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

for

CH2M HILL Australia Pty Ltd

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EFFECTS OF BLUESCOPE STEEL SCP PROPOSED SALT WATER COOLING ON PLANKTON OF PORT KEMBLA HARBOUR

This report is an addition to the desktop study recently undertaken by NSG Consulting Pty Ltd in August 2006 addressing the ecological issues related to the operation of the proposed BlueScope Steel's Steelworks Cogeneration Plant (SCP). Specifically, the current report addresses issues related to the potential effects of the SCP operation on the plankton of Port Kembla Harbour.

This assessment consists of two major parts. First, a review and summary of the general biology and ecology of plankton and the current knowledge of the ecology of plankton within Port Kembla Harbour. Second, an evaluation of several major issues related to the operation of the SCP and the ecology of plankton within Port Kembla. These issue include :

- Comparison of predicted extraction index pre-SCP and post-SCP;
- Evaluating the effects of entrainment on plankton
- Evaluation of planktonic residence time within Port Kembla; and
- Effects of tidal flushing on plankton.
- Potential for the SCP to create plankton blooms.

GENERAL BIOLOGY AND ECOLOGY OF PLANKTON

Animals and plants that drift within the water column, or on the surface of the water, are described as plankton (Newell and Newell 1977). Although these organisms are generally at the mercy of the currents, they do have limited motility which can be important to their survival (Newell and Newell 1977, Kingsford 1995). They are separated into two basic plant and animal groups – phytoplankton and zooplankton. Plankton have an enormous range of sizes from bacteria of 1μm in length to jellyfish with bells up to 1m in diameter and tentacles they can extend for 10 m.

Most marine organisms spend at least part of their lives as plankton (Newell and Newell 1977). These meroplankton include the larvae of fish, bivalves, gastropods, crabs, barnacle and sea-squirts and the propagules of algae (e.g. macroalage such as kelp). Holoplankton spend their entire lives as plankton. Holoplankton include the diatoms (often the most abundant phytoplankton), dinoflagellates (very abundant single celled zooplankton which can be poisonous), crustaceans such as copepods (often the most abundant multicellular zooplankton) and other zooplankton such as salps (free living tunicates).

Generally, the planktonic food chain is driven by phytoplankton which utilise nutrients and light to grow and reproduce. The phytoplankton are grazed by small zooplankton which, in turn, may themselves become prey for other zooplankton (i.e. copepods). Both phytoplankton and zooplankton are grazed upon by suspension feeders such as sessile species like mussels and mobile species such as fish and whales.

The abundance and diversity of plankton varies greatly through time. Generally, there is a seasonal influence with many organisms releasing eggs and sperm, larvae or propagules at specific times of the year. In temperate waters, the abundance of phytoplankton usually peaks in Spring, with zooplankton usually increasing in abundance shortly after this. Nevertheless, sporadic increases in phytoplankton can also occur due to increased nutrient input from upwellings (i.e. caused by offshore wind), run-off from storms or anthropogenic inputs; often seen for dinoflagellates as blooms or red tides.

The lifespans of holoplankton and planktonic stages of meroplankton can vary enormously. The planktonic stage for many benthic invertebrates can be as short as a few hours - where larvae are released from the parent and settle shortly afterwards (e.g. bryozoans, colonial ascidians). Generally, however, their planktonic stages include the release of eggs and sperm into the water (broadcast spawners), fertilization, development of the embryo and the larval stage. Hence, their planktonic stage can range from a few days to several months (e.g. crabs, barnacles, solitary ascidians; Table 1).

Many holoplankton can have relatively long lifespans – up to, and in some cases longer than, a year (e.g. copepods, jellyfish). Even phytoplankton, which often have short lifespans of only several hours or a few days (e.g. diatoms), often divide asexually to become two new diatoms. In this way, the individual may live for an indefinite period (i.e. the same individual undergoes division many times).

Plankton can be moved long distances by currents (e.g the East Australia Current) during their lives (or planktonic lives). They can also be entrained by features of coastlines such as headlands or embayments. In this way, embayments (including harbours) can act as plankton sinks by entraining some of the plankton from the coast if they are not at times drawn back out by prevailing currents (e.g. tides or wind driven currents). Embayments can also act as source populations where plankton are produced (e.g. fish spawning) or themselves reproduce and rapidly increase in abundance to then be withdrawn from the embayment by prevailing currents.

