Technical Report F

Marine Ecology Investigations

Cardno Ecology Lab

Shaping the Future

Marine and Freshwater Studies

Offshore Artificial Reefs

Marine Ecology Investigations

Job Number: EL0809031 A

Prepared for:

Industry and Investment NSW

September 2009

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Cover Image: Still taken from Baited Remote Underwater Video Station, January 2009. Cardno Ecology Lab

Document Control

Job Number	Status	Date	Author		Reviewers	
EL0809031 A	Draft	31 August 2009	Kate Reeds Marcus Lincoln Smith	KR MLS	Arthur Dye/Craig Blount	AD/CB/ MLS
EL0809031 A	Final Draft	28 September 2009	Kate Reeds	KR MLS	Marcus Lincoln Smith	MLS

Executive Summary

The Department of Industry and Investment NSW (I&I NSW), with funding from the Recreational Fishing Trust, aim to improve recreational fishing opportunities in NSW through the development of offshore artificial reefs (OARs) at three metropolitan areas within NSW.

The proposal is subject to Part 3A of the *Environmental Planning and Assessment Act 1979* as it is considered to be of State planning significance. It will also be subject to approval under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the Commonwealth *Environment Protection* (*Sea Dumping*) *Act 1981*(*EP*(*SD*)*Act*). As such, the project is being assessed in the format of a single Environmental Assessment/ draft Public Environment Report (EA/draft PER) which assesses the requirements of both State and Commonwealth legislation.

The Department of Industry and Investment NSW, (previously the NSW Department of Primary Industries) has commissioned Cardno Ecology Lab Pty Ltd (formerly The Ecology Lab Pty Ltd) to prepare the EA /draft PER. As part of the assessment process the current study aims specifically to address ecological issues in the EA/draft PER by investigating existing conditions within the study areas, assessing potential impacts on marine ecology and recommending suitable mitigation and monitoring procedures.

The proposed artificial reefs have been designed and located specifically for the benefit of recreational fishing. Other potential user groups such as commercial fishing operators would not be excluded from utilising the reefs provided that such activities could be managed safety.

Three metropolitan regions have been selected for the installation of OARs (Newcastle, Sydney and Wollongong) (Figure ES1). At each region, four individual 'reef units' would be deployed at water depths between 30 m – 40 m. The combination of the four 'reef units' would collectively create a 'reef set' (i.e. the multi-component artificial reef). As a minimum, the units would be spaced between 200 m and 600 m apart. Reef units would rest directly on the seabed and would be anchored by the weight of the unit itself. It is estimated that an area of seabed approximately 1 km x 1 km would be required per reef set. The proposed design has drawn upon the extensive research and development undertaken in Korea and Japan where artificial reefs have successfully been used to enhance fisheries for over 30 years. The design has been refined to suit local conditions and increase the effectiveness of artificial reefs by specifically targeting recreational species such as snapper and yellowtail kingfish.

As part of the assessment process, initial studies were done in 2007/8, including location and constraints mapping (The Ecology Lab 2008a), consultation with government authorities and preparation of a Preliminary Environmental Assessment (PEA – The Ecology Lab 2008b). A key criterion in terms of aquatic ecology for the selection of prospective sites was that they be placed on soft sediments and not on or near to natural rocky reef. This would minimise the risk of attracting reef fish away from established populations on natural populations and on to the artificial reefs.

The final Director Generals Requirements (DGRs) were received by I&I NSW in July 2008. This report addresses issues that were identified in the DGRs related to marine flora and fauna, sediments and water and identifies any further ecological issues.

The main aims of the study were to:

- Provide a detailed description of existing conditions at the three proposed OAR sites in relation to benthic ecology, fish, sediment particle size distribution, heavy metal contaminants and water quality;
- Assess potential impacts on important biological components of the marine environment (including threatened and protected species);
- Recommend measures to mitigation or manage potential adverse impacts and procedures to monitor key components of the marine environment.

The scientific literature shows that artificial reefs are used as a tool for fisheries enhancement in many countries including Australia. This literature also highlights the issues that require consideration in the planning and successful operation of artificial reefs. In order to fully address the requirements of the DGRs and any further issues identified, field investigations were required. Field investigations were carried out during January 2009 on

benthic ecology, fish, sediment characteristics, potential heavy metal contaminants and water quality at each of the three metropolitan regions (hereafter referred to as 'study regions'). Sampling was done at a proposed location for deployment of reef units in each of the three study regions (Newcastle, Sydney and Wollongong) and at control locations (i.e. locations with similar habitat but remote from the proposed reefs).

Samples collected for analysis of benthic assemblages (macroinvertebrates), and sediments were collected by deploying a Ponar benthic grab from a boat. Fish were sampled using BRUVS (Baited, Remote, Underwater, Video, Stations). Water quality was measured with a Yeokal 611 water quality probe and meter. All sampling locations were recorded with a hand-held GPS unit accurate to less than 5 m. Benthos and BRUVS videos were analysed at Cardno Ecology Lab and all sediment samples sent to an accredited laboratory for analysis of sediment particle size distribution and concentrations of heavy metal contaminants.

Results showed that in general, habitat type at the three proposed OAR locations was similar, consisting of relatively flat, sandy substratum with shell grit deposited between sand waves (or in patches) and evidence of polychaete tubes. Benthic assemblages in all study regions were diverse and characterised by high numbers of crustaceans and polychaetes with relatively fewer representatives of other Phyla. Analyses of macrofaunal communities showed evidence of broad and small-scale variation between study regions and between the sites within the control and impact locations. These results were similar to earlier studies of benthic assemblages of sandy habitats along the mid-NSW coast, where overall, the benthic assemblages were found to be fairly typical of those expected in sandy offshore habitats.

Fish assemblages consisted predominantly of demersal species commonly associated with sandy habitat, although some partly pelagic and reef-associated species were also observed. Broad-scale variation and also variation between locations (within regions) was evident. A total of 22 species and 14 families of fish were identified from the three study regions surveyed. The greatest number of individuals (667) was recorded at the Newcastle study region, followed by Sydney (592 individuals) and Wollongong (208 individuals). Although the greatest numbers of individuals were recorded at the Newcastle study region, this was the least diverse in terms of species number (17). Sydney was the most diverse (23 species) and Wollongong had 20 species. The most abundant species in the survey was the chinaman leatherjacket (*Nelusetta ayraudi*) although this was only abundant in the Newcastle and Sydney regions. Long-spine flathead *(Platycephalus longispinus*), silver trevally (*Pseudocaranx dentex*) and clupeids (herrings, sardines and pilchards) were also abundant throughout the survey.

Water quality was similar in all regions, with percentage saturation of dissolved oxygen (DO) below ANZECC/ARMCANZ recommended guidelines. Concentrations of heavy metals recorded in sediment samples were all well within the recommended ANZECC/ARMCANZ guideline levels.

Relevant databases, including the DEWHA *EPBC Act* database, the NSW government 'BioNet' database and the NSW DECCW threatened species database, were searched for threatened species, populations and communities listed in relevant Schedules of the NSW *Threatened Species Conservation Act 1995 (TSC Act)*, the *Fisheries Management Act 1994 (FM Act)*, the *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*) and *National Parks and Wildlife Act* (*NP&W Act*) that would be likely or predicted to occur in the three study regions. The search was carried out in February 2009 and included marine fishes, mammals, reptiles, algae/vegetation, invertebrates and seabirds. Searches covered areas defined by Catchment Management Authorities (CMAs), marine zone CMA sub-regions or by the relevant Natural Resource Management Region (NRMR) i.e. the Hunter/Central Rivers, Sydney Metro and Southern Rivers CMA's/NRMR's. In total, 101 threatened or protected species (not including seabirds) were listed across the three CMA/NRMR's, consisting of 43 species of marine mammal, (cetaceans and pinnipeds), 51 species of fish (37 of which were syngnathiformes, i.e. seahorses, pipefish, pipehorses, ghost pipefish, seamoths and seadragons) and 7 species of marine reptiles (including seasnakes and marine turtles). Seabirds found to occur in the three study regions included albatrosses, petrels, shearwaters, terns, skuas, gulls, gannets and the endangered population of little penguins (*Eudyptula minor*) at Manly. Assessments of significance were carried out for species known or likely to occur within the study regions. It was considered that the proposal had potential to exacerbate Key Threatening Processes (KTPs) namely harm or injury from entanglement in discarded fishing gear or anthropogenic debris. However, providing that the OARs are properly managed and monitored as recommended, the potential to exacerbate KTPs are likely to be negligible. It was not considered that further assessment by means of a Species Impact Statement would be necessary for any of the threatened or protected species identified.

A number of potential impacts and issues were identified through a risk assessment process. This involved a risk assessment of general impacts relating to ecology and fisheries and a further species specific productivity susceptibility analysis (PSA) a tool commonly used in fisheries management. The majority of issues identified in the general assessment (including issues of high significance) were related to the pelagic environment, and risk to recreationally important, commercially important and threatened species from increased fishing mortality and incidental capture, for example. Obstruction to commercial fishing was also considered a potential impact of high significance as the location of the proposed Newcastle OAR has been strongly opposed by commercial trawling interests.

Results of the PSA highlighted species that are likely to be most vulnerable to fishing mortality associated with the proposal and should therefore be prioritised for future monitoring and management.

Recommendations to mitigate or minimise potential impacts include:

- Re-positioning the OAR units in the Newcastle study region to minimise potential obstruction to commercial fishing and notifying trawlers of the exact positions of the reef units.
- Spacing of the units at 200 m apart (as opposed to 600 m) and configured in a line running parallel with depth contours (approximately north to south) where feasible. This is not considered to impact on the effectiveness of the OARs, but is likely to minimise impacts on commercial trawling by significantly reducing the area lost to trawling from approximately 0.4 km^2 to 0.01 km^2 (approximately 97 % reduction) and improve navigation for trawlers past the OARs.
- Maximum separation of OAR units from existing natural reef. The Wollongong OAR units should be relocated approximately 500 m to the west/north-west of the present location (but still within the direct study area).
- Establishing an OAR management area. A code of conduct should be established for within the management area, including implementation of selective access controls such as temporal or spatial restrictions.
- Ensuring that OAR user groups are informed of:
    - general salt water fishing rules and regulations, water traffic rules and boating safety;
    - the code of conduct and regulations within the defined OAR management area;
    - mechanisms for reporting incidents of conflict;
    - safety recommendations for spear fishing/free diving and personal liabilities.
- Minimising impacts on threatened and protected species by:
    - ensuring there are mechanisms to report sightings or incidental capture of threatened and protected species;
    - education on threatened and protected species identification, best practice for returning incidentally captured fish, minimising risks to seabirds and boating restrictions in the vicinity of large cetaceans;
    - education on the potential impacts of harmful marine debris on marine life and the responsible disposal of litter and discarded fishing gear.
- Prioritising species of recreational and commercial importance (and threatened species) considered to be of 'high risk' for monitoring and management. Species at moderate risk but considered target species should also be considered.
- Development of an environmental management plan (EMP) detailing how maintenance, operation and management of the site (within a defined management area) should be implemented.

