Project Application

Volume 3

Inner West Marina
Parramatta River, Sydney

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Contents

Volume 1

1. Executive Summary
2. Introduction and Scope
3. The Site and Existing Environment
4. Proposed Development
5. Justification for the Proposal
6. Consultation
7. Statutory Context and Planning Controls
8. Requirements of The Director General of The NSW Department of Planning
9. Alternatives Considered
10. Identification of Issues
11. Environmental Assessment
    - 11.1 Contamination
    - 11.2 Visual Amenity
    - 11.3 Navigation and Safety
    - 11.4 Public Access
    - 11.5 Soils Sediment and Water
    - 11.6 Traffic
    - 11.7 Noise
    - 11.8 Aquatic Flora and Fauna
    - 11.9 Avian Fauna
    - 11.10 Air Quality
    - 11.11 Waste Management
    - 11.12 Social
    - 11.13 Heritage
    - 11.14 Hazard Assessment
    - 11.15 Economic
    - 11.16 Construction Impacts
    - 11.17 Cumulative Impacts
    - 11.18 Approvals and Licences
12. Statement of Commitments
13. Conclusion

Volume 2

Appendix 1:

- Drawings
- Photographs of Indicative Elements
- NSW Maritime Authority Plans
- Hydrographic Survey Drawings HS01 and HS02

Appendix 2:

- Major Project Declaration and Director-Generals Requirements

Appendix 3:

- Land Owner's Consent

Volume 3

Appendix 4:

- Aquatic Environmental Assessment
- Aquatic Ecology Studies

Volume 4

Appendix 5:

- Construction and Operational Noise Assessment

Appendix 6:

- Historical and Aboriginal Heritage Impact Statement

Appendix 7:

- Traffic and Parking Report

Volume 5

Appendix 8:

- Visual Assessment Report

Volume 6

Appendix 9:

- Estuary Hydrodynamics and Physical Sedimentary Environment Report incorporating Turbidity Investigation

Volume 7

Appendix 10:

- Construction Environmental Management Plan
- Operational Environmental Management Plan

Volume 8

Appendix 11:

- Berth Demand Study

Appendix 12:

- Construction Management Plan

  Attachments

  - Drawings CMP00, CMP01, CMP02, CMP03 and CMP04
  - Geotextile Information

Volume 9

Appendix 13:

- Sediment Management Report
- Declaration of Remediation Fill from Environment Protection Agency
- Site Auditor Advice – Letter from GHD

Volume 10

Appendix 14:

- Assessment of Impact on Avian Fauna

Appendix 15:

- Marina Management Plan

Appendix 16:

- Community Consultation Report

Appendix 17:

Navigation Information

- Drawing N01
- NSW Maritime Plan: Traffic Coordination of the Parramatta River
- Ferry Timetable
- NSW Maritime Schedules of Moored and Registered Vessels

APPENDIX 4:

- AQUATIC ENVIRONMENTAL ASSESSMENT

Cardno Ecology Lab

Shaping the Future

Marine and Freshwater Studies

Inner West Marina Sydney

Aquatic Environmental Assessment

330809A

Breakfast Point Pty Ltd

Final October 2009

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Executive Summary

Background

Breakfast Point Pty Ltd has proposed that a commercial marina consisting of 172 berths and associated infrastructure be constructed on the western shore of Kendall Bay, on the southern bank of the Parramatta River, Sydney. The proposed marina development would involve the following works:

- Placement of a geotextile blanket and basalt rock ballast on top of the underlying sediment;
- Construction of a low level jetty with sewage pump out facilities, security gate, manager's office, small amenity area, small kiosk and a ferry wharf;
- Construction of eight floating arms supporting a total of 172 wet berths for boats ranging in length from 8 m to 25 m; and
- On land parking.

These works would be undertaken in six stages. During Stage 1, the geotextile blanket and rock ballast would be laid on top of the sediment below the Proposed Marina Location using a combination of divers, a barge and GPS controlled excavator. The placement of this blanket is intended to meet the requirements of a Remediation Order with respect to prevention of disturbance to the bed sediment of Kendall Bay within 200 m of the land-based boundary of the former gasworks. During Stage 2, the jetty would be constructed using steel piles, timber beams and timber decking. This work would be done using a barge-mounted crane. The concrete piles required to support the floating arms and modular pontoons comprising the arms would be brought to the site on board barges and installed during Stages 3-5. The pontoon and ramp would be installed during Stage 6. The proposed development will not require any dredging or reclamation works and there will be no removal or destruction of areas of marine vegetation.

Cardno Ecology Lab Pty Ltd was commissioned by Breakfast Point Pty Ltd to undertake the aquatic ecology component of the Environmental Assessment for the development required under Section 75F of the Environmental Planning and Assessment Act 1979.

Existing Aquatic Environment

In May 2009, qualitative observations were made of the fauna and flora associated with artificial habitats adjacent to the Proposed Marina Location. Quantitative surveys were also undertaken of the infauna (animals living within sediments), epibenthic fauna (animals living on or in close proximity to the estuary bed), mobile fish and invertebrate fauna at the Proposed Marina Location and two nearby Reference Locations (Sydney Rowing Club in Hen and Chicken Bay and Kissing Point Bay). The results of these studies are described in detail in a separate report prepared by Cardno Ecology Lab (Cardno Ecology Lab 2009B). The major findings are summarised below.

Aquatic Habitats

The foreshore adjacent to the Proposed Marina Location has been modified extensively and now consists of a vertical sandstone seawall and sloping sandstone revetment with a narrow fringe of rubble below some parts. There is also a small sandy beach in front of part of the revetment which is subject to winnowing by wave action, primarily from Rivercat ferries. There is a mudflat with mangrove trees and a sandy beach at the southern end of Kendall Bay and a rocky shore consisting of natural outcrops of sandstone extending along the western shore of Cabarita Park.

The subtidal sediments along the shallow inshore edge of the Proposed Marina Location are dominated by sand, but also contain small amounts of clay, silt and gravel. The subtidal sediments in deeper water and shallow subtidal sediments at the southern end of Kendall

Bay are dominated by fines with a particle size of less than 75 µm. The proportion of fines increases southwards along the length of the Proposed Marina Location, probably due to a decrease in the strength of hydrodynamic processes (e.g. wave action from Rivercat ferries). The sediments in the nearshore area are more variable than those offshore, with respect to the proportion of fines. The sediment at the site closest to Breakfast Point is dominated by sand, reflecting its exposure to waves generated by vessels and tidal currents.

The sediments along the western foreshore contain various contaminants, many of which emanate from the former Mortlake gasworks. The concentrations of cyanide and BTEX compounds (benzene, toluene, ethylbenzene and xylene) were generally below the limit of laboratory reporting, but concentrations of total petroleum hydrocarbons (TPHs) and polycyclic aromatic hydrocarbons (PAHs) were measurable. TPH concentrations were an order of magnitude greater in some areas of the Proposed Marina Location. Total PAH concentrations in the sediments exceeded the Interim Sediment Quality Guidelines (ISQG) Low value for a large proportion of the Proposed Marina Location and the ISQG-High value in a few areas. Concentrations of arsenic, chromium and copper in the sediment were generally in excess of their respective ISQG-Low values but not their ISQG-High values, whilst those of lead, mercury and zinc were above their respective ISQG-High values in at least half the sites. Potential acid sulphate soils occur at a depth of 0.2-0.4 m in the sub-surface sediment. These, however, will not be excavated, so an acid sulphate management plan will not be required.

In the water column, copper concentrations exceeded the ANZECC/ARMCANZ 95% trigger values at all sites and were at or slightly above the 90% trigger value on one occasion, but between the 80% and 90% trigger values on the other. Zinc concentrations exceeded the 99% trigger value at all sites, but were close to the 95% trigger value at two sites during low tide on the first sampling occasion. The concentrations of chromium and nickel were below their respective 99% and 95% trigger values, but those of lead were below the 95% trigger value, but close to or slightly in excess of their 99% trigger value in some of the samples collected.

Aquatic Biota

The base of the sandstone revetment adjacent to the Proposed Marina Location was covered by a mixture of the green, red, brown and blue-green algae. Rock oysters, mussels, barnacles and various species of gastropods were also conspicuous. Most of these organisms were also found on the adjoining vertical seawall.

The piles at Cabarita Wharf were covered in green, red and brown algae, mussels and two species of barnacles. Similar organisms may grow on the marina structures. The bedrock and natural boulders to the east of the wharf supported a greater variety of animals, including a finger sponge, an encrusting bryozoan, mussels, barnacles, crabs and various species of gastropods and five different species of algae.

The Proposed Marina Location supports a diverse range of infauna, despite the contamination of the sediment. Thirty taxa (17 polychaete, 5 crustacean, 5 mollusc and 3 others) were found living in the sediment, with one family of bivalve molluscs and five families of polychaete worms being the most abundant taxa. The spatial patterns in the infauna did not appear to be linked with the concentrations of the major contaminants at the Proposed Marina Location. The assemblages at the Proposed Marina Location differed from those at the Reference Locations, suggesting that the infauna at the Proposed Marina Location was not typical of that region of the estuary. The infauna at all three locations was less abundant generally than that observed in a 1996 study.

The epibenthic fauna within Kendall Bay, sampled using beam trawls, consisted of 64 taxa (6 fish, 11 polychaete, 25 crustacean, 16 mollusc and 6 others), with a bivalve mollusc, mysid, amphipod and shrimp being the most abundant species. The epibenthic fauna in

Kendall Bay was similar to that at the Reference Locations combined, suggesting that it was typical of that region of the estuary.

A total of 15 species (1 jellyfish, 6 crustacean and 8 fish) were caught off the sandy beach near the Proposed Marina Location in seine nets, with two fish and one mysid species being the most abundant. The mobile fish and invertebrate assemblages at the Proposed Marina Location did not appear to be typical of that region of the estuary.

Aquatic Habitats, Flora and Fauna of Conservation Significance

None of the critical habitats listed on the NSW Register occur within Kendall Bay. None of the aquatic species, populations or communities of conservation significance listed under the *Threatened Species Conservation Act 1995*, *Fisheries Management Act 1994* or *Environment Protection and Biodiversity Conservation Act 1999* has been recorded within Canada Bay LGA. There are no protected wetlands along the western foreshore of Kendall Bay adjacent to the Proposed Marina Location, but there some at the southern end of Kendall Bay and to the east around Cabarita Wharf and Cabarita Point. In September 2007, a small, sparse patch of the seagrass *Halophila ovalis* was observed off the rock platform near Cabarita Wharf.

A key threatening process listed under the *FM Act 1994*, "Introduction of non-indigenous fish and marine vegetation to the coastal waters of NSW", is relevant to the marina project, because these organisms can be spread through fouling of boats and boating equipment.

No protected or threatened faunal taxa were found in May 2009.

Environmental Issues Associated with the Proposed Marina

The key environmental issues for aquatic habitats and biota associated with the construction, presence and operation of the proposed marina are as follows:

Construction of the marina

- The subtidal soft bottom habitat and its infauna would be lost when the geotextile blanket is laid;
- The existing fines-dominated soft sediment habitat would be replaced by a layer of basalt rock onto which fines would settle over time;
- Subtidal soft bottom habitats and their biota occurring at the margins and beyond textile blanket would be disturbed indirectly by resuspension and subsequent settlement of sediment when the blanket is laid;
- The biota within the water column encircled by the silt curtain would be disturbed indirectly by the resuspension of sediment and increase in turbidity resulting from pile driving;
- The resuspension and subsequent settlement of sediment would alter the bioavailability of contaminants in the sediment and water column; and
- Aquatic biota would be disturbed by underwater noise and vibrations generated by pile driving and construction vessels.

Presence of the Marina

- The pontoons, pilings and jetty comprising the marina would provide novel habitats for a variety of aquatic organisms to colonise and may even attract organisms away from surrounding natural habitats;
- The floating pontoons, jetties and walkways associated with the marina would shade the water and reduce the amount of light available to photosynthetic organisms in the water column and on the bottom; and
- Subtidal soft bottom habitats and their biota would be disturbed indirectly by changes in the sedimentation patterns within the bay resulting from the marina structure reducing the effects of vessel and wind generated waves.

Operation of the Marina

- The combustion of fuel in boat engines, accidental spills of sewage, fuel, motor and other oils and release of toxic components from anti-fouling paints applied to the hulls of boats and marina structures could alter the bioavailability of contaminants in the aquatic environment;
- Boats mooring at the marina may introduce non-indigenous species which could compete with local aquatic flora and fauna.
- Aquatic biota would be disturbed by underwater noise and vibrations generated by the additional boat traffic associated with the marina.

Potential Impacts on Aquatic Habitats and Mitigation/Management Measures

Loss and/or disturbance of subtidal soft sediment habitats and associated biota

The subtidal soft-sediment habitat that currently exists at the Proposed Marina Location would be replaced by layers of basalt rock when the geotextile blanket is installed. Most of the organisms that occur within or on the surface of the soft sediment would perish shortly after the blanket is laid. The loss of this habitat and associated biota would also reduce the amount of benthic food available for consumption by epibenthic and pelagic organisms. Approximately 29% of the subtidal soft sediment habitat within Kendall Bay would be affected, but there are extensive areas of these habitats elsewhere in the estuary. The basalt rock would eventually be colonised by benthic organisms, but the assemblages that develop on them would differ from those in the existing fines-dominated habitat. Infaunal assemblages that are more comparable with those occurring at present would develop once sufficient fine sediment has been deposited within the rock matrix.

During and after installation of the geotextile blanket fine sediment particles (less than 74 µm) in the upper sediment layer will pass through the geotextile blanket. It is estimated that the amount of sediment penetrating the blanket would be equivalent to a 10 mm thick layer of fine particles within the rock armour immediately above the blanket. During operation of the marina this material has the potential to be resuspended in to the water column, allowing it to be transported within and away from the proposed marina site. It is estimated that the fine material could be transported to the mangrove habitat near the head of the bay and, over a year-long period, could result in the deposition of a maximum of 1 mm of sediment (GbaCOASTAL 2009). It is unlikely that contamination associated with such a small quantity of sediment would have a detectable impact on the mangrove habitat. Currently, the mangrove habitat near the head of Kendall Bay appears to be in good condition despite being adjacent to heavily contaminated sediments (URS 2006b), and the geotextile blanket would limit the potential for settlement of contaminated fine particles in this habitat compared to the existing situation.

Provision of Novel Habitat

The floating pontoons, pilings and jetty forming the structure of the marina would provide artificial habitat for macroalgae and sessile invertebrates, such as mussels, ascidians and sponges and serve as habitats for mobile fish and invertebrates. The marina structures would increase the abundance of taxa found in association with hard substrata within the bay, but not offset the impacts on soft-bottom assemblages resulting from their introduction. The assemblages that develop on the artificial structures would also differ from those on natural hard substrata.

Potential Impacts on Aquatic Biota and Mitigation/Management Measures

Indirect Disturbance Associated with Resuspension of Sediment

The laying of the geotextile blanket, insertion of the piles needed to support the marina structure and manoeuvring of construction vessels would disturb soft sediments on the bed of the Proposed Marina Location and generate sediment and turbidity plumes. The total

area of the bed of Kendall Bay disturbed by pile driving would be very small (< 1%). Sediment resuspension during pile driving would be restricted to the immediate vicinity of each pile, and persist only whilst the pile is inserted and for a short-time thereafter. Pile driving is consequently unlikely to have a significant impact on photosynthetic activity, growth and productivity of phytoplankton and benthic algae or on the respiratory and feeding mechanisms of animals within Kendall Bay. Species that are able to move away from areas of the water column with elevated suspended sediment concentrations and turbidity levels are even less likely to be adversely affected. The laying of the blanket would cause more sediment to be re-suspended and greater increases in turbidity than pile driving, because a relatively large area of bed sediments (57,000 m^2) would be disturbed over a prolonged period (30 weeks). The re-suspended sediment and increased turbidity could potentially have adverse effects on pelagic and epibenthic biota.

The spread of sediment and turbidity plumes into the nearby protected wetlands, other areas of Kendall Bay and the estuary would be minimised by deploying silt curtains around the area in which the works are taking place. The proposed deployment of silt curtains around large portions of the Proposed Marina Location would prevent the movement of mobile fauna outside the encircled area, limit the area to which entrapped mobile organisms could move to avoid sediment and turbidity plumes and reduce the overall amount of food available to them. Daily opening of panels in the silt curtain to allow movement of construction vessels would allow mobile organisms to escape.

During marina operation, the small amount of fine particles from the basalt armour suspended in the water column due to boat wash is unlikely to have a detectable impact on mobile fauna such as fish.

Changes in the Bioavailability of Contaminants

The resuspension of sediments resulting from deployment of the blanket has the potential to release contaminants from surface sediments into the water column, while that resulting from pile driving activities has the potential to release contaminants sequestered in both surface and deeper layers of the sediment. PAHs have a low solubility in water and a strong affinity for particulate matter and are therefore unlikely to be released into the water column in large concentrations. Heavy metals occur in dissolved, colloidal and particulate forms, but are generally more concentrated in sediments. Oxidation of deeper sediments and decomposition of organic matter, including the decay of the organisms trapped under the blanket, could lead to release of heavy metals from sediments. It is consequently suggested that elutriate tests be done to determine the concentrations that might be released into the water column when the geotextile blanket is laid and the piles are inserted. Organisms, such as zooplankton and bivalve molluscs, that feed on suspended particulates are more likely to take up these contaminants than those that are exposed to their water-soluble phases. Algae and bivalves are more likely to accumulate these contaminants than fish and crustaceans, both of which have the enzymes necessary to metabolise, eliminate or sequester PAHs and heavy metals. The threat to organisms resulting from elevated concentrations of contaminants on suspended particulate matter would be minimised by using silt curtains to confine and prevent the spread of sediment and turbidity plumes.

The leaching of toxic components from anti-fouling paints applied to boat hulls, combustion of fuel in boat engines, accidental spillages of fuel, oils, bilge water and sewage, and onboard washing of boats could also introduce contaminants into Kendall Bay. The use of copper-based anti-fouling paints is of particular concern, because a large number of boats moored within a confined area are likely to contribute significant amounts of copper to the water column over an extended period. As the total copper concentrations within the water column already fall between the ANZECC/ARMCANZ (2000) 90% and 80% trigger values, it is recommended that appropriate measures be incorporated into the environmental management plan for the marina to reduce the possibility of greater harm to biota arising. The impacts of contamination associated with boating could be mitigated by:

- Educating boat owners about the environmental problems associated with use of copper-based anti-fouling paints; discouraging them from *in-situ* cleaning of hulls that have been treated with copper paints and encouraging them to switch to non-toxic anti-fouling paints.
- Prohibiting boat owners from discharging sewage and bilge water directly into Kendall Bay and encouraging them to use the sewage pump-out facility proposed for the landward end of the jetty and to remove oil from bilge water by using bilge removing pads.
- Containing accidental spillages of fuels and oils within floating booms and cleaning them up as soon as possible; and
- Encouraging use of environmentally friendly cleaning agents for on board washing of boats.

It is also recommended that the concentration of copper within the sediment and water column be monitored regularly and screened against the appropriate ANZECC/ARMCANZ guidelines.

Shading of the Water Column and Substratum

Impacts due to shading from the proposal are difficult to assess due to a paucity of information on the aquatic flora of Kendall Bay and the variability in the number of boats in the marina at any one time that will cast shadows into the water. Primary productivity in the bay comes from the photosynthetic activity of two types of plants: microscopic, floating algae and diatoms in the water column and attached, foliose algae.

The floating pontoons, jetty and walkways of the marina and boats moored alongside them will shade the underlying water column and reduce the amount of light available to photosynthetic organisms. Because background turbidity in the marina area probably already limits photosynthesis in the water column, and the footprint of the marina covers < 17% of the bay, it is unlikely that small, further reductions due to marina structures will have measurable adverse effects on the density, growth and productivity of aquatic flora in the water column. The jetty would shade a small section of the vertical seawall, potentially resulting in a localised reduction in the abundance of macroalgae with localised flow-on effects to the community structure. The algae growing on the seawall along most of the shoreline and small patch of seagrass near Cabarita Wharf would not be affected by the marina.

Generation of Underwater Noise and Vibrations

The insertion of the piles needed to support the marina structure, use of barges and construction vessels to lay the geotextile blanket and manoeuvre the floating structures and piles into position, and eventual usage of the marina by motorised boats will increase ambient noise levels. The underwater noise generated by pile-driving hammers has the potential to physically damage fish and decapod crustaceans occurring in the immediate vicinity of the pile being driven into the substratum and disturb animals in the general vicinity of the pile driving operations. The sounds generated by boat propellers and engines also have the potential to elicit behavioural and physiological responses in fish. The impact of these activities is difficult to assess because of the lack of information on background noise levels in Kendall Bay and on noise levels and vibrations likely to be generated during construction and operation of the marina. Little is also known about the responses of marine organisms, other than mammals, to underwater noise. The noise produced by boats accessing the marina, however, would be similar to that of existing traffic and intermittent in nature, so their impact is unlikely to be significant.

Potential impacts arising from the generation of underwater noise and vibration during construction of the marina would be minimised by limiting the hours that works can take place and the number of piles that may be inserted per day. Consideration should also be given to managing pile driving activities so that the underwater noise generated increases

incrementally, reducing the level of underwater noise generated by creating a bubble curtain or screen around the area in which piles are being driven and using a hammer cushion. The impact of the noise generated by boats accessing the marina could be reduced by implementing and enforcing speed restrictions.

Introduction of Non-Indigenous Species

The hulls of vessels utilising the marina are a potential pathway for the introduction of non-native flora and fauna, including marine pests, into Kendall Bay. Marine pest species are of particular concern, because they are able to compete with existing native species, alter local gene pools and/or modify the physical environment. Two known or likely exotic marine species, the yellowfin goby *Acanthogobius flavimanus* and bryozoan *Watersipora subtorquata*, have already been recorded in Kendall Bay.

The introduction of non-indigenous species could be minimised by prohibiting the cleaning of hulls and discharge of bilge water from boats moored at the marina. Boat owners should also be encouraged to inspect their hulls, anchors, fishing gear and general boating equipment for non-indigenous species, such as *Caulerpa taxifolia* which occurs in Sydney Harbour, and dispose of them in an appropriate manner. A targeted marine pest survey should also be undertaken prior to the marina commencing operations to determine whether any known marine pests are present and provide a baseline for comparison during the operational life of the marina. The biota on the piles and jetty comprising the marina and in the underlying soft sediments should also be inspected periodically to determine whether non-indigenous species have been introduced. The origin of vessels arriving at the marina should be determined so that a list of potential introduced species can be drawn up.

Table of Contents

Executive Summary ..... **ii**
Glossary ..... **xi**
1 Introduction **1**
2 Background Information **2**
2.1 Remediation Issue 2
2.2 Environmental Issues Associated with Marinas 2
2.2.1 Construction of Marinas 2
2.2.2 Physical Presence of Marinas 3
2.2.3 Operation of Marinas 3
3 Existing Aquatic Environment **4**
3.1 Physical Setting 4
3.2 Aquatic Habitats 4
3.2.1 Intertidal 4
3.2.2 Subtidal 5
3.3 Aquatic Fauna and Flora 6
3.3.1 Hard Substrata 6
3.3.2 Soft Substrata 7
3.3.3 Epibenthic Assemblages 8
3.3.4 Mobile Fish and Invertebrate Assemblages 9
3.4 Aquatic Habitats, Flora and Fauna of Conservation Significance 9
3.4.1 Critical Habitats 9
3.4.2 Threatened Species 9
3.4.3 Threatened Populations 10
3.4.4 Threatened Ecological Communities 10
3.4.5 Protected Species and Habitats 10
3.4.6 Key Threatening Processes 10
3.4.7 Listed Marine and Migratory Species 10
4 Environmental Issues, Potential Impacts, Mitigation and Management Measures 11
4.1 Description of Proposed Works 11
4.1.1 Outline of Works 11
4.1.2 Blanket Construction 11
4.2 Environmental Issues Associated with the Proposed Works 13
4.2.1 Construction Phase 13
4.2.2 Physical Presence of the Marina 13
4.2.3 Operation of the Marina 13
4.3 Marina Construction - Impacts, Mitigation and Management Measures 13
4.3.1 Loss and Direct Disturbance of Aquatic Habitats and Associated Biota 13

4.3.1.1 Potential Impact 13
4.3.1.2 Mitigation and Management Measures 14
4.3.2 Indirect Disturbance Associated with Resuspension of Sediment 14
4.3.2.1 Potential Impact 14
4.3.2.2 Mitigation and Management Measures 16
4.3.3 Changes in the Bioavailability of Contaminants 16
4.3.3.1 Potential Impact 16
4.3.3.2 Mitigation and Management Measures 17
4.3.4 Generation of Underwater Noise and Vibrations 18
4.3.4.1 Potential Impact 18
4.3.4.2 Mitigation and Management Measures 18
4.4 Marina Structure - Impacts, Mitigation and Management Measures 19
4.4.1 Changes in Sedimentation Patterns 19
4.4.1.1 Potential Impacts 19
4.4.1.2 Mitigation and Management Measures 19
4.4.2 Provision of Novel Habitat 19
4.4.2.1 Potential Impacts 19
4.4.2.2 Mitigation and Management Measures 20
4.4.3 Shading of the Water Column and Substratum 20
4.4.3.1 Potential Impacts 20
4.4.3.2 Mitigation and Management Measures 20
4.5 Marina Operation - Impacts, Mitigation and Management Measures 21
4.5.1 Indirect Disturbance Associated with Sediment Resuspension 21
4.5.1.1 Potential Impacts 21
4.5.1.2 Mitigation and Management Measures 21
4.5.2 Changes in the Bioavailability of Contaminants 21
4.5.2.1 Potential Impacts 21
4.5.2.2 Mitigation and Management Measures 22
4.5.3 Introduction of Non-Indigenous Species 22
4.5.3.1 Potential Impacts 22
4.5.3.2 Mitigation and Management Measures 23
4.5.4 Underwater Noise 23
4.5.4.1 Potential Impacts 23
4.5.4.2 Mitigation and Management Measures 23
5 Recommendations 24
6 Acknowledgements 25
7 References 26

Glossary

Assemblage	Group of organisms that live together in the same place and at the same time
Bioavailability	The extent to which organisms are exposed to contaminants in water, sediment and food
Contamination	Chemicals that have been introduced into the environment that can harm organisms
Critical Habitat	An area or areas occupied by a species, population or ecological community that is/are essential for their survival.
Ecological Community	Assemblage of species occupying a particular area
Epibenthic	Animals that live on or close to the seabed or estuary bed
Flux	Rate of flow across a given area and time
Infauna	Animals that live within the sediment
Key threatening process	Activities that harm threatened species or could cause other species to become threatened.
Protected species	Species that are protected from fishing and collecting so that they do not become threatened at some time in the future
Reference Location	Locations elsewhere in the Parramatta River that would not have been affected by sediment contamination resulting from activities at the AGL Mortlake gasworks
Threatened Species/Populations/Communities	Species/Populations/ Communities that face a high risk of extinction in the near to medium term future

1 Introduction

Breakfast Point Pty Ltd has proposed that a commercial marina consisting of 172 berths and associated infrastructure be constructed in Kendall Bay, on the southern shore of the Parramatta River, Sydney. The proposed Inner West Marina Sydney would be situated to the east of the Breakfast Point residential development, extend approximately 150 m into Kendall Bay. A submission for the marina has been lodged with the NSW Department of Planning (DoP). The latter have determined that an Environmental Assessment is required under Section 75F of the Environmental Planning and Assessment Act 1979.

Breakfast Point Pty Ltd commissioned Cardno Ecology Lab Pty Ltd to undertake the aquatic ecology component of the environmental assessment. The scope of the works for this component included:

- A description of the existing environment;
- A general overview of environmental impacts of the proposed works on aquatic flora, fauna and habitats;
- An assessment of the potential impacts of the project on aquatic flora and fauna, including any cumulative impacts from construction activities and from all craft that would use the marina;
- A description of measures that would be implemented to minimise, mitigate, offset, manage and or monitor the impacts of the project on aquatic biota;.
- A detailed assessment of the potential for the marina project to disturb contaminated marine sediments and details of any proposed remediation works required and their impacts on aquatic flora and fauna; and
- An assessment of any impacts on critical habitats, threatened species, populations or ecological communities and the habitats in the region.

These are the requirements of the Director-General, NSW Department of Planning specified under Section 75F (3) of the Environmental Planning and Assessment Act 1979:

The proposed marina development would involve the following works:

- Placement of a geotextile blanket and basalt rock ballast on top of the underlying sediment;
- Construction of a low level jetty with sewage pump out facilities, security gate, manager's office, small amenity area, small kiosk and a ferry wharf;
- Construction of eight floating arms supporting a total of 172 wet berths for boats ranging in length from 8 m to 25 m; and
- On land parking.

These works would be undertaken in six stages, each lasting between 2 and 30 weeks. During the first stage, the geotextile blanket and rock ballast would be laid on top of the sediment below the Proposed Marina Location using a combination of divers, a barge and GPS controlled excavator. The proponent envisages that the placement of this blanket would meet the requirements of the Remediation Order with respect to disturbance of the bed sediment of Kendall Bay within 200 m of the land-based boundary of the former gasworks (see Section 2.1). During Stage 2, the jetty would be constructed using steel piles, timber beams and timber decking. This work would be done using a barge-mounted crane. The concrete piles required to support the floating arms and modular pontoons comprising the arms would be brought to the site on board barges and installed during Stages 3-5. The pontoon and ramp would be installed during Stage 6. The proposed development will not require any dredging or reclamation works and there will be no removal or destruction of areas of marine vegetation.

2 Background Information

2.1 Remediation Issue

In May 2004, the bed of the Parramatta River at Kendall Bay, within 200 m of the land-based boundary of the former AAGL Mortlake Gasworks site, was declared a Remediation Site under Section 21 of the Contaminated Land Management Act 1997, due to its contamination with polycyclic aromatic hydrocarbons (PAHs) and total petroleum hydrocarbons (TPHs) from the former gasworks. The nature and extent of the contamination has been investigated and an Environmental Risk Assessment (ERA) and a Human Health Risk Assessment for the site have been prepared by URS Australia Pty Ltd (2006a and b). These investigations have shown that PAH concentrations in the sediments exceed the Interim Sediment Quality Guidelines (ISQG's) (ANZECC & ARMCANZ 2000). There is consequently a potential for these contaminants to have adverse effects on benthic organisms that occur in association with these sediments.

In June 2007, the NSW Maritime Authority, the owner of the estuary bed and overlying sediments, was issued a remediation order in relation to these sediments under Section 23 of the Contaminated Land Management Act 1997. The remediation order states that NSW Maritime must refrain from carrying out, permitting or allowing another person to conduct works or activities at the site that would result in disturbance or further disturbance of the bed sediment of Kendall Bay and the Parramatta River in the area adjacent to the former Mortlake gasworks and which fall within 200m of the land-based boundary of the former gasworks site. This order is applicable to construction and maintenance works, such as dredging and excavation activities for boating facilities including piers, wharves, slipways and marinas, and infrastructure works including bridges and pipelines. The NSW Maritime Authority can consequently not agree to lease the area to Breakfast Point Pty Ltd unless they can satisfy the requirements of DECC with respect to the implementation of specific measures directed at minimising disturbance and migration of contaminants in the bed sediments.

Two areas within Kendall Bay have subsequently been identified for remediation: an 8340 m^2 area at the southern end of Kendall Bay (referred to subsequently as Remediation Area A) approximately 100 - 150 m away from the proposed marina development and an area of 957 m^2 in the vicinity of the former wharf along the western side of the Kendall Bay (referred to subsequently as Remediation Area B), which was used to transfer coal from vessels to the gasworks (URS 2008). Jemena Ltd (formerly Alinta LGA Ltd) has entered into a voluntary remediation agreement for these areas with the Department of Environment and Climate Change (DECC) (then DEC) and have proposed that contaminated sediments be excavated from the beach area at the southern end of Kendall Bay and that nearshore sediments be excavated where the former pier that serviced the gasworks joined the land. The latter remediation has implications for the proposed marina development, because Breakfast Point Pty Ltd has proposed that part of the marina infrastructure, a low level jetty, be constructed in this area.

2.2 Environmental Issues Associated with Marinas

The key environmental issues associated with the construction, physical presence and operation of marinas are outlined below.

2.2.1 Construction of Marinas

- Land-based earthworks, dredging and insertion of piles will disturb, mobilise and resuspend bed sediments and increase turbidity levels in the water column.
- Nutrients and contaminants that are bound to the sediments may be mobilised and resuspended by activities such as pile driving and dredging.

- Construction activities such as dredging and pile driving will also disturb intertidal and subtidal habitats and their associated biota.
- The resuspension of sediments and mobilisation of contaminants will also have indirect effects on aquatic habitats and biota through reduced water quality.
- The underwater noise and vibrations generated by pile driving operations at the marina site, construction vessels and workboats may disturb aquatic biota.

2.2.2 Physical Presence of Marinas

- Marinas can lead to changes in water circulation and sedimentation patterns, particularly if water flow is reduced when it encounters physical structures (Turner *et al.* 1997).
- The pontoons, pilings and jetties associated with marina developments provide artificial habitats for colonisation by a variety of aquatic organisms.
- Marina structures may attract fish away from surrounding natural habitats and make them more vulnerable to exploitation;
- The floating pontoons, jetties and walkways associated with marinas shade the water and reduce the amount of light available to photosynthetic organisms in the water column and on the bottom.
- The anti-fouling agents used on marina pilings may reduce the diversity of infauna in surrounding sediments (Weis and Weis 1996).

2.2.3 Operation of Marinas

- The wash and wake from boats accessing the marina may disturb and resuspend sediments and erode the shoreline.
- In shallow water, the turbulence generated by boat propellers may also disturb and erode bottom sediments and facilitate their resuspension in the water column.
- Disturbance and resuspension of sediment levels resulting from boat wash and wake and propeller turbulence may increase turbidity levels within the water column and mobilise contaminants and nutrients sequestered in the sediment.
- Propeller turbulence may damage organisms living on or just below the surface of the sediments.
- The boats mooring at the marina could introduce non-indigenous species which may compete with local aquatic flora and fauna.
- Introduction of hydrocarbon contaminants and heavy metals via boat engine exhausts (McGee *et al.* 1995).
- Stormwater run-off from impermeable surfaces, such as hard stand dry berths, repair workshops and maintenance facilities associated with marinas can also introduce a variety of contaminants.
- Accidental spills of sewage, organic pollutants such as fuel, motor and other oils and release of toxic components from hull anti-fouling paints can introduce contaminants into the aquatic environment (Underwood and Anderson 1997).

3 Existing Aquatic Environment

The description of the existing environment is based on qualitative observations of artificial habitats and on quantitative surveys of infauna, epibenthic fauna, mobile fish and invertebrates associated with the soft sediments at the Proposed Marina Location and two nearby Reference Locations (Sydney Rowing Club in Hen and Chicken Bay and Kissing Point Bay) undertaken in May 2009. The accompanying technical report includes a detailed description of the methodology used and results obtained during these surveys and a review of the major findings of previous ecological studies undertaken in Kendall Bay (Cardno Ecology Lab 2009b). The data obtained in May 2009 are also compared with those from the earlier studies undertaken by The Ecology Lab (1989 and 1996), where appropriate. The information presented on sediment characteristics is based primarily on the sampling undertaken by AECOM in May 2009. The information presented on occurrence of threatened species, populations and communities was obtained by using the NSW Critical Habitat Register, BioNet database and Protected Matters Search Tool to identify conservation assets of state and national significance (DECC 2008; NSW Government 2005; DEWHA 2008).

3.1 Physical Setting

Kendall Bay is situated approximately 8.5 km west of the Sydney CBD on the southern shore of the Parramatta River between Cabarita Point and Breakfast Point. The water at the Proposed Marina Location is mostly within the 2-5 m (Lowest Astronomical Tide, L.A.T.) depth range, except in the vicinity of the former wharf where the depth increases to 5-10m, due to historic dredging (URS 2006a). The main channel of the Parramatta River which runs across the top of Kendall Bay ranges in depth from 10 to 19.8 m. The southern end of the bay is shallow with depths of < 2 m.

The Proposed Marina Location is protected to some extent by the adjacent residential buildings, but is exposed to weather conditions form the north through to the east-southeast and to waves generated by wind and vessels, particularly the Rivercat ferry. The proposed marina would be located at least 170 m from the main navigation channel along the Parramatta River and at least 90m from the route of the commuter ferries approaching and departing Cabarita Ferry Wharf.

3.2 Aquatic Habitats

3.2.1 Intertidal

The shoreline adjacent to the Proposed Marina Location has been modified extensively and now consists of a vertical seawall composed of sandstone blocks and a sloping revetment composed of irregular-shaped sandstone boulders. There is a narrow fringe of rubble below some parts of the seawall and revetment providing an additional hard substratum for estuarine organisms. The exposed sandstone outcrop on the north-eastern tip of Breakfast Point has been enclosed partially by a seawall. There is a small coarse-grained sandy beach in front of the revetment which is subject to winnowing by wave action, primarily from the Rivercat ferry. The only remaining natural shoreline features are the mudflat and sandy beach at the southern end of Kendall Bay and the rocky shore which extends along the western shore of Cabarita Park. There is a small stand of grey mangroves (*Avicennia marina*) on the mudflat at the southern end of the bay, reportedly planted by the local Council to promote regrowth of mangroves in the Parramatta River (The Ecology Lab 1989).

3.2.2 Subtidal

The subtidal region of the Remediation Site within Kendall Bay is covered in a 1.5 m thick layer of predominantly muddy sediments overlying terrestrial clays (URS 2006b). The typical profile is as follows:

- 0.0 m – 0.02 m – recently deposited layer of hydrous brown/green muds with broken shell material that is oxic and has a low density;
- 0.02 m - 0.1 m – green/grey estuarine muds;
- 0.1 m - 1.5 m – very soft, black to olive grey marine mud with traces of fine-grained sand and discrete pockets of bivalve shells; and
- 1.5 m – firm grey to orange sandy clay with fine sand and bivalve shells.

The shallow subtidal sediments (~ 2 m L.A.T.) along the inshore edge of the Proposed Marina are dominated by sand (>70%), but also contain small amounts of clay (12-15%), silt (6-7%) and gravel (1-8%) (AECOM 2009). The shallow subtidal sediments at the southern end of Kendall Bay, however, are dominated (> 90% of the total) by fines with a particle size of less than 75 µm (Cardno Ecology Lab 2009b).

The subtidal sediments in the deeper part (3 - 5 m L.A.T.) of the Proposed Marina Location are also dominated by fine material, but to a lesser extent (> 75% of the total) than at the southern end of the bay. The remainder of the sediment consists of sand, except for a small (> 1%) amount of gravel in some of the deeper areas (Sites BG2 and BG4). The proportion of fines increases southwards along the length of the Proposed Marina Location, probably due to a decrease in the strength of hydrodynamic processes in the inner part of the bay (e.g. wave action from the Rivercat ferry). The grain size of the sediments in the nearshore sites is more variable than that in the offshore sites, particularly with respect to the proportion of fines. At BG1, the site closest to Breakfast Point, sand (particles > 75 µm but less than 2mm) accounts for 70% of the sediment and fines made up the remaining 30% (Cardno Ecology Lab 2009b). The coarser nature of the sediment at this site probably reflects localised erosion resulting from repeated exposure of the site to waves generated by ferries and other vessels and/or tidal currents.

The sediments along the foreshore adjacent to the site of the former Mortlake gasworks are contaminated with oils, grease, chromium, copper, zinc and lead (Dames and Moore 1989). Within the Remediation Site, PAH concentrations are generally in excess of the ISQG-High trigger values in surface and sub-surface layers of nearshore sediments, but generally between the ISQG-Low and ISQG-High trigger values in sediments from the middle and outer boundary (URS 2006b). The total organic carbon content of the sediments within the Remediation Site varied from 0.6 to 5.1 % which is within the range reported in Sydney Harbour (URS 2006b).

In May 2009, studies of sediment contamination within and adjacent to the Proposed Marina Location were undertaken by AECOM (2009). The free cyanide concentrations in all sediment cores and sections thereof were below the limit of laboratory reporting, as were most of the total cyanide concentrations, except where the landward end of Floating Arm 3 and nearshore end of the proposed jetty would be located. At these positions, the total cyanide concentration was generally greater in deeper than surface sediments. The concentrations of BTEX compounds (benzene, toluene, ethylbenzene and xylene) in the sediment cores were also below the limit of reporting, except where the landward end of Floating Arm 5 and the nearshore end of the proposed jetty would be located. These were also the locations with the greatest TPH concentrations, with some values being an order of magnitude greater than found in most of the other cores. In 14 of the 28 piston cores, the TPH concentrations increased with depth. The following table shows the number of piston core samples from the different layers in which the concentrations of total PAHs, the contaminant of greatest concern, were below the ISQG- Low, between the ISQG-Low and ISQG-High value and in excess of the ISQG-High value.

Layer	Less than ISQG-Low	Between ISQG-Low and ISQG-High values	Exceeds ISQG-High value
Surface 0.0 - 0.02 m	7	17	4
Sub-surface 0.02 - 0.1 m	4	19	5
Deep 0.2 - 0.5 m	7	14	7

Data suggest that PAH contamination also increased with depth, but not in all cores. This is consistent with the findings of URS (2006c) who noted that contaminated sediments in some areas of the Remediation Site were overlain by relatively clean material, but in other areas clean sediments were overlain by contaminated sediments. The most contaminated surface sediments were situated below where the landward ends of Floating Arm 1, the nearshore end of the proposed jetty and the middle of Floating Arm 4 would be located. The most contaminated sub-surface layers were located at these positions and where the landward end of Floating Arm 2 would be positioned. The most contaminated deeper sediments were found where the landward end of Floating Arms 1, 2 and 6, mid to seaward end of Arm 3, and the nearshore end of the proposed jetty would be located.

The Acid Sulfate Sediment Soil Map (Edition 2) for Prospect/Parramatta River indicates that there is a 'High Probability' of occurrence of ASS within the 'Bottom Sediments', and that there is a potential for severe environmental risk if bottom sediments are disturbed by activities such as dredging (DLWC 1997). The laboratory analyses for Suspension Peroxide Oxidation Combined Acidity and Sulfate (SPOCAS) undertaken as part of the Sediment Investigation for the Proposed Marina indicated that potential acid sulphate soils occur at a depth of 0.2-0.4 m in the sub-surface sediment at the five locations tested (AECOM 2009). It is understood that an acid sulphate management plan will not be required, because these sediments will not be excavated.

The concentration of heavy metals in surficial sediments and in the water column has also been assessed recently (Cardno Ecology Lab 2009b). Concentrations of arsenic, chromium and copper in the sediment were generally in excess of their respective ISQG-Low values but not their ISQG-High values, whilst those of lead, mercury and zinc were above their respective ISQG-High values in at least half the sites. It was also noted that concentrations of chromium, copper, lead, nickel, zinc, and to some extent arsenic, were greater in sediment collected from deep than shallow sites. This difference probably reflects the exposure of sediments in shallow areas to greater hydrodynamic forces. In the water column, copper concentrations exceeded the ANZECC/ARMCANZ 95% trigger values at all sites and were at or slightly above the 90% trigger value on one occasion, but between the 80% and 90% trigger values on the other. Zinc concentrations exceeded the 99% trigger value at all sites, but were close to the 95% trigger value at two sites during low tide on the first sampling occasion. The concentrations of chromium and nickel were below their respective 99% and 95% trigger values, but those of lead were below the 95% trigger value, but close to or slightly in excess of their 99% trigger value in some of the samples collected.

3.3 Aquatic Fauna and Flora

3.3.1 Hard Substrata

The base of the sandstone revetment adjacent to the Proposed Marina Location was covered with an algal turf consisting of a mixture of the green algae *Ulva* sp. and

Enteromorpha sp. and the red algae *Corallina officinalis*. The brown alga, *Sargassum* sp., red algae*, Gelidium* sp. and *Pterocladia capillacea,* and an unidentified blue-green alga were also present. The Sydney rock oyster (*Saccostrea glomerata),* blue mussel (*Mytilus edulis* or *Xenostrobus pulex*), the barnacles *Elminius modestus* and *Tesseropora rosea* and gastropods *Patelloida mimula, Notoacmaea* sp. and *Bembicium auratum* were the most conspicuous animals. All of the above species, except for *Pterocladia capillacea*, *Tesseropora rosea* and *Notoacmaea* sp. were also found on the vertical seawall adjacent to the Proposed Marina Location. Two additional species, the limpet *Siphonaria denticulata* and barnacle *Chthamalus antennatus* were also observed on this seawall.

The piles at Cabarita Wharf were inspected to gain an understanding of what type of aquatic biota might colonise the proposed marina structures. The piles at Cabarita Wharf are covered in a green filamentous alga, most likely *Enteromorpha* sp., *Ulva* sp., the red algae *Gelidium* sp. and *Gracilaria* sp. and an unidentified brown filamentous alga. Three animals were observed: mussels (*Mytilus edulis* or *Xenostrobus pulex*) and the barnacles *Chthamalus antennatus* and *Tesseropora rosea*. The bedrock and natural boulders to the east of the wharf support a greater variety of animals, with a small yellow finger sponge, an encrusting bryozoan *Watersipora subtorquata*, the gastropods *Turbo undulatus*, *Clanculus undulatus* and *Bembicium auratum,* and crabs *Ozius truncatus* and *Paragrapsus laevis* being present in addition to mussels (*Mytilus edulis* or *Xenostrobus pulex*) and the barnacle *Chthamalus antennatus*. Five different types of algae were observed: *Ulva* sp. *Corallina officinalis*, *Dictyota dichotoma*, *Sargassum* sp. and a green filamentous alga (most likely *Enteromorpha* sp.).

3.3.2 Soft Substrata

In May 2009, samples of sediment collected using a Van Veen grab were used to assess differences in the composition and relative abundance of the infauna at eight sites within the Proposed Marina Location and two sites at the southern end of Kendall Bay. The sites within the Proposed Marina Location were distributed across four positions along the shore and over two strata (nearshore and offshore). The samples from the Proposed Marina Location contained 30 taxa (17 polychaete, 5 crustacean, 5 mollusc and 3 others), with mactrid bivalves, capitellid, nephtyid, sabellid, spionid and lumbrinerid polychaete worms being the most abundant. The samples from Kendall Bay South contained 17 taxa (8 polychaete, 3 crustacean, 4 mollusc and 2 others) and were dominated numerically by nephtyids and nemerteans (ribbon worms). The difference in number of taxa at these locations probably reflects a difference in sampling intensity.

The infauna in the nearshore and offshore strata were similar in terms of mean numbers of taxa and animals per sample and structure of assemblages. Similar mean numbers of taxa and animals were also found at the four positions surveyed along the Proposed Marina Location, but the assemblages at the southernmost position were significantly different from and more variable than those at the other positions. The dissimilarity in these assemblages was due to differences in average abundances of taxa with tellinid bivalves, capitellids and lumbrinerids being consistently less abundant and opheliid, spionid and polynoid worms and laternulid bivalves more abundant at the southernmost position. The variation in mean numbers of taxa and animals and in structure of assemblages was not significant among offshore sites. Significant differences in the mean number of animals and in the structure of assemblages, however, were evident among nearshore sites.

The nearshore assemblages within the Proposed Marina Location also differed from those at the southern end of Kendall Bay. The dissimilarity between these assemblages was also due primarily to differences in abundances of taxa, with some being more abundant (e.g. capitellid worms and mactrid bivalves) and others less so (e.g. nephtyid worms) at the Proposed Marina Location.

The spatial pattern in the infauna at the Proposed Marina Location did not appear to be linked with the concentrations of the major contaminants.

The mean number of taxa within samples from the Proposed Marina Location was similar to that at both Reference Locations, but the mean number of animals was similar to that at only one Reference Location. The overall structure of the assemblages at the Proposed Marina Location, however, was significantly different from that at both Reference Locations. This suggests that the infaunal assemblages at the Proposed Marina Location are not typical of that region of the estuary. The dissimilarity in these assemblages was due to lower abundances of capitellid and nephtyid worms and greater abundances of mactrid bivalves at the Proposed Marina Location.

3.3.3 Epibenthic Assemblages

In May 2009, benthic fish and mobile macroinvertebrates associated with offshore soft sediments at three sites within and immediately adjacent to the Proposed Marina Location were sampled by means of beam trawling. A total of 64 taxa (11 polychaete, 25 crustacean, 16 mollusc, 6 fish and 6 other taxa) were collected at these sites with the mactrid bivalve *Spisula trigonella,* mysid *Haplostylis dakini,* amphipod *Corophium* sp. and shrimp *Philocherus* sp. being the most abundant. The total numbers of individuals and taxa and most abundant taxa collected at each site are summarised below:

Site	Total no. of Taxa	Total no. of Animals	Most Abundant Taxa
Kendall Bay North	48	903	*Spisula trigonella* *Haplostylis dakini* *Corophium* sp. *Philocherus* sp
Kendall Bay Mid	35	1844	*Spisula trigonella* *Haplostylis dakini* *Philocherus* sp *Corophium* sp.
Kendall Bay South	28	922	*Spisula trigonella* *Haplostylis dakini* Nemertea (ribbon worms) *Philocherus* sp.

The mean numbers of taxa and animals and overall structure of the epibenthic assemblages in Kendall Bay were similar to those at the Reference Locations combined. This suggests that the epibenthic assemblage at the Proposed Marina Location was typical of that region of the estuary. The mean numbers of taxa and animals were also similar among sites, however, it should be noted that the catches of the beam trawls were highly variable. The only significant difference found in the structure of the epibenthic assemblages was between those at Kendall Bay North and Kissing Point Bay. The dissimilarity between these assemblages was due to differences in composition in addition to differences in abundances of taxa.

The fish component of the epibenthic assemblages at Kendall Bay North and Kendall Bay South were significantly different from that at Kendall Bay Mid and Kissing Point Bay. The exquisite goby (*Favonigobius exquisitus*) accounted for most of the dissimilarity in these assemblages and was more abundant on average at Kendall Bay Mid and Kissing Point Bay.

3.3.4 Mobile Fish and Invertebrate Assemblages

In May 2009, the fish and mobile macroinvertebrates associated with nearshore soft sediments at the Proposed Marina Location, Sydney Rowing Club and Kissing Point Bay were sampled using a beach seine net. Fifteen taxa (1 jellyfish, 6 crustacean and 8 fish) were caught off the sandy beach near the Proposed Marina Location, with the transparent goby *Gobiopterus semivestitus*, mysid *Haplostylis dakini* and glassy *Ambassis jacksoniensis* being the most abundant.

Significantly fewer taxa were caught at the Proposed Marina Location than at either Reference Location. Intermediate numbers of taxa were caught at Kendall Bay South. There was some indication of a difference in the structure of these assemblages among sites, with that at the Proposed Marina Location being distinct from that at Kendall Bay South.

3.4 Aquatic Habitats, Flora and Fauna of Conservation Significance

Aquatic habitats, flora and fauna of conservation significance are protected under both State and Federal legislation. In NSW, threatened species, populations and ecological communities of animals and plants are protected under the *Threatened Species Conservation Act 1995* (referred to hereafter as the *TSC Act 1995*). This Act does not generally apply to threatened species, populations and ecological communities of fish and marine vegetation which are protected under the *Fisheries Management Act 1994* (referred to hereafter as the *FM Act 1994*). The *TSC Act 1995* and *FM Act 1994* also list a number of key threatening processes that may threaten the survival of species, populations and ecological communities. The *Environment Protection and Biodiversity Conservation Act 1999* (referred to hereafter as the *EPBC Act 1999* protects wetlands of international importance, Commonwealth Marine Areas, nationally threatened species and ecological communities and migratory species, nuclear actions and world and national heritage places. None of the taxa caught in May 2009 at the Proposed Marina Location were of conservation significance.

3.4.1 Critical Habitats

The NSW Critical Habitat Register indicates that there are no critical habitats within Kendall Bay (DECC 2008).

3.4.2 Threatened Species

Six threatened marine mammal species listed under the *TSC Act 1995* are known to occur and another species is predicted to occur within the Sydney Metro Area Marine Zone (DECC 2005) (Table 4). No threatened marine invertebrates or algal species are listed within this zone. The BIONET database indicates that none of the threatened species have been recorded within the local government area (Canada Bay LGA) which incorporates Kendall Bay. The distribution range and habitat preferences of the critically endangered and endangered species listed under the *FM Act 1994* indicate that they are unlikely to occur in Kendall Bay. The BIONET records indicate that none of these species have been recorded in Canada Bay LGA and the Australian Museum Ichthyology Database indicates that none of them have been recorded in Sydney Harbour (Australian Museum 2006). Black cod *(Epinephelus daemelii)*, one of the species listed as vulnerable under the *FM Act 1994*, is known to occur in Sydney Harbour (Australian Museum 2006), but does not appear to have been recorded within Kendall Bay or the Canada Bay LGA.

The Protected Matters Tool indicates that 14 threatened species listed under the *EPBC Act* 1999 occur within Canada Bay LGA, however, these are all terrestrial species and therefore outside of Cardno Ecology Lab's brief.

3.4.3 Threatened Populations

None of the Threatened Populations listed under the *TSC Act 1995* as occurring in the Sydney Metro Area have been found within Kendall Bay or its immediate vicinity (DECC 2005).

3.4.4 Threatened Ecological Communities

None of the Threatened Ecological Communities listed under the *TSC Act 1995* as occurring in the Sydney Metro Area have been found within Kendall Bay or its immediate vicinity (DECC 2005). There are no critically endangered or vulnerable ecological communities listed under the *FM Act 1994*. None of the endangered ecological communities listed under this Act occur within Kendall Bay. Only one threatened ecological communities listed under the *EPBC Act 1999* occurs within the Canada Bay LGA, however, this is not relevant to the current study as it is terrestrial.

