman Abrolhos WA to southern Qld, and Kent Group Tas.	Edgar 2000	
	0ptivus agastos		MSE & CEC 1992 (as *0ptivus elongatus*)	Port Phillip Bay Vic to Noosa Qld, and south to Freycinet Peninsula Tas.	Gomon 2004	
	Parablennius tasmanianus		MSE & CEC 1992; Pollard & Pethebridge 2002	Ceduna SA to Eden NSW, and around Tas.	Edgar 2000	11 to 23
	Parma microlepis		MSE & CEC 1992	Port Phillip Bay Vic to Byron Bay NSW, and south to Maria Is Tas.	Edgar 2000	11 to 27
	Parma unifasciata	OH only	MSE & CEC 1992	Montague Is NSW to Noosa Head Qld.	Edgar 2000	16 to 27
	Parupeneus signatus		MSE & CEC 1992	Tropical Aust south to Geographe Bay WA and Mallacoota Vic.	Edgar 2000	
	Pelates quadrilineatus		MSE & CEC 1992; Pollard & Pethebridge 2002			
	Pempheris affinis		MSE & CEC 1992	Montague Is NSW to Hervey Bay Qld.	Edgar 2000	

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Pempheris multiradiata	OH only for P & P 2002	MSE & CEC 1992; Pollard & Pethebridge 2002	Jurien Bay WA to Terrigal NSW, and around Tas.	Edgar 2000	
	Pervagor janthinosoma	OH only	Pollard & Pethebridge 2002			
	Petroscirtes lupus	OH only for P & P 2002	MSE & CEC 1992; Pollard & Pethebridge 2002	Merimbula NSW to southern Qld.	Edgar 2000	15 to 27
	Plagiotremus tapeinosoma		MSE & CEC 1992			
	Platycephalus bassensis	OH only	Pollard & Pethebridge 2002	Bremer Bay WA to Jervis Bay NSW, and around Tas.	Edgar 2000	11 to 24
	Platycephalus fuscus		MSE & CEC 1992; MSE 2002; Pollard & Pethebridge 2002	Wilsons Promontory Vic to Mackay Qld.	Edgar 2000	
	Platycephalus sp.		Pollard & Pethebridge 2002			
	Pomacentrus coelestis	OH only	MSE & CEC 1992	Tropical Pacific waters to southern NSW.	Kuiter 1993	Down to 15
	Pomatomus saltatrix		MSE & CEC 1992 MSE 1996 (both as *P. saltator*); MSE 2002; Pollard & Pethebridge 2002	Onslow WA to Fraser Is Qld, and around Tas.	Edgar 2000	
	Pseudocaranx dentex		MSE & CEC 1992; MSE 2002	North West Cape WA to southern Qld, and around Tas.	Edgar 2000	Mean critical thermal maximum varied from 30.8 to 36.1°C, depending on acclimation temp (Tsuchida 1995)
	Pseudolabrus luculentus		MSE & CEC 1992	Mallacoota Vic to Byron Bay NSW.	Edgar 2000	15 to 27
	Pseudolabrus psittaculus		MSE & CEC 1992	Albany WA to Sydney NSW, and around Tas.	Edgar 2000	11 to 24
	Pseudorhombus arsius		MSE & CEC 1992	Tropical waters south to southern Australia except Vic and Tas.	Kuiter 1993	