The effectiveness of the OARs would be addressed by the implementation of a Monitoring Plan to be reviewed at regular stages and incorporated as appropriate into management.

Monitoring would include additional surveys at impact and control locations before the OARs are deployed and continued monitoring should occur at all locations after deployment.

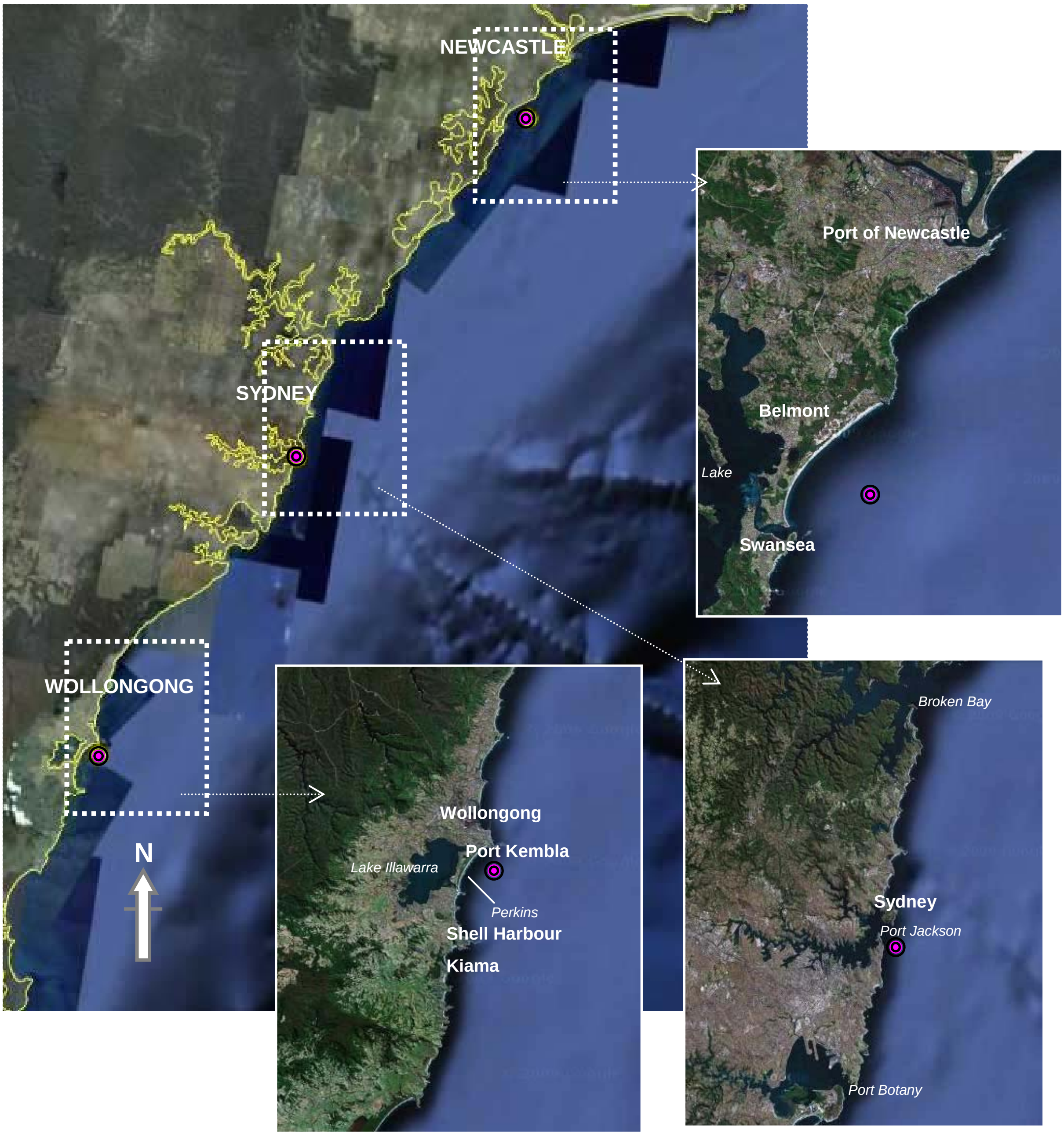
Providing that the above recommendations are adhered to and a strict monitoring program (with adequate pre-deployment surveys and replication) is undertaken, impacts that could potentially occur as a result of the proposal are likely to be minimal and/or identified before they become an issue.

ES References

The Ecology Lab Pty Ltd (2008a). Offshore Artificial Reefs – Location Selection and Constraints Mapping. Report to NSW Department of Primary Industries. The Ecology Lab Pty Ltd, Brookvale, NSW.

The Ecology Lab Pty Ltd (2008b). Pilot Offshore Artificial Reefs – Preliminary Environmental Assessment. Report to NSW Department of Primary Industries. The Ecology Lab Pty Ltd, Brookvale, NSW.

Figure ES1: Proposed Offshore Artificial Reef (OAR) locations in the Newcastle-Central Coast, Sydney and Wollongong regions.



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Glossary

Artificial reef	A man-made structure placed underwater to promote marine life in areas of generally featureless bottom.
Benthic	Living on or in the seabed
Benthos	The collection of organisms attached to or resting on the bottom sediments (i.e. epifauna) and those which burrow into the sediments (i.e. infauna).
Biodiversity	The variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part.
Biomass	Total quantity or weight of organisms in a given area.
Biota	The flora and fauna of a given area.
Bioturbation	The mixing of sediments by macrofauna.
Carrying capacity	The maximum equilibrium population size in a given area or habitat.
Cartilaginous	Refers to fishes which have a skeleton made of cartilage (soft and flexible gristle-like, material that provides support to the body) i.e. sharks and rays.
Commercial species	Species in a catch that are kept and sold due to their commercial value.
Continental shelf	The gently sloping seabed extending from the shore to a depth of approximately 200 m.
Demersal	Living at or occurring near or on the seabed (c.f. pelagic).
Density dependence	Usually refers to negative effects whereby population growth is curtailed by crowding, predators and competition.
Ecosystem	All the organisms in a community, together with the associated physical environmental factors (living and non-living) with which they interact.
Epifauna	Animals that live on the surface of the seabed.
Estuarine	Habitat lying at the interface between freshwater and marine environments; usually the mouths of streams and rivers.
Fecundity	A measure of the ability to produce offspring by the maternal adult.
Fishing effort	A function of the number of participating fishers, number of fishing events (e.g. fishing trips) and time (days/hours) spent fishing.
Incidental catch	Species caught which are not the primary target of a fishing operation.
Infauna	Aquatic animals living within the sediment.
Intertidal	The portion of shoreline between low and high tide marks, that is intermittently submerged.

Invasive marine pest	Organisms (usually transported by humans) which successfully establish themselves and then overcome otherwise intact, pre-existing native ecosystems.
Leaching	The process by which soluble materials in the soil, such as salts, nutrients, pesticide chemicals, or contaminants, are washed into a lower layer of soil or are dissolved and carried away by water.
Macrofauna	Organisms associated with sediment and retained in a sieve of 1.0 mm.
Marine Protected Area	An area especially dedicated to the protection and maintenance of biological diversity and associated natural and cultural resources and is managed through legal means.
ORP (mV)	Oxidation Reduction Potential (ORP) is a measure of a water systems capacity to release or gain electrons in chemical reactions.
pH	pH gives an indication of the acidity or alkalinity of a solution by its ability to gain or lose hydrogen ions.
Pelagic	Organisms that inhabit open water.
Plankton	The diversity of organisms (generally less than 0.5 mm in size) that drift with the ocean currents.
Population	Any collection of potentially interbreeding organisms in a given area.
Productivity	When applied to fish stock, the term productivity gives an indication of the birth, growth and death rates of a stock.
Salinity (ppt).	Salinity is the dissolved salt content in a body of water which will directly influence the types of organisms present depending on their tolerance range.
Subtidal	Waters below the low-tide mark.
Taxon (plural taxa)	The named taxonomic unit to which individuals, or sets of species, are assigned (e.g. genus, species, family etc).
Total length (fish)	Length from tip of the snout to the tip of the tail.
Turbidity (ntu)	Turbidity gives an indication of water clarity.
Maximum size	The maximum reported size of an organism.

1 Introduction

1.1 Background

The Department of Industry and Investment NSW (previously the Department of Primary Industries), with funding from the Recreational Fishing Trust, aims to improve recreational fishing opportunities in NSW through the development of offshore artificial reefs (OARs) in three metropolitan areas within NSW.

The proposal is subject to Part 3A of the *Environmental Planning and Assessment Act 1979* as it is considered to be of State planning significance. It will also be subject to approval under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*) and the Commonwealth *Environment Protection* (*Sea Dumping*) *Act 1981* (*EP*(*SD*)*Act*). As such, the project is being assessed in the format of a single Environmental Assessment/draft Public Environment Report (EA/ draft PER) which assesses the requirements of both State and Commonwealth legislation.

I&I NSW has commissioned Cardno Ecology Lab Pty Ltd (formerly The Ecology Lab Pty Ltd) to prepare the EA/draft PER. As part of the approval process, the current study aims to specifically address ecological issues related to the EA/draft PER by investigating existing conditions within the study areas, assessing potential impacts on marine ecology and recommending suitable mitigative and monitoring procedures.

The main aim of the proposal is to improve recreational fishing opportunity in NSW by creating new fish habitat and providing additional fishing locations. The proposal also includes the implement a long-term scientific monitoring program to assess the effectiveness and impacts of the proposed artificial reefs over time. Three metropolitan regions have been selected for the installation of OARs (Newcastle-Central Coast, Sydney and Wollongong). At each region, four individual ‘reef units' would be deployed at water depths between 30 m – 40 m offshore. The combination of the four ‘reef units' would collectively create a ‘reef set' i.e. the multi-component artificial reef. The units would be spaced between 200 m - 600 m apart. Reef units would sit directly on the seabed and would be anchored by their own weight. It is estimated that an area of seabed approximately 1 km x 1 km would be required per reef set. The proposed design has drawn upon the extensive research and development undertaken in Korea and Japan where artificial reefs have successfully been used to enhance commercial fisheries for over 30 years. The design has been refined to suit local conditions and increase the effectiveness of artificial reefs by specifically targeting recreational species such as snapper (*Pagrus auratus*) and yellowtail kingfish (*Seriola lalandi*).

The aims of this study were to:

- Review existing information relevant to the proposal and study areas;
- Outline relevant conservation legislation;
- Provide a detailed description of existing conditions at the three proposed OAR sites (through field investigations) in relation to benthic ecology, fish, sediment particle size distribution, heavy metal contaminants and water quality;
- Assess potential impacts on threatened species, populations, ecological communities and areas of conservation significance;
- Assess potential impacts of the proposal on biological components of the marine environment;
- Assess potential impacts of the proposal on water and sediment quality;
- Recommend mitigation measures to minimise or eliminate potential impacts identified as a result of the proposal;
- Recommend procedures for monitoring of the artificial reefs in order to detect change and evaluate the effectiveness of the proposal.