3.4.5 Protected Species and Habitats

One order of fish, the Syngnathiformes (seahorses, seadragons, pipefish, pipehorses and seamoths) and eight individual species of marine or estuarine fish are listed as protected under the *FM Act 1994* (DPI NSW 2005a). A review of the distribution range and habitat preferences of these species indicates that four species, elegant wrasse (*Anampses elegans*), eastern blue devil fish (*Paraplesiops bleekeri*), estuary cod *(Epinephelus coioides)* and weedy seadragons (*Phyllopteryx taeniolatus*) could potentially occur in Sydney Harbour. The Australian Museum Ichthyology Database indicates that 20 species within the family Syngnathiformes and all of afore-mentioned species, except estuary cod, have been recorded in the harbour (Australian Museum 2006). The BIONET database indicates that none of these protected species have been recorded within Canada Bay LGA. It should, however, be noted that these databases only include records from government agencies. The limited sampling undertaken within Kendall Bay by other groups indicates that a member of the Syngnathiformes, the Hairy Pipefish (*Urocampus carinirostris*) was present at the southern end of Kendall Bay in 1988 (The Ecology Lab 1989). This species, however, was not found in the area in 1996 or during the current study.

Wetlands are protected under Part 6, Clauses 61 - 63 of the Sydney Regional Environmental Plan (SREP) (Sydney Harbour Catchment). The accompanying Wetlands Protection Area Maps (Sheets 2 and 3) indicate there are no protected wetlands along the western foreshore of Kendall Bay adjacent to the Proposed Marina Location. There are, however, protected wetlands at the southern end of Kendall Bay and to the east around Cabarita Wharf and Cabarita Point. A small, sparse patch of the seagrass *Halophila ovalis* was found off the rock platform near Cabarita Wharf during a survey of the distribution of aquatic macroflora within Kendall Bay undertaken in September 2007 (The Ecology Lab, unpublished).

3.4.6 Key Threatening Processes

Only one of the seven key threatening processes currently listed under the *FM Act 1994* is relevant to the marina project. This is “Introduction of non-indigenous fish and marine vegetation to the coastal waters of NSW”, which has been listed because they could cause species, populations or ecological communities that are not currently threatened to become threatened (DPI NSW 2005b). Fouling of boats and boating equipment is one of the mechanisms that can lead to the spread of non-indigenous fish and marine vegetation.

3.4.7 Listed Marine and Migratory Species

The Protected Matters Tool indicates that 13 marine species and 15 migratory species listed under the *EPBC Act* 1999 occur within Canada Bay LGA, however, these are all birds. There are no marine species which will be affected by the development.

4 Environmental Issues, Potential Impacts, Mitigation and Management Measures

This section comprises a description of the proposed works, an overview of the environmental issues likely to arise from these works, an assessment of the potential impacts of the development on aquatic habitats, flora and fauna and a review of potential mitigation and management measures that could be used to ameliorate these impacts. Impacts on assets of conservation significance have not been addressed, because there is no evidence that any exist within the Proposed Marina Location.

4.1 Description of Proposed Works

4.1.1 Outline of Works

The proposed Inner West Marina would be situated to the east of the Breakfast Point residential development off the western shoreline of Kendall Bay, on the Parramatta River, Sydney. The marina would be situated up to 160 m east of the mean high water mark, at least 140 m away from the main navigation channel along the Parramatta River and approximately 90 m away from the access path of the commuter ferries servicing Cabarita Ferry Wharf. The marina would extend out approximately 150 m into Kendall Bay. The proposed marina development includes:

- The placement of a geotextile blanket and basalt rock ballast on top of the underlying sediment;
- Construction of a low level jetty with sewage pump out facilities, security gate, manager's office, small amenity area, small kiosk and a ferry wharf;
- Construction of eight floating arms supporting a total of 172 wet berths, 20 of which will be for casual mooring; and
- On land parking.

The Construction Management Plan (TLB Engineers 2009) indicates that the development would be undertaken in the following stages:

- Blanket Construction – 30 weeks;
- Fixed Jetty and associated infrastructure – 24 weeks;
- Floating Arms 4, 5, 6, 7 and 8 and associated piles -14 weeks;
- Floating Arm 3 and associated piles – 10 weeks;
- Floating Arms 1 and 2 and associated piles – 18 weeks; and
- Pontoon and Ramp – 2 weeks.

It is understood that work would be restricted to the period between 07h00 and 17h30 from Monday to Friday and from 07h00 to 13h00 on Saturday. The materials and equipment for the construction would be brought to the site on board barges.

4.1.2 Blanket Construction

The placement of a geotextile blanket over the sediment below the Proposed Marina Location is proposed to meet the requirement of the Remediation Order with respect to disturbance of the bed sediment of Kendall Bay within 200 m of the land-based boundary of the former gasworks (see Section 2.1).

In preparation for work in the Proposed Marina Location, a series of temporary piles would be driven around the perimeter of the work area. Pile driving would be done with temporary silt curtains around the barge and pile insertion point. The temporary piles would serve to anchor the outer silt curtain that would remain in place for the duration of the works, and provide a secure mooring for the barges used to deploy the blanket. After placement of the outer silt curtain, and inner, moveable silt curtain would be placed parallel to the outer

curtain. These curtains would prevent the spread of any sediment resuspended during the construction works. Both curtains will have a section that can be opened to allow passage of barges, construction vessels and floating pontoons.

The blanket would be positioned within the inner curtain by laying overlapping pre-made sheets of geotextile with a plan area of 40 m x 100 m over the side of a barge (TLB Engineers 2009). It would be constructed from west to east with work on the western edge commencing at or above mid tide levels, maintaining a minimum water depth of 2m. As the geotextile sheets are laid, an excavator with a GPS-controlled bucket would be used to place a 300 mm thick layer of basalt rock ballast over the geotextile. Divers would position the initial section of each geotextile sheet and ensure no gaps between adjacent sheets. Once the blanket is in place the inner silt curtain would be moved over the laid blanket to surround areas for pile insertion, minimising disturbance of the seabed. Insertion of piles into the estuary bed to support the floating arms and jetty would be done by driving piles through the geotextile fabric at pre-determined locations. Construction barges would be manoeuvred into place using mooring lines, without the use of propellers or tug boats.

The general blanket concept design consists of a 300 mm thick rock profile, but with thickening to 400 mm in critical zones between Arms 3 and 4 and at the inshore end between Arms 1 and 2 (GbaCOASTAL Pty Ltd 2009). The 300 mm thick blanket would be made up of 2-5 layers of rock, probably basalt, varying in diameter from 70 to 160 mm, whereas the thickener areas would be composed of 2-3 layers of rock varying in diameter from 140 to 235 mm. The rock blanket would be separated from the underlying bed sediments by a 5.7 mm thick heavy duty, non-woven polypropylene, geotextile filter such as Elcomax 1200R, which has the smallest equivalent opening size available (i.e. < 75 µm).

During Stages 2 and 3, the inner silt curtain would be placed over the blanket around the area where the jetty and Floating Arms 4-8 would be constructed and during Stages 4 and 5 it would be placed around the area where Floating Arms 1-3 would be constructed (TLB Engineers 2009). The floating arms would be constructed from modular pontoons and would be supported by concrete piles, with diameters varying from 400 mm for vessels up to 16 m in length to 600 mm for larger vessels. The floating arms would be assembled off site and towed to the site by a barge when required. The segments of the floating structure would be secured to the concrete piles by pile guide brackets. Each pile would be fitted with a purpose-made shoe capable of displacing the ballast and cutting the geotextile locally when driven. They would be positioned using a GPS and then driven into the substratum.

A low level jetty composed of steel piles, timber beams and timber decking would be constructed at the location of the original high level wharf used to transfer coal to the AGL gasworks (TLB Engineers 2009). Once the piles on each line have been installed, an HDPE sleeve would be placed over each pile and then a steel headstock would be inserted and secured in position. A barge-mounted crane would be used to install the timber beams between the headstocks and then the timber decking would be placed over the timber beams (TLB Engineers 2009). Temporary piles would be installed to assist in positioning the barges used to install the piles. The Construction Management Plan indicates that a total of 160 piles would need to be installed and that on average two piles would be installed per day.

The berths at the proposed marina would serve vessels varying in length from 8 m – 25 m. These vessels would generally be motor-powered and have relatively shallow draft and above water profiles less than 4m in height. The northern most vessels moored in the marina would be situated 140 m south of Breakfast Point, and at least 25 m east of the mean high water mark, in an area where there is sufficient water depth without the need for dredging. The berths would be located over depths varying from approximately 3.0 m at the landward end of the arms to approximately 5.0 m at the outer end of Floating Arms 4-7. The smaller berths would be located at the foreshore end of Floating Arms 1-5 and along the entire length of Floating Arms 6-8. The largest berths would be situated along the inner

section of Floating Arm 3. The section of the waterway between the foreshore and marina structure would be accessible to kayaks. The proposed marina will not have a boat lift or maintenance facilities (TLB Engineers 2007). The proposed development will not require any dredging or reclamation works and there will be no removal or destruction of areas of marine vegetation.

4.2 Environmental Issues Associated with the Proposed Works

4.2.1 Construction Phase

- Subtidal soft bottom habitats and their associated biota would be lost when the geotextile blanket is laid;
- The existing fines-dominated habitat would be replaced by a layer of basalt rocks into which fines would settle over time;
- The biota within the water column encircled by the silt curtains would be disturbed indirectly by the resuspension of sediment and concomitant increase in turbidity resulting from blanket laying and pile driving;
- Subtidal soft bottom habitats and their associated biota located immediately beyond the geotextile blanket would be disturbed indirectly by resuspension and subsequent settlement of sediment when the blanket is laid;
- The resuspension and subsequent settlement of sediment may alter the bioavailability of contaminants in the water column; and
- Aquatic biota would be disturbed by underwater noise and vibrations generated by pile driving operations and construction vessels.

4.2.2 Physical Presence of the Marina

- The pontoons, pilings and jetty comprising the marina would provide novel habitats for a variety of aquatic organisms to colonise and may attract organisms away from surrounding natural habitats;
- The floating pontoons, jetties and walkways associated with the marina would shade the water and reduce the amount of light available to photosynthetic organisms in the water column and that may settle on the bottom; and
- Subtidal soft bottom habitats and their associated biota would be disturbed indirectly by changes in the sedimentation patterns within the bay resulting from the marina structure reducing the effects of short period vessel and wind generated waves within Kendal Bay (TLB 2007).

4.2.3 Operation of the Marina

- Boats mooring at the marina could introduce non-indigenous species which may compete with local aquatic flora and fauna; and.
- The combustion of fuel in boat engines, accidental spills of sewage, fuel, motor and other oils and release of toxic components from anti-fouling paints applied to boat hulls would alter the bioavailability of contaminants in the aquatic environment.

4.3 Marina Construction - Impacts, Mitigation and Management Measures

4.3.1 Loss and Direct Disturbance of Aquatic Habitats and Associated Biota

4.3.1.1 Potential Impact

The fines-dominated (particle size of < 75 µm) soft-sediment habitat that occurs in the area at present would be replaced by an approximately 30 - 40 cm thick layer of basalt rocks when the geotextile blanket is installed. Most of the organisms that occur within or on the

surface of the soft sediment would be unable to move away when the geotextile blanket is laid and would perish shortly thereafter. The loss of the fine sediments would reduce the overall amount of food available to mobile epibenthic and pelagic organisms that feed on infauna. It is estimated that 28.9% of the total area of subtidal soft sediment habitat within Kendall Bay (outer boundary delimited by a line extending from Breakfast Point to Cabarita Point) would be lost as a result of the installation of the geotextile blanket and basalt rock layer however, there are extensive areas of these habitats elsewhere in the estuarine section of the Parramatta River. The soft sediments and biota situated outside the immediate footprint of the proposed geotextile blanket may also be disturbed as sediment is squeezed out the margins as the blanket is laid.

4.3.1.2 Mitigation and Management Measures

The basalt rocks deposited on top of the geotextile blanket are likely to be colonised by a variety of organisms, either as a result of recruitment of propagules or immigration by juveniles and adults from populations elsewhere in the estuary. These organisms are likely to be species that are adapted for life on very coarse or hard substrata rather than soft sediments, hence the assemblages that develop on the rocks would have different characteristics to those existing at present. The timeframe of colonisation is difficult to predict, but is likely to be fairly slow initially, because of the paucity of similar habitats with source populations elsewhere within the estuary. The assemblages that develop on the upper and lower surface of the rocks and on the substratum between the rocks are also likely to differ, because of the different physical, chemical and biological characteristics of these microhabitats.

An infauna that is more comparable with that occurring at present may develop once sufficient fine sediment has been deposited within and on top of the layers of basalt rock. The rate of development of such infaunal assemblages is likely to be slow, because of its dependence on the deposition of sufficient sediment above the geotextile blanket. Recent studies indicate that up to 2.5 mm of sediment may be deposited each day within the Remediation Site (URS 2006d). If sediment that is resuspended locally is a major contributor to SPM flux, the rate of sediment deposition would be considerably lower, because a large area of surface sediment will be overlain by the geotextile blanket. Once the floating pontoons, pilings and jetty forming the marina are in place, the rate of deposition of sediment is likely to increase, because the decrease in wind-generated wave energy resulting from the presence of these structures would provide conditions that are more favourable for sediment deposition. The sediment that settles would be mainly derived from other areas of Kendall Bay, the Parramatta River and Sydney Harbour

The piles inserted into the bed of the estuary would provide a novel, albeit artificial, hard substratum extending from the subtidal into the intertidal zone. Qualitative observations of the flora and fauna on the piles at the nearby Cabarita Wharf indicate that the intertidal portion of the piles are likely to be colonised by a variety of sessile organisms, including mussels, barnacles and algae, none of which occur in soft sediments. The artificial habitats provided by the marina piles would be colonised by biota that differs from that lost and from that on adjacent natural hard substrata (Barros *et al* 2001). The artificial habitats provided by the piles should therefore not be viewed as a form of environmental compensation.

4.3.2 Indirect Disturbance Associated with Resuspension of Sediment

4.3.2.1 Potential Impact

The laying of the geotextile blanket and insertion of the 160 piles needed to support the marina structure both have the potential to disturb soft sediments on the bed of the Proposed Marina Location. The resuspension of sediments in the water column and concomitant increase in turbidity could reduce the penetration of light. This, in turn, has the potential to alter chemistry and temperature of the water, limit primary production of

phytoplankton, benthic micro- and macroalgae via reduced photosynthetic capacity and reduce the visual acuity and hence foraging success of predatory fish (Wilber and Clarke 2001). Increases in the concentration of suspended sediment can also affect the development of eggs and larvae, clog respiratory and feeding mechanisms of animals, reduce pumping rates of bivalve molluscs and even cause direct mortality (Wilber and Clarke 2001). Mobile organisms are likely to move away from suspended sediment and turbidity plumes, however, there is a possibility of some species being attracted to the plumes because of the reduced risk of predation (Blaber and Blaber 1980; Cyrus and Blaber 1992).

The resuspension of sediment and increase in turbidity arising from the laying of the geotextile blanket and insertion of piles is only likely to have adverse effects on estuarine biota if the suspended sediment load and turbidity exceed the general background levels to which the biota are normally exposed or occur for longer. An appreciation of the effects of natural disturbances and other anthropogenic activities on suspension of sediments and/or turbidity is consequently needed to assess potential impacts on aquatic organisms arising from the deployment of the blanket and pile driving. The major processes contributing to background levels of sediment resuspension and turbidity in Kendall Bay are wind-generated waves, tidal currents and movements of boats, particularly the Rivercat ferry (URS 2006a). The turbidity levels in the bay are generally low (< 20 NTU), except at the southern end where ENE winds at low tide resuspend surface sediments and when the passing of the Rivercat results in a short-term, 20-fold increase in near bed turbidity (URS 2006a).

The extent to which the disturbed sediment would be re-suspended and turbidity of the water column increased depends on the size, density and quality of the material being disturbed, the way in which the piles are inserted and blanket is deployed and the hydrodynamic conditions prevailing at the time of the works. The amount of sediment resuspended during pile driving would be relatively small, restricted to the immediate vicinity of each pile, and likely to persist only whilst the pile is inserted and for a short-time thereafter. As the construction plan indicates insertion of two piles only per day, the disturbance to the sediment within the bay resulting from pile driving would also be intermittent. The area of the seabed that would be disturbed per day would be very small, varying from approximately 1 - 2.25 m^2, depending on the diameter of the pile. The total area of the bed disturbed by pile driving would thus be very small (< 1%) relative to the rest of the bay. The small areal extent and transient nature of the turbidity plumes generated during pile driving suggest that they are unlikely to have a significant impact on photosynthetic activity, growth and productivity of phytoplankton and benthic algae or on the respiratory and feeding mechanisms of animals within Kendall Bay.

The total area of the bed that would be disturbed by deployment of the geotextile blanket, would be considerably greater, with each sheet covering an area of 4000 m^2 and the total coverage being 57,000 m^2. It is expected that the upper 100 mm of very soft sediments within this area would probably be disturbed during blanket laying (Douglas Partners 2009). It is understood that blanket construction would take 30 weeks, involve the deployment of 11 sheets below the Proposed Marina Location and commence on the western side and Breakfast Point end of the location at high tide. Deployment of the geotextile blanket could cause much greater amounts of sediment to be re-suspended and cause much greater increases in turbidity than pile driving, but the impact would be restricted to the construction period.

The settlement of the bed surface under the weight of the blanket would result in upward release of interstitial water through the geotextile and rock layers into the water column. The displacement of interstitial fluid is likely to be complete to a stable state well before the construction phase of the development is completed. Geosynthetic Testing Services have assessed the potential for migration of fine sediment particles by static and hydrodynamic testing of the non-woven blanket with samples of sediment from the proposed marina location. These tests respectively indicate that between 0.2 - 1.3% and 5.8-39% of fine sediments could potentially migrate through the geotextile once it has been laid. The results

of the static testing are believed to be more representative of the hydraulic loading environment during the construction phase (GbaCOASTAL Pty Ltd 2009). A small amount of potentially contaminated fine sediment is expected to still migrate through the blanket for several months, resulting in the equivalent of a 10 mm layer of fine sediment. In the year after construction, it is estimated that boat wash would resuspend this material, allowing it to be transported beyond the immediate area of the proposed marina. It is predicted that material of the equivalent of a 1 mm layer of fine sediment may be deposited in the mangrove habitat near the head of Kendall Bay (GbaCOASTAL 2009). While these sediments are likely to contain some contaminates, they are likely to be impossible to detect against background levels of contaminants in existing sediments adjacent to the mangrove habitat. The presence of the blanket would markedly reduce the quantity of fine sediments that can be resuspended compared to the existing situation.

4.3.2.2 Mitigation and Management Measures

During Stage 1, two silt curtains attached to floating booms would be deployed from the shoreline to a distance 2 m beyond the area encompassing the blanket (see CMP01B). The outer curtain will remain in the same position during Stages 2-5, but the inner curtain will be moved so that it encircles the area encompassing Floating Arms 4-8 during Stages 2-3 of the development (see CMP02B) and the area encompassing Floating Arms 1-3 during Stages 4 and 5 (see CMP03B). The deployment of these curtains would minimise the spread of resuspended sediment into nearby protected wetlands, other areas of Kendall Bay and the estuary, provided that they are properly maintained and inspected regularly. Unfortunately, the silt curtains may trap mobile organisms such as fish within the marina footprint. This could reduce the overall amount of food available to them, given that benthic organisms on which some species feed will be unavailable under the blanket. There may also be a progressive impact on organisms that feed on plankton and nekton, because the normal replenishment of these resources within the Proposed Marina Location by tidal and wind-induced currents would be prevented by the silt curtains. The impacts on these organisms would be more acute during Stages 2-3 and 4-5 when progressively smaller areas would be encircled by the inner silt curtain. The twice daily opening of panels in the silt curtains to allow passage of construction vessels would mitigate this impact by allowing fish out of the curtained area, and replenishing supplies of plankton and nekton.

4.3.3 Changes in the Bioavailability of Contaminants

4.3.3.1 Potential Impact

The resuspension of sediments resulting from deployment of the geotextile blanket has the potential to release contaminants from surface sediments into the water column, while that resulting from pile driving activities has the potential to release contaminants sequestered in both surface and deeper layers of the sediment (See Section 2.3). The contaminants that are remobilised may enter estuarine organisms living in the water column via adsorption onto body surfaces, ingestion of suspended particles or food, exchange of water at respiratory and feeding surfaces (Kennish 1992). The uptake of contaminants is dependent on their bioavailability and the physiology of the organism. The bioavailability of contaminants is dependent on a number of processes, including dissolution, redox reactions and sorption-desorption of compounds, currents and tidal exchange, microbial degradation and bioturbation (Kennish 1992). The major biological factors determining uptake are the size of the organism, its ingestion rate, growth rate, membrane permeability, ventilation rate, gut residence time and osmoregulation (Juhasz and Naidu 2000). The impact of contaminants on estuarine biota is also difficult to predict because they vary considerably in their sensitivity to these toxicants and in their ability to metabolise and eliminate them.

The contaminants of greatest concern are PAHs and the heavy metals, chromium, copper, lead, mercury and zinc, all of which occur at concentrations in excess of the ISQG-Low values in the sediments below a large proportion of the Proposed Marina Location. In some

areas, the concentrations of PAHs, lead, mercury and zinc exceed the ISQG-High value (see Section 3.2.2).

PAHs are hydrophobic, have a low solubility in water and a strong affinity for particulate matter (Kennish 1992), so it is unlikely that large concentrations of these contaminants would be released into the water column. The PAH concentrations in water within 0.5 m of the estuary bed have been shown to be below the ANZECC/ARMCANZ water quality guideline 95% trigger values (URS 2006c). This implies that there is normally no detectable flux of dissolved contaminants from the sediment into the water column and that the potential for adverse ecological effects on organisms residing in the water column at the Remediation Site is currently low. This is consistent with previous studies (The Ecology Lab 1996) that indicated that benthic infaunal organisms in direct contact with sediments (and, in some cases directly ingesting sediments) contained levels of PAHs significantly higher than baseline, while PAHs levels were lower in bottom-feeding fish species collected near the site, and may have accumulated as fish ingested contaminated benthic infaunal prey. In the longer term, the presence of the blanket represents and improvement in the current condition by virtue of substantially isolating contaminated sediments from the marine food chain.

Heavy metals exist in dissolved, colloidal and particulate phases, but are generally more concentrated in the sediment than in the water column. In estuaries, dissolution, desorption and autolytic biological processes can release heavy metals into the water column. The analyses of water and sediment samples suggest that estuarine organisms that ingest contaminated sediment are more likely to exhibit toxic effects than those which take up heavy metals by diffusion (Cardno Ecology Lab 2009b). The oxidation of sediments and decomposition of organic matter, including the decay of the organisms trapped under the blanket, could facilitate the mobilisation of heavy metals from sediments (Kennish 1992).

The threat to organisms, such as zooplankton and bivalve molluscs that feed on suspended particulates, however, is generally much greater than to organisms which are exposed to water-soluble contaminants through ventilated water (Meador *et al.* 1995). Organisms that feed on filter-feeders may also be exposed to PAHs and heavy metals. Organisms, such as algae and bivalves, which lack the enzymes necessary to metabolise and eliminate PAHs and heavy metals are more likely to accumulate large amounts of these contaminants PAHs in their tissues than fish and crustaceans which are able to metabolise, eliminate or sequester PAH compounds and heavy metals.

4.3.3.2 Mitigation and Management Measures

The threat to organisms resulting from a potential increase in the concentration of contaminants on suspended particulate matter would be minimised by using silt curtains to confine and prevent the spread of sediment and turbidity plumes. As pile driving has the potential to disturb and resuspend both surface and deeper sediments it is recommended that small turbidity curtains be installed around the areas in which the individual piles are to be inserted prior to them being driven into the estuary bed. This would reduce the likelihood of mobile organisms being exposed to contaminants. The exposure of benthic organisms to an increase in the bioavailability of contaminants will not be an issue within the Proposed Marina Location, because these organisms would have perished shortly after the geotextile blanket was laid. The dispersion of soluble contaminants through the silt curtains could pose a threat to organisms outside the Proposed Marina Location, if concentrations exceed the ANZECC/ARMCANZ guidelines (2000).

Post-construction, the small amount of fine sediments within the basalt armour that could be resuspended by boat wash and settle into nearby mangrove habitats is small, and the impact of such settlement on mangrove habitats is likely to be impossible to distinguish from impacts of other contaminated sediments near the head of the bay (URS 2006b). The geotextile blanket would limit the potential for settlement of contaminated fine particles in this habitat compared to the existing situation.

4.3.4 Generation of Underwater Noise and Vibrations

4.3.4.1 Potential Impact

The driving in of the piles required to support the marina structure and use of barges and construction vessels to lay the geotextile blanket and manoeuvre the floating structures and piles into position will cause temporary increases in ambient noise levels. At present, the major sources of background underwater noise are the action of wind, waves and rain on the surface of the water, boat traffic within Kendall Bay and the main channel of the Parramatta River (including the regular passage of the River Cat ferries) and noise produced by organisms such as fish and crustaceans.

The underwater noise generated by pile-driving hammers has the potential to physically damage fish, decapod crustaceans and marine mammals occurring in the immediate vicinity of the pile being driven into the substratum and disturb animals in the general vicinity of the pile driving operations. The sounds emitted during pile driving operations depend on the type and diameter of the pile installed, type of hammer used and underlying substratum. The information that is currently available about the effects of exposure to sound from pile driving is limited and results of the few studies that have been undertaken equivocal (Hastings and Popper 2005). Despite this, there is evidence that pile driving can damage the organs and tissues of fish and even kill some species, particularly if they are close to the source of the sounds. Further away, where the levels of sound are probably considerably lower, little or no effects on mortality and behaviour have been reported. The degree of damage caused is likely to depend on received level and duration of the sound exposure rather than the distance of the fish from the pile.

The sounds generated by boat propellers and engines have the potential to disturb fish and marine mammals that rely on hearing to find prey, avoid predators or communicate (Popper 2003, Popper *et al.* 2004). There is growing evidence that boat-generated noise can elicit behavioural and physiological responses in fish. For example, Vabø *et al.* (2002) have shown that passing vessels can elicit avoidance behavioural responses, such as body tilting as well as vertical and horizontal swimming in fish. Physiological responses such as changes in auditory sensitivity, elevated production of stress hormones and increased cardiac output have also been reported (Scholik and Yan 2002; Wysocki *et al.* 2006, Graham and Cooke 2008).

The impact of these activities is difficult to assess because of the lack of information on background noise levels in Kendall Bay, on noise levels and vibrations likely to be generated during construction and responses of aquatic organisms, other than mammals, to underwater noise.

4.3.4.2 Mitigation and Management Measures

Limitations on the times that construction activities can take place (see Section 4.1) and restriction of pile driving to 2 per day would assist in limiting impacts resulting from the generation of underwater noise and vibrations. Consideration should also be given to additional ways of reducing the level and frequency of noises emitted during such operations. Pile driving activities could, for example, be managed so that the underwater noise generated increases incrementally. This would enable mobile fauna to move away before maximum noise levels are achieved. The level of underwater noise generated during pile driving could also be reduced by creating a bubble curtain or screen around the area in which piles are being driven (Würsig *et al.* 2000). The fine bubbles of air produced by such devices attenuate the peak underwater sound pressure levels that have the potential to adversely affect sensitive fauna in the vicinity. If a hydraulic impact hammer is to be used to insert piles, an additional mitigation measure in the form of a hammer cushions could be used.

4.4 Marina Structure - Impacts, Mitigation and Management Measures

4.4.1 Changes in Sedimentation Patterns

4.4.1.1 Potential Impacts

The floating pontoons, pilings and jetty forming the structure of the marina will change the depositional/hydrodynamic regime by decreasing the effects of wind-generated wave energy. The more sheltered environment will increase the rate of deposition of suspended particulate matter advected in from other parts of the Parramatta River and Sydney Harbour and reduce the potential for disturbance and resuspension of fine sediment once it accumulates above the basalt rock. The change in sedimentation patterns would reduce the amount of suspended particulate matter available to filter-feeding organisms residing in the water column, but increase supplies to benthic organisms that will colonise the gravel layer over the blanket.

4.4.1.2 Mitigation and Management Measures

The change in sedimentation pattern associated with the marina structures can not be mitigated.

4.4.2 Provision of Novel Habitat

4.4.2.1 Potential Impacts

The floating pontoons, piles and jetty forming the structure of the marina would provide artificial habitat for a variety of organisms, including macroalgae, invertebrates and fish (Glasby 1999a; Connell 2000 and 2001). The presence of these structures has the potential to alter the distribution, diversity and abundance of organisms in the environment (Connell and Glasby 1999; People 2006). The assemblages of epibiota that develop on the pontoons, piles and jetty are likely to differ, because the structures themselves differ in terms of their orientation, composition and depth (Glasby 1999a; Glasby and Connell 2001). The sides and under surfaces of the submerged portions of the floating walkways at the nearby Westport Marina, for example, are covered in mussels which in turn provides a surface for growth of green, red and brown algae. The marina piles also supported mussels, but these were most abundant within 1 m of the water surface, with a matrix of turfing algae and invertebrates, including large ascidians and sponges occurring at greater depths (The Ecology Lab 1999). The infaunal assemblages that eventually develop in the soft sediments that accumulate below marinas are also likely to differ from those found at comparable sites without pontoons, etc. (Van Dolah *et al.* 1992; McGee *et al.* 1995; Lindegarth 2001). This could be due to a reduction in benthic primary productivity, increase in sedimentation of detritus and/or the attraction of greater numbers of predatory fish and crustaceans to artificial structures (Weston 1992; Davis *et al.* 1982).

Floating pontoons, piles and jetty may also serve as habitats for fish and pelagic invertebrates and may even attract fish away from surrounding natural habitats. Small-bodied species of fish, for example, may be attracted to piles and pontoons, because they provide shelter, protection from predators and/or food. Marina structures in Sydney Harbour and Pittwater have marked effects on the distribution and abundance of fish, with twice as many species occurring around piles than pontoons and nearby open water (Clynick 2008). The structure of the assemblages associated with pontoons and piles also differed from that in the open water, but differences in assemblages between pontoons and piles were found only at some marinas on some occasions. The dissimilarity between the assemblages in open water and around marina structures was due to large mobile species, such as yellowfin bream and yellowtail that moved between these habitats, and species, such as hula fish, stripey and immaculate damsels, that were abundant only around pontoons and piles. It is

difficult to make specific predictions about the impacts of the proposed Inner West Marina on fish assemblages, because there is considerable variation in fish assemblages among marinas and no indication, at this stage, of the factors responsible for this variation (Clynick 2008).

4.4.2.2 Mitigation and Management Measures

The artificial structures will increase the overall abundance of taxa normally found in association with hard substrata within the bay, but will not offset impacts on soft-bottom assemblages resulting from the introduction of these novel habitats. The assemblages that would develop on the artificial structures are also likely to differ from those on natural hard substrata and could even have adverse effects on adjacent natural habitats (Barros *et al.* 2001). The introduction of these artificial surfaces should not therefore be considered a form of environmental compensation.

4.4.3 Shading of the Water Column and Substratum

4.4.3.1 Potential Impacts

The floating pontoons, jetty and walkways forming the structure of the marina and boats moored alongside will shade the underlying water column and reduce the amount of light available to photosynthetic organisms including phytoplankton in the water column and benthic micro- or macroalgae that develop on the underlying substratum (Burdick and Short 1999). A reduction in photosynthetic ability could have adverse effects on the density, growth and productivity of aquatic flora, which could in turn have adverse effects on the animals that feed on phytoplankton and benthic algae. The landward end of the jetty would also shade the small section of the vertical seawall directly below it.

Impacts due to shading from the current proposal are difficult to assess, because of the paucity of information on the aquatic flora of Kendall Bay. The amount of shading will vary with the occupancy of the marina by boats and depend on the position of the sun. As the footprint of the marina would cover < 17% of the area of the bay (193,600 m^2 as delimited by a line between Breakfast Point and Cabarita Point) it is unlikely to have a significant impact on primary productivity, because this would already be limited by the turbid nature of the estuary. There is also a possibility that losses in primary productivity through shading may be compensated for to some extent by the growth of algae on piles located in relatively well illuminated areas (Iannuzzi *et al.* 1996). The shading of the seawall is likely to result in a localised reduction in the abundance of macroalgae and grazing molluscs and increase in sessile invertebrates (Glasby 1999b; Blockley 2007). The extensive growth of macroalgae on the revetment and seawall away from the jetty and the patch of seagrass near Cabarita Wharf would not be impacted by the marina development.

4.4.3.2 Mitigation and Management Measures

Shading effects of the jetty, pontoons and walkways could be mitigated by:

- minimising the length and width of floating structures;
- using mesh or similar material that allows light to penetrate through the structures; and
- restricting the time that boats berth at structures (NSW Fisheries 1999).

4.5 Marina Operation - Impacts, Mitigation and Management Measures

4.5.1 Indirect Disturbance Associated with Sediment Resuspension

4.5.1.1 Potential Impacts

The wash and wake from boats accessing the proposed marina have the potential to disturb, resuspend and erode sediment in intertidal and shallow subtidal areas and increase turbidity levels within the water column of Kendall Bay. The magnitude of the waves generated by boats depends on the speed, size and displacement of the vessel, the distribution of weight within the vessel, the shape of the hull, volume of the vessel as distributed along its length, the nature of the water body and the habitat through which the vessel is moving (The Green Blue 2008). The effects of increases in turbidity on estuarine organisms have been described previously (Section 4.3.2). Boat wash can also affect the structure of infaunal and epifaunal assemblages (Bishop 2004; Bishop and Chapman 2004; Bishop 2007).

A field-based investigation of the effects of boat wash on turbidity has been undertaken to determine whether boating activities at the proposed marina are likely to cause re-suspension of sediments over and above that attributed to background processes (i.e. wind action, tidal currents and wash from existing boat traffic) (Gary Blumberg and Associates 2007). The study showed that when a small boat (11 m) was manoeuvred at four knots underway it had a significant impact on turbidity in shallow water (2 m), but caused only a minimal change relative to background levels at depths of 3 - 5 m. Manoeuvring of a medium boat (14 m) at four knots underway resulted in minimal to small bed disturbance at a depth of 3 m and minimal disturbance at depths of 4 m and 5 m. The manoeuvring of a large boat (25 m) had significant impacts on turbidity at a depth of 4 m, but only minimal impacts at a depth of 5 m when underway at four knots. This study indicates that small and medium-sized boats operated at a depth of 4 m would not have a significant impact on turbidity. Tests were also performed on boats under full thrust but are not described here, because vessels using the marina are unlikely to be moving at this speed. The significant impacts that were detected were short-lived lasting less than 10 minutes. The cumulative effect of a number of boats leaving or arriving at the marina at the same time or in rapid succession, however, is likely to be much greater.

4.5.1.2 Mitigation and Management Measures

The potential impacts of boat wash on sediment and turbidity would be mitigated by limiting the size of berths situated over shallower areas of the Proposed Marina Location. Potential impacts would also be minimised by implementing and enforcing no wash zones and speed restrictions in and around the marina and indicating the maximum wave height and wave period that boats are permitted to generate on signage. The exposure of benthic organisms to boat wash will not be an issue within the Proposed Marina Location, because these organisms will be lost when the geotextile blanket is laid.

4.5.2 Changes in the Bioavailability of Contaminants

4.5.2.1 Potential Impacts

The release of toxic components from anti-fouling paints applied to boat hulls, combustion of fuel in boat engines, accidental spillages of fuel, oils, bilge water and sewage, and onboard washing of boats could introduce a variety of chemical contaminants into Kendall Bay.

In Australia, anti-fouling paints which gradually leach copper into the environment are generally used to control the growth of organisms on the hulls of vessels. The average *in situ* release rate of copper (8.2 µg/cm^2/day) from antifouling paint on the hulls of pleasure craft reported in the literature indicates that a large number of boats moored within a

localised area are likely to contribute significant amounts of copper over an extended period of time (Valkirs *et al.* 2003). Hull cleaning practices can also influence the rate at which copper is leached into the water from recreational boats. Estuarine organisms take up copper via ingestion of food and particulate matter and via diffusion of dissolved metals (Kennish 1992). The effects of copper on aquatic flora and fauna are difficult to predict, because this metal is essential for normal life processes and only becomes toxic when organisms are unable to regulate excessive concentrations, a capacity that varies from organism to organism. Organisms that assimilate and accumulate copper also differ in their ability to detoxify this heavy metal (Kennish 1992). It should, however, be noted that dissolved copper levels similar to those found at some marinas have been shown to be harmful to mussels, oysters, scallops, sea urchins and crustaceans (Carson *et al.* 2002).

The sediments below the proposed Marina Location have copper concentrations in excess of the ISQG-Low values. In the water column, total copper concentrations exceeded the ANZECC/ARMCANZ 95% trigger values at all sites and were at or slightly above the 90% trigger value on one occasion, but between the 80% and 90% trigger values on the other. If boat owners continue to use copper-based anti-fouling paints, boating activities at the marina are likely to result in concentrations in the water column becoming more harmful to biota.

Contaminants that remain in solution could have adverse effects on organisms residing in the water column. Heavy metals, PAHs and by-products of anti-fouling paints, however, are more likely to absorb onto particulate matter and accumulate in bed sediments (Voudrias and Smith 1986; Marcus *et al*. 1988). This could result in an increase in the existing contaminant loading of surface sediments below and adjacent to the Proposed Marine Location and, if the contaminants were bioavailable, increase the likelihood of adverse effects on benthic biota.

4.5.2.2 Mitigation and Management Measures

The following mitigation/management should be implemented to reduce potential threats to aquatic biota:

- The provision of a sewage pump-out facility at the landward end of the jetty would help mitigate any impacts arising from the disposal of sewage. Boat owners should also be prohibited from discharging sewage and bilge water directly into Kendall Bay and encouraged to remove oil from bilge water by using bilge removing pads.
- Boat owners should be educated about the environmental problems associated with use of copper-based anti-fouling paints; discouraged from *in-situ* cleaning of boat hulls that have been treated with copper paints and encouraged to switch to non-toxic anti-fouling paints.
- Accidental spillages of fuels and oils should be contained within floating booms and cleaned up as soon as possible to prevent weathering and subsequent deposition of heavy fractions.
- The potential for introduction of contaminants during on board washing of boats could be reduced by encouraging the use of environmentally friendly cleaning agents (i.e. those that do not contain chlorine or phosphate-based ingredients).

4.5.3 Introduction of Non-Indigenous Species

4.5.3.1 Potential Impacts

The hulls of vessels utilising the marina are a potential pathway for the introduction of non-native flora and fauna, including marine pests, into Kendall Bay. Marine pest species are of particular concern, because they are able to compete with existing native species, alter local gene pools and/or modify the physical environment. The occurrence of introduced species has been assessed in Sydney Harbour, but not in the tidal bays and section of the Parramatta River extending to the west of Rozelle Bay and Gore Cove (AMBS 2002). Two

known or likely exotic marine species, the bivalve *Theora lubrica* and bryozoan *Bugula flabellata,* and *Watersipora subtorquata,* a species of bryozoan believed to be introduced, have been found in Rozelle Bay. The yellowfin goby *Acanthogobius flavimanus* and bryozoan *Watersipora subtorquata* are the only introduced species known to occur in Kendall Bay (The Ecology Lab 1989 and 1996; Cardno Ecology Lab, this study).

4.5.3.2 Mitigation and Management Measures

The risk of inadvertent introduction of non-indigenous species can be reduced by prohibiting the cleaning of hulls and discharge of bilge water from boats moored at the marina. Boat owners should also be encouraged to inspect their hulls, anchors, fishing gear and general boating equipment for non-indigenous species, such as *Caulerpa taxifolia* which occurs in Sydney Harbour, and dispose of them in an appropriate manner. The biota on the piles and jetty comprising the marina and in the underlying soft sediments should be inspected periodically to determine whether non-indigenous species are present. The origin of vessels arriving at the marina should be determined so that a list of potential introduced species can be drawn up. A targeted marine pest survey and literature review should also be undertaken prior to the marina commencing operations to determine whether any known marine pests are present. This will provide a baseline for comparison during the operational life of the marina.

4.5.4 Underwater Noise

4.5.4.1 Potential Impacts

The usage of the marina will result in an increase in the amount of underwater noise generated by boats. The major sources of background underwater noise at present are the action of wind, waves and rain on the surface of the water, boat traffic within Kendall Bay and the main channel of the Parramatta River and noise produced by organisms such as fish and crustaceans. The increase in boat-generated noise has the potential to have adverse effects on fish and crustaceans (see Section 4.3.4). The impact of the increase in noise levels is difficult to assess because of the lack of information on background noise levels in Kendall Bay, on noise levels and vibrations likely to be generated by boats entering and departing the marina, likely patterns of movements of boats and responses of aquatic organisms, other than mammals, to underwater noise. As the noise produced by boats accessing the marina would be similar to that of existing traffic and intermittent in nature, the impact is unlikely to be significant.

4.5.4.2 Mitigation and Management Measures

The impact of the noise generated by the additional boating could be reduced by implementing and enforcing speed restrictions in and around the marina.

5 Recommendations

- As the concentrations of PAHs and some heavy metals within the sediment below the Proposed Marina Location exceed the ISQG-Low values and the ISQG-High values in some areas, it is recommended that elutriate tests be undertaken to determine the concentrations that might be released into the water column when the geotextile blanket is laid and the piles are inserted.
- As the total copper concentrations within the water column are already in excess of the ANZECC/ARMCANZ 95% trigger values, it is recommended that measures to encourage boat owners to use non-copper based anti-fouling compounds be incorporated into the environmental management plan for the marina. The concentration of copper within the sediment and water column should also be monitored regularly and screened against the appropriate ANZECC/ARMCANZ guidelines, once the marina commences operation.

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APPENDIX 4:

- AQUATIC ECOLOGY STUDIES

Cardno Ecology Lab

Shaping the Future

Marine and Freshwater Studies

Inner West Marina Sydney

Aquatic Ecology Studies

330809B

Prepared for TLB Engineers for Breakfast Point Pty Ltd

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Cover Image: Seine netting at Proposed Marine Location, 22 May 2009. Photographer Daniel Aveling, Cardno Ecology Lab

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Executive Summary

This technical report describes the methodology and results of field studies undertaken in May 2009 to inform a separate report on the aquatic ecology component of the Environmental Assessment for the proposed Inner West Marina, Sydney prepared by Cardno Ecology Lab Pty Ltd. These studies focused on:

- Rates of sedimentation and concentrations of key contaminants in suspended particulate matter;
- Sediment grain size;
- Infauna (i.e. animals living within the sediment);
- Epibenthic fauna (i.e. animals occurring within the upper 0.5 m of the estuary bed); and
- Mobile fish and invertebrates.

Observations were also made of the fauna and flora associated with artificial habitats adjacent to the Proposed Marina Location. The objectives and major findings of previous studies on these ecological components undertaken in Kendall Bay are also reviewed.

Overview of Proposed Development

The proposed development includes:

- Commercial marina with eight floating arms supporting 172 wet berths;
- A low level jetty with sewage pump out facilities, security gate, manager's office, small amenity area, small kiosk and a ferry wharf; and
- On land parking.

In response to the Remediation Order on the site, which requires no disturbance to estuarine sediments within 200 m of the former AGL Gasworks site, it is proposed that a geotextile blanket and basalt ballast be placed on the area underlying the proposed development prior to construction.

Overview of Marine Habitats within Kendall Bay

The following habitats are present:

- Sandy shore adjacent to a seawall, with sand winnowed by wakes for River Cat ferries;
- Rocky shores, including:
- areas of natural sandstone outcrops and
- artificial "shores" consisting of a boat ramp near the head of Kendall Bay and extensive rock retaining walls;
- Existing ferry wharf with pylons;
- Mangroves;
- Subtidal soft sediments consisting of estuarine muds and sands; and
- A small, sparse patch of the seagrass *Halophila ovalis* off the rock platform just to the west of Cabarita Wharf.

Previous Studies

In 1988, the marine environment adjoining the AGL Mortlake gasworks site in Kendall Bay was described and a survey of aquatic flora and fauna undertaken to identify any potential constraints to shoreline development. A qualitative description of the aquatic flora and fauna associated with the intertidal portion of the vertical seawall and jetty piles was prepared and quantitative analyses were undertaken of the benthic invertebrates, fish and mobile invertebrates associated with soft sediments at sites within and adjacent to Kendall Bay. This study showed that although the original shoreline had been modified and sediments had been contaminated, the aquatic flora and fauna was well developed.

In 1996, the infauna, epibenthic fauna, mobile fish and invertebrate assemblages associated with soft sediments at sites adjacent to the former AGL Mortlake gasworks were compared

with those at nearby Reference Locations in Hen and Chicken Bay, Kissing Point Bay, and in some cases Majors Bay, to determine whether contamination from the gasworks site had had any impacts on aquatic ecology. The levels of various contaminants in samples of benthic infauna and fish were also determined. The spatial variation in composition and abundance of the infauna was found to be consistent with observations and measurements of contamination. The patterns in fish and mobile invertebrates, however, did not show any effects consistent with contamination of the sediments. The benthic infauna from Mortlake contained greater amounts of polycyclic aromatic hydrocarbons (PAHs) than that from the Reference Locations, suggesting that the gasworks had had an impact on benthic infauna. The levels of contaminants found in fish, however, were similar across all three locations.

In 2006, sediment traps were used to compare spatial and temporal variation in rates of settlement and concentrations of chemical contaminants bound to suspended particulate matter (SPM) at sites within Kendall Bay with that at two Reference Locations, east of Bedlam Point and Abbotsford Bay. This study was undertaken as part of an assessment of the potential for mobilisation of contaminants within the Kendall Bay Remediation Site. The SPM fluxes varied across locations during each deployment and increased in magnitude across the three deployments. It was estimated that up to 2.5 mm of sediment may be deposited each day within the Remediation Site. The mean SPM fluxes within the Remediation Site were similar to those at the Reference Locations, which suggests that the processes of sediment resuspension and settling within the Remediation Site were typical of that elsewhere in the Parramatta River. The concentrations of total petroleum hydrocarbons (TPHs), benzene, toluene, ethylbenzene and xylene (BTEX compounds), free and total cyanide in the SPM were generally below the Limit of Reporting. The normalized concentrations of individual PAHs, low molecular weight PAHs, high molecular weight PAHs and total PAHs in the SPM, however, exceeded the Interim Sediment Quality Guidelines - Low (ISQG - Low) trigger values at some sites on some occasions.

In September 2007, a small, sparse patch of the seagrass *Halophila ovalis* was found off the rock platform to the west of Cabarita Wharf (The Ecology Lab, unpublished).

Ecological Studies Undertaken in 2009

Rate of sedimentation and concentrations of key contaminants on suspended matter

The rates of sedimentation of settling particulate matter (SPM) were assessed by deploying sediment traps at three locations within the Proposed Marina Location on three separate 14 day-long occasions. The total wet weight of the SPM collected in the traps was measured and used to estimate SPM flux. The concentrations of PAHs, TPHs, BTEXs, cyanide (free and total) and total organic carbon content of the SPM were also determined. The SPM flux varied from 264-303 g/m2/d and from 195-256 g/m2/d during the first and second deployments. The concentrations of TPHs, BTEXs, cyanide (free and total) and of three PAH analytes in the SPM samples from these deployments were below the Limit of Reporting. The mean normalised concentrations of various combinations (i.e. low molecular weight, high molecular weight and total) of PAHs in the SPM samples exceeded their respective ISQG-Low trigger values only after the second deployment. The normalised concentrations of one individual PAH analyte, acenaphthylene, were consistently between the ISQG-Low and ISQG-High values in SPM for all locations and deployments. The normalised concentrations of several other individual PAH analytes exceeded their respective ISQG-Low values, but not during all three deployments and in most cases not across all sampling locations. The detection of PAHs in excess of the ISQG-Low values on SPM at the Proposed Marina Location is not surprising given that 62% of surficial sediments within Port Jackson have total PAH concentrations in excess of this guideline and that concentrations increase towards the end of bays. The fact that the normalised concentrations of acenaphthylene in SPM were in excess of the ISQG-Low value, but not those in the sediment samples, suggests that urban runoff and aeolian transport of particulate matter from high temperature combustion processes may be important

contributors to PAH contamination in Kendall Bay, in addition to localised resuspension of contaminated sediments.

Heavy metal contaminants

Samples of surficial sediments and water were collected from various sites within the Proposed Marina Location for determination of concentrations of heavy metal contaminants. Concentrations of arsenic, chromium and copper in the sediment were generally in excess of their respective ISQG-Low values but not their ISQG-High values, whilst those of lead, mercury and zinc were above their respective ISQG-High values in at least half the sites. The concentrations of chromium, copper, lead, nickel, zinc, and to some extent arsenic, were greater in sediment collected from deep than shallow sites. This difference probably reflects the exposure of sediments in shallow areas to greater hydrodynamic forces.

In the water column, copper concentrations exceeded the ANZECC/ARMCANZ 95% trigger values at all sites and were at or slightly above the 90% trigger value on one occasion, but between the 80% and 90% trigger values on the other. Zinc concentrations exceeded the 99% trigger value at all sites, but were close to the 95% trigger value at two sites during low tide on the first sampling occasion. The concentrations of chromium and nickel were below their respective 99% and 95% trigger values, but those of lead were below the 95% trigger value, but close to or slightly in excess of their 99% trigger value in some of the samples collected.

These results suggest that estuarine organisms that ingest contaminated sediment are more likely to be exposed to these contaminants than those which take up heavy metals by diffusion. It is suggested that the potential for increase in copper concentrations associated with boating be addressed as part of the environmental management for the project.

Sediment grain size and infauna

Samples of subtidal sediments were collected for grain size analysis from ten study sites on the western side of Kendall Bay and three sites each at the Reference Locations: Sydney Rowing Club and Kissing Point Bay, using a Van Veen grab. Most of the sites within Kendall Bay and all the sites at Kissing Point Bay were dominated by fine sediment (i.e. particles < 75 µm), whereas that at Sydney Rowing Club was dominated by sand (i.e. particles > 75 µm but < 2mm). The sediments within Kendall Bay were not uniform, with the proportion of fines increasing from the outer to innermost position and differing among all nearshore sites, but only some offshore sites, and Site BG1 at the mouth of the bay having a large proportion of sand. The increase in proportion of fines is probably due to the more sheltered nature of the inner bay. The coarser nature of the sediment at BG1, the closest site to Breakfast Point, probably reflects localised erosion resulting from repeated exposure of the site to waves generated by ferries and other vessels and tidal currents.

Infauna

Samples of sediment were also collected for extraction of infauna from the above sites. The sediments at the Proposed Marina Location contained 30 infaunal taxa with mactrid bivalves and capitellid, nephtyid, sabellid, spionid and lumbrinerid polychaete worms being the most abundant.

The mean numbers of taxa and animals per sample were similar in nearshore and offshore strata and among the four positions surveyed along this location. The structure of the assemblages was also similar in the two strata, but the assemblage at the southernmost position was significantly different from that at the other positions. The dissimilarity in these assemblages was due to differences in average abundances of taxa with tellinid bivalves, capitellids and lumbrinerids being consistently less abundant and ophelid, spionid and polynoid worms and laternulid bivalves more abundant at the southernmost position.

The variation in mean numbers of taxa and animals and in structure of assemblages was not significant among offshore sites. Significant differences in the mean number of animals and in the structure of assemblages, however, were evident among nearshore sites. The nearshore assemblages within the Proposed Marina Location also differed from those at the southern end of Kendall Bay. The dissimilarity between these assemblages was also due primarily to differences in abundances of taxa, with some being more abundant and others less so at the Proposed Marina Location.

The spatial pattern in the infauna at the Proposed Marina Location does not appear to be linked with the concentrations of the major contaminants. This is not surprising given that factors such as particle size composition, exposure to water movements, food availability, competition, recruitment, predation and other forms of anthropogenic disturbances also affect the distribution and abundance of infaunal organisms.

The mean number of taxa within samples from the Proposed Marina Location was similar to that at both Reference Locations, but the mean number of animals was similar to that at only one Reference Location. The overall structure of the assemblages at the Proposed Marina Location, however, was significantly different from that at both Reference Locations. The dissimilarity in these assemblages was due to differences in abundances of taxa with capitellid and nephtyid worms and mactrid bivalves being the major contributors. The larger-scale spatial variation in infaunal assemblages observed in 2009 was not entirely consistent with that in 1996. This was due to a change in the assemblages at the Reference Locations, rather than between the Proposed Marina Location and Reference Locations. Significant temporal changes in the assemblages were detected at all three locations and were due mostly to a reduction in the abundance of taxa relative to 1996.

Epibenthic Fauna

The epibenthic fauna adjacent to the northern, middle and southern end of the western foreshore of Kendall Bay and at the two Reference Locations were sampled using a beam trawl. The epibenthic fauna within Kendall Bay consisted of 64 taxa and was dominated numerically by the mactrid bivalve *Spisula trigonella*, mysid *Haplostylis dakini*, amphipod *Corophium* sp. and shrimp *Philocherus* sp. The total number of taxa caught within Kendall Bay decreased from 48 in the north to 28 in the south.

The mean numbers of taxa and animals and overall structure of the epibenthic assemblages in Kendall Bay were similar to those at the Reference Locations combined. The mean numbers of taxa and animals were also similar among sites, however, it should be noted that catches were highly variable. At the scale of sites, the only significant difference found in the structure of the epibenthic assemblages was between Kendall Bay North and Kissing Point Bay. The dissimilarity between these assemblages was due to differences in composition in addition to differences in abundances of taxa.