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Pseudorhombus jenynsii	OH only	Pollard & Pethebridge 2002	Fremantle WA to southern Qld.	Edgar 2000	
	Rhabdosargus sarba		MSE & CEC 1992; Pollard & Pethebridge 2002	Coral Bay to Albany WA, and Lakes Entrance Vic to Qld.	Edgar 2000	
	Scatophagus argus		MSE & CEC 1992			
	Schuettea scalaripinnis		MSE & CEC 1992	NSW to southern Qld.	Kuiter 1993	
	Scobinichthys granulatus	OH only for P & P 2002	MSE & CEC 1992; Pollard & Pethebridge 2002	Shark Bay WA to Maroochydore Qld, and northern Tas.	Edgar 2000	
	Scomber australasicus	OH only	MSE & CEC 1992	Around Aust mainland and Tas.	Edgar 2000	
	Scomberomorus commerson		MSE 2002			
	Scorpis lineolata	OH only for P & P 2002	MSE & CEC 1992 Pollard & Pethebridge 2002 (both as *S. lineolatus*)	Port Phillip Bay Vic to Noosa Head Qld, and around Tas.	Edgar 2000	
	Sillago bassensis	OH only	MSE & CEC 1992			
	Sillago ciliata	OH only for P & P 2002	MSE & CEC 1992; MSE 1996; MSE 2002; Pollard & Pethebridge 2002			
	Sillago maculata		Pollard & Pethebridge 2002	Tropical Aust, south to Geographe Bay WA and Narooma NSW.	Edgar 2000	Down to 16
	Simplisetia aequisetis		MSE 1996			
	Suezichthys gracilis		MSE & CEC 1992			
	Synchiropus calauropomus	OH only	Pollard & Pethebridge 2002			
	Terapon jarbua		MSE & CEC 1992			Lethal bounds are 13.49 to 37.55 for fish acclimated to 20°C (Rajaguru & Ramachandran 2001)
	Tetractenos glaber		MSE & CEC 1992	Port Lincoln SA to Moreton Bay Qld, and around Tas.	Edgar 2000	

Higher Taxon	Species	Comments	Port Kembla record	Known geographic distribution	Source of distribution information	Temp range (°C) corresponding with distribution, unless stated otherwise.
	Tetractenos hamiltoni		MSE & CEC 1992; MSE 2002	Townsville Qld to southern NSW.	Kuiter 1993	15 to 30
	Torquigener pleurogramma		MSE & CEC 1992	Coral Bay WA to Adelaide SA, and Narooma NSW to Hervey Bay Qld.	Edgar 2000	14 to 29
	Torquigener squamicauda		MSE & CEC 1992	Wollongong NSW to Yeppoon Qld.	Edgar 2000	17 to 28
	Trachinops taeniatus		MSE & CEC 1992	Cape Conran Vic to Noosa Head Qld.	Edgar 2000	
	Trachinotus blochii		MSE & CEC 1992			
	Trachinotus coppingeri	OH only	MSE & CEC 1992; Pollard & Pethebridge 2002			
	Trachurus novaezelandiae		MSE & CEC 1992	Widespread in southern waters to southern Qld.	Edgar 2000	
	Tridentiger trigonocephalus		MSE & CEC 1992; Pollard & Pethebridge 2002			
	Tylosurus gavialoides		MSE & CEC 1992; MSE 2002			
	Upenichthys lineatus		MSE & CEC 1992	Mallacoota Vic to southern Qld.	Edgar 2000	
	Upenichthys vlamingii		MSE & CEC 1992	Jurien Bay WA to Wilson et al.s Promontory Vic, and around Tas.	Edgar 2000	

References

Bock, P.E. (1982) Bryozoans. In: Shepherd, S.A. & Davies, M. (Eds) *Marine Invertebrates of Southern Australia. Part I*. Flora and Fauna of South Australia Handbooks Committee. SA Government Printer, Adelaide. Ch. 9, pp. 319-394.

Conte, M.H., Thompson, A., Lesley, D. & Harris, R.P. (1998) Genetic and physiological influences on the alkenone/alkenoate versus growth temperature relationship in *Emiliania huxleyi* and *Gephyrocapsa oceanica*. *Geochimica et Cosmochimica Acta*. 62: 51-68.

Dodge, J.D. & Marshal, H.G. (1994) Biogeographic analysis of the armored planktonic dinoflagellate *Ceratium* in the North Atlantic and adjacent seas. *Journal of Phycology*. 30: 905-922.

Edgar, G.J. (2000) *Australian marine life: the plants and animal of temperate waters*. (Revised edition) Reed New Holland, Sydney, NSW.

Edmonds, S.J. (1982) Sipunculans. In: Shepherd, S.A. & Davies, M. (Eds) *Marine Invertebrates of Southern Australia. Part I*. Flora and Fauna of South Australia Handbooks Committee. SA Government Printer, Adelaide. Ch. 7, pp 299-311.

