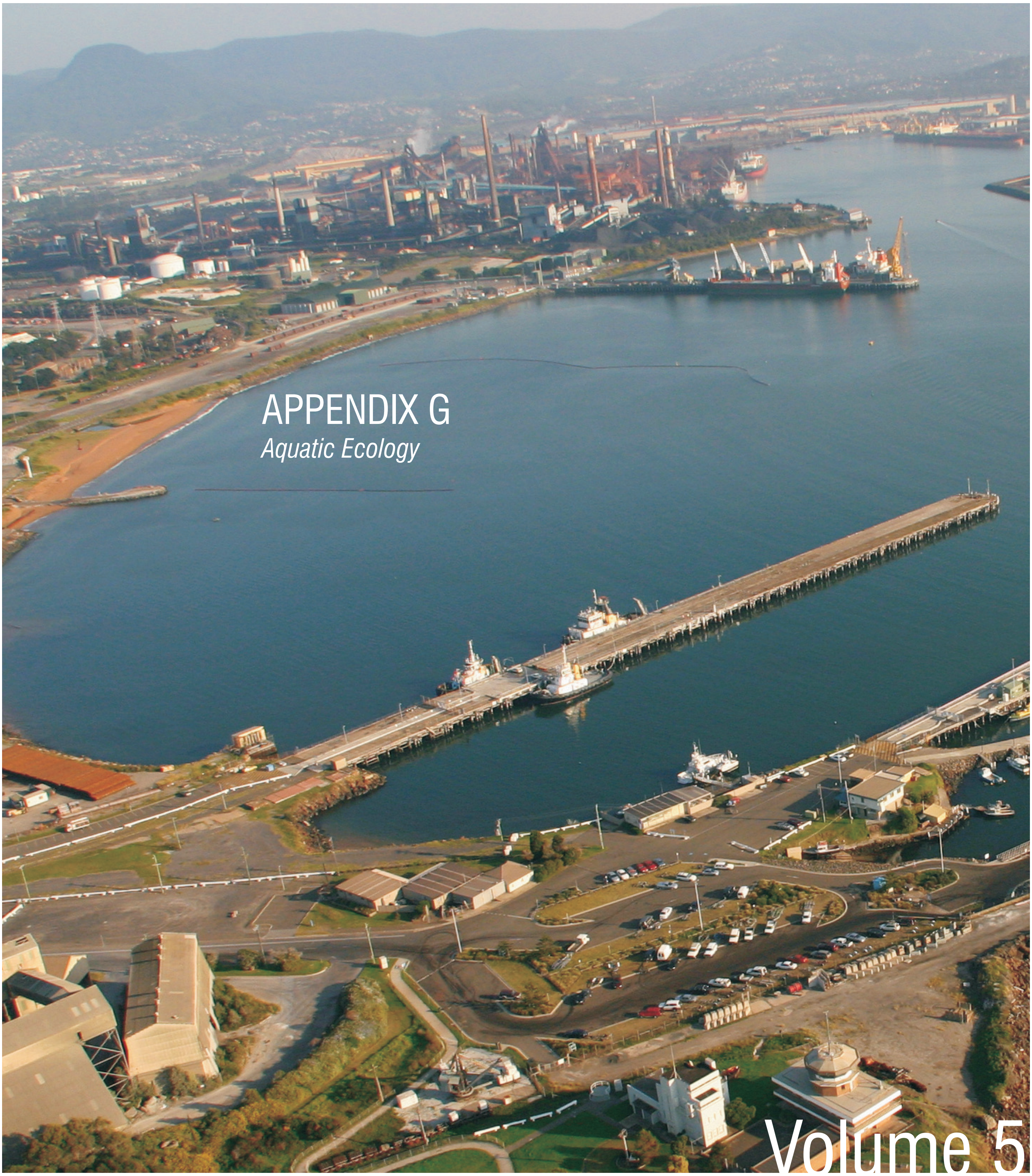

APPENDIX G

Aquatic Ecology

Volume 5

Survey of marine faunal communities in the area of the proposed Port Kembla Outer Harbour Development

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September 2009

Executive Summary

Port Kembla Port Corporation (PKPC) proposes to develop additional port side and landside facilities in the Outer Harbour of Port Kembla. The development requires a 42 ha reclamation, which is proposed to be carried out in stages, and a creation of 1770 metres of new berth length. Fill materials for the reclamation are proposed to be sourced from dredging the berthing basins and approaches for the new berths. Additional sources of fill would be acquired outside the project area. This report was commissioned by AECOM to undertake surveys of aquatic biota that may be potentially impacted by the Port Kembla Outer Harbour Development. The overall objective of the surveys is to provide a specialist report on marine flora and fauna in Port Kembla Outer Harbour upon which the environmental assessment will be made. This report provides the results of the surveys, describes the distribution of soft sediment infauna, fish and hard substrate biota within the Outer Harbour of Port Kembla, and suggests some potential impacts of the project on local marine communities.

Soft sediment infauna were sampled by Van Veen grab at five locations: two locations within the reclamation footprint (L3 – L4), two locations outside the direct project footprint (L1 – L2) and one location in Salty Creek (SC). At each location four sites were sampled and two replicate samples were collected from each site. The method of sample collection was consistent for Locations L1 - L4 and slightly modified for Salty Creek due to depth differences.

Fish surveys using visual census techniques were carried out at four locations: two locations on the Eastern Breakwall, one location at Jetty 6 and one location at Jetty 4. Subtidal epibiota were also surveyed at these four locations using photo-quadrat techniques. Both jetties would be directly impacted by the project while the Eastern Breakwall is outside the project footprint.

Sediment samples were very diverse and consisted of thirty-five taxa, including twenty-three families of Polychaete. The soft sediment habitat within the reclamation footprint (L3 – L4) had a similar infaunal assemblage composition and abundance to the habitat outside (L1 – L2) and therefore the overall diversity of the soft sediment community in the Outer Harbour is unlikely to be reduced by the proposed development. Potentially toxic dinoflagellate cysts (*Alexandrium* sp.) were identified at 3 sites from locations L2 (Sites A and B) and SC (Site A). The resuspension of toxic dinoflagellate cysts during dredging activities can result in the occurrence of toxic dinoflagellate blooms in enclosed high nutrient waters, however, this has not been reported from Port Kembla Harbour during previous dredging activities.

Sediments collected from L1 – L4 were composed of silty sand. In comparison, sediments collected from Salty Creek were mostly sand. Salty Creek had a distinct infaunal composition in comparison with L1 - L4 (likely related to sediment composition and depth) and included Oligochaetes and Nereid Polychaetes which were not present at the other locations. Salty Creek is within the proposed development area and may be impacted by the resuspension and deposition of finer sediments than those currently present. Dispersion of any suspended sediments toward Salty Creek during the dredging works in Outer Harbour will need to be controlled without affecting the existing flushing characteristics of the creek.

Fish and hard substrate assemblages were similar along the Eastern Breakwall, but breakwall assemblages differed to those at the jetties. Fish were more diverse and abundant at the breakwall compared to the jetties. Hard substrate assemblages were more diverse on Jetties 4 and 6 than the Eastern Breakwall which was dominated by barnacles and encrusting algae. None of the species identified during the surveys are listed as threatened or protected and no marine pest species occurred at the locations sampled.

Results from the survey indicate that the Outer Harbour of Port Kembla presents a similar habitat to other local estuaries with regards to the composition of soft sediment assemblages (e.g. Botany Bay; Morrisey et al. 1992), hard substrate assemblages (e.g. Port Hacking; Dafforn et al. 2009) and fish (e.g. Sydney Harbour; Clynick et al. 2007). There is no evidence to suggest that any of the species identified in the current study are endemic to Port Kembla. Recruitment from outside the project footprint is likely to be sufficient to secure recovery of most vertebrate and invertebrate populations that may potentially be negatively affected by the proposed development.

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List of Acronyms and Abbreviations

ANOVA	Analysis of variance
CAP	Canonical analysis of principle coordinates
DF	Degrees of freedom
F	F value
MS	Mean squares
MLWS	Mean Low Water Springs
NIS	Non-indigenous species
P	Probability
PERMANOVA	Permutational multivariate analysis of variance
PKPC	Port Kembla Port Corporation
SE	Standard Error
SS	Sum of squares
UNSW	The University of New South Wales

1. Introduction

General Background

Port Kembla Port Corporation (PKPC) is seeking planning approval under Part 3A for the Port Kembla Outer Harbour Development. This development will comprise:

- At least 42 hectares of reclamation, carried out in stages to accommodate a new multi-purpose terminal and a new container terminal
- 1770 metres total new berth length.
- A total of seven new berths, including:
  - Four container berths with a total berth length of 1150 metres;
  - Two new multi purpose / bulk berths with a total berth length of 620 metres; and
  - A new multi purpose / bulk berth at the site of the existing Jetty 6 (Port Kembla Gateway).
- Retention of the existing oil berth on the northern breakwater of the Outer Harbour.
- Berthing basins and approaches with up to 15m water depth below Port Kembla Harbour Datum (PKHD) for new berths.
- Road and rail infrastructure to support the expansion.

This report was commissioned by AECOM on behalf of PKPC to provide a specialist report of the results of the quantitative surveys of marine flora and fauna in Port Kembla Outer Harbour upon which the environmental impact assessment will be made.

Box 1

- The aim of the report is to describe the marine flora and fauna of the Outer Harbour and based on the results of this survey and previous studies to support the environmental impact assessment of the Port Kembla Outer Harbour Development
- Surveys of soft sediment infauna, fish species abundance and distribution and a quantitative assessment of the hard-substrate biota were carried out in June 2009 and potentially toxic dinoflagellate cysts were surveyed in September 2009.

2. Experimental Design and Data Collection

Soft sediment infauna, fish and hard-substrate sampling was conducted in the Outer Harbour of Port Kembla, during the week of 15th to 19th June, 2009. Soft sediment sampling for the identification of potentially toxic dinoflagellate cysts was conducted on September 3rd 2009.

2.1. Soft sediment infauna

Samples of soft sediment assemblages were collected using a Van Veen grab in four locations approximately 5 m below mean low water springs (MLWS) (Figure 1). Two locations were in the area proposed to be reclaimed (L3 – L4), and two were in area of the Outer Harbour outside the reclamation zone (L1 – L2). Within each location we sampled at four sites, spaced approximately 100 - 300 m apart. The positions of sites were predetermined and located with GPS by boat. Two replicate grabs were taken at each site, 2 - 5 m apart. This hierarchical sampling design addresses spatial variation in soft sediment assemblages found in previous studies (Morrisey et al. 1992, Stark 2000) and within site replicates were taken to obtain a better estimate of the site infaunal abundances. Infauna were also sampled at four sites in Salty Creek, spaced in 20 m intervals upstream from the mouth of Salty Creek (Figure 1). The mean low water level prevented the use of a boat and Van Veen grab, therefore two replicates samples were collected 2 - 5 m apart at each site by hand. Upon collection a 750 mL sample of sediment was taken from each grab and core, and preserved immediately in 7% buffered formaldehyde in seawater.

Subsamples of 200 mL were sieved through 0.5 mm mesh and sorted in trays under microscopes and all fauna removed for identification. Type specimens were collected from each subsample and preserved in 90% ethanol. Polychaetes were identified to family and other taxa to phylum (molluscs) or sub-phylum (crustaceans). To assess sediment grain size characteristics, subsamples of 70 ml were sieved through 63 μm mesh to separate the coarse (sand > 63 μm) and fine (silt < 63 μm) fractions. Excess water was siphoned off and the sediments dried and weighed.

Soft sediment sampling for the identification of potentially toxic dinoflagellate cysts was conducted in an identical manner to that for soft sediment infauna (described above) except that samples were not preserved in formalin. Instead, the surface layer of the grab sample was identified (by oxidation colour), separated and preserved immediately in a dark container refrigerated at 4 degrees. Subsamples were delivered to taxonomic experts for sorting and identification of potentially toxic dinoflagellate cysts. Two replicate subsamples were assessed from each of 2 – 4 sites in each location (L1 = A – D, L2 = A – B, L3 = A – D, L4 = A – B, SC = A – B).