1.2 Study Areas

An overview map of the proposed study regions is given in Figure 1a. Hereafter, each metropolitan area (Newcastle, Sydney and Wollongong) is referred to as a ‘study region'. An area of approximately 4 km^2 including the area occupied by each reef set, is referred to as the ‘direct study area' and the area outside of this (within each study region) as the ‘wider study area'. These terms apply to the scale and extent of potential impacts. The exact locations of the three reef sets are outlined below:

- Newcastle study region (Swansea) - The proposed OAR site is located approximately 5.71 km (3.09 nm) from the entrance to Swansea channel and approximately 4.81 km (2.6 nm) south of Red Head.

- Sydney study region (South Sydney) - The proposed OAR site is located 1.47 km (0.69 nm) south east of South Head and approximately 1.64 km (0.8 nm) south of North Head.
- Wollongong study region (Port Kembla) - The proposed OAR site is located 2.45 km (1.3 nm) south of the Five Islands Nature Reserve and approximately 3.37 km (1.82 nm) offshore from Perkins Beach.

1.3 Relevant Legislation

1.3.1 State

Environmental Planning and Assessment Act 1979 (EP&A)

The Act provides a framework for environmental planning in NSW and includes provisions to ensure that proposals with the potential to significantly affect the environment are subject to detailed assessment. The Act details various planning instruments including State Environmental Planning Policies, Regional Environment Plans and Local Environment Plans and specifies which types of developments require development consent.

The objectives of this Act include:

- the proper management, development and conservation of natural and artificial resources, including agricultural land, natural areas, forests, minerals, water, cities, towns and villages for the purpose of promoting the social and economic welfare of the community and a better environment;
- the protection of the environment, including the protection and conservation of native animals and plants, including threatened species, populations and ecological communities, and their habitats;
- promoting ecologically sustainable development.

Under Part 3A of the *EP&A Act* the proposal is considered a Major Project and will require approval by the Minister for Planning. Under clause 75B 2(b) of the *EP&A Act,* Part 3A projects include an activity for which the proponent (I&I NSW) is also the determining authority.

Threatened Species Conservation Act 1995 (TSC Act)

In NSW, the *TSC Act* (administered through the NSW Department of Environment, Climate Change and Water) includes provisions to declare threatened species, populations, ecological communities and key threatening processes. Species populations and communities identified as 'endangered' are listed in Schedule 1 of the *TSC Act*. Species populations and communities identified as 'critically endangered' are listed in Schedule 1A of the *TSC Act* and species populations and communities identified as 'vulnerable' are listed in Schedule 2 of the *TSC Act*. The *TSC Act* also lists 'key threatening processes' that may threaten the survival of those species, populations and ecological communities. Marine birds, mammals and reptiles are included in schedules of the *TSC Act*. In addition, the *Threatened Species Conservation Act* provides for the identification of habitat that is that is critical to the survival of an endangered species, population or ecological community.

Fisheries Management Act 1994 (FM Act)

Provisions for the protection of fish and marine plants are administered through the Department of Industry and Investment NSW (I&I NSW) and listed in schedules of the *FM Act*. Species populations and communities identified as 'endangered' are listed in Schedule 4 of the *FM Act*. Species populations and communities identified as 'critically endangered' are listed in Schedule 4A of the *FM Act* and species populations and communities identified as 'vulnerable' are listed in Schedule 5 of the *FM Act*. The *FM Act* also lists 'key threatening processes' that may threaten the survival of those species, populations and ecological communities. Part 2 (19) of the *FM Act* allows for the declaration of 'protected species', which, though not currently declining, must be protected so they do not become threatened in future. Provisions for the protection of aquatic habitats and aquatic reserves are included under Part 7 of the Act. In addition, Division 3 of the *Fisheries Management Act* provides for the identification of habitat that is that is critical to the survival of an endangered species, population or ecological community.

National Parks and Wildlife Act 1974 and the *National Parks and Wildlife Regulation 2002*

Under the *National Parks and Wildlife Act*, the Director-General of the NPWS is responsible for the care, control and management of all national parks, historic sites, nature reserves, reserves, Aboriginal areas and State game reserves. State conservation areas, karst conservation reserves and regional parks are also administered under the Act. The Director-General is also responsible under this legislation for the protection and care of native fauna and flora, and Aboriginal places and objects throughout NSW. *The National Parks and Wildlife Regulation* came into effect on 1 September 2002. It governs various activities under the National Parks and Wildlife Act 1974, including:

- the regulation of the use of national parks and other areas administered by the NPWS (Part 2);
- the protection of fauna (Part 5) including the protection of certain types of marine mammals (Division 3A);
- advisory committees constituted under section 24 of the National Parks and Wildlife Act 1974 (Part 8).

The regulation replaces the former *National Parks and Wildlife* (*Land Management*) *Regulation 1995*, the *National Parks and Wildlife* (*Administration*) *Regulation 1995* and the *National Parks and Wildlife* (*Fauna Protection*) *Regulation 2001*.

Coastal Protection Act 1979

The *CP Act* applies to the coastal region of NSW and is administered by the NSW Department of Planning. The objects of this Act are to provide for protection of the coastal environment of the State and to generally supervise activities affecting the coastal zone (i.e. the area between the western boundary of the land in the coastal zone, as defined under the Act, and the outward limit of the coastal waters of NSW (i.e. 3 nm). The placement location of the OARs is in the coastal zone. Developments and activities occurring in the coastal zone that may adversely affect the sea, beach and other habitats in the coastal zone, or that are potentially inconsistent with the principles of ecologically sustainable development, require concurrence from the Minister for Planning.

Crown Lands Act 1989

Submerged land is generally classified as a type of Crown land. Bordering the coast of New South Wales, it lies below the mean high water mark. Submerged land includes most coastal estuaries, many large riverbeds, many wetlands and the State's territorial waters, which extend 3 nautical miles (5.5 km) out to sea. The principles of Crown land management are that:

- environmental protection principles be observed in relation to the management and administration of Crown land;
- the natural resources of Crown land (including water, soil, flora, fauna and scenic quality) be conserved wherever possible;
- public use and enjoyment of appropriate Crown land be encouraged;
- where appropriate, multiple use of Crown land be encouraged;
- where appropriate, Crown land should be used and managed in such a way that both the land and its resources are sustained in perpetuity;
- Crown land be occupied, used, sold, leased, licensed or otherwise dealt with in the best interests of the State consistent with the above principles.

1.3.2 Commonwealth

Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act).

The Commonwealth EPBC Act is administered by the Department of the Environment, Water, Heritage and the Arts (DEWHA) and aims to:

- provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance (NES);
- promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources;
- promote the conservation of biodiversity;
- provide for the protection and conservation of heritage.

In the aquatic environment, the Act lists the following matters of NES:

- nationally threatened species, ecological communities, critical habitats and key threatening processes (including marine species);
- migratory species;
- Ramsar wetlands of national significance;
- Commonwealth marine areas (this extends from 3 to 200 nautical miles from the coast).

Threatened fauna and flora are listed in any one of the following categories as defined in Section 179 of the *EPBC Act* as:

- Extinct;
- Extinct in the wild;
- Critically endangered;
- Endangered;
- Vulnerable;
- Conservation dependent.

Species listed as ‘extinct’ or ‘conservation dependent’ however, are not considered matters of national environmental significance (protected matters).

It is noted that from 3 February 2009, the eastern Australian population of gemfish (eastern gemfish) and school shark were placed in the ‘conservation dependent’ category on the national threatened species list. The two species were eligible for the category as they had undergone severe population declines in the past but were currently subject to robust fisheries management measures designed to rebuild their stocks (Web Reference 1).

Environment Protection (Sea Dumping) Act 1981

Under this Act permits are required for controlled material and artificial reefs. Permit conditions usually require research and monitoring (at the applicants expense) to be undertaken for dumping or artificial reef placement.

Under the Act, ‘artificial reef’ means a structure or formation placed on the seabed for the purposes of:

- increasing or concentrating populations of marine plants and animals; and/or
- being used in human recreational activities.

DEWHA has advised that the guidelines issued for the EA/draft PER have been scoped to meet the information requirements of both the *EPBC* and *Sea Dumping Acts* and so only one assessment under Commonwealth legislation is required.

2 Review of Existing Information

Cardno Ecology Lab has an extensive, specialised library, with over 23,000 journal articles from the scientific literature and more than 3,000 books and technical reports. This was used as the basis for the search of relevant literature. Current literature was also provided by I&I NSW and by targeted searches using the internet.

2.1 Artificial Reefs

2.1.1 Background

Artificial reefs have been defined as 'a submerged structure deliberately placed on the seabed to mimic some characteristics of a natural reef' (EARRN 1998). Objectives for the deployment of artificial reefs include the enhancement of recreational and commercial fishing, diving, coastal protection and mitigation of habitat loss and damage (Seaman and Jensen, 2000).

2.1.2 Artificial Reefs Worldwide

Artificial Reefs have been deployed in up to 40 countries around the world (Baine, 2001) for over three decades. Global trends show that older well-established reef deployment practices have been used to enhance artisanal, commercial and recreational fishing, including some SCUBA diving and spearfishing. Newer practices emerging in the past 10 – 20 years include aquaculture, recreational diving, habitat restoration, environmental mitigation and reefs constructed purely for experimental research (Seaman 2002). The two principle goals of these applications are economic/community development and more recently environmental resource conservation (Seaman 2002). In many countries artificial reefs have now become important elements of integrated fisheries management plans (Santos and Monteiro 2007). There has also been a trend towards the use of specifically designed structures as opposed to opportunistic waste materials (Section 2.1.4).

In the United States (US), greater demand for recreational fishing opportunity and habitat enhancement have been the main drivers for an exponential increase in the number of permitted artificial reefs (Bohnsack 1997). US artificial reefs have also been used for aquaculture, such as oyster culture in Chesapeake Bay (east coast) and restoration of Kelp Beds in San Clemente (west coast). Patented 'reef ball' technology (using purpose built, moulded concrete modules) has been extensively used in almost all coastal States, with approximately 29 projects in Florida alone (Web Reference 3). In South Carolina, permits were given for the continued development of 38 artificial reef construction sites along the coast, located at depths between 3 m to 37 m, ranging from inshore locations to areas as far as 56 km offshore (Web Reference 2). The US National Oceanic and Atmospheric Administration (NOAA) has since developed a National Artificial Reef Plan including practical guidelines for the siting, development and construction of artificial reefs to assist in managing the escalating number of artificial reef projects.

In Europe, the construction of artificial reefs began in the late 1960's and they have since been in deployed in Norway, Poland, Finland, UK, France, Germany, Greece, Turkey, Spain, Italy, Netherlands, Israel, Russia and Portugal. The artificial reef complex of the Algarve (Southern Portugal), deployed for the purpose of restoring and enhancing fisheries resources is currently the largest structure of its kind in Europe, extending over 43.5 km^2 (Ramos *et al*. 2007) and consisting of seven artificial reef systems (Boaventura *et al*. 2006). The large-scale reefs were approved after the success of a 14 year pilot project run by the Portuguese Institute of Marine Research (IPIMAR). In Italy, ten artificial reef sites were developed in the Ligarian Sea over a 30 year period. Extensive research over this period has resulted in the main aims of these reefs (protection against otter trawling and increase in species diversity/biomass) being achieved (Santos and Monteiro 2007). Artificial reefs in the UK have been developed for fisheries enhancement (by creation of habitat for lobster) and more recently for recreational diving (Plymouth, south-west coast) and surfing (Bournemouth, south coast). Research on decommissioned gas and oil rigs as artificial reefs has also been undertaken in the North Sea and Adriatic as an alternative to disposal (Baine 2002, Massimo *et al.* 2002, Fabi *et al.* 2004, Løkkeborg *et al.* 2002). Although results have shown some increases in total catch and species diversity in and around the platforms there is a sharp division between stakeholder proponents and opponents and use of decommissioned oil rigs remains controversial in the UK.