The fish component of the epibenthic assemblages at Kendall Bay North and Kendall Bay South was significantly different from that at Kendall Bay Mid and Kissing Point Bay. The exquisite goby (*Favonigobius exquisitus*) accounted for most of the dissimilarity in these assemblages and was more abundant on average at Kendall Bay Mid and Kissing Point Bay.

There was a statistically significant difference between 1996 and 2009 in the structure of the epibenthic assemblages at Kendall Bay South, but not at the other sites. This was due primarily to exquisite, transparent and large-mouthed gobies being more abundant in 1996 than in 2009. Kendall Bay South was also the only site to show a significant difference within surveys, but the pattern of difference was not consistent.

Mobile fish and invertebrate assemblages

A fine-meshed beach seine net was used to collect fish and mobile invertebrates from the beach near the Proposed Marina Location, the southern end of Kendall Bay, Sydney Rowing

Club and Kissing Point Bay. Fifteen taxa were caught off the sandy beach near the Proposed Marina Location, with the transparent goby *Gobiopterus semivestitus*, mysid *Haplostylis dakini* and glassy *Ambassis jacksoniensis* being the most abundant. None of the species caught at this location were of conservation significance.

Significantly fewer taxa were caught at the Proposed Marina Location than at either Reference Location. Intermediate numbers of taxa were caught at Kendall Bay South. There was some indication of a difference in the structure of these assemblages among sites, with that at the Proposed Marina Location being distinct from that at Kendall Bay South.

Flora and Fauna Associated with Hard Substrata

The base of the sandstone revetment adjacent to the Proposed Marina Location was covered by a mixture of the green, red, brown and blue-green algae. Rock oysters, mussels, barnacles and various species of gastropods were also conspicuous. Most of these organisms were also found on the adjoining vertical seawall.

The piles at Cabarita Wharf were covered in green, red and brown algae, mussels and two species of barnacles. The bedrock and natural boulders to the east of the wharf supported a greater variety of animals, including a finger sponge, an encrusting bryozoan, mussels, barnacles, crabs and various species of gastropods and five different species of algae.

Conclusions

Kendall Bay appears to be relatively typical of an upper-estuarine bay in the Parramatta River. The subtidal sediments within the Proposed Marina Location support a diverse range of benthic taxa and a variety of mobile fish and invertebrate taxa, despite containing elevated concentrations of some contaminants. The epibenthic assemblage at the Proposed Marina Location appeared to be typical of that region of the estuary, but not the infauna or mobile fish and invertebrate assemblages. The differences that were detected appeared to be due to taxa being less abundant rather than absent from the Proposed Marina Location. The presence of a diverse fauna suggests that the contaminants may not actually be having adverse effects on the fauna, or if they are, only some components of the fauna are affected.

Table of Contents

Executive Summary ..... **ii**
Glossary ..... **x**
1 Introduction **1**
1.1 Background and Aims 1
1.2 Existing Information 2
1.2.1 Sedimentation Rates and Contamination of Settled Particles 2
1.2.2 Aquatic Habitats 3
1.2.3 Aquatic Flora and Fauna Associated with Hard Substrata 4
1.2.4 Infauna 4
1.2.5 Epibenthic Fauna 5
1.2.6 Fish and Mobile Invertebrate Fauna 6
1.2.6.1 Seine netting 6
1.2.6.2 Gill Netting 6
1.2.7 Bioaccumulation in Estuarine Biota 7
2 Field Investigations **8**
2.1 Study Area 8
2.1.1 Regional Comparisons 8
2.1.2 Proposed Marina Location 8
2.2 Study Methods 8
2.2.1 Aquatic Habitats 8
2.2.2 Sedimentation Rates and Contamination of Settled Particles 8
2.2.3 Sediment Grain Size and Infauna 9
2.2.3.1 Sampling Design 9
2.2.3.2 Sampling Methodology 9
2.2.3.3 Statistical Analyses 10
2.2.4 Heavy Metal Contaminants 11
2.2.4.1 Sampling Methodology 11
2.2.4.2 Data Analysis 11
2.2.5 Epibenthic Fauna 11
2.2.5.1 Sampling Methodology 11
2.2.5.2 Statistical Analyses 11
2.2.6 Fish and Mobile Invertebrate Fauna 12
2.2.6.1 Sampling Methodology 12
2.2.6.2 Statistical Methods 12
3 Results **13**

3.1 Aquatic Habitats in Kendall Bay 13
3.1.1 Intertidal Habitats 13
3.1.2 Aquatic Flora and Fauna Associated with Artificial Substrata 13
3.1.3 Subtidal Habitats 13
3.2 Sedimentation Rates and Contamination of Settled Particles 15
3.2.1 SPM Fluxes 15
3.2.2 Contaminants in SPM 15
3.2.2.1 Deployment 1 15
3.2.2.2 Deployment 2 15
3.2.2.3 Deployment 3 16
3.3 Sediment Grain Size 16
3.3.1 General Findings 16
3.3.2 Statistical Analyses 16
3.4 Heavy Metal Contaminants 16
3.5 Infauna 17
3.5.1 General Findings 17
3.5.2 Statistical Analyses 18
3.5.2.1 Comparison of Positions and Strata within the Proposed Marina Location 18
3.5.2.2 Comparison of Sites within Strata at the Proposed Marina Location 18
3.5.2.3 Relationships between Spatial Patterns in Infauna and Contaminants in Kendall Bay 18
3.5.2.4 Comparisons among Locations 19
3.5.2.5 Comparisons between 1996 and 2009 19
3.6 Epibenthic Fauna 20
3.6.1 General Findings 20
3.6.2 Comparisons among Sites 20
3.6.3 Comparisons between Kendall Bay and Reference Locations 21
3.6.4 Comparisons of Fauna between 1996 and 2009 21
3.7 Fish and Mobile Invertebrate Fauna 21
3.7.1 General Findings 21
3.7.2 Comparisons among Sites 22
3.7.3 Comparisons between Kendall Bay and Reference Locations 22
4 Discussion 23
4.1 Sedimentation Rates 23
4.2 Contamination of Settled Particles 23
4.3 Sediment Grain Size 24
4.4 Heavy Metal Contaminants 24

4.5 Infauna 25
4.5.1 Spatial Variation within the Proposed Marina Location 25
4.5.2 Spatial and Temporal Variation among Locations 25
4.5.3 Relationship between Patterns in Biota and Contaminants within Kendall Bay 26
4.6 Epibenthic Fauna 26
4.7 Fish and Mobile Invertebrate Fauna 26
5 Conclusions 27
6 Acknowledgements 28
7 References 29
8 Tables 30
9 Figures 71
10 Plates 98
11 Appendices 102

Glossary

Assemblage	Group of organisms that live together in the same place and at the same time
Bioaccumulation	Ability of organisms to accumulate contaminants at concentrations several orders of magnitude greater than is found in their environment
Contamination	Chemicals that have been introduced into the environment that can harm organisms
Epibenthic	Animals that live on or close to the seabed or estuary bed
Flux	Rate of flow across a given area and time
Infauna	Animals that live within the sediment
Multivariate Analyses	Statistical methods that are used to compare measures from multiple variables (e.g. abundances of different taxa or concentrations of different contaminants) simultaneously.
Reference Locations	Locations elsewhere in the Parramatta River that would not have been affected by sediment contamination resulting from activities at the AGL Mortlake gasworks
Univariate Analyses	Statistical methods that are used to compare measures of individual variables (e.g. abundance of species among locations)

1 Introduction

1.1 Background and Aims

Breakfast Point Pty Ltd has proposed that a commercial marina consisting of 172 berths and associated infrastructure be constructed in Kendall Bay, on the southern shore of the Parramatta River, Sydney. The proposed Inner West Marina, Sydney would be situated to the east of the Breakfast Point residential development and would extend approximately 150 m out into Kendall Bay and would cover a total area of approximately 2 ha. The proposed development would involve the following works:

- Placement of a geotextile blanket and basalt ballast on top of the underlying sediment;
- Construction of a low level jetty with sewage pump out facilities, security gate, manager's office, small amenity area, small kiosk and a ferry wharf;
- Construction of eight floating arms supporting a total of 172 wet berths, 20 of which will be for casual mooring;
- Construction of a new timber skid allowing kayaks, small sailing vessels and other small watercraft to access the waterway; and
- On land parking.

These works would be undertaken in six stages, each lasting between 2 and 30 weeks. During the first stage, the geotextile blanket and basalt ballast would be laid on top of the sediment below the Proposed Marina Location using a combination of divers, a barge and GPS controlled excavator. The placement of this blanket would meet the requirements of a Remediation Order with respect to disturbance of the bed sediment of Kendall Bay within 200 m of the land-based boundary of the former gasworks. During Stage 2, the jetty would be constructed using steel piles, timber beams and timber decking. This work would be done using a barge-mounted crane. The concrete piles required to support the floating arms and modular pontoons comprising the arms would be brought to the site on barges and installed during Stages 3-5. The pontoon and ramp would be installed during Stage 6. The proposed development will not require any dredging or reclamation works and there will be no removal or destruction of areas of marine vegetation.

Breakfast Point Pty Ltd has a lodged a Project application for the marina (07_0006) with the NSW Department of Planning. The latter have determined that an Environmental Assessment is required under Section 75F of the Environmental Planning and Assessment Act 1979, and Director General's requirements have been issued.

Taylor Lauder Bersten (TLB) Engineers, on behalf of Breakfast Point Pty Ltd, commissioned Cardno Ecology Lab to undertake the aquatic ecology component of the environmental assessment. The scope of the works for this component included:

- A description of the existing environment;
- A general overview of the environmental impacts of the proposed works on aquatic flora, fauna and habitats;
- An assessment of the potential impacts of the project on aquatic flora and fauna, including any cumulative impacts from construction activities and from all craft that would use the marina;
- A description of measures that would be implemented to minimise, mitigate, offset, manage and or monitor the impacts of the project on aquatic biota;.
- A detailed assessment of the potential for the marina project to disturb contaminated marine sediments and details of any proposed remediation works required and their impacts on aquatic flora and fauna; and
- An assessment of any impacts on critical habitats, threatened species, populations or ecological communities and the habitats in the region.

These are the requirements of the Director-General, NSW Department of Planning specified under Section 75F (3) of the Environmental Planning and Assessment Act 1979.

The description of the existing aquatic environment presented in the Development Application (Aquatic Environmental Assessment, Cardno Ecology Lab 2009) is based on a review of previous studies of sediment characteristics, water quality, aquatic flora and fauna undertaken over the past twenty years and information on current sediment contamination levels, distribution and abundance of benthic fauna and fish assemblages obtained during the course of fieldwork undertaken in May 2009. The following technical report includes a review of the major findings of the previous ecological studies undertaken in Kendall Bay; a detailed description of the study methods and results of the ecological component of the May 2009 field work which focused on:

- Rate of sedimentation and concentrations of key contaminants in the suspended particulate matter;
- Benthic infaunal assemblages;
- Epibenthic fish and invertebrate assemblages; and
- Fish assemblages.

The data obtained in May 2009 have also been compared with those collected from the same locations using similar sampling methods in February and March 1996, where appropriate. The ecological studies done in May 2009 complement the detailed sediment investigations undertaken by AECOM (2009).

1.2 Existing Information

In 1988, the marine environment adjoining the AGL Mortlake gasworks site was described and a survey of aquatic flora and fauna undertaken to identify any potential constraints to shoreline development (The Ecology Lab 1989). In 1996, the benthic macroinvertebrates, fish and mobile invertebrates associated with soft sediments at sites adjacent to the former AGL gasworks were compared with those at nearby Reference Locations in Hen and Chicken Bay, Kissing Point Bay, and in some cases Majors Bay, to determine whether contamination from the gasworks site had had any impacts on aquatic ecology (The Ecology Lab 1996). In 2005/2006, the rate of sedimentation and chemical properties of suspended particulate matter in Kendall Bay were examined as part of an assessment of the potential for mobilisation of contaminants within the Kendall Bay Remediation Site (URS 2006a).

1.2.1 Sedimentation Rates and Contamination of Settled Particles

Spatial and temporal variation in rates of settlement and concentrations of chemical contaminants bound to suspended particulate matter (SPM) have been measured at four sites within the Remediation Site (Old Wharf, Breakfast Point (south), Bennzoil Plant to the west of Breakfast Point and at Kendall Bay) and compared with that at two Reference Locations (east of Bedlam Point and Abbotsford Bay) (URS 2006a). The rates of settlement of SPM were measured by deploying stacked arrays of sediment traps for periods ranging from 19 to 24 days on three separate occasions between December 2005 and February 2006. After each deployment, the SPM deposited in the bottom and upper traps in each array was weighed and these measurements were converted to estimates of SPM flux in g/m2/d after taking into account the duration of deployment and surface area of the sediment trap.

Total petroleum hydrocarbons C6-C36 (TPHs), Benzene, toluene, ethylbenzene and xylene (BTEXs), polycyclic aromatic hydrocarbons (PAHs), cyanide (free and total) were the contaminants measured. The total organic carbon in the SPM samples was also measured so that the concentrations of the contaminants could be normalised to 1% organic carbon for comparison with the ANZECC/ARMCANZ (2000) Interim Sediment Quality Guidelines (ISQG-Low and ISQG-High trigger values) that are available for 12 individual PAHs, the sum of low molecular weight PAHs, high molecular weight PAHs and total PAHs. ISQG Values are not available for TPH, BTEX or cyanides.

The SPM fluxes measured during the three deployments varied as follows:

- 1 - 425 g/m^2/d at Kendall Bay bottom trap to 1,345 g/m^2/ d at Bennzoil Plant bottom trap;
- 2 - 516 g/m^2/d at Kendall Bay bottom trap to 1,561 g/m^2/ d at Old Wharf bottom trap;

- 3 - 704 g/m^2/d at Breakfast Point South bottom trap to 2,462 g/m^2/ d at Abbotsford Bay upper trap

These data show that the SPM fluxes varied across locations during each deployment and that there was an increase in SPM flux across the three deployments. Despite this, the following consistent patterns were observed:

- SPM fluxes in the bottom sediment traps were >= 50% greater than those in the upper sediment traps at two locations within the Remediation Site, the Old Wharf and Bennzoil Plant.
- At Old Wharf, Kendall Bay and Abbotsford Bay, there was a 2-5 fold increase in SMP flux from Deployment 1 to Deployment 3;
- SPM fluxes were similar at Breakfast Point (south) and Kendall Bay and also similar at the two Reference Locations.

The SPM fluxes were 36% - 82% greater in the bottom than corresponding upper sediment trap, suggesting that the SPM included locally resuspended sediment. For both the upper and lower traps, the mean SPM fluxes at locations within the Remediation Site were similar to those at the Reference Locations. This suggested that the processes of sediment resuspension and settling that occurred within the Remediation Site were typical of those that occurred regionally throughout the Parramatta River. It is important to note that the SPM fluxes at each location represent matter advected from other locations in the Parramatta River and Sydney Harbour, in addition to contributions from local sediment. Particle settling rates in excess of 1,000 g/m2/ d suggest that up to 2.5 mm of sediment may be deposited each day within the Remediation Site. URS (2006a) also noted that rainfall, wind strength and wind direction during the deployments had no detectable effect on SPM fluxes.

The concentrations of TPHs, BTEX compounds, free and total cyanide in the SPM samples were generally below the Limit of Reporting. The normalized concentrations of PAH analytes, and various combinations thereof (i.e. low molecular weight, high molecular weight and total PAHs) in SPM were below the ISQG-High guideline values for all three deployments, but exceeded the ISQG-Low guideline values in the bottom trap at Old Wharf and Kendall Bay on Deployments 2 and 3 and in the upper trap at Old Wharf on Deployment 3. The concentrations of PAHs in SPM differed among locations as well as among deployments. The concentrations of PAH analytes in SPM from the bottom traps were generally higher compared to those in upper traps, suggesting a dilution of the contaminant concentrations in SPM in the upper sediment traps.

1.2.2 Aquatic Habitats

In 1988, the most conspicuous feature of the shoreline adjacent to the former AGL gasworks was the almost continuous vertical sandstone seawall extending along the waterfront, below which there was often a narrow rubble fringe (The Ecology Lab 1989). The piles of the large jetty in Kendall Bay provided another artificial habitat for estuarine biota. The only natural shoreline features were the sandstone outcrops at Breakfast Point and below the large jetty and the wide mudflat at the southern end of Kendall Bay which supported a small stand of the grey mangrove (*Avicennia marina*).in Kendall Bay. In September 2007, a small, sparse patch of the seagrass *Halophila ovalis* was found off the rock platform to the west of Cabarita Wharf (The Ecology Lab, unpublished).

The sediments in the shallow areas (+0.56 m) close to the seawall were composed of coarse-grained material with some sandstone rubble, whilst those in deeper water (-1.15 m and – 2.60 m) consisted of very fine mud. The sediment samples showed evidence of contamination with oils noted at a site to the west of Breakfast Point and slag found to the west of Breakfast Point and at sites within Kendall Bay. Piles of decomposing leaf litter were also noted at several sites.

In 1996, the distribution of aquatic habitats was similar to that described above, except for the removal of two small jetties from the western shoreline and the appearance of two small beaches in front of the seawall to the west and south of Breakfast Point (The Ecology Lab

1996). The proportion of fine matter (< 75µm) in the sediment ranged from 7% at one of the Sydney Rowing Club sites to 66% at one of the sites along the western foreshore of Kendall Bay. The variation in the proportion of fines was significant among the sites at all the locations, except Sydney Rowing Club. The subtidal sediment samples from adjacent to the former gasworks site had elevated concentrations of total PAHs and individual PAHs (i.e. acenaphthylene, phenanthrene, fluoranthene, pyrene and chrysene). The sediments from the baseline sites had relatively low concentrations of PAHs and no detectable phenols.

1.2.3 Aquatic Flora and Fauna Associated with Hard Substrata

In 1988, the intertidal portion of the seawalls located adjacent to the former gasworks were covered in a more or less continuous band of barnacles, with *Elminius covertus* occurring around the high tide mark and *Balanus amphitrite* at the mid to low tide level (The Ecology Lab 1989). The green alga *Ulva sp.* was also present on many parts of the seawall. The gastropod *Bembicium auratum* was found among the crevices along the seawall and the estuarine crab *Paragrapsis laevis* was common under the rocks at the base of the seawall. The bryozoan, *Membranipora membranacea* was observed low down on the seawall and on rocks and rubble.

The piles of the large jetty in Kendall Bay were dominated by the barnacles *Elminius covertus* and *Balanus amphitrite*. The mussel *Xenostrobis securis* and numerous unidentified hydroids were also present (The Ecology Lab 1989).

1.2.4 Infauna

In 1988, the infauna (i.e. animals found within the sediment) in shallow, medium and deep strata at two sites (western and southern side) in Kendall Bay were compared with those occurring at three sites to the west of Breakfast Point and one site in Glades Bay (The Ecology Lab 1989). At the site on the western side of Kendall Bay, the assemblages in all three strata were dominated by the spionid worm *Minuspio cirrifera*. The second most abundant animal was an unidentified amphipod in the shallow strata and an aorid amphipod in the medium and deep strata. The assemblages in the shallow strata towards the southern end of the Kendall Bay were dominated by an unidentified nereid worm, whereas those in the medium strata were dominated by the bivalve *Tellina deltoidalis*, *Minuspio cirrifera* and another bivalve *Spisula* (formerly *Notospisula*) *trigonella,* while those in the deep strata were dominated by an unidentified amphipod, capitellid worm and *Tellina deltoidalis*. The medium strata at the southern end of the Kendall Bay had significantly fewer species than the other sites and the shallow strata had fewer species than four of the other sites.

In 1996, the infaunal assemblages associated with subtidal sediments adjacent to the northern and western boundary of the gasworks were significantly different from those at the two Reference Locations (The Ecology Lab 1996). This difference was due primarily to capitellid polychaetes, the bivalves *Tellina deltoidalis* and *Sanguinolaria donacoides* and crustacean *Callianassa arenosa* being less abundant and the bivalve *Spisula trigonella* more abundant at the gasworks locations. The infaunal assemblages at the three sites adjacent to the gasworks that had the greatest level of chemical contaminants (one on the northern and two on the western boundary) were found to be distinct from those at the other sites. Their dissimilarity was due to them having smaller numbers of the species identified above.

Statistical analyses showed that polychaete worms, two major families of polychaete worms (capitellids and lumbrinerids) and *Tellina deltoidalis* were significantly less abundant at the gasworks than at the baseline locations. Significant differences in total number of taxa and abundances of infaunal taxa were also evident among the sites sampled on the northern and western boundaries of the gasworks. Differences along the western boundary are of particular interest, because of their proximity to the proposed marina. The two sites closest to the AGL wharf had significantly fewer animals, taxa, polychaetes, molluscs, capitellid worms, *Spisula trigonella* and *Sanguinolaria donacoides* than the site closest to Breakfast Point. The total numbers of crustaceans, lumbrinerid worms, nephtyid worms and *Callianassa arenosa*, in contrast, were similar at the three sites along the western boundary.

It was concluded that the patterns in composition and abundance of the infauna were consistent with those in contamination of sediments. This, combined with the fact that infaunal organisms from adjacent to the gasworks contained significant levels of PAHs relative to those at the baseline locations, suggested that the levels of contaminants in some areas of Kendall Bay had had an impact on benthic infauna.

1.2.5 Epibenthic Fauna

The fish and invertebrates occurring close to the estuary bed along the northern, south-western and north-western boundaries of the former AGL gasworks within Kendall Bay were sampled in 1988 and 1996 using beam trawls (The Ecology Lab 1989 and 1996). Beam trawling along the south-western boundary yielded a total of eight fish, five crustacean, and two species of molluscs in 1989 as opposed to a total of six fish, twelve crustacean and seven mollusc species in 1996 (Table 1). The trawling along the north-western boundary yielded five fish, one crustacean and one mollusc species in 1989 and eight fish, thirteen crustacean and five molluscs species in 1996. The northern boundary of the gasworks yielded six fish, three crustacean and one mollusc species in 1989 and four fish, eight crustacean and six mollusc species in 1996 (The Ecology Lab 1989 and 1996). Differences in the dimensions and mesh of the beam trawl and timing of the studies (September/November 1988 vs March 1996) are likely to have contributed to differences in catches between the two surveys.

In 1988, the bivalve *Spisula trigonella*, Swan River goby (*Pseudogobius olorum*), transparent goby (*Gobiopterus semivestitus*) and striped shrimp (*Macrobrachium intermedium*) were the most abundant species found along the south-western boundary of the gasworks. The hauls along the north-western boundary were dominated by transparent gobies, Tamar River gobies (*Favonigobius tamarensis*) and Swan River gobies. *Spisula trigonella*, an unidentified mysid shrimp, the crab *Halicarcinus* sp. and Swan River gobies dominated the trawls off the northern boundary (The Ecology Lab 1989). Two of the species caught, snub-nosed pipefish (*Urocampus carinirostris*) and large-tooth flounder (*Pseudorhombus arsius*) were found only along the south-western boundary.

In 1996, *Spisula trigonella*, mysid *Haplostylis dakini*, exquisite goby (*Favonigobius exquisitus*), dogwhelk *Nassarius burchardi,* eastern king prawn (*Penaeus plebejus*) and bivalve *Theora fragilis* were the most abundant species found along the south-western boundary of the gasworks. The hauls along the north-western boundary were dominated by the bivalves *Spisula trigonella* and *Theora fragilis*, mysid *Haplostylis dakini* and dogwhelk *Nassarius burchardi*. The trawls off the northern boundary were dominated by *Theora fragilis*, followed by *Spisula trigonella* and the oval spider crab *Halicarcinus ovatus*.

In 1996, beam trawling was also conducted at three nearby baseline sites and a total of 12 fish, 12 crustacean and eight mollusc species were caught at Sydney Rowing Club, compared with nine fish, 10 crustacean and five mollusc species at Majors Bay and seven fish, seven crustacean and five mollusc species at Kissing Point Bay (The Ecology Lab 1996). *Spisula trigonella* and *Nassarius burchardi* were the most abundant species caught off Sydney Rowing Club and Kissing Point Bay, but the samples from Majors Bay were dominated by transparent gobies, followed by the bivalves *Spisula trigonella* and *Theora fragilis*. Statistical analyses showed that the assemblages of fish and macroinvertebrates adjacent to the gasworks did not differ from the baseline condition; however there were differences among sites in Kendall Bay with that closest to the AGL wharf being distinct from the assemblages sampled on the two sides of Breakfast Point. Large-mouth gobies (*Redigobius macrostoma*) were significantly more abundant adjacent to the gasworks, but total numbers of individuals, taxa and macroinvertebrates and abundances of 12 other common species did not differ between the gasworks and baseline conditions. These results suggest that the fish and macroinvertebrate assemblages within Kendall Bay are typical of that section of the Parramatta River.

In 1996, significant differences in the total abundance and number of commercial species and in abundances of Tamar River gobies, eastern king prawns and bivalve *Spisula trigonella* were evident among sites adjacent to the boundaries of the gasworks (The Ecology Lab 1996). The

two sites along the western shore yielded significantly more commercial fish (numbers and species) and *Spisula trigonella* than the site along the northern shore. Tamar River gobies, however, were more abundant at the two northern sites than at the site closest to the gasworks wharf.

1.2.6 Fish and Mobile Invertebrate Fauna

The fish and mobile invertebrates occurring along the northern, south-western and north-western boundaries of the former AGL gasworks within Kendall Bay were sampled in 1988 and 1996 using beach seine and gill nets (The Ecology Lab 1989 and 1996).

1.2.6.1 Seine netting

In 1988, seine hauls were made over the mud flat at the southern end of Kendall Bay and off the beach at Cabarita Point (The Ecology Lab 1989). The seine hauls at the southern end of the bay yielded a similar total number of fish (22 vs 23) and the same number of crustacean species to those off Cabarita Point. The average number of fish caught per haul, however, was twice as great in Kendall Bay (1329) as off Cabarita Point (633). It is important to note that several species of commercial importance, including yellowfin bream (*Acanthopagrus australis*), trumpeter whiting (*Sillago maculata*), silver biddies (*Gerres subfasciatus*), sea mullet (*Mugil cephalus*) and flat-tail mullet (*Liza argentea*), were caught in Kendall Bay and that many of the fish collected were juveniles (Table 2). This suggested that commercial species may utilise the mud flat at the southern end of Kendall Bay as a nursery area.

In 1996, a single beach seine haul yielded a total of 54 fish from seven species along the northern boundary of the gasworks and a total of 1,277 fish from 11 species plus one crustacean along the north-western boundary (Table 2). At Kissing Point Bay, one of the baseline locations, a total of 123 fish from nine species plus one mollusc were caught. At Sydney Rowing Club, the other reference location, total of 2,605 fish from 20 species, three specimens of the cuttlefish, *Sepia plangon*¸ five eastern king prawns and two shrimps were caught. The relatively high numbers of fish caught along the north-western boundary and at Sydney Rowing Club reflected the presence of schools of sandy sprat (*Hyperlophus vittatus*), which accounted for over 90% of the fish caught at each location. Port Jackson perchlet (*Ambassis jacksoniensis)* and sea mullet were caught only along the northern boundary of the gasworks, while bar-tailed goatfish (*Upeneus tragula*) and exquisite gobies (*Favonigobius exquisitus*) were found only along the north-western boundary. Trumpeter whiting, tailor (*Pomatomus saltatrix*) and silver biddy were the only representatives of the 26 fish species caught that were common to all four locations. The significance of the apparent differences and similarities in distribution, however, cannot be assessed because of the limited amount of sampling undertaken.

1.2.6.2 Gill Netting

In 1988, gill nets were deployed along the northern, south-western and mid-western boundaries of the gasworks (The Ecology Lab 1989). A total of four fish and 2 crustacean species were caught off the south-western shore compared with one fish and 2 crustacean species off the mid-western boundary and three fish species off the northern boundary (Table 3). Yellowfin bream was the only species caught at all three locations.

In 1996, gill nets were deployed along the western and northern boundary of the gasworks and at two reference locations, Kissing Point Bay and Sydney Rowing Club. The netting undertaken along the western and northern boundaries of the gasworks yielded three and eight species of fish, whereas the reference locations yielded five and six species of fish, respectively. Two species of crustaceans were caught along both of the gasworks boundaries, but only one species was caught at each of the reference locations. All of the fish species caught off the gasworks were also found at the reference locations. Two species, silver biddies and trevally (*Pseudocaranx dentex*) were caught only at one of the reference locations. The number of each species caught was low, ranging from 1 to 7 during both studies.

1.2.7 Bioaccumulation in Estuarine Biota

In 1996, the benthic infauna at two sites adjacent to the former Mortlake gasworks was found to contain a wide range of PAHs, whereas infauna from reference sites contained only a few PAH compounds and in much smaller concentrations (The Ecology Lab 1996). Phenols were not detected in any of the benthic infaunal samples. Specimens of two species of benthic-feeding fish, trumpeter whiting (*Sillago maculata*) and silver biddy (*Gerres subfasciatus*) caught at sites adjacent to the former gasworks contained cyanide and PAHs, but no phenols. The specimens of dusky flathead (*Platycephalus fuscus*) and blue swimmer crab (*Portunus pelagicus*) examined, however, did not contain detectable amounts of phenols, cyanide or PAHs. All the fish and crabs examined contained heavy metals, but the concentrations of these contaminants in specimens from Mortlake were similar to those from baseline sites (The Ecology Lab 1996). It should be noted that contaminants were measured in composite samples of benthic infauna rather than specific taxa and that estuarine invertebrates differ in their ability to accumulate and metabolise PAHs.

2 Field Investigations

2.1 Study Area

2.1.1 Regional Comparisons

The estuarine invertebrate and fish fauna occurring at the Proposed Marina Location were compared with those at two nearby Reference Locations, Sydney Rowing Club and Kissing Point Bay (Figure 1; Plate 1). This was done to determine whether or not the composition and abundance of the fauna at the Proposed Marina Location was typical of that region of the Parramatta River.

2.1.2 Proposed Marina Location

The area of Kendall Bay within 200 m of the land-based boundary of the former AGL gasworks site is subject to a remediation order due to the contamination of sediments resulting from the activities at the former gasworks. The Proposed Marina Location is situated completely within this area. Sedimentation studies and finer-scale spatial variation in the infauna were examined within the Proposed Marina Location only.

2.2 Study Methods

2.2.1 Aquatic Habitats

The aquatic habitats within Kendall Bay were observed and photographed on multiple visits to the site during April, May and June 2009. The wharf pilings at Cabarita Wharf were also examined at low tide to assist in predicting what types of biota were likely to grow on new marina structures such as jetties and pontoons.

2.2.2 Sedimentation Rates and Contamination of Settled Particles

The rates of sedimentation of settling particulate matter (SPM) were assessed by deploying sediment traps at three locations within the Proposed Marina Location (indicated by SS1-3 on Figure 2). Sediment traps were deployed on three occasions from 24 April to 8 May, 8 May to 22 May and 22 May to 5 June 2009. Each sediment trap consisted of a bundle of three 600 mm long x 100 mm diameter polyvinyl chloride (PVC) collection tubes which were sealed at one end and had a 2 cm rubber-stoppered drainage hole approximately 10 cm above their base (Plate 2). The traps were deployed from a small boat at low tide and anchored so that the opening of the bottom tube was approximately 1 m above the estuary bed. The traps were retrieved 14 days later at low tide by lifting them vertically from the bed to avoid disturbance of bottom sediments. The overlying water was drained from each collection tube by removing the rubber bungs from the drainage holes. The methodology used was similar to that described by URS (2006a), except that the array of sediment traps was not vertically stacked.

In the laboratory, the remaining SPM/water mixture in each tube was poured into a 4 L bucket and any SPM left on the sides of the collectors was rinsed into the bucket using seawater. Any fish or crustaceans found in the collectors were removed. The buckets containing the SPM samples were stored in a refrigerator overnight to allow the SPM to settle to the bottom of the bucket. The settled SPM samples were decanted by siphoning off the overlying water using a small diameter hose and then the SPM sample was transferred into one or more unpreserved 250 ml glass sample jars. A wash bottle filled with ambient seawater was used to assist in the transfer of the SPM sample from the 4 L bucket into the 250 ml glass jars.

Samples were sent to ALS Environmental, a NATA accredited laboratory, for determination of PAHs, TPHs, BTEX, cyanide (free and total) and total organic carbon. Concentrations of low molecular weight PAHs were estimated by summing the concentrations of acenaphthene, acenaphthylene, anthracene, fluorene, 2-methylnaphthalene, naphthalene and phenanthrene.

Concentrations of high molecular weight PAHs were estimated by summing the concentrations of benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, fluoranthene and pyrene. The concentrations of the various individual PAH analytes and combinations thereof were compared with their respective ANZECC/ARMCANZ interim sediment quality guidelines and with the contaminant concentrations in adjacent surface grab samples. The total wet weight of the SPM collected in the traps was also measured and sedimentation rates expressed as g/m^2/d. The settling particulate flux was calculated using the equation:

$F = M/3D\pi R^2$ where

F is the SPM flux (in g/m^2/d),

M is the wet weight (g) of captured SPM;

D is the duration of the deployment (in days); and

R is the sediment trap cylinder radius (in m).

2.2.3 Sediment Grain Size and Infauna

2.2.3.1 Sampling Design

Samples of sediment for analysis of particle size distribution and extraction of infauna were collected from ten study sites on the western side of Kendall Bay (indicated by BG1-10 on Figures 2 and 3). Eight of these study sites were established within the Proposed Marina Location, with four being situated within 75 m of the seawall (Nearshore Positions: BG 1, BG3, BG5, BG7) and the others between 150 m and 180 m from the seawall (Offshore Positions: BG2, BG4, BG6, BG8). The depths of the nearshore sites varied from 3 m to 4 m, whilst those of the offshore sites varied from 4 to 5 metres. These study sites were stratified to help determine the depth over which the nominated remediation measure (geotextile blanket with crushed rock) should be applied. The other two sites, BG9 and BG10, were situated around the 2m depth contour, approximately 80 m beyond Remediation Area A at the southern end of the bay. Samples for comparative purposes were collected from two Reference Locations, one situated along the seawall at the south-eastern end of Kissing Point Bay on the northern shore of the Parramatta River and the other along the seawall near the Sydney Rowing Club at the north-eastern end of Hen and Chicken Bay on the southern shore of the river (Figure 1). Previous studies (The Ecology Lab 1996) established that these sites were sufficiently similar in their physical characteristics to be used as Reference Locations. Three study sites were established at each reference location. The sites at the Reference Locations ranged in depth from 3 to 4 m. Each study site covered an area of approximately 3 m^2. The GPS coordinates for each site are presented in Appendix 1

2.2.3.2 Sampling Methodology

The infauna and sediment grain size samples were collected on 6 and 7 May 2009. At each site, four samples of sediment and associated infauna were collected using a Van Veen grab. This grab was deployed from a small boat and collected a volume of 0.0047 m^3 over a surface area of 0.06 m^2 of sediment and penetrated the sediment to a maximum depth of 10 cm. Each sample of sediment was placed into a plastic bag and secured. Two additional grab samples for analysis of sediment grain size were also collected at each site. Approximately 100 ml of surficial sediment was removed from each of these samples, placed in a plastic specimen jar and refrigerated prior to transport to a certified laboratory for grain size analysis (Particle Size Distribution).

In the laboratory, each infaunal sample was rinsed through a 1 mm mesh sieve and the material remaining on the sieve bagged and preserved in 10% formaldehyde solution containing Rose Bengal. The latter is a dye which stains live animals pink, making them easier to sort from the sediment. After a minimum of three days preservation, excess formalin was decanted from the samples, rinsed in tap water. Animals were extracted from the material retained on the sieve and sorted into groups using a binocular microscope. Animals were identified to the lowest practical taxonomic level, usually family level for major groups such as polychaetes, amphipods

and molluscs. All samples were retained in appropriate containers and preservative to allow further examination at a later date if required. After checks on identifications, numbers of each type of animal were entered into spreadsheet format and data checked before analysis.

2.2.3.3 Statistical Analyses

Statistical analyses were undertaken using the software package Primer (Plymouth Routines in Multivariate Ecological Research) version 6.1.1.1 (Clarke and Gorley 2006) and PERMANOVA + Version 1.0.1 (Anderson *et al.* 2008).

Univariate Analyses

Differences in mean number of taxa and animals among places and times were compared using permutational analysis of variance (PERMANOVA+). This approach does not require that the data come from a normal distribution or that variances are homogeneous, as is the case with "traditional" ANOVA. After calculating a Euclidean distance matrix of all possible pairs of samples of the variable of interest, the underlying distribution of the data was determined by repeated randomisation of the samples in the matrix, enabling exact tests for all levels of the experimental design (Anderson *et al*. 2008). The relative importance of factors and their interactions to the overall variance of the data was assessed by examining their respective components of variance. Five comparisons were undertaken:

- among the Proposed Marina Location, Sydney Rowing Club and Kissing Point Bay;
- among the four positions and between the two strata of the Proposed Marina Location;
- among the six nearshore sites (i.e. those within the Proposed Marina Location plus the two sites at the southern end of the bay) within Kendall Bay;
- among the four offshore sites within the Proposed Marina Location; and
- among the Proposed Marina Location, Sydney Rowing Club and Kissing Point Bay between 1996 and 2009.

Multivariate Analyses

First, differences in the types and relative abundance of the taxa in each pair of replicate samples were estimated by calculating their respective Bray-Curtis similarity coefficients. PERMANOVA, a non-parametric permutation test, was then used to test for significant differences in the structure of assemblages among places and times, as described in Section 2.1.3.1. Spatial and temporal patterns in the composition of the infaunal assemblages were also examined by means of non-metric Multi Dimensional Scaling (MDS) (Clarke 1993). MDS provides a graphical representation of assemblages based on their similarity within and among places or times sampled. In MDS plots, samples which have similar types and numbers of organisms are grouped closer together than ones containing different sets of organisms. The SIMPER routine was used to determine which taxa were responsible for discriminating between pairs of locations (Clarke 1993).

The link between the benthic assemblages and two environmental variables (i.e. % fines and total organic carbon content) and concentrations of key contaminants (TPHs, low molecular weight, high molecular weight and total PAHs) was examined by superimposing bubble plots of each of these environmental variables in turn onto the biotic ordination derived from centroids of Sites BG1 to BG10. This method is useful for identifying consistent differences in environmental variables between biotic clusters (Field *et al.* 1982). The BEST procedure was then used to determine which subset of environmental variables (i.e. concentrations of individual PAHs, % fines and total organic carbon content) 'best" explained the multivariate patterns of the assemblages at Sites BG1 to BG10.

2.2.4 Heavy Metal Contaminants

2.2.4.1 Sampling Methodology

2.2.4.1.1 Surface Sediments

On 5 June 2009, surficial sediment samples were collected with a Van Veen grab to a depth of approximately 10 cm from 14 sites within the Proposed Marina Location for determination of heavy metal concentrations. The sites were located using a GPS. The total concentrations of eight heavy metals, arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc, and percentage moisture content of the samples were determined by ALS, a registered analytical laboratory. An inductively coupled plasma mass spectrometer (ICP-ORC-MS) equipped with an octopole reaction cell was used to determine the heavy metal concentrations.

2.2.4.1.2 Estuarine Water

On 2 and 6 July 2009, samples of estuarine water were collected from 50 cm below the surface at four of the sites where surface grab samples were collected (SG5, SG7, SG9 and SG12). These sites were located towards the centre of the Proposed Marina Location. On both days, separate samples of water were collected from each site at low and high tide. These samples were kept on ice and then transported to ALS for analysis. The analyses were undertaken using OCR-ICP-MS

2.2.4.2 Data Analysis

The concentrations of the heavy metal analytes in the sediment samples were screened against their respective ISQG-Low and ISQG-High values (ANZECC/ARMCANZ 2000). The total concentrations of heavy metals in water samples were screened against their respective ANZECC/ARMCANZ (2000) 99%, 95%, 90% and 80% trigger values for slightly-moderately disturbed systems. These trigger values signify the percentage of species expected to be protected.

2.2.5 Epibenthic Fauna

2.2.5.1 Sampling Methodology

The epibenthic fauna adjacent to the northern, middle and southern end of the western foreshore within Kendall Bay and at the two Reference Locations (i.e. Sydney Rowing Club and Kissing Point Bay), were sampled using a beam trawl (Figure 4). Beam trawl samples were collected on 19 May 2009 using a 1 m wide x 0.5 m high x 2.5 m long net, with 5 mm mesh around the metal frame and 2.5 mm in the bag (Plate 3a). At each site, three separate hauls were made by towing the beam trawl behind a small boat for a maximum duration of 4 minutes per haul. The depth of the hauls varied from 2.5 to 4.5 m. After each tow the contents of the net were transferred to a labelled plastic bag and preserved with 10% formalin.

2.2.5.2 Statistical Analyses

The basic statistical techniques used to compare epibenthic assemblages were similar to those described for infauna (see Section 2.1.3). The following comparisons were undertaken of the entire epibenthic assemblages:

- among the five study sites;
- between Kendall Bay and the Reference Locations; and
- among study sites in 1996 and 2009.

The first two comparisons were also repeated using data on the occurrence and abundance of fish species only. For the comparison among study sites in 1996 and 2009, it is important to note that only two sites along the western foreshore were sampled in 1996. The first of these was equivalent to two of the sites (KBN and KBM) sampled in 2009 and has been labelled KBN/M.

2.2.6 Fish and Mobile Invertebrate Fauna

2.2.6.1 Sampling Methodology

On 22 May 2009, a 10 m long and 1 m deep seine net with 2 mm mesh was used to collect fish and mobile invertebrates from four locations: the beach at the Proposed Marina Location, southern end of Kendall Bay, Sydney Rowing Club and Kissing Point Bay (Figure 4). The net was run out from the shore in a U-shape and then hauled up on to the bank (Plate 3b). The animals that collected in the cod end, the middle of the net were quickly transferred to a fish box with minimal handling and stress (Plate 3c-d). Where catches were small, the animals were identified, counted and measured and then released on site. Where catches were too large to identify and count in the field, animals collected were placed in a plastic bag, preserved and returned to the laboratory for sorting. Three seine hauls were undertaken at the Kendall Bay locations, but only two were done at the Reference Locations.

2.2.6.2 Statistical Methods

The basic statistical techniques used to compare fish assemblages were similar to those described for infauna (see Section 2.1.3). The following comparisons were undertaken:

- across the four study sites; and
- between Kendall Bay and the Reference Locations.

Data from 2009 could not be compared with those from 1996, because of differences in the size of seine net used to capture fish and mobile invertebrates.

3 Results

3.1 Aquatic Habitats in Kendall Bay

3.1.1 Intertidal Habitats

The shoreline adjacent to the Proposed Marina Location has been modified extensively and now consists of a vertical seawall composed of sandstone blocks and a sloping revetment composed of irregular-shaped sandstone boulders. There was a narrow fringe of rubble below some parts of the seawall and revetment providing an additional hard substratum for estuarine organisms. The exposed sandstone outcrop on the north-eastern tip of Breakfast Point has been enclosed partially by a seawall. There was a small coarse-grained sandy beach in front of the revetment which is subject to winnowing by wave action, primarily from the Rivercat ferries (Plate 1a). The only remaining natural shoreline features are the mudflat and sandy beach at the southern end of Kendall Bay and the rocky shore which extends along the western shore of Cabarita Park. There was a small stand of grey mangroves (*Avicennia marina*) on the mudflat at the southern end of the bay, reportedly planted by the local Council to promote regrowth of mangroves in the Parramatta River (The Ecology Lab 1989) (Plate 1b).

3.1.2 Aquatic Flora and Fauna Associated with Artificial Substrata

The base of the sandstone revetment adjacent to the Proposed Marina Location was covered with an algal turf consisting of a mixture of the green algae *Ulva* sp. and *Enteromorpha* sp. and the red algae *Corallina officinalis* (Plate 4a). The brown alga, *Sargassum* sp., red algae, *Gelidium* sp. and *Pterocladia capillacea,* and an unidentified blue-green alga were also present. The Sydney rock oyster (*Saccostrea glomerata),* blue mussel (*Mytilus edulis* or *Xenostrobus pulex*), the barnacles *Elminius modestus* and *Tesseropora rosea* and gastropods *Patelloida mimula, Notoacmaea* sp. and *Bembicium auratum* were the most conspicuous animals (Plate 4b). All of the above species, except for *Pterocladia capillacea*, *Tesseropora rosea* and *Notoacmaea* sp. were also found on the vertical seawall adjacent to the Proposed Marina Location. Two additional species, the limpet *Siphonaria denticulata* and barnacle *Chthamalus antennatus* were also observed on this seawall.

The piles at Cabarita Wharf were covered in a green filamentous alga, most likely *Enteromorpha* sp., *Ulva* sp., the red algae *Gelidium* sp. and *Gracilaria* sp. and an unidentified brown filamentous alga (Plate 4c-d). Three animals were observed: mussels (*Mytilus edulis* or *Xenostrobus pulex*) and the barnacles *Chthamalus antennatus* and *Tesseropora rosea*. The bedrock and natural boulders to the east of the wharf support a greater variety of animals, with a small yellow finger sponge, an encrusting bryozoan *Watersipora subtorquata*, the gastropods *Turbo undulatus*, *Clanculus undulatus* and *Bembicium auratum,* and crabs *Ozius truncatus* and *Paragrapsus laevis* being present in addition to mussels (*Mytilus edulis* or *Xenostrobus pulex*) and the barnacle *Chthamalus antennatus*. Five different types of algae were observed: *Ulva* sp. *Corallina officinalis*, *Dictyota dichotoma*, *Sargassum* sp. and a green filamentous alga (most likely *Enteromorpha* sp.)

3.1.3 Subtidal Habitats

The subtidal region of the Remediation Site within Kendall Bay is covered in a 1.5 m thick layer of predominantly muddy sediments overlying terrestrial clays (URS 2006b). The typical profile was as follows:

- 0.0 m – 0.02 m – recently deposited layer of hydrous brown/green muds with broken shell material that is oxic and has a low density;
- 0.02 m - 0.1 m – green/grey estuarine muds;
- 0.1 m - 1.5 m – very soft, black to olive grey marine mud with traces of fine-grained sand and discrete pockets of bivalve shells; and
- 1.5 m – firm grey to orange sandy clay with fine sand and bivalve shells.

The shallow subtidal sediments (~ 2 m L.A.T.) along the inshore edge of the Proposed Marina are dominated by sand (>70%), but also contain small amounts of clay (12-15%), silt (6-7%) and gravel (1-8%) (AECOM 2009). The shallow subtidal sediments at the southern end of Kendall Bay, however, are dominated (> 90% of the total) by fines with a particle size of less than 75 µm (Cardno Ecology Lab 2009b and AECOM 2009).

The subtidal sediments in the deeper part (3 - 5 m L.A.T.) of the Proposed Marina Location are also dominated by fine material, but to a lesser extent (> 75% of the total) than at the southern end of the bay. The remainder of the sediment consists of sand, except for a small (> 1%) amount of gravel in some of the deeper areas (Sites BG2 and BG4). The proportion of fines increases southwards along the length of the Proposed Marina Location, probably due to a decrease in the strength of hydrodynamic processes in the inner part of the bay (e.g. wave action from the Rivercat ferries). The grain size of the sediments in the nearshore sites is more variable than that in the offshore sites, particularly with respect to the proportion of fines. At BG1, the site closest to Breakfast Point, sand (particles > 75 µm but less than 2 mm) accounts for 70% of the sediment and fines made up the remaining 30%. The coarser nature of the sediment at this site probably reflects localised erosion resulting from repeated exposure of the site to waves generated by ferries and other vessels and/or tidal currents.

The sediments along the foreshore adjacent to the site of the former Mortlake gasworks are contaminated with oils, grease, chromium, copper, zinc and lead (Dames and Moore 1989). Within the Remediation Site, PAH concentrations were generally in excess of the ISQG-High trigger values in surface and sub-surface layers of nearshore sediments, but generally between the ISQG-Low and ISQG-High trigger values in sediments from the middle and outer boundary (URS 2006b). The total organic carbon content of the sediments within the Remediation Site varied from 0.6 to 5.1 % which is within the range reported in Sydney Harbour (URS 2006b).

Data from May 2009 indicated that free cyanide concentrations in all sediment cores and sections thereof were below the limit of laboratory reporting, as were most of the total cyanide concentrations, except where the landward end of Floating Arm 3 and nearshore end of the proposed jetty would be located. At these positions, the total cyanide concentration was generally greater in deeper than surface sediments. The concentrations of BTEX compounds (benzene, toluene, ethylbenzene and xylene concentrations) in the sediment cores were also below the limit of reporting, except where the landward end of Floating Arm 5 and the nearshore end of the proposed jetty would be located. These were also the locations with the greatest TPH concentrations, with some values being an order of magnitude greater than found in most of the other cores. In 14 of the 28 piston cores, the TPH concentrations increased with depth. The following table shows the number of piston core samples from the different layers in which the concentrations of total PAHs, the contaminant of greatest concern, were below the ISQG-Low, between the ISQG-Low and ISQG-High value and in excess of the ISQG-High value.

Layer	Less than ISQG-Low	Between ISQG-Low and ISQG-High values	Exceeds ISQG-High value
Surface 0.0 - 0.02 m	7	17	4
Sub-surface 0.02 - 0.1 m	4	19	5
Deep 0.2 - 0.5 m	7	14	7

Data suggested that PAH contamination also increased with depth, but not in all cores. This is consistent with the findings of URS (2006c) who noted that contaminated sediments in some areas of the Remediation Site were overlain by relatively clean material, but in other areas clean sediments were overlain by contaminated sediments. The most contaminated surface

sediments were situated below where the landward ends of Floating Arm 1, the landward end of the proposed jetty and the middle of Floating Arm 4 would be located. The most contaminated sub-surface layers were located at these positions and where the landward end of Floating Arm 2 would be positioned. The most contaminated deeper sediments were found where the landward end of Floating Arms 1, 2 and 6, mid to seaward end of Arm 3, and the nearshore end of the proposed jetty would be located.

3.2 Sedimentation Rates and Contamination of Settled Particles

3.2.1 SPM Fluxes

Two replicate sediment traps at the site closest to Breakfast Point were lost during the first deployment (24 April to 8 May 2009). The remaining replicate trap at the site was scuffed, indicating the likely loss of the other two traps to boat movements. For the second and third deployments at this site, the traps were relocated approximately 10 m closer to shore to avoid interference by boats. For the second deployment, the trap deployed at the new position consisted of only two collections tubes, but of three tubes during the third deployment.

The SPM that collected in the sediment traps consisted of brown mud. The estimates of mean fluxes were as follows (see Figure 2 for locations of suspended sediment traps SS1-3:

- Deployment 1 - SS1 - 278 g/m^2/d; SS2 - 264 g/m$^{2/}$d; and SS3 -303 g/m^2/d;
- Deployment 2 - SS1 - 195 g/m^2/d; SS2 - 215 g/m$^{2/}$d; and SS3 -246 g/m^2/d;
- Deployment 3 – SS1 - 164 g/m^2/d; SS2- 248 g/m$^{2/}$d; and SS3 -346 g/m^2/d.

From the above it is clear that the SPM fluxes differed amongst locations and over time. Figure 5 indicates that the SPM flux generally increased from SS1 to SS3 (i.e. in a southerly direction) and was smaller at SS2 and SS3 during deployment 2 than in deployments 1 and 3. The SPM flux at SS1, in contrast, showed a gradual decrease across the three deployments.

3.2.2 Contaminants in SPM

The mean concentrations of TPHs, BTEXs, PAHs, and other substances measured in the traps deployed each time are presented in Tables 4-6 and the concentrations measured in the individual collectors comprising each trap are presented in Appendices 2-5.

3.2.2.1 Deployment 1

The concentrations of TPHs, BTEXs, free and total cyanide and of three individual PAHs (7.12-Dimethylbenz(a)anthracene, N-2-Fluorenyl Acetamide and 3-Methylcholanthrene) were below the LOR in all the SPM samples (Table 4). The mean concentrations of normalised low molecular weight PAHs, high molecular weight PAHs and total PAHs in the SPM samples were below their respective ISQG-Low trigger values. The concentrations of these contaminants in the SPM from one of the individual collectors deployed at SS2, however, were between the ISQG-Low and ISQG-High trigger values (Appendix 2). The mean concentrations of two individual PAH compounds, Acenaphthylene and Fluorene, in all three traps were above their respective ISQG-Low values. The mean concentrations of two other PAHs, Benzo(a)pyrene and Dibenz(a.h)anthracene exceeded the ISQG-Low values in two traps (Table 4). The SPM collected at SS2 had four individual PAHs in excess of the ISQG-Low values, whereas that from SS1 and SS3 had only three.

3.2.2.2 Deployment 2

The concentrations of TPHs, BTEXs, free cyanide and of three individual PAHs (7.12-Dimethylbenz(a)anthracene, N-2-Fluorenyl Acetamide and 3-Methylcholanthrene) were again below the LOR in all samples (Table 5; Appendix 3). On this occasion, the concentrations of total cyanide were either at or below the LOR. The mean concentrations of normalised low molecular weight PAHs, high molecular weight PAHs and total PAHs in the SPM samples were above their respective ISQG-Low trigger values (Table 5). The mean concentrations of five individual PAH compounds, Acenaphthene, Acenaphthylene, Benzo(a)pyrene,

Dibenz(a.h)anthracene and Fluorene in all three traps were above their respective ISQG-Low values. The mean concentrations of three other PAHs, Anthracene, Benz(a)anthracene and Pyrene exceeded the ISQG-Low values in two traps (Table 5). The SPM collected at SS1 and SS3 had eight individual PAHs in excess of the ISQG-Low values, whereas that from SS2 had only five.