2.2. Fish

Fish were sampled using visual diver surveys along four 50 m transects (Figure 1). Two transects were conducted along existing piers of Jetty 6 and 4 (T1 and T2 respectively) and two were along the Eastern Breakwall (T3 and T4). Divers swam once along each transect at a steady pace and recorded all fish observed. Transects were at 3 m depth below MLWS to be consistent with the hard substrate survey. At the end of each transect the divers remained stationary at 3 m for 5 min, and recorded all fish observed. The stationary count aimed to reduce the bias caused by fish avoidance of moving divers, but counts from the transects and the stationary observations were similar and were therefore combined to produce a better estimate of fish diversity and abundance at each location.

2.3. Hard substrate biota

Hard substrate biota were sampled using photo-quadrats along four transects (Figure 1). Two transects surveyed existing piles of Jetty 6 and 4 (T1, T2 respectively) and two surveyed the Eastern Breakwall (T3, T4). The survey locations along the two jetties are in the direct footprint of the project and the Eastern Breakwall locations are outside the direct project area. High resolution digital photographs were taken of 25 x 25 cm photo-quadrats along each transect at 3 m depth. This depth is consistent with previous studies of hard substrate assemblages in Port Kembla (Piola and Johnston 2006, Johnston and Clark 2007, Dafforn et al. 2009). The distance between photo-quadrats on the breakwall was determined by the distance between the jetty piles (~ 5m). On Jetty 6, the surveyed transect was located on the northwest side and on Jetty 4 it was on the east side of the jetty. Photo-quadrats on jetty piles were taken on the pile side facing the berthing basin. Fifteen replicate photo-quadrats were taken along each transect. Twenty five randomly positioned points were superimposed onto a digital image of each photo-quadrat, and the flora and fauna occurring under each point were recorded. This method has previously been used to sample hard substrate assemblages and gives a suitable level of precision (Preskitt et al. 2004, Glasby et al. 2007, Dafforn et al. 2008). Flora and fauna were identified to the lowest taxonomic level discernable from the photographs.

2.4. Data Analyses

The distributions of soft sediment infauna in L1 – L4 were analysed using nested ANOVA, with the factors Location (a=4), Site nested within location (b=4), and two replicates per site (n=2). This design was also used for multivariate analysis of assemblage data using PERMANOVA (Anderson 2005). Soft sediment infauna were patchily distributed in Salty Creek and could not be analysed statistically, therefore means and standard errors are compared.

Fish observations on abundance and distribution were compared between sites and displayed in a table. Abundances were grouped into categories (X = 1-5, XX = 6-20, XXX = 21-100, XXXX = 101-1000, XXXXX = >1000). Swimming transects and stationary counts for each species were in the same abundance category indicating the absence of sampling bias and were therefore combined.

Hard substrate taxa occupying > 5 % space were analysed using ANOVA with the factor Transect (a=4) and 15 replicates per transect (n=15). Hard substrate assemblages were also compared between transects with canonical analysis of principle coordinates (CAP). All data were assessed for normality and homogeneity of variance using Cochran's C test and In (x + 1) transformations were used to obtain homogeneous variances where necessary.

Box 2

- Soft sediment infauna were quantified in sediment samples collected with a Van Veen grab except in Salty Creek where they were collected using a handheld core
- Fish assemblages were assessed using diver transects and stationary counts
- Hard substrate biota were quantified from photo-quadrats
- Data were assessed with multivariate and univariate analytical techniques including PERMANOVA, CAP and ANOVA

3. Results

3.1. Soft Sediment Infauna

Sediment sampled collected from locations L1 – L4 had similar proportions of sand and silt while Salty Creek samples were composed almost entirely of sand (Figure 2). Thirty-five taxa were identified from the sediment samples (Table 1). Most locations were dominated by polychaete worms which comprised twenty-three families. Crustaceans were also very abundant in most locations and were represented in 6 orders. The soft sediment infaunal assemblages at Locations L1-L4 were were dominated by an abundance of Polychaetes (families Cirratulidae, Spionidae, Syllidae, Opheliidae, Arabellidae, Capitellidae, Orbiniidae) Nematodes, Ophiuroids and Decapods (Table 1; Figure 3).

Multivariate analysis of spatial variation showed that soft sediment assemblages were similar between Locations L1 - L3, but differed significantly at L4 (Table 2). Abundances of the Polychaete families appeared to differ between locations and sites, although this was only significant for Spionidae and Cirratulidae (Figure 3; Table 3). Spionid Polychaetes were most abundant at L3 while Cirratulid Polychaetes differed between sites at L2 and were most abundant at Site C (Tukeys test, $p < 0.01$). Other taxa included Crustaceans, Bivalves, Nematodes and Nemerteans did not differ between locations or sites within locations (Figure 4; Table 4).

Soft sediment infauna at Salty Creek varied between sites were characterized by the presence of Bivalves, Nereid Polychaetes and Oligochaetes (Table 1). No infauna were found in samples from Site A and a single Bivalve was found at Site

B (Figures 3 – 4; Table 1). Sites C and D supported more diverse assemblages including 3 of the twenty-three Polychaete families as well as Crustacean and Molluscan representatives and Oligochaetes (only at Site C) (Table 1). Nereid Polychaetes were between 8 – 10 times more abundant at Site D than C (Table 1).

Potentially toxic dinoflagellate cysts (*Alexandrium* sp.) were identified at 3 sites from locations L2 (Sites A and B) and SC (Site A) (Table 5). Abundances of *Alexandrium* sp. were low; 5/ml (L2A), 2/ml (L2B) and 1/ml (SCA) and the toxic dinoflagellate *Gymnodinium catenatum* was not identified in any of the samples (Table 5).

3.2. Fish

Twenty-four species of fish were identified during the survey (Table 6). The most abundant and widely distributed species was Yellowtail, which was present at all locations (Table 6). Yellowfin bream, Mado and Moon wrasse were also very abundant, but were not noted at all locations. Yellowfin bream were only found around the jetties and Moon Wrasse were only found along the breakwall. Mado were very abundant on the breakwall, and a few individuals were found at Jetty 4. Four fish species occurred in low numbers (< 5 individuals) and were only found around the jetties including the Eastern smooth boxfish, Immaculate damsel, Eastern rock blackfish and Yellow-finned leatherjacket.

3.3. Hard Substrate Biota

The main taxa identified in photo-quadrats included Colonial Ascidians, Solitary Ascidians, Barnacles, Polychaetes, Bivalves, Bryozoans, Poriferans, Turfing Algae and Encrusting Algae (Table 7). CAP highlighted similarities between the northern and southern transects along the Eastern Breakwall (T3 and T4). The Eastern Breakwall was characterized by the presence of Encrusting Algae and Barnacles (Figure 6). Solitary Ascidians, Bivalves and Colonial Ascidians occupied most space along Jetty 6 (T1) and Poriferans, Bryozoans, Polychaetes, Cnidarians and Bare Space characterized Jetty 4 (T2) (Figure 5). Univariate ANOVAs found similar distributional patterns to CAP, with Colonial and Solitary Ascidians occupying most space along T1 (Figure 5; Table 7). Barnacles and Encrusting Algae were the dominant space occupiers along T3 and T4, and Poriferans, Bryozoans, Polychaetes, Cnidarians and Bare Space were the dominant cover along T2 (Figure 5; Table 7).

3.4. Introduced marine pest species

Non-indigenous species (NIS) were identified in the photo-quadrat survey of the hard substrate. These included two species of Ascidian (*Botrylloides violaceus and Styela plicata)* and two species of Bryozoan *(Schizoporella errata* and *Watersipora subtorquata)*. NIS were only found on the jetty piles with *W. subtorquata* the exception that was found on the breakwall. These are not listed pest species known to pose environmental risk. NSW Department of Primary Industries lists 10 marine pests and none were found in Port Kembla Outer Harbour in the current study.

Box 3

- Multivariate analysis of spatial variation found differences in the soft sediment assemblage composition between L4 and L1 – L3.
- Analysis of variance revealed no significant differences in individual soft sediment taxa between locations or sites, apart from Spionidae (most abundant at L3) and Cirratulidae (differed between sites at L2).
- Soft sediment infauna varied between sites within Salty Creek and were almost absent from Site A and B. Oligochaetes were only found at Site C and Nereid Polychaetes were between 8 – 10 times more abundant at Site D than C.
- Fish assemblages were more diverse at the breakwall.
- Most abundant fish species was Yellowtail which was recorded at all the surveyed locations.
- Hard substrate biota were similar along the Eastern Breakwall, but differed between the breakwall and the two jetty locations, which were also different from each other.

4. Discussion

Sediments in Port Kembla Harbour are known to be contaminated by heavy metals, PAHs, cyanide and phenols (He and Morrison 2001). Disturbances such as dredging within Port Kembla Harbour can result in the resuspension of sediments and release of contaminants into the water column (Hedge et al. 2009). Micro- and macro-algae absorb contaminants through diffusion into their tissues and invertebrates take up contaminants through permeable body surfaces and by ingestion of contaminated material e.g. filtering sediment from the water column or bioturbating benthic sediments (Bryan 1971). The transfer of contaminants to higher trophic levels is also of major concern, especially when the organism in question is an important human food source (Keithly et al. 1999). The proposed redevelopment within Port Kembla Outer Harbour therefore has the potential for temporary impacts on marine communities when sediments are resuspended. Dispersion of contaminated sediment plumes will need to be contained during the dredging works in the Outer Harbour. Ecological changes may also arise due to the loss of soft sediment habitat under the reclamation footprint.

4.1. Soft Sediment Infauna

Sediment samples were very diverse and consisted of thirty-five taxa, including twenty-three families of polychaete worm. Community assemblage was similar across locations L1 – L3, but differed at L4. Univariate analysis of the major taxa found little spatial variation in infaunal abundance apart from two families of polychaete; Spionidae which was most abundant at L3 and Cirratulidae which differed between sites at L2. These differences could be related to patchy recruitment (Morrisey et al. 1992) and small-scale variation in environmental differences (Jayaraj et al. 2008) that are outside the scope of the current study. Since sediment composition was consistent across L1 – L4, differences are unlikely to be related to the fines content.

Another study of soft sediment assemblages in a local estuary (Botany Bay) found a similar composition, including Polychaetes (Cirratulidae, Syllidae, Sabellidae and Spionidae), Amphipods and Caprellids (Morrisey et al. 1992). Spionidae were also found to vary between locations (km's apart) which is a similar finding to the current study. Cirratulidae was the most abundant polychaete family in the current survey which is similar to a previous survey of Port Kembla Outer Harbour (AWI, 1999). The soft sediment habitat within the reclamation footprint (L3 – L4) has a similar infaunal assemblage composition and abundance to the habitat outside (L1 – L2) and therefore the overall diversity of the soft sediment community in the Outer Harbour is unlikely to be reduced by the proposed development.

Sediments collected from locations L1 – L4 were composed of silty sand. In comparison, sediments collected from Salty Creek were mostly sand. Salty Creek is within the proposed development area and therefore may be impacted by the resuspension and deposition of finer sediments that those currently present. The proposed development has the potential to alter sediment composition and result in a change in community composition, although there is evidence that sandy communities have the capacity to recover after moderate deposition of fine sediments (e.g. 2.5 mm deposit of fine sediment; Wulff et al. 1997). Dispersion of any suspended sediments toward Salty Creek during the dredging works in Outer Harbour will need to be controlled without affecting the existing flushing characteristics of the creek.

Potentially toxic dinoflagellate cysts have previously been recorded from sediments of Port Kembla Harbour (Pollard and Pethebridge 2002) and from other coastal estuaries in NSW (Hallegraeff et al. 1991). Toxic dinoflagellate cysts (*Alexandrium* sp.) were detected in low abundances during the current study at two sites within the proposed development zone in L2 and also at one site in Salty Creek. The resuspension of toxic dinoflagellate cysts during dredging activities can result in the occurrence of toxic dinoflagellate blooms in enclosed high nutrient waters, however, this has not been reported from Port Kembla Harbour during previous dredging activities.