Since 1995, the European Artificial Reef Research network (EARRN) a collaboration of over 50 scientists from 36 laboratories, has been active in artificial reef research. The network aimed to promote awareness of artificial reef programs throughout Europe, improve collaboration between projects and help reach a consensus on the direction of future research.

Overexploitation of fisheries and degradation of coastal and marine habitats has prompted extensive development of large-scale artificial reefs in South-East Asia (Pauley and Chua 1988). Artificial reefs have been developed in Malaysia, Thailand, the Philippines, Taiwan, Singapore, Brunei, Indonesia, Hong Kong and Japan. Early reef designs were constructed mainly from car tyres, but also from concrete culverts and scrap vessels, although many initial exercises failed due to poor planning and incorrect site selection (Kennish *et al.* 2002). Recently, Japan and Korea have become leaders in research and development of purpose built, large-scale artificial reefs for fisheries enhancement. Results of long-term monitoring studies showed that artificial reefs yielded catch volumes 2 – 13 times greater than those of natural reefs (Kim 2001). In 2001, Korea subsequently planned to invest over $2 billion (US) in coastal fisheries enhancement projects over a 6 year period. Many of the world's largest reefs have been deployed in Japan as part of the national fisheries program for enhancement of commercial fish stocks. They consist of both shallow water reefs targeting shellfish and deeper water reefs for finfish.

2.1.3 Artificial Reefs in Australia

There have been at least four detailed reviews of artificial reefs in Australia (Pollard and Mathews 1985; Kerr 1992; Branden *et al*. 1994 and Coutin, 2001). Collectively these reviews detail the development of Australian artificial reef design, construction, deployment and monitoring from 1965 to 2001. Artificial reefs have been constructed in Australia since the mid-1960s. The first was created from concrete pipes laid in Port Phillip Bay (Kerr 1992). Within a few years there were reefs constructed of various materials (tyres, concrete rubble and or car bodies) in NSW, South Australia, Western Australia and Queensland. The main purpose of artificial reefs in Australia has been for recreational fishing and diving (Branden *et al,* 1994) and historically, materials of opportunity (waste material) have been the main materials used in their construction (Pollard, 1989; Kerr, 1992). In NSW, the use of artificial reefs began in 1966, with the deployment of a series of multi-component artificial reefs in Lake Macquarie using car bodies and tyres (Pollard and Mathews, 1985; Pollard, 1989). Augmentation of these reefs continued in the 1970's with additional reefs constructed in Batemans Bay, Port Stephens and Port Hacking using car tyres (Coutin, 2001). In addition to these tyre and car body reefs, up to 12 vessels were scuttled beginning in the mid 1970's to create single-component artificial reefs in NSW coastal waters, beginning with the retired-ferry the 'Dee Why' in 1976 (Pollard and Mathews, 1985; Pollard, 1989; Coutin, 2001) sunk off Long Reef at a depth of 45 m.

From the mid 1980's a lack of funding meant that artificial reef construction in NSW effectively ceased until the introduction of the general recreational fishing fee in 2001, when funds became available for the further investigation of the use of artificial structures as a fisheries enhancement tool. In 2002, a fish aggregating device (FAD) program was established in NSW to provide additional fishing opportunities for sport fishing and game fishers. FADs provide a fixed location where fast-growing pelagic fish species can be targeted by recreational fishers. The FADs consist of a single 600 mm float, moored to the sea-bed at varying depth and distance from the coast. Monitoring of recreational catch composition and factors effecting catch rates of dolphinfish (*Coryphena hippurus*) (Folpp & Lowry 2006) has been conducted on the FADs. This project has developed into a long running recreational fisheries enhancement program, with 25 FADs deployed from October to June annually from Tweed Heads to Eden and two trial FADs in the Lord Howe Island Marine Park.

In 2004, I&I NSW began investigations into artificial reefs in coastal estuaries, progressing earlier work done by the Department in the 1970's (Pollard and Mathews, 1985). Using reef ball technology, a number of small multi-component artificial reefs were deployed in Lake Macquarie in December 2005, followed by Botany Bay in June 2006 and St. Georges Basin in February 2007. The reef systems vary in size with the largest system in Lake Macquarie consisting of six artificial reef sets (one reef group), utilising a total of 600 Reef Balls, covering an area of more than 3000 m^2 with a volume of 400 m^3. A long-term monitoring program has been established to evaluate their effectiveness. Preliminary results indicate that the artificial habitat has been successful in maintaining an increase in fish abundance and diversity, accompanied by extensive marine plant growth on the surface of the reef ball units. The reefs have also been a success in terms of enhancing recreational fishing opportunities. Eight months after construction, catch abundance, catch diversity, and catch rates of recreational species on the artificial reefs were found to be as good as or better than control sites (naturally occurring reefs) within Lake Macquarie (University of Newcastle, *unpublished data*). The pilot estuarine artificial reefs project has provided the necessary monitoring and management experience required for the investigation of the potential implementation of large multi-component artificial reefs in NSW coastal waters.

A number of Ex-naval vessels have been scuttled in Australian waters with the purpose of creating artificial recreational dive reefs. Examples include the Ex-HMAS Swan (off Dunsborough, WA) the Ex-HMAS Hobart (off Yankalilla Bay, South Australia), the Ex-HMAS Perth (off King George Sound in Albany, WA) and the Ex-HMAS

Brisbane (off the Sunshine Coast in Queensland) and most recently there are plans to scuttle the Ex-HMAS Adelaide offshore from Terrigal NSW (The Ecology Lab 2008a).

2.1.4 Materials and Design

Historically, artificial reefs have been created out of a range of opportunistic or secondary (waste) materials (Pollard 1989, Kerr 1992). Examples include decommissioned vessels, car bodies, discarded tyres, railway cars and surplus military equipment. Although the deployment of such opportunistic structures remains the more common option in artificial reef construction, there is a growing trend towards dedicated reef designs (Pickering and Whitmarsh 1997).

Specifically designed and manufactured reef structures are now deployed in many countries including Japan and Korea (considered the world leaders in artificial reef technology). Such 'design specific' structures are considered a more suitable alternative to using opportunistic materials as they are demonstrated to be more effective in achieving specific fisheries management objectives (Sherman *et al*. 2002). While the use of opportunistic materials may be cheaper initially (mainly due to the lack of design and manufacture cost), a purpose built artificial reef design is preferable over opportunistic materials for the following reasons:

- the proposed manufactured design facilitates long-term planning and budgeting as the project is not dependent on the availability of suitable secondary materials;
- purpose built designs can be engineered to suit the specific aims and objectives of the artificial reef program targeting specific species, user groups and fishing gears;
- purpose built designs can also be manufactured to suit a chosen location in terms of depth, oceanography and substratum type;
- a choice of suitable material can maximise the duration, durability and compatibility of the structure in the marine environment. Problems potentially associated with material toxicity or cleaning can be avoided;
- the overall effectiveness and lifespan of the manufactured design is considered to yield comparatively greater cost-benefits than the use of secondary materials.

A variety of alternative materials have been developed for manufactured artificial reefs, with the aim of fisheries enhancement. These include concrete, iron and steel, reinforced concrete (concrete and steel), ceramic, plastic, plastic concrete (concrete mixed with polyethylene, polypropylene sand and iron) and fibre reinforced plastic amongst others (O'Leary *et al.* 2001). Designs include concrete blocks in a variety of shapes (e.g. blocks, cylinders and domes) dimensions and configurations, patented reef balls of varying dimensions and high relief, complex steel structures.

Artificial reefs for fisheries enhancement are now being designed according to the types of target species, as different species of fish may respond to hard objects differently (Kim 2008). For example, in large steel and concrete reefs designed in Korea the differing ecological needs of target species for shelter, guided the design of box reefs to enhance productivity in marine ranching. The effect of these and other structures on fisheries catch rates are considered positive (Seaman 2007).

2.1.5 Benthic Ecology

Factors affecting Benthic Assemblages

Benthic assemblages occurring on hard surfaces of reefs (natural or artificial) are strongly influenced by a wide range of environmental variables including water depth (Rule and Smith 2007, Moura *et al*. 2007), orientation in relation to prevailing currents (Baynes and Szmant 1989), orientation of surfaces (Glasby and Connell 2001, Knott *et al*. 2004), complexity of surfaces and structure (Edwards and Smith 2005, Moura *et al*. 2007) and rates of sedimentation (Baynes and Szmant 1989 in Walker *et al*. 2007). Ecological processes such as recruitment (Perko-Finkel and Benayahu 2007) and succession (Nicoletti *et al*. 2007) are also influential.

Comparisons of benthic assemblages on natural and artificial reefs indicate that although they may share many similar taxa, there may be differences in the overall assemblages. Some taxa may be more abundant and diversity may be greater on natural compared to artificial reefs and vice-versa (Edwards and Smith 2005). Diversity of species on new reefs (such as artificial reefs) generally increases through time to a point of relative stability (Ardizzone *et al*. 1989 in Edwards and Smith 2005).

Colonisation

A study of macrobenthic (animals > 1.0 mm) communities colonising artificial reefs in Southern Portugal (Moura *et al*. 2007) indicated that small differences in depth (16 m – 20 m) and structure influenced species assemblages (particularly for colonial organisms and barnacles) after 6 months of immersion. Three months after immersion more than half the sample area was colonised by macrobenthic species and after 6 months, the entire surface was covered. Sessile encrusting organisms such as barnacles, bryozoans, polychaete worms (family: Serpulidae) and ascidians colonised the surfaces with a clear dominance of barnacles (Boaventura *et al*. 2006). These taxonomic groups have been seen to colonise artificial reefs in various types of artificial reef structures (Boaventura *et al*. 2006) although the sequence of macrobenthic colonisation appears to vary according to seasons and locations.

Colonisation of sunken vessels by sessile invertebrates has proven to be relatively rapid. For example, the Ex-HMAS Brisbane (Queensland) became colonised within three months of deployment by red, brown and blue/green algae, limpets and goose barnacles (Queensland EPA 2007). Mobile invertebrates such as crabs, shrimps, crayfish and octopus were recorded within nine months. A diverse assemblage of mobile marine invertebrates including nudibranchs, opisthobranchs, cuttlefish, octopus and starfish have been observed around the wreck of the Ex-HMAS Hobart (South Australia) following its deployment in November 2002. Sessile sponges, ascidians, polychaete worms and soft corals are now well established. Biological monitoring of the HMAS Swan (Western Australia) over a two year period has shown that the structure was initially colonised by hydroids, covering approximately 70% – 90% of the area surveyed (Morrison 2001). Algal growth also dominated the encrusting marine life during the summer months, particularly on the upper surfaces. Other sessile groups such as sponges, ascidians, anemones and soft corals were shown to proliferate on shaded portions of the vessel.