Phytoplankton are restricted to the photic zone (i.e. light influence; Jeffrey and Hallegraeff 1990). Zooplankton often remain below this zone during the day, avoiding predators, and move up towards the surface at night to graze on the phytoplankton (Kingsford 1995, Nybakken 2001). Many species also vary their position in the water column depending on their life or larval stage. Copepods, for example, remain in deep waters during their non-feeding nauplii stage (early stage) and move toward the surface as they get older and finally go to the surface once they have moulted to become adults (Nybakken 2001). Similarly, larvae of many benthic invertebrates (e.g. barnacles, sea-squirts, bryozoans etc.) will be photo-negative initially (i.e. avoid light) then become photo-positive just before they prepare to settle (Svane & Young 1989).

Vertical position can also influence the movement of plankton as currents at different depths often move at different speeds and in different directions (Kingsford 1995). By regulating their position in the water column plankton can travel in different directions. This is important for plankton within embayments which may be able to use currents to remain circulating within an estuary and avoid being washed out to sea (Kingsford 1995).

PLANKTON WITHIN PORT KEMBLA HARBOUR

Although little sampling of the plankton appears to have been done in Port Kembla Harbour, three relevant studies have been identified – MSE and CEC (1992), MSE (1996) and Pollard and Pethebridge (2002). Each of these studies involved only qualitative sampling of the plankton with the aim of gaining a general description of the planktonic assemblage within the Harbour. Plankton species names, details of occurrence and temperature ranges from these studies are summarised in Johnston *et al*. (2006; Annexure A).

MSE and CEC 1992

MSE and CEC carried out plankton sampling in the Inner and Outer Harbours during February/March and September 1991 as part of a much larger study on the general distribution of marine flora within Port Kembla. Sampling methods involved towing plankton nets or pumping harbour water through plankton mesh along the surface of the water or at a depth of 6 m (MSE and CEC 1992).

The planktonic assemblage in the Outer Harbour was found to be the most diverse consisting of copepods (the dominate taxa), decapods (e.g. prawns and crab larvae), sergestids (crustaceans), chaetognaths (commonly referred to as arrow head worms) and cnidarian medusae (jellyfish). Fish larvae and eggs were also collected in the plankton nets and some of the larvae were identified as those belonging to the family Gobiidae (i.e. gobies).

The planktonic assemblages in the Outer Harbour showed some resemblance to those usually found in coastal waters or less disturbed estuaries. The diversity and abundance of most taxa were, however, smaller than those of coastal waters and were missing several major planktonic groups that would be expected to have occurred in such waters. For example, no barnacle nauplii or mollusc larvae were collected in the plankton nets. Also, few diatoms and no dinoflagellates (0.2 – 200µm and 2 – 200µm in size, respectively: Jeffrey and Hallengraeff 1990) were captured in the nets. This, however, may have been due to the relatively large mesh-size of the plankton nets (100-250 µm).

The planktonic assemblages within the Inner Harbour were less diverse, with far fewer species and fewer individuals than those in the Outer Harbour (MSE and CEC 1992). Nevertheless, there were some similarities, for example, the Inner Harbour assemblages contained cnidarian medusae, copepods (although fewer species and fewer individuals), decapods and chaetognaths. Goby larvae were especially abundant in some Inner Harbour trawls and particularly so in the deeper ones (i.e. 6m).

The planktonic assemblages in September 1991 (Spring) were far less diverse at all sites. They did, however, have greater abundances of copepods - specifically a calanoid copepod, possibly of the *Acartia* genus which was also present in the February/March (Autumn) samples.

The assemblages seemed to vary among sites with regard to presence and abundance of taxa. Similarly, the number of taxa and the presence and abundances of taxa appeared to differ between times of sampling indicating that assemblages also vary temporally, over short time scales of days.

The small number of samples and the substantial temporal and spatial variation among the samples make it difficult to determine whether the planktonic assemblages at the surface differed from those at 6 m. However, goby larvae showed a strong pattern of being more abundant at 6 m than at the surface.

Similarly, there appeared to be no difference between the assemblages collected at the ebb and flood tides. Some comment is made in the MSE and CEC (1992) report that assemblages collected at night were much more diverse, across the whole range of taxa, than those collected during the day.