4.2. Fish

We recorded twenty-four taxa during the study which is comparable to previous surveys of the Outer Harbour e.g. AWI (1999) found twenty-eight taxa, but were sampling with gill nets in addition to swimming transects. Thirteen species found in the current study were also found by AWI (1999). In the current study, fish assemblages appeared to be more diverse and species more abundant along the Eastern Breakwall compared to Jetties 4 and 6. This may have been related to habitat type and habitat preference or proximity to the open ocean resulting in greater exchange of biota. Recent studies suggest that fish assemblages differ around different hard substrates, including artificial structures such as jetty piles and natural rocky reefs (Clynick et al. 2007, 2008). Breakwalls present a more similar habitat to rocky reefs than jetty piles and so we would expect differences in fish assemblages between breakwalls and piles, as observed in the current survey. Some species were particularly abundant including the Yellowtail (around the jetty piles), while others were represented by a single individual during sampling e.g. Eastern Blue Groper.

Potential impacts from the development may differentially affect different fish species depending on their distribution within the harbour. If fish are restricted to locations where they were observed in the current survey, the development will differentially affect five fish species that were associated only with the Jetty 4 and 6. These included the abundant Yellowfin bream, but also the Eastern smooth boxfish, Immaculate damsel, Eastern rock blackfish and Yellow-finned leatherjacket which were represented by less than five individuals. The Eastern smooth boxfish, Immaculate damsel and Eastern rock blackfish have predominantly solitary habits and are generally found in low abundances (Williams and Bax 2001, Clynick et al. 2007, Malcolm et al. 2007). A previous survey of the Outer Harbour also found that these species were only present between Jetties 6 and 4 (which is within the current reclamation footprint) apart from the Yellow-finned leatherjacket which was also found at the Northern Breakwall (AWI, 1999). Many damselfish display territorial behaviour (Brawley and Adey 1977, Abrey 2005) and populations within the footprint are therefore more likely to be impacted than the blackfish, which are capable of large range shifts (Stuart-Smith et al. 2008) or bream, which are roaming pelagics and can move up to 2600km in a year (Hindell et al. 2008).

4.3. Hard Substrate Biota

The hard substrate assemblages identified during the photo-quadrat survey supported a broad range of sessile invertebrate taxa including Colonial Ascidians, Solitary Ascidians, Barnacles, Polychaetes, Bivalves, Bryozoans, Poriferans, Turfing Algae and Encrusting Algae. Similar hard substrate taxa, including the NIS found in the current study, have been previously identified in Port Kembla on settlement plates (Dafforn et al. 2009). Northern and southern transects along the Eastern Breakwall were similar and were dominated by Barnacles and Encrusting Algae. Jetties 4 and 6 supported a greater range of taxa than the Eastern Breakwall locations, but differed from each other with respect to composition, for example Solitary Ascidians, Bivalves and Colonial Ascidians occupied more space at Jetty 6 than Jetty 4 and the opposite was true for Cnidarians, Polychaetes, Poriferans and Bryozoans. These differences between breakwall and jetty transects (and between Jetties 4 and 6) are likely related to substrate composition as well as the orientation (the jetties present a vertical substrate, while the breakwall surface is at an angle) and shading of the jetties (Anderson and Underwood 1994, Connell 1999, Glasby 1999). Tweed (2004) found hard substrate assemblages on Port Kembla breakwall similar to other local breakwalls (Wollongong and Groyne) and suggested spread of species from the breakwall to nearby rocky reef, but made no comparisons with piles.

The hard substrate biota have been regularly sampled in Port Kembla since 2004 and impacts of background contamination and recent operations on the local marine ecology of Port Kembla Harbour have been assessed (Johnston and Clark 2007, Dafforn et al. 2009, Hedge et al. 2009, Knott et al. 2009). Filter-feeding invertebrates represent important assemblages in these areas, inhabiting hard substrates such as rocky reefs (Carballo and Naranjo 2002). These assemblages are biologically diverse (Johnston and Keough 2005) and play important functional roles in the system, providing food and habitat for fish and mobile invertebrates and contributing to improved water quality through filter feeding in areas with little oceanic flushing (Hily 1991). Delicate filter-feeding mechanisms may become clogged under heavy suspended sediment loads, and they have been shown to rapidly accumulate heavy metals in their tissues under polluted conditions (Hansen et al. 1995, Cebrian et al. 2003).

Historically, the Inner Harbour of Port Kembla has been more contaminated than the Outer Harbour (He and Morrison 2001) and transplant experiments have shown increased survival and growth of filter-feeding invertebrates upon relocation from the Inner to Outer Harbour (Johnston and Clark 2007). The proposed redevelopment has the potential to reduce water quality in the Outer Harbour during the construction works through the resuspension of contaminated sediments and the possible release of pollutants into the water column, and result in decreases in the recruitment of sessile invertebrates (Knott et al. 2009). The resuspension of sediments may release large quantities of metals and PAHs into the water column (for examples of such events, see (Eggleton and Thomas 2004) and result in toxic effects on sessile invertebrates (Nayar et al. 2004). A bioaccumulation study (Hedge et al. 2009) conducted during dredging in Port Kembla found that oysters (*Saccostrea glomerata*, Gould 1850) deployed in Port Kembla accumulated two or three times greater metal concentrations during dredging compared with before dredging.

Heavy metal contaminants in estuaries can also influence the distribution of marine NIS and have been well studied in marine invertebrate communities (Brown et al. 2000, Morrisey et al. 2003, Dafforn et al. 2009). The build-up of heavy metals in estuaries has been posited as a major driver of invasion outcomes through the provision of a competitive advantage to more tolerant NIS (Piola & Johnston, 2007) and metal contamination has been shown to be an important correlate with invertebrate species distributions (Dafforn et al. 2009). The release of contaminants from sediment resuspension from the proposed development may therefore initially create conditions that favour recruitment of metal-tolerant NIS over native species. The resuspension of contaminated sediments in the outer Harbour areas also has the potential to reduce recruitment of the dominant species (e.g. barnacles and polychaete worms) and other species (although the evidence for this is less conclusive) for an extended period before recovery begins (up to 4 months; Knott et al. 2009). New hard substrate constructed after the dredging operations have ceased is likely to be colonized relatively slowly with recruits arriving from vessel hulls as well as other hard substrate in the area (e.g. Eastern Breakwall).

It is difficult to separate the effects of the resuspended contaminants from the effect of increased turbidity, however Knott et al. (2009) suggest that the former is of greater importance. The resuspension of sediments during the proposed Outer Harbour development may also result in increased sediment loads, which can damage or block feeding and respiratory organs (Airoldi 2003, Maldonado et al. 2008). Knott et al. (2009) found that turbidity levels were not greatly elevated from a dredging event or at levels likely to cause mortality and argue that the contaminants in the sediments pose more of a risk to hard substrate assemblages than the suspended sediment load.

4.4. Threatened Species

None of the species identified in the surveys are listed as threatened in the NSW *Threatened Species Conservation Act 1995* or the *Fisheries Management Act 1994*.

Where organisms were identified to higher taxonomic group (e.g. class, order, family) there are no threatened species listed within these groups.

5. Acknowledgements

Marty Hing and Luke Hedge assisted with the field and lab sampling of soft sediment infauna, fish and hard substrate biota. Rene Reinfrank provided advice on sediment sorting and taxonomic resources and Brett Mulder assisted in sediment sorting and identification of organisms. Identification of dinoflagellate cysts in the sediments was undertaken by Martina Doblin. We thank Stefica Key for her helpful comments that improved the report.

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7. Figures

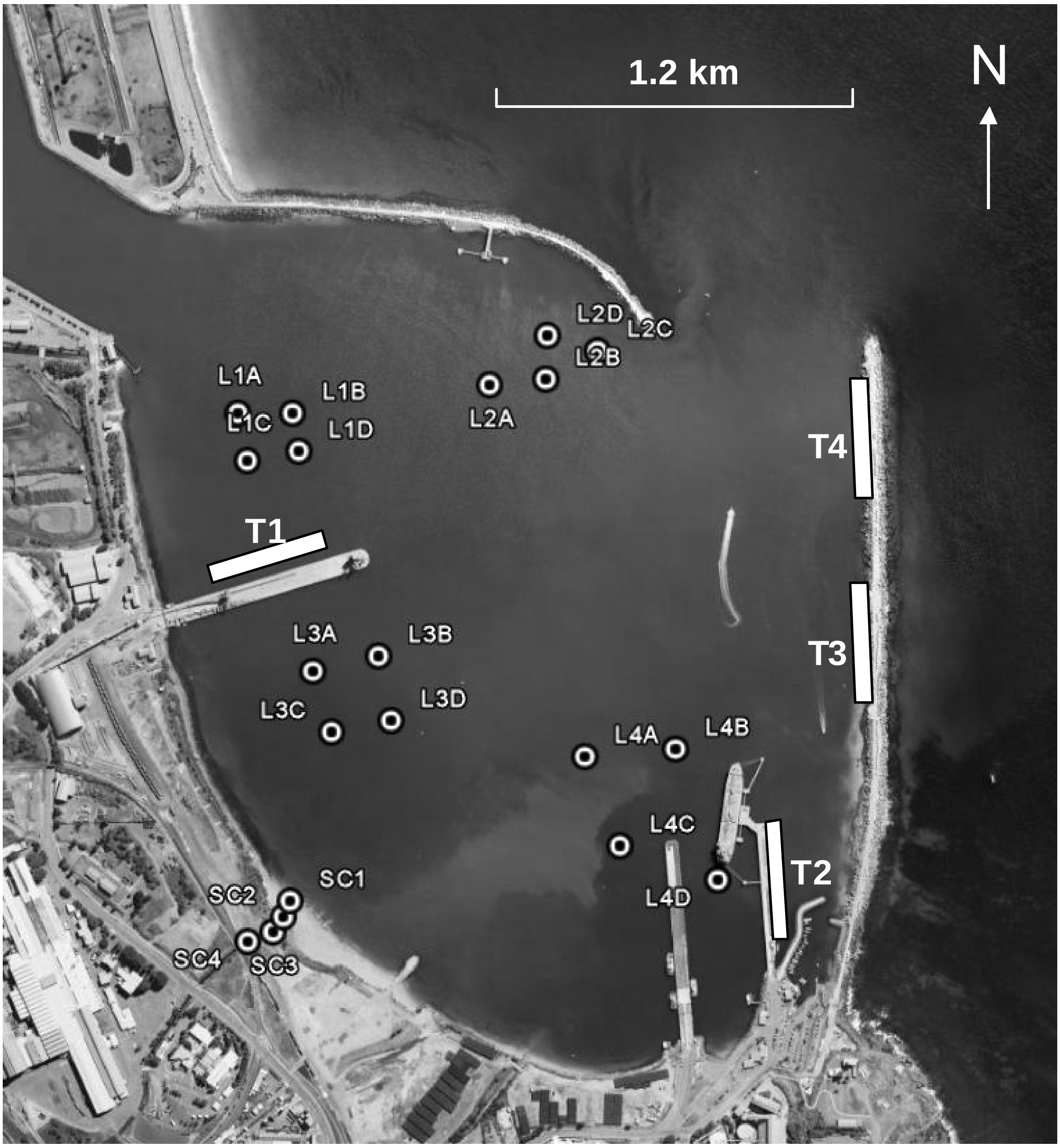

Figure 1. Map of sampling locations in Port Kembla Outer Harbour. White circles denote sampling sites A to D within five locations (L1 – L4, SC). Fish assemblages and hard substrate biota were sampled at 3m below the MLWS along the four transects shown in white (T1 – T4).