Long-term studies investigating the succession of benthic artificial reef communities show that even after a number of years communities are undergoing changes. Perkol-Finkel and Benayahu (2004) monitored benthic communities on a purpose-built pyramidal artificial reef in Eilat (Israel) over a 10 year period. Results demonstrated a shift in species composition over time from a community dominated by soft corals (up to 2 years) to a sponge dominated community (year 10). Comparisons with neighbouring natural reefs indicate that the artificial reef assemblages may continue to adapt even after this time. A study in the Tyrrhenian Sea of Italy (Nicoletti *et al*. 2007) distinguished five different phases in artificial reef colonisation over a 20 year period: After 1 month - pioneer species recruitment (hydroids, serpulid polychaetes, barnacles and molluscs), after 3 months – mussel dominance (*Mytilus galloprovincialis*), after 3 years – mussel regression (increase in soft bottom species), 10 years – mussel absence (a new benthic assemblage characterised by soft bottom species established on the hard surfaces) and finally, after 20 years - dominance of bryozoans (characterised by 'bioconstructing bryozoans and a strong increase in diversity of hard and soft bottom species.

The impacts of artificial reefs on surrounding soft bottom habitats have also been investigated (Wilding 2006, Barros *et al*. 2001, Ambrose and Anderson 1990, Davis *et al*. 1982, Fabi *et al* 2002, Steimle *et al*. 2002). Soft bottom assemblages may consist of 'infauna' which burrow to depths of about 50 cm into the sediments, and 'epifauna' which live on the surface of the sediments. Soft bottom habitats adjacent to artificial reefs may be affected by altered wave field and current patterns which in turn, can influence sediment grain size, scouring and sand ripple patterns (Davis *et al*. 1982). These physical factors appear to affect the composition and abundance of infaunal communities more than biological factors such as predation (Fabi *et al*. 2002).

While some studies have found no difference in densities of infaunal and epifaunal assemblages at distances away from an artificial reef (Davis *et al*. 1982) others have shown that densities of some species were enhanced while others were depressed (Ambrose and Anderson 1990) or that assemblages were spatially more variable closer to reefs (Barros *et al*. 2001). Artificial reefs have potential to alter the trophic structure of the nearby fauna by changing the available forage food if some of the species associated with a new artificial reef feed on surrounding soft-bottom habitats. There is evidence that feeding halos can occur around artificial reefs so that abundance and species richness of flora or prey items decreases (Bortone *et al*. 1998). This has potential to affect the food of demersal fish living on soft-bottom habitats and fish of natural reefs, if artificial reefs are nearby.

2.1.6 Fish Ecology

Factors affecting Fish Assemblages

Size, relief, complexity, location and biological factors can all influence assemblages of fishes on artificial reefs (Bohnsack *et al*. 1994, Kim *et al*. 1994). The types of species that recruit to and colonise the artificial structure is also likely to depend on the time of year that they are deployed.

Reef size and its influence on species abundance is an ongoing debate. Where biomass has been reported in association with large artificial reefs, it may be composed of large but few individuals (Pickering and Whitmarsh 1997). Bohnsack *et al*. (1994) found greater densities of fish on smaller artificial reefs. The relief (or height) of artificial reefs can influence abundance and diversity. In temperate waters, diversity has been shown to be greater on low-relief artificial structures than on natural structures (e.g. Ambrose and Swarbrick 1989) but a study of high-relief reefs found greater diversity on natural reefs than on artificial reefs (Burchmore *et al*. 1985). In tropical waters the effects may be different. A study of low-relief artificial structures did not show the same effect as for temperate waters (e.g. Bohnsack *et al*. 1994) and greater diversity and abundance (relative to natural reefs) has been shown to occur on high-relief structures (Rilov and Benayahu 2000).

It follows that the more complex an environment, the more ecological niches are created. Artificial structures have potential to be complex in terms of their physical makeup and in how they may alter water flow, turbulence and light levels around them. For example, the variety of crevices can contribute significantly to the species composition of artificial reefs (Anderson *et al*. 1989, Carr and Hixon 1997), or small fish, which need a place to rest may prefer the lee side of artificial structures (Dean 1983 in Pickering and Whitmarsh 1997). Regardless, of the number of niches created by an artificial reef, they are likely to be different to natural reefs and for this reason it is not uncommon for assemblages on artificial reefs to be different from those on natural reefs (e.g. Lincoln Smith *et al*. 1988).

The location of an artificial reef can be particularly important to diversity and abundance (Burchmore *et al*. 1985). Some fish, for example, may not occur at particular depths. Burchmore *et al*. (1985) also suggested that the proximity of artificial reefs to existing reefs or the ocean (in the case of estuarine artificial reefs) could increase the chance of recruitment or visitation from neighbouring oceanic areas. Further, the proximity of water circulation patterns that provide nutrients or food or substrata that provide sources of food is also likely to be important.

Biological factors can be important. Adult fishes may limit the number of juveniles able to settle (Russell *et al*. 1974) as may other competitors. Encounters with predators have been shown to be less on artificial reefs compared to natural reefs (Sweatman and Robertson 1994) and this may influence mortality (Connell 1997). This effect may be associated with the often isolated nature of artificial reefs.

Colonisation

Initial colonisation of artificial reefs by fish is likely to be rapid. This is due to the behavioural response of fish to hard objects, such as the tendency of certain species to move towards structure, rather than bare, featureless habitat (Brickhill *et al*.2005). Over time, fish assemblages colonising artificial reefs may become similar in species composition to neighbouring natural reefs (Clynick *et al*. 2008, Santos and Monteiro 2007, Relini *et al. 2002*), although similarities between natural and artificial reefs are considered to be largely dependent on the similarity of structural properties of the artificial reefs (Perkol-Finkel *et al*. 2006, Edwards and Smith 2005).

Species of fish colonising an artificial reef may live permanently on the structure (residents) or be transient visitors. The artificial reef initially provides refuge until colonised by sedentary and attendant organisms which also provide food for the resident fishes. Transient fish (visitors) are thought to use the artificial reef as a temporary refuge, but do not feed constantly there.

Markevich (2005) investigated fish colonisation of an experimental artificial reef in St. Peter the Great Bay, the Sea of Japan. Colonisation by fishes was generally found to occur within two to six months with final stabilisation occurring after two years with only slight changes thereafter. The season of deployment was also considered an important factor in determining the type and abundance of species that colonised the artificial reef. For example, Markevich (2005) found that an artificial reef deployed in spring or early summer were more rapidly colonised than those deployed in autumn due to patterns of plankton settlement.

Fish species occurring on the wreck of the Ex-HMAS Brisbane were monitored the first year after deployment. Within weeks, common hardyhead, yellowtail scad and baitfish (transient visitors) were observed on the wreck. After three to six months a number species including batfish, blennies and emporer fish (residents), slimy mackerel, yellowtail kingfish, whiting, sweetlips, amberjack, flounder, flathead, rays, dolphinfish, trevally, leatherjacket and pilchards (transient species) were observed. Within six to nine months, greasy cod, red firefish, scorpion fish, damsel fish guitarfish and spotted wobbegongs were found to be permanent on the wreck. Anglerfish, lionfish, garfish, triggerfish, snapper and bonito (among others) were also observed. Monitoring of the Ex- HMAS Swan over a two year period showed an increase in average species richness from 2 to 32 species and an increase in abundance from 10 to approximately 1300 individuals when compared to a control site. The fish community showed a gradual increase in abundance over the monitoring period with a rapid increase in mean diversity within the first two months of deployment. The assemblage on the wreck showed a rapid shift from omnivorous weed/sand fishes to one dominated by planktivorous and carnivorous reef fishes. The ten most common species found on the wreck were rough bullseye, tarwhine, globe fish, silver trevally, footballer sweep, black-headed puller, long-finned pike, King George whiting, black spotted wrasse and the southern blue-spotted flathead. The species diversity and abundance on the wreck became similar to that of existing natural reefs although the species composition on the vessel remained distinctly different.

Attraction v Production

There is an ongoing debate in the scientific community about whether artificial reefs increase overall production of a defined area (as they provide new habitat in an otherwise saturated environment) or whether they merely attract and aggregate existing fish to a new location i.e. the artificial reef attracts fishes, which would have settled, survived and grown on natural habitats in its absence (Brickhill *et al*. 2005). This has become known as the 'attraction versus production' issue.

Attraction is defined as the net movement of individuals from natural to artificial habitats whereas a simplified definition of production is accumulation of biomass over time (Carr and Hixon 1997). In assessing the effects of artificial reefs on production, it is essential to define explicitly the region or management area in question (Carr and Hixon 1997) as well as the loss of production to habitat that artificial reefs replace. The size of a management area and the spatial distribution of reefs within that area can influence interpretation of the effects of an artificial reef. For example, if no natural reef occurs in a management area containing an artificial reef, then any obligate reef organism on the artificial reef has necessarily enhanced production on reefs within that management area. Clearly, the smaller the management area, then the greater the contribution of the artificial reef to that area will be. However, there may also be a loss of production from the habitat replaced by the artificial reef (usually soft sediment) and this is seldom taken into account.

The question of whether artificial reefs merely redistribute fishes from surrounding areas, or whether they in fact increase production of reef fish is not clear. To increase overall reef productivity, artificial reefs must provide additional habitat which increases carrying capacity. This could be done by:

- providing new substrata for benthic fauna and flora (food sources of fishes);
- providing shelter from predation; recruitment habitat; spawning habitat and/or;
- reducing harvesting pressure on natural reefs (Pickering and Whitmarsh 1997).

In support of the production hypothesis, artificial reefs have been found to increase the local biomass of benthic invertebrates and fishes (Pickering and Whitmarsh 1997). Brickhill *et al*. (2005) report that production is more likely to occur with the addition of more reefs, or more complex reefs and that artificial reefs can also act as nursery areas for economically important species. One theory states that concentrating food resources and/or increasing feeding efficiency by deployment of artificial reefs can increase localised fish productivity in the long-term, through trophic linkages (Leitao *et al*. 2007, 2008).

This does not however, indicate unequivocally that biomass increases at a regional scale asit is difficult to discern whether:

- fishes that settle or are attracted to artificial reefs would have found suitable habitat if these reefs were not present;
- fishes would have better survival, growth or recruitment on artificial reefs than on natural habitats;
- foraging success and food web efficiencies have improved; or
- habitat is vacated by fishes moving from natural habitats to artificial reefs (Bohnsack *et al.* 1994).

Wilson *et al*. (2001) suggest that both attraction and production are likely to interact in driving artificial-natural reef complexes and that much of the question relates to the role of larval supply and density-dependence driving fish dynamics in general (Hixon 1998, Tupper and Hunte 1998). Osenburg (2002) also considers that attraction and production are not mutually exclusive and can be considered as extremes along a gradient. Furthermore, while artificial reefs may simply attract and aggregate some species, they may promote the production of others and the situation is likely to lie between the two extremes. (Bohnsack 1989 in Leitao *et al.* 2008).