3.2.2.3 Deployment 3

The concentrations of TPHs, BTEXs, free and total cyanide and of three individual PAHs (7.12-Dimethylbenz(a)anthracene, N-2-Fluorenyl Acetamide and 3-Methylcholanthrene) were below the LOR in all samples (Table 6; Appendix 4). On this occasion, the mean concentrations of normalised low molecular weight PAHs, high molecular weight PAHs and total PAHs in the SPM samples were less than their respective ISQG-Low trigger values (Table 6). The concentrations of only one of the individual PAH compounds, Acenaphthylene, were above the ISQG-Low value in all the replicate samples (Appendix 4).

3.3 Sediment Grain Size

3.3.1 General Findings

The sediment at all but one of the study sites within Kendall Bay and at the three sites at Kissing Point Bay were dominated (> 75% of the total) by fine material with a particle size of less than 75 µm (Appendix 5). Sand (particles > 75 µm but less than 2 mm) accounted for 70% of the sediment at Site BG1 in Kendall Bay and for 44% to 55.5 % of the particles at Sites 1-3, Sydney Rowing Club. A small (> 1%) amount of gravel (particles > 2 mm) was found in one of the samples from Sites BG2 and BG4. Cobbles (particles > 6 cm) were absent from all sites.

3.3.2 Statistical Analyses

There were significant differences in the proportion of fines among locations. The proportion of fines in the sediments at the Proposed Marina Location was similar to that at Kissing Point Bay, but significantly greater than at Sydney Rowing Club (Table 7; Figure 6).

The variation in proportion of fines among positions was not consistent in the nearshore and offshore strata at the Proposed Marina Location (i.e. there was a significant Position x Stratum interaction in Table 8). In the nearshore stratum, the proportion of fines differed among all six pairs of positions, however, in the offshore stratum the proportion of fines differed between the all the pairs of positions, except the outermost two (i.e. Positions 1 and 2) (Figure 7). There was a marked increase in the proportion of fines between Positions 1 and 2 and a gradual increase from Position 2 to Position 4 (Figure 8a). Figure 8b indicates that the variation in the proportion of fines was greater in the nearshore than offshore strata (note the difference in length of the standard error bars) and that there were more fines on average in the offshore than nearshore stratum.

In both the nearshore and offshore strata, there were significant differences in the proportion of fines among sites.(Table 9) The differences between all but two pairs (BG7 vs BG 10 and BG 9 vs BG 10) of nearshore sites were significant (Figure 9a). The differences between all six pairs of offshore sites were significant (Figure 9b).

3.4 Heavy Metal Contaminants

At all 14 sites, the cadmium concentrations of the sediment were below the limit of reporting. The nickel concentrations were below the appropriate ISQG-Low value at all the sites, except Site SG12 (Table 10). Concentrations of arsenic, chromium and copper in the sediment, however, were generally in excess of their respective ISQG-Low values but not the ISQG-High value, whilst those of lead, mercury and zinc were above their respective ISQG-High values in at least half the sites.

,Arsenic concentrations were greater in the sediment collected from the deeper (> 3m) than the shallow (2-3 m) sites at the northern end of the Proposed Marina Location, but no consistent spatial pattern was evident at the southern end of the location. Chromium, copper, lead, nickel and zinc concentrations were generally greater in sediment collected from deep than shallow sites. There was no obvious spatial pattern in mercury contamination.

The total concentrations of cadmium and mercury in all the water samples were below the limits of detection during high and low tides and on both sampling occasions (Appendix 6). The copper concentrations exceeded the ANZECC/ARMCANZ 95% trigger value (1.3 µG/L) at all the sites during high and low tide on both sampling occasions and were at or slightly above the 90% trigger value (3 µG/L) on 2 July, but between the 80% and 90% trigger values on 6 July 2009. The zinc concentrations exceeded the 99% trigger value at all sites, but were equivalent to the 95% trigger value at SG12 and slightly in excess at SG7 during low tide on the first sampling occasion. The concentrations of chromium and nickel were below their respective 99% and 95% trigger values. The concentrations of lead were below the 95% trigger value, but close to or slightly in excess of their 99% trigger value in some of the samples collected on 2 July 2009.

3.5 Infauna

3.5.1 General Findings

The 64 grab samples yielded a total of 994 animals from 40 taxa (17 polychaete worm, 8 crustacean, 9 mollusc and 6 others) (Appendix 7). The three most abundant taxa, capitellid and nephtyid worms and mactrid bivalves, together accounted for approximately 66% of the total number of animals found. The total number of individuals and taxa and most abundant taxa found at each study location are summarised below:

Location	Total no. of Taxa	Total no. of Animals	Most Abundant Taxa
Proposed Marina	30	409	Mactridae (bivalves) Capitellidae (worms) Nephtyidae (worms) Sabellidae (worms) Spionidae (worms) Lumbrineridae (worms)
Southern end of Kendall Bay	17	134	Nephtyidae Nemertea (ribbon worms)
Sydney Rowing Club	24	300	Capitellidae Nephtyidae Mactridae Lumbrineridae
Kissing Point Bay	24	151	Nephtyidae Mactridae Capitellidae

Although this table suggests that the infauna at the Proposed Marina Location is more diverse and richer in terms of total number of animals than the other locations, it should be noted that considerably more samples were collected at this location.

3.5.2 Statistical Analyses

3.5.2.1 Comparison of Positions and Strata within the Proposed Marina Location

The differences in mean numbers of taxa and animals between strata (i.e. nearshore vs offshore) and among positions were not significant (Table 11; Figures 10a and b). There were significant differences in the structure of infaunal assemblages among positions, but not between strata (Table 12). The assemblages at the southernmost position (Position 4 - Sites BG7 and BG8) were significantly different from those at the other positions, but differences between assemblages in the other pairs of positions were not significant (Table 5b). Most of the taxa that contributed to 90% of the average dissimilarity in these assemblages were common to all three comparisons. Three of these taxa, tellinids, capitellids, and lumbrinerids, were less abundant on average at Position 4 than at the other positions, while ophelid, spionid and polynoid worms and laternulid bivalves were more abundant on average at Position 4 than at the other positions (Table 13). The MDS plot suggests that the assemblages at Position 4 are not only generally different, but also considerably more variable than those at the other positions (Figure 11).

3.5.2.2 Comparison of Sites within Strata at the Proposed Marina Location

There were significant differences in mean number of animals and in the structure of the assemblages but not in mean numbers of taxa among nearshore sites (Tables 14a and 15a; Figure 12). The samples from Sites BG3, BG5 and BG7 within the Proposed Marina Location and Site BG9 on the southern shore contained significantly fewer animals on average than those collected at BG10, the other southern site (Table 14a; Figure 12a). The samples from BG3, BG7 and BG9 also contained significantly fewer animals than those collected at BG1. The assemblages at both BG9 and BG10 were significantly different from those at BG3, BG5 and BG7 (Table 15a). The assemblage at the other nearshore site (i.e. BG1) within the Proposed Marina Location was significantly different from only one of the sites at the southern end of the bay (i.e. BG10). The MDS plots shows that the nearshore assemblages at the Proposed Marina Location were more variable and generally different from those at the southern end of Kendall Bay (Figure 13a). Thirteen taxa were responsible for 90% of the average dissimilarity between the assemblages along the western and southern sides of Kendall Bay (Table 16). Seven of these taxa were more abundant and six less abundant or absent on the south side. The three principal discriminators, nephtyid, capitellids and mactrids, accounted for > 50% of the average dissimilarity between these assemblages. Nephtyid worms were less abundant whereas capitellids and mactrids were more abundant on the western side. The assemblages found at BG1 were also significantly different from those at BG7.

Differences in mean numbers of taxa and animals and in structure of assemblages were not significant among offshore sites (Tables 14b and 15; Figure 6). The MDS plot shows no distinct clusters of sites (Figure 13b).

3.5.2.3 Relationships between Spatial Patterns in Infauna and Contaminants in Kendall Bay

The spatial pattern in the infaunal assemblages at the sites within Kendall Bay (BG1 – BG10) did not reflect the % of fines (particles < 75 µm), total organic content of the sediment, low molecular weight PAHs, high molecular weight PAHs, total TPHs or total PAHs found in the sediment (Figures 14 -16). The BEST procedure showed that the concentration of Dibenz(a,h) anthracene provided the best match with the spatial pattern in the infaunal assemblages and that the match decreased as more contaminants were added. It should, however, be noted that the correlation between the concentration of Dibenz(a,h)anthracene and the multivariate pattern in the infaunal assemblage was not significant.

3.5.2.4 Comparisons among Locations

The differences in mean number of taxa among locations and sites within locations were not significant (Table17a; Figure 17a). The differences in mean number of animals were significant among locations, but not sites within locations (Table 17b). Significantly more animals were present in the sediments at Sydney Rowing Club than in those from the Proposed Marina Location and Kissing Point Bay, both of which yielded similar numbers of animals (Figure 17b).

Significant differences in the structure of the infaunal assemblages were detected among locations as well as among sites within locations (Table 18a). The assemblages at the Proposed Marina Location were significantly different from those within each Reference Location (Table 18b). The MDS plot shows the assemblages at Kissing Point Bay were less variable and fairly distinct from those at the other two locations (Figure 18). Sixteen taxa were responsible for 90% of the average dissimilarity between the assemblages at the Proposed Marina Location and Reference Locations combined (Table 19). The average abundances of nine of these taxa were greater at the Reference Locations combined than at the Proposed Marina Location. The differences in abundances of these taxa, however, were relatively small with only capitellids, nepthyids, nassariids, laternulids and venerids showing a greater than two-fold difference in numbers. The other six taxa were more abundant on average at the Proposed Marina Location than at the Reference Location, however, only Mactridae, Sabellidae, Opheliidae and Oweniidae were more than twice as abundant. It should, however, be noted that some of the differences in average abundance of the taxa may not be significant statistically. The three principal discriminators, capitellids, nephtyids and mactrids, together accounted for 60% of the overall dissimilarity between these assemblages. The two worm families were more abundant on average at the Reference Locations, but mactrids were more abundant at the Proposed Marina Location. Differences in assemblages among sites within locations could not be resolved (Table 18c).

3.5.2.5 Comparisons between 1996 and 2009

The variation in mean numbers of taxa and animals among locations was consistent across the two surveys (Table 20). There was, however, a significant difference between surveys in the mean number of taxa and animals collected, with numbers of both being significantly greater in 1996 than in 2009. This difference was evident at all three locations and the difference in total numbers of animals was more marked than that in total number of taxa (Figure 19). There was also a significant difference in the mean number of animals collected among locations, but only between the two Reference Locations.

Differences in the structure of the infaunal assemblages among locations were not consistent across the two surveys (Table 21). The assemblages at the Proposed Marina Location were consistently different from those at the Reference Locations. The assemblages at Sydney Rowing Club and Kissing Point Bay, however, were similar to each other in 1996, but not in 2009. There were also significant temporal differences in assemblages at each location. The MDS plot shows little overlap in the symbols representing the two surveys (Figure 20). This also suggests that there were marked temporal differences in the assemblages at the three locations.

Sixteen taxa contributed to the first 90% of the dissimilarity in the assemblages at the Proposed Marina Location (Table 22a). The majority of these taxa were more abundant in 1996 than in 2009. Two of the exceptions, psammobiid and semelid bivalves, were present in low numbers in 1996 but not recorded in 2009. The other exception sabellid worms were more abundant in 2009 than in 1996. Mactrid bivalves, nephtyid and capitellid worms accounted for >60% of the overall dissimilarity in these assemblages.

Nine taxa contributed to the first 90% of the dissimilarity in the assemblages at Sydney Rowing Club (Table 22b). Most of these taxa were also more abundant in 1996 than in 2009. The two exceptions, the bivalve families Tellinidae and Psammobiidae, were present in low numbers in 1996 but not recorded in 2009. Mactrid bivalves, nephtyid and capitellid worms also accounted

for >60% of the overall dissimilarity between these assemblages, however, at this location capitellids were the principal discriminator followed by mactrids and nephtyids.

Eleven taxa contributed to the first 90% of the dissimilarity in the assemblages at Kissing Point Bay (Table 22c). Only five of these taxa were more abundant in 1996 than in 2009. Four taxa, the bivalve families Tellinidae and Psammobiidae, the crustacean Callianassidae and echinoderm Holothuroidea were found in low numbers in 1996 but not recorded in 2009. The remaining taxa, nephtyid and nemertean worms were more abundant in 2009 than in 1996. At this location, capitellids, followed by mactrids and tellinids were the principal discriminators between the assemblages.

3.6 Epibenthic Fauna

3.6.1 General Findings

The 15 hauls yielded a total of 7,919 animals from 73 taxa (13 polychaete, 27 crustacean, 18 mollusc, 8 fish and 7 other) (Appendix 8). The five most abundant taxa, mactrid bivalve *Spisula trigonella*, mysid *Haplostylis dakini*, amphipod *Corophium* sp., shrimp *Philocherus* sp. and Exquisite goby (*Favonigobius exquisitus*), together accounted for approximately 80% of the animals captured. Fish accounted for only 3.6% of the animals caught. The epibenthic fauna within Kendall Bay consisted of 64 taxa and was dominated numerically by the mactrid bivalve *Spisula trigonella,* mysid *Haplostylis dakini,* amphipod *Corophium* sp. and shrimp *Philocherus* sp. Considerably fewer taxa were caught at the individual sites within Kendall Bay, with total numbers decreasing from 48 in the north to 28 in the south. The total number of individuals and taxa and most abundant taxa collected at each of the five study sites are summarised below:

Site	Total no. of Taxa	Total no. of Animals	Most Abundant Taxa
Kendall Bay North	48	903	*Spisula trigonella Haplostylis dakini Corophium* sp. *Philocherus* sp
Kendall Bay Mid	35	1844	*Spisula trigonella Haplostylis dakini Philocherus* sp *Corophium* sp.
Kendall Bay South	28	922	*Spisula trigonella Haplostylis dakini* Nemertea (ribbon worms) *Philocherus* sp.
Kendall Bay – all three sites combined	64	3669	*Spisula trigonella Haplostylis dakini Corophium* sp. *Philocherus* sp.
Sydney Rowing Club -	48	1803	*Spisula trigonella Corophium* sp. Hippolytidae (shrimps) *Philocherus* sp *Haplostylis dakini*
Kissing Point Bay	28	2447	*Haplostylis dakini Spisula trigonella Favonigobius exquisitus*

3.6.2 Comparisons among Sites

The differences in mean number of taxa and animals among sites were not significant (Table 23a; Figure 21). The large standard errors indicate that the number of fish caught per haul was highly variable at four sites (Figure 21b). There were significant differences in the overall structure of the epibenthic assemblages among sites (Table 24a), but these were restricted to

Kendall Bay North and Kissing Point Bay. Seventeen taxa contributed to the first 50% of the average dissimilarity between these assemblages (Table 25). Three of these taxa were absent and five others were less abundant at Kendall Bay North than at Kissing Point Bay. The contribution of the individual taxa to the average dissimilarity was small with the two principal discriminators, *Corophium* sp. and *Haplostylis dakini,* accounting for 6.8 and 4.6% of the average dissimilarity, respectively. The MDS plot suggests that the assemblages at Kendall Bay North and Kendall Bay Mid were also distinct (Figure 22a).

There were also significant differences in the overall structure of the fish component of the assemblage among sites (Table 26a) The fish assemblages in Kendall Bay North and Kendall Bay South were significantly different from those in Kendall Bay Mid and Kissing Point Bay, but not from each other or the assemblages at the Sydney Rowing Club (Figure 22b). The exquisite goby was the major discriminator and accounted for >80% of the dissimilarity in these assemblages (Table 27). The average abundance of this species was greater at Kendall Bay Mid and Kissing Point Bay than at Kendall Bay North and Kendall Bay South.

3.6.3 Comparisons between Kendall Bay and Reference Locations

The mean number of taxa and animals and structure of the epibenthic assemblages in Kendall Bay were not significantly different from that at the Reference Locations combined (Tables 24b; Figure 22a). The structure of the fish assemblages also did not differ between these two sets of locations (Table 26b; Figure 22b).

3.6.4 Comparisons of Fauna between 1996 and 2009

The variation in the structure of epibenthic assemblages among sampling locations was not consistent across the two surveys (Table 28). The assemblages at Kendall Bay South were significantly different from those at Sydney Rowing Club and Kissing Point Bay in 1996 and 2009, respectively. Kendall Bay South was the only site in which a significant difference in assemblages was detected between years. This difference was due primarily to the abundances of exquisite, transparent and large-mouthed gobies being greater in 1996 than in 2009 (Table 29). No distinct groupings of assemblages are evident in the MDS plot (Figure 23).

3.7 Fish and Mobile Invertebrate Fauna

3.7.1 General Findings

The 10 seine hauls yielded a total of 5,341 animals from 41 taxa (26 fish, 9 crustacean, 4 mollusc and 2 others) (Appendix 9). The five most abundant taxa, transparent goby *(Gobiopterus semivestitus*), sergestid shrimp (*Acetes sibogae)*, exquisite goby (*Favonigobius* exquisitus), Hippolytidae (shrimps) and mysid *Haplostylis dakini* together accounted for approximately 81% of the animals captured. Fish accounted for only 3.6% of the animals caught. The total number of individuals and taxa and most abundant taxa collected at each of the five study sites are summarised below:

Site	Total no. of Taxa	Total no. of Animals	Most Abundant Taxa
Kendall Bay North	15	295	*Gobiopterus semivestitus* *Haplostylis dakini* *Ambassis jacksoniensis*
Kendall Bay South	19	1703	*Acetes sibogae* *Favonigobius exquisitus* *Gobiopterus semivestitus* *Ambassis jacksoniensis* *Spisula trigonella*
Sydney Rowing Club -	24	928	*Gobiopterus semivestitus* *Atherinosoma ogilbyi* Hippolytidae (shrimps) *Favonigobius exquisitus*

Kissing Point Bay	22	2415	*Gobiopterus semivestitus* Hippolytidae (shrimps) *Haplostylis dakini* *Favonigobius exquisitus* *Ambassis jacksoniensis*

3.7.2 Comparisons among Sites

There were significant differences in mean number of taxa, but not in mean number of animals among sites (Table 30a; Figure 24). Significantly fewer taxa were caught at the Proposed Marina Location than at either Reference Location (Figure 13a). Intermediate numbers of taxa were caught in Kendall Bay South. The large standard errors in Figure 24b indicate that the number of animals caught per haul was highly variable. There was also some indication of a difference in the overall structure of assemblages among sites, but this was not significant (P = 0.06) (Table 31a). The MDS plot indicates that the assemblages at the Proposed Marina Location were distinct from those at Kendall Bay South and that the assemblages at both of these sites were distinct from those at the Reference Locations (Figure 25). The assemblages at the Proposed Marina Location also appear to be more variable than those at the other sites.

3.7.3 Comparisons between Kendall Bay and Reference Locations

There was a significant difference in mean number of taxa between Kendall Bay and the Reference Locations combined, but not in mean number of animals (Table 30b; Figure 11). Significantly fewer taxa were caught at Kendall Bay than at the Reference Locations. There was also a significant difference in the structure of the overall assemblages (Table 31b; Figure 25). Eight of the ten principal taxa contributing to the first 50% of the dissimilarity between these assemblages were more abundant on average at the Reference Locations than in Kendall Bay (Table 32).

4 Discussion

4.1 Sedimentation Rates

Although the SPM flux appeared to increase from location SS1 to SS3, it should be noted that it was not possible to determine whether the differences among locations were statistically significant, because replicate sediment traps were not deployed at each location for any on deployment. The spatial trend is most likely due to a diminution in the strength of hydrodynamic processes in the more sheltered region of the bay which would favour greater deposition of sediment. The changes in SPM flux at the three sampling stations within the Proposed Marina Location that occurred over the three deployments probably reflect differences in the contribution from locally-resuspended sediments and sediments advected from other regions of the Parramatta River and Sydney Harbour due to changes in the strength of tidal and wind-generated currents and degree of resuspension of sediment by boating activities. The range of SPM fluxes measured within the Proposed Marina Location (164- 346 g/m^2/d) is much smaller than that reported for the bottom tube of the sediment traps deployed at comparable sites within the Remediation Site (425-2433 g/m^2/d) by URS (2006a). This could be due to differences in the structure of the traps (three collection tubes at the same height versus a stacked array of three tubes), sampling locations or differences in the environmental conditions prevailing at the time of the two studies. In Sydney Harbour, sediment resuspension rates are greater during warmer conditions (i.e. summer) (Taylor 2000), so it is likely that differences in the timing of the studies (December to February versus May) are also a contributing factor.

4.2 Contamination of Settled Particles

The spatial and temporal patterns in contaminants on settled particles at the Proposed Marina Location were similar to those reported within the Remediation Site by URS (2006a), but only in some respects. In both studies, the concentrations of TPHs, BTEX compounds, free and total cyanide were generally below the Limit of Reporting. Detectable concentrations of most individual PAHs were found during the recent three deployments, but only during the 2nd and 3rd deployments undertaken by URS. In both studies, the normalised concentrations of PAH analytes and of various combinations thereof (i.e. low molecular weight, high molecular weight and total PAHs) in SPM were below the ISQG-High values for all three deployments. During the current study, the normalised mean concentrations of the various combinations of PAHs (i.e. low molecular weight, high molecular weight and total) in SPM were above the ISQG-Low values during the 2nd deployment only, but at all locations. URS (2006a) noted that normalised concentrations of combined PAHs exceeded the ISQG-Low values during two trap deployments only, but not at all locations within the Remediation Site. During the current study, the normalised concentrations of one PAH analyte, acenaphthylene, were consistently between the ISQG-Low and ISQG-High values in SPM for all locations and deployments. The normalised concentrations of several other individual PAH analytes exceeded their respective ISQG-Low values, but not during all three deployments and in most cases not across all sampling locations. The URS (2006a) data also showed that trends in PAH analytes were not consistent across locations or deployments. The detection of PAHs in SPM in excess of the ISQG-Low values is not surprising given that 62% of surficial sediments within Port Jackson have total PAH concentrations in excess of this guideline and that concentrations increase towards the end of embayments (McCready *et al.* 2000). Although PAH exceedences above the ISQG-Low guideline may indicate a contribution from resuspension of the local contaminated sediments, it is important to note that PAHs may also enter Kendall Bay via urban runoff and aeolian transport of particulate matter from high temperature combustion processes. The fact that the normalised concentrations of acenaphthylene in SPM were in excess of the ISQG-Low value, but not those in the sediment samples analysed by AECOM (2009) suggests that other sources of PAHs may be important contributors to contamination in Kendall Bay.

These finding have implications for the use of a geotextile blanket with gravel ballast as a long-term remediation measure for the Proposed Marina Location. The presence of PAHs in excess

of ISQG-Low values in suspended sediments implies that, after installation of the blanket, it will not be possible to separate PAHs from water column sources from those that may be attached to very fine sediment particles (<75 µm) that will pass through the geotextile blanket and into the water column. However, the geotextile blanket will effectively isolate the majority of sediments, preventing them from becoming suspended in the water column, and hence decrease the total amount of contaminants potentially present in the water column compared to the current situation.

4.3 Sediment Grain Size

The sediments at most of the study sites within Kendall Bay and those at Kissing Point Bay were dominated by fine material, whereas those at the sites near Sydney Rowing Club were dominated by sand. The difference in sediment grain size suggests that the sites at Sydney Rowing Club are probably exposed to more erosive forces and that this location may not therefore be suitable as a Reference. The sediments within Kendall Bay were not uniform; the proportion of fines mainly increased from Breakfast Point towards the head of Kendall Bay, with a similar but less distinctive trend at the offshore sites. The increase in proportion of fines is probably due to the more sheltered nature of the inner bay. The coarser nature of the sediment found at BG1, the site closest to Breakfast Point, is probably due to localised erosion resulting from repeated exposure of the site to waves generated by ferries and other vessels and tidal currents (URS 2006b).

4.4 Heavy Metal Contaminants

This study has shown that the concentrations of lead, mercury and zinc in sediments from at least half of the sites exceed the ANZECC/ARMCANZ ISQG High values. This suggests that these contaminants may have already had or be having adverse effects on infaunal organisms that ingest sediment and particulate matter. They could also be having indirect adverse effects on organisms that feed on infauna, particularly on species which have the ability to accumulate heavy metals in their tissues. The heavy metals that occur at concentrations in excess of the ISQG-Low value could also be having adverse effects on the infauna. It is important to bear in mind that estuarine organisms differ in their ability to accumulate, store, remove and detoxify metal contaminants. Filter-feeding bivalve molluscs are renowned for their ability to accumulate heavy metals in certain tissues, but many species of fish and crustaceans are able to regulate heavy metal concentrations in their muscle tissue, sequester free metal ions and prevent their toxic action on specific tissue sites (Kennish 1992). Estuarine organisms also exhibit a variety of physiological, reproductive and developmental responses to the toxic effects of heavy metals. Estuarine organisms can also take up heavy metals via diffusion of dissolved metals at respiratory and feeding surfaces. Copper and zinc were the only heavy metals that occurred in the water column at total concentrations in excess of the ANZECC/ARMCANZ 95% trigger values. The copper concentrations were at or slightly above the 90% trigger value on one sampling occasion, but between the 80% and 90% trigger values on the other. The zinc concentrations exceeded the 99% trigger value at all sites, but were close to the 95% trigger value at two sites during low tide on the first sampling occasion. It is recommended that the potential for increase in copper concentrations associated with boating be addressed as part of the environmental management for the project.

Chromium, copper, lead, nickel and zinc concentrations were generally greater in sediment collected from deep than shallow sites. A similar trend was seen with arsenic, but only at the northern end of the Proposed Marina Location. The difference in concentrations of these metals in deep and shallow sites probably reflects the exposure of sediments in shallow areas to greater hydrodynamic forces.

4.5 Infauna

4.5.1 Spatial Variation within the Proposed Marina Location

The sediments within the Proposed Marina Location contained at least 30 infaunal taxa with bivalves from the family Mactridae and polychaete worms from the families Capitellidae, Nephtyidae, Sabellidae, Spionidae and Lumbrineridae being the most abundant numerically. The mean numbers of taxa and animals were similar in nearshore and offshore strata, among the four positions surveyed along the Proposed Marina Location and across the offshore sites. Significant differences in the mean number of animals, but not taxa present, however, were evident among nearshore sites. The structure of the assemblages was also similar in the two strata, but differed between some positions (i.e. Position 4 vs Positions 1, 2 and 3), across the nearshore sites and between the Proposed Marina Location and southern end of Kendall Bay. The dissimilarity in these assemblages was due to differences in average abundances of taxa rather than differences in composition. The small-scale variation in diversity and structure of the assemblages is likely to reflect natural factors, such as differences in particle size composition, exposure to water movements, food availability, competition, recruitment and numbers and types of predators in addition to anthropogenic factors such as exposure to contaminants and disturbances from boat wake.

In 1988, significantly fewer taxa were found in both the shallow and medium depth strata at the southern end of Kendall Bay than adjacent to the eastern boundary of the gasworks. The variation in total number of animals, however, was not significant in any of the three depth strata examined (The Ecology Lab 1989). In 1996, the mean numbers of infaunal taxa and animals was greater at one of the three sites surveyed along the western boundary of the former gasworks (The Ecology Lab 1996). The structure of the assemblages, however, differed across all three sites. The taxa that contributed to the dissimilarity between these assemblages were not described, however, it is clear from the univariate analyses presented that AGL5 and AGL6 had smaller numbers of capitellids and *Sanguinolaria donacoides* than AGL4 and that there was a significant decline in abundance of *Spisula trigonella* from AGL4 to AGL6.

4.5.2 Spatial and Temporal Variation among Locations

In 2009, the mean number of taxa within samples from the Proposed Marina Location was similar to that at the Reference Locations, but the mean number of animals was similar to that at only one of the Reference Locations. The overall structure of the assemblages at the Proposed Marina Location, however, was significantly different from that at both Reference Locations. In 1996, the infaunal assemblages adjacent to the former Mortlake gasworks were also found to be significantly different from those at the Reference Locations (The Ecology Lab 1996). In both surveys, the dissimilarity in these assemblages was due to differences in abundances of taxa rather than their composition. The major contributors to the dissimilarity in these assemblages were capitellid worms, nephtyid worms and mactrid bivalves in 2009 and capitellid worms, the mactrid bivalve *Spisula trigonella*, tellinid bivalves *Tellina deltoidalis* and *Sanguinolaria donacoides* and crustacean *Callianassa arenosa* in 1996. Although this suggests that there was some similarity in these assemblages over time, the analyses presented in the current report show that the spatial variation in infaunal assemblages observed in 2009 was not entirely consistent with that in 1996. This was because there were significant differences in the structure of assemblages between the Reference Locations in 2009 but not in 1996. The assemblages at the Proposed Marina Location, in contrast, were significantly different from those at the Reference Location during both surveys. The mean numbers of taxa and animals collected (averaged across all three locations) was also significantly greater in 1996 than in 2009. Differences in sampling gear and timing of the surveys (i.e. cores of sediment collected by divers in March 1996 versus grab samples in May 2009) may have contributed to the dissimilarity in the infaunal assemblages between the two surveys.

4.5.3 Relationship between Patterns in Biota and Contaminants within Kendall Bay

The Ecology Lab (1996) noted that the assemblages at three sites adjacent to the former gasworks were distinct from those at the nearby sites as well as those at the Reference Locations. As these three sites had the greatest concentrations of PAHs, they concluded that the patterns of variability in the benthic infauna were consistent with the level of contamination around the Mortlake property. No attempt was made to link the patterns in the biota observed across all the study sites with the concentrations of contaminants. The study undertaken in May 2009, however, has shown that the spatial pattern in the infaunal assemblages within Kendall Bay does not reflect any of the individual contaminants measured or combinations thereof. The lack of any obvious link between the spatial patterns in infaunal assemblages and concentrations of contaminants could be due to the high levels of variability in both factors.

4.6 Epibenthic Fauna

In 2009, the epibenthic fauna within Kendall Bay included 64 taxa and was dominated numerically by the mactrid bivalve *Spisula trigonella,* mysid *Haplostylis dakini,* amphipod *Corophium* sp. and shrimp *Philocherus* sp. Considerably fewer taxa were present at the individual sites, with total numbers decreasing from 48 in the north to 28 in the south of Kendall Bay. Although there was considerable variation in the catches, the epibenthic assemblages in Kendall Bay appeared to be typical of that region of the estuary. Kendall Bay North and Kissing Point Bay was the only pair of sites to show significant differences in the structure of epibenthic assemblages. The dissimilarity between these assemblages was due to differences in composition in addition to differences in abundances of taxa.

Analyses based solely on the fish component of these assemblages indicated that Kendall Bay North and Kendall Bay South were significantly different from Kendall Bay Mid and Kissing Point Bay. In this case, one species, the exquisite goby, accounted for most of the dissimilarity.

There was a significant difference between 1996 and 2009 in the structure of the epibenthic assemblage at Kendall Bay South, but not at the other sites. This was due primarily to exquisite, transparent and large-mouthed gobies being more abundant in 1996 than in 2009. Kendall Bay South was also the only site to show a significant difference within surveys, but this was not consistent.

4.7 Fish and Mobile Invertebrate Fauna

In 2009, a total of 15 fish and mobile invertebrate taxa were sampled off the sandy beach adjacent to the Proposes Marina Location, with the transparent goby *Gobiopterus semivestitus*, mysid *Haplostylis dakini* and Port Jackson perchlet *Ambassis jacksoniensis* being the most abundant taxa. The mean number of taxa caught was significantly lower at the Proposed Marina Location than at either Reference Location. Intermediate numbers of taxa were caught in Kendall Bay South. The variation in total number of animals was large, but not significant among sites. The overall structure of the assemblages, however, appeared to differ among sites and the assemblage within Kendall Bay was significantly different from that at the Reference Locations combined. Most of the taxa that contributed to the dissimilarity in these assemblages were more abundant on average at the Reference Locations than in Kendall Bay.

The fish and mobile invertebrate fauna sampled in 2009 can not be compared statistically with that of the earlier surveys, because the seine net used in 1988 and 1996 was much larger (25 m long x 3 m deep with an 8 mm mesh) than that used in the current study (10 m long and 1 m deep seine net with 2 mm mesh). It is, however, worth noting that sandy sprat, trumpeter whiting, silver biddy and exquisite goby were caught at the Proposed Marina Location in 1996 and 2009 and that yellowfin bream, flat-tailed mullet, bridled goby, exquisite goby, transparent goby and eastern king prawn were caught at Kendall Bay South in 1988 and 2009.

5 Conclusions

Although the subtidal sediments at the Proposed Marina Location still contain elevated concentrations of some contaminants, it is clear from the current study and those undertaken by The Ecology Lab (1989 and 1996) that they support a diverse range of benthic taxa and that a variety of mobile fish and invertebrates live in the water column above the sediments. The current study suggests that the epibenthic assemblages at the Proposed Marina Location were typical of that region of the estuary, but not the infauna or mobile fish and invertebrate assemblages. The continued presence of a diverse fauna suggests that the contaminants may not actually be having adverse effects on the fauna, or if they are, only some components of the fauna are affected.

In estuarine waters, the bioavailability of contaminants depends on a variety of processes including currents and tidal exchange, dissolution, redox reactions, sorption-desorption of compounds, microbial degradation and bioturbation (Kennish 1992). Contaminants enter aquatic organisms via ingestion with detritus and food, exchange of water at feeding and respiratory surfaces and adsorption of chemicals onto body surfaces. The effects of contaminants on organisms depend on the concentration of the contaminant, duration of exposure and ability of organisms to metabolise and eliminate contaminants. PAHs, the major contaminant of concern in Kendall Bay, tend to accumulate in bottom sediments and are therefore more likely to be taken up by benthic and epibenthic organisms than those living and feeding within the water column. Aquatic organisms, however, differ in their ability to metabolise and hence accumulate PAHs. Fish, crustaceans and annelid worms, for example, have enzymes capable of metabolising PAHs, whereas bivalve molluscs do not (Kennish 1992). This suggests that bivalves are likely to accumulate significant concentrations of PAHs than these other organisms and be better indicators of their adverse effects.

The studies on infauna certainly do not support the statement in the Remediation Order issued to NSW Maritime by the Environmental Protection Agency (now part of the Department of Environment and Climate Change) that there is a lack of benthic fauna in the nearshore sediments adjoining the former gasworks site. The review of the 1988 study presented in The Ecology Lab (1996), in fact, states that “there was little evidence to suggest that any of the sites was depauperate (i.e. had few taxa or animals) in terms of benthic infauna”. The Ecology Lab (1996) did, however, note that the assemblages at the sites with the greatest concentrations of PAHs were distinct from those found at the other sites and that this distinctness was due to them having smaller numbers of some taxa. They concluded that the spatial variation in composition and abundance of the infauna was consistent with the levels of contaminants found in the sediments at Mortlake. The current study, however, has shown that the spatial patterns in infaunal assemblages within the Proposed Marina Location are not closely linked with the concentrations of the major contaminants. This is not altogether surprising given that the distribution and abundance of taxa in soft sediments is governed by a variety of factors, including differences in particle size composition, exposure to water movements, food availability, competition, recruitment and numbers and types of predators and disturbances from other anthropogenic activities besides exposure to contaminants.

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8 Tables

Table 1: Species of fish and invertebrates caught in beam trawls undertaken at sites adjacent to the Proposed Marina in 1989 and 1996.

Table 2: Species of fish and invertebrates caught in seine net hauls undertaken at sites adjacent to the Proposed Marina in 1989 and 1996.

Table 3: Species of fish and invertebrates caught in gill nets deployed at sites adjacent to the Proposed Marina in 1989 and 1996.

Table 4: Mean (± S.E.) concentrations of BTEXs, TPHs, PAHs and other substances measured in SPM samples from the Sediment Traps deployed at Sites SS1, SS2 and SS3 between 24 April and 5 May 2009 (1st Deployment).

Table 5: Mean (± S.E.) concentrations of BTEXs, TPHs, PAHs and other substances measured in SPM samples from the Sediment Traps deployed at Sites SS1, SS2 and SS3 between 5 May and 22 May 2009 (2nd Deployment).

Table 6: Mean (± S.E.) concentrations of BTEXs, TPHs, PAHs and other substances measured in SPM samples from the Sediment Traps deployed at Sites SS1, SS2 and SS3 three times between 22 May and 5 June 2009 (3rd Deployment).

Table 7: Results of PERMANOVA tests comparing the proportion of fines (< 75 µm) in the sediment at the Proposed Marina Location and Reference Locations.

Table 8: Results of PERMANOVA tests comparing the proportion of fines (< 75 µm) in the sediment sampled from the four positions and two strata within the Proposed Marina Location.

Table 9: Results of PERMANOVA tests comparing the proportion of fines (< 75 µm) in sediment in (a) nearshore and (b) offshore sites within Kendall Bay.

Table 10: Concentrations of heavy metals in and percentage moisture content of surficial sediment samples collected from sites within and adjacent to the Proposed Marina Location on 2 June 2009.

Table 11: Results of PERMANOVA tests comparing the total numbers of (a) taxa and (b) infaunal animals collected among the four positions and two strata sampled within the Proposed Marina Location.

Table 12: Results of PERMANOVA tests comparing the structure of infaunal assemblages across the four positions and two strata sampled within the Proposed Marina Location.

Table 13: Results of SIMPER tests showing the contribution of the major taxa to the dissimilarity between infaunal assemblages at selected positions within the Proposed Marina Location.

Table 14: Results of PERMANOVA tests comparing the total numbers of (a) taxa and (b) infaunal animals collected among (a) nearshore and (b) offshore sites in Kendall Bay.

Table 15: Results of PERMANOVA tests comparing the structure of infaunal assemblages among (a) nearshore and (b) offshore sites in Kendall Bay.

Table 16: Results of SIMPER tests showing the major taxa contributing to the dissimilarity between infaunal assemblages at nearshore sites along the western and southern sides of Kendall Bay.

Table 17: Results of PERMANOVA tests comparing the total numbers of (a) taxa and (b) infaunal animals collected at sites within the Proposed Marina Location and Reference Locations.

Table 18: Results of PERMANOVA tests comparing the structure of infaunal assemblages at sites within the Proposed Marina Location and Reference Locations.

Table 19: Results of SIMPER test showing the contribution of the major taxa to the dissimilarity between infaunal assemblages in the Proposed Marina Location and the Reference Locations combined.

Table 20: Results of PERMANOVA tests comparing the total numbers of (a) taxa and (b) infaunal animals collected at the Proposed Marina Location and Reference Locations, Sydney Rowing Club and Kissing Point Bay, during the 1996 and 2009 surveys.

Table 21: Results of PERMANOVA tests comparing the structure of infaunal assemblages among the Proposed Marina Location and Reference Locations, Sydney Rowing Club and Kissing Point Bay in 1996 and 2009.

Table 22: Results of SIMPER tests showing the major taxa contributing to the dissimilarity between the infaunal assemblages at (a) the Proposed Marina Location (b) Sydney Rowing Club and (c) Kissing Point Bay in 1996 and 2009.

Table 23: Results of PERMANOVA tests comparing the total numbers of taxa and animals in the epibenthic assemblages sampled at (a) the five study sites and (b) the sites in Kendall Bay vs Reference Locations.

Table 24: Results of PERMANOVA tests comparing the structure of epibenthic assemblages across (a) the five study sites and (b) at Kendall Bay vs Reference Locations.

Table 25: Results of SIMPER tests showing the major taxa that contributed > 2% to the overall dissimilarity between the epibenthic assemblages in the northern part of Kendall Bay (KPN) and Kissing Point Bay (KPB).

Table 26: Results of PERMANOVA tests comparing the structure of the fish component of the epibenthic assemblages (a) across the five study sites the northern, mid and southern section of Kendall Bay, (KBN, KBM and KBS, respectively), Sydney Rowing Club (SRC) and Kissing Point Bay (KPB) in May 2009.

Table 27: Results of SIMPER tests showing the major species of fish that contributed > 2% to the overall dissimilarity between the fish component of the epibenthic assemblages sampled in the northern part of Kendall Bay and Kissing Point Bay.

Table 28: Results of PERMANOVA tests comparing the structure of epibenthic assemblages among the sampling locations in Kendall Bay, Sydney Rowing Club and Kissing Point Bay in 1996 and 2009.

Table 29: Results of SIMPER test showing the major species of fish that contributed > 90% of the overall dissimilarity between the fish component of the epibenthic assemblages sampled in 1996 and 2009.

Table 30: Results of PERMANOVA tests comparing the total numbers of taxa and animals collected by seine netting (a) across the four study sites and (b) in Kendall Bay versus the Reference Locations combined.

Table 31: Results of PERMANOVA test comparing the structure of nearshore fish and mobile invertebrate assemblages at (a) the four study sites and (b) in Kendall Bay vs the Reference Locations combined.

Table 32: Results of SIMPER tests showing the major taxa that contributed > 2% to the overall dissimilarity between the nearshore fish and mobile invertebrate assemblages sampled in Kendall Bay and the Reference Locations combined.

Table 1: Species of fish and invertebrates caught in beam trawls undertaken at sites adjacent to the Proposed Marina in 1989 and 1996.

Species Name	Common Name	Site					
		Kendall Bay (S)		Kendall Bay (N)		Parrammatta River	
		1989	1996	1989	1996	1989	1996
FISH							
Urocampus carinirostris	Snub Nose Pipefish	√					
Acanthogobius flavimanus	Oriental Goby	√	√	√		√	
Favonigobius exquisitus	Exquisite Goby	√	√		√	√	√
Favonigobius tamarensis	Tamar River Goby	√		√		√	
Gobiopterus semivestitta	Transparent Goby	√	√	√	√	√	√
Pseudogobius olorum	Swan River Goby	√	√	√		√	
Redigobius macrostoma	Large-mouth Goby	√	√	√	√	√	√
Arenigobius bifrenatus	Bridled Goby		√		√		√
	Unidentified Goby				√		
Pseudorhombus arsius	Large-tooth Flounder	√					
Pseudorhombus jenynsii	Small-toothed flounder				√		
Sillago ciliata	Sand Whiting				√		
Paramonacanthus otiensis	Dusky leatherjacket				√		
Total Number of Fish Species		8	6	5	8	6	4
CRUSTACEANS							
Penaeus plebejus	Eastern King Prawn	√	√		√		√
Penaeus esculentus	Brown Tiger Prawn		√				
Metapenaeus macleayi	School Prawn	√					
Metapenaeus bennettae	Greasy Back Prawn		√				
	Unidentified penaeid prawn		√		√		
Macrobrachium intermedium	Striped shrimp	√				√	
Alpheus sp.	Snapping shrimp	√					
Alpheus pacifica			√		√		√
Haplostylis dakini	Mysid shrimp		√		√		√
Mysid sp.						√	
Callianassa arenosa					√		
Tanaids			√		√		√
Unidentified carid shrimp							√
Caprella sp.	Skeleton shrimp		√		√		
Halicarcinus sp.	Spider crab	√		√		√	
Halicarcinus ovatus	Oval spider crab		√		√		√
Crab sp. 1			√		√		√
Crab sp.2							√
Exoediceros fossor	Amphipod		√		√		
Gammaropsis sp. 1			√		√		
Corophium volutator					√		
Unidentified amphipod					√		
Total Number of Crustacean Species		5	12	1	13	3	8
MOLLUSCS							
Notospisula trigonella		√	√	√	√	√	√
Theora fragilis		√	√		√		√
Fulvia tenuicostata			√		√		√
Tellina deltoidalis							√
Hiatella australis			√				
	Unidentified bivalve		√		√		
Nassarius burchardi	Dogwhelk		√		√		√
Nassarius jonasi			√				
	Unidentified seahare						√
Total Number of Mollusc Species		2	7	1	5	1	6

Table 2: Species of fish and invertebrates caught in seine net hauls undertaken at sites adjacent to the proposed Kendall Bay Marina in 1989, 1996 and 2009.

Species Name	Common Name	Site			
		Proposed Marina Location		Kendall Bay South	
		1996	2009	1989	2009
FISH					
Hyperlophus vittatus	Sandy Sprat	√	√		
Herklotsichthys castelnaui	Southern Herring			√	
Spratelloids robustus	Blue Sprat			√	
Engraulis australis	Anchovy			√	
Atherinomorus ogilbyi	Ogilby's Hardyhead	√			√
Urocampus carinirostris	Snub-nosed Pipefish			√	
Centropogon australis	Fortesque			√	
Ambassis jacksoniensis	Port Jackson Perchlet		√		√
Priopidichthys marianus	Yellow Perchlet			√	
Pelates sexlineatus	Striped Trumpeter				√
Sillago maculata	Trumpeter Whiting	√	√		√
Pomatomus saltatrix	Tailor	√		√	
Gerres subfasciatus	Silver biddy	√	√	√	
Acanthopagrus australis	Yellowfin bream			√	√
Pagrus auratus	Snapper	√			
Rhabdosargus sarba	Tarwhine			√	
Upeneus tragula	Bar-tailed Goatfish	√			
Mugil cephalus	Sea Mullet			√	
Liza argentea	Flat-tailed Mullet		√	√	√
Acanthogobius flavimanus	Oriental Goby	√		√	
Arenigobius bifrenatus	Bridled Goby			√	√
Arenigobius frenatus	Bridled Goby			√	
Favonigobius exquisitus	Exquisite Goby	√	√	√	√
Favonigobius tamarensis	Tamar River Goby			√	
Gobiopterus semivestitta	Transparent Goby		√	√	√
Pseudogobius olorum	Swan River Goby			√	
Redigobius macrostoma	Large-mouth Goby			√	
Bathygobius kreffti	Krefft's goby				√
Pseudorhombus arsius	Large-tooth Flounder	√			
Tetractenos hamiltoni	Hamilton's Toadfish	√			√
Tetractenos glaber	Smooth Toadfish			√	
Tetractenos pleurogramma	Banded Toadfish			√	
Number of fish species		11	7	22	11
MOLLUSCS					
Sepia plangon	Cuttlefish				
CRUSTACEANS					
Unidentified carid shrimp				√	
Unidentified prawn		√			
Metapenaeus macleayi	Eastern school prawn		√		√
Penaeus plebejus	Eastern King Prawn		√	√	√
Alpheus levinsculus	Snapping shrimp			√	
Number of crustacean species		1	2	3	2

Table 3: Species of fish and invertebrates caught in gill nets deployed at sites adjacent to the Proposed Marina in 1989 and 1996.

Species Name	Common Name	Site					
		Kendall Bay South		Kendall Bay North		River	
		1989	1996	1989	1996	1989	1996
FISH							
Platycephalus fuscus	Dusky Flathead	√			√		√
Sillago maculata	Trumpeter Whiting						√
Pomatomus saltatrix	Tailor				√		√
Gerres subfasciatus	Silver biddy					√	
Acanthopagrus australis	Yellowfin bream	√		√		√	√
Rhabdosargus sarba	Tarwhine					√	
Mugil cephalus	Sea Mullet	√					√
Liza argentea	Flat-tailed Mullet	√					√
Pseudorhombus arsius	Large-tooth Flounder						√
Paramonacanthus otisensis	Dusky Leatherjacket				√		√
CRUSTACEANS							
Portunus pelagicus	Blue-swimmer Crab	√		√	√		√
Scylla serrata	Mud crab	√		√	√		
Alima laevis	Mantis shrimp						√

Table 4: Mean (± S.E.) concentrations of BTEXs, TPHs, PAHs and other substances measured in SPM samples from the Sediment Traps deployed at Sites SS1, SS2 and SS3 between 24 April and 5 May (i.e. 1st Deployment). Note that concentrations of organic compounds that are above the Limit of Reporting (LOR) have been normalised to 1% total organic carbon. Highlighted values exceed the ANZECC/ARMCANZ (2000) ISQG-Low Trigger values. (n/a = no ISQG-Low or High guidelines; <LOR is below the Limit of Reporting).

Analyte					Site					
	Units	LOR	SQG-Low	SQG-High	SS1		SS2		SS3	
				Replicate	Mean	S.E.	Mean	S.E.	Mean	S.E.
				n	1		3		3	
BTEX										
Benzene	mg/kg	0.2	n/a	n/a	<LOR		<LOR		<LOR	
Toluene	mg/kg	0.5	n/a	n/a	<LOR		<LOR		<LOR	
Ethylbenzene	mg/kg	0.5	n/a	n/a	<LOR		<LOR		<LOR	
meta- & para-Xylene	mg/kg	0.5	n/a	n/a	<LOR		<LOR		<LOR	
ortho-Xylene	mg/kg	0.5	n/a	n/a	<LOR		<LOR		<LOR	
Total Petroleum Hydrocarbons										
C6 - C9 Fraction	mg/kg	10	n/a	n/a	<LOR		<LOR		<LOR	
C10 - C14 Fraction	mg/kg	50	n/a	n/a	<LOR		<LOR		<LOR	
C15 - C28 Fraction	mg/kg	100	n/a	n/a	<LOR		<LOR		<LOR	
C29 - C36 Fraction	mg/kg	100	n/a	n/a	<LOR		<LOR		<LOR	
TPH(V)/BTEX Surrogates										
1.2-Dichloroethane-D4	%	0.2	n/a	n/a	33.79		33.41	0.60	32.86	1.44
Toluene-D8	%	0.2	n/a	n/a	31.03		31.26	0.66	33.21	1.73
4-Bromofluorobenzene	%	0.2	n/a	n/a	29.49		29.71	0.51	31.77	1.87
Polycyclic Aromatic Hydrocarbons										
3-Methylcholanthrene	µg/kg	10	n/a	n/a	<LOR		<LOR		<LOR	
2-Methylnaphthalene	µg/kg	10	n/a	n/a	22.06		27.44	1.28	27.89	2.81
7.12-Dimethylbenz(a)anthrac	µg/kg	10	n/a	n/a	<LOR		<LOR		<LOR	
Acenaphthene	µg/kg	10	16	500	11.03		12.47	1.26	10.89	1.96
Acenaphthylene	µg/kg	10	44	640	161.76		164.62	15.11	158.03	5.33
Anthracene	µg/kg	10	85	1100	62.50		66.08	4.46	60.76	2.29
Benz(a)anthracene	µg/kg	10	261	1600	205.88		209.48	15.12	187.12	7.83
Benzo(a)pyrene	µg/kg	10	430	1600	437.50		438.93	25.85	396.15	14.39
Benzo(b)fluoranthene	µg/kg	10	n/a	n/a	371.32		454.07	38.53	391.71	49.69
Benzo(e)pyrene	µg/kg	10	n/a	n/a	242.65		241.91	13.89	212.62	8.69
Benzo(g.h.i)perylene	µg/kg	10	n/a	n/a	132.35		279.29	17.81	285.01	10.35
Benzo(k)fluoranthene	µg/kg	10	n/a	n/a	338.24		179.72	16.59	193.64	22.54
Chrysene	µg/kg	10	384	2800	183.82		194.53	13.22	175.03	4.88
Coronene	µg/kg	10	n/a	n/a	11.03		61.14	5.64	66.99	2.36
Dibenz(a.h)anthracene	µg/kg	10	63	2600	40.44		66.08	4.46	68.18	2.01
Fluoranthene	µg/kg	10	600	5100	301.47		312.98	23.31	283.26	6.43
Fluorene	µg/kg	10	19	540	22.06		26.17	2.10	25.50	1.75
Indeno(1.2.3.cd)pyrene	µg/kg	10	n/a	n/a	117.65		210.73	12.63	210.60	4.22
N-2-Fluorenyl Acetamide	µg/kg	100	n/a	n/a	<LOR		<LOR		<LOR	
Naphthalene	µg/kg	10	160	2100	55.15		62.34	4.46	59.49	4.51
Perylene	µg/kg	10	n/a	n/a	77.21		83.51	7.43	74.05	4.95
Phenanthrene	µg/kg	10	240	1500	125.00		140.89	10.15	127.62	4.54
Pyrene	µg/kg	10	665	2600	408.09		426.43	28.46	396.34	8.07
Low molecular weight PAHs	µg/kg		552	3160	459.56		500.02	38.43	470.18	22.89
High Molecular weight PAHs	µg/kg		1700	9600	1577.21		1648.45	110.33	1506.08	40.34
Total PAHs	µg/kg		4000	45000	3327.21		3658.84	230.87	3410.86	94.71
Miscellaneous										
Moisture Content	%	1	n/a	n/a	73.4		73.20	0.21	72.80	0.17
Free Cyanide	mg/kg	1	n/a	n/a	<LOR		<LOR		<LOR	
Total Cyanide	mg/kg	1	n/a	n/a	<LOR		<LOR		<LOR	
Total Organic Carbon	%	0.02	n/a	n/a	2.72		2.67	0.02	2.74	0.05

Table 5: Mean (± S.E.) concentrations of BTEXs, TPHs, PAHs and other substances measured in SPM samples from the Sediment Traps deployed at Sites SS1, SS2 and SS3 between 5 May and 22 may (i.e. 2nd Deployment). Note that concentrations of organic compounds that are above the Limit of Reporting (LOR) have been normalised to 1% total organic carbon. Highlighted values exceed the ANZECC/ARMCANZ (2000) ISQG-Low Trigger values. (n/a = no ISQG-Low or High guidelines; <LOR is below the Limit of Reporting).