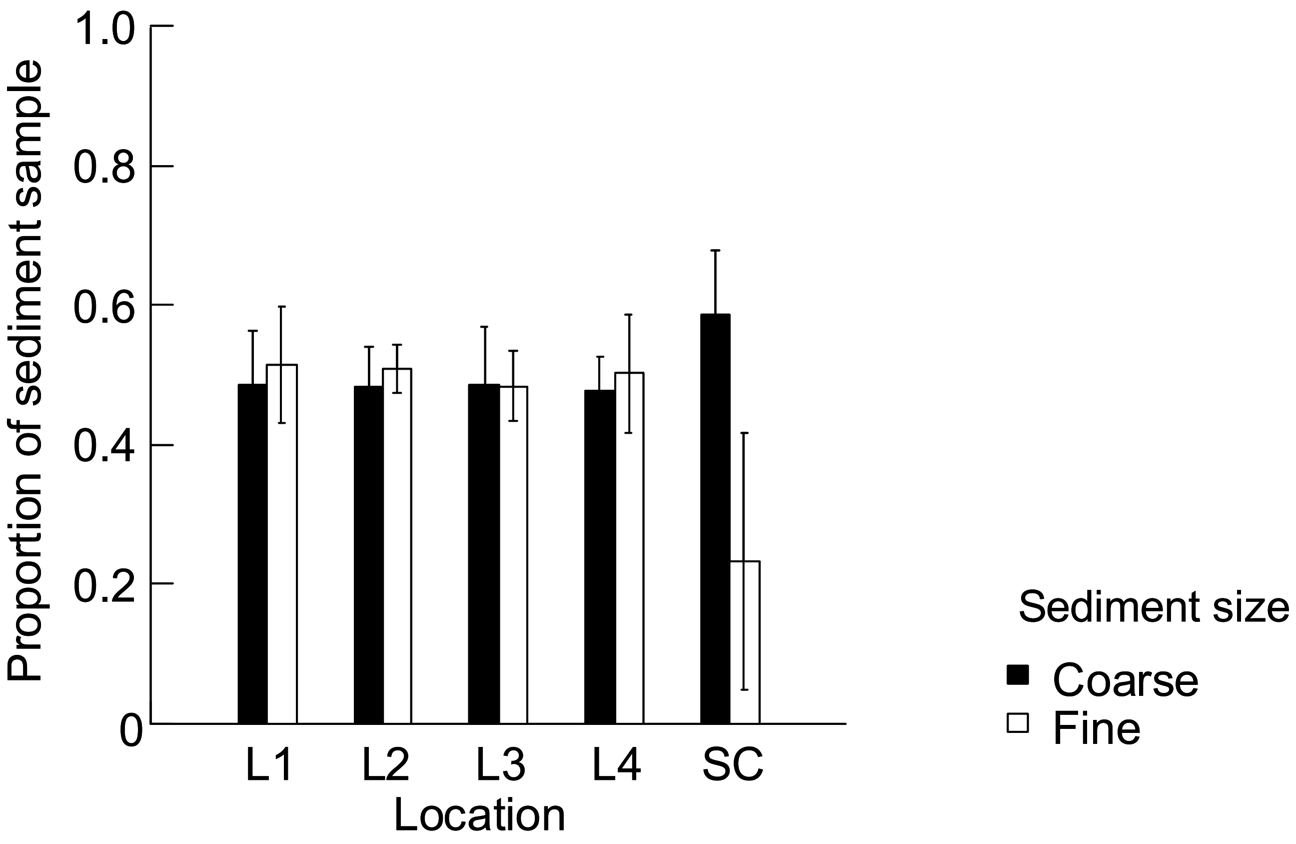

Figure 2. Proportion of sand (coarse) and silt (fine) in the sediments from each location in Port Kembla Outer Harbour.

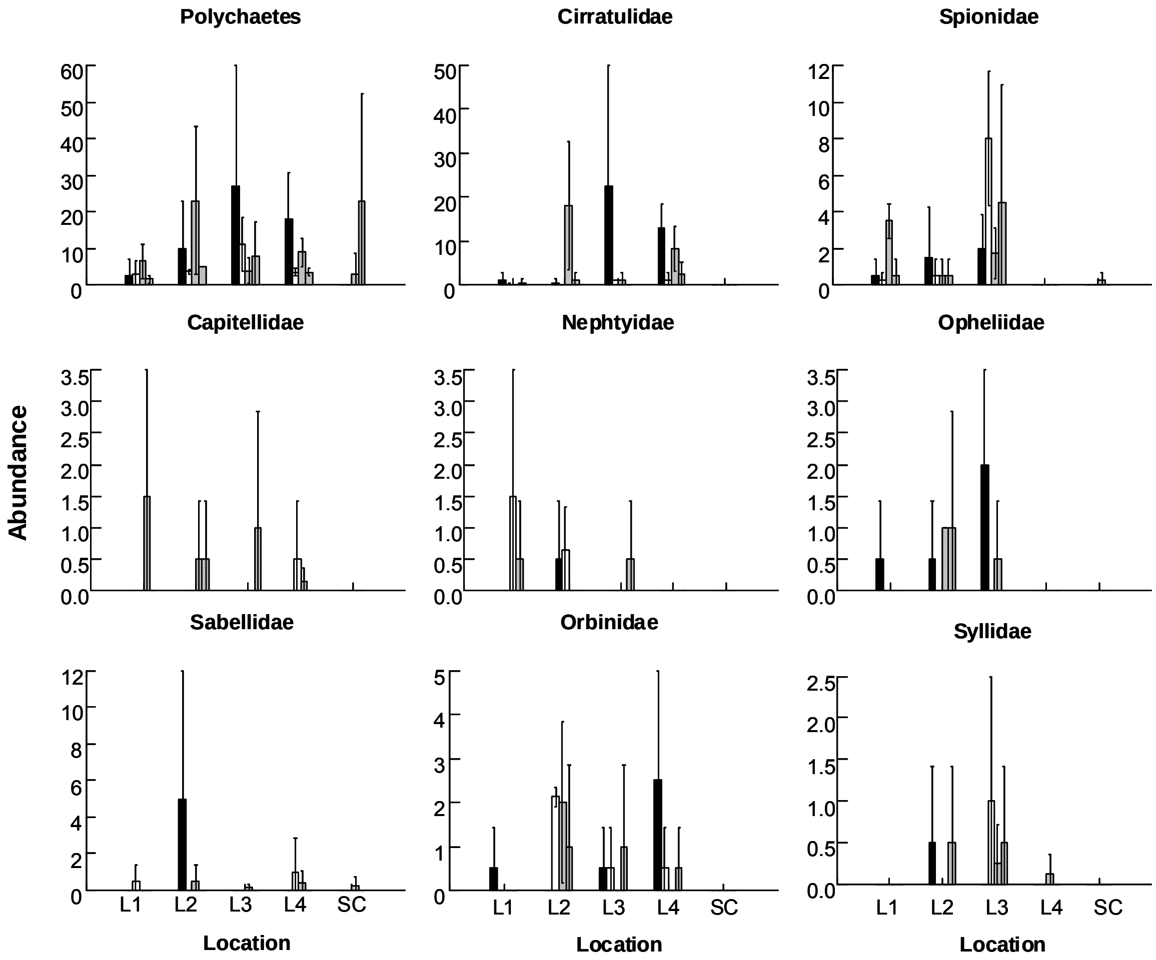

Figure 3. Spatial variation in the abundance of polychaetes and the main polychaete families in soft sediment samples.

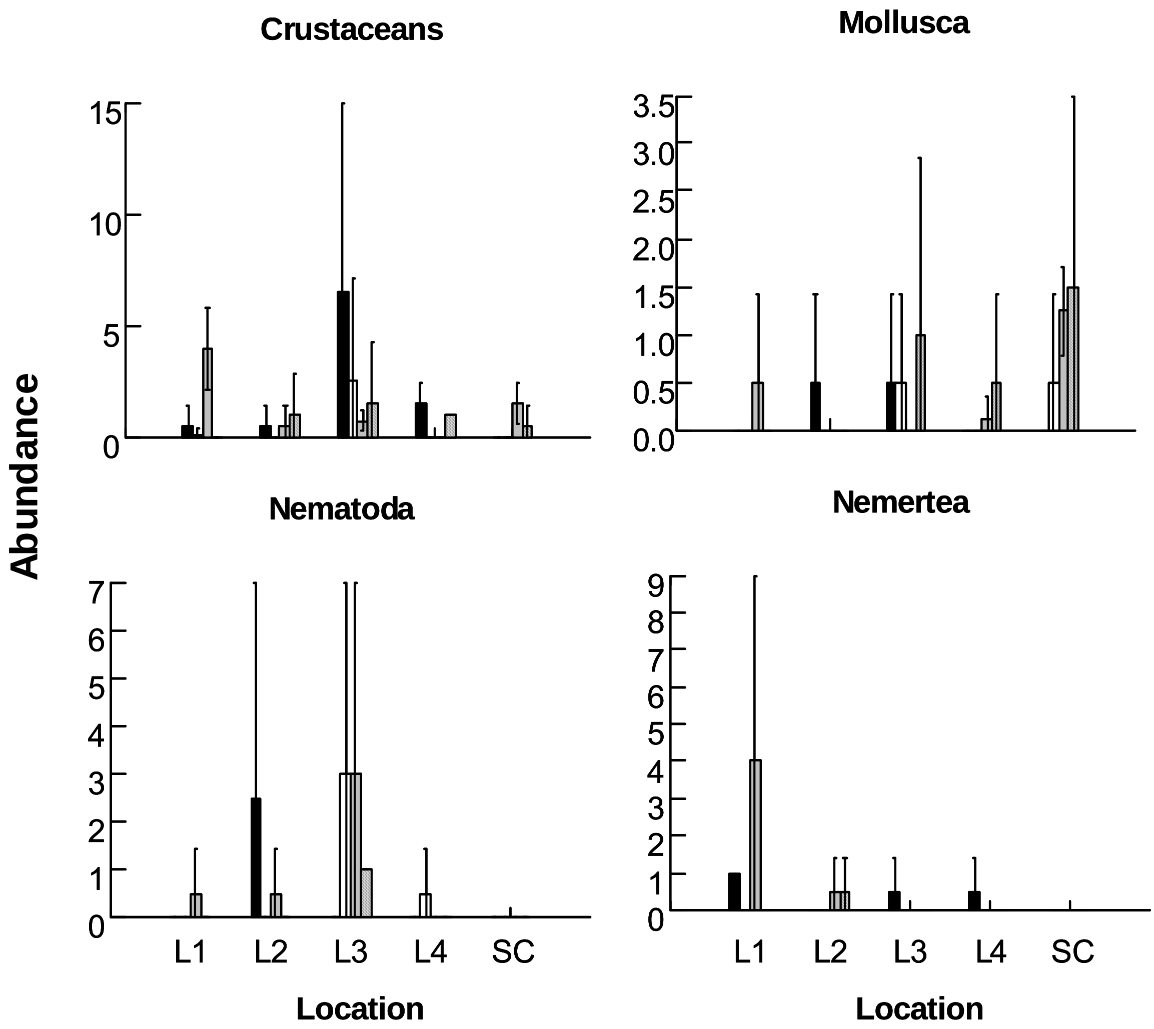

Figure 4. Spatial variation in the abundance of the other main taxa in soft sediment samples.