Species most likely to benefit in terms of increased biomass (a surrogate for production) are reef limited, demersal, philopatric (i.e. those that return to their place of origin to breed), territorial and obligatory reef species. The attraction hypothesis is likely to hold for locations where natural reef habitat is abundant and where species have a high fishing mortality, are recruitment limited, pelagic, highly mobile, partially reef-dependent or opportunists (Bohnsack, 1989), which describes at least some of the species for which the NSW OAR would be designed, e.g. snapper and kingfish.

Overall, and ignoring the concept of which is the dominant factor, there is a body evidence that properly designed and managed artificial reefs, particularly when deployed in less complex or reef-limited habitats, can increase the abundance and in many cases diversity of fish assemblages (in comparison to control locations), making them useful management tools in fisheries enhancement and habitat rehabilitation (Santos and Monteiro 2007, Pollard and Matthews 1985, Golani and Diamant 1999, Terashima *et al*. 2007, Rilov 2000, Chua *et al*. 2004, Markevich 2005, Herrera *et al.* 2002).

Increased Fishing Mortality

A major concern with artificial reefs is that they could potentially make recreationally and commercially important species more easily harvestable by aggregating them in one place, thereby facilitating increased fishing mortality. When reefs are located close to boat ramps and their positions mapped, artificial reefs can increase access, and potentially fishing effort to hard-bottom surfaces in an area (McGlennon and Branden 1994). The problem is exacerbated if new reefs attract fishers who previously did not fish hard-bottom areas due to a prior lack of availability, thus increasing overall fishing effort within a management area.

Another potentially adverse effect of artificial reefs is increased predation on fish associated with them that leads to an overall increase in natural mortality (Leitao *et al*. 2008). It is feasible that this could potentially decrease recruitment to populations if predators and prey are attracted to artificial reefs when the latter may be more vulnerable. It is possible however, that the opposite can occur (i.e. where predators are fewer on artificial reefs compared to natural reefs) as a result the isolated nature of artificial reefs.

2.1.7 Contamination

Artificial reefs in the marine environment tend to corrode over time potentially affecting water quality and sediments in the vicinity. Many organisms can accumulate contaminants from surrounding waters, sediment or their food, which persist within their tissues for long periods of time or are transferred to consumers higher up the food chain i.e. bioaccumulate (Amiard-Triquet *et al*. 1993). Where these organisms also function as habitat (e.g. kelp forests), there is potential for accumulated contaminants to negatively effect associated epifauna (Roberts *et al*. 2008). The ocean has great dispersive properties but there is potential for accumulations of contaminants to be locally significant. Monitoring of the sediment around the Ex-HMAS Swan after it was scuttled indicated marked increases in aluminium, chromium, copper, iron, lead and zinc (Morrison 2001). This was attributed to corrosion of the superstructure and leaching from antifouling paints. Although these metals do not generally cause toxicity at low concentrations or accumulate in food chains, others such as mercury and tin can (Clark 1997). The effects of leachates from tyre reefs in freshwater (e.g. Nelson *et al*. 1994) and coal fly ash reefs in the marine environment (Norton 1985, Kress 1993) have been investigated with mixed results.

Some studies have suggested that metal toxicity to organisms attached to metal surfaces can be problematic. For example, some damselfishes (Pomacentridae) prefer artificial substrata for their nests and in doing so can expose their larvae to metal toxicity which can reduce the number of viable larvae at hatching (Kerr 1996).

2.2 Study Regions

2.2.1 Soft Sediment Environment

Offshore Artificial Reefs are considered to be most effective when placed in bare sandy 'habitat limited' environments. Selection of OAR sites has therefore focused on areas known or likely to consist of sandy substratum away from areas of naturally occurring reef. Soft sediment habitats can support extremely diverse macrofaunal communities. Macrofauna (organisms > 1.0 mm) generally comprise polychaetes, crustaceans and molluscs (Hutchings 1998 1999, Snelgrove 1999). Additional taxa recorded include worm-like invertebrates such as nemerteans, echiurids, phoronids and sipunculids and other groups such as echinoderms, sponges, cnidarians and tunicates. Benthic assemblages are found to vary considerably with depth but less so with latitude. Benthic macrofauna are also considered to be good indicators of environmental conditions as they are relatively sedentary, diverse and abundant. In general, the benthic environment of the Newcastle study region consists of proportionally less area of natural rocky reef habitat than at the Sydney and Wollongong study regions and greater expanses of uninterrupted bare sand. Surveys carried out by The Ecology Lab Pty Ltd (2001 and 2003) in the Newcastle study region investigated benthic assemblages and sediment characteristics of sites in the vicinity of the Newcastle Harbour spoil ground using benthic grabs and ROV (Remote Operated Vehicle). In the 2001 survey, control sites between 18 m and 28 m were sampled offshore from South Stockton Beach and offshore from Red Head Point. ROV observations at both sites showed that the seafloor appeared clean with shells and shell fragments in ripples across the seafloor. Sea urchin tests (skeletons) and small starfish were observed at some locations. Assemblages of benthic invertebrates consisted mainly of polychaete worms (family Cirratulidae), amphipod crustaceans (family Phoxocephalidae), isopod crustaceans (family Anthuridae) and bivalve molluscs (family Veneridae). Sediment particle size composition at both control sites was similar and consisted of approximately 98 % sand and the remainder gravel. A later study, (The Ecology Lab 2003) showed that dominant families collected in benthic samples were again isopod crustaceans, amphipod crustaceans, polychaete worms and bivalve molluscs, although the composition of families was slightly different. In general, larger numbers of individuals were found in deeper sediments. Sediments at the control sites were characterised as 'natural shelf sediments' and were (as expected) composed of mainly of sand with a small amount of gravel. A small proportion of rock fragments and quartz were also found at some locations. Overall, the benthic assemblage was typical of that expected in sandy offshore habitats.

As there are detailed, seabed maps available for the Sydney study region (Public Works Department NSW 1989), broad areas of sand and rocky reef habitat are easily identified. Substratum within the proposed Sydney study area is shown to consist of fine to medium grained, golden coloured sand with 10 % shell from the rocky reef shoreline, seaward to a depth of approximately 60 m. Sandy habitats off Sydney have been found to support diverse and abundant assemblages of macroinvertebrates and that major changes occur in these assemblages with increasing depth, even over a relatively narrow range (e.g. between 20 m - 30 m). Studies have also found that: a) the invertebrates are, at least within shallower areas (e.g. 20-25 m), capable of rapid recolonisation if disturbed; and b) they show detectable responses to storm activity, even at depths of 65 m (The Ecology Lab 1993). This suggests that these assemblages are resilient to physical disturbance.

Soft sediments in the Wollongong study region were investigated by The Ecology Lab (2001), offshore from Belambi Point and to the north of Bellambi. Samples were taken from two sites at three depths (10 m, 15 m and 20 m) at each location. Sediment type consisted mainly of fine to medium brown sand, with some samples containing a small percentage of silt and some gravel (as broken shells). No significant differences in grain size were detected between these locations and it is expected that a similar sediment composition exists throughout this study area, excluding the spoil grounds located outside the entrance of Port Kembla and areas adjacent. Analyses of soft sediment assemblages (The Ecology Lab 2001), found that benthic infauna associated with sandy sediments consisted of amphipod crustaceans, polychaetes and a high number of gastropod molluscs of the family Trochidae. Significant differences in assemblages were also found to be related to depth.

Compared to reef habitats, sandy soft sediment habitats have less physical structure. The variation observed in fish assemblages among sandy areas, however, suggests that fishes do discriminate among them (Lincoln Smith and Jones 1995 in Underwood and Chapman 1995). In NSW a few common groups make up the fish fauna of sandy areas (Connell and Lincoln Smith 1999). The elasmobranchs are often represented by Urolophid and Rhinobatid rays. There may also be many small planktivorous fishes. Other common and commercially important groups are the flatheads (Platycephalidae), which are voracious predators and whiting (Sillaginidae), which are benthic feeders.

2.2.2 Rocky Reef Environment

The location of rocky reef habitat in relation to the proposed OAR sites is an important factor to be considered in achieving the objectives of the OAR project. The site selection process (The Ecology Lab 2008b) aimed to choose sites consisting of bare sand with adequate separation from existing natural reef. This is for three main reasons:

- to provide new alternative fishing locations to relieve pressure on existing natural reef;
- to avoid potential for 'draw-down' effects, i.e. attraction of fish from existing natural reef to the artificial reefs;
- to provide a stable substratum on which the reef units would be placed.

The optimal separation between reef units and natural reef can vary broadly depending on the relative sizes of nearby natural reef (Kim 2008), but falls in the range of 500 m to 1000 m. A distance of 500 m is generally regarded as the maximum range over which two groups of fish resident in a natural/artificial reef are likely to interact.

Rocky reefs support very different communities to the sandy habitats. This is because:

- they have solid substrata which provide points of attachment for sessile organisms such as macroalgae, sponges and corals (rare on soft substrata); and

- Habitat complexity, whereby organisms are adapted to a variety of microhabitats such as vertical or horizontal surface, crevices, shelter, etc (The Ecology Lab 1993).

Rocky reef assemblages also show some degree of 'zonation', with turfing macroalgae and kelp occurring in shallower waters, bare rock (which is actually covered by encrusting red algae) in intermediate areas and 'sponge gardens' in deeper water (Underwood *et al.* 1991). These habitats are structured by a variety of physical and biological processes. Reef habitat is likely to be less resilient to disturbance than sandy habitat and is also utilised heavily by humans.

Subtidal rocky reefs harbour fishes that depend on this habitat for food, shelter and/or spawning sites at some stage during their lives. Many species are affected by the topography of the reef and are more abundant in areas of greater physical complexity. Some reef fishes may be very active, including wrasses and leatherjackets, and can traverse large areas of reef. There are also many less mobile, reef associated, species, which spend most of their time on or near the bottom and cryptic species that remain within caves, overhangs and crevices. Bottom dwelling fish include Serranidae and Scorpaenidae while species which inhabit caves and crevices include Pempheridae, Moridae and Muraenidae. Rocky reefs also support a range of highly mobile fishes which visit these reefs but range over a much greater area. Examples include Carangidae and Carcharhinidae (Cardno Ecology Lab 2009).

In the Newcastle study area, maps of near shore sub-tidal marine reef and soft sediment produced by NSW National Parks and Wildlife Service, show no near shore reefs located in the direct study area of the proposed Newcastle OAR. The closest area of mapped reef is located approximately 4 km south west of the proposed OAR location.