Analyte					Site					
	Units	LOR	SQG-Low	SQG-High	SS1		SS2		SS3	
				Replicate	Mean	S.E.	Mean	S.E.	Mean	
				n	1		3		3	
BTEX										
Benzene	mg/kg	0.2	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Toluene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Ethylbenzene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
meta- & para-Xylene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
ortho-Xylene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Total Petroleum Hydrocarbons										
C6 - C9 Fraction	mg/kg	10	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
C10 - C14 Fraction	mg/kg	50	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
C15 - C28 Fraction	mg/kg	100	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
C29 - C36 Fraction	mg/kg	100	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
TPH(V)/BTEX Surrogates										
1.2-Dichloroethane-D4	%	0.2	n/a	n/a	37.57	0.25	38.36	0.90	37.51	0.35
Toluene-D8	%	0.2	n/a	n/a	32.40	0.48	33.44	0.33	33.95	0.43
4-Bromofluorobenzene	%	0.2	n/a	n/a	31.33	0.75	32.96	0.23	33.81	0.59
Polycyclic Aromatic Hydrocarbons										
3-Methylcholanthrene	µg/kg	10	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
2-Methylnaphthalene	µg/kg	10	n/a	n/a	67.17	12.83	49.13	4.67	62.14	4.70
7.12-Dimethylbenz(a)ant	µg/kg	10	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Acenaphthene	µg/kg	10	16	500	27.24	9.12	24.61	4.66	26.54	4.07
Acenaphthylene	µg/kg	10	44	640	248.70	34.93	176.77	18.79	211.76	28.42
Anthracene	µg/kg	10	85	1100	105.29	14.71	81.03	7.59	96.38	12.41
Benz(a)anthracene	µg/kg	10	261	1600	295.90	42.28	235.68	18.94	280.22	35.54
Benzo(a)pyrene	µg/kg	10	430	1600	579.03	42.79	464.09	21.19	603.56	123.29
Benzo(b)fluoranthene	µg/kg	10	n/a	n/a	531.84	42.71	459.06	10.68	609.26	121.02
Benzo(e)pyrene	µg/kg	10	n/a	n/a	350.35	42.38	278.63	22.11	312.10	32.16
Benzo(g.h.i)perylene	µg/kg	10	n/a	n/a	228.70	11.30	184.18	17.22	244.60	48.00
Benzo(k)fluoranthene	µg/kg	10	n/a	n/a	354.06	85.94	263.86	7.49	305.82	15.62
Chrysene	µg/kg	10	384	2800	317.69	49.58	251.67	23.31	295.63	35.30
Coronene	µg/kg	10	n/a	n/a	25.41	0.05	19.65	2.50	25.36	4.46
Dibenz(a.h)anthracene	µg/kg	10	63	2600	81.68	5.59	67.53	6.32	86.21	15.75
Fluoranthene	µg/kg	10	600	5100	473.77	46.23	472.65	44.07	560.46	79.39
Fluorene	µg/kg	10	19	540	47.20	7.35	35.59	3.23	43.10	4.79
Indeno(1.2.3.cd)pyrene	µg/kg	10	n/a	n/a	217.81	14.91	175.57	16.44	225.66	40.73
N-2-Fluorenyl Acetamide	µg/kg	100	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Naphthalene	µg/kg	10	160	2100	143.41	20.22	97.01	8.44	120.54	12.13
Perylene	µg/kg	10	n/a	n/a	119.81	14.74	95.72	7.67	109.12	12.14
Phenanthrene	µg/kg	10	240	1500	199.68	25.77	165.74	15.19	199.18	22.16
Pyrene	µg/kg	10	665	2600	680.72	75.65	566.05	22.86	738.17	145.60
Low molecular weight PA	µg/kg		552	3160	838.70	124.93	629.88	60.89	759.66	83.16
High Molecular weight P.	µg/kg		1700	9600	2200.11	261.71	1872.19	123.74	2272.79	328.09
Total PAHs	µg/kg		4000	45000	5095.46	599.08	4164.20	264.11	5155.82	771.18
Miscellaneous										
Moisture Content	%	1	n/a	n/a	76.80	0.10	76.77	0.34	77.10	0.57
Free Cyanide	mg/kg	1	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Total Cyanide	mg/kg	1	n/a	n/a	<LOR	<LOR	1.00	0.00	<LOR	<LOR
Total Organic Carbon	%	0.02	n/a	n/a	2.76	0.00	2.72	0.02	2.63	0.04

Table 6: Mean (± S.E.) concentrations of BTEXs, TPHs, PAHs and other substances measured in SPM samples from the Sediment Traps deployed at Sites SS1, SS2 and SS3 between 22 May and 5 June (i.e. 3rd Deployment). Note that concentrations of organic compounds that are above the Limit of Reporting (LOR) have been normalised to 1% total organic carbon. Highlighted values exceed the ANZECC/ARMCANZ (2000) ISQG-Low Trigger values. (n/a = no ISQG-Low or High guidelines; <LOR is below the Limit of Reporting).

Analyte					Site					
	Units	LOR	SQG-Low	SQG-High	SS1		SS2		SS3	
				Replicate	Mean	S.E.	Mean	S.E.	Mean	
				n	3		3		3	
BTEX										
Benzene	mg/kg	0.2	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Toluene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Ethylbenzene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
meta- & para-Xylene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
ortho-Xylene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Total Petroleum Hydrocarbons										
C6 - C9 Fraction	mg/kg	10	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
C10 - C14 Fraction	mg/kg	50	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
C15 - C28 Fraction	mg/kg	100	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
C29 - C36 Fraction	mg/kg	100	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
TPH(V)/BTEX Surrogates										
1.2-Dichloroethane-D4	%	0.2	n/a	n/a	30.21	0.67	30.49	1.58	30.44	0.55
Toluene-D8	%	0.2	n/a	n/a	27.89	0.79	28.65	1.43	28.46	0.37
4-Bromofluorobenzene	%	0.2	n/a	n/a	28.87	0.93	29.46	1.47	28.86	0.43
Polycyclic Aromatic Hydrocarbons										
3-Methylcholanthrene	µg/kg	10	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
2-Methylnaphthalene	µg/kg	10	n/a	n/a	12.46	0.00	11.42	1.04	11.42	1.04
7.12-Dimethylbenz(a)ant	µg/kg	10	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Acenaphthene	µg/kg	10	16	500	6.23	0.00	5.19	1.04	6.23	0.00
Acenaphthylene	µg/kg	10	44	640	74.77	4.76	76.84	6.32	83.07	8.50
Anthracene	µg/kg	10	85	1100	24.92	1.80	28.04	1.80	30.11	2.75
Benz(a)anthracene	µg/kg	10	261	1600	91.38	7.27	104.88	9.23	116.30	9.23
Benzo(a)pyrene	µg/kg	10	430	1600	202.49	14.05	227.41	22.54	229.49	18.02
Benzo(b)fluoranthene	µg/kg	10	n/a	n/a	183.80	17.71	225.34	27.06	233.64	27.92
Benzo(e)pyrene	µg/kg	10	n/a	n/a	104.88	6.81	121.50	11.79	118.38	8.99
Benzo(g.h.i)perylene	µg/kg	10	n/a	n/a	103.84	6.32	120.46	14.65	112.15	9.52
Benzo(k)fluoranthene	µg/kg	10	n/a	n/a	85.15	5.49	106.96	8.50	94.50	11.98
Chrysene	µg/kg	10	384	2800	98.65	6.81	114.23	9.23	118.38	10.79
Coronene	µg/kg	10	n/a	n/a	11.42	1.04	16.61	1.04	15.58	1.80
Dibenz(a.h)anthracene	µg/kg	10	63	2600	34.27	1.80	38.42	4.15	36.34	2.75
Fluoranthene	µg/kg	10	600	5100	145.38	11.98	181.72	20.85	181.72	16.22
Fluorene	µg/kg	10	19	540	12.46	0.00	11.42	1.04	13.50	1.04
Indeno(1.2.3.cd)pyrene	µg/kg	10	n/a	n/a	92.42	5.49	104.88	11.42	97.61	8.31
N-2-Fluorenyl Acetamide	µg/kg	100	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Naphthalene	µg/kg	10	160	2100	22.85	1.04	22.85	3.74	23.88	1.04
Perylene	µg/kg	10	n/a	n/a	38.42	2.75	43.61	3.60	43.61	3.60
Phenanthrene	µg/kg	10	240	1500	50.88	4.15	62.31	7.19	64.38	4.53
Pyrene	µg/kg	10	665	2600	214.95	17.16	262.72	29.79	266.87	22.77
Low molecular weight PA	µg/kg		552	3160	204.57	11.42	218.07	21.21	232.61	18.02
High Molecular weight P	µg/kg		1700	9600	787.12	58.18	929.39	94.84	949.12	78.32
Total PAHs	µg/kg		4000	45000	1611.63	112.44	1886.81	184.30	1897.20	141.40
Miscellaneous										
Moisture Content	%	1	n/a	n/a	77.63	0.35	77.07	0.15	76.57	0.27
Free Cyanide	mg/kg	1	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Total Cyanide	mg/kg	1	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Total Organic Carbon	%	0.02	n/a	n/a	2.45	0.10	2.18	0.25	2.46	0.51

Table 7: Results of PERMANOVA tests comparing the proportion of fines (< 75 µm) in the sediment at the Proposed Marina Location and Reference Locations.

Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Location	2	6609.3	3304.7	12.135	**<0.001**	3969
Residual	29	7897.4	272.32			
Total	31	14507				

Pairwise Tests of Locations

Locations	t-value	P(MC)	Unique perms
PML v KPB	1.489	0.153	198
PML v SRC	3.796	**0.002**	257
SRC v KPB	15.011	**<0.001**	81

Table 8: Results of PERMANOVA tests comparing the proportion of fines (< 75 µm) in the sediment sampled from the four positions and two strata within the Proposed Marina Location.

Main Test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Position	3	4733.50	1577.80	970.97	R	4988
Strata	1	702.25	702.25	432.15	R	4279
Position x Strata	3	1680.30	560.08	344.67	**<0.001**	4985
Residual	8	13.00	1.63			
Total	15	7129.00				

Pairwise Tests of Positions within the Nearshore Stratum

Position	t-value	P(MC)	Unique perms
1, 2	27.892	**0.001**	3
1, 3	26.000	**0.002**	2
1, 4	34.500	**0.001**	2
2, 3	11.000	**0.007**	2
2, 4	23.000	**0.002**	2
3, 4	Denominator is 0		

Pairwise Tests of Positions within the Offshore Stratum

Position	t-value	P(MC)	Unique perms
1, 2	2.828	0.104	3
1, 3	18.336	**0.004**	3
1, 4	23.000	**0.003**	2
2, 3	14.758	**0.005**	3
2, 4	19.000	**0.003**	2
3, 4	5.000	**0.036**	2

Table 9: Results of PERMANOVA tests comparing the proportion of fines (< 75 µm) in sediment in (a) nearshore and (b) offshore sites within Kendall Bay. (note that nearshore comprises Sites BG1, BG3, BG5 and BG7 within the Proposed Marina Location and Sites BG9 and BG10 at the southern end of Kendall Bay).

(a) Nearshore Sites

Main Test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Inique perms
Position	5	13180.00	2636.10	596.85	**<0.001**	1012
Residual	6	26.50	4.42			
Total	11	13207.00				

Pairwise tests

Source of variation	t	P(MC)	Unique perms
BG1 v BG3	27.892	**0.002**	3
BG1 v BG5	25.726	**0.001**	3
BG1 v BG7	34.500	**0.001**	2
BG1 v BG9	31.500	**0.000**	2
BG1 v BG10	25.800	**0.001**	3
BG3 v BG5	8.583	**0.011**	3
BG3 v BG7	23.000	**0.002**	2
BG3 v BG9	11.000	**0.007**	2
BG3 v BG10	4.427	**0.051**	3
BG5 v BG7	47.381	**0.001**	2
BG5 v BG9	30.414	**0.001**	2
BG5 v BG10	7.951	**0.018**	3
BG7 v BG9	enominator is		
BG7 v BG10	3.000	0.098	2
BG9 v BG10	1.000	0.414	1

(b) Offshore Sites

Main Test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Inique perms
Position	3	1527.80	509.25	407.40	**<0.001**	58
Residual	4	5.00	1.25			
Total	7	1532.80				

Pairwise tests

Source of variation	t	P(MC)	Unique perms
BG2 v BG4	4.000	**0.039**	3
BG2 v BG6	23.101	**0.001**	3
BG2 v BG8	31.828	**0.001**	2
BG4 v BG6	18.484	**0.003**	3
BG4 v BG8	26.173	**0.001**	2
BG6 v BG8	5.000	**0.037**	2

Table 10: Concentrations of heavy metals in and percentage moisture content of surficial sediment samples collected from sites within and adjacent to the Proposed Marina Location on 2 June 2009. Pale and dark grey shading indicates concentrations are above the ANZECC/ARMCANZ (2000) Interim Sediment Quality Guidelines Low and High values respectively.

Analyte	Units	LOR	ISQG-Low	ISQG-High	Site						
					SG1	SG2	SG3	SG4	SG5	SG6	SG7
Arsenic	mg/kg	5	20	70	20	14	28	21	31	20	28
Cadmium	mg/kg	1	1.5	10	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Chromium	mg/kg	2	80	370	45	41	150	37	168	47	159
Copper	mg/kg	5	65	270	66	44	160	47	174	77	154
Lead	mg/kg	5	50	220	181	74	244	148	265	181	237
Mercury	mg/kg	0.1	0.15	1	0.5	0.5	1.6	5.2	2.4	0.4	1.5
Nickel	mg/kg	2	21	52	13	5	18	9	19	11	17
Zinc	mg/kg	5	200	410	212	171	623	195	667	254	597
Moisture Content	%					30.8	60	40.8	58.4	43.3	54

Analyte	Units	LOR	ISQG-Low	ISQG-High	Site						
					SG8	SG9	SG10	SG11	SG12	SG13	SG16
Arsenic	mg/kg	5	20	70	25	29	26	24	38	27	27
Cadmium	mg/kg	1	1.5	10	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Chromium	mg/kg	2	80	370	83	173	161	123	214	153	127
Copper	mg/kg	5	65	270	145	184	183	133	240	157	137
Lead	mg/kg	5	50	220	190	269	274	194	364	229	202
Mercury	mg/kg	0.1	0.15	1	2	1.8	1.7	1.3	2.3	1.6	1.5
Nickel	mg/kg	2	21	52	19	20	19	15	25	18	16
Zinc	mg/kg	5	200	410	492	686	660	493	858	588	510
Moisture Content	%				54.9	56	53.7	45.7	69.8	50.2	54.1

Table 11: Results of PERMANOVA tests comparing the total numbers of (a) taxa and (b) infaunal animals collected among the four positions and two strata sampled within the Proposed Marina Location.

A. Total number of taxa

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Position	3	20.25	6.75	1.18	0.337	4995
Strata	1	0.13	0.13	0.02	0.880	4877
Position x Strata	3	8.63	2.88	0.50	0.678	4995
Residual	24	137.00	5.71			
Total	31	166				

B. Total number of animals

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Position	3	190.34	63.45	0.82	0.484	4991
Strata	1	47.53	47.53	0.61	0.448	4950
Position x Strata	3	51.84	17.28	0.22	0.871	4984
Residual	24	1855.80	77.32			
Total	31	2145.50				

Table 12: Results of PERMANOVA tests comparing the structure of infaunal assemblages across the four positions and two strata sampled within the Proposed Marina Location.

A. Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Position	3	14410.00	4803.20	1.99	**0.010**	4979
Strata	1	4489.00	4489.00	1.86	0.075	4977
Position x Strata	3	7845.50	2615.20	1.09	0.367	4971
Residual	24	57829.00	2409.60			
Total	31	84574.00				

B. Pairwise tests of Positions

Positions	t-value	P(MC)	Unique perms
1, 2	1.141	0.266	4979
1, 3	1.043	0.363	4983
1, 4	1.594	**0.033**	4986
2, 3	0.659	0.828	4985
2, 4	1.614	**0.025**	4979
3, 4	1.731	**0.015**	4980

Table 13: Results of SIMPER tests showing the contribution of the major taxa to the dissimilarity between the infaunal assemblages at selected positions within the Proposed Marina Location.

(a) Position 1 v 4
Average dissimilarity = 83.6%

Taxon	Average Abundance		Av.Diss	Diss/SD	Contrib%	Cum.%
	Position 1	Position 4				
Mactridae	5.50	2.25	21.29	1.13	25.46	25.46
Capitellidae	4.63	0.25	17.51	1.23	20.93	46.39
Nephtyidae	2.25	1.75	9.92	1.02	11.86	58.25
Opheliidae	0.00	1.88	6.47	0.78	7.74	65.99
Lumbrineridae	0.75	0.25	3.51	0.67	4.19	70.18
Spionidae	0.25	1.00	3.41	0.72	4.08	74.26
Nereididae	0.63	0.38	3.08	0.68	3.68	77.94
Sabellidae	0.50	0.63	2.45	0.66	2.93	80.87
Trichobranchidae	0.63	0.00	2.14	0.68	2.55	83.42
Polynoidae	0.00	0.75	2.12	0.52	2.53	85.96
Laternulidae	0.13	0.25	1.89	0.35	2.26	88.22
Glyceridae	0.13	0.00	1.43	0.32	1.71	89.93
Oenonidae	0.13	0.13	1.14	0.44	1.36	91.30

(b) Position 2 v 4
Average dissimilarity = 80.2%

Taxon	Average Abundance		Av.Diss	Diss/SD	Contrib%	Cum.%
	Position 2	Position 4				
Mactridae	3.25	2.25	17.35	1.33	21.63	21.63
Capitellidae	2.63	0.25	11.67	1.62	14.55	36.17
Nephtyidae	1.38	1.75	7.43	1.17	9.27	45.44
Opheliidae	0.00	1.88	6.97	0.83	8.69	54.13
Sabellidae	1.50	0.63	6.85	0.56	8.54	62.67
Oenonidae	0.75	0.13	4.49	0.72	5.60	68.26
Spionidae	0.13	1.00	3.59	0.76	4.47	72.74
Nassariidae	0.38	0.00	2.58	0.52	3.21	75.95
Lumbrineridae	0.50	0.25	2.46	0.80	3.07	79.02
Nereididae	0.13	0.38	2.30	0.64	2.87	81.89
Polynoidae	0.00	0.75	2.29	0.53	2.85	84.74
Laternulidae	0.13	0.25	2.17	0.43	2.70	87.44
Nemertea	0.25	0.13	2.04	0.56	2.54	89.98
Fish: Gobiidae	0.38	0.00	1.67	0.54	2.08	92.06

(c) Position 3 v 4
Average dissimilarity = 80.2%

Taxon	Average Abundance		Av.Diss	Diss/SD	Contrib%	Cum.%
	Position 3	Position 4				
Mactridae	3.00	2.25	17.46	1.09	21.33	21.33
Capitellidae	3.63	0.25	16.96	1.27	20.71	42.04
Nephtyidae	0.75	1.75	7.76	1.09	9.48	51.52
Opheliidae	0.13	1.88	7.12	0.86	8.70	60.22
Spionidae	0.75	1.00	5.42	0.98	6.63	66.84
Nereididae	0.50	0.38	3.57	0.85	4.37	71.21
Polynoidae	0.25	0.75	3.03	0.74	3.70	74.91
Lumbrineridae	0.63	0.25	2.99	0.88	3.65	78.55
Sabellidae	0.25	0.63	2.83	0.77	3.46	82.01
Nemertea	0.50	0.13	2.31	0.71	2.82	84.84
Oenonidae	0.25	0.13	1.94	0.61	2.37	87.21
Laternulidae	0.00	0.25	1.84	0.35	2.25	89.46
Syllidae	0.25	0.00	1.34	0.52	1.64	91.09

Table 14: Results of PERMANOVA tests comparing the total numbers of (a) taxa and (b) infaunal animals collected among (a) nearshore and (b) offshore sites in Kendall Bay.

(a) Nearshore sites
Total number of taxa

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Sites	5	20.88	4.18	1.09	0.397	116
Residual	18	68.75	3.82			
Total	23	89.63				

Total number of animals
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Sites	5	716.71	143.34	6.97	**0.001**	1061
Residual	18	370.25	20.57			
Total	23	1087.00				

Pairwise test of sites

Sites	t	P(MC)	Unique perms
BG1 v BG3	2.468	**0.049**	15
BG1 v BG5	2.197	0.073	14
BG1 v BG7	4.736	**0.003**	14
BG1 v BG9	2.761	**0.031**	13
BG1 v BG10	1.662	0.143	14
BG3 v BG5	0.235	0.816	11
BG3 v BG7	1.216	0.268	11
BG3 v BG9	0.162	0.883	11
BG3 v BG10	3.169	**0.023**	21
BG5 v BG7	1.499	0.181	7
BG5 v BG9	0.404	0.698	9
BG5 v BG10	2.988	**0.025**	13
BG7 v BG9	1.074	0.325	6
BG7 v BG10	4.372	**0.004**	18
BG9 v BG10	3.349	**0.016**	16

(b) Offshore sites
Total number of taxa

Source of variation	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Sites	3	16.19	5.40	0.63	0.604	173
Residual	12	102.25	8.52			
Total	15	118.44				

Total number of animals

Source of variation	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Sites	3	33.50	11.17	0.08	0.969	1379
Residual	12	1680.50	140.04			
Total	15	1714.00				

Table 15: Results of PERMANOVA test comparing the structure of infaunal assemblages among (a) nearshore and (b) offshore sites in Kendall Bay.

(a) Comparison of nearshore sites
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Sites	5	24911.00	4982.20	2.79	**<0.001**	4964
Residual	18	32143.00	1785.70			
Total	23	57055.00				

Pairwise Tests of Sites - based on 35 unique permutations

Positions	t-value	P(MC)
BG1 v BG3	1.350	0.174
BG1 v BG5	1.371	0.159
BG1 v BG7	1.464	0.098
BG1 v BG9	1.491	0.096
BG1 v BG10	2.494	**0.008**
BG3 v BG5	0.991	0.444
BG3 v BG7	1.315	0.177
BG3 v BG9	1.874	**0.032**
BG3 v BG10	2.550	**0.004**
BG5 v BG7	1.352	0.163
BG5 v BG9	1.947	**0.029**
BG 5 v BG10	2.642	**0.005**
BG 7 v BG9	1.070	0.358
BG7 v BG10	1.741	**0.037**
BG9 v BG10	1.882	**0.029**

(b) Comparison of offshore sites
Main test

Source of variation	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Sites	3	11318.000	3772.500	1.382	0.157	4957
Residual	12	32752.000	2729.300			
Total	15	44070.000				

Table 16: Results of SIMPER tests showing the major taxa contributing to the dissimilarity between infaunal assemblages at nearshore sites along the western and southern sides of Kendall Bay.

Average dissimilarity = 72.9%

Taxon	Average Abundance		Av.Diss	Diss/SD	Contrib%	Cum.%
	West	South				
Nephtyidae	2.13	8.38	22.25	1.82	30.51	30.51
Capitellidae	3.00	1.13	9.23	1.02	12.65	43.15
Mactridae	2.69	0.88	9.09	0.88	12.46	55.61
Nemertea	0.13	2.00	5.96	0.96	8.17	63.78
Opheliidae	0.50	0.75	3.78	0.64	5.19	68.97
Lumbrineridae	0.56	0.50	2.46	0.81	3.38	72.35
Alpheidae	0.00	0.63	2.45	0.61	3.35	75.70
Oenonidae	0.56	0.00	2.40	0.66	3.29	78.99
Paraonidae	0.06	0.88	2.34	0.58	3.21	82.20
Veneridae	0.06	0.38	2.04	0.57	2.79	84.99
Spionidae	0.25	0.38	2.03	0.63	2.78	87.77
Sabellidae	0.25	0.00	1.09	0.54	1.50	89.27
Callianassidae	0.31	0.00	1.07	0.63	1.46	90.74

Table 17: Results of PERMANOVA tests comparing the total numbers of (a) taxa and (b) infaunal animals collected at sites within the Proposed Marina Location and Reference Locations.

(a) Total number of taxa
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Location	2	36.262	18.131	3.7512	0.058	506
Site(Location)	11	53.167	4.8333	0.84583	0.592	4986
Residual	42	240	5.7143			
Total	55					

(b) Total number of animals
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Location	2	1420.50	710.24	10.67	**0.002**	2786
Site(Location)	11	732.39	66.58	0.77	0.665	4981
Residual	42	3650.00	86.91			
Total	55	5802.90				

(b) Pairwise Tests of Locations

Locations	t-value	P(MC)	Unique perms
KB v SRC	4.081	**0.003**	107
KB v KPB	0.098	0.924	64
SRC v KPB	2.891	**0.042**	7

Table 18: Results of PERMANOVA tests comparing the structure of infaunal assemblages at sites within the Proposed Marina Location and Reference Locations.

(a) Main comparison
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Location	2	31428.000	15714.000	4.774	**<0.001**	4601
Site(Location)	11	36207.000	3291.500	1.632	**<0.001**	4956
Residual	42	84721.000	2017.200			
Total	55	152360.000				

(b) Pairwise Tests of Locations

Locations	t-value	P(MC)	Unique perms
KB v SRC	1.732	**0.005**	164
KB v KPB	2.415	**0.001**	165
SRC v KPB	2.694	**0.002**	10

(c) Pairwise Tests of Sites within Locations - based on 35 unique permutations

Location	Site	t-value	P(MC)
Kendall Bay	BG1 v BG2	1.200	0.252
	BG1 v BG3	1.350	0.168
	BG1 v BG4	1.220	0.231
	BG1 v BG5	1.371	0.147
	BG1 v BG6	1.654	0.077
	BG1 v BG7	1.464	0.091
	BG1 v BG8	1.441	0.124
	BG2 v BG3	0.991	0.426
	BG2 v BG4	0.949	0.471
	BG2 v BG5	1.016	0.385
	BG2 v BG6	1.036	0.382
	BG2 v BG7	1.432	0.106
	BG2 v BG8	1.087	0.321
	BG3 v BG4	0.873	0.542
	BG3 v BG5	0.991	0.418
	BG3 v BG6	1.012	0.393
	BG3 v BG7	1.315	0.176
	BG3 v BG8	1.320	0.168
	BG4 v BG5	0.756	0.704
	BG4 v BG6	1.274	0.205
	BG4 v BG7	1.209	0.221
	BG4 v BG8	1.366	0.145
	BG5 v BG6	1.633	0.074
	BG5 v BG7	1.352	0.148
	BG5 v BG8	1.547	0.060
	BG6 v BG7	1.722	0.057
	BG6 v BG8	1.297	0.186
	BG7 v BG8	0.914	0.508
Sydney Rowing Club	SRC1 v SRC2	1.3891	0.158
	SRC1 v SRC3	1.1785	0.269
	SRC2 v SRC3	1.1543	0.270
Kissing Point Bay	KPB1 v KPB2	1.2542	0.203
	KPB1 v KPB3	1.5011	0.089
	KPB 2 KPB3	1.1701	0.259

Table 19: Results of SIMPER tests showing the contribution of the major taxa to the dissimilarity between assemblages within the Proposed Marina Location (PML) and Reference Locations combined (REF).

Average dissimilarity = 75.3%

Taxon	Average Abundance		Av.Diss	Diss/SD	Contrib%	Cum.%
	PML	REF				
Capitellidae	2.78	7.42	19.55	1.11	25.96	25.96
Nephtyidae	1.53	4.58	14.83	1.07	19.70	45.65
Mactridae	3.50	1.29	11.02	1.04	14.63	60.28
Lumbrineridae	0.53	0.71	2.80	0.88	3.71	64.00
Sabellidae	0.72	0.33	2.60	0.47	3.46	67.45
Spionidae	0.53	0.38	2.54	0.67	3.37	70.82
Nemertea	0.25	0.46	1.88	0.81	2.49	73.31
Laternulidae	0.13	0.33	1.80	0.39	2.39	75.71
Nereididae	0.41	0.29	1.80	0.61	2.39	78.10
Opheliidae	0.50	0.04	1.72	0.37	2.29	80.38
Nassariidae	0.16	0.42	1.53	0.51	2.03	82.42
Oenonidae	0.31	0.08	1.48	0.51	1.96	84.38
Veneridae	0.09	0.21	1.25	0.49	1.66	86.04
Trichobranchidae	0.22	0.21	1.16	0.60	1.54	87.58
Callianassidae	0.16	0.25	0.98	0.61	1.30	88.89
Syllidae	0.16	0.25	0.96	0.52	1.28	90.17

Table 20: Results of PERMANOVA tests comparing the total numbers of (a) taxa and (b) animals collected at the Proposed Marina Location and Reference Locations, Sydney Rowing Club and Kissing Point Bay, during the 1996 and 2009 surveys.

A. Total number of taxa

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Year	1	272.69	272.69	18.718	**0.046**	177
Location	2	25.937	12.968	0.88174	0.533	180
Year x Location	2	29.416	14.708	2.2417	0.112	4976
Residual	95	623.300	6.5611			
Total	100	1025.700				

B. Total number of animals

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Year	1	142740.00	142740.00	3413.40	**<0.001**	180
Location	2	2473.50	1236.70	108.57	**0.007**	180
Year x Location	2	22.78	11.39	0.01	0.994	4991
Residual	95	169800.00	1787.40			
Total	100	335530.00				

(b) Comparison of locations

Location	t-value	P(MC)	Unique perms
PM v SRC	9.355	0.067	6
PM v KPB	1.333	0.411	6
SRC v KPB	20.201	**0.037**	3

Table 21: Results of PERMANOVA test comparing the structure of infaunal assemblages among the Proposed Marina Location (PML) and Reference Locations, Sydney Rowing Club (SRC) and Kissing Point Bay (KPB) in 1996 and 2009.

(a) Comparison of nearshore sites
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Year	1	47797.00	47797.00	4.26	0.007	180
Location	2	24602.00	12301.00	1.08	0.434	180
Year x Location	2	22771.00	11386.00	5.84	**<0.001**	4986
Residual	95	185160.00	1949.10			
Total	100	286720.00				

(b) Comparison of locations within years

Year	Location	t-value	P(MC)	Unique perms
1996	PML v SRC	2.325	**0.001**	4977
	PML v KPB	2.407	**0.001**	4984
	SRC v KPB	1.423	0.088	4983
2009	PML v SRC	2.056	**0.001**	4982
	PML v KPB	2.907	**<0.001**	4984
	SRC v KPB	3.224	**<0.001**	4967

(b) Comparison of years within locations

Location	t-value	P(MC)	Unique perms
PM v SRC	2.880	**<0.001**	4977
PM v KPB	3.398	**<0.001**	4978
SRC v KPB	5.029	**<0.001**	4979

Table 22: Results of SIMPER tests showing the major taxa contributing to the dissimilarity between the infaunal assemblages at (a) the Proposed Marina Location (b) Sydney Rowing Club and (c) Kissing Point Bay in 1996 and 2009.

(a) Proposed Marina Location
Average dissimilarity = 82.9%

Taxon	Average Abundance		Av.Diss	Diss/SD	Contrib%	Cum.%
	1996	2009				
Mactridae	41.10	3.50	25.18	1.19	30.36	30.36
Nephtyidae	8.40	1.53	13.67	1.03	16.48	46.84
Capitellidae	17.70	2.78	12.77	1.14	15.40	62.24
Lumbrineridae	3.02	0.53	3.70	1.21	4.46	66.70
Synalpheidae	1.23	0.03	3.03	0.53	3.65	70.35
Nassaridae	2.35	0.16	2.63	0.46	3.17	73.53
Callianassidae	2.02	0.16	2.33	0.78	2.81	76.33
Spionidae	3.58	0.53	2.16	0.51	2.61	78.94
Psammobiidae	3.47	0.00	1.96	0.67	2.36	81.30
Sabellidae	0.45	0.72	1.78	0.48	2.14	83.45
Cirratulidae	2.58	0.03	1.05	0.44	1.27	84.72
Lucinidae	0.56	0.06	1.05	0.29	1.27	85.98
Gobiidae	0.33	0.09	0.95	0.56	1.15	87.13
Polynoidae	0.56	0.25	0.92	0.50	1.10	88.23
Nereididae	0.45	0.41	0.90	0.60	1.08	89.31
Semelidae	0.56	0.00	0.89	0.35	1.07	90.39

(b) Sydney Rowing Club
Average dissimilarity = 70.2%

Taxon	Average Abundance		Av.Diss	Diss/SD	Contrib%	Cum.%
	1996	2009				
Capitellidae	40.54	14.17	21.40	1.50	30.50	30.50
Mactridae	24.98	1.75	16.94	1.31	24.15	54.66
Nephtyidae	10.53	2.50	6.55	1.60	9.34	64.00
Tellinidae	6.94	0.00	5.85	1.64	8.33	72.33
Lumbrineridae	5.60	0.92	3.88	1.91	5.53	77.86
Psammobiidae	4.03	0.00	3.29	0.80	4.69	82.55
Callianassidae	3.81	0.50	3.14	1.20	4.47	87.02
Nassaridae	1.46	0.58	1.52	0.77	2.17	89.19
Cirratulidae	0.90	0.25	0.91	0.57	1.29	90.48

(c) Kissing Point Bay
Average dissimilarity = 83.3%

Taxon	Average Abundance		Av.Diss	Diss/SD	Contrib%	Cum.%
	1996	2009				
Capitellidae	39.54	0.67	32.18	2.08	38.63	38.63
Mactridae	11.09	0.83	9.72	2.42	11.67	50.30
Tellinidae	6.72	0.00	8.02	1.23	9.63	59.92
Lumbrineridae	7.62	0.50	6.24	2.09	7.49	67.41
Psammobiidae	5.04	0.00	4.10	0.87	4.93	72.33
Callianassidae	3.70	0.00	3.53	1.21	4.24	76.57
Nephtyidae	6.05	6.67	3.40	1.19	4.07	80.65
Spionidae	3.81	0.42	3.08	1.22	3.69	84.34
Holothurioidea	1.90	0.00	2.15	0.87	2.58	86.92
Nassaridae	1.90	0.25	1.93	0.67	2.31	89.23
Nemertea	0.45	0.50	1.00	0.64	1.21	90.44

Table 23: Results of PERMANOVA tests comparing the total numbers of taxa and animals in the epibenthic assemblages sampled at (a) the five study sites (n = 3 trawls per site) and (b) the sites in Kendall Bay vs Reference Locations (n = 9 vs 6).

(a) Comparison across sites
Total number of taxa
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Location	4	382.40	95.60	3.03	0.073	719
Residual	10	315.33	31.53			
Total	14	697.73				

Total number of animals
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Location	4	531130.00	132780.00	1.35	0.320	4972
Residual	10	987000.00	98700.00			
Total	14	1518100.00				

(b) Comparison between Kendall Bay and Reference Locations
Total number of taxa
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Location	1	4.01	4.01	0.08	0.783	74
Residual	13	693.72	53.36			
Total	14	697.73				

Total number of animals
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Location	1	293090.00	293090.00	3.11	0.102	1792
Residual	13	1225000.00	94234.00			
Total	14	1518100.00				

Table 24: Results of PERMANOVA test comparing the structure of the epibenthic assemblages at (a) across the five study sites and (b) at Kendall Bay vs Reference Locations.

(a) Comparison across sites
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Location	4	8152.00	2038.00	2.13	**0.020**	4969
Residual	10	9579.00	957.90			
Total	14	17731.00				

Pairwise Tests of Sites - based on 10 unique permutations

Locations	t-value	P(MC)
KBN v KBM	1.560	0.100
KBN v KBS	1.452	0.129
KBN v SRC	1.271	0.210
KBN v KPB	2.323	**0.015**
KBM v KBS	1.261	0.238
KBM v SRC	1.036	0.387
KBM v KPB	1.738	0.059
KBS v SRC	1.198	0.278
KBS v KPB	1.194	0.286
SRC v KPB	1.645	0.091

(b) Comparison between Kendall Bay and Reference Locations
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
KB v RL	1	1721.40	1721.40	1.40	0.228	3137
Res	13	16010.00	1231.50			
Total	14	17731				

Table 25: Results of SIMPER tests showing the major taxa that contributed ⩾2% to the overall dissimilarity between the epibenthic assemblages in the northern part of Kendall Bay (KPN) and Kissing Point Bay (KPB).

Average dissimilarity = 62.2%

Taxon	Average Abundance		Av.Diss	Diss/SD	Contrib%	Cum.%
	KBN	KPB				
Corophium sp.	2.81	0.00	4.23	5.64	6.80	6.80
Haplostylis dakini	2.18	4.14	2.84	1.55	4.57	11.37
Tanaidae	1.58	0.00	2.35	10.32	3.77	15.14
Hippolytidae	1.50	0.00	2.31	2.66	3.71	18.86
Theora fragilis	0.00	1.50	2.25	7.73	3.62	22.48
Aoridae	1.44	0.00	2.19	4.09	3.52	26.00
Nephtyidae	0.00	1.43	2.13	3.72	3.43	29.43
Spisula trigonella	2.81	4.18	2.12	1.61	3.41	32.84
Oedicerotidae	1.21	0.00	1.81	6.77	2.91	35.75
Favonigobius exquisitus	1.12	2.27	1.80	1.23	2.90	38.65
Laternula creccina	0.33	1.55	1.76	1.90	2.82	41.47
Pachycheles granti	1.20	0.33	1.62	1.31	2.60	44.07
Nemertea	0.80	1.87	1.60	1.46	2.57	46.64
Anadora trapezia	1.06	0.00	1.52	1.33	2.44	49.09
Serpulidae	1.00	0.00	1.50	7.53	2.42	51.50
Nassarius burchardi	1.19	0.86	1.37	1.36	2.20	53.70
Paphia undulata	0.00	0.87	1.25	1.30	2.01	55.71

Table 26: Results of PERMANOVA test comparing the structure of the fish component of the epibenthic assemblages across the five study sites in May 2009. (KBN = Kendall Bay North, KBM = Kendall Bay Mid, KBS = Kendall Bay South, SRC = Sydney Rowing Club; KPB = Kissing Point

(a) Comparison across sites
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Location	4	9737.80	2434.40	2.49	**0.032**	4966
Residual	9	8813.90	979.32			
Total	13	18552.00				

Pairwise Tests of Sites - based on 10 unique permutations

Locations	t-value	P(MC)
KBN v KBM	9.125	**0.001**
KBN v KBS	0.802	0.542
KBN v SRC	0.936	0.451
KBN v KPB	3.199	**0.020**
KBM v KBS	2.603	**0.023**
KBM v SRC	1.302	0.257
KBM v KPB	0.640	0.646
KBS v SRC	0.943	0.464
KBS v KPB	2.265	**0.041**
SRC v KPB	1.090	0.353

(b) Comparison between Kendall Bay and Reference Locations
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
KB v RL	1	2032.00	2032.00	1.48	0.234	2438
Res	12	16520.00	1376.60			
Total	13	18552.00				

Table 27: Results of SIMPER tests showing the major species of fish that contributed > 2% to the overall dissimilarity between the fish component of the epibenthic assemblages sampled in the northern part of Kendall Bay (KPN) and Kissing Point Bay (KPB).

(a) Kendall Bay North vs Kendall Bay Mid
Average dissimilarity = 51.8%

Species	Average Abundance		Av.Diss	Diss/SD	Contrib%	Cum.%
	KBN	KBM				
Favonigobius exquisitus	8.00	24.00	47.93	17.65	92.56	92.56

(b) Kendall Bay North vs Kissing Point Bay
Average dissimilarity = 58.1%

Species	Average Abundance		Av.Diss	Diss/SD	Contrib%	Cum.%
	KBN	KPB				
Favonigobius exquisitus	8.00	27.33	46.63	3.88	80.31	80.31
Gobiopterus semivestitus	0.00	1.33	4.31	0.64	7.42	87.72
Redigobius macrostoma	0.00	1.67	3.83	0.88	6.59	94.32

(c) Kendall Bay Mid vs Kendall Bay South
Average dissimilarity = 63.2%

Species	Average Abundance		Av.Diss	Diss/SD	Contrib%	Cum.%
	KBM	KPS				
Favonigobius exquisitus	24.00	6.33	56.61	3.01	89.53	89.53
Redigobius macrostoma	0.00	1.67	4.04	0.67	6.39	95.93

(c) Kendall Bay South vs Kissing Point Bay
Average dissimilarity = 65.2%

Species	Average Abundance		Av.Diss	Diss/SD	Contrib%	Cum.%
	KBS	KPB				
Favonigobius exquisitus	6.33	27.33	53.57	2.89	82.16	82.16
Redigobius macrostoma	1.67	1.67	5.31	1.07	8.15	90.31

Table 28: Results of PERMANOVA tests comparing the structure of epibenthic assemblages among the sampling locations in Kendall Bay, Sydney Rowing Club and Kissing Point Bay in 1996 and 2009.

(a) Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Year	1	7806.00	7806.00	1.65	0.216	3955
Location	3	6356.50	2118.80	1.09	0.376	4983
Year x Location	3	14282.00	4760.80	2.44	**0.010**	4978
Residual	21	40988.00	1951.80			
Total	28	70016.00				

(b) Comparison of locations within years

Year	Location	t-value	P(MC)	Unique perms
1996	KBN vs KBS	1.551	0.114	35
	KBN vs SRC	1.349	0.174	35
	KBN vs KPB	1.066	0.359	35
	KBS vs SRC	2.086	**0.032**	35
	KBS vs KPB	1.598	0.073	35
	SRC v KPB	0.376	0.940	35
2009	KBN vs KBS	1.658	0.102	56
	KBN vs SRC	0.975	0.409	56
	KBN vs KPB	1.284	0.226	56
	KBS vs SRC	0.943	0.471	10
	KBS vs KPB	2.265	**0.033**	10
	SRC v KPB	1.090	0.345	10

(b) Comparison of years within locations

Location	t-value	P(MC)	Unique perms
KBN	1.651	0.086	126
KBS	2.470	**0.018**	35
SRC	1.265	0.244	10
KPB	1.522	0.112	35

Table 29: Results of SIMPER test showing the major taxa that contributed > 90% of the overall dissimilarity between the fish component of the epibenthic assemblages sampled in 1996 and 2009.

Average dissimilarity = 77.4%

Species	Average Abundance		Av.Diss	Diss/SD	Contrib%	Cum.%
	1996	2009				
Favonigobius exquisitus	47.50	6.33	51.14	3.13	66.08	66.08
Gobiopterus semivestitus	10.25	0.67	13.34	1.02	17.24	83.32
Redigobius macrostoma	4.50	1.67	5.45	1.15	7.04	90.36

Table 30: Results of PERMANOVA test comparing the total numbers of taxa and animals collected by seine netting (a) across the four study sites and (b) in Kendall Bay versus the Reference Locations combined.

(a) Comparison across Sites
Total number of taxa
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Site	3	175.27	58.42	8.69	**0.014**	464
Residual	6	40.33	6.72			
Total	9	215.60				

Pairwise Tests of Sites

Locations	t-value	P(MC)	Unique perms
PML v KBS	1.648	0.177	7
PML v SRC	7.678	**0.005**	7
PML v KPB	9.418	**0.003**	7
KBS v SRC	2.127	0.119	9
KBS v KPB	1.592	0.203	7
SRC v KPB	1.265	0.335	2

Total number of animals
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Site	3	1489800.00	496610.00	1.62	0.270	3436
Residual	6	1843900.00	307310.00			
Total	9	3333700.00				

(b) Comparison between Kendall Bay and the Reference Locations combined
Total number of taxa
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Site	1	147.27	147.27	8.69	**0.005**	35
Residual	8	68.33	8.54			
Total	9	215.60				

Total number of animals
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Site	1	606620.00	606620.00	1.78	0.219	209
Residual	8	2727100.00	340880.00			
Total	9	3333700.00				

Table 31: Results of PERMANOVA test comparing the structure of nearshore fish and mobile invertebrate assemblages at (a) the four study sites and (b) in Kendall Bay vs the Reference Locations combined.

(a) Comparison across sites
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
Site	3	9628.00	3209.30	1.93	0.060	3424
Residual	6	9985.40	1664.20			
Total	9	19613.00				

(b) Comparison between Kendall Bay and Reference Locations
Main test

Source of variation	df	SS	MS	Pseudo-F	P(MC)	Unique perms
KB v RL	1	4584.50	4584.50	2.44	0.046	210
Res	8	15029.00	1878.60			
Total	9	19613.00				

Table 32: Results of SIMPER tests showing the major taxa that contributed > 2% to the overall dissimilarity between the fish and mobile invertebrate assemblages sampled in Kendall Bay (KB) and the Reference Locations combined (REF).

Average dissimilarity = 67.8%

Taxon	Average Abundance		Av.Diss	Diss/SD	Contrib%	Cum.%
	KB	REF				
Hippolytidae	0.20	3.13	6.70	3.99	9.89	9.89
Gobiopterus semivestitus	2.30	4.31	4.92	1.24	7.26	17.15
Atherinosoma ogilbyi	0.36	1.97	4.12	1.32	6.08	23.23
Ambassis jacksoniensis	1.61	1.07	3.46	1.34	5.11	28.33
Acetes sibogae	1.00	1.13	3.32	1.12	4.89	33.23
Favonigobius exquisitus	1.92	2.66	3.21	1.28	4.73	37.96
Haplostylis dakini	0.53	0.94	2.74	0.70	4.05	42.01
Arenigobius bifrenatus	0.26	1.22	2.61	1.38	3.85	45.86
Pelates sexlineatus	0.24	1.15	2.46	1.40	3.63	49.49
Metapenaeus macleayi	1.12	0.41	2.24	1.28	3.31	52.80
Liza argentea	1.01	0.00	2.20	1.29	3.25	56.04
Redigobius macrostoma	0.00	0.91	2.07	1.59	3.05	59.09
Centropogon australis	0.00	0.80	1.85	1.57	2.73	61.82
Hyperlophus vittatus	0.48	0.67	1.72	1.04	2.53	64.35
Sillago maculata	0.86	1.37	1.44	1.03	2.13	66.48
Nassarius burchardi	0.39	0.44	1.38	0.71	2.04	68.52
Tectractenos hamiltoni	0.64	0.25	1.37	1.06	2.02	70.54
Spisula trigonella	0.55	0.3	1.37	0.71	2.01	72.56

9 Figures

Figure 1: Aerial photograph showing the position of the Proposed Marina Location relative to the Reference Locations, Sydney Rowing Club in Hen and Chicken Bay and Kissing Point Bay.

Figure 2: Map showing the position of suspended sediment traps and infaunal sampling sites relative to the sites where surface grab and piston core samples were collected within the Proposed Marina Location and at the southern end of Kendall Bay.

Figure 3: Map showing the position of sediment grain size and infaunal sampling sites within the Proposed Marina Location (BG1-BG8) and at the southern end of Kendall Bay (BG9 and BG10).

Figure 4: Aerial photograph showing the position of the sites in Kendall Bay and at the Reference Locations (Sydney Rowing Club and Kissing Point Bay) where the epibenthic fauna was sampled with a beam trawl and fish and mobile invertebrates were sampled with a beach seine net.

Figure 5: Mean (± S.E.) Suspended Particulate Matter Flux ($g/m^2/d$) measured in the sediment traps deployed on three occasions at Sites SS1, SS2 and SS3 within the Proposed Marina Location.

Figure 6: Mean (± S.E) proportion of fines (< 75 µm) in subtidal sediments at the Proposed Marina Location (PML) and Reference Locations, Kissing Point Bay and Sydney Rowing Club.

Figure 7: Mean (± S.E) proportion of fines (< 75 µm) in subtidal sediments at each of the positions sampled in (a) the nearshore stratum and (b) offshore stratum within the Proposed Marina Location.

Figure 8: Mean (± S.E) proportion of fines (< 75 µm) in subtidal sediments at (a) each of the positions and (b) in nearshore and offshore strata of the Proposed Marina Location.

Figure 9: Mean (± S.E) proportion of fines (< 75 µm) in subtidal sediments at (a) each of the nearshore and (b) offshore sites sampled in Kendall Bay.

Figure 10: Mean (± S.E.) number of taxa and animals at (a) each position and (b) each stratum within the Proposed Marina Location.

Figure 11: 3D-MDS plot comparing the structure of infaunal assemblages among positions and between strata at the Proposed Marina Location within Kendall Bay.

Figure 12: Mean (± S.E.) number of taxa and animals at (a) nearshore and (b) offshore sites sampled within Kendall Bay.

Figure 13: 3D-MDS plots comparing the structure of infaunal assemblages among (a) nearshore and (b) offshore sites within and/or adjacent to the Proposed Marina Location within Kendall Bay.

Figure 14: MDS plots showing (a) the pattern in infaunal assemblages across the sites BG1-BG10 with (b) % of fines and (c) total organic content of the sediment superimposed on the patterns in biota.

Figure 15: MDS plots showing (a) the pattern in infaunal assemblages across the sites BG1-BG10 with concentrations of (b) low molecular weight PAHs and (c) high molecular weight PAHs superimposed on the patterns in biota.

Figure 16: MDS plots showing (a) the pattern in infaunal assemblages across the sites BG1-BG10 with concentrations of (b) total petroleum hydrocarbons (TPHs) and (c) total polycyclic aromatic hydrocarbons (PAHs) in the sediment at each site superimposed on the patterns in biota.

Figure 17: Mean (± S.E.) number of (a) taxa and (b) animals in the benthic grab samples collected at the Proposed Marina Location and Reference Locations, Sydney Rowing Club and Kissing Point Bay.

Figure 18: 3D-MDS plot comparing the structure of infaunal assemblages among sites within the Proposed Marina Location and Reference Locations, Sydney Rowing Club and Kissing Point Bay.

Figure 19: Mean (± S.E.) number of (a) taxa and (b) animals in the benthic grab samples collected at the Proposed Marina Location and Reference Locations, Sydney Rowing Club (SRC) and Kissing Point Bay in 1996 and 2009.

Figure 20: 3D-MDS plot comparing the structure of infaunal assemblages within the Proposed Marina Location and Reference Locations, Sydney Rowing Club and Kissing Point Bay in 1996 and 2009.

Figure 21: Mean (± S.E.) number of (a) taxa and (b) animals in epibenthic assemblages sampled at Kendall Bay North (KBN), Kendall Bay Mid (KBM), Kendall Bay South (KBS), Sydney Rowing Club (SRC) and Kissing Point Bay.

Figure 22: 2D-MDS plot comparing (a) total epibenthic assemblages and (b) fish component of the assemblages sampled at north, mid and south Kendall Bay, Sydney Rowing Club (SRC) and Kissing Point Bay (KPB).

Figure 23: 2D-MDS plot comparing epibenthic assemblages at north, mid and south Kendall Bay, Sydney Rowing Club (SRC) and Kissing Point Bay (KPB) in 1996 and 2009.

Figure 24: Mean (± S.E.) number of (a) taxa and (b) animals in nearshore fish assemblages sampled at the Proposed Marina Location (PML), Kendall Bay South (KBS), Sydney Rowing Club (SRC) and Kissing Point Bay.

Figure 25: 2D-MDS plot comparing the structure of nearshore fish assemblages at the Proposed Marina Location (PML), southern end of Kendall Bay (KBS), Sydney Rowing Club (SRC) and Kissing Point Bay (KPB).

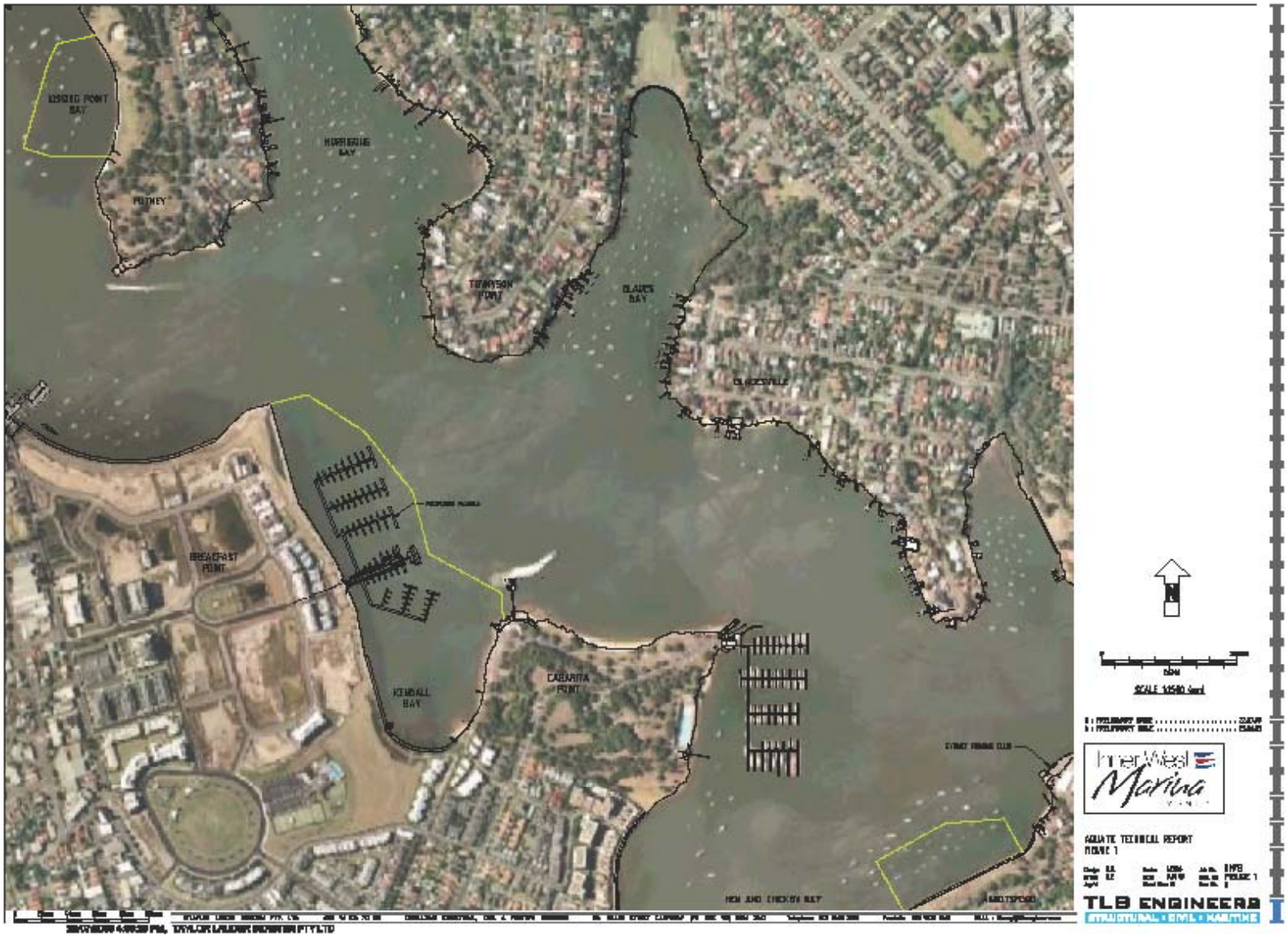


Figure 1: Aerial photograph showing the position of the Proposed Marina Location relative to the Reference Locations, Sydney Rowing Club in Hen and Chicken Bay and Kissing Point Bay.