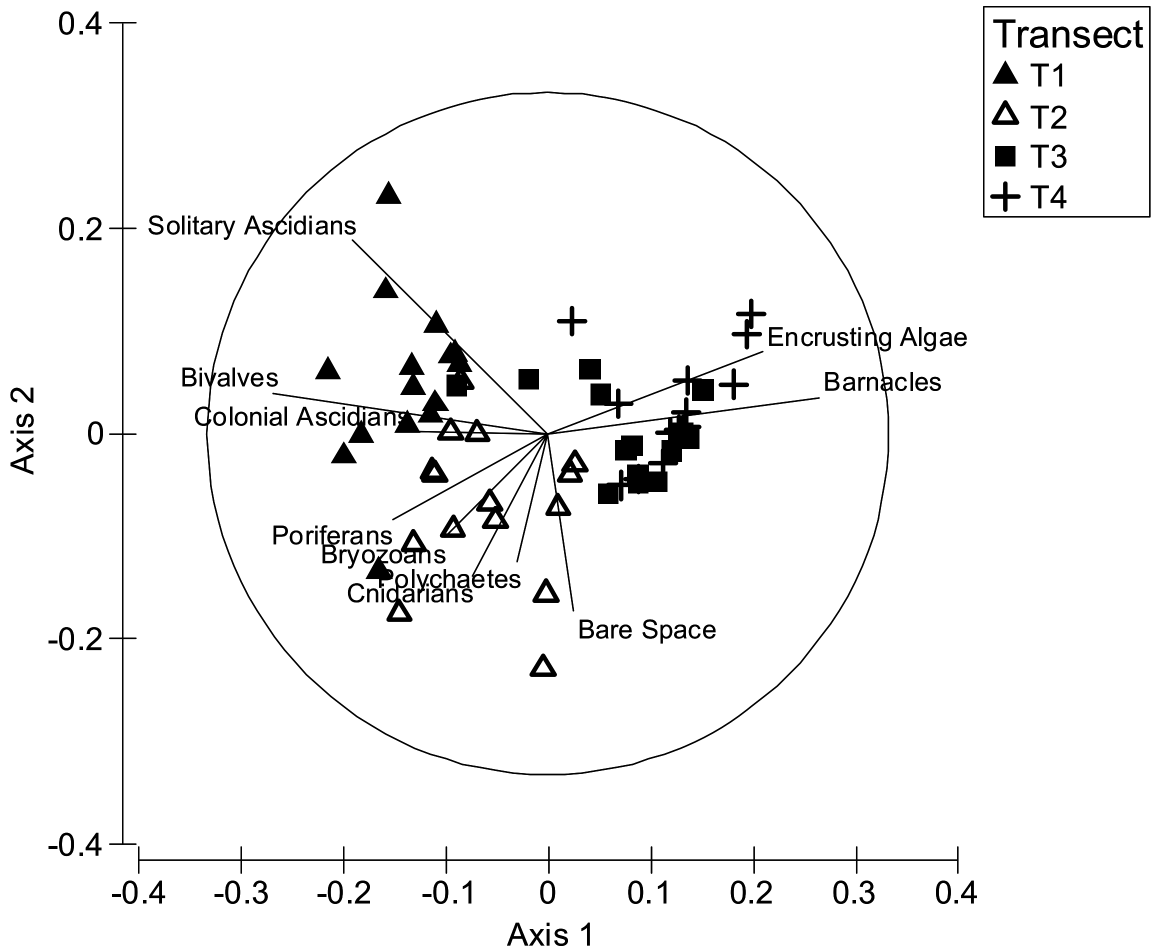

Figure 5. CAP plot of hard substrate biota along four transects within the Outer Harbour.

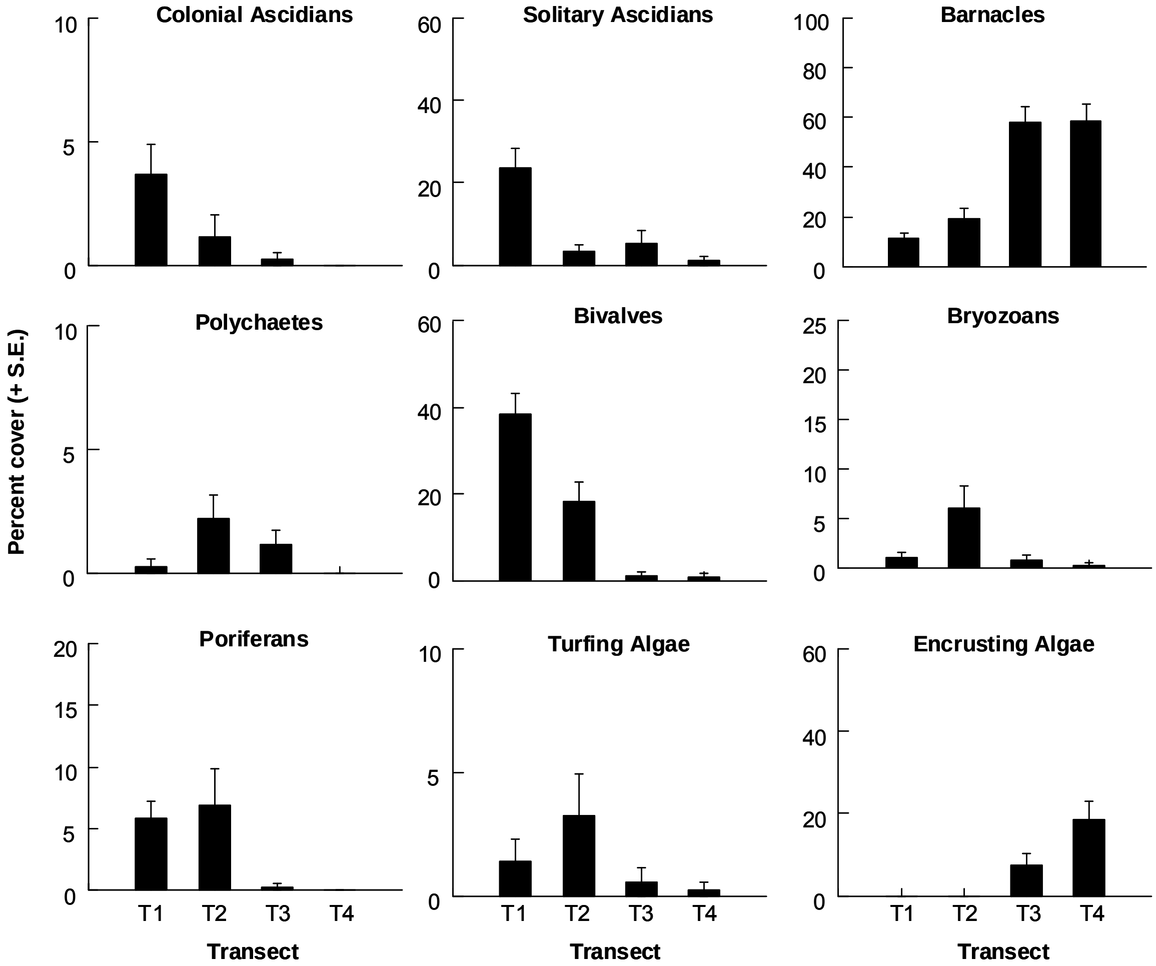

Figure 6. Spatial variation in percent cover of hard substrate biota along four transects within the Outer Harbour.

8. Tables

Table 1. Soft sediment taxa, mean and SE of the two replicate samples at sites and locations within Port Kembla Outer Harbour

Taxa	L1A Mean	L1A SE	L1B Mean	L1B SE	L1C Mean	L1C SE	L1D Mean	L1D SE
Arabellidae	0	0	0	0	0	0	0	0
Capitellidae	0	0	0	0	1.5	1.5	0	0
Chaetopteridae	0	0	0	0	0	0	0	0
Cirratulidae	1	1	0.125	0.125	0	0	0.5	0.5
Dorvilleidae	0	0	0	0	0	0	0	0
Glyconidae	0	0	0.5	0.5	0	0	0	0
Goniadidae	0	0	0	0	0	0	0	0
Hesionidae	0	0	0	0	0	0	0	0
Maldonidae	0	0	0	0	0	0	0	0
Nephtyidae	0	0	1.5	1.5	0.5	0.5	0	0
Nereididae	0	0	0	0	0.5	0.5	0.5	0.5
Opheliidae	0.5	0.5	0	0	0	0	0	0
Orbiniidae	0.5	0.5	0	0	0	0	0	0
Pilargidae	0	0	0.125	0.125	0	0	0	0
Sabellidae	0	0	0.5	0.5	0	0	0	0
Spionidae	0.5	0.5	0.25	0.25	3.5	0.5	0.5	0.5
Spirorbidae	0	0	0	0	0.5	0.5	0	0
Syllidae	0	0	0	0	0	0	0	0
Polychaete sp. 1	0	0	0	0	0	0	0	0
Polychaete sp. 2	0	0	0	0	0	0	0	0
Polychaete sp. 3	0	0	0	0	0	0	0	0
Polychaete sp. 4	0	0	0	0	0	0	0	0
Polychaete sp. 5	0	0	0	0	0	0	0	0
Amphipoda	0	0	0.125	0.125	4	1	0	0
Copepoda	0	0	0	0	0	0	0	0
Decapoda	0.5	0.5	0	0	0	0	0	0
Isopoda	0	0	0	0	0	0	0	0
Ostrocoda	0	0	0	0	0	0	0	0
Tanaidacea	0	0	0	0	0	0	0	0
Bivalvia	0	0	0	0	0.5	0.5	0	0
Gastropoda	0	0	0	0	0	0	0	0
Fish	0	0	0	0	0	0	0	0
Fly larvae	0	0	0	0	0	0	0	0
Nematoda	0	0	0	0	0.5	0.5	0	0
Nemertea	1	0	0	0	4	4	0	0
Oligochaeta	0	0	0	0	0.5	0.5	0	0
Ophiuroidea	0	0	0	0	0	0	0	0
Summary Statistics								
Number of individuals	4	3	3.125	3.125	16	10	1.5	1.5
Number of taxa	6	5	7	7	10	10	3	3
Number of polychaete taxa	4	4	6	6	5	5	3	3
Number of crustacean taxa	1	1	1	1	1	1	0	0
Number of molluscan taxa	0	0	0	0	1	1	0	0
Number of other taxa	1	0	0	0	3	3	0	0

Table 1. cont.

Taxa	L2A Mean	L2A SE	L2B Mean	L2B SE	L2C Mean	L2C SE	L2D Mean	L2D SE
Arabellidae	0	0	0	0	0.5	0.5	0.5	0.5
Capitellidae	0	0	0	0	0.5	0.5	0.5	0.5
Chaetopteridae	0	0	0	0	0	0	0	0
Cirratulidae	0.5	0.5	0	0	18	8	1	1
Dorvilleidae	0	0	0	0	0	0	0	0
Glyconidae	0	0	0	0	0	0	0	0
Goniadidae	0.5	0.5	0.125	0.125	0	0	0	0
Hesionidae	0.5	0.5	0.125	0.125	0	0	0	0
Maldonidae	0	0	0	0	0	0	0	0
Nephtyidae	0.5	0.5	0.625	0.375	0	0	0	0
Nereididae	0	0	0	0	0	0	0	0
Opheliidae	0.5	0.5	0	0	1	0	1	1
Orbiniidae	0	0	2.125	0.125	2	1	1	1
Pilargidae	0	0	0	0	0	0	0	0
Sabellidae	5	5	0	0	0.5	0.5	0	0
Spionidae	1.5	1.5	0.5	0.5	0.5	0.5	0.5	0.5
Spirorbidae	0	0	0	0	0	0	0	0
Syllidae	0.5	0.5	0	0	0	0	0.5	0.5
Polychaete sp. 1	0	0	0	0	0	0	0	0
Polychaete sp. 2	0.5	0.5	0	0	0	0	0	0
Polychaete sp. 3	0	0	0	0	0	0	0	0
Polychaete sp. 4	0	0	0	0	0	0	0	0
Polychaete sp. 5	0	0	0	0	0	0	0	0
Amphipoda	0	0	0	0	0	0	0	0
Copepoda	0	0	0	0	0	0	0	0
Decapoda	0.5	0.5	0.125	0.125	0.5	0.5	0.5	0.5
Isopoda	0	0	0	0	0	0	0	0
Ostrocoda	0	0	0	0	0	0	0	0
Tanaidacea	0	0	0	0	0	0	0.5	0.5
Bivalvia	0.5	0.5	0	0	0	0	0	0
Gastropoda	0	0	0	0	0	0	0	0
Fish	0	0	0	0	0	0	0	0
Fly larvae	0	0	0	0	0	0	0	0
Nematoda	2.5	2.5	0	0	0.5	0.5	0	0
Nemertea	0	0	0	0	0.5	0.5	0.5	0.5
Oligochaeta	0	0	0	0	0	0	0	0
Ophiuroidea	0	0	0	0	1	1	1	0
Summary Statistics								
Number of individuals	13.5	13.5	3.625	1.375	25.5	13.5	7.5	6.5
Number of taxa	12	12	6	6	11	10	11	10
Number of polychaete taxa	9	9	5	5	7	6	7	7
Number of crustacean taxa	1	1	1	1	1	1	2	2
Number of molluscan taxa	1	1	0	0	0	0	0	0
Number of other taxa	1	1	0	0	3	3	2	1

Table 1. cont.