ELA (2004) *Ecological Assessment for Proposed Berth - EB4*. (Project No. 48-02) Report prepared for Port Kembla Port Corporation. Eco Logical Australia Pty Ltd, Sutherland, NSW.

Gomon, M.F. (2004) Two new species of roughy (Trachichthyidae: *Optivus*) from coastal waters of southern Australia. *Records of the Australian Museum*. 56(2): 173-78.

Johnston, E.L. & Clark, G.F. (2004) *No effect of dredging on hard-substrate invertebrates in Port Kembla harbour*. Report for Port Kembla Port Corporation. School of Biological, Earth and Environmental Science, University of New South Wales, Sydney, NSW.

Jones, D.S. & Morgan, G.J. (1994) *A field guide to crustaceans of Australian waters*. Reed, Chatswood, NSW.

Kuiter, R.H. (1993) *Coastal Fishes of South-eastern Australia*. Crawford House Press, Bathurst, NSW.

Lamprell, K. & Healy, J. (1998) *Bivalves of Australia. Volume 2*. Backhuys Publishers, Leiden, Neth.

METOC (2006) *Coastal Sea Surface Temperatures*. Royal Australian Navy's Directorate of Oceanography & Meteorology, Garden Island, Sydney, NSW. <http://www.metoc.gov.au/products/data/aussst.html>, accessed 7/3/2006.

Moran, P.J. 1981) Use of numerical, frequency and binary data in classification of marine fouling communities. *Australian Journal of Marine and Freshwater Research*. 32:805-812.

Moran, P.J. & Grant, T.R. (1989) The effects of industrial pollution on the development and succession of marine fouling communities. I. Analysis of species richness and frequency data. *Marine Ecology*. 10:231-246.

MSE. (1996) *Allans Creek Study 1995*. Report to BHP Steel, Slab and Plate Products Division. Marine Science & Ecology Pty Ltd, Essendon, Vic.

MSE. (2002) *Allans Creek Fish Study*. Report to BHP Steel Ltd. Marine Science & Ecology Pty Ltd, Essendon, Vic.

MSE & CEC. (1992) *Port Kembla Harbour Study 1991*. Report to BHP Steel, Slab and Plate Products Division. Marine Science & Ecology, Essendon, Vic. and Coastal Environmental Consultants Pty Ltd, Elsternwick, Vic.

Museum Victoria. (1996) *Marine Crustaceans of Southern Australia*. <http://www.museum.vic.gov.au/crust/page1a.html>, accessed 30/3/2006.

NIMPIS. (2002) *National Introduced Marine Pest Information System*. Eds: Hewitt C.L., Martin R.B., Sliwa C., McEnnulty, F.R., Murphy, N.E., Jones T. & Cooper, S. Web publication <http://crimp.marine.csiro.au/nimpis>, accessed 29/4/2005 - 22/3/2006.

Pedersen, G. & Tande, K.S. (1992) Physiological plasticity to temperature in *Calanus finmarchicus* - reality or artifact? *Journal of Experimental Marine Biology and Ecology*. 155: 183-197.

Petersen, J.K. & Riisgard, H.U. (1992) Filtration capacity of the ascidian *Ciona intestinalis* and its grazing impact in a shallow fjord. *Marine Ecology Progress Series*. 88: 9-17.

Pollard, D.A. & Pethebridge, R.L. (2002) *Report on Port Kembla Introduced Marine Pest Species Survey*. Report to Port Kembla Port Corporation. NSW Fisheries Office of Conservation, Cronulla, NSW.

Poore, G.B.C. (2004) *Marine decapod Crustacea of Southern Australia : a guide to identification*. CSIRO Publishing, Collingwood, Vic.

Rajaguru, S & Ramachandran, S. (2001) Temperature tolerance of some estuarine fishes. *Journal of Thermal Biology*. 26: 41-45.

Ritz, D., Swadling, K., Hosie, G. & Cazassus, F. (2003) *Guide to the Zooplankton of South Eastern Australia*. Fauna of Tasmania Committee, University of Tasmania, Hobart, Tas.