MSE 1996

This study was also part of a much larger study on the distribution of marine fauna within Port Kembla. A component of this study involved plankton and specifically targeted Allans Creek (and part of the Inner Harbour). Samples were taken in

March (Autumn) and October (Spring) 1995 and were collected at a depth of 1.5 m using a 250 µm net with trawls over a distance of 200 m (at a speed of 1 knot).

Juvenile prawns and crabs, copepods, sergestids, jellyfish, hydroids and fish larvae were all found in trawls along the lower sections of Allans Creek (including up to the Roll On- Roll-Off Berth in the Inner Harbour). Barnacle nauplii and molluscan veligers (larval stages) were also found in these trawls which were not detected in the previous study. No phytoplankton or dinoflagellates were collected in these samples. The study reported that there was generally greater diversity in the planktonic assemblages in the March samples (Autumn) than in the October samples (Spring). MSC (1996) were surprised by this as usually the opposite pattern is generally found in regards to the season (see ecological review below), although it was a very similar pattern to that found in 1991 (MSE and CEC 1992). It was reported (MSC 1996) that this pattern of diversity may have been due to the temperature increases in Allans Creek disturbing the normal reproductive cycles of the organisms.

Sampling was also done at night in this study. The diversity and abundance of the plankton in the night trawls of the lower section of Allans Creek and into the Inner Harbour were far greater than those done during the day.

Pollard and Pethebridge 2002

Plankton sampling formed a small section of this study which was designed to specifically identify introduced species within Port Kembla Harbour. Protists (single celled organisms) such as diatoms (phytoplankton) and dinoflagellates (zooplankton) were targeted (by using a 20 µm plankton net). This was due to concern about the presence of introduced dinoflagellates that cause toxic blooms.

Two sites were sampled: one in the middle of the Inner Harbour and the other in the middle of the Outer Harbour. Three replicate samples were taken at each site (probably within a short time of one another). Only the presence or absence of plankton species were recorded for these samples, but a 1 litre water sample was also taken at each site at a depth of 1.5 m and the numbers of each species were counted to estimate the density of each species.

The small number of samples and the mainly presence/absence data make it difficult to distinguish whether the assemblages differed between the two sites. Most species of diatoms, dinoflagellates and other protists tended to occur at both sites with similar frequency. The dinoflagellate *Alexandrium sp.*, a toxic species, was found in one sample in the Inner Harbour but not in any other samples or elsewhere in the Harbour. A species from the same genus which is also thought to be toxic, *Alexandrium ostenfeldii/peruvianum*, was collected in both the Inner and Outer Harbour.

Comparison and summary of all Port Kembla Harbour Plankton studies

Based on the current available literature regarding planktonic assemblages in Port Kembla Harbour and Allans Creek, several general trends have been identified:

1. There appeared to be a trend of greater diversity and abundance of plankton in the Outer Harbour than the Inner Harbour.
2. Planktonic assemblages in Port Kembla Harbour appeared to be generally less diverse and abundant than those of the open coast or less disturbed estuaries (based on MSE 1996 report).
3. The assemblages comprise a wide range of taxa from tiny phytoplankton (e.g. diatoms) and zooplankton (e.g. dinoflagellates) to an abundant and diverse array of copepods, to larvae of many benthic invertebrates (e.g. barnacles, crabs etc.), larval fish and macro-plankton like jellyfish.
4. The diversity and abundance of taxa generally appeared to decrease from the Outer to Inner Harbour. It is likely that this is due to the position along the estuary which is likely to decrease the effects of tidal flushing and possibly due to greater levels of pollution within the Inner Harbour and its catchment compared to the Outer Harbour. The reduced influence of tidal flushing may enhance the relative effect of anthropogenic activities within the Inner Harbour. Elevated levels of pollutants in the Harbour more generally (He and Morrison 2001) may be one explanation for the smaller

diversity and abundances of some planktonic taxa in the Harbour compared to those in less disturbed estuaries or the open coast.

5. There seemed to be variation in the diversity and abundance of the plankton throughout the harbour (both horizontally and vertically) and through time (e.g. days, seasons and years).
6. The assemblages seemed to vary greatly between seasons being much more diverse and abundant in Autumn than in Spring., This variation is different to the general seasonal changes reported for other coastal areas in the literature (Kingsford 1995).
7. There appeared to be a strong pattern of the available plankton in the water column being much more diverse and abundant at night than during the day. This is probably due to the behaviour of plankton moving into the upper sections of the water column at night increasing the likelihood of capture in shallow water plankton tows.