Taxa	L3A Mean	L3A SE	L3B Mean	L3B SE	L3C Mean	L3C SE	L3D Mean	L3D SE
Arabellidae	0	0	0	0	0	0	0	0
Capitellidae	0	0	0	0	0	0	1	1
Chaetopteridae	0	0	0	0	0	0	0.5	0.5
Cirratulidae	22.5	21.5	1	0	1	1	0	0
Dorvilleidae	0	0	0	0	0	0	0	0
Glyconidae	0	0	0	0	0	0	0	0
Goniadidae	0	0	0	0	0	0	0	0
Hesionidae	0	0	0	0	0	0	0	0
Maldonidae	0	0	0	0	0	0	0	0
Nephtyidae	0	0	0	0	0	0	0.5	0.5
Nereididae	0	0	0.5	0.5	0	0	0	0
Opheliidae	2	1	0	0	0.5	0.5	0	0
Orbiniidae	0.5	0.5	0.5	0.5	0	0	1	1
Pilargidae	0	0	0	0	0	0	0	0
Sabellidae	0	0	0	0	0.125	0.125	0	0
Spionidae	2	1	8	2	1.75	0.75	4.5	3.5
Spirorbidae	0	0	0	0	0	0	0	0
Syllidae	0	0	1	1	0.25	0.25	0.5	0.5
Polychaete sp. 1	0	0	0	0	0.125	0.125	0	0
Polychaete sp. 2	0	0	0	0	0.125	0.125	0	0
Polychaete sp. 3	0	0	0	0	0	0	0	0
Polychaete sp. 4	0	0	0	0	0	0	0	0
Polychaete sp. 5	0	0	0	0	0	0	0	0
Amphipoda	3.5	3.5	0.5	0.5	0.625	0.375	1	1
Copepoda	0	0	0	0	0	0	0	0
Decapoda	0	0	0	0	0	0	0.5	0.5
Isopoda	0	0	0	0	0	0	0	0
Ostrocoda	0	0	0.5	0.5	0	0	0	0
Tanaidacea	3	3	1.5	1.5	0.125	0.125	0	0
Bivalvia	0	0	0	0	0	0	0	0
Gastropoda	0.5	0.5	0.5	0.5	0	0	1	1
Fish	0	0	0	0	0	0	0	0
Fly larvae	0	0	0	0	0	0	0	0
Nematoda	0	0	3	3	3	3	1	0
Nemertea	0.5	0.5	0	0	0	0	0	0
Oligochaeta	0	0	0	0	0	0	0	0
Ophiuroidea	0	0	1	0	0	0	1	0
Summary Statistics								
Number of individuals	34.5	31.5	18	10	7.625	6.375	12.5	9.5
Number of taxa	8	8	11	9	10	10	11	9
Number of polychaete taxa	4	4	5	4	7	7	6	6
Number of crustacean taxa	2	2	3	3	2	2	2	2
Number of molluscan taxa	1	1	1	1	0	0	1	1
Number of other taxa	1	1	2	1	1	1	2	0

Table 1. cont.

Taxa	L4A Mean	L4A SE	L4B Mean	L4B SE	L4C Mean	L4C SE	L4D Mean	L4D SE
Arabellidae	0	0	0	0	0	0	0	0
Capitellidae	0	0	0.5	0.5	0.125	0.125	0	0
Chaetopteridae	0	0	0	0	0	0	0	0
Cirratulidae	13	3	1	1	8.25	2.75	2.5	1.5
Dorvilleidae	0	0	0.5	0.5	0	0	0	0
Glyconidae	0	0	0	0	0	0	0	0
Goniadidae	0	0	0	0	0	0	0	0
Hesionidae	0	0	0	0	0	0	0	0
Maldonidae	2	2	0	0	0	0	0	0
Nephtyidae	0	0	0	0	0	0	0	0
Nereididae	0.5	0.5	0	0	0	0	0	0
Opheliidae	0	0	0	0	0	0	0	0
Orbiniidae	2.5	1.5	0.5	0.5	0	0	0.5	0.5
Pilargidae	0	0	0	0	0	0	0	0
Sabellidae	0	0	1	1	0.375	0.375	0	0
Spionidae	0	0	0	0	0	0	0	0
Spirorbidae	0	0	0	0	0	0	0	0
Syllidae	0	0	0	0	0.125	0.125	0	0
Polychaete sp. 1	0	0	0	0	0	0	0	0
Polychaete sp. 2	0	0	0	0	0	0	0	0
Polychaete sp. 3	0	0	0	0	0	0	0	0
Polychaete sp. 4	0	0	0	0	0	0	0	0
Polychaete sp. 5	0	0	0	0	0	0	0.5	0.5
Amphipoda	0.5	0.5	0	0	0	0	0.5	0.5
Copepoda	0	0	0	0	0	0	0	0
Decapoda	1	0	0	0	0	0	0.5	0.5
Isopoda	0	0	0	0	0	0	0	0
Ostrocoda	0	0	0	0	0	0	0	0
Tanaidacea	0	0	0	0	0	0	0	0
Bivalvia	0	0	0	0	0	0	0	0
Gastropoda	0	0	0	0	0.125	0.125	0.5	0.5
Fish	0.5	0.5	0	0	0	0	0	0
Fly larvae	0	0	0	0	0	0	0	0
Nematoda	0	0	0.5	0.5	0	0	0	0
Nemertea	0.5	0.5	0	0	0	0	0	0
Oligochaeta	0	0	0.5	0.5	0	0	0.5	0.5
Ophiuroidea	0	0	0	0	0	0	0	0
Summary Statistics								
Number of individuals	20.5	8.5	4.5	4.5	9	3.5	5.5	4.5
Number of taxa	8	7	7	7	5	5	7	7
Number of polychaete taxa	4	4	5	5	4	4	3	3
Number of crustacean taxa	2	1	0	0	0	0	2	2
Number of molluscan taxa	0	0	0	0	1	1	1	1
Number of other taxa	2	2	2	2	0	0	1	1

Table 1. cont.

Taxa	SCA Mean	SCA SE	SCB Mean	SCB SE	SCC Mean	SCC SE	SCD Mean	SCD SE
Arabellidae	0	0	0	0	0	0	0	0
Capitellidae	0	0	0	0	0	0	0	0
Chaetopteridae	0	0	0	0	0	0	0	0
Cirratulidae	0	0	0	0	0	0	0	0
Dorvilleidae	0	0	0	0	0	0	0	0
Glyconidae	0	0	0	0	0	0	0	0
Goniadidae	0	0	0	0	0	0	0	0
Hesionidae	0	0	0	0	0	0	0	0
Maldonidae	0	0	0	0	0	0	0	0
Nephtyidae	0	0	0	0	0	0	0	0
Nereididae	0	0	0	0	2.5	2.5	22.5	15.5
Opheliidae	0	0	0	0	0	0	0	0
Orbiniidae	0	0	0	0	0	0	0	0
Pilargidae	0	0	0	0	0	0	0	0
Sabellidae	0	0	0	0	0.25	0.25	0	0
Spionidae	0	0	0	0	0.25	0.25	0	0
Spirorbidae	0	0	0	0	0	0	0	0
Syllidae	0	0	0	0	0	0	0	0
Polychaete sp. 1	0	0	0	0	0	0	0	0
Polychaete sp. 2	0	0	0	0	0	0	0	0
Polychaete sp. 3	0	0	0	0	0	0	0	0
Polychaete sp. 4	0	0	0	0	0	0	0.5	0.5
Polychaete sp. 5	0	0	0	0	0	0	0	0
Amphipoda	0	0	0	0	1.25	0.75	0	0
Copepoda	0	0	0	0	0.25	0.25	0	0
Decapoda	0	0	0	0	0	0	0	0
Isopoda	0	0	0	0	0	0	0.5	0.5
Ostrocoda	0	0	0	0	0	0	0	0
Tanaidacea	0	0	0	0	0	0	0	0
Bivalvia	0	0	0.5	0.5	0.5	0.5	0.5	0.5
Gastropoda	0	0	0	0	0.75	0.75	1	1
Fish	0	0	0	0	0	0	0	0
Fly larvae	0	0	0	0	0	0	1.5	1.5
Nematoda	0	0	0	0	0	0	0	0
Nemertea	0	0	0	0	0	0	0	0
Oligochaeta	0	0	0	0	24.75	11.25	1	1
Ophiuroidea	0	0	0	0	0	0	0	0
Summary Statistics								
Number of individuals	0	0	0.5	0.5	30.5	16.5	27.5	20.5
Number of taxa	0	0	1	1	8	8	7	7
Number of polychaete taxa	0	0	0	0	3	3	2	2
Number of crustacean taxa	0	0	0	0	2	2	1	1
Number of molluscan taxa	0	0	1	1	2	2	2	2
Number of other taxa	0	0	0	0	1	1	2	2

Table 2. Multivariate analysis (PERMANOVA) of spatial variation of the abundance of soft sediment taxa collected in grab samples from Port Kembla Outer Harbour. Bold values indicate statistically significant results ($P < 0.05$). Results of pairwise comparisons for the factor Location are also presented.

Source	Degrees of freedom (df)	Mean Squares (MS)	F-value	P-value
Location	3	7009	2.27	**0.004**
Site (Location)	12	3084	1.11	0.275
Residual	16	2775		

Pairwise comparisons

Location: L1 = L2 = L3 ≠ L4

Table 3. Analysis of variance of spatial variation of the abundance of polychaetes collected in grab samples from Port Kembla Outer Harbour. Bold values indicate statistically significant results (P < 0.05). *indicates ln (x+1) transformation.

Source	**df**	**MS**	**P-value**	**MS**	**P-value**	**MS**	**P-value**
		(a) Polychaetes*		(b) Cirratulidae*		(c) Spionidae*	
Location	3	1.5204	0.1542	2.5172	0.2864	2.7717	**0.0035**
Site (Location)	12	0.7255	0.2881	1.7782	**0.0159**	0.3487	0.2478
Residual	16	0.5420		0.5545		0.2437	
		(d) Capitellidae*		(e) Nephtyidae*		(f) Opheliidae	
Location	3	0.0067	0.9841	0.1081	0.3862	0.8646	0.2757
Site (Location)	12	0.1311	0.5590	0.0981	0.5849	0.5938	0.1523
Residual	16	0.1444		0.1120		0.3438	
		(g) Sabellidae*		(h) Orbiniidae		(i) Syllidae*	
Location	3	0.2004	0.4481	1.9707	0.2379	0.1324	0.0901
Site (Location)	12	0.2113	0.6332	1.2207	0.2217	0.0484	0.8567
Residual	16	0.2588		0.8145		0.0895	

Table 4. Analysis of variance of spatial variation of the abundance of other taxa collected in grab samples from Port Kembla Outer Harbour. Bold values indicate statistically significant results (P < 0.05). *indicates ln (x+1) transformation.

Source	**df**	**MS**	**P-value**	**MS**	**P-value**
		(a) Crustaceans		(b) Mollusca	
Location	3	0.4439	0.4310	0.2676	0.2551
Site (Location)	12	0.4491	0.5329	0.1738	0.8017
Residual	16	0.4768		0.2832	
		(c) Nematoda		(d) Nemertea*	
Location	3	4.7083	0.1107	0.2343	0.3561
Site (Location)	12	1.8958	0.8073	0.1975	0.5372
Residual	16	3.1250		0.2109	

Table 5. Presence/absence of potentially toxic dinoflagellates at five locations within Port Kembla Outer Harbour.