For Sydney, a significant outcrop of subtidal reef (Dunbar Head) is located less than 0.5 km south of the proposed artificial reef location. There are also shipwrecks in the area that function ecologically as artificial reefs, often supporting similar assemblages of fish and invertebrates to nearby rocky reef. Fish have been surveyed on natural reef occurring within the wider Sydney study area at Cabbage Tree Bay Aquatic Reserve (The Ecology Lab 2006). The reserve is located approximately 4.2 km north of the direct study area from south Manly to the headland north of Cabbage Tree Bay. Mado (*Atypichthys strigatus*), were the most abundant species recorded over a 2 year period contributing to 35 % to 45 % of relative abundance. Other numerically dominant species included one-spot puller (*Chromis hypselepis*), southern batfish (*Schuettea scalaripinnis*) and yellowtail scad (*Trachurus novaezelandiae*) which were often observed forming dense schools. Luderick (*Girella tricuspidata*), a commercial important species, was also common (contributing to 6 % relative abundance). Several species protected in NSW under the *FM Act* were also observed including blue groper (*Achoerodus viridis*), elegant wrasse (*Anampses elegans*) and blue devil fish (*Paraplesiops bleekeri*). Species such as the grey nurse shark and black cod could also be expected to be found in the area around Cabbage Tree Bay.

Maps of near shore sub-tidal marine reef and soft sediment indicate that the rocky reef habitat which forms the Five Islands Nature Reserve is located approximately 2.4 km north of the proposed Wollongong study region. Anecdotal evidence (Brown, D 2008 Pers. Comm) suggests that there are areas of subtidal reef to the north, east and south of the Wollongong (Port Kembla) direct study area.

The EPA (Environment Protection Authority, 1992) surveyed rocky reef habitat within the Five Islands area, outside of Port Kembla. Depths between 20 m - 22 m were characterised by a diverse assemblage of encrusting flora and fauna including sponges, bryozoans, cnidarians ascidians and algae. The Ecology Lab (2001) found that sub-tidal rocky reef communities in the Port Kembla area were variable amongst control locations, but that they also consisted of sponges, ascidians, encrusting and foliose algae. Weedy seadragons occur north of Wollongong Harbour and on the northern side of Big Island with the interface of reef and sand (depth 15 m – 20 m) appearing to be favoured by this species (The Ecology Lab, 1999). In 2007 The Ecology Lab carried out fish transect surveys in the Wollongong study region in relation to the Illawarra Waste Water Strategy. Control sites (located over reefs approximately 8 km north of the direct study area) were compared with the Wollongong outfall site (located offshore of Port Kembla) approximately 6 km north of the direct study area. Results of the surveys indicated that fish abundance and diversity at the outfall site (post-commissioning) was greater than at nearby rocky reefs but that the fish assemblages at the outfall were different to that of rocky reefs (The Ecology Lab 2007a). Twenty species of fish were recorded at the outfall site compared to an average of 15.6 species at the three control sites. It is likely that the structure of the outfall (which was colonised by algae and other organisms) was a factor in attracting fish due to additional habitat and food availability. As discussed in Section 2.1.6, the difference in assemblages between the control and outfall site is likely to be a result of structural and morphological differences in habitat. Bullseye (*Pempheris* spp.), silver sweep, mado and silver trevally were the most numerically abundant species at the outfall site. Hula fish (*Trachinops taeniatus*), crimson banded wrasse (*Notolabrus gymnogenis*), maori wrasse (*Opthalmolepis lineolatus*), white ear

(*Parma microlepis*) and mado were numerically abundant at control locations. Commercially and recreationally important species observed at the outfall site included yellowtail scad, red morwong (*Cheilodactylus fuscus*), silver trevally and snapper. Red morwong, black reef leatherjacket (*Eubalichthys bucephalus*), silver trevally and yellowtail were also observed at control sites but overall abundance was greater at the outfall site.

2.2.3 Pelagic Environment

The pelagic environment includes the water mass between the surface and the seabed. This habitat is utilised by a diverse range of organisms including plankton, planktivorous and predatory fishes and marine mammals and reptiles.

Plankton is made up of two general groups: meroplankton, which spend part of their life in the plankton, usually as larvae; and holoplankton, which spend their entire life in the plankton (Kingsford 1995). A number of biotic and abiotic factors are important in determining the taxonomic composition and relative abundances of individual planktonic taxa present in the water column (Gray and Miskiewicz 2000), such as seasonal differences in the East Australian Current and spawning times. Ocean currents intercepted by the OARs would form a wake or zone of flow disturbance in the lee of the structures (e.g. Rissik *et al*. 1997). Where deep water is involved, flow disturbance can uplift cool, nutrient-rich water in the eddies thereby increasing production of phytoplankton there and zooplankton that feed on them (Rissik *et al*. 1997). Although the OARs would be unlikely to increase nutrient levels by this process because of their location and depth, there would be potential to create small eddies that may act as retention zones, trapping water and particulates behind the structures that may facilitate increased localised concentrations of plankton. Although this phenomenon has been reported only for large island masses (e.g. Hernandez-Leon 1988) the structures may have a smaller scale, but similar effect. Planktivorous fishes have potential to aggregate where concentrations of plankton are greater (Rissik and Suthers 2000). Such concentrations of fishes on the OARs (which may be prey to some species) are likely to attract, larger predatory fish that live in the pelagic environment, including for example, yellowtail kingfish (*Seriola lalandii*), Australian bonito (*Sarda australis*) and tailor (*Pomatomus saltatrix*).

There have been few offshore studies of fish carried out in the Newcastle study region apart from those related to offshore spoil disposal which have concentrated on the benthos and associated sediments.

Sandy habitats off Sydney have been found to support diverse and abundant assemblages of fish. A diverse assemblage of demersal (bottom dwelling) fish have been recorded in the Sydney area, with stingarees, flatheads, gurnards, flounder, box fish, school whiting, cardinal fish, bellowsfish, nannygai and john dory found to be particularly abundant (The Ecology Lab 1993). Clear patterns in species assemblages related to depth have also been observed. Marine turtles and marine mammals live in the pelagic environment, often passing close to shore where the OARs would be situated. Some of these have potential to occur in the study area all year round (i.e. marine turtles, seals and dolphins) while others such as the much larger baleen whales (e.g. humpback whale, *Megaptera novaeangliae*) and southern right whale, *Eubalaena australis*) are seasonal. Many of these species are threatened or protected and as such are described in more detail in Section 2.4.

2.3 Commercial and Recreational Fishing

2.3.1 Commercial

Commercial fisheries potentially affected by the proposal are those that can operate in NSW State waters. These include those under the jurisdiction of the State of NSW and also those under the jurisdiction of the Commonwealth of Australia that may operate within the 3 nm limit under Section 37 permit (The Ecology Lab 2007b).

The Ocean Hauling Fishery

The Ocean Hauling Fishery targets approximately 20 finfish species using commercial hauling and purse seine nets from sea beaches and in ocean waters within 3 nautical miles of the NSW coast. On average 3,500 t of fish, mainly including sea mullet (*Mugil cephalus*), luderick (*Girella tricuspidata*), yellowtail scad (*Trachurus novaezelandiae*), blue mackerel (*Scomber australasicus*), pilchards (*Sardinops neopilchardus*) and sea garfish (*Hyporhamphus melanochir*) is taken by the whole fishery each year (Web Reference 5). Purse seining for garfish, yellowtail scad and blue mackerel occasionally occurs within the proposed study areas but the majority of this fishery takes place from ocean beaches and is therefore unlikely to be affected by the proposal.

The Ocean Trap and Line Fishery

The Ocean Trap and Line Fishery is a multi-method, multi-species fishery targeting demersal and pelagic fishes along the NSW coast (NSW DPI 2006). Snapper (*Pagrus auratus*), spanner crabs (*Ranina ranina*), yellowtail kingfish (*Seriola lalandii*), leatherjackets (Monacanthidae), bonito (*Sarda australis*) and silver trevally (*Pseudocaranx dentex*) form the bulk of the commercial catch (Web Reference 6). Blue morwong (*Nemadactylus douglasi*), blue-eye (*Hyperoglyphe antarctica*), gummy shark (*Mustelus antarcticus*), bar cod (*Epinephalus septemfasciatus*) and yellowfin bream (*Acanthopagrus australis*) are also key species. The fishery uses a variety of methods, most commonly involving a line with hooks, or traps. Trap and line fishing usually occurs along the edge of reef and sand. As the placement locations are on bare sand it is unlikely that fishers would currently be active in the direct study areas but are likely to operate within the wider study areas (particularly in the Wollongong study region). Handlining for schooling baitfish such as yellowtail could also occur in the direct study areas. Consultation with local trap and line fishermen suggests that none of the proposed OAR locations are particularly important for the trap and line fishery. It is, however, likely that some traps would be set in the vicinity of the OAR units.

The Ocean Trawl Fishery

There are two sectors to the NSW Ocean Trawl Fishery, the prawn trawl sector and the fish trawl sector. Both sectors use similar gear, the otter trawl net, and many of the fishers endorsed for fish trawling are also endorsed for prawn trawling. Endorsements for the fish trawl sector are divided into the ocean fish trawl (north) and ocean fish trawl (south). Endorsements for the prawn trawl sector are divided into the inshore, offshore and deepwater sectors, whereby the offshore sector would be most relevant to the current proposal.

The fish trawl sector targets a large number of species, including silver trevally, tiger flathead (*Platycephalus richardsoni*), redfish (*Centroberyx gerrardi*), john dory (*Zeus faber*) and numerous species of sharks and rays. Total catches reported by fish trawl operators from NSW managed waters in 2000/01 were 1,171 t, valued at $4 million at first point of sale (Web Reference 7). The commercial fishers operating in the study regions consulted in relation to the proposed OAR locations did not raise any issues in relation to the proposed Sydney and Wollongong OAR locations, but did indicate that the proposed Newcastle OAR location would interfere with areas frequently trawled by the Sydney groups. Anecdotal evidence also suggests that most commercial fishing in the Wollongong study region takes place in deeper shelf waters well beyond the limit of the suitable OAR depth range.

The prawn trawl sector, the most valuable fishery in NSW, is worth around $32 million at first point of sale each year (Web Reference 8). In 2000/01 the total catch for the fishery was 3,411 t with 1,739 t of that being prawns only. Prawn trawlers use trawl nets to target prawns on soft sediments. Incidental catches of other species of fish may also be landed. The main species harvested include school prawns, school whiting and eastern king prawns. As for the fish trawl sector, it is only the Newcastle study area which is considered likely to interfere with prawn trawling.

The Lobster Fishery

The NSW Lobster Fishery is a small but valuable fishery. Eastern rock lobster (*Jasus verreauxi*) is the main species harvested but occasionally, southern rock lobster, *Jasus edwardsii*, and tropical rock lobster, *Panulirus longipes* and *Panulirus ornatus*, are also caught. The Fishery extends from the Queensland border to the Victorian border and includes all waters under the jurisdiction of NSW to around 80 miles from the coast. There are inshore and offshore sectors, whereby inshore fishers use small beehive or smaller square traps in waters up to 10 m in depth whilst the offshore fishers use large rectangular traps (Web Reference 37). It is unlikely that lobster fishing occurs in the proposed OAR locations, as the offshore sector operates in much deeper water. No issues were raised in relation to the proposal by the Lobster Fishery MAC.