There appears to be little data on the general abundances and diversity of planktonic assemblages in estuaries along the NSW coast. As such, there is little recent data available to compare the Port Kembla Harbour assemblages against. Most of the recent studies have targeted specific taxa (i.e. larvae of specific fish species; Kinsgford and Suthers 1994) or specific species (e.g. the dinoflagellate *Noctiluca scintillans*; Dela-Cruz *et al*. 2002) rather than quantifying the diversity and abundance of a range of plankton.

POTENTIAL EFFECTS OF INCREASES IN COOLING WATER INTAKE CAUSED BY THE SCP

An increase in cooling water intake has the potential to impact on plankton in Port Kembla Harbour. The following issues are discussed in relation to the potential effects on plankton as a result of this increase.

Extraction Index

The commissioning of the SCP will lead to an increase in the volume of Harbour water used for cooling. According to the extraction index (Table 2) provided by

Cardno Lawson Treloar (Sept 2006), which is the proportion of time take to turn over the Harbour water compared to the time with which this could be done due only to the intake of cooling water, indicates that the increase required cooling water could increase the extraction of plankton by approximately 30 % in both summer and winter under typical operating conditions. The relative increase in the extraction index will, however, be smaller during the times of peak load in summer (approximately 12 %; Table 2).

An increase in the extraction of plankton by 30 % would appear to be a matter for concern, if three assumptions hold. First, that the plankton are distributed evenly throughout the Harbour and any increase in the volume of intake water should lead to proportional entrainment of plankton. The plankton, however, do not appear to be evenly distributed. Instead they show substantial spatial variation among within and between the Inner and Outer Harbour. Nevertheless, the intake channel is located at the Cut, between the Inner and Outer Harbour, and is therefore likely to collect a general sample of the plankton from the Harbour (i.e. potentially from both the Inner and Outer Harbours).

Hence, an increase in the extraction of water due to the commissioning of the SCP would be likely to entrain more plankton from the Harbour.

The second assumption is that the plankton act as passive particles. If, however, they use their limited motility and avoid the intake currents, as they may to avoid natural currents or tidal influences, then the effects of the increase in entrainment may not be directly proportional to any increase in extraction. It is, however, likely that the flow velocities of the intake are likely to overwhelm the limited motility of any plankton in the immediate vicinity of the intake and render them essentially as passive particles and thus more likely to be entrained with an increase in the extraction of cooling water from the Harbour.

The third assumption, that entrainment into cooling water systems would result in 100% mortality of the plankton, will be assessed in the following section of this report.

Effects of Entrainment

The most critical assumption of the predicted increase in the extraction of plankton is that entrainment causes substantial levels of mortality for plankton. The extent of the mortality of plankton caused by mechanical damage, changes in temperature and pressure and the presence of biocides (see section 'Cooling Water Biocides' below) during the cooling water processes is, however, unclear. Several studies on entrainment of plankton into cooling water systems of power stations have estimated that the mortality will be great [Carpenter *et al*. 1974: 70% mortality of copepods; Heinle 1976: significant and extensive mortality; Taylor 2000: 92 and 100% mortality of fish (*Solea solea*) and oyster (*Crassostrea gigas*) larvae], while others have suggest that the mortality rates should be much smaller (Coughlan and Davis1981: 22% mortality of copepods; Bamber and Seaby 2004: 10 – 20% of copepods and larval shrimp and lobster) or do not exist (Markowski 1959).

A recent review confirmed that mortality rates were likely to vary among taxa (Taylor 2006) making it difficult to generalise across a range of taxa. Further complication may arise in drawing conclusions from the studies if treatment and utilisation of the cooling water at BlueScope Steel differs greatly from that which generally occurs at power stations.

On the basis of the available literature, an assumption of 100% mortality is conservative. Nevertheless, no adequate estimate of the effects of entrainment can be provided due to the apparent variation in effects among the planktonic taxa.

Cooling Water Biocides

In general, it has been the mechanical damage and changes in temperature and pressure that are considered to cause most of the plankton mortality during extraction (Taylor 2006). Plankton mortality may also be affected by the use of biocides (Bamber and Seaby 2004, Taylor 2006).