Location	Site	Average cysts/ml	*Alexandrium*	*Gymnodinium catenatum*
L1	A	246	-	-
L1	B	163	-	-
L1	C	324	-	-
L1	D	191	-	-
L2	A	348	+	-
L2	B	373	+	-
L3	A	117	-	-
L3	B	22	-	-
L3	C	30	-	-
L3	D	10	-	-
L4	A	135	-	-
L4	B	91	-	-
SC	A	2	+	-
SC	B	0	-	-

Table 6. Presence and abundance of fish at four locations within Port Kembla Outer Harbour (X = 1-5, XX = 6-20, XXX = 21-100, XXXX = 101-1000, XXXXX = >1000)

Scientific name	Common name	Jetty 6 T1	Jetty 4 T2	Eastern Breakwall (south) T3	Eastern Breakwall (north) T4
Girella tricuspidata	Luderick	XX	X		XX
Achoerodus viridis	Eastern Blue Groper			X	
Anoplocapros inermis	Eastern Smooth Boxfish	X			
Acanthropagrus australis	Yellowfin Bream	XXXX	X		
Mecaenichthys immaculatus	Immaculate Damsel		X		
Girella elevata	Eastern Rock Blackfish		X		
Parupeneus spilurus	Blackspot Goatfish		X	X	
Cirrhitichthys aprinus	Blotched Hawkfish			X	
Trachinops taeniatus	Eastern Hulafish		XXX		XXX
Meuschenia trachylepis	Yellow-finned Leatherjacket		X		
Nelusetta ayraudi	Chinaman Leatherjacket			X	
Atypichthys strigatus	Mado		XXX	XXXXX	XXXXX

Table 6. cont.

Scientific name	Common name	Jetty 6 T1	Jetty 4 T2	Eastern Breakwall (south) T3	Eastern Breakwall (north) T4
Thalassoma lunare	Moon wrasse			X	XXXXX
Zanclus cornutus	Moorish Idol			X	
Enoplosus armatus	Old wife			X	XX
Schuettea scalaripinnis	Ladder-finned Pomfret			XXX	
Cheilodactylus fuscus	Red Morwong	X	XX	X	X
Crinodus lophodon	Rock Cale			X	X
Trachurus novaezelandiae	Yellowtail	XXXX	XXXX	XXXXX	XXXXX
Prionurus microlepidotus	Sawtail Surgeonfish			X	X
Scorpis lineolatus	Silver Sweep	XX	XXX	X	
Heteroclinus roseus	Rosy Weedfish			X	
Parma microlepis	White Ear			X	
Chelmonops truncates	Eastern Talma			X	

Table 7. Analysis of variance of spatial variation of percent cover of the main hard substrate biota along four transects in Port Kembla Outer Harbour. Bold values indicate statistically significant results (P < 0.05).

Source	**df**	**MS**	**P-value**	**MS**	**P-value**	**MS**	**P-value**
		Colonial Ascidians		Solitary Ascidians		Barnacles	
Transect	3	43.51	**0.003**	1566.27	**<0.001**	9293.23	**<0.001**
Residual	55	8.36		131.41		366.89	
		Polychaetes		Bivalves		Bryozoans	
Transect	3	11.69	**0.020**	4691.13	**<0.001**	101.22	**0.002**
Residual	55	3.31		155.72		17.97	
		Poriferans		Turfing Algae		Encrusting Algae	
Transect	3	144.76	**0.002**	24.13	0.117	1152.82	**<0.001**
Residual	55	26.58		11.74		92.82	

9. Appendices

Appendix 1. Presence/absence of non-toxic dinoflagellates at five locations within Port Kembla Outer Harbour.

Location	Site	Average cysts/ml	Diplopsalid	*Gymnodinium* (non *catenatum*)	*Gonyaulax*	*Pentapharsodin*	*Polykrikos*	*Protoceratium*	*Protoperidinium*	*Scrippsiella*
L1	A	246	-	+	-	-	-	-	+	+
L1	B	163	-	-	+	-	-	+	+	+
L1	C	324	-	+	+	-	+	-	+	+
L1	D	191	-	+	+	-	-	-	+	+
L2	A	348	+	+	+	+	+	-	+	+
L2	B	373	+	+	+	-	+	-	+	+
L3	A	117	+	+	-	-	-	-	+	+
L3	B	22	-	+	-	-	-	-	+	+
L3	C	30	-	+	-	-	+	-	+	+
L3	D	10	-	-	-	-	-	-	+	-
L4	A	135	-	+	+	-	-	-	+	+
L4	B	91	-	+	+	-	-	-	+	+
SC	A	2	-	+	-	-	-	-	-	-
SC	B	0	-	-	-	-	-	-	-	-

Appendix 2. Hard substrate taxa, mean and SE of the fifteen replicate photo-quadrats along transects within Port Kembla Outer Harbour

Taxa	Transect	Mean	SE	Taxa	Transect	Mean	SE
Bare Space	**T1**	13.9	2.6	**Encrusting Algae**	**T1**	0.0	0.0
	T2	35.7	6.3		**T2**	0.0	0.0
	T3	24.8	5.5		**T3**	7.5	2.8
	T4	20.0	4.7		**T4**	18.7	4.1
Barnacles	**T1**	11.2	2.2	**Polychaetes**	**T1**	0.3	0.3
	T2	19.4	3.4		**T2**	2.0	0.8
	T3	57.9	6.1		**T3**	1.1	0.5
	T4	58.7	6.5		**T4**	0.0	0.0
Bivalves	**T1**	38.4	4.8	**Poriferans**	**T1**	5.1	1.2
	T2	18.3	4.1		**T2**	6.0	2.3
	T3	1.3	0.7		**T3**	0.3	0.3
	T4	1.1	0.7		**T4**	0.0	0.0
Bryozoans	**T1**	1.1	0.5	**Solitary Ascidians**	**T1**	23.5	4.7
	T2	6.0	2.1		**T2**	3.4	1.5
	T3	0.8	0.4		**T3**	5.3	3.1
	T4	0.3	0.3		**T4**	1.1	1.1
Cnidarians	**T1**	0.0	0.0	**Turfing Algae**	**T1**	1.3	0.8
	T2	4.6	2.4		**T2**	3.1	1.4
	T3	0.0	0.0		**T3**	0.5	0.5
	T4	0.0	0.0		**T4**	0.3	0.3
Colonial Ascidians	**T1**	3.7	1.2				
	T2	1.1	0.8				
	T3	0.3	0.3				
	T4	0.0	0.0				

PORT KEMBLA
PORT CORPORATION

18 December 2009

Mr Allan Lugg
Senior Conservation Manager
Industry & Investment NSW
PO Box 97
Huskisson NSW 2540

Dear Mr Lugg,

Aquatic Habitat Offsets for the Proposed Outer Harbour Development, Port Kembla

I refer to correspondence received from Industry & Investment NSW (I&I) via the Department of Planning and recent teleconferences regarding the proposed Outer Harbour Development at Port Kembla. I understand that I&II is seeking a commitment from Port Kembla Port Corporation (PKPC) to undertake adequate compensatory measures to offset for the loss of aquatic habitat that will result from the proposed development. The purpose of this letter is to propose an indicative set of measures for your consideration in this regard (see Attachment A).

PKPC has identified several opportunities to incorporate hard substrate habitat features within the proposed development. Additional soft substrate habitat measures are proposed for Tom Thumb Lagoon and Garungaty Waterway. Both the Lagoon and the Waterway are tidal waterbodies which offer soft sediment habitat for fish and other aquatic fauna within the catchment of Port Kembla Harbour.

PKPC has initiated discussions with Wollongong City Council and Conservation Volunteers Australia (CVA) regarding potential habitat improvement projects at Tom Thumb Lagoon and Garungaty Waterway. The measures proposed are consistent with Council's (2007) *Estuary Management Plan* and the *Plan of Management* prepared for CVA in 2006. Council and CVA have jointly managed volunteers undertaking restoration works at Tom Thumb Lagoon for several years.

PKPC intends to seek a long-term (e.g. 10 yr) partnership arrangement with Council and CVA to fund the improvement works plus ongoing monitoring and maintenance to ensure that effective habitat outcomes are achieved and sustained on the site.

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ABN: 52 656 351 300

The attached set of measures is to give a preliminary indication of the works which PKPC is prepared to fund for discussion purposes. Once we are in broad agreement on the type and extent of works to be undertaken PKPC will formalise the offsets package for your consideration.

I look forward to discussing these measures with you in the near future. Please contact me (ph: 4275 0114, e: thb@portkembla.com.au) if you wish to discuss.

Yours faithfully,

Trevor Brown
Sustainability Coordinator

ATTACHMENT A

Port Kembla Outer Harbour Development
Indicative Compensatory Measures for Aquatic Habitat

The offset measures listed below are suggested to compensate for the loss of aquatic habitat as a result of proposed reclamation activities in the Outer Harbour. Refer to the Environmental Assessment report for the proposed development for a description of the development and its potential impact on aquatic habitats.

The value of existing aquatic habitats in the Outer Harbour is limited by:

- Sediment contamination;
- Several previous emplacements of dredge spoil on the bed of the harbour, the most recent of which occurred in 2008;
- Presence of many exotic and cryptogenic species including potentially toxic dinoflagellate cysts;
- Lack of seagrass, mangroves, saltmarsh, reefs or other natural habitat features that might provide high value habitat for fish.

Proposed Offset Measures

Hard Substrate Habitats

PKPC proposes to increase the length and diversity of hard substrate habitats in the Outer Harbour by creating new berth faces, pile-supported deck areas and rock revetments as part of the development. The berths and revetments will incorporate habitat features described in *Environmentally Friendly Seawalls: A Guide to Improving the Environmental Value of Seawalls and Seawall-lined Foreshores in Estuaries* (Sydney Metro CMA & DECC, 2009) including:

1. boulder-sized rocks placed without cement to form revetments will offer crevices in the intertidal and subtidal zones for the use of fish and invertebrates;
2. artificial rock pools in revetments to provide habitat for species such as sea-hares, sea urchins and octopus;
3. objects such as concrete knobs attached to vertical wall structures to add texture and form for the benefit of colonising organisms.

Pile-supported deck areas will have sloping rock revetments beneath them on the landward side with similar habitat features and values as those described at items 1 and 2 above. Where steel piles have been used in existing Outer Harbour structures there has been prolific growth of marine invertebrates (Fig. 1) indicating that they provide significant habitat value without needing further enhancement.

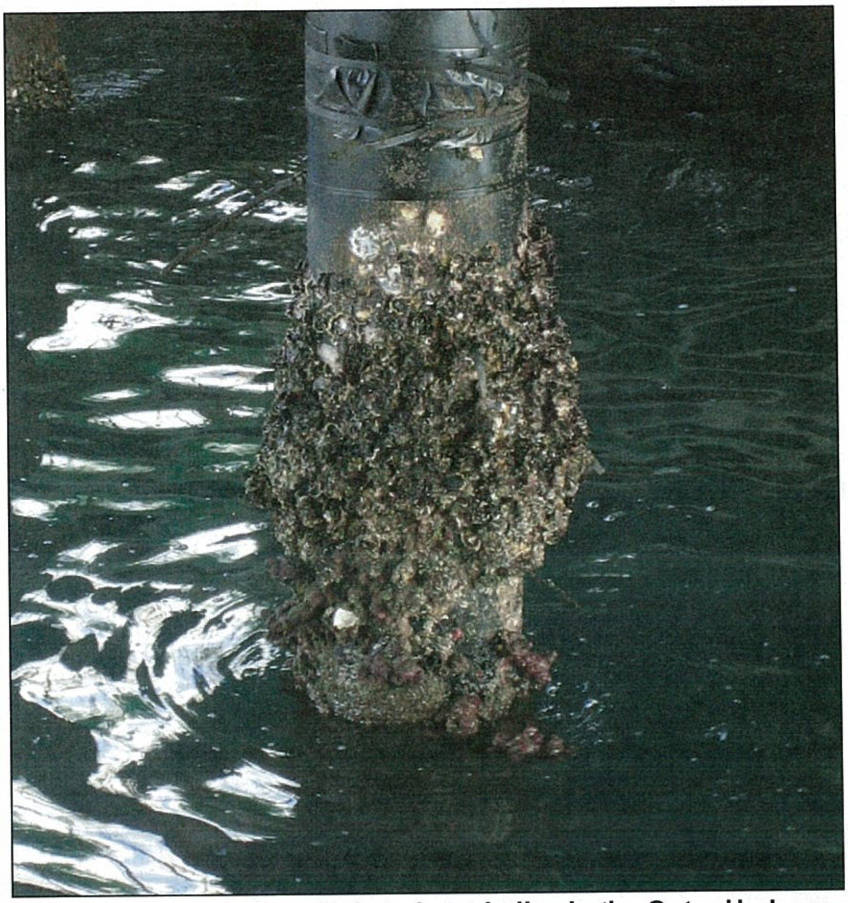


Fig. 1 Marine growth on jacketed steel piles in the Outer Harbour

Soft Substrate Habitats

The soft-substrate habitat areas to be lost as a result of Outer Harbour reclamation are mostly deep water areas (i.e. > 3m depth below low water level) with little or no habitat features. The proposed offsets for soft-substrate habitats will create and enhance higher-value shallow, vegetated areas in Garungaty Waterway and Tom Thumb Lagoon. The aim of the proposed measures is to complement existing restoration programs in these areas by increasing fish passage, tidal exchange and promoting estuarine communities such as saltmarsh, mangroves and seagrass which are currently under-represented in the catchment of the harbour. The measures are intended to increase aquatic biodiversity and provide greater opportunities for breeding and development of juvenile fish.