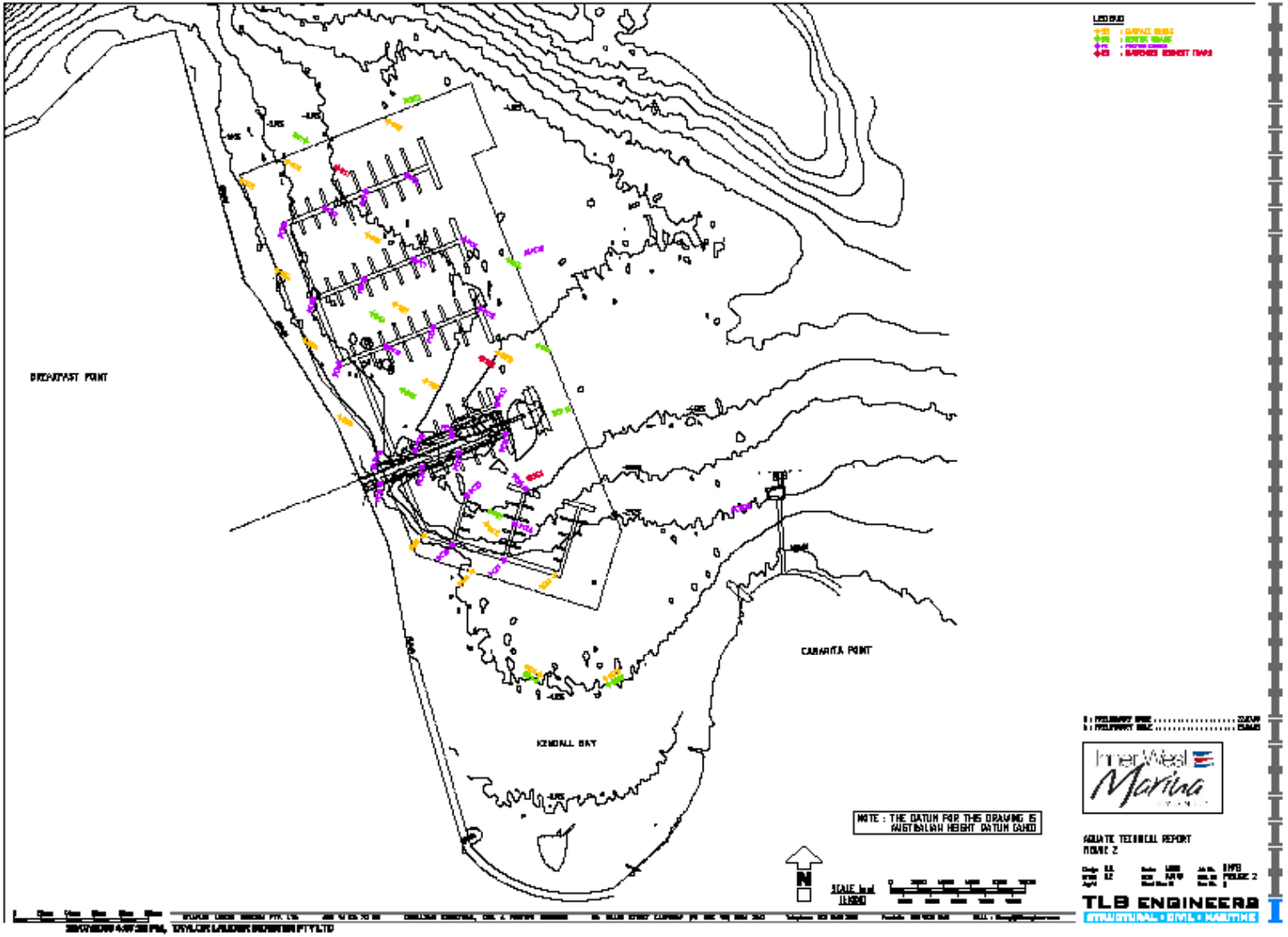


Figure 2: Map showing the position of suspended sediment traps and infaunal sampling sites relative to the sites where surface grab and piston core samples were collected within the Proposed Marina Location and at the southern end of Kendall Bay. Dashed line is proposed outline of geotextile fabric blanket on seabed.

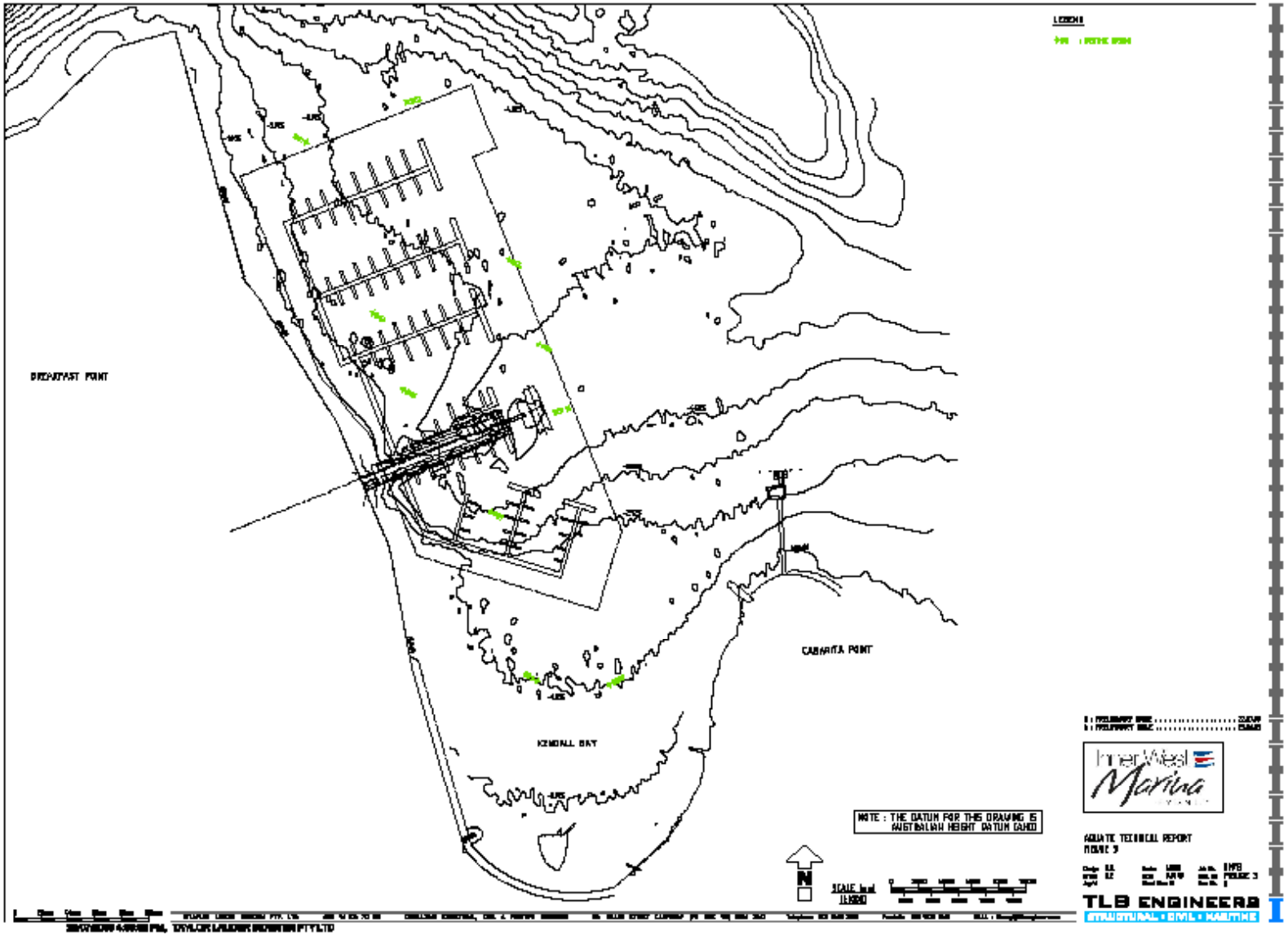


Figure 3: Map showing the position of suspended sediment traps and infaunal sampling sites within the Proposed Marina Location and at the southern end of Kendall Bay. Dashed line is proposed outline of geotextile fabric blanket on seabed.

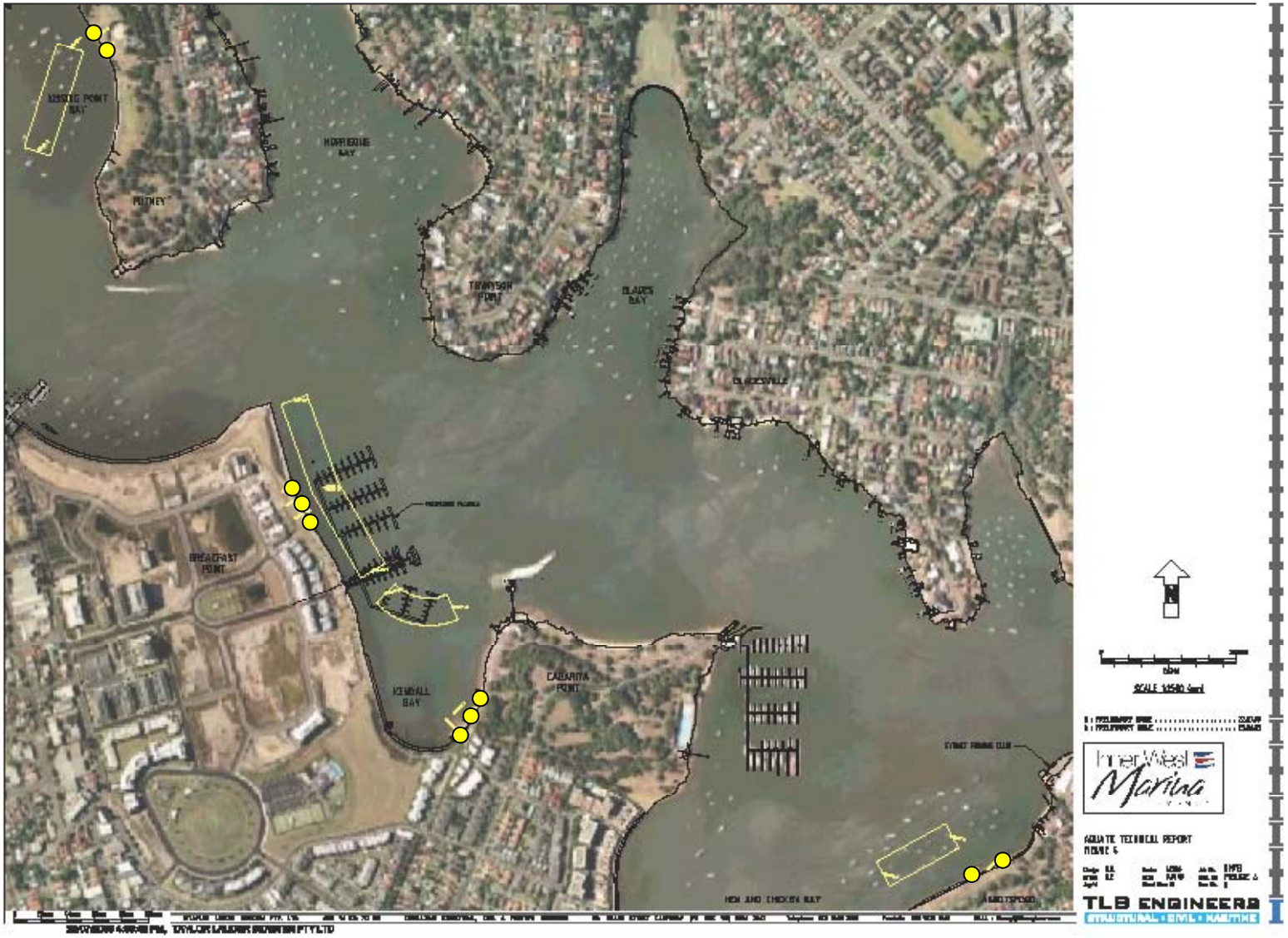


Figure 4: Aerial photograph showing the position of the sites in Kendall Bay and at the Reference Locations (Sydney Rowing Club and Kissing Point Bay) where the epibenthic fauna was sampled with a beam trawl (yellow polygons) and fish and mobile invertebrates were sampled with a beach seine net (yellow circles).

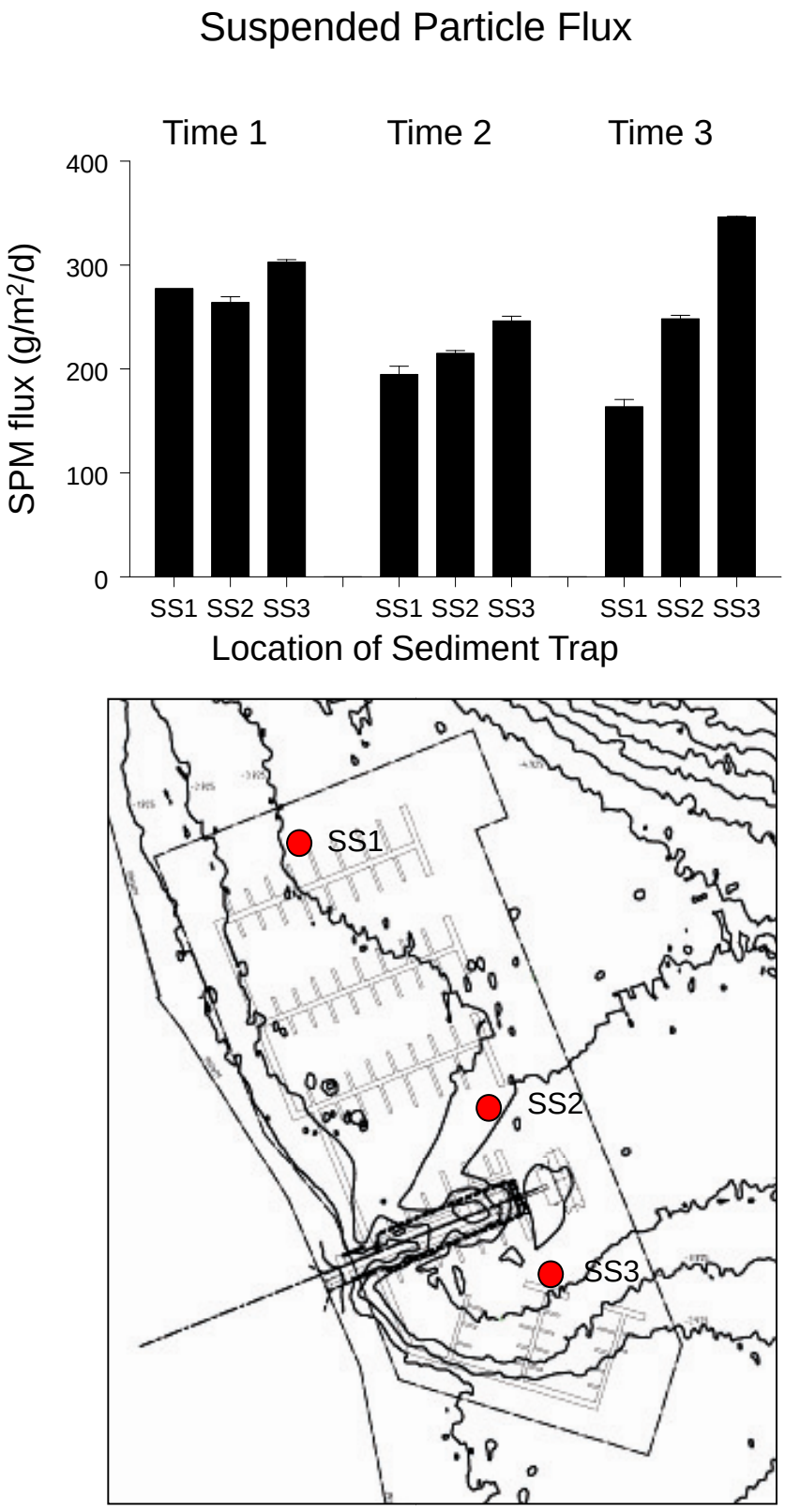
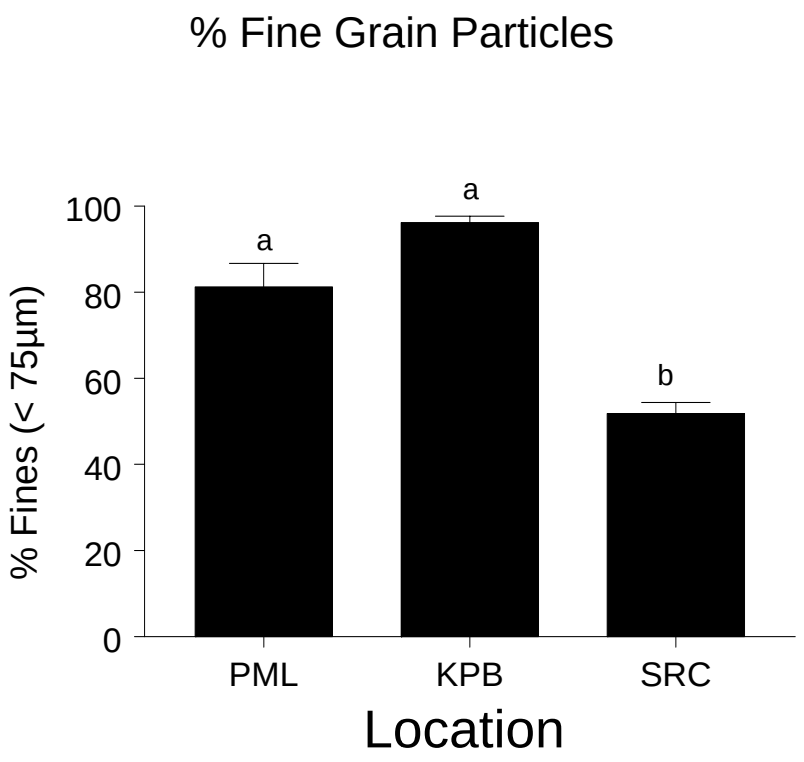


Figure 5: Mean (± S.E.) Suspended Particulate Matter Flux (g/m^2/d) measured in the sediment traps deployed on three occasions at Sites SS1, SS2 and SS3 within the Proposed Marina Location (*n* = 3 for each deployment at SS2 and SS3 but increased from 1 to 3 at SS1).



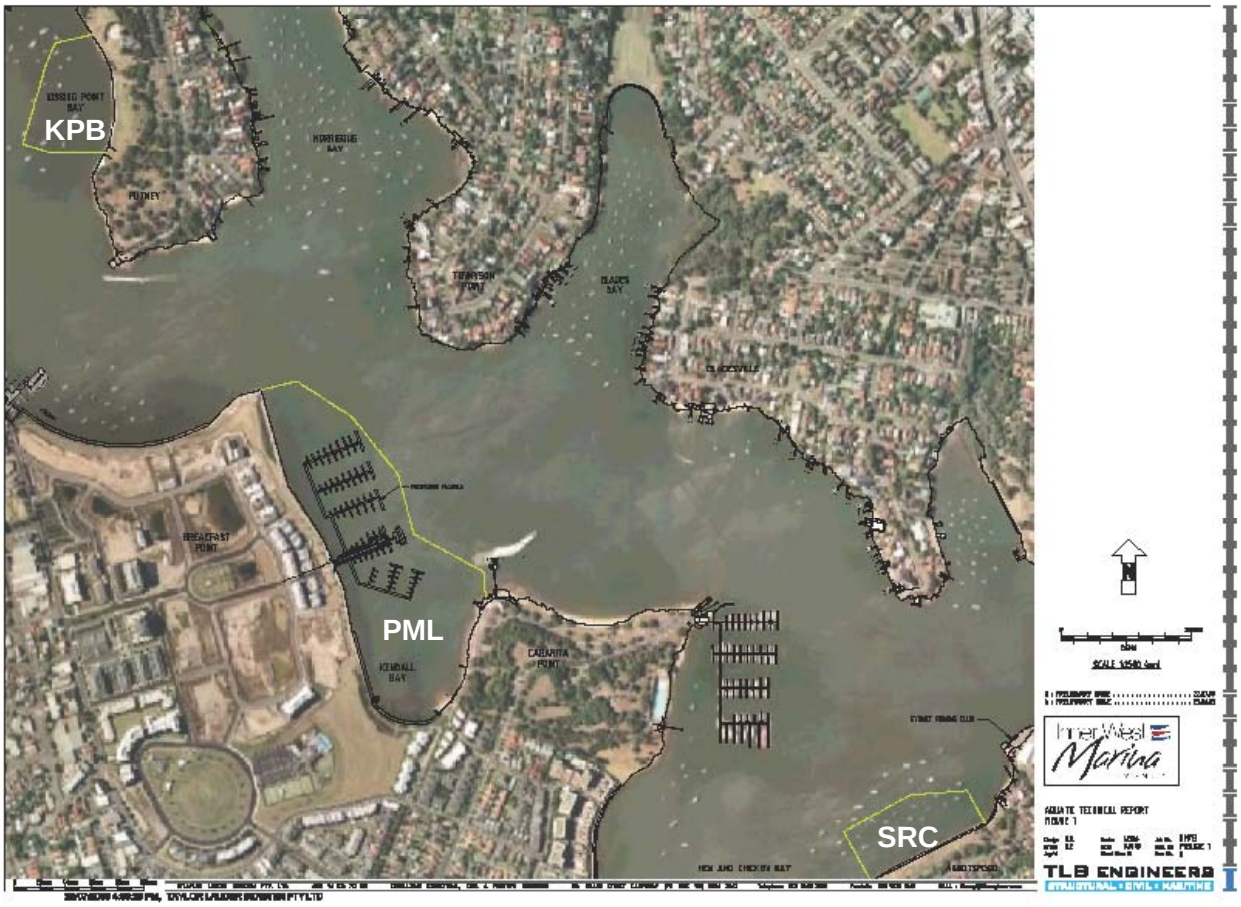


Figure 6: Mean (± S.E) proportion of fines (< 75 µm) in subtidal sediments at the Proposed Marina Location (PML) and Reference Locations, Kissing Point Bay (KPB) and Sydney Rowing Club (SRC); *n* = 20 for PML and 6 for KPB and SRC).

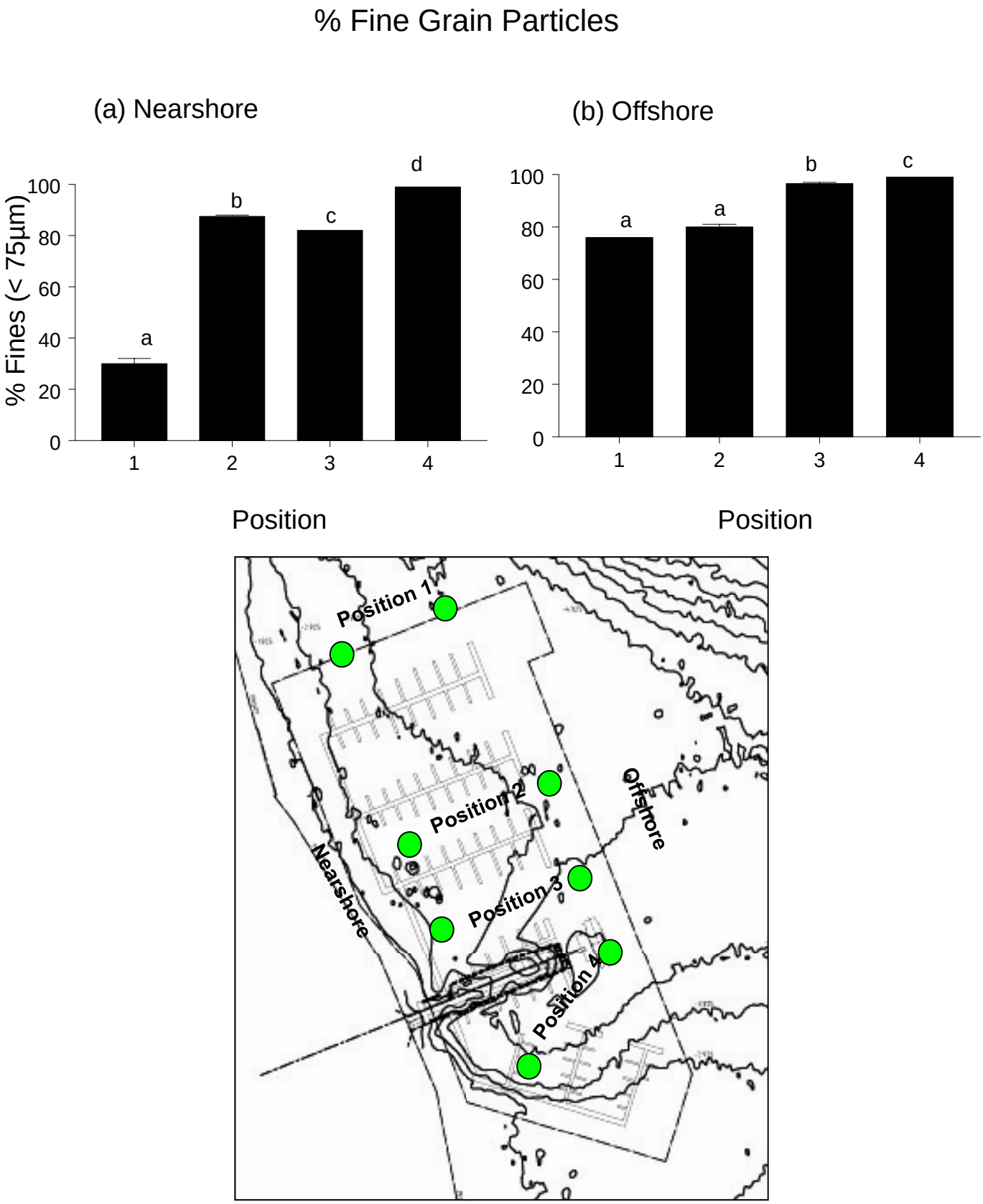


Figure 7: Mean (± S.E) proportion of fines (< 75 µm) in subtidal sediments at each of the positions sampled in (a) the nearshore stratum and (b) offshore stratum within the Proposed Marina Location; *n* = 2 per site). Different symbols above bars indicate assemblages are significantly different at these locations.

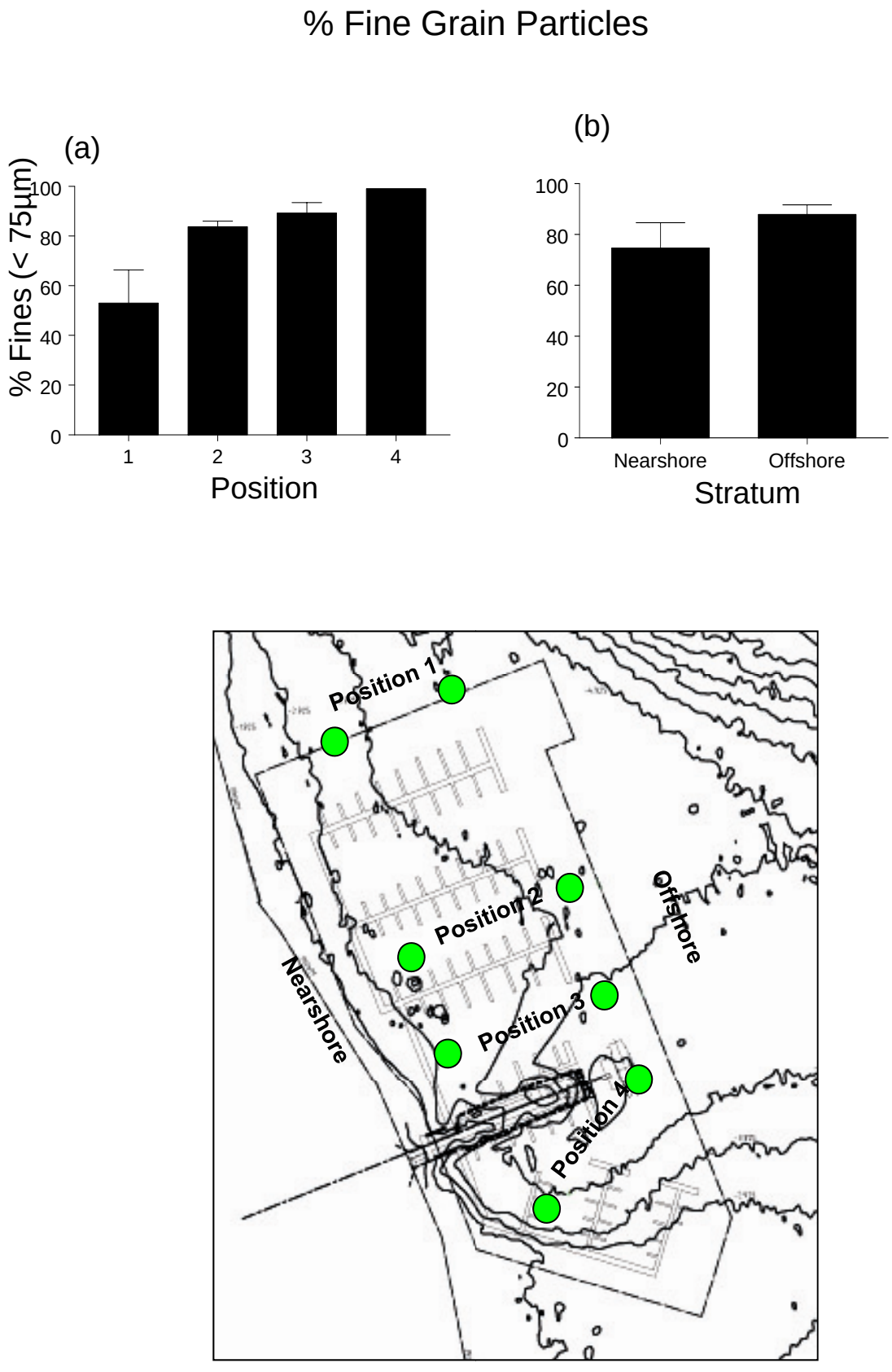


Figure 8: Mean (± S.E) proportion of fines (< 75 µm) in subtidal sediments at (a) each of the positions and (b) in nearshore and offshore strata of the Proposed Marina Location (*n* = 4 for position and 8 for each stratum).

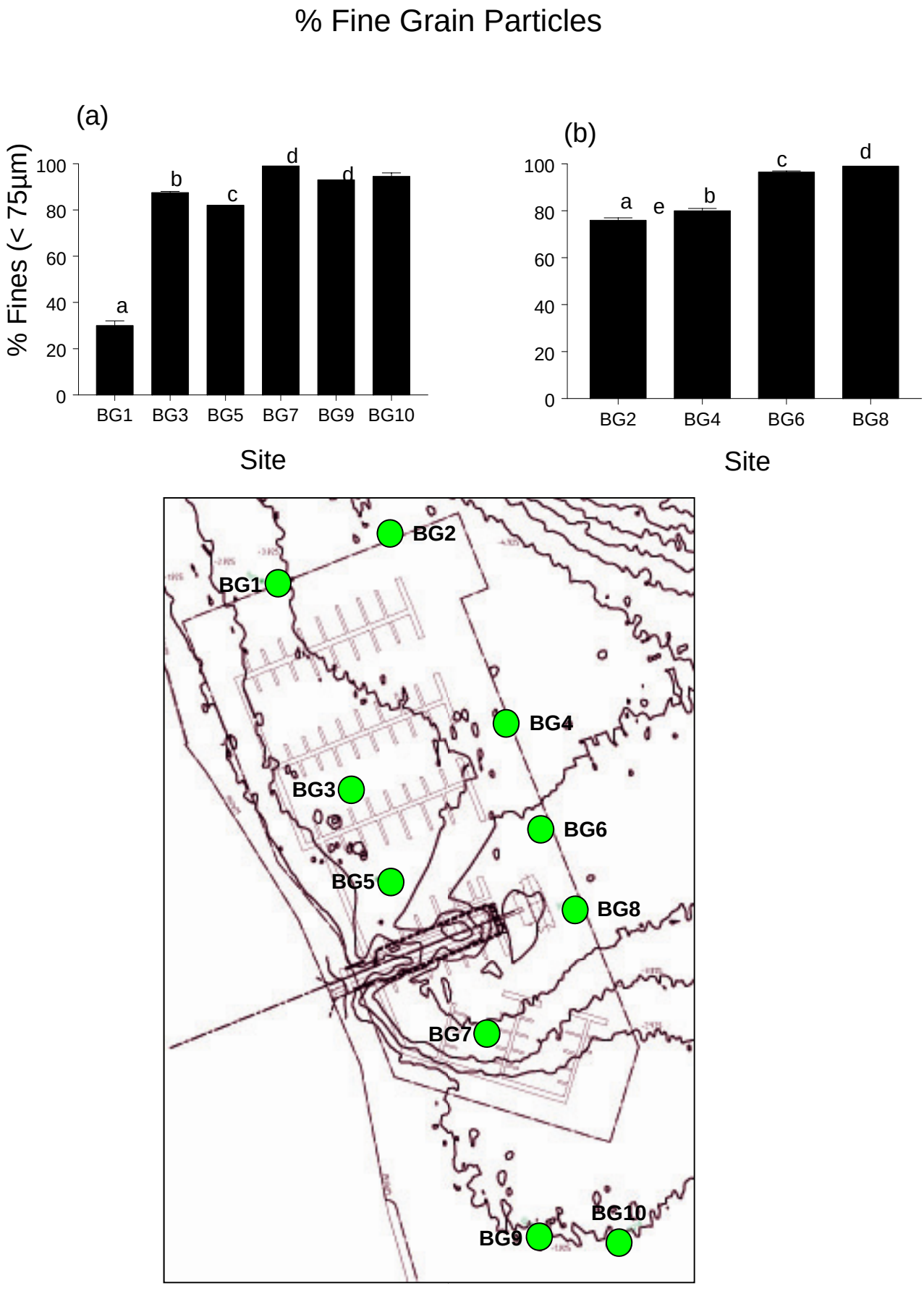


Figure 9: Mean (± S.E) proportion of fines (< 75 µm) in subtidal sediments at (a) each of the nearshore and (b) offshore sites sampled in Kendall Bay. (note that sites BG1-BG8 are situated within the Proposed Marina Location; *n* = 2 per site).

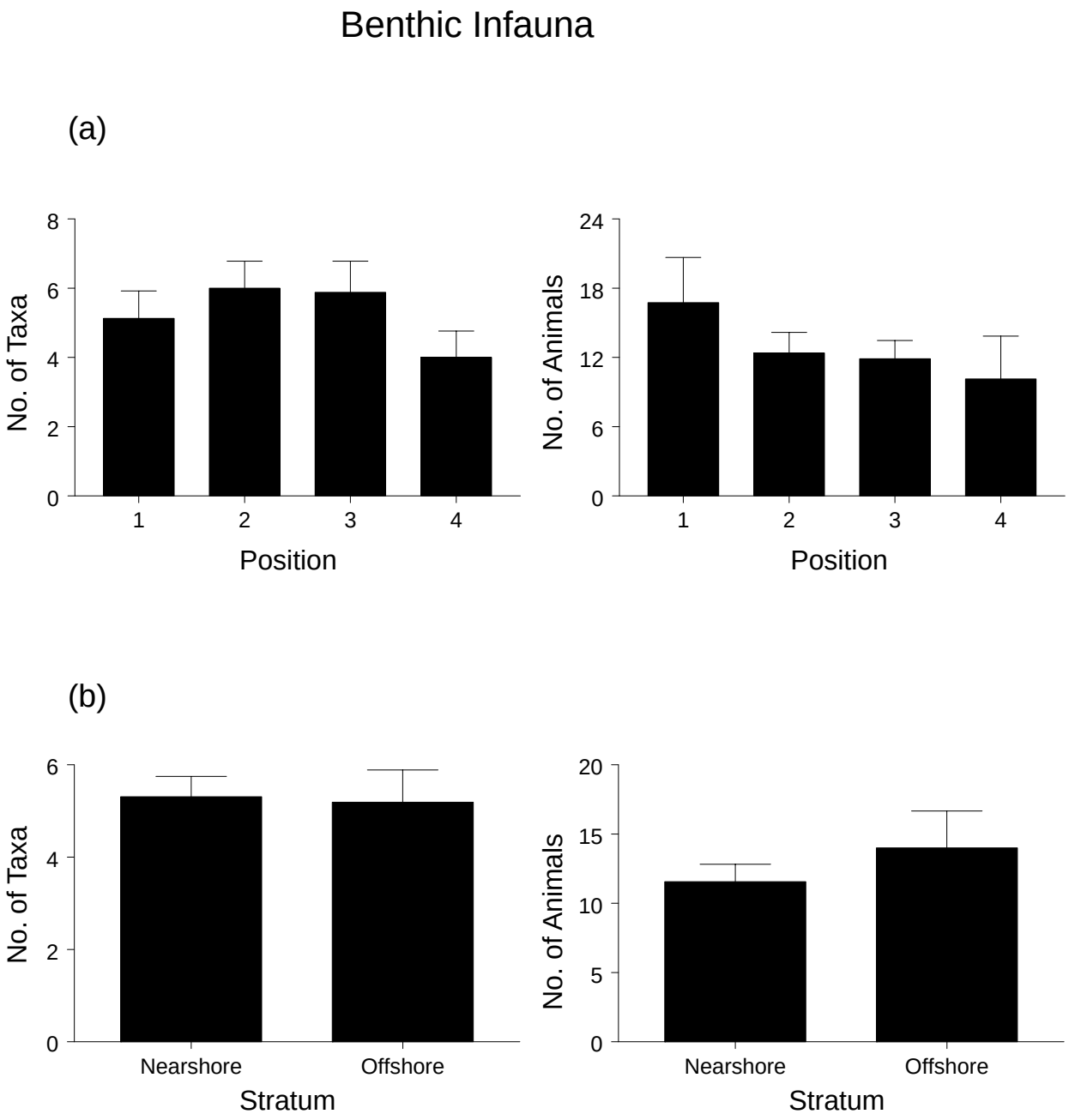


Figure 10: Mean (± S.E.) number of taxa and animals at (a) each position and (b) each stratum within the Proposed Marina Location (*n* = 8 per position and 16 per stratum).

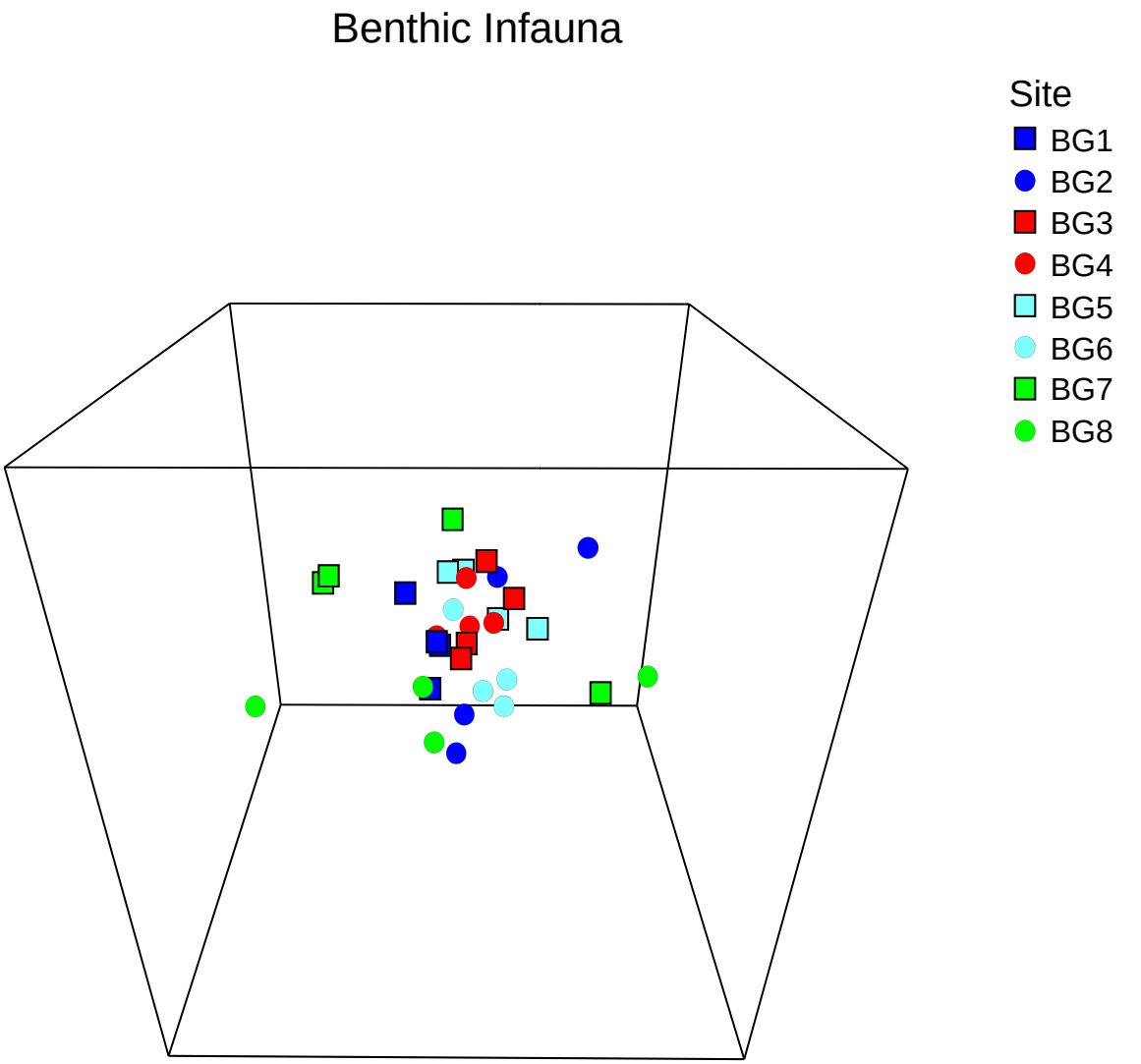


Figure 11: 3D-MDS plot comparing the structure of infaunal assemblages among positions and between strata at the Proposed Marina Location within Kendall Bay. Blue, red, pale blue and green symbol represent Positions 1-4, respectively while squares and circles symbols represent nearshore and offshore sites respectively (Stress value = 0.12).

Benthic Infauna

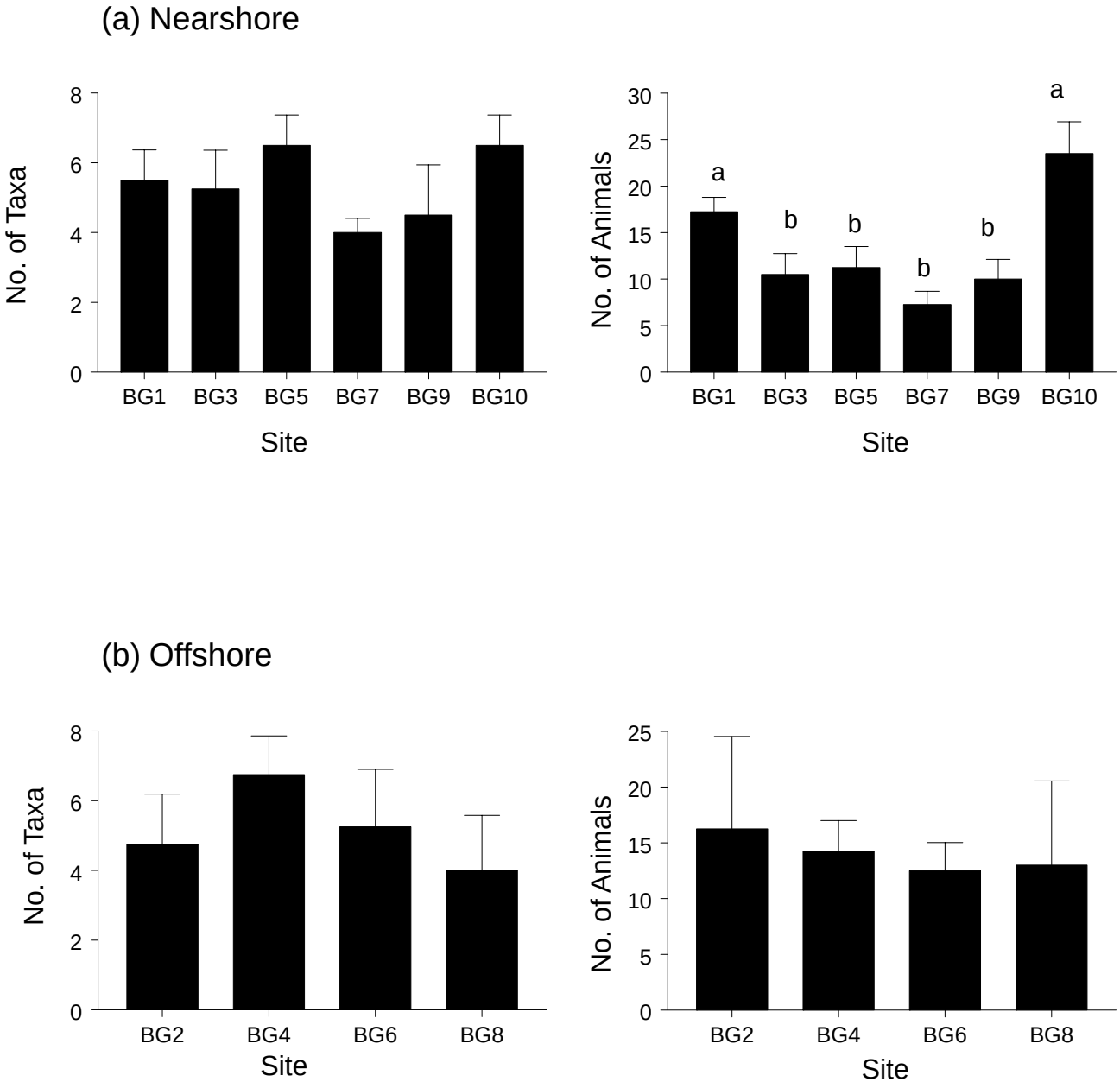


Figure 12: Mean (± S.E.) number of taxa and animals at (a) nearshore and (b) offshore sites sampled within Kendall Bay (note that sites BG1-BG8 are situated within the Proposed Marina Location (*n* = 4 per site). (Different symbols above bars indicate assemblages are significantly different at these sites) .

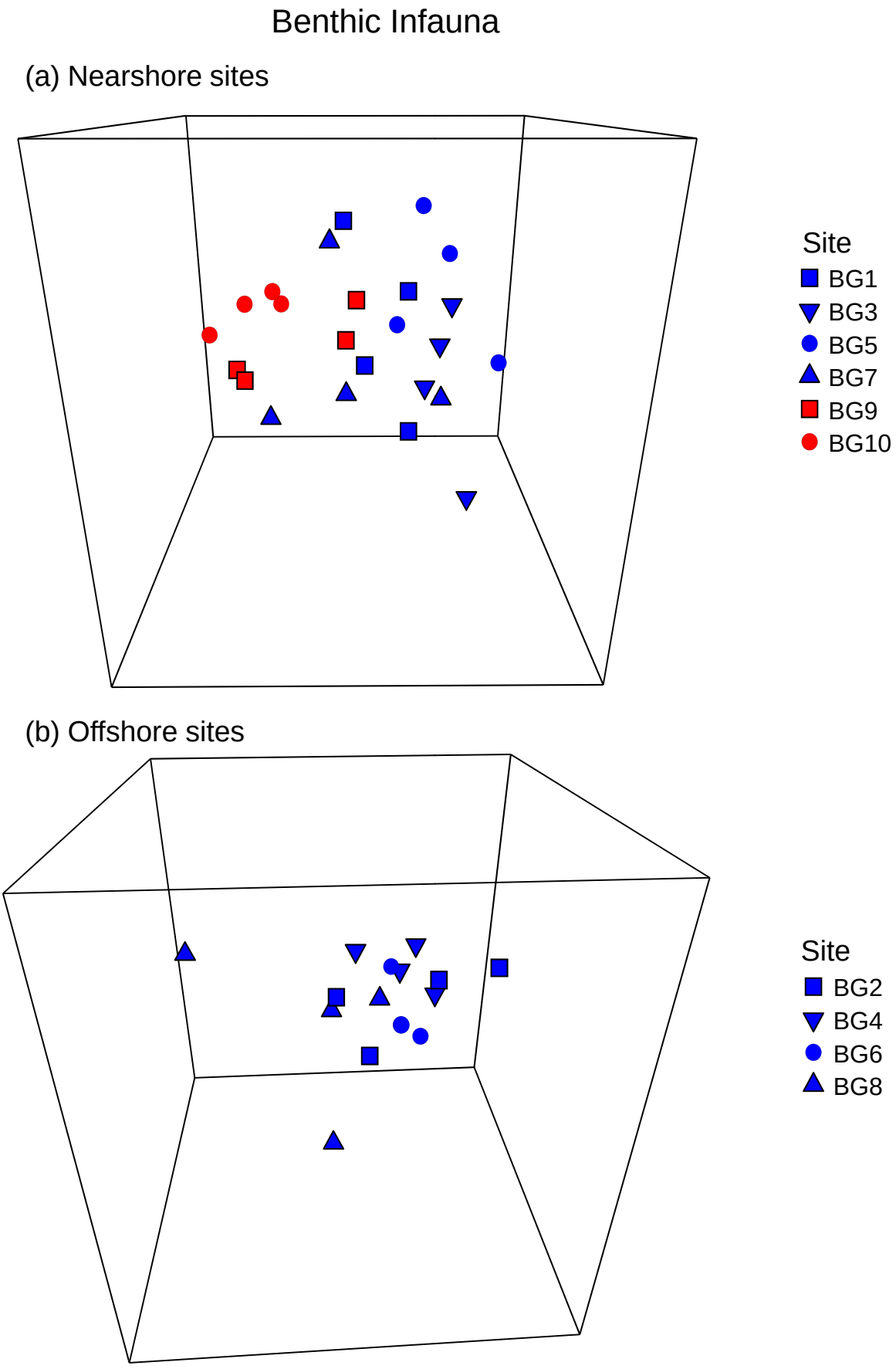


Figure 13: 3D-MDS plots comparing the structure of infaunal assemblages among (a) nearshore and (b) offshore sites within and/or adjacent to the Proposed Marina Location within Kendall Bay. Blue symbols represent sites within the Proposed Marina Location. Red symbols represent sites at the southern end of Kendall Bay. (Stress value = 0.12 for a and 0.05 for b).

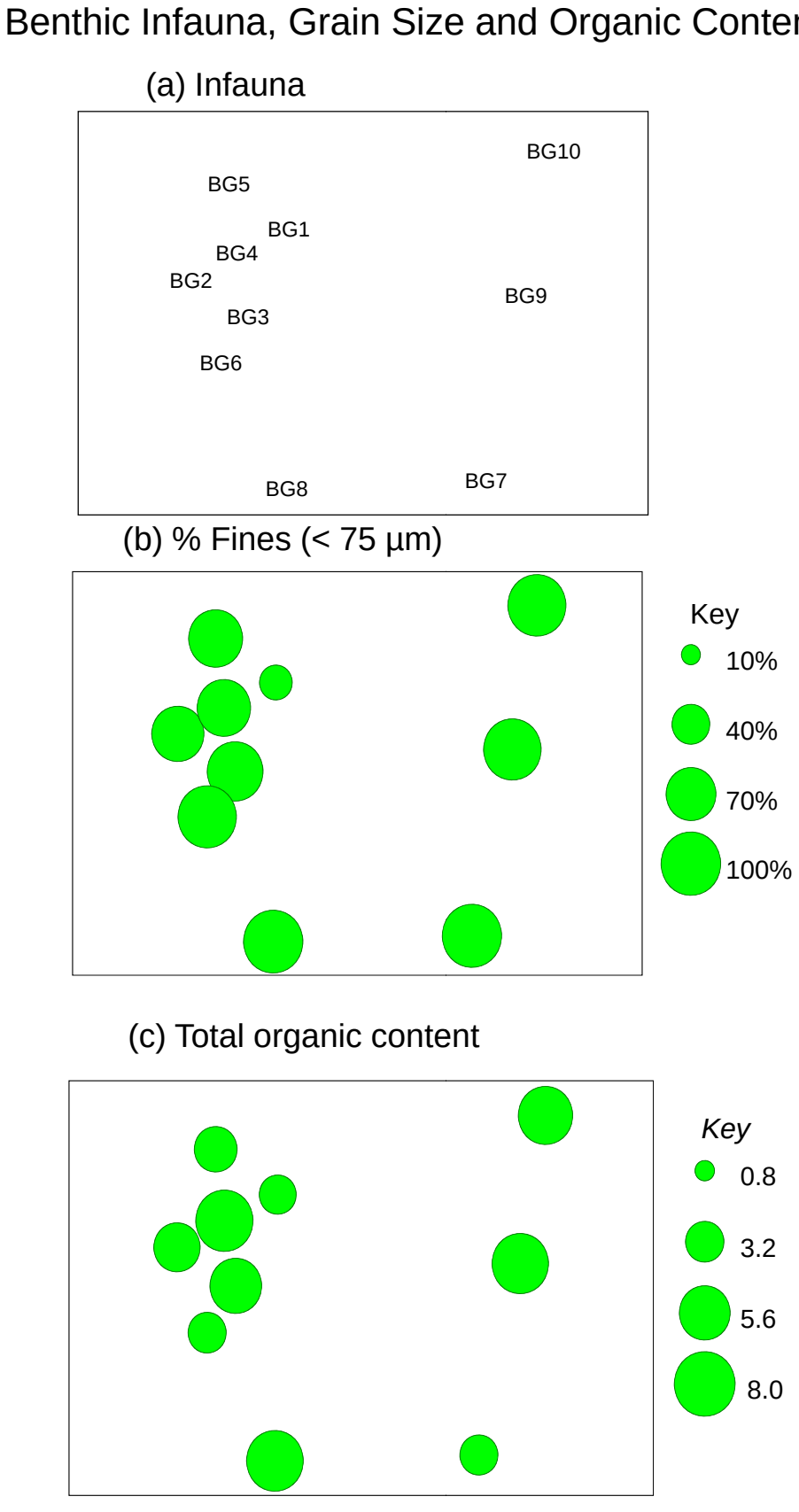


Figure 14: MDS plots showing (a) the pattern in infaunal assemblages across the sites BG1-BG10 with (b) % of fines and (c) total organic content of the sediment superimposed on the patterns in biota.