The biocide used by BlueScope Steel, (Clamtrol II) is a quaternary ammonium based compound and is currently dosed acutely (12 hours every 30 days) as opposed to a chronically. Assuming this regime is continued, the direct exposure of plankton to biocide will only be for a relatively short period of time. The current acute dosing rate was based on results of CSIRO toxicity assessments (CSIRO 2004a, 2004b) based on several of their studies (Adams *et al*. 2004, Binet *et al*. 2005) and was intended to minimise this impact on the habitats surrounding the cooling water outfall.

The CSIRO studies identified that exposure to Clamtrol II for 1 hour resulted in acute toxicological effects on sea urchin fertilization and the development of scallop larvae at concentrations found at the outfall of the cooling water system (Adams *et al*. 2004, Binet *et al*. 2005). The passage of plankton through the cooling water system is estimated to take less than 20 minutes (Cardno Lawson Treloar October 2006). It is likely, therefore, that the concentrations of Clamtrol II in the cooling water system during the dosing period would still affect plankton and potentially lead to mortality. Nevertheless, this would only occur for approximately half a day every month (i.e. 2 % of the time), if the current dosing regime was maintained.

Planktonic life span and cooling water turnover time

The relationship between the planktonic life span of the organisms in the Harbour and the time taken to turn over the water within the Harbour due to the BlueScope Steel cooling water intake alone (Ti; Table 1) was also examined to provide some comparison of the likelihood of various taxa being entrained into the cooling water system during their planktonic lives. Table 1 lists some of the common kinds of plankton found in Port Kembla Harbour and those that are likely to be present (due to the occurrence of sessile adults) or may be present and of commercial value (e.g. they have larval forms and adults are found nearby the Harbour).

Their planktonic life-spans vary enormously from a few hours (e.g. ascidian and bryozoan larvae) to more than a year (e.g. copepods). Considering that the time taken to pump the equivalent volume of Port Kembla Harbour through the steelworks (Ti) under current operating parameters is between 26.9 and 28.5 days (depending on the season; Table 1) it would appear that many taxa would already be likely to be entrained into the cooling water system during their lives (i.e. their planktonic lives are longer than Ti). For many taxa, this would be likely to occur multiple times (e.g. copepods), if they were not moved out of the Harbour or there were no refuges from the entrainment within the Harbour.

Probably the only taxa to avoid substantial losses to the cooling water system, under such circumstances, would be the larvae of the sessile invertebrates with larval stages shorter than 26 days (e.g. ascidians, barnacles and bryozoans; Table 1) as these species may be able to settle out of the plankton and attach to a hard substrata before being entrained by the cooling water system.

With the commissioning of the SCP, it is predicted that the Ti will decrease to approximately 18 days. This decrease will mean that a wider range of taxa including some more sessile invertebrates (e.g. barnacles) may be likely to pass through the cooling system as their larval stage can last longer than 18 days (Table 1).

Despite the potential additional removal of plankton due to the cooling water intake, there are clearly many kinds of plankton that inhabit the Harbour and at times they can be relatively abundant (see previous section ‘Plankton within Port Kembla Harbour’). It is not known whether the existence of these assemblages is due to replenishment by the entrainment of more plankton into the Harbour from the open coast, production of plankton from entrainment refuges within the Harbour (and the spatial mixing of these plankton across the Harbour) or survival of plankton through the entrainment process. It is likely that it is a combination of all three possible explanations.

Effects of Tidal Flushing on Port Kembla Harbour

Estimates of tidal flushing of the Harbour indicate that its water could be turned-over within less than 5 days (Cardno Lawson Treloar October 2006). This suggests that the tidal flushing would have a far greater influence on the movement of water and plankton in the Harbour than that due to the intake of the cooling water system.

It is likely that plankton are moved into and out of the Harbour under tidal influence thereby replenishing the assemblages within the Harbour, unless the behaviour and motility of the plankton enable them to stay within the Harbour. This would mean that many of the organisms would be unlikely to spend all of their lives or planktonic stages within the Harbour (i.e. those with planktonic lives of greater than 5 days). They would, therefore, be unlikely to become locally extinct within Port Kembla Harbour due to entrainment into the BlueScope Steel cooling system.

Instead it is likely that entrainment will result in the removal of a percentage of plankton that move in and out of the Harbour. This percentage is unknown, but the increase in the intake volume for the SCP would be likely to increase the proportion of plankton entrained into the system.