Measure	Ecological Benefit
1. Plant additional mangroves along Garungaty Waterway	Enhanced intertidal habitat for juvenile fish and invertebrates along 900 m of channel, stabilise sediments and trap nutrients
2. Partial removal of Garungaty Causeway	Increased tidal range to benefit saltmarsh, improved fish passage providing greater access to 1.7 km of tidal waterway upstream
3. Excavate channels & introduce seagrass in subtidal areas	Enhanced fish habitat in close proximity to mangroves
4. Excavate kikuyu areas and extend saltmarsh	Reduce weed infestation, increase saltmarsh area
5. Link isolated ponds with the main channel	Improved water quality in ponds, improved fish passage
6. Batter and stabilise steep banks in northern section of Garungaty Waterway	Reduced erosion and sedimentation from 500 m length of bank, essential precursor to restoration of riparian vegetation
7. Progressively restore appropriate riparian vegetation communities on Garungaty Waterway and the embankment south of Tom Thumb Lagoon	Provide vegetated buffer to protect aquatic habitats (i.e. mangroves, saltmarsh, seagrass and tidal channel) along 1.7 km long channel from weed invasion, edge effects, disturbances and pollution.

Establishment and enhancement of seagrass, mangroves, saltmarsh and riparian vegetation is consistent with *Policy & Guidelines: Aquatic Habitat Management & Fish Conservation* (NSW Fisheries, 1999). Partial removal of the Garungaty Causeway is consistent with the *NSW Weirs Policy*.

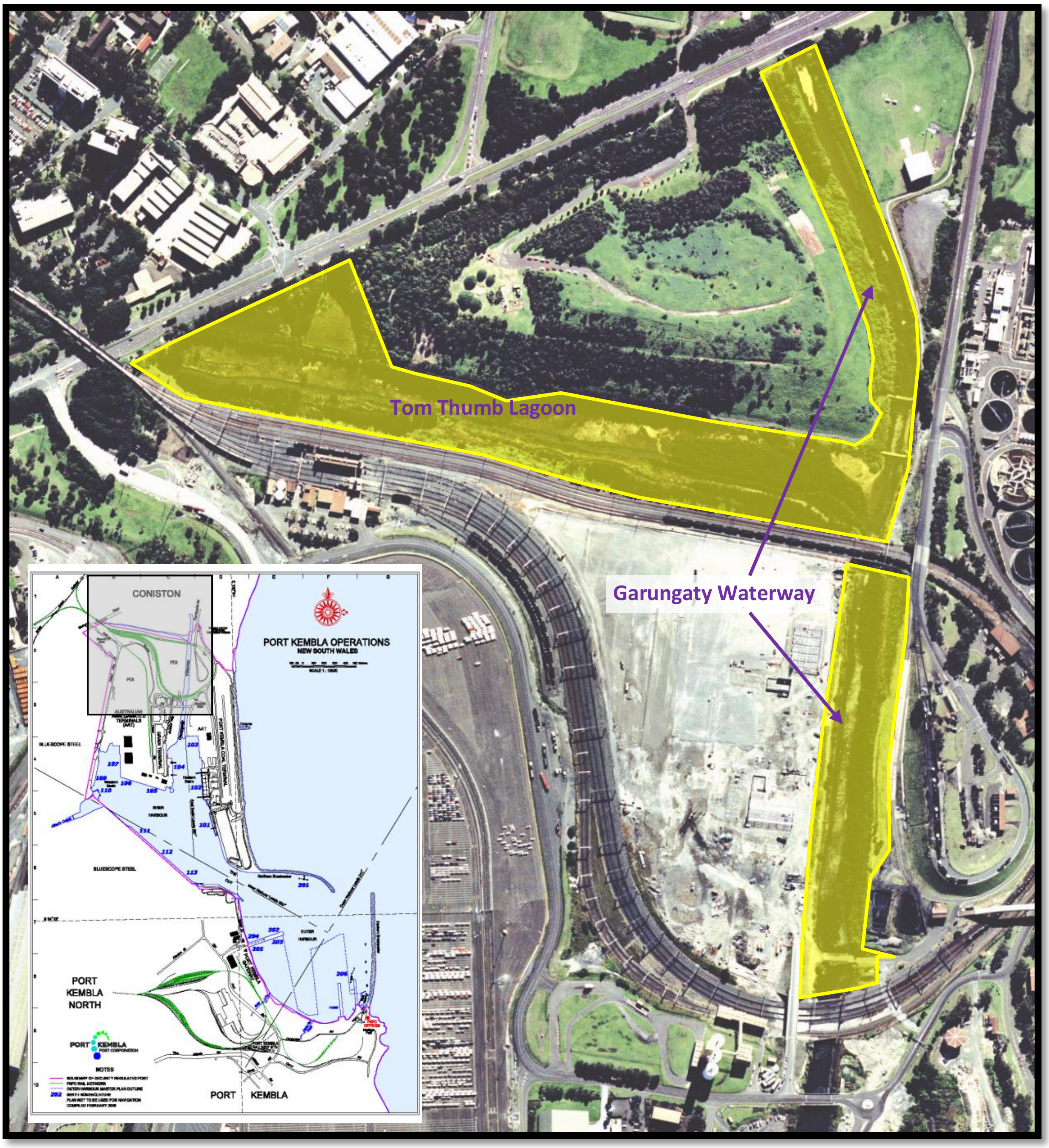
Additional community benefits to accrue from the proposed measures include:

- Expanded role for existing volunteer programs managed by Wollongong City Council and Conservation Volunteers Australia in the restoration and management of aquatic habitats at the site.
- Much of the site is on community land that is accessible to the public.
- Interpretive signage will be provided to allow visitors to gain an appreciation of the ecological values of the site
- Additional educational values will be realised through delivery of resources contained in *Conservation of Tom Thumb Lagoon – A Teacher's Resource Kit* (CVA, 2009) to primary and secondary students visiting the site.

The proposed offset measures will be described in more detail, including specific areas, timeframes and performance measures prior to commencement of the development.

Port Kembla Outer Harbour Development

Proposed Aquatic Habitat Offset Area – Garungaty Waterway and Tom Thumb Lagoon



From: Trevor Brown [THB@portkembla.com.au]
Sent: Wednesday, 23 December 2009 1:56 PM
To: Andrew Dunne; Tonilee Andrews; Geoff Cornwall; Bowden, Deborah; Hattingh, Neville
Subject: FW: Port Kembla Outer Harbour Development - Aquatic Habitat Offsets

See below a positive response from Industry & Investment NSW to our proposed offset measures. I have spoken to Allan Lugg and he indicated that he is happy for the EA to be amended in accordance with our letter and exhibited prior to sorting out any further details re the timing, cost, etc of the measures.

Regarding the works north of Springhill Road that he proposes, I mentioned to Allan that Wollongong City Council has already installed a large CDS unit on the major arm of the creek immediately south of the Church and Swan St intersection and has undertaken riparian vegetation works between there and Springhill Road. I will have another look at the area later this afternoon and see whether there is scope for additional planting on some of the other arms.

Cheers,

Trevor Brown
Sustainability Coordinator
Port Kembla Port Corporation

Ph: 02 4275 0114
Fax: 02 4276 2142
Email: thb@portkembla.com.au

Please consider the environment before printing this E-mail

From: allan.lugg@industry.nsw.gov.au [mailto:allan.lugg@industry.nsw.gov.au]
Sent: Wednesday, 23 December 2009 11:24
To: Trevor Brown
Cc: trevor.daly@industry.nsw.gov.au
Subject: Re: Port Kembla Outer Harbour Development - Aquatic Habitat Offsets

Hi Trevor,

Thanks for the outline of compensatory measures.

I can advise that the approach outlined is acceptable to I&I NSW.

It would be useful if you could produce a map which shows the extent of the area where works would be undertaken.

I suggest that there is scope to extend the works up into the creek that passes under Springhill Road and into JJ Kelly Park. This creek carries a large sediment, nutrient and gross pollutant load from the Wollongong CBD, and removal of anoxic sediments and installation of sediment and gross pollutant traps at the discharge point would help improve water quality throughout the system.

Similarly, sediment and gross pollutant traps at other discharge points could be factored into the proposal.

Trevor Daly and I would be pleased to meet with you and others in the new year to inspect the area and further discuss options and approaches to habitat rehabilitation.

January is looking very full for me with response to severe drought in the Lachlan catchment as well as some leave, so early February would be best.

Regards Allan

Allan Lugg | Senior Fisheries Conservation Manager | Aquatic Habitat Protection
Industry & Investment NSW | PO Box 97 | 4 Woollamia Road | HUSKISSON NSW 2540 |
T: 02 4428 3401 | F: 02 4441 8961 | M: 0409 912 686 | E: Allan.Lugg@industry.nsw.gov.au
W: www.industry.nsw.gov.au | www.dpi.nsw.gov.au

From: "Trevor Brown" <THB@portkembla.com.au>
To: <allan.lugg@industry.nsw.gov.au>, <trevor.daly@industry.nsw.gov.au>
Cc: "Andrew Dunne" <ARD@portkembla.com.au>, "Geoff Cornwall" <GJC@portkembla.com.au>, "Tonilee Andrews" <TLA@portkembla.com.au>, "Hattingh, Neville" <Neville.Hattingh@aecom.com>, "Bowden, Deborah" <Deborah.Bowden@aecom.com>
Date: 18/12/2009 12:05 PM
Subject: Port Kembla Outer Harbour Development - Aquatic Habitat Offsets

---

Allan and Trevor,

Please find attached a letter and indicative measures proposed to compensate for aquatic habitat impacts associated with the Outer Harbour development. This is intended as a discussion-starter and we would welcome an opportunity to discuss further with you in a meeting or via teleconference at your earliest convenience.

Regards, <<Letter to I&I Fisheries re Habitat Offsets - Attachment A.pdf>> <<Letter to I&I Fisheries re Habitat Offsets.pdf>>

Trevor Brown

Sustainability Coordinator

Port Kembla Port Corporation

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P **Please consider the environment before printing this E-mail** [attachment "Letter to I&I Fisheries re Habitat Offsets - Attachment A.pdf" deleted by Allan Lugg/DII/NSW] [attachment "Letter to I&I Fisheries re Habitat Offsets.pdf" deleted by Allan Lugg/DII/NSW]

PORT KEMBLA OUTER HARBOUR DEVELOPMENT

Environmental Assessment Volumes

Volume 1

Main Environmental Assessment Document
Appendix A: Consultation Supplementary Documentation

Volume 2

Appendix B: Contamination: Sediment Quality - Main Document

Volume 3

Appendix B: Contamination: Sediment Quality - Laboratory Results

Volume 4

Appendix C: Contamination: Soils and Groundwater Quality
Appendix D: Qualitative Human Health and Ecological Risk Assessment: InSitu Sediment and Groundwater Contamination

Volume 5

Appendix E: Preliminary Hazard Analysis
Appendix F: Coastal Hydrodynamic Processes
Appendix G: Aquatic Ecology

Volume 6

Appendix H: Terrestrial Ecology Supplementary Documentation
Appendix I: Traffic and Transport
Appendix J: Noise and Vibration
Appendix K: Air Quality

Volume 7

Appendix L: Landscape and Visual Amenity
Appendix M: Heritage
Appendix N: Climate Change