Scott, T.D., Glover, C.J.M. & Southcott, R.V. (1974) *The Marine and Freshwater Fishes of South Australia*. Government Printer, SA.

Staples, D.A. (1997) Sea spiders or pycnogonids. In: Shepherd, S.A. & Davies, M. (Eds) *Marine Invertebrates of Southern Australia. Part III*. South Australian Research and Development Institute in conjunction with the Flora and Fauna of South Australia handbooks Committee. SA Government Printer, Adelaide. Ch. 21, pp. 1040-1072.

Tsuchida, S. (1995) The relationship between upper temperature tolerance and final preferendum of Japanese marine fish. *Journal of Thermal Biology*. 20: 35-41.

Wallis. R.L. (1975) Thermal tolerance of *Mytilus edulis* of eastern Australia. *Marine Biology*. 30: 183-191.

Wallis. R.L. (1977) Some aspects of the thermal tolerance of *Trichomya hirsuta* (Mollusca: Bivalvia) of eastern Australia. *Marine Biology*. 43: 217-223.

Watson, J.E. (1982) Hydroids. In: Shepherd, S.A. & Davies, M. (Eds) *Marine Invertebrates of Southern Australia. Part I*. Flora and Fauna of South Australia Handbooks Committee. SA Government Printer, Adelaide. pp 77-115.

Wilson, B., Wilson, C. & Baker, P. (1993) *Australian marine shells. Pt. 1. Prosobranch gastropods*. Odyssey Publishing, Leederville, W.A.

Wilson, B., Wilson, C. & Baker, P. (1994) *Australian marine shells. Pt. 2. Neogastropods*. Odyssey Publishing, Leederville, W.A.

Womersley, H.B.S. (1996) *The marine benthic flora of Southern Australia. Rhodophyta - Part IIIB*. Australian Biological Resources Study, Canberra, ACT.

Womersley, H.B.S. (2003) *The marine benthic flora of Southern Australia. Rhodophyta - Part IIID*. Australian Biological Resources Study, Canberra, and State Herbarium of South Australia, Adelaide.

APPENDIX B.1

SEARCH LISTS AND DETAILS

Annexure B.1 Search lists and details

Databases searched in the University of Melbourne library

ISI Web of Science, Biosis and Current Contents.

Search terms and results

Searches terms	Resulting records	Reviewed
(thermal range or thermal tolerance or thermal effect or temperature range or temperature tolerance or temperature effect) and (plankton or phytoplankton or zooplankton)	124	71
(thermal range or thermal tolerance or thermal effect or temperature range or temperature tolerance or temperature effect) and mollusc*	107	31
(thermal range or thermal tolerance or thermal effect or temperature range or temperature tolerance or temperature effect) and polychaet*	16	3
(thermal range or thermal tolerance or thermal effect or temperature range or temperature tolerance or temperature effect) and crustacea*	78	17
(thermal range or thermal tolerance or thermal effect or temperature range or temperature tolerance or temperature effect) and bryozoa*	98	36
(thermal range or thermal tolerance or thermal effect or temperature range or temperature tolerance or temperature effect) and ascidia*	5	1
(thermal range or thermal tolerance or thermal effect or temperature range or temperature tolerance or temperature effect) and (marine or estuarine) fish*))	53	27

Databases searched in UNSW Library Metasearch

Aquatic Science and Fisheries Abstracts, Web of Science and Zoological Record.