2.3.2 Recreational

Recreational fishing generally includes spearfishing, sports fishing, charter boat fishing and game fishing. Spearfishing mainly takes place in coastal marine waters, often near rocky headlands. Red morwong (*Cheilodactylus fuscus*), rock blackfish (*Girella elevata*), leatherjackets (Monacanthidae), luderick (*Girella tricuspidata*) and kingfish (*Seriola lalandi*) are the more commonly targeted species (Lincoln Smith *et al.* 1989). Sports fishing uses hook and line to target demersal reef species such as yellowfin bream (*Acanthopagrus australis*), silver trevally (*Pseudocaranx dentex*), mulloway (*Agyrosomus hololepidotus*), snapper (*Pagrus auratus*) and pelagics such as kingfish (*Seriola lalandi*) on offshore reefs and species such as leatherjackets (Monacanthidae) and flathead (Platycephalidae) over sand. Because of its proximity to densely populated areas and its inexpensiveness, the sportsfishing industry is estimated to cater to over 150, 000 anglers and catch in excess of 1000 t of fish per annum

(Web Reference 42). The charter boat fishery operates in fresh and marine waters with species caught varying accordingly. There are approximately 200 charter vessels actively operating along the NSW coast. The gamefish fishery occurs mainly in deeper waters adjacent to the edge of the continental shelf, where billfish (black, blue and striped marlin), tuna (albacore, yellowfin, striped) and sharks (whalers, mako, blue) are target species. Gamefishing has a strong and well-organised club component and fishing activities under the auspices of angling clubs involve an increasing emphasis on the tagging and release of caught fish, rather than their retention. Recreational fishing in NSW is managed by catch controls (bag and size limits), restrictions on the type of gear (no fish traps or nets), closed areas and seasons and protected species.

Recreational fishing in the Newcastle study region is popular, with three I&I NSW-listed charter vessels operating out of the Hunter (Web Reference 8) and a number of other vessels operating from the surrounding suburbs (National Oceans Office, 2004). It should be noted however that I&I listed vessels (those wishing to be listed) represent approximately 70% of all registered vessels operating in the area so the actual figure is likely to be greater.

Popular offshore fishing spots in the wider study area (south of the Port of Newcastle) include spots known as Middle Reef and North Reef offshore from the port entrance (targeted for bream, mulloway and teraglin), the dumping ground around Nobby's Head and reefs south of Nobby's Head (thought to be good locations for snapper and mulloway). Directly south of Nobby's Head and east of Redhead are several sections of reef productive for a mixture of reef fish. The wreck of the Bonnie Dundee (approximately 5 km offshore from Swansea) is a favoured spot for mulloway and baitfish (McEnally and McEnally 2004). Surveys of offshore recreational fishing carried out at Norah Head (between Sydney and Newcastle) from March 2007 to February 2008 by I&I NSW (Web Reference 21) indicated that the top ten species observed by anglers were: silver trevally, *Pseudocaranx dentex* (19.3 %), eastern blue-spotted flathead, *Platycephalus caeruleopunctatus* (10.4 %), blue morwong, *Nemadactylus douglasii* (9.5 %), snapper, *Pagrus auratus* (9.2 %), chinaman leatherjacket *Nelusetta ayuraudi* (8.4 %), silver sweep, *Scorpis lineolata* (4.1 %), tailor, *Pomatomus saltatrix* (3.5 %), nannygai, *Centroberyx affinis* (3.3 %), yellowfin bream, *Acanthopagrus australis* (3.1 %) and yellowtail *Trachurus novaezelandiae* (3.0 %). Thirty seven other species were recorded in the survey which accounted for 26.3 % of the observations. The survey was based on a total of 270 interviews with fishing parties.

Recreational fishing from boats occurs throughout the Sydney study region. There are 39 I&I-listed chartered fishing boats operating in the study region including those listed in the Hawkesbury, Port Jackson, Port Botany and Port Hacking (Web Reference 8). Trolling for pelagic species such as tailor (*Pomatomus saltatrix*) and kingfish is also common (McEnally and McEnally 2004). Game fishing for pelagic fish, including sharks, tunas, billfish, bonito, frigate mackerel, tailor and Australian salmon generally takes place off the Sydney coastline towards the edge of the continental shelf, although they may be found anywhere beyond the estuaries (The Ecology Lab 1993). Spearfishing and lobster gathering is popular on headlands and reefs. In NSW, these activities are permitted using snorkel (i.e. no SCUBA or surface air supply) and are generally restricted to waters of 20 m depth or less. Surveys of offshore recreational fishing carried out at Long Reef (approximately 10 km north of the Sydney study area) from March 2007 to February 2008 by I&I NSW (Web Reference 22), indicated that the top ten species observed by anglers were: silver trevally (15.2 %), eastern blue-spotted flathead (14.8 %), snapper (10.2 %), tailor, (8.9 %), chinaman leatherjacket (8.5 %), silver sweep (7.0 %), yellowtail (5.5 %), slimy mackerel (4.4 %), kingfish (3.6 %) and blue morwong (3.5 %). Forty six other species were recorded in the survey which accounted for 18.3 % of the observations. The survey was based on a total of 281 interviews with fishing parties.

In the Wollongong study region, drift fishing for flathead is thought to be productive along the entire stretch of coast. Offshore from Wollongong Harbour (between 1.5 km and 2.5 km) and west of Big Island, patches of gravel substratum and reef provide good fishing for snapper. Fishing around the Five Islands (offshore from Port Kembla) is also known for kingfish, snapper and mulloway, with bream, tailor and salmon occurring in shallower waters. (Ross 1998).

Surveys of offshore recreational fishing carried out at Port Kembla (immediately north of the Wollongong study area) from March 2007 to February 2008 by I&I NSW (Web Reference 23), indicated that the top ten species observed by anglers were: eastern blue-spotted flathead (19.1 %), snapper (11.6 %), yellowtail (9.5 %), silver trevally (7.8 %), silver sweep (5.4 %), slimy mackerel (5.0 %), chinaman leatherjacket (4.8 %), blue morwong (4.5 %), tailor (2.8 %) and six-spined leatherjacket, *Meuschenia freycineti* (2.6 %). Sixty seven other species were recorded in the survey which accounted for 26.9 % of the observations. The survey was based on a total of 723 interviews with fishing parties.

2.4 Threatened and Protected Species and Areas of Conservation Significance

2.4.1 Assessment Under State Legislation

State legislation relevant to threatened and protected species, populations and ecological communities are the NSW *Threatened Species Conservation Act 1995* (*TSC Act*), the NSW *Fisheries Management Act 1994* (*FM Act*) and the NSW *National Parks and Wildlife Act* (*NP&W Act*).

Relevant databases, including the NSW government 'BioNet' database (Web Reference 10) and the NSW DECCW threatened species database (Web Reference 9) were searched for threatened species, populations and communities listed in relevant Schedules of the *TSC Act* and *FM Act* that are likely or predicted to occur in the three study regions. The search was carried out in February 2009 and included species of marine fish, marine mammals, marine reptiles, marine algae/vegetation, marine invertebrates and seabirds. 'Bionet' searches covered areas defined by the relevant Catchment Management Authorities (CMAs) i.e. the Hunter/Central Rivers, Sydney Metro and Southern Rivers. DECCW database searches were carried out according to the relevant marine zone CMA sub-regions. This allowed a broad-scale assessment of all threatened and protected species that could potentially occur in the study regions. Results of database searches for threatened and protected species, populations and communities potentially occurring in the relevant CMAs/ marine zone CMA sub-regions are listed in Tables 11, 12 and 13 respectively.

Species protected under the *TSC/FM Act* potentially occurring in the Hunter/Central Rivers search area, included one species 'presumed extinct (green sawfish, *Pristis zijsron*), one critically endangered species (grey nurse shark, *Carcharias taurus*), four 'endangered' species including the blue whale (*Balaenoptera musculus*), dugong (*Dugong dugon*), southern bluefin tuna (*Thunnus maccoyii*) and the loggerhead turtle (*Caretta caretta*) and nine 'vulnerable' species. Under the *FM Act*, 50 species identified as 'protected' (mainly syngnathiforms i.e. seahorses, pipefish, pipehorses, ghost pipefish, seamoths and seadragons) were also listed.

In the Sydney Metro search area one species that is identified as 'critically endangered' (grey nurse shark), four species identified as 'endangered' (blue whale, dugong, southern bluefin tuna and loggerhead turtle), nine 'vulnerable' and 42 'protected' species were listed under the *TSC/FM Act*.

In the Southern Rivers search area, one 'critically endangered' species (grey nurse shark), three 'endangered' species (blue whale, dugong and southern bluefin tuna), nine 'vulnerable' species and 64 'protected' species were listed.

Searches for seabirds occurring in the relevant CMAs/marine zone CMA sub-regions were carried out separately. Only seabirds likely to forage offshore and in the direct study areas were included in the database search. Intertidal and wading birds such as sandpipers, curlews and plovers (for example) were excluded from the assessment as they are unlikely to be affected by the proposal. The main groups of seabirds that were found to occur in the three study regions included albatrosses, petrels, shearwaters, terns, skuas, gulls, gannets and the endangered population of little penguins (*Eudyptula minor*) at Manly.

In the Hunter/Central Rivers CMA/NRMR, 30 species were listed as 'protected', four listed as 'endangered' and 16 species listed as' vulnerable'(Table 11)..

In the Sydney Metro CMA/NRMR 46 species were listed as 'protected', four listed as 'endangered' and 13 species listed as' vulnerable'(Table 12).

In the Southern Rivers CMA/NRMR, 43 species were listed as 'protected', four listed as 'endangered' and 14 species listed as' vulnerable'(Table 13).

From the list of species identified in the initial search, only those known or considered likely to occur in the direct or wider study areas (based on general species distribution databases) and/or known to utilise habitat in the study area, were considered for further assessment. All seabirds were assessed collectively, apart from the little penguin which was assessed individually.

For legislation to have relevance, there must be likelihood that one or more threatened species occur in or encroach upon the wider study area which could be impacted upon by the proposal. Therefore, only threatened species (from the initial search) that were known or considered likely to occur in the wider study areas (based on general species distribution databases) and/or known to utilise habitat in the study areas, were considered for further Assessment of Significance. These species were assessed according to DECCW/I&I threatened species assessment guidelines

(DECC 2007, DEC 2004). It should be noted that this does not include 'protected' or 'conservation dependent' species, which do not require an Assessment of Significance.

Assessments of Significance (State)

Individual species assessments are given in Appendix 5. Overall, five species of fish (including bony and cartilaginous fishes), three species of marine turtle, four species of cetacean, two pinnipeds and one sirenian (the dugong) were assessed according to DECCW/I&I threatened species assessment guidelines (DECC 2007, DEC 2004). A generic assessment was undertaken for seabirds, apart from the little penguin which (due to the endangered population occurring at Manly), was assessed individually.

Fish

Species of fish (protected under State legislation) considered likely to occur within the wider Newcastle, Sydney and Wollongong study areas are:

- The *critically endangered* grey nurse shark (*Carcharias taurus*);
- The *vulnerable* great white shark (*Carcharodon carcharias*);
- The *presumed extinct* green sawfish (*Pristis zijsron*);
- The *endangered* southern bluefin tuna (*Thunnus macoyii*);
- The *vulnerable* black cod (*Epinephelus daemelii*);

Records suggest the southern bluefin tuna and black cod are likely to be found only within the wider Sydney study region. Potential issues which could occur, or be exacerbated by the proposed OARs on fish were identified