Replenishment of plankton would appear to minimise the local impacts of the cooling water increase within Port Kembla Harbour. This may, however, result in the Harbour acting as a plankton sink – where plankton may be entrained into the Harbour and may possibly be lost from the wider coastal system. The plankton assemblages downstream of the Harbour may be reduced in abundance and diversity. Similarly, there may also be an effect on benthic invertebrate assemblages dependent on larval recruitment from those assemblages (e.g. crabs, abalone, ascidians etc).

Potential for the SCP to create plankton blooms

Many species of zooplankton and phytoplankton have been found within Port Kembla Harbour (e.g. the dinoflagellate *Alexandrium* spp. and phytoplankta *Psuedo-nitzchia* spp.; Pollard and Pethebridge 2002). Many of these zoo- and phyto-plankton are also found in other estuaries of NSW (Hallegraeff et al. 1998) and can cause large plankton blooms (i.e. rapid population increases). Such blooms can poison fish and/or cause eutrophication also leading to the death of fish (Anderson et al 2002). Conditions within Port Kembla would appear suitable for plankton blooms to occur (Sui et al 1998), but such blooms have not been observed within the Harbour.

Nutrients are considered to be the key factor in causing plankton blooms (Anderson et al. 2002). Environmental conditions such as temperature, however, can influence the uptake of nutrients (e.g. ammonium; Anderson 2002) and thereby indirectly affect the creation of plankton blooms. It is unlikely that the SCP would influence the nutrients within the Harbour, but the predicted increase in the water temperature associated with the plant could increase the uptake of nutrients already in the Harbour. This increase is predicted, however, to be generally less than 0.8°C (Cardno Lawson Treloar 2006) and so the chances of such blooms may be unlikely to increase (assuming the water temperatures change only as predicted).

SUMMARY

Impacts on planktonic assemblages are likely to occur as a result of increasing the salt water intake for cooling purposes. However, due to a limited amount of available data, the precise impact cannot be ascertained.

Some general comments can be made:

- Planktonic assemblages in Port Kembla Harbour were generally less diverse and abundant than those of the open coast or less disturbed estuaries;
- There is greater diversity and abundance of plankton in the Outer Harbour than the Inner Harbour;
- The extraction index suggests that an increase in the extraction index of 30% is likely under typical conditions post-SCP in summer and winter and 12% during summer peak conditions post-SCP. However, this is based on several assumptions including the lack of motility of plankton and an even distribution of plankton throughout Port Kembla Harbour and the water column;
- Entrainment and the exposure to increased temperature will result in varied mortality rates ranging from 20-100% depending on individual taxa;
- Exposure to Clamtrol II (biocide) may increase plankton mortality, however, the dosing regime undertaken by BlueScope (approximately 12 hours over a 30 day period) is infrequent therefore would be likely to only have a relatively small effect on plankton in Port Kembla Harbour. Further, dosing rates are as recommended

by the CSIRO to minimise impact on the fauna and flora in the receiving environment

- Considering the planktonic life span and the Harbour turnover time due to the BSS cooling water system (Ti), it would appear that the predicted reduction in residence time may result in the potential increase in the numbers and types of plankton entrained in the salt water cooling system with barnacle larvae being potentially more affected.
- Considering the estimates of tidal flushing of the Harbour, however, indicates that plankton are likely to be moved in and out of the Harbour due to tidal flushing and less likely to spend all of their lives within the Harbour.
- The increased intake of cooling water associated with the operation of the SCP is, however, likely to increase the proportion of plankton entrained into the system. If mortality of the plankton is relatively high within the cooling water system, then this may affect the planktonic assemblages within the Harbour and those down stream or surrounding the Harbour.
- Plankton blooms have not been reported for Port Kembla Harbour, and the chances of such blooms occurring is unlikely to increase if the changes in water temperature occur as predicted (i.e. generally less than 0.8°C change).

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APPENDIX A

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APPENDIX B

Tables

TABLES

Table 1. The ratio of life or larval span of common or commercially important planktonic organisms and the residency time of water in Port Kembla Harbour. An index value greater than 1 indicates that the taxon will be likely to be entrained into the cooling water system during its life or larval span. As life and larval spans may vary greatly for many taxa both the general lower and upper estimates of life and larval spans are presented. Predicted indexes are presented for summer (average and peak loads) and winter (average loads) both before and after the commissioning of the SCP.