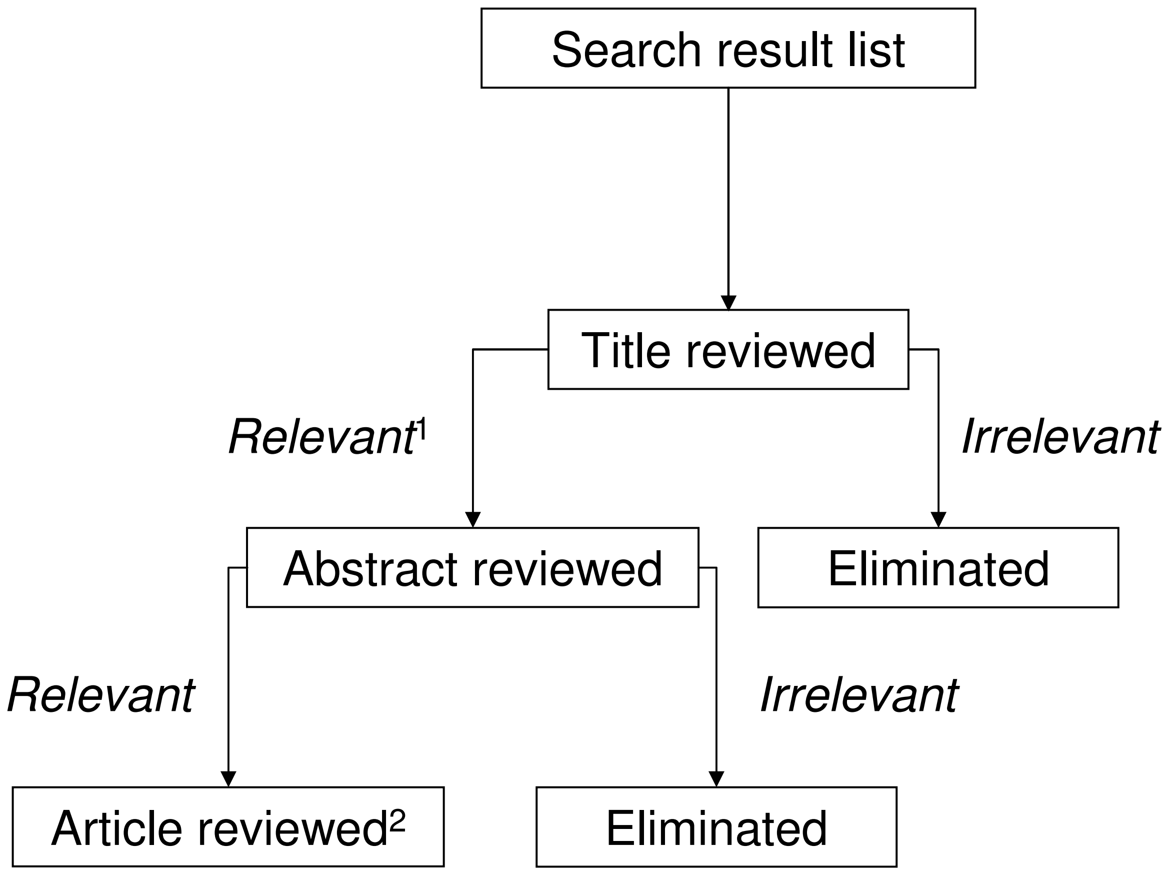
Search terms and results

Searches terms	Resulting records	Reviewed
marine and toxicant and temperature	25	24
marine and heavy metal and temperature	84	78
marine and temperature and polyaromatic hydrocarbons	8	3
polyaromatic and review	10	3
metal and eco* and review	154	100
marine and temperature and polycylclic aromatic hydrocarbon	7	3
marine and temperature and heavy metal	84	59
marine and temperature and contaminant	72	27
marine and temperature and aromatic	177	43
invertebrat*and temperature and metal	41	18
invertebrat* and temperature and contamin*	89	53
invertebrate and temperature and contaminant	1	3
heavy metal and toxicity and review	15	13
aromatic and toxicity and review	31	16
accumulation and temperature and metal	89	39

APPENDIX B.2

REVIEWING PROTOCOL

Reviewing protocol



[1] *Relevant articles were required to involve effects of heavy metals or PAHs on either toxicity or accumulation; and involve marine or estuarine taxa from temperate or tropical regions.*

[2] *If available at the UNSW library.*

Annexure B.2: Reviewing protocol

APPENDIX C

SELECTED SEA SURFACE TEMPERATURE DATA

Annexure C. Selected sea surface temperature data.