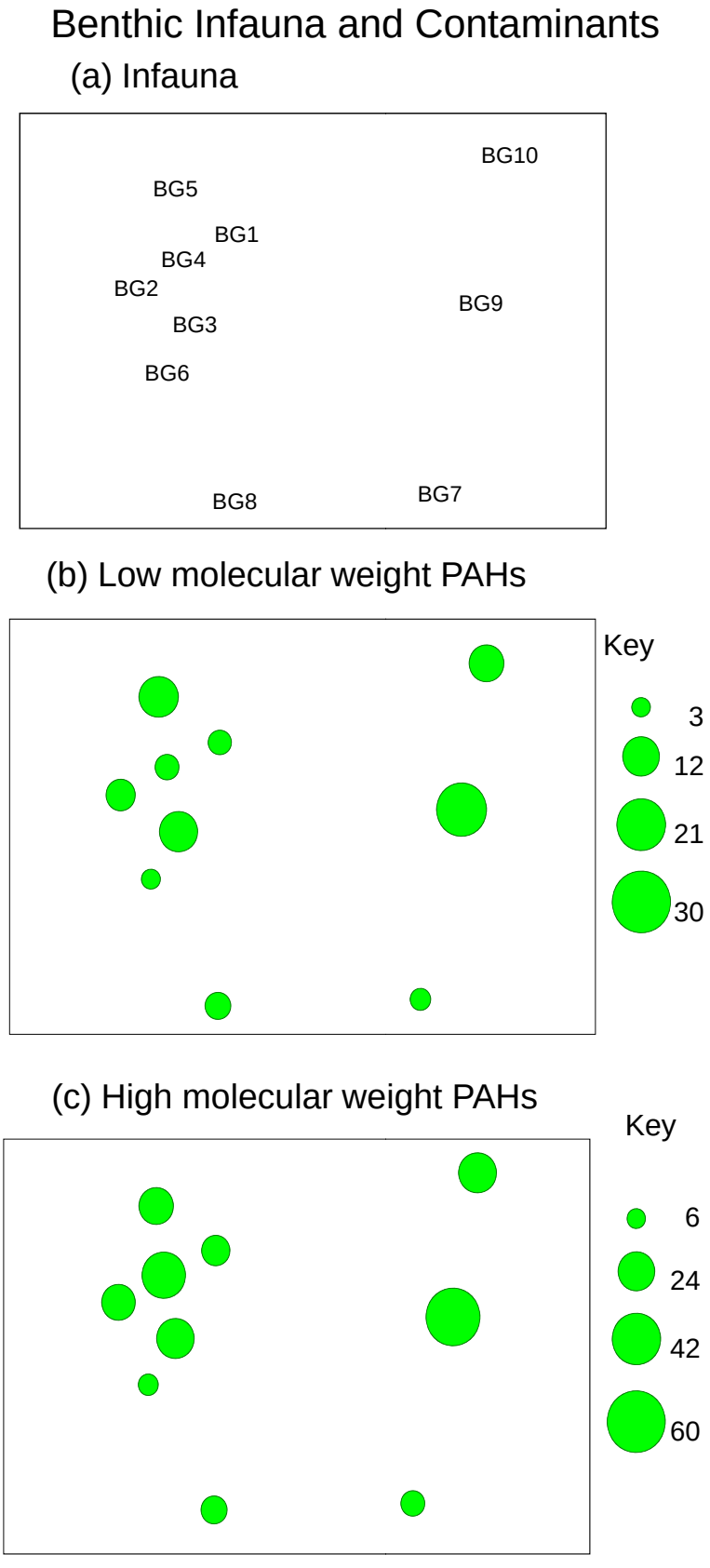


Figure 15: MDS plots showing (a) the pattern in infaunal assemblages across the sites BG1-BG10 with concentrations of (b) low molecular weight PAHs and (c) high molecular weight PAHs superimposed on the patterns in biota.

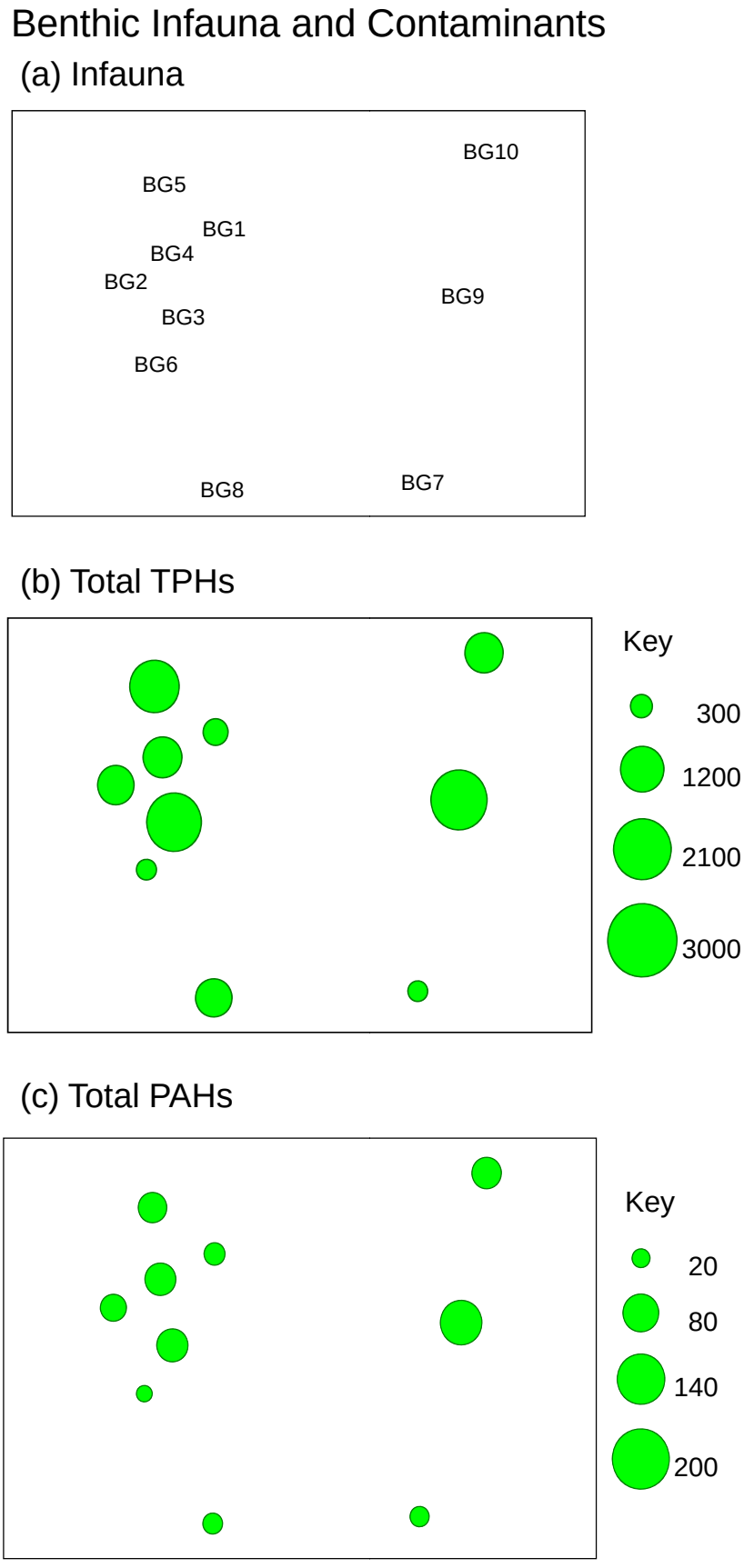


Figure 16: MDS plots showing (a) the pattern in infaunal assemblages across the sites BG1-BG10 with concentrations of (b) total petroleum hydrocarbons (TPHs) and (c) total polycyclic aromatic hydrocarbons (PAHs) in the sediment at each site superimposed on the patterns in biota.

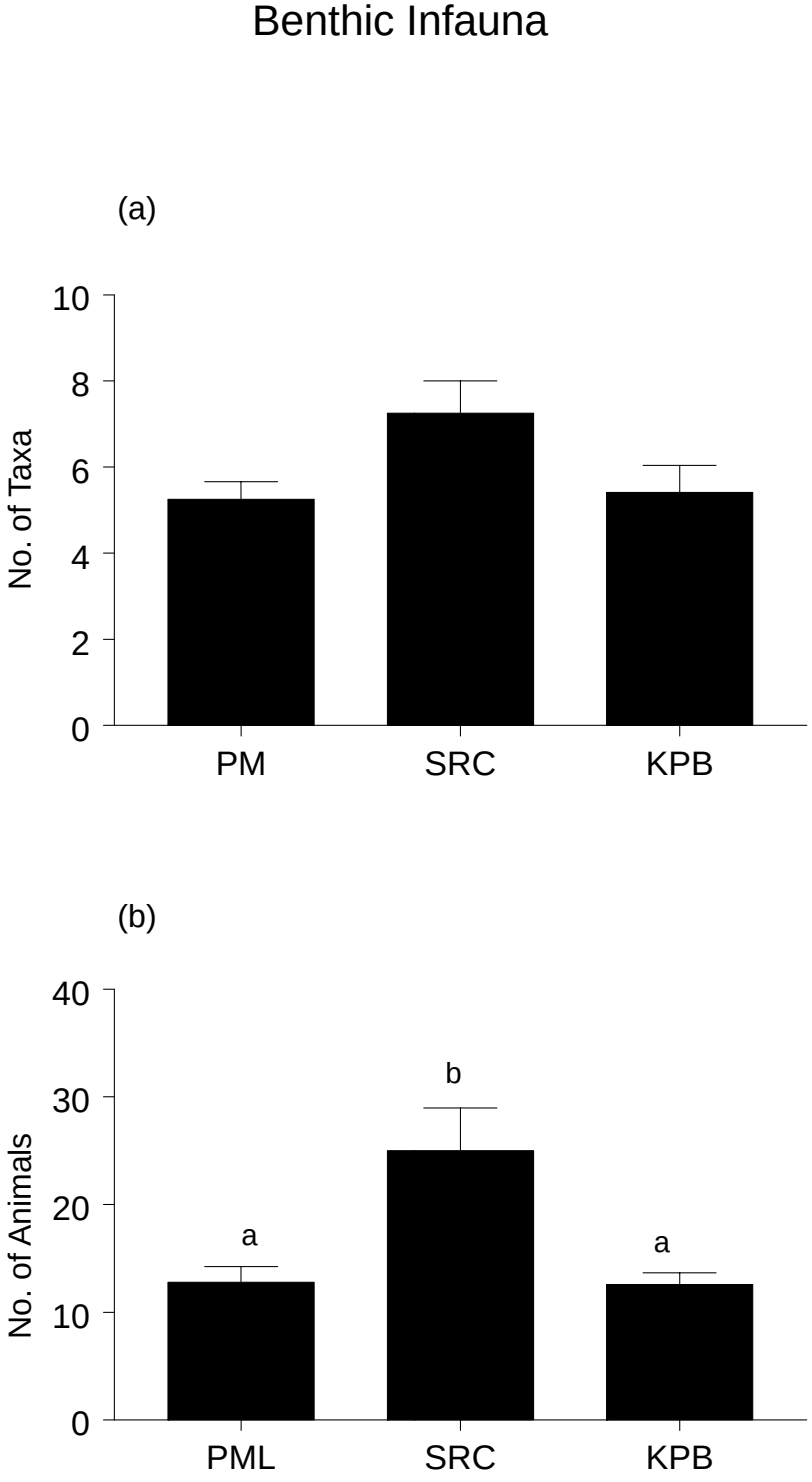


Figure 17: Mean (± S.E.) number of (a) taxa and (b) animals in the benthic grab samples collected at the Proposed Marina Location (PML) and Reference Locations, Sydney Rowing Club (SRC) and Kissing Point Bay (*n* = 32 for PM and 12 for SRC and KPB). Different symbols above bars indicate assemblages are significantly different at these locations.

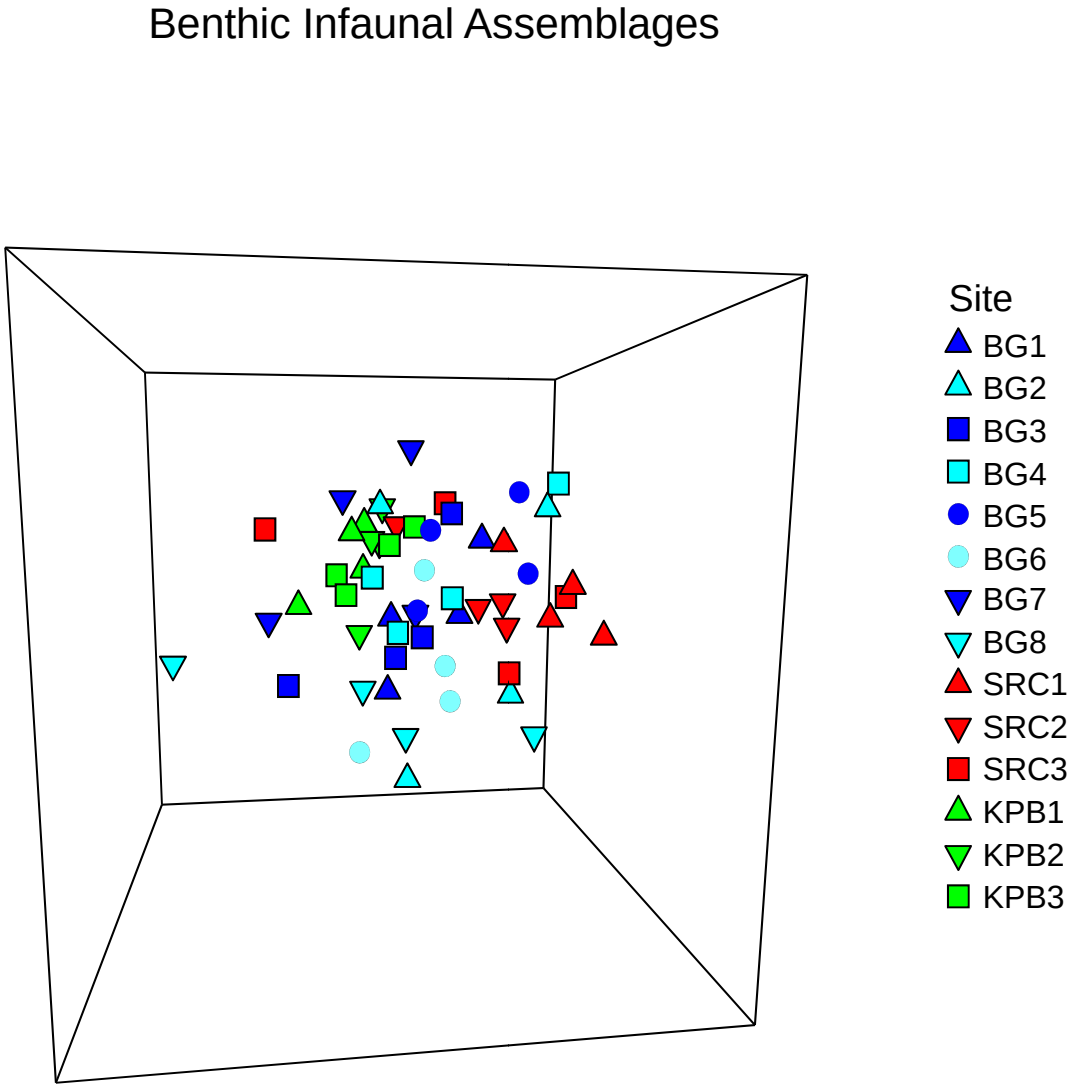


Figure 18: 3D-MDS plot comparing the structure of infaunal assemblages among sites within the Proposed Marina Location and Reference Locations, Sydney Rowing Club (SRC) and Kissing Point Bay (KPB). Dark blue and pale blue symbols represent nearshore and offshore sites respectively within the proposed marina location (Stress value = 0.13).

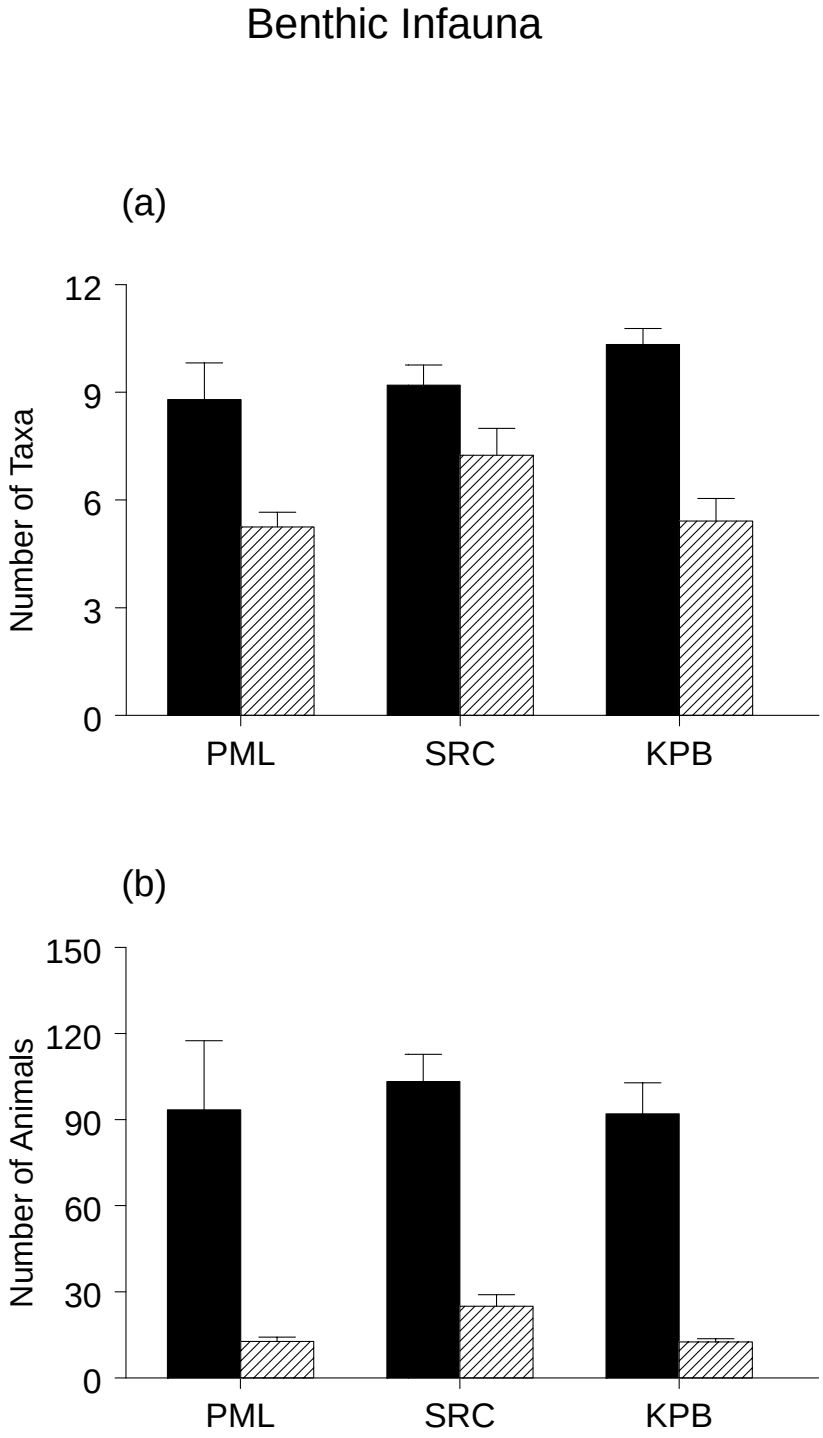


Figure 19: Mean (± S.E.) number of (a) taxa and (b) animals in the benthic grab samples collected at the Proposed Marina Location (PML) and Reference Locations, Sydney Rowing Club (SRC) and Kissing Point Bay in 1996 (solid bar) and 2009 (shaded bar) (*n* = 15 per location in 1996, but *n* = 32 for PML and 12 for SRC and KPB in 2009)

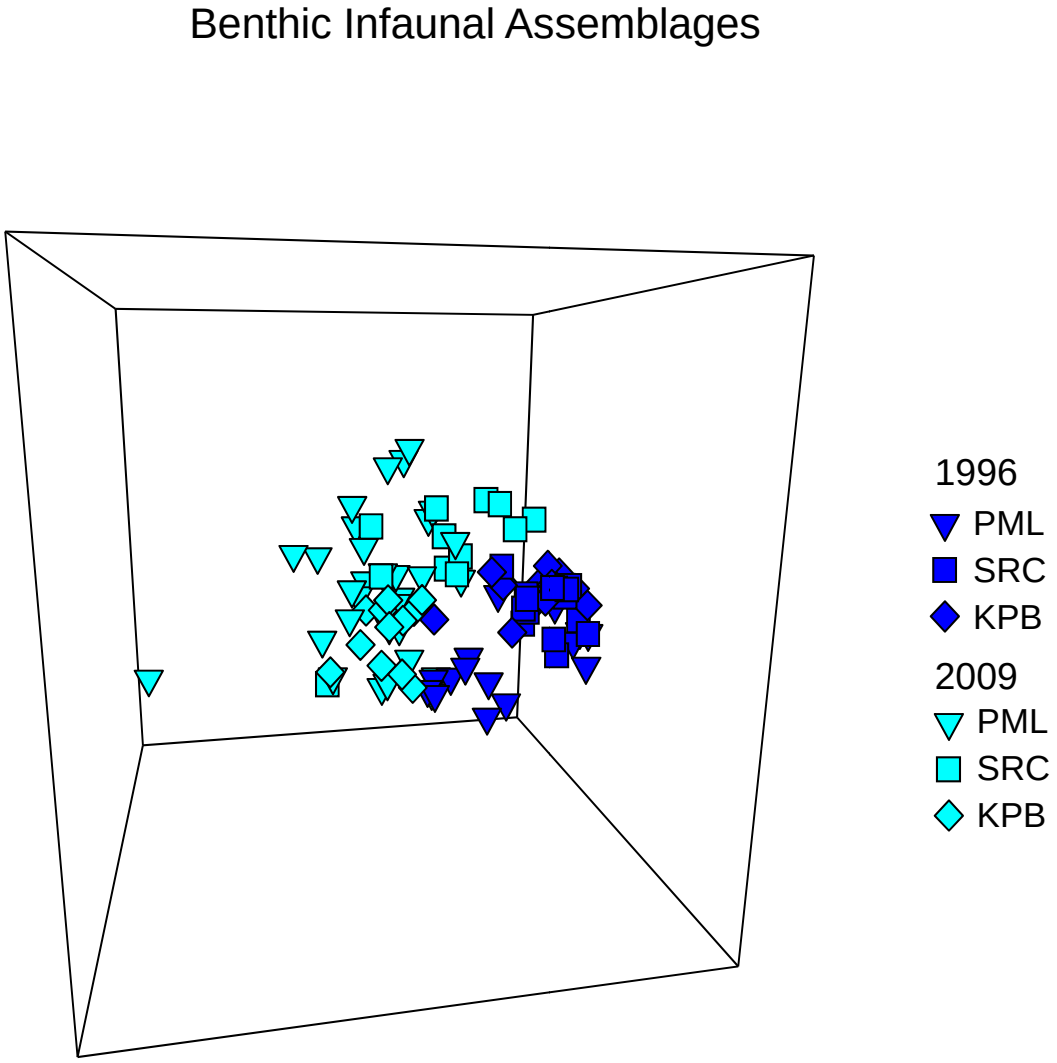


Figure 20: 3D-MDS plot comparing the structure of infaunal assemblages within the Proposed Marina Location and Reference Locations, Sydney Rowing Club (SRC) and Kissing Point Bay (KPB) in 1996 (dark blue) and 2009 (pale blue) (Stress value = 0.11).

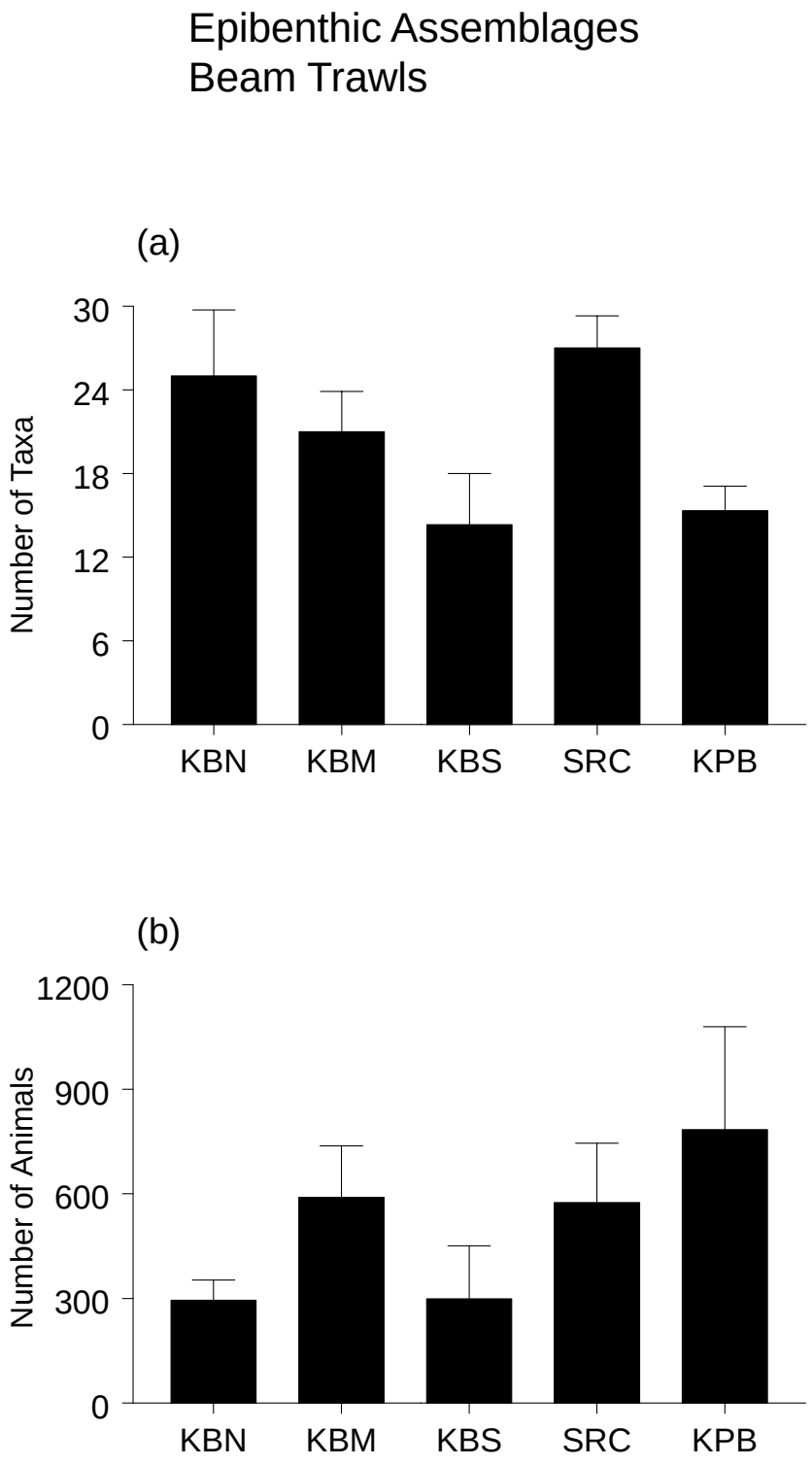


Figure 21: Mean (± S.E.) number of (a) taxa and (b) animals in epibenthic assemblages sampled at Kendall Bay North (KBN), Kendall Bay Mid (KBM), Kendall Bay South (KBS), Sydney Rowing Club (SRC) and Kissing Point Bay. Data from 2009.

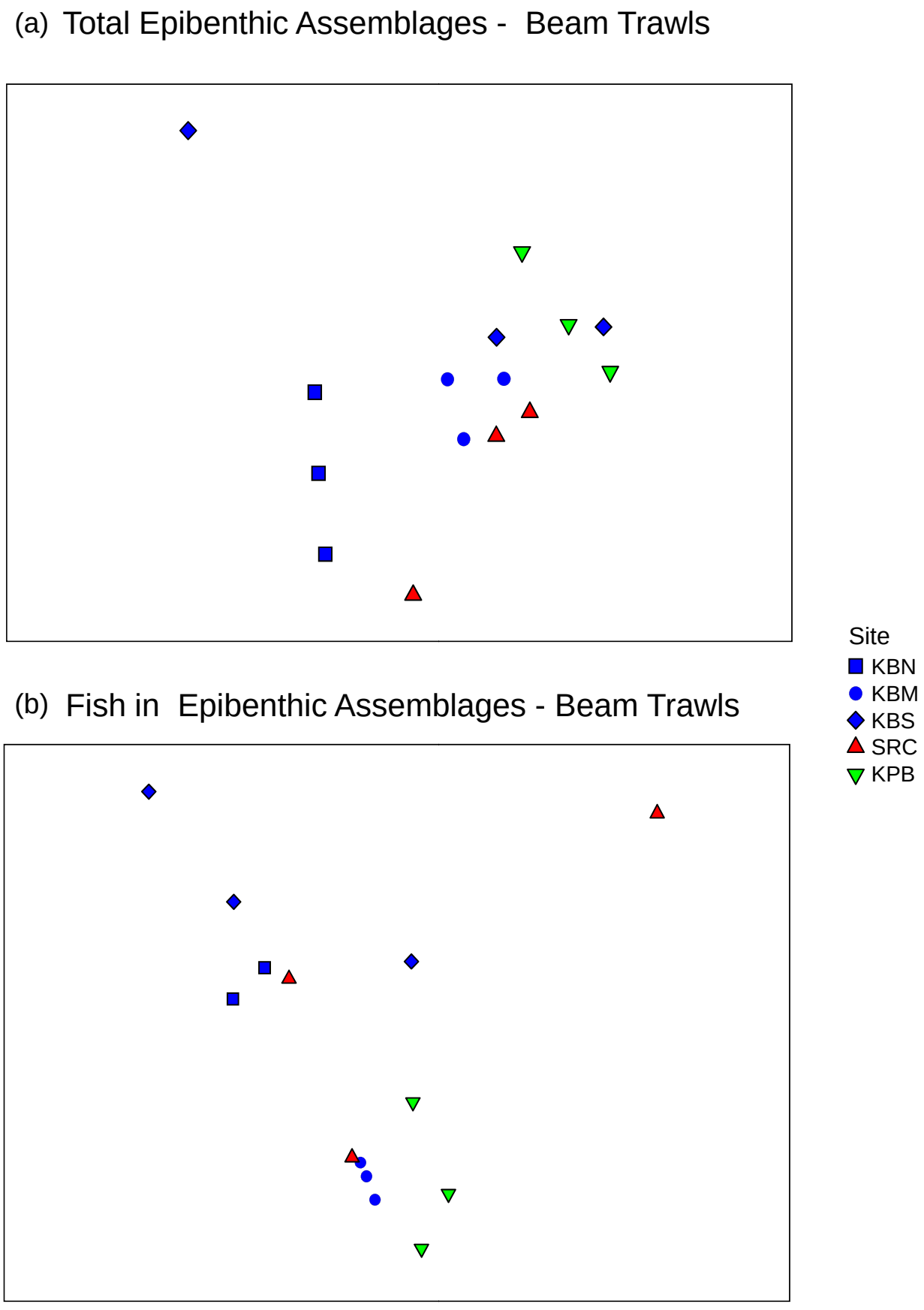


Figure 22: 2D-MDS plot comparing (a) total epibenthic assemblages and (b) fish component of the assemblages sampled at north, mid and south Kendall Bay, Sydney Rowing Club (SRC) and Kissing Point Bay (KPB). (Stress value = 0.09 and 0.03, respectively).

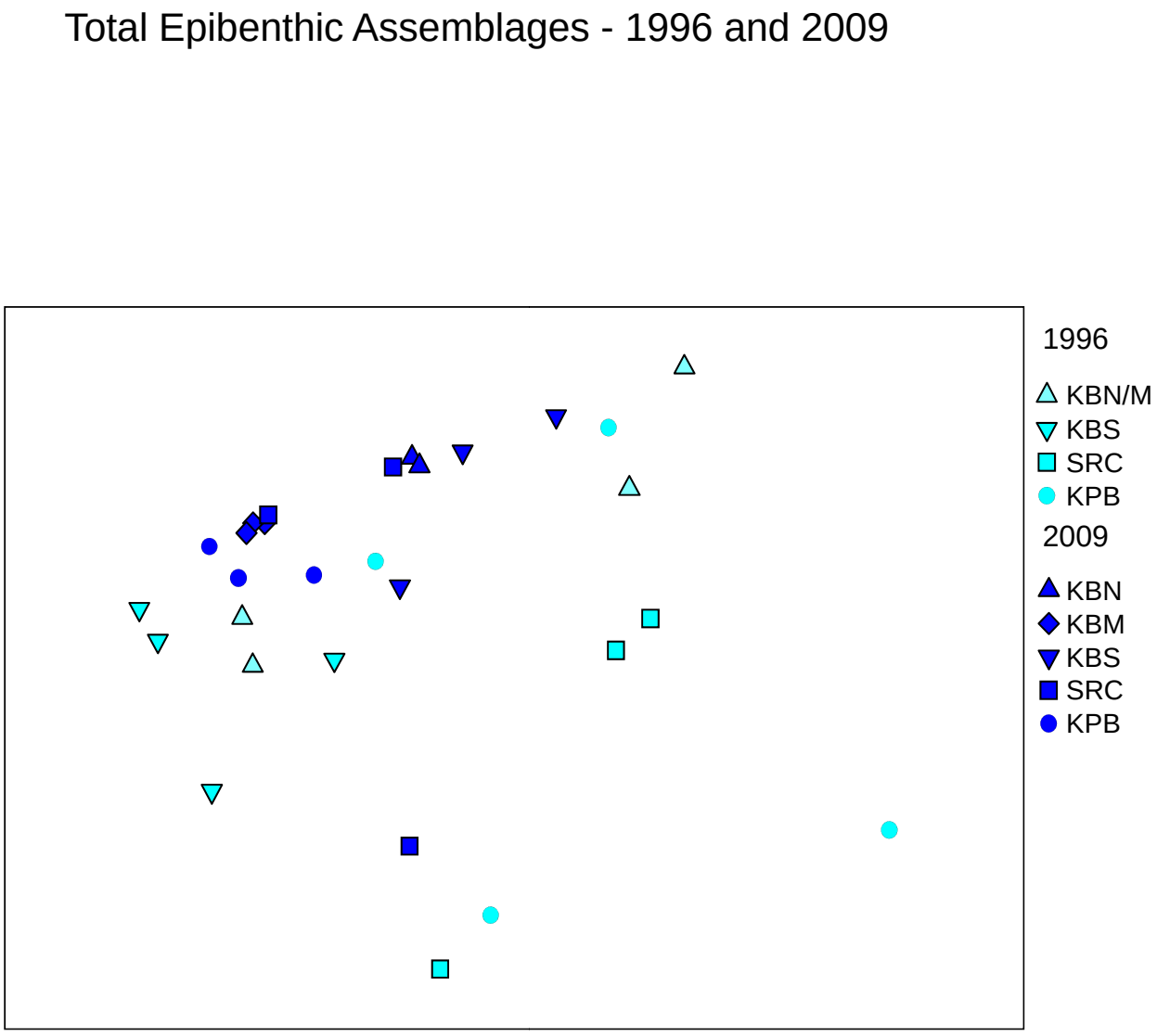


Figure 23: 2D-MDS plot comparing epibenthic assemblages at north, mid and south Kendall Bay, Sydney Rowing Club (SRC) and Kissing Point Bay (KPB) in 1996 and 2009. (Stress value = 0.11).

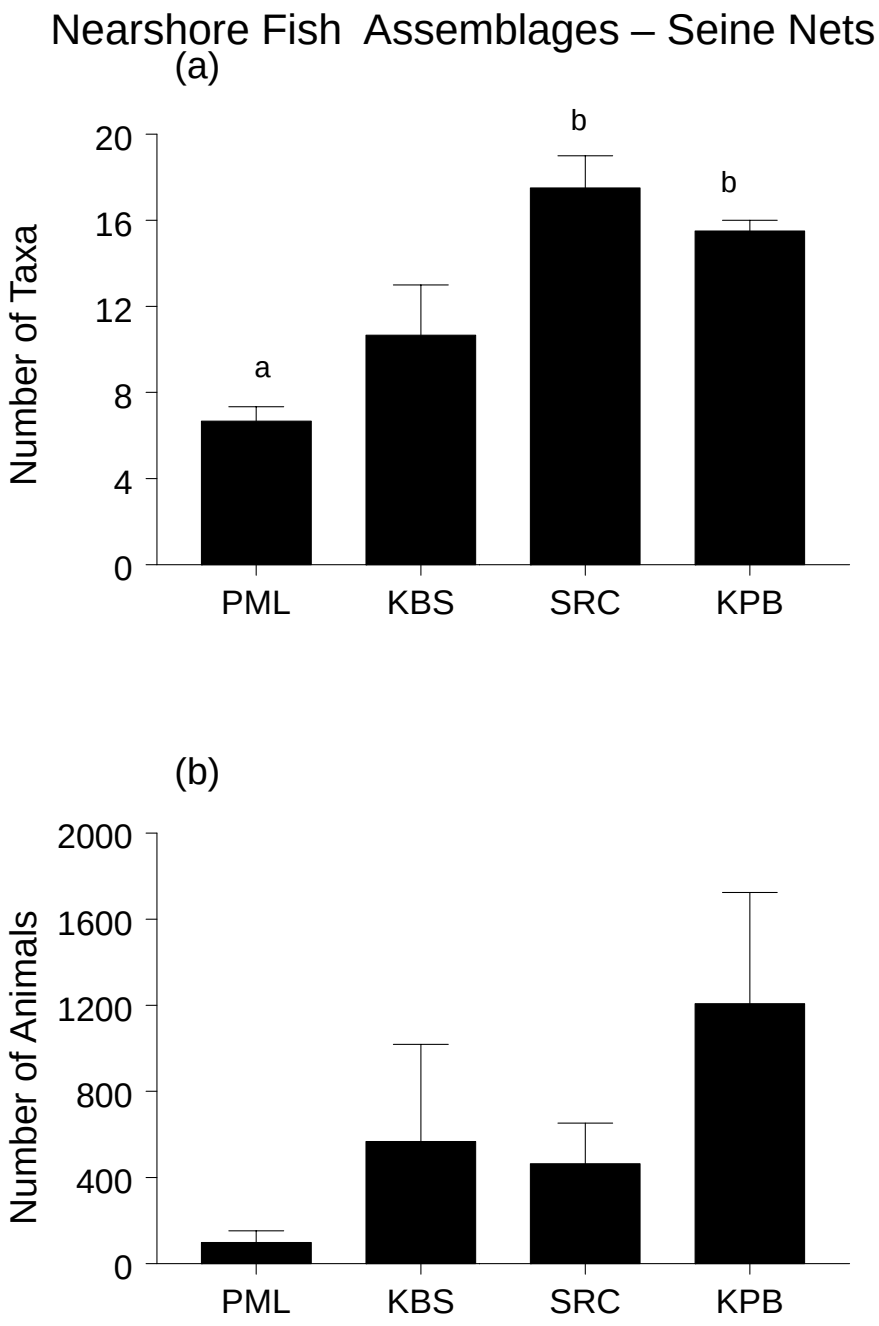


Figure 24: Mean (± S.E.) number of (a) taxa and (b) animals in nearshore fish assemblages sampled at the Proposed Marina Location (PML), Kendall Bay South (KBS), Sydney Rowing Club (SRC) and Kissing Point Bay.

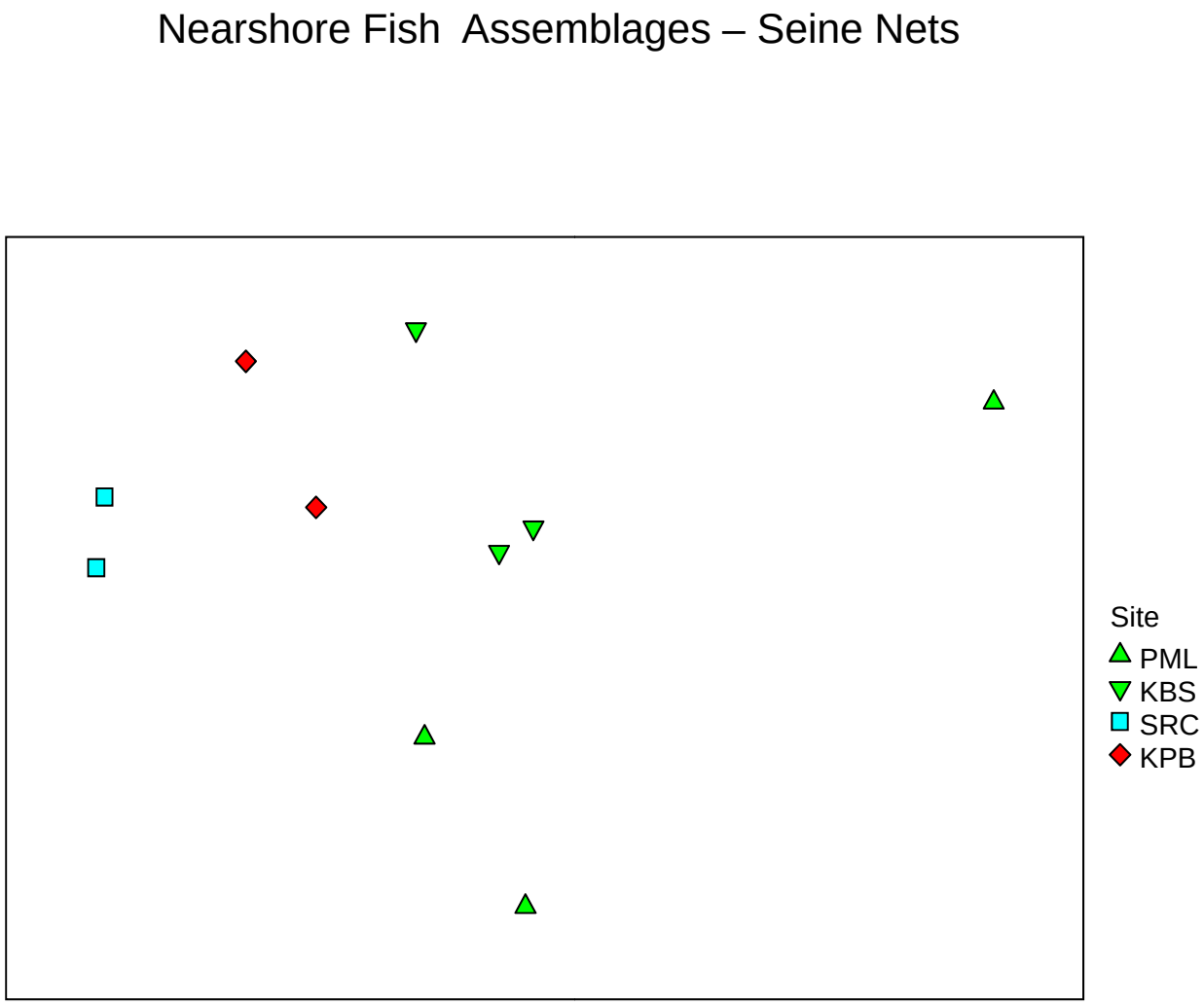


Figure 25: 2D-MDS plot comparing the structure of nearshore fish assemblages at the Proposed Marina Location (PML), southern end of Kendall Bay (KBS), Sydney Rowing Club (SRC) and Kissing Point Bay (KPB). (Stress value = 0.1).

10 Plates

Plate 1: (a) – (d) Inner West Marina aquatic ecology study locations:

(a) Potential Marina Location (PML) looking southward along the rock wall;

(b) Kendall Bay South (KBS) where the grey mangrove (*Avicennia marina*) lines the foreshore;

(c) Kissing Point Bay (KPB) reference location; and

(d) Sydney Rowing Club (SRC) reference location.

Plate 2:

(a) Suspended sediment collector prior to deployment in Kendall Bay; and

(b) Suspended sediment collectors were deployed in groups of three units per site.

Plate 3:

(a) Beam trawl net used in the survey;

(b) Seine net used in the survey;

(c) *Zostera* seagrass wrack and fish (hardyheads) caught in the beach seine at Sydney Rowing Club; and

(d) Close-up of Hardyhead (*Atherinosoma ogilbyi*).

Plate4:

(a) Base of the revetment in Kendall Bay is covered in algal turf and oysters;

(b) Close-up of stones in the revetment showing green algae, oysters, barnacles and periwinkles;

(c) Algae and barnacles on the jetty piles at Cabarita Wharf; and

(d) Close-up of a jetty pile showing mussels covered by green and red algae.

(a)

(b)

(c)

(d)

Plate 1: (a) – (d) Inner West Marina aquatic ecology study locations:

(a) Potential Marina Location (PML) looking southward along the rock wall;

(b) Kendall Bay South (KBS) where the grey mangrove (*Avicennia marina*) lines the foreshore;

(c) Kissing Point Bay (KPB) reference location; and

(d) Sydney Rowing Club (SRC) reference location.

(a)

(b)

Plate 2:

(a) Suspended sediment collector prior to deployment in Kendall Bay; and

(b) Suspended sediment collectors were deployed in groups of three units per site.

(a)

(b)

(c)

(d)

Plate 3:

(a) Beam trawl net used in the survey;

(b) Seine net used in the survey;

(c) *Zostera* seagrass wrack and fish (hardyheads) caught in the beach seine at Sydney Rowing Club; and

(d) Close-up of Hardyhead (*Atherinsoma ogilbyi*).

(a)

(b)

(c)

(d)

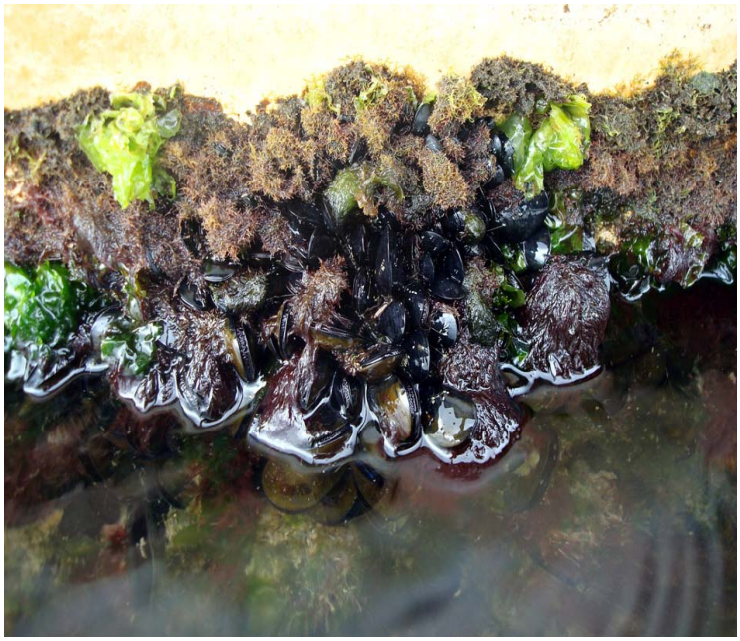


Plate 4:

(a) Base of the revetment in Kendall Bay is covered in algal turf and oysters;

(b) Close-up of stones in the revetment showing green algae, oysters, barnacles and periwinkles;

(c) Algae and barnacles on the jetty piles at Cabarita Wharf; and

(d) Close-up of a jetty pile showing mussels covered by green and red algae.

11 Appendices

Appendix 1: GPS coordinates of the sampling sites for A) Sediment traps (suspended sediment contamination and settlement rates), B) Benthic grabs (infauna and particle size), C) Beam trawls (epibenthic assemblages) and D) Seine nets (nearshore fish).

Appendix 2: Concentrations of BTEXs, TPHs, PAHs and other substances measured in SPM samples from the Sediment Traps deployed at Sites SS1, SS2 and SS3 between 24 April and 5 May 2009 (1st Deployment).

Appendix 3: Concentrations of BTEXs, TPHs, PAHs and other substances measured in SPM samples from the Sediment Traps deployed at Sites SS1, SS2 and SS3 between 5 May and 22 May (2nd Deployment).

Appendix 4: Concentrations of BTEXs, TPHs, PAHs and other substances measured in SPM samples from the Sediment Traps deployed at Sites SS1, SS2 and SS3 between 22 May and 5 June (3rd Deployment).

Appendix 5: Proportion of each of the replicate sediment samples collected at the 16 study sites passing through sieves with mesh sizes varying from 75 µm to 9.5 mm.

Appendix 6: Concentrations of heavy metals measured in water samples collected from four sites (SG5, SG7, SG9 and SG12) within the Proposed Marina Location at low and high tide on (a) 2 July and (b) 6 July 2009.

Appendix 7: Numbers of each infaunal taxon found in the grab samples collected at each of the study sites at the Proposed Marina Location, southern end of Kendall Bay and Reference Locations, Sydney Rowing Club and Kissing Point Bay.

Appendix 8: Numbers of each taxon found in the beam trawl samples collected on 19 and 20 may 2009 at each of the study sites at the Proposed Marina Location, southern end of Kendall Bay and Reference Locations, Sydney Rowing Club and Kissing Point Bay.

Appendix 9: Numbers of each taxon found in the seine net samples collected on 22 May 2009 at each of the study sites in Kendall Bay and at the Reference Locations, Sydney Rowing Club and Kissing Point Bay.

Appendix 1: GPS coordinates of the sampling sites for A) Sediment traps (suspended sediment contamination and settlement rates), B) Benthic grabs (infauna and particle size), C) Beam trawls (epibenthic assemblages), and D) Seine nets (nearshore fish).

Type of Sample Unit	Parameter sampled	Site Code	Coordinates (MGA 94)	
			Easting	Northing
A. Sediment traps	Suspended sediments (SPM), settlement rates	SS1	325401	6254122
		SS2	325508	6253981
		SS3	325543	6253893
B. Benthic grabs	Benthic infauna, particle size	BG1	325377	6254142
		BG2	325452	6254171
		BG3	325426	6254015
		BG4	325527	6254054
		BG5	325449	6253958
		BG6	325550	6253992
		BG7	325514	6253868
		BG8	325571	6253943
		BG9	325548	6253742
C. Beam Trawls	Epibenthic assemblages (bottom-dwelling fish and invertebrates)	KBS - BT	325495	6253874
		KBS - BT	325618	6253849
		KBN - BT	325325	6254230
		KBN - BT	325382	6254069
		KBM - BT	325382	6254069
		KBM - BT	325470	6253916
		KPB - BT	324911	6254882
		KPB - BT	324850	6254691
		SRC - BT	326541	6253423
		SRC - BT	326415	6253354
D. Seine nets	Nearshore fish assemblages	KBS - BS	325620	6253650
		KBS - BS	325607	6253638
		KBS - BS	325647	6253648
		PML - BS	325327	6254077
		PML - BS	325337	6254050
		PML - BS	325352	6254026
		SRC - BS	326609	6253364
		SRC - BS	326569	6253345
		KPB - BS	324968	6254878
		KPB - BS	324958	6254905

Appendix 2: Concentrations of BTEXs, TPHs, PAHs and other substances measured in SPM samples from the Sediment Traps deployed at Sites SS1, SS2 and SS3 between 24 April and 5 May 2009 (1st Deployment). Note that concentrations of organic compounds that are above the Limit of Reporting (LOR) have been normalised to 1% total organic carbon. Highlighted values exceed the ANZECC/ARMCANZ (2000) ISQG-Low Trigger values. (n/a = no ISQG-Low or High guidelines; <LOR is below the Limit of Reporting).