Taxa	**Life or larval span (days)**	**Summer-Pre-Ave (Ti = 28.5 days)**		**Summer-Post-Ave (Ti = 18.4 days)**		**Winter-Pre-Ave (Ti = 29.6 days)**	
		Lower	Upper	Lower	Upper	Lower	Upper
Diatoms	3 - 7	0.11	0.25	0.16	0.38	0.11	0.26
Dinoflagellates	3 - 7	0.11	0.25	0.16	0.38	0.11	0.26
Jellyfish	90 - 365	3.16	12.81	4.89	19.84	3.35	13.57
Copepods	90 - 365	3.16	12.81	4.89	19.84	3.35	13.57
Penaid prawns	90 - 365	3.16	12.81	4.89	19.84	3.35	13.57
Bryozoan larvae	0.05 - 5	0.00	0.18	0.00	0.27	0.00	0.19
Barnacle larvae	14 - 21	0.49	0.74	0.76	1.14	0.52	0.78
Crab larvae	90 - 365	3.16	12.81	4.89	19.84	3.35	13.57
Crayfish larve	90 - 180	3.16	12.81	4.89	19.84	3.35	13.57
Mussel larvae	3 - 7	0.11	0.25	0.16	0.38	0.11	0.26
Oyster larvae	3 - 7	0.11	0.25	0.16	0.38	0.11	0.26
Abalone larvae	3 - 7	0.11	0.25	0.16	0.38	0.11	0.26
Urchin larvae	3 - 7	0.11	0.25	0.16	0.38	0.11	0.26
Ascidian larvae	0.05 - 7	0.00	0.25	0.00	0.38	0.00	0.26
Fish larvae	90 - 730	3.16	25.61	4.89	39.67	3.35	27.14

Continued.

Table 1. (Continued)

Taxa	**Life or larval span (days)**	**Winter -Post-Ave (Ti = 18.4 days)**		**Summer-Pre-Peak (Ti = 26.9 days)**		**Summer-Post-Peak (Ti = 17.9 days)**	
		Lower	Upper	Lower	Upper	Lower	Upper
Diatoms	3 - 7	0.11	0.25	0.16	0.38	0.11	0.26
Dinoflagellates	3 - 7	0.11	0.25	0.16	0.38	0.11	0.26
Jellyfish	90 - 365	3.16	12.81	4.89	19.84	3.35	13.57
Copepods	90 - 365	3.16	12.81	4.89	19.84	3.35	13.57
Penaid prawns	90 - 365	3.16	12.81	4.89	19.84	3.35	13.57
Bryozoan larvae	0.05 - 5	0.00	0.18	0.00	0.27	0.00	0.19
Barnacle larvae	14 - 21	0.49	0.74	0.76	1.14	0.52	0.78
Crab larvae	90 - 365	3.16	12.81	4.89	19.84	3.35	13.57
Crayfish larve	90 - 180	3.16	12.81	4.89	19.84	3.35	13.57
Mussel larvae	3 - 7	0.11	0.25	0.16	0.38	0.11	0.26
Oyster larvae	3 - 7	0.11	0.25	0.16	0.38	0.11	0.26
Abalone larvae	3 - 7	0.11	0.25	0.16	0.38	0.11	0.26
Urchin larvae	3 - 7	0.11	0.25	0.16	0.38	0.11	0.26
Ascidian larvae	0.05 - 7	0.00	0.25	0.00	0.38	0.00	0.26
Fish larvae	90 - 730	3.16	25.61	4.89	39.67	3.35	27.14

Table 2. Influence of the SCP on the hydrology and plankton extraction in Port Kembla Harbour. Data are from CLT 2006.

Ti = Time taken to extract the volume of water equal to that in the Harbour; Tr = Average residence time of water in the Harbour.

Parameter	Summer-Pre-Ave	Summer-Post-Ave	Winter-Pre-Ave	Winter-Post-Ave	Summer-Pre-Peak	Summer-Post-Peak
Flows (m3/s)	9.85	15.26	10.43	15.26	10.44	15.72
Ti (days)	28.5	18.4	26.9	18.4	26.9	17.9
Tr (days)	3.8	3.2	6.5	6.0	3.2	2.4
Extraction Index (Ti/Tr)	7.5	5.8	4.1	3.1	8.4	7.5
Difference in extraction: Pre and Post SCP	29.3%		32.3%		12.0%	