Monthly mean of sea surface temperatures (°C) within 1 degree radius of the specified coastal town, based on historical data extracted from the NODC - WORLD OCEAN ATLAS 98.
Note from source: "*Average sea surface temperatures can vary by 0.1-1.5°C*" (METOC 2006)

Coastal Town	Minimum Monthly Mean	Maximum Monthly Mean	Yearly Average of Monthly Means
Adelaide SA	14.2	18.9	16.55
Albany WA	15.7	19.5	17.73
Aldinga Beach SA	14.2	18.9	16.55
Alyangula NT	24.5	30.8	27.72
Augusta WA	17.5	22.0	19.75
Aurukun QLD	25.7	30.2	28
Bald Head WA	25.7	30.2	28
Ballina NSW	21.0	26.0	23.29
Barrow Islands WA	23.5	29.0	26.03
Batemans Bay NSW	16.3	22.7	19.54
Bathurst Island NT	27.0	30.8	29.1
Beachport SA	13.7	17.6	15.57
Bermagui NSW	16.3	22.7	19.54
Bongaree QLD	21.9	26.6	24.36
Bougainville Reef QLD	24.9	29.0	26.86
Bribie Island QLD	21.9	26.6	24.36
Brisbane QLD	21.5	26.5	23.95
Broad Sound QLD	21.7	27.9	25
Broken Bay NSW	17.7	23.5	20.6
Broome WA	24.3	29.5	27.31
Broughton Islands NSW	18.8	24.6	21.64
Bunbury WA	18.4	22.1	20.35
Bundaberg QLD	22.4	27.0	24.72
Burnett Heads QLD	22.4	27.0	24.72
Burnie TAS	12.0	18.0	14.54
Busselton WA	17.5	22.0	19.75
Byron Bay NSW	21.0	26.1	23.34

Coastal Town	Minimum Monthly Mean	Maximum Monthly Mean	Yearly Average of Monthly Means
Caledon Bay NT	25.3	30.5	27.98
Cape Barren Island TAS	13.0	18.7	15.64
Cape Direction QLD	24.5	29.5	26.99
Cape Flattery QLD	24.7	28.9	26.68
Cape Grafton QLD	24.6	28.9	26.57
Cape Grenville QLD	24.6	29.7	27.21
Cape Grim TAS	12.6	17.5	14.58
Cape Howe NSW	15.4	21.7	18.42
Cape Keer-Weer QLD	25.3	30.4	27.99
Cape Knob WA	15.6	19.4	17.69
Cape Leveque WA	25.6	29.8	28.14
Cape Londonderry WA	26.4	30.4	28.7
Cape Manifold QLD	22.2	27.8	24.78
Cape Melville QLD	24.6	29.5	27.04
Cape Naturaliste WA	18.4	22.3	20.4
Cape Nelson VIC	13.8	17.6	15.6
Cape Otway VIC	13.8	17.6	15.6
Cape Palmerston QLD	22.4	28.5	25.65
Cape Sorell TAS	12.1	15.7	13.83
Cape Spencer SA	14.1	18.9	16.47
Cape Townshend QLD	21.7	27.9	25
Cape Tribulation QLD	24.7	28.9	26.68
Cape Wessel NT	25.5	29.9	28
Cape York QLD	25.1	30.3	27.83
Carnarvon WA	21.4	26.3	23.58
Casey AUS	-00.6	-02.1	-1.65
Christmas Island AUS	26.3	28.9	27.8
Coburg Peninsula NT	26.4	30.6	28.54
Cocos Islands AUS	26.3	28.5	27.48
Coolum BeachQLD	21.9	26.6	24.36
Currie King Is TAS	13.4	18.0	15.23
Darwin NT	26.9	30.7	29.02
Denham WA	21.0	25.7	23.11