Analyte					Site						
	Units	LOR	ISQG-Low	SQG-High	SS1	SS2			SS3		
				Replicate	1	1	2	3	1	2	3
BTEX											
Benzene	mg/kg	0.2	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Toluene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Ethylbenzene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
meta- & para-Xylene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
ortho-Xylene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Total Petroleum Hydrocarbons											
C6 - C9 Fraction	mg/kg	10	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
C10 - C14 Fraction	mg/kg	50	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
C15 - C28 Fraction	mg/kg	100	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
C29 - C36 Fraction	mg/kg	100	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
TPH(V)/BTEX Surrogates											
1.2-Dichloroethane-D4	%	0.2	n/a	n/a	33.79	33.75	32.25	34.24	35.70	31.08	31.79
Toluene-D8	%	0.2	n/a	n/a	31.03	32.10	29.96	31.70	33.81	35.86	29.96
4-Bromofluorobenzene	%	0.2	n/a	n/a	29.49	30.49	28.75	29.89	35.17	31.44	28.71
Polycyclic Aromatic Hydrocarbons											
3-Methylcholanthrene	µg/kg	10	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
2-Methylnaphthalene	µg/kg	10	n/a	n/a	22.06	29.96	25.83	26.52	22.64	28.78	32.26
7.12-Dimethylbenz(a)anthracene	µg/kg	10	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Acenaphthene	µg/kg	10	16	500	11.03	14.98	11.07	11.36	7.55	10.79	14.34
Acenaphthylene	µg/kg	10	44	640	161.76	194.76	147.60	151.52	150.94	154.68	168.46
Anthracene	µg/kg	10	85	1100	62.50	74.91	62.73	60.61	56.60	61.15	64.52
Benz(a)anthracene	µg/kg	10	261	1600	205.88	239.70	195.57	193.18	173.58	187.05	200.72
Benzo(a)pyrene	µg/kg	10	430	1600	437.50	490.64	413.28	412.88	369.81	399.28	419.35
Benzo(b)fluoranthene	µg/kg	10	n/a	n/a	371.32	528.09	398.52	435.61	320.75	366.91	487.46
Benzo(e)pyrene	µg/kg	10	n/a	n/a	242.65	269.66	228.78	227.27	196.23	215.83	225.81
Benzo(g.h.i)perylene	µg/kg	10	n/a	n/a	132.35	314.61	265.68	257.58	305.66	273.38	275.99
Benzo(k)fluoranthene	µg/kg	10	n/a	n/a	338.24	157.30	169.74	212.12	203.77	226.62	150.54
Chrysene	µg/kg	10	384	2800	183.82	220.97	180.81	181.82	166.04	176.26	182.80
Coronene	µg/kg	10	n/a	n/a	11.03	71.16	51.66	60.61	71.70	64.75	64.52
Dibenz(a.h)anthracene	µg/kg	10	63	2600	40.44	74.91	62.73	60.61	71.70	64.75	68.10
Fluoranthene	µg/kg	10	600	5100	301.47	359.55	291.51	287.88	271.70	284.17	293.91
Fluorene	µg/kg	10	19	540	22.06	29.96	25.83	22.73	22.64	25.18	28.67
Indeno(1.2.3.cd)pyrene	µg/kg	10	n/a	n/a	117.65	235.96	199.26	196.97	218.87	205.04	207.89
N-2-Fluorenyl Acetamide	µg/kg	100	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Naphthalene	µg/kg	10	160	2100	55.15	71.16	59.04	56.82	52.83	57.55	68.10
Perylene	µg/kg	10	n/a	n/a	77.21	97.38	81.18	71.97	64.15	79.14	78.85
Phenanthrene	µg/kg	10	240	1500	125.00	161.05	132.84	128.79	120.75	125.90	136.20
Pyrene	µg/kg	10	665	2600	408.09	483.15	402.21	393.94	381.13	399.28	408.60
Low molecular weight PAHs	µg/kg		552	3160	459.56	576.78	464.94	458.33	433.96	464.03	512.54
High Molecular weight PAHs	µg/kg		1700	9600	1577.21	1868.91	1546.13	1530.30	1433.96	1510.79	1573.48
Total PAHs	µg/kg		4000	45000	3327.21	4119.85	3405.90	3450.76	3249.06	3406.47	3577.06
Miscellaneous											
Moisture Content	%	1	n/a	n/a	73.4	73.1	73.6	72.9	72.5	73.1	72.8
Free Cyanide	mg/kg	1	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Total Cyanide	mg/kg	1	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Total Organic Carbon	%	0.02	n/a	n/a	2.72	2.67	2.71	2.64	2.65	2.78	2.79

Appendix 3: Concentrations of BTEXs, TPHs, PAHs and other substances measured in SPM samples from the Sediment Traps deployed at Sites SS1, SS2 and SS3 between 5 May and 22 May 2009 (2nd Deployment). Note that concentrations of organic compounds that are above the Limit of Reporting (LOR) have been normalised to 1% total organic carbon. Highlighted values exceed the ANZECC/ARMCANZ (2000) ISQG-Low Trigger values. (n/a = no ISQG-Low or High guidelines; <LOR is below the Limit of Reporting).

Analyte					Site							
	Units	LOR	SQG-Low	SQG-High	SS1		SS2			SS3		
				Replicate	1	2	1	2	3	1	2	3
BTEX												
Benzene	mg/kg	0.2	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Toluene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Ethylbenzene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
meta- & para-Xylene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
ortho-Xylene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Total Petroleum Hydrocarbons												
C6 - C9 Fraction	mg/kg	10	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
C10 - C14 Fraction	mg/kg	50	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
C15 - C28 Fraction	mg/kg	100	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
C29 - C36 Fraction	mg/kg	100	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
TPH(V)/BTEX Surrogates												
1.2-Dichloroethane-D4	%	0.2	n/a	n/a	37.32	37.82	36.63	39.64	38.83	37.26	37.06	38.20
Toluene-D8	%	0.2	n/a	n/a	31.92	32.87	33.63	32.80	33.88	34.66	34.00	33.18
4-Bromofluorobenzene	%	0.2	n/a	n/a	30.58	32.07	33.07	32.51	33.30	34.02	34.71	32.70
Polycyclic Aromatic Hydrocarbons												
3-Methylcholanthrene	µg/kg	10	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
2-Methylnaphthalene	µg/kg	10	n/a	n/a	54.35	80.00	56.18	50.91	40.29	71.43	58.82	56.18
7.12-Dimethylbenz(a)anthracene	µg/kg	10	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Acenaphthene	µg/kg	10	16	500	18.12	36.36	33.71	21.82	18.32	26.32	19.61	33.71
Acenaphthylene	µg/kg	10	44	640	213.77	283.64	194.76	196.36	139.19	266.92	196.08	172.28
Anthracene	µg/kg	10	85	1100	90.58	120.00	89.89	87.27	65.93	120.30	90.20	78.65
Benz(a)anthracene	µg/kg	10	261	1600	253.62	338.18	254.68	254.55	197.80	349.62	258.82	232.21
Benzo(a)pyrene	µg/kg	10	430	1600	536.23	621.82	501.87	461.82	428.57	849.62	466.67	494.38
Benzo(b)fluoranthene	µg/kg	10	n/a	n/a	489.13	574.55	479.40	454.55	443.22	849.62	513.73	464.42
Benzo(e)pyrene	µg/kg	10	n/a	n/a	307.97	392.73	299.63	301.82	234.43	372.18	301.96	262.17
Benzo(g.h.i)perylene	µg/kg	10	n/a	n/a	217.39	240.00	205.99	196.36	150.18	338.35	215.69	179.78
Benzo(k)fluoranthene	µg/kg	10	n/a	n/a	268.12	440.00	273.41	269.09	249.08	334.59	301.96	280.90
Chrysene	µg/kg	10	384	2800	268.12	367.27	277.15	272.73	205.13	360.90	286.27	239.70
Coronene	µg/kg	10	n/a	n/a	25.36	25.45	22.47	21.82	14.65	33.83	23.53	18.73
Dibenz(a.h)anthracene	µg/kg	10	63	2600	76.09	87.27	74.91	72.73	54.95	116.54	78.43	63.67
Fluoranthene	µg/kg	10	600	5100	427.54	520.00	520.60	512.73	384.62	714.29	517.65	449.44
Fluorene	µg/kg	10	19	540	39.86	54.55	37.45	40.00	29.30	52.63	39.22	37.45
Indeno(1.2.3.cd)pyrene	µg/kg	10	n/a	n/a	202.90	232.73	194.76	189.09	142.86	304.51	203.92	168.54
N-2-Fluorenyl Acetamide	µg/kg	100	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Naphthalene	µg/kg	10	160	2100	123.19	163.64	108.61	101.82	80.59	142.86	117.65	101.12
Perylene	µg/kg	10	n/a	n/a	105.07	134.55	101.12	105.45	80.59	131.58	105.88	89.89
Phenanthrene	µg/kg	10	240	1500	173.91	225.45	183.52	178.18	135.53	240.60	192.16	164.79
Pyrene	µg/kg	10	665	2600	605.07	756.36	610.49	534.55	553.11	1015.04	521.57	677.90
Low molecular weight PAHs	µg/kg		552	3160	713.77	963.64	704.12	676.36	509.16	921.05	713.73	644.19
High Molecular weight PAHs	µg/kg		1700	9600	1938.41	2461.82	2037.45	1949.09	1630.04	2928.57	1964.71	1925.09
Total PAHs	µg/kg		4000	45000	4496.38	5694.55	4520.60	4323.64	3648.35	6691.73	4509.80	4265.92
Miscellaneous												
Moisture Content	%	1	n/a	n/a	76.70	76.90	76.10	77.20	77.00	76.30	78.20	76.80
Free Cyanide	mg/kg	1	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Total Cyanide	mg/kg	1	n/a	n/a	<LOR	<LOR	<LOR	1.00	1.00	<LOR	<LOR	<LOR
Total Organic Carbon	%	0.02	n/a	n/a	2.76	2.75	2.67	2.75	2.73	2.66	2.55	2.67

Appendix 4: Concentrations of BTEXs, TPHs, PAHs and other substances measured in SPM samples from the Sediment Traps deployed at Sites SS1, SS2 and SS3 between 22 May and 5 June 2009 (3rd Deployment). Note that concentrations of organic compounds that are above the Limit of Reporting (LOR) have been normalised to 1% total organic carbon. Highlighted values exceed the ANZECC/ARMCANZ (2000) ISQG-Low Trigger values. (n/a = no ISQG-Low or High guidelines; <LOR is below the Limit of Reporting).

Analyte					Site								
	Units	LOR	ISQG-Low	SQG-High	SS1			SS2			SS3		
				Replicate	1	2	3	1	2	3	1	2	3
BTEX													
Benzene	mg/kg	0.2	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Toluene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Ethylbenzene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
meta- & para-Xylene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
ortho-Xylene	mg/kg	0.5	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Total Petroleum Hydrocarbons													
C6 - C9 Fraction	mg/kg	10	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
C10 - C14 Fraction	mg/kg	50	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
C15 - C28 Fraction	mg/kg	100	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
C29 - C36 Fraction	mg/kg	100	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
TPH(V)/BTEX Surrogates													
1.2-Dichloroethane-D4	%	0.2	n/a	n/a	31.46	30.00	29.16	33.64	28.79	29.03	31.00	30.97	29.35
Toluene-D8	%	0.2	n/a	n/a	29.31	27.76	26.60	31.46	27.69	26.79	29.03	28.60	27.76
4-Bromofluorobenzene	%	0.2	n/a	n/a	30.16	29.38	27.07	32.40	28.07	27.91	29.07	29.47	28.04
Polycyclic Aromatic Hydrocarbons													
3-Methylcholanthrene	µg/kg	10	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
2-Methylnaphthalene	µg/kg	10	n/a	n/a	12.46	12.46	12.46	12.46	12.46	9.35	12.46	12.46	9.35
7.12-Dimethylbenz(a)anthracene	µg/kg	10	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Acenaphthene	µg/kg	10	16	500	6.23	6.23	6.23	6.23	6.23	3.12	6.23	6.23	6.23
Acenaphthylene	µg/kg	10	44	640	68.54	84.11	71.65	77.88	87.23	65.42	77.88	99.69	71.65
Anthracene	µg/kg	10	85	1100	24.92	28.04	21.81	28.04	31.15	24.92	31.15	34.27	24.92
Benz(a)anthracene	µg/kg	10	261	1600	84.11	105.92	84.11	109.03	118.38	87.23	112.15	133.96	102.80
Benzo(a)pyrene	µg/kg	10	430	1600	190.03	230.53	186.92	230.53	264.80	186.92	227.41	261.68	199.38
Benzo(b)fluoranthene	µg/kg	10	n/a	n/a	174.45	218.07	158.88	249.22	255.45	171.34	230.53	283.49	186.92
Benzo(e)pyrene	µg/kg	10	n/a	n/a	99.69	118.38	96.57	124.61	140.19	99.69	118.38	133.96	102.80
Benzo(g.h.i)perylene	µg/kg	10	n/a	n/a	102.80	115.26	93.46	102.80	149.53	109.03	124.61	118.38	93.46
Benzo(k)fluoranthene	µg/kg	10	n/a	n/a	87.23	93.46	74.77	118.38	112.15	90.34	84.11	81.00	118.38
Chrysene	µg/kg	10	384	2800	93.46	112.15	90.34	118.38	127.73	96.57	118.38	137.07	99.69
Coronene	µg/kg	10	n/a	n/a	12.46	12.46	9.35	15.58	18.69	15.58	18.69	15.58	12.46
Dibenz(a.h)anthracene	µg/kg	10	63	2600	34.27	37.38	31.15	34.27	46.73	34.27	40.50	37.38	31.15
Fluoranthene	µg/kg	10	600	5100	127.73	168.22	140.19	186.92	214.95	143.30	183.80	208.72	152.65
Fluorene	µg/kg	10	19	540	12.46	12.46	12.46	12.46	12.46	9.35	12.46	15.58	12.46
Indeno(1.2.3.cd)pyrene	µg/kg	10	n/a	n/a	90.34	102.80	84.11	93.46	127.73	93.46	105.92	105.92	81.00
N-2-Fluorenyl Acetamide	µg/kg	100	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Naphthalene	µg/kg	10	160	2100	21.81	24.92	21.81	28.04	24.92	15.58	24.92	24.92	21.81
Perylene	µg/kg	10	n/a	n/a	37.38	43.61	34.27	43.61	49.84	37.38	43.61	49.84	37.38
Phenanthrene	µg/kg	10	240	1500	46.73	59.19	46.73	62.31	74.77	49.84	65.42	71.65	56.07
Pyrene	µg/kg	10	665	2600	196.26	249.22	199.38	267.91	311.53	208.72	274.14	302.18	224.30
Low molecular weight PAHs	µg/kg		552	3160	193.15	227.41	193.15	227.41	249.22	177.57	230.53	264.80	202.49
High Molecular weight PAHs	µg/kg		1700	9600	725.86	903.43	732.09	947.04	1084.11	757.01	956.39	1081.00	809.97
Total PAHs	µg/kg		4000	45000	1523.36	1834.89	1476.64	1922.12	2186.92	1551.40	1912.77	2133.96	1644.86
Miscellaneous													
Moisture Content	%	1	n/a	n/a	78.20	77.00	77.70	77.10	76.80	77.30	77.10	76.30	76.30
Free Cyanide	mg/kg	1	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Total Cyanide	mg/kg	1	n/a	n/a	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Total Organic Carbon	%	0.02	n/a	n/a	2.42	2.30	2.64	1.78	2.65	2.10	3.21	1.48	2.70

Appendix 5: Proportion of each of the replicate sediment samples collected at the 16 study sites passing through sieves with mesh sizes varying from 75 µm to 9.5 mm. Wet sieve method only.

		Location/Site															
		Proposed Marina Location															
Sieve Mesh Size	Site	BG1		BG2		BG3		BG4		BG5		BG6		BG7		BG8	
	Replicate	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
75 µm		68	72	23	25	12	13	19	21	18	18	4	3	1	1	1	1
150 µm		62	66	14	17	4	4	8	10	9	9	2	1		1		
300 µm		44	47	5	7	2	2	2	4	5	4	1	1				
425 µm		21	24	1	4	1	1	1	3	3	3	1	1				
600 µm		4	4		3	1	1	1	2	2	2		1				
1180 µm					2	1			2	1							
2.36 mm					2				2	1							
4.75 mm					2				1								
9.5 mm					2												
Median Grain Size (mm)		0.3	0.3	<0.075	<0.075	<0.075	<0.075	<0.075	<0.075	<0.075	<0.075	<0.075	<0.075	<0.075	<0.075	<0.075	<0.075
% Fines		32	28	77	75	88	87	81	79	82	82	96	97	99	99	99	99
% Sand		68	72	23	23	12	13	19	19	17	18	4	3	1	1	1	1

		Location/Site															
		Kendall Bay South				Kisisng Point Bay						Sydney Rowing Club					
Sieve Mesh Size	Site	BG9		BG10		KPB1		KPB2		KPB3		SRC1		SRC2		SRC3	
	Replicate	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
75 µm		7	7	7	4	8	9	1	1	2	2	53	58	43	45	48	42
150 µm		2	2	2	1	5	6	1		1	1	44	49	35	38	40	35
300 µm		1	1	1	1	4	4			1	1	20	23	17	20	19	16
425 µm				1		3	2	2			1	1	7	8	6	6	4
600 µm				1		2	1			1		1	1	1	1	1	
1180 µm						1	1							1			
2.36 mm						1											
4.75 mm																	
9.5 mm																	
Median Grain Size (mm		<0.075	<0.075	<0.075	<0.075	<0.075	<0.075	<0.075	<0.075	<0.075	<0.075	0.15	0.15	<0.075	<0.075	<0.075	<0.075
% Fines		93	93	93	96	92	91	99	99	98	98	47	42	57	55	52	58
% Sand		7	7	7	4	7	9	1	1	2	2	53	58	43	45	48	42

Appendix 6: Total concentrations (µg/L) of heavy metals in estuarine water samples collected from four sites (SG5, SG7, SG9 and SG12) within the Proposed Marina Location at low and high tide on (a) 2 July and (b) 6 July 2009. Determinations based on OCR-ICPMS. Values in grey are equal to or above the 95% trigger value.

(a) Samples collected on 2 July 2009

Analyte	LOR	ANZECC (2000) 95% trigger vlaue	Date/Tide/Site 02/07/09							
			Low Tide				High Tide			
			SG5	SG7	SG9	SG12	SG5	SG7	SG9	SG12
Arsenic	0.50		1.5	1.5	1.4	1.55	1.6	1.8	1.6	1.6
Cadmium	0.20	5.5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	0.50	27.4	0.7	0.85	0.9	0.8	0.7	0.65	0.55	1.05
Copper	1.00	1.3	3	5	3.5	3.5	3	3.5	3	3
Lead	0.20	4.4	1.5	2.2	2.75	2.65	1.45	1.45	1.4	2.45
Nickel	0.50	70.0	0.75	0.95	1	1.1	0.6	0.6	0.65	0.7
Zinc	5.00	15.0	13	15.5	13	15	11.5	11.5	12	14.5
Mercury	0.0001	0.7	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

(b) Samples collected on 6 July 2009

Analyte	LOR	ANZECC (2000) 95% trigger vlaue	Date/Tide/Site 06/07/09							
			Low Tide				High Tide			
			SG5	SG7	SG9	SG12	SG5	SG7	SG9	SG12
Arsenic	0.50		2.25	2.85	1.5	1.45	1.65	1.85	1.75	2
Cadmium	0.20	5.5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	0.50	27.4	1.05	1.1	0.8	0.8	0.85	0.85	0.8	0.95
Copper	1.00	1.3	4	4	4	5	4.5	4.5	5	7
Lead	0.20	4.4	1.45	1.5	1.4	1.25	1.2	1.25	1.15	1.25
Nickel	0.50	70.0	<0.5	0.75	0.8	0.75	0.8	<0.5	<0.5	<0.5
Zinc	5.00	15.0	11	12	13	11.5	9.5	9.5	9	9.5
Mercury	0.0001	0.7	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Appendix 7: Numbers of each infaunal taxon found in the grab samples collected on 6 and 7 May 2009 at each of the study sites: the Proposed Marina Location (BG 1- BG8), southern end of Kendall Bay (BG 9 - BG10) and Reference Locations, Sydney Rowing Club (SCR1-Src2) and Kissing Point Bay (KPB1-KBP2).

Taxon	Location	Proposed Marina											
	Site	BG1				BG2				BG3			
	Replicate	1	2	3	4	1	2	3	4	1	2	3	4
Polychaete worms													
Capitellidae		7	2	8	1	13	1	0	5	2	3	3	0
Cirratulidae		0	0	1	0	0	0	0	0	0	0	0	0
Glyceridae		0	0	0	0	0	1	0	0	0	0	0	0
Hesionidae		0	0	0	0	0	0	0	0	0	0	0	0
Lumbrineridae		0	0	4	0	0	0	1	1	0	1	1	0
Nephtyidae		4	5	5	3	1	0	0	0	2	1	2	0
Nereididae		0	0	0	0	4	0	1	0	0	0	0	0
Oenonidae		0	0	0	1	0	0	0	0	0	3	1	1
Opheliidae		0	0	0	0	0	0	0	0	0	0	0	0
Paraonidae		0	0	0	0	0	0	0	0	0	0	0	0
Phyllodocidae		0	0	0	0	0	0	0	0	0	0	0	0
Polynoidae		0	0	0	0	0	0	0	0	0	0	0	0
Sabellidae		0	0	0	0	4	0	0	0	0	1	0	0
Spionidae		0	0	0	0	2	0	0	0	0	0	0	0
Syllidae		1	0	0	1	0	0	0	0	0	0	0	0
Terebellidae		0	0	0	0	0	0	0	0	0	0	0	0
Trichobranchidae		1	0	0	0	3	0	0	1	0	0	0	0
Crustaceans													
Aoridae/Isaeidae/Photidae		0	0	0	0	0	0	0	0	0	0	0	0
Corophiidae		0	0	0	0	0	0	0	0	0	0	0	0
Melitidae		0	0	0	0	0	0	0	0	0	0	0	0
Anthuridae		1	0	0	0	0	0	0	0	0	0	0	0
Penaeidae		0	0	0	0	0	0	0	0	0	0	0	0
Alpheidae		0	0	0	0	0	0	0	0	0	0	0	0
Callianassidae		1	1	0	0	0	0	0	0	0	0	1	0
Grapsidae		0	0	1	0	0	0	0	0	0	0	0	0
Molluscs													
Nassariidae		1	0	0	0	0	0	1	0	0	0	0	1
Unidentified Opistobranch		0	0	0	0	0	0	0	0	0	0	0	0
Unidentified Nudibranch		0	0	0	0	0	0	0	0	0	0	0	0
Cardiidae		0	0	0	0	0	0	0	0	0	0	0	0
Laternulidae		0	0	0	0	1	0	0	0	0	0	1	0
Leptonidae		0	0	0	0	0	0	0	0	0	0	0	0
Lucinidae		0	0	0	0	0	0	0	0	0	0	0	0
Mactridae		4	5	0	11	11	1	12	0	7	1	6	2
Veneridae		0	0	0	0	0	0	0	0	0	0	0	0
Other worms													
Nematoda		0	0	0	0	0	0	0	0	0	0	0	0
Nemertea		0	0	0	0	1	0	0	0	0	0	0	1
Other phyla													
Anthozoa: Actinaria		0	0	0	0	0	0	0	0	0	0	1	0
Ascidiacea		0	0	0	0	0	0	0	0	0	0	0	0
Bryozoa		0	0	0	0	0	0	0	0	0	0	0	0
Fish: Gobiidae		0	0	0	0	0	0	0	0	0	0	0	0
Total number of animals		20	13	19	17	40	3	15	7	11	10	16	5
Total number of taxa		8	4	5	5	9	3	4	3	3	6	8	4

Continued…

Appendix 7 continued:

Taxon	Location	Proposed Marina											
	Site	BG4				BG5				BG6			
	Replicate	1	2	3	4	1	2	3	4	1	2	3	4
Polychaete worms													
Capitellidae		2	2	5	4	10	3	2	5	0	3	3	3
Cirratulidae		0	0	0	0	0	0	0	0	0	0	0	0
Glyceridae		0	0	0	0	1	0	0	0	0	0	0	0
Hesionidae		0	0	0	1	0	0	0	1	0	0	0	0
Lumbrineridae		0	0	0	2	1	1	0	0	0	1	0	2
Nephtyidae		1	2	1	2	1	2	0	1	0	0	0	2
Nereididae		0	0	1	0	0	0	0	0	0	0	2	2
Oenonidae		1	0	0	0	0	1	0	1	0	0	0	0
Opheliidae		0	0	0	0	1	0	0	0	0	0	0	0
Paraonidae		0	0	0	0	0	0	0	0	0	0	0	0
Phyllodocidae		0	0	0	0	0	0	0	0	0	0	0	0
Polynoidae		0	0	0	0	1	0	0	0	0	0	1	0
Sabellidae		0	0	10	1	0	1	1	0	0	0	0	0
Spionidae		0	0	1	0	0	0	1	0	0	3	0	2
Syllidae		0	0	0	1	0	0	0	1	0	0	1	0
Terebellidae		0	0	0	0	0	0	0	0	0	1	0	0
Trichobranchidae		1	0	0	1	0	0	0	0	0	0	0	0
Crustaceans													
Aoridae/Isaeidae/Photidae		0	0	0	0	0	0	0	0	0	0	0	0
Corophiidae		0	0	0	0	0	0	1	0	0	0	0	0
Melitidae		0	0	0	0	0	0	0	0	0	0	0	0
Anthuridae		0	0	0	0	0	0	0	0	0	0	0	0
Penaeidae		0	0	0	0	0	0	0	0	0	0	0	0
Alpheidae		0	0	0	0	0	0	0	0	0	0	0	1
Callianassidae		0	0	0	0	1	0	1	0	0	0	0	0
Grapsidae		0	0	0	0	0	0	0	0	0	0	0	0
Molluscs													
Nassariidae		0	2	0	0	0	0	0	0	0	0	0	0
Unidentified Opistobranch		0	0	0	0	0	0	0	0	0	0	0	0
Unidentified Nudibranch		0	0	0	0	0	0	0	0	0	0	0	0
Cardiidae		0	0	0	0	0	0	0	0	0	0	0	0
Laternulidae		0	0	0	0	0	0	0	0	0	0	0	0
Leptonidae		0	0	0	0	0	0	0	0	0	0	0	0
Lucinidae		0	0	1	0	0	0	0	0	0	0	0	0
Mactridae		4	2	0	4	1	1	3	0	5	6	6	2
Veneridae		0	0	0	1	0	0	0	0	0	0	0	1
Other worms													
Nematoda		0	0	0	0	0	0	0	0	0	0	0	0
Nemertea		0	1	0	0	1	0	0	0	0	0	2	1
Other phyla													
Anthozoa: Actinaria		0	0	0	0	0	0	0	0	0	0	0	0
Ascidiacea		0	0	0	0	0	0	0	0	0	0	0	0
Bryozoa		0	0	0	0	0	0	0	0	0	0	0	0
Fish: Gobiidae		0	1	0	2	0	0	0	0	0	0	0	0
Total number of animals		9	10	19	19	18	9	9	9	5	14	15	16
Total number of taxa		5	6	6	10	9	6	6	5	1	5	6	9

Continued…

Appendix 7 continued:

Taxon	Location	Proposed Marina								Southern Kendall Bay			
	Site	BG7				BG8				BG9			
	Replicate	1	2	3	4	1	2	3	4	1	2	3	4
Polychaete worms													
Capitellidae		0	0	2	0	0	0	0	0	0	2	0	3
Cirratulidae		0	0	0	0	0	0	0	0	0	0	0	0
Glyceridae		0	0	0	0	0	0	0	0	0	0	0	0
Hesionidae		0	0	0	0	0	0	0	0	0	0	0	0
Lumbrineridae		0	0	1	0	1	0	0	0	0	1	0	0
Nephtyidae		2	4	2	0	3	3	0	0	6	2	5	6
Nereididae		1	0	0	0	1	0	1	0	0	0	0	0
Oenonidae		1	0	0	0	0	0	0	0	0	0	0	0
Opheliidae		0	0	5	2	7	0	0	1	0	0	0	0
Paraonidae		0	1	0	0	0	0	0	0	0	0	0	0
Phyllodocidae		0	0	0	0	0	1	0	0	0	0	0	0
Polynoidae		0	0	0	0	3	3	0	0	0	0	0	0
Sabellidae		0	1	0	0	4	0	0	0	0	0	0	0
Spionidae		0	1	0	2	5	0	0	0	0	0	0	2
Syllidae		0	0	0	0	0	0	0	0	0	0	0	0
Terebellidae		0	0	0	0	0	0	0	0	0	0	0	0
Trichobranchidae		0	0	0	0	0	0	0	0	0	0	0	0
Crustaceans													
Aoridae/Isaeidae/Photidae		0	0	0	0	0	0	0	0	0	0	0	0
Corophiidae		0	0	0	0	0	0	0	0	0	0	0	0
Melitidae		0	0	0	0	0	0	0	0	0	0	0	0
Anthuridae		0	0	0	0	0	0	0	0	0	0	0	0
Penaeidae		0	0	0	0	0	0	0	0	0	1	0	0
Alpheidae		0	0	0	0	0	0	0	0	0	0	2	0
Callianassidae		0	0	0	0	0	0	0	0	0	0	0	0
Grapsidae		0	0	0	0	0	0	0	0	0	0	0	0
Molluscs													
Nassariidae		0	0	0	0	0	0	0	0	0	1	0	0
Unidentified Opistobranch		0	0	0	0	0	0	0	0	0	0	0	0
Unidentified Nudibranch		0	0	0	0	0	0	0	0	0	0	0	0
Cardiidae		0	0	0	0	0	0	0	0	0	0	0	1
Laternulidae		0	0	0	0	0	0	0	2	0	0	0	0
Leptonidae		0	0	0	0	0	0	0	0	0	0	0	0
Lucinidae		0	0	1	0	0	0	0	0	0	0	0	0
Mactridae		0	0	0	2	10	6	0	0	0	0	0	2
Veneridae		0	0	0	1	0	0	0	0	1	2	0	0
Other worms													
Nematoda		0	0	0	0	0	0	0	0	0	0	0	0
Nemertea		0	0	0	0	0	1	0	0	0	1	0	1
Other phyla													
Anthozoa: Actinaria		0	0	0	0	0	0	0	0	0	0	0	0
Ascidiacea		0	0	0	0	0	0	0	0	0	0	0	0
Bryozoa		0	0	0	0	0	0	0	0	0	0	0	0
Fish: Gobiidae		0	0	0	0	0	0	0	0	0	0	0	1
Total number of animals		4	7	11	7	34	14	1	3	7	10	7	16
Total number of taxa		3	4	5	4	8	5	1	2	2	7	2	7

Continued…

Appendix 7 continued:

Taxon	Location	Southern Kendall Bay				Sydney Rowing Club							
	Site	BG10				SRC1				SRC2			
	Replicate	1	2	3	4	1	2	3	4	1	2	3	4
Polychaete worms													
Capitellidae		0	0	2	2	36	9	31	16	16	14	13	2
Cirratulidae		0	0	1	0	0	0	0	0	0	1	0	0
Glyceridae		0	0	0	0	0	0	0	0	0	0	0	0
Hesionidae		0	0	0	0	0	0	0	0	0	0	0	0
Lumbrineridae		1	1	0	1	2	0	2	3	1	1	0	0
Nephtyidae		9	14	14	11	0	3	3	1	3	6	3	5
Nereididae		0	0	0	0	1	0	0	0	0	0	1	0
Oenonidae		0	0	0	0	0	0	0	0	0	0	0	0
Opheliidae		3	0	3	0	0	0	0	0	0	0	0	0
Paraonidae		0	5	2	0	0	0	0	0	0	0	0	1
Phyllodocidae		0	0	0	0	1	0	0	0	2	0	0	0
Polynoidae		0	0	1	0	0	0	0	0	0	0	0	0
Sabellidae		0	0	0	0	0	0	0	0	1	0	0	0
Spionidae		0	0	1	0	0	1	0	2	0	0	0	0
Syllidae		0	0	0	0	1	0	0	0	0	0	0	0
Terebellidae		0	0	0	0	0	0	0	0	0	0	0	0
Trichobranchidae		0	0	0	0	0	0	0	1	0	1	1	0
Crustaceans													
Aoridae/Isaeidae/Photidae		0	0	0	0	0	0	0	0	0	0	0	0
Corophiidae		0	0	0	0	0	0	0	0	0	0	0	0
Melitidae		0	0	1	0	0	0	0	0	0	0	0	0
Anthuridae		0	0	0	0	0	0	0	0	0	0	0	0
Penaeidae		0	0	0	0	0	0	0	0	0	0	0	0
Alpheidae		0	2	0	1	0	1	0	0	0	0	1	0
Callianassidae		0	0	0	0	1	0	1	1	0	0	0	0
Grapsidae		0	0	0	0	0	0	0	0	0	0	0	0
Molluscs													
Nassariidae		0	0	0	0	1	0	1	0	3	0	0	0
Unidentified Opistobranch		0	0	0	0	0	1	2	0	0	0	0	0
Unidentified Nudibranch		0	0	0	0	0	0	1	0	0	0	0	0
Cardiidae		0	0	0	0	0	0	0	0	0	0	0	0
Laternulidae		0	0	0	0	0	0	1	0	0	0	0	0
Leptonidae		0	0	0	0	0	0	0	0	0	0	0	0
Lucinidae		0	0	0	0	0	0	0	0	0	0	0	0
Mactridae		1	2	1	1	1	0	1	0	4	4	2	0
Veneridae		0	0	0	0	0	0	0	0	0	0	0	0
Other worms													
Nematoda		0	0	0	0	0	0	0	0	0	0	0	0
Nemertea		3	8	0	3	1	0	0	2	1	0	0	0
Other phyla													
Anthozoa: Actinaria		0	0	0	0	0	0	0	0	0	0	0	0
Ascidiacea		0	0	0	0	0	0	0	0	0	0	0	0
Bryozoa		0	0	0	0	1	0	1	1	0	0	0	0
Fish: Gobiidae		0	0	0	0	0	1	0	0	0	0	0	0
Total number of animals		17	32	26	19	46	16	44	27	31	27	21	8
Total number of taxa		5	6	9	6	10	6	10	8	8	6	6	3

Continued…

Appendix 7 continued:

Taxon	Location	Sydney Rowing Club				Kissing Point Bay							
	Site	SRC3				KPB1				KPB2			
	Replicate	1	2	3	4	1	2	3	4	1	2	3	4
Polychaete worms													
Capitellidae		21	9	3	0	1	1	0	0	0	1	0	1
Cirratulidae		0	2	0	0	1	1	0	0	0	0	0	0
Glyceridae		0	0	0	0	0	0	0	0	0	0	0	0
Hesionidae		0	0	0	0	0	0	0	0	0	0	0	0
Lumbrineridae		1	0	1	0	0	1	0	0	0	0	1	0
Nephtyidae		2	2	2	0	7	4	5	3	11	6	5	7
Nereididae		3	0	0	0	0	0	0	0	2	0	0	0
Oenonidae		0	0	0	0	0	0	1	0	0	0	0	1
Opheliidae		0	0	0	0	0	0	0	0	0	0	0	1
Paraonidae		1	0	0	0	0	0	0	0	1	1	0	0
Phyllodocidae		0	0	0	0	0	0	1	0	0	0	0	0
Polynoidae		0	0	0	0	0	0	0	0	0	0	0	0
Sabellidae		1	4	1	0	0	0	0	0	0	0	0	1
Spionidae		0	0	0	1	0	1	0	0	0	0	0	0
Syllidae		3	2	0	0	0	0	0	0	0	0	0	0
Terebellidae		0	0	0	0	0	0	0	0	0	0	0	0
Trichobranchidae		0	0	0	0	0	0	1	0	0	0	0	0
Crustaceans													
Aoridae/Isaeidae/Photidae		0	0	0	0	1	0	0	0	0	0	0	0
Corophiidae		0	0	0	0	0	0	0	0	0	0	0	0
Melitidae		0	0	0	0	0	0	0	0	0	0	0	0
Anthuridae		0	0	0	0	0	0	0	0	0	0	0	0
Penaeidae		0	0	0	0	0	1	0	0	0	0	0	0
Alpheidae		0	0	0	0	0	0	0	0	0	0	0	0
Callianassidae		1	1	1	0	0	0	0	0	0	0	0	0
Grapsidae		0	0	0	0	0	0	0	0	0	0	0	0
Molluscs													
Nassariidae		1	1	0	0	0	3	0	0	0	0	0	0
Unidentified Opistobranch		0	0	0	0	0	0	0	0	1	0	0	0
Unidentified Nudibranch		0	0	0	0	0	0	0	0	0	0	0	0
Cardiidae		0	0	0	0	0	0	0	0	0	0	0	0
Laternulidae		0	0	0	0	0	1	1	4	0	0	0	0
Leptonidae		0	0	0	0	0	0	0	0	0	0	0	2
Lucinidae		0	0	0	0	0	0	0	0	0	0	0	0
Mactridae		0	8	0	1	0	1	0	2	3	0	0	0
Veneridae		0	0	1	1	1	1	0	1	0	0	0	0
Other worms													
Nematoda		0	2	0	0	0	0	0	0	0	0	0	0
Nemertea		0	0	1	0	0	1	0	0	0	1	0	0
Other phyla													
Anthozoa: Actinaria		0	0	0	0	0	0	0	0	0	0	0	0
Ascidiacea		0	1	0	0	0	0	0	0	0	0	0	0
Bryozoa		0	1	0	0	0	0	0	0	0	0	0	0
Fish: Gobiidae		0	0	0	0	0	0	0	0	0	0	0	0
Total number of animals		34	33	10	3	11	16	9	10	18	9	6	13
Total number of taxa		9	11	7	3	5	11	5	4	5	4	2	6

Continued…

Appendix 7 continued:

Taxon	Location	Kissing Point Bay			
	Site	KPB3			
	Replicate	1	2	3	4
Polychaete worms					
Capitellidae		0	2	2	0
Cirratulidae		0	0	0	0
Glyceridae		0	0	0	0
Hesionidae		0	0	0	0
Lumbrineridae		0	2	2	0
Nephtyidae		6	8	8	10
Nereididae		0	0	0	0
Oenonidae		0	0	0	0
Opheliidae		0	0	0	0
Paraonidae		0	0	0	0
Phyllodocidae		0	0	0	0
Polynoidae		0	0	1	0
Sabellidae		0	0	0	0
Spionidae		0	3	1	0
Syllidae		0	0	0	0
Terebellidae		0	0	0	0
Trichobranchidae		1	0	0	0
Crustaceans					
Aoridae/Isaeidae/Photidae		0	0	0	0
Corophiidae		0	0	0	0
Melitidae		0	0	0	0
Anthuridae		0	0	0	0
Penaeidae		0	0	0	0
Alpheidae		2	0	1	0
Callianassidae		0	0	0	0
Grapsidae		0	0	0	0
Molluscs					
Nassariidae		0	0	0	0
Unidentified Opistobranch		0	0	0	0
Unidentified Nudibranch		0	0	0	0
Cardiidae		0	0	0	0
Laternulidae		0	0	0	1
Leptonidae		0	0	0	0
Lucinidae		0	0	0	0
Mactridae		2	1	0	1
Veneridae		0	0	0	0
Other worms					
Nematoda		0	0	0	0
Nemertea		1	1	1	1
Other phyla					
Anthozoa: Actinaria		0	0	0	0
Ascidiacea		0	0	0	0
Bryozoa		0	0	0	0
Fish: Gobiidae		1	0	0	0
Total number of animals		13	17	16	13
Total number of taxa		6	6	7	4

Appendix 8: Number of each taxon found in the beam trawl samples collected on 19 and 20 May 2009 at each of the study sites at the Proposed Marina Location, southern end of Kendall Bay and Reference Locations, Sydney Rowing Club and Kissing Point Bay.

Taxon		Location	Kendall Bay								
		Site	North			Mid			South		
		Replicate	1	2	3	1	2	3	1	2	3
Fish	**Common Name**										
Ambassis sp.	Glassfish		0	0	0	0	0	0	0	0	0
Pseudorhombus jenynsii	Small-toothed		1	0	0	0	0	0	0	0	0
Arenigobius bifrenatus	Bridled goby		0	0	0	0	0	1	0	0	0
Bathygobius kreffti	Krefft's goby		0	0	0	0	0	0	0	0	0
Favonigobius exquisitus	Exquisite goby		8	0	8	22	24	26	10	3	6
Gobiopterus semivestitus	Glass goby		0	0	0	0	0	0	2	0	0
Redigobius macrostoma	Large-mouth goby		0	0	0	0	0	0	5	0	0
Centropogon australis	Eastern fortescue		1	0	0	0	0	0	0	0	0
Polychaetes											
Capitellidae			0	0	0	1	0	0	0	0	0
Cirratulidae			0	1	0	0	0	0	1	0	0
Lumbrineridae			0	0	0	2	0	0	1	0	3
Nephtyidae			0	0	0	1	0	0	40	0	0
Opheliidae			0	0	0	0	0	0	0	0	0
Polynoidae			0	0	1	0	0	0	0	0	0
Sabellidae			1	1	2	5	3	0	0	0	0
Serpulidae			1	1	1	1	0	0	0	1	0
Sigalionidae			0	0	0	0	0	0	0	0	0
Spionidae			0	0	0	30	1	1	6	0	10
Syllidae			1	0	3	0	0	0	1	0	0
Terebellidae			0	0	1	0	0	0	0	0	0
Trichobranchidae			0	0	0	0	0	0	1	0	1
Crustaceans											
Haplostylis dakini			94	20	3	62	106	44	23	0	187
Ampithoidae			0	0	0	0	0	0	0	0	0
Aoridae			7	5	2	0	0	0	0	0	0
Caprellidae			1	0	0	1	0	0	0	0	0
Corophium sp.			36	100	64	62	0	32	0	0	0
Eusiridae			0	2	0	0	0	0	0	0	0
Leucothoidae			0	0	3	0	0	2	0	0	0
Oedicerotidae			3	1	3	4	5	4	0	0	1
Synopiidae			1	0	0	0	0	0	0	0	0
Cirolanidae			0	0	0	0	0	0	0	0	0
Munnidae			0	1	0	0	0	0	0	0	0
Paranthuridae			2	0	0	0	0	0	0	0	0
Sphaeromatidae			0	3	0	1	0	0	0	0	0
Leptocheliidae			0	0	3	0	0	0	0	0	0
Tanaidae			6	3	12	8	0	0	0	0	0
Bodotriidae			1	0	0	0	0	0	0	0	0
Metapenaeus benettae	Greasyback prawn		17	11	22	11	18	24	10	0	7
Alpheidae	Snapping shrimp		0	0	1	0	0	0	1	1	1
Philocherus sp.			26	5	43	24	78	33	2	0	43
Hippolytidae			16	5	1	9	3	2	0	1	2
Callianassidae	Ghost shrimp		0	0	0	0	1	0	0	0	0
Pachycheles grant	Porcelain crab		0	15	7	1	0	1	0	5	3
Grapsidae			1	0	1	0	0	2	3	0	0
Halicarcinus ovatus			0	0	0	1	0	0	4	0	0
Xanthidae			0	1	0	0	0	0	0	0	0
Balanidae			0	0	1	0	0	0	0	0	0
Cypridinidae			0	0	1	0	0	1	0	0	0

Continued…

Appendix 8 continued

Taxon		Location	Kendall Bay								
		Site	North			Mid			South		
		Replicate	1	2	3	1	2	3	1	2	3
Molluscs											
Sepiolidae	Dumpling squid		0	0	1	0	0	0	0	0	0
Columbellidae			0	0	0	0	0	0	0	0	0
Bedeva hanleyi	Oyster drill		0	0	3	4	5	2	0	0	0
Nassarius burchardi	Dog whelk		4	0	22	19	18	9	1	8	5
Pyramidellidae			0	0	1	0	0	0	0	0	0
unidentified Opisthobranch			0	0	0	2	0	0	0	0	0
Philinidae			0	0	1	0	0	1	0	0	0
unidentified Nudibranch			0	0	3	0	0	0	0	0	0
Anadora trapezia	Sydney cockle		0	4	10	0	0	0	0	0	0
Fulvia tenuicostata	Strawberry cockle		0	1	1	5	3	1	1	0	2
Galeommatidae			0	0	0	1	0	0	0	0	0
Hiatella australis			0	0	0	0	0	0	0	0	0
Laternula creccina	Lantern shell		0	1	0	5	3	3	3	0	11
Lucinidae			0	0	0	0	0	0	0	0	1
Spisula trigonella			63	15	179	309	579	157	103	23	266
Musculus varicosus			0	0	1	0	0	0	0	0	0
Theora fragilis			0	0	0	25	7	2	3	0	10
Paphia undulata			0	0	0	0	2	1	0	0	0
Echinoderms			0	0	0	0	0	0	0	0	0
Ophiuroidea			0	1	0	0	0	0	0	0	0
Other worm phyla			0	0	0	0	0	0	0	0	0
Nematoda			0	0	2	0	0	0	0	0	0
Nemertea			0	4	1	11	6	5	84	0	13
Oligochaeta			0	0	0	0	0	0	0	0	0
Other phyla			0	0	0	0	0	0	0	0	0
Styela sp.			0	1	1	0	0	1	0	1	0
Porifera			0	0	1	0	0	0	0	0	0
Aurelia aurita	Moon jelly		0	0	0	0	0	0	0	0	2
Total number of taxa			18	23	34	26	16	21	18	7	18
Total number of individuals			281	202	402	605	838	328	288	40	568

Continued…

Appendix 8 continued

Taxon	Location	Sydney Rowing Club			Kissing Point Bay		
	Site						
	Replicate	1	2	3	1	2	3
Fish	**Common Name**						
Ambassis sp.	Glassfish	0	0	1	0	0	0
Pseudorhombus jenynsii	Small-toothed	0	0	0	0	1	0
Arenigobius bifrenatus	Bridled goby	0	0	0	1	0	0
Bathygobius kreffti	Krefft's goby	1	0	0	0	0	0
Favonigobius exquisitus	Exquisite goby	21	6	9	29	35	18
Gobiopterus semivestitus	Glass goby	0	35	0	0	0	4
Redigobius macrostoma	Large-mouth goby	0	4	0	4	1	0
Centropogon australis	Eastern fortescue	0	0	0	0	0	0
Polychaetes		0	0	0	0	0	0
Capitellidae		0	0	0	2	0	0
Cirratulidae		0	0	0	0	0	0
Lumbrineridae		3	0	12	3	0	0
Nephtyidae		1	0	2	12	4	1
Opheliidae		8	7	0	0	0	0
Polynoidae		0	0	0	0	0	0
Sabellidae		19	0	1	1	0	1
Serpulidae		0	1	0	0	0	0
Sigalionidae		0	0	1	0	0	0
Spionidae		7	0	1	1	0	2
Syllidae		0	4	0	1	0	0
Terebellidae		0	0	0	0	0	0
Trichobranchidae		2	0	3	0	0	0
Crustaceans		0	0	0	0	0	0
Haplostylis dakini		21	36	37	110	171	968
Ampithoidae		0	1	0	0	0	0
Aoridae		6	55	1	0	0	0
Caprellidae		0	36	0	0	0	0
Corophium sp.		32	446	3	0	0	0
Eusiridae		0	0	0	0	0	0
Leucothoidae		0	0	0	0	0	0
Oedicerotidae		4	2	1	0	0	0
Synopiidae		0	0	0	0	0	0
Cirolanidae		0	1	0	0	0	0
Munnidae		0	1	0	0	0	0
Paranthuridae		0	1	0	0	0	0
Sphaeromatidae		0	23	0	0	0	0
Leptocheliidae		0	0	0	0	0	0
Tanaidae		0	7	0	0	0	0
Bodotriidae		0	0	0	0	0	0
Metapenaeus benettae	Greasyback prawn	29	0	5	3	8	3
Alpheidae	Snapping shrimp	1	0	0	0	1	0
Philocherus sp.		8	8	99	3	1	5
Hippolytidae		2	113	0	0	0	0
Callianassidae	Ghost shrimp	0	0	0	0	0	0
Pachycheles grant	Porcelain crab	0	17	0	1	0	0
Grapsidae		0	0	0	0	0	1
Halicarcinus ovatus		2	1	3	1	0	0
Xanthidae		0	0	0	0	0	0
Balanidae		1	0	0	0	0	0
Cypridinidae		0	0	0	0	0	0

Continued…

Appendix87 continued

Taxon		Location	Sydney Rowing Club			Kissing Point Bay		
		Site						
		Replicate	1	2	3	1	2	3
Molluscs								
Sepiolidae	Dumpling squid		0	1	1	0	0	0
Columbellidae			0	2	0	0	0	0
Bedeva hanleyi	Oyster drill		2	2	1	0	0	0
Nassarius burchardi	Dog whelk		12	32	13	0	6	1
Pyramidellidae			0	0	0	0	0	0
unidentified Opisthobranch			0	0	0	0	0	0
Philinidae			1	0	0	0	0	0
unidentified Nudibranch			2	0	0	0	0	0
Anadora trapezia	Sydney cockle		0	22	0	0	0	0
Fulvia tenuicostata	Strawberry cockle		4	2	7	1	0	3
Galeommatidae			0	0	0	0	0	0
Hiatella australis			0	1	0	0	0	0
Laternula creccina	Lantern shell		2	1	3	17	1	7
Lucinidae			0	0	0	0	0	0
Spisula trigonella			148	58	276	402	194	351
Musculus varicosus			0	0	0	1	0	1
Theora fragilis			3	1	18	8	4	4
Paphia undulata			0	1	3	4	0	2
Echinoderms			0	0	0	0	0	0
Ophiuroidea			0	0	0	0	0	0
Other worm phyla			0	0	0	0	0	0
Nematoda			0	0	0	0	0	0
Nemertea			7	18	5	21	6	13
Oligochaeta			0	0	0	0	1	0
Other phyla			0	0	0	0	0	0
Styela sp.			0	1	0	0	0	0
Porifera			0	0	0	0	0	0
Aurelia aurita	Moon jelly		0	0	1	0	1	1
Total number of taxa			27	31	23	18	12	16
Total number of individuals			327	902	497	592	398	1364

Appendix 9: Number of each taxon found in seine net samples collected on 22 May 2009 at each of the study sites in Kendall Bay and at the Reference Locations, Sydney Rowing Club and Kissing Point Bay.

Taxon			Kendall Bay						Sydney Rowing Club		Kissing Point Bay	
Scientific Name	Common Name	Site	PML	PML	PML	KBS	KBS	KBS	SRC	SRC	KPB	KPB
		Rep	1	2	3	1	2	3	1	2	1	2
Fish												
Ambassis jacksoniensis	Port Jackson glassfish		0	30	0	39	93	9	0	0	117	1
Atherinosoma ogilbyi	Ogilby's hardyhead		0	0	0	2	0	1	21	256	9	0
Pseudorhombus jenynsii	Small-toothed flounder		0	0	0	0	0	0	2	0	1	0
Repomucenus calcaratus	Spotted dragonet		0	0	0	0	0	0	0	0	1	0
Hyperlophus vittatus	Sandy sprat		0	2	8	0	0	0	0	8	1	0
Gerres subfasciatus	Silver biddy		1	0	0	0	0	0	0	0	1	2
Arenigobius bifrenatus	Bridled goby		0	0	0	0	6	0	8	10	0	4
Bathygobius kreffti	Krefft's goby		0	0	0	0	0	1	0	0	2	0
Favonigobius exquisitus	Exquisite goby		0	1	1	49	342	45	38	32	110	42
Gobiopterus semivestitus	Transparent goby		0	46	73	18	186	42	144	210	263	1242
Redigobius macrostoma	Large-mouth goby		0	0	0	0	0	0	1	3	0	3
Unidentified goby			1	0	0	0	0	0	0	0	0	0
Monacanthus chinensis	Fan-bellied leatherjacket		0	0	0	0	0	0	2	0	0	0
Monacanthus sp.	leatherjacket		0	0	0	0	0	0	1	1	0	0
Liza argentea	Flat-tail mullet		3	0	9	0	17	1	0	0	0	0
Upeneus tragula	Bar-tailed goatfish		0	0	0	0	0	0	1	0	0	0
Platycephalus fuscus	Dusky flathead		0	0	0	0	0	0	0	0	0	1
Pomatomus saltator	Tailor		0	0	0	0	0	0	2	0	0	0
Centropogon australis	Eastern fortescue		0	0	0	0	0	0	2	0	1	1
Sillago maculata	Trumpeter whiting		5	2	0	0	3	2	1	4	6	5
Acanthopagrus australis	Yellowfin bream		0	0	0	0	0	1	0	0	0	0
Larval Sparidae			0	0	0	0	0	0	0	0	0	2
Stigmatopora nigra	Wide bodied pipefish		0	0	0	0	0	0	2	0	0	0
Pelates sexlineatus	Striped trumpeter		0	0	0	0	4	0	3	6	0	9
Larval Terapontidae			0	0	0	0	0	0	0	0	3	0
Tectractenos hamiltoni	Common toadfish		0	0	0	2	3	3	1	0	0	0
Crustaceans												
Mysidae	Haplostylis dakini		0	0	104	0	0	0	0	0	0	202
Corophiidae	Corophium sp.		0	0	3	1	0	0	0	0	0	0
Cymothoidae			0	0	0	0	0	0	0	1	0	0
Metapenaeus macleayi	Eastern school prawn		1	0	0	8	28	9	0	0	0	7
Metapenaeopsis sp.			0	0	0	0	3	0	0	0	0	0
Penaeus plebejus	Eastern king prawn		0	1	0	0	4	0	2	0	0	0
Alpheidae	Snapping shrimp		0	0	0	0	0	0	0	0	1	1
Hippolytidae			0	2	0	0	0	0	42	93	98	196
Acetes sibogae	Sergestid shrimp		1	0	0	0	634	0	0	0	77	6
Molluscs												
Euprymna sp.	Dumpling squid		0	0	0	0	0	0	1	2	0	0
Nassarius burchardi	Dog whelk		0	0	0	0	30	0	0	10	0	0
Spisula trigonella			0	0	0	0	116	0	0	2	0	0
Saccostrea glomerata	Sydney rock oyster		0	0	0	0	1	0	0	0	0	0
Other Phyla												
Styela sp.			0	0	0	0	0	0	0	14	0	0
Aurelia aurita	Moon jelly		0	1	0	0	0	0	1	1	0	0
Total number of taxa			6	8	6	7	15	10	19	16	15	16
Total number of animals			12	85	198	119	1470	114	275	653	691	1724