Coastal Town	Minimum Monthly Mean	Maximum Monthly Mean	Yearly Average of Monthly Means
Devonport TAS	12.0	18.0	14.54
Disaster Bay NSW	15.4	21.7	18.42
Dongara WA	19.5	23.6	21.44
Dunk Island QLD	24.8	29.1	26.65
Eden NSW	15.9	22.2	19.01
Edithburgh SA	14.1	18.9	16.48
Edward River QLD	24.1	30.5	27.6
Esperence WA	15.6	20.2	18.1
Evans Head NSW	21.0	26.0	23.29
Exmouth WA	23.0	28.3	25.56
Flinders Island TAS	13.0	18.7	15.64
Flinders Reefs QLD	24.8	28.9	26.62
Foster NSW	19.5	25.3	22.34
Fraser Island QLD	22.2	26.8	24.52
Fremantle WA	18.8	22.2	20.55
Freycinet Peninsular TAS	11.8	17.3	14.45
Gabo Island VIC	15.4	21.7	18.42
Galiwinku NT	25.6	30.2	28.05
Gambier Islands SA	15.0	19.0	17.04
George Town TAS	12.0	18.0	14.54
Geraldton WA	19.5	23.6	21.44
Gerringong NSW	17.7	23.5	20.6
Gladstone QLD	21.6	27.1	24.15
Gold Coast QLD	21.2	26.4	23.67
Goolwa SA	14.3	18.9	16.56
Great Keppel Island QLD	21.6	27.1	24.15
Green Cape NSW	15.4	21.7	18.42
Groote Eylandt NT	24.5	30.8	27.72
Halifax Bay QLD	24.6	29.1	26.53
Hervey Bay QLD	22.6	27.2	24.9
Hinchinbrook Island QLD	24.8	29.1	26.65
Hobart TAS	12.2	16.8	14.33
Holmes Reef QLD	24.8	28.9	26.7

Coastal Town	Minimum Monthly Mean	Maximum Monthly Mean	Yearly Average of Monthly Means
Horn Island QLD	25.5	29.3	27.62
Houtman Abrolhos WA	20.1	24.3	22.03
Innisfail QLD	24.8	29.1	26.65
Jervis Bay NSW	17.2	23.2	20.25
Joseph Bonaparte Gulf WA	25.8	30.5	28.15
Jurien Bay WA	19.9	23.6	21.71
Jurien WA	19.9	23.6	21.71
Karratha WA	24.0	29.2	26.65
Karumba QLD	22.2	30.6	26.71
Keeling Islands AUS	26.3	28.5	27.48
Keppel Bay QLD	21.6	27.1	24.15
Kiama NSW	17.7	23.5	20.6
Kingscote Kangaroo Is SA	14.1	18.9	16.49
Kingston SE SA	14.0	18.5	16.25
Kingston TAS	12.2	16.8	14.33
Lakes Entrance VIC	14.2	20.0	16.95
Lancelin WA	19.1	22.5	20.8
Leeman WA	19.5	23.6	21.44
Lord Howe Island NSW	19.2	24.4	21.47
Mackay QLD	22.4	28.5	25.65
Macquarie Island	2.4	5.2	3.52
Mallacoota VIC	15.4	21.7	18.42
Mandurah WA	18.6	22.2	20.47
Maningrida NT	25.9	30.6	28.14
Maria Island TAS	11.8	17.3	14.45
Marlo VIC	14.2	20.0	16.95
Maroochydore QLD	21.9	26.6	24.36
Melbourne VIC	13.1	18.5	15.27
Melville Island NT	26.5	30.5	28.67
Merimbula NSW	15.4	21.7	18.42
Milingimbi NT	25.8	30.4	28.12
Montague Island NSW	16.3	22.7	19.54
Mooloolabah QLD	21.9	26.6	24.36

Coastal Town	Minimum Monthly Mean	Maximum Monthly Mean	Yearly Average of Monthly Means
Moreton Island QLD	21.9	26.6	24.36
Mornington Island QLD	22.0	30.8	26.68
Moruya NSW	16.3	22.7	19.54
Mossman QLD	24.7	28.9	26.64
Nelson Bay NSW	18.8	24.6	21.64
Newcastle NSW	18.8	24.6	21.64
Nhulunbuy NT	25.5	29.9	28
Noosa Head QLD	21.9	26.6	24.36
Noosa QLD	21.9	26.6	24.36
Norah Head NSW	18.8	24.6	21.64
Norfolk Island AUS	18.9	23.9	21.29
North Bruny TAS	12.2	16.8	14.33
North Solitary Island NSW	20.4	25.4	22.96
Numbulwar NT	24.3	30.7	27.61
Onslow WA	23.0	28.3	25.56
Orford TAS	11.8	17.3	14.45
Osprey Reef QLD	24.9	29.1	27.05
Palm Islands QLD	24.6	29.1	26.53
Perpendicular Point NSW	19.7	25.2	22.52
Perth WA	18.8	22.2	20.55
Phillip Island VIC	13.1	18.5	15.24
Port Alma QLD	21.6	27.1	24.15
Port Augusta SA	15.0	19.0	17.04
Port Arthur TAS	12.2	16.8	14.33
Port Elliot SA	14.3	18.9	16.56
Port Fairy VIC	13.6	17.3	15.2
Port Hedland WA	23.8	29.2	26.85
Port Jackson NSW	17.7	23.5	20.6
Port Kembla NSW	17.7	23.5	20.6
Port Lincoln SA	14.1	18.9	16.48
Port MacDonnell SA	13.8	17.6	15.6
Port Macquarie NSW	19.7	25.2	22.52
Port Pirie SA	15.0	19.0	17.04

Coastal Town	Minimum Monthly Mean	Maximum Monthly Mean	Yearly Average of Monthly Means
Port Victoria SA	14.1	18.9	16.48
Portland VIC	13.8	17.6	15.6
Prince of Wales Island QLD	25.5	29.3	27.62
Proserpine QLD	23.4	28.6	25.96
Redcliffe QLD	21.9	26.6	24.36
Robe SA	14.0	18.5	16.25
Rockingham Bay QLD	24.8	29.1	26.65
Rockingham WA	18.6	22.2	20.47
Schouten Island TAS	11.8	17.3	14.45
Seabird WA	19.5	23.1	21.28
Shoalwater Bay QLD	22.2	27.9	25
Sir Edward Pellew Group NT	22.8	31.0	27.08
Smoky Cape NSW	20.4	25.4	22.96
South Bruny TAS	12.2	16.8	14.33
South Solitary Island NSW	20.4	25.4	22.96
South West Cape TAS	11.4	14.8	13.04
St Helens Point TAS	12.4	18.2	15.21
Stanley TAS	12.6	17.5	14.58
Stenhouse Bay SA	14.1	18.9	16.47
Stockton NSW	18.8	24.6	21.64
Sugarloaf Point NSW	19.7	25.2	22.52
Sunday Island VIC	12.9	18.9	15.43
Swain Reefs QLD	23.1	27.9	25.34
Sydney NSW	17.7	23.5	20.6
Tathra NSW	16.3	22.7	19.54
Tewantin QLD	21.9	26.6	24.36
Thursday Island QLD	25.5	29.3	27.62
Torquay VIC	13.4	18.2	15.24
Townsville QLD	24.6	29.1	26.53
Trial Bay NSW	20.4	25.4	22.96
Tumby Bay SA	15.0	19.0	17.04
Tuncurry NSW	19.5	25.3	22.34
Tweed Heads NSW	21.0	26.1	23.34

Coastal Town	Minimum Monthly Mean	Maximum Monthly Mean	Yearly Average of Monthly Means
Ulladulla NSW	17.2	23.2	20.25
Ulverstone TAS	12.0	18.0	14.54
Vanderlin Island NT	22.8	31.0	27.08
Victor Harbour SA	14.3	18.9	16.56
Wadeye NT	26.1	30.4	28.33
Wallaroo SA	15.0	19.0	17.04
Walpole WA	16.4	21.3	18.76
Weipa QLD	25.7	29.4	27.7
Wellesley Islands QLD	22.0	30.8	26.68
Wessel Islands NT	25.5	29.9	28
Whitsunday Island QLD	22.4	28.5	25.65
Whyalla SA	15.0	19.0	17.04
Wilsons Promontory VIC	13.1	19.0	15.64
Wollongong NSW	17.7	23.5	20.6
Wonthaggi VIC	13.0	18.8	15.36
Wynyard TAS	12.0	18.0	14.54
Yamba NSW	20.7	25.7	23.09
Yeppoon QLD	21.9	27.5	24.48

METOC (2006) *Coastal Sea Surface Temperatures*. Royal Australian Navy's Directorate of Oceanography & Meteorology, Garden Island, Sydney, NSW. <http://www.metoc.gov.au/products/data/aussst.html>, accessed 7/3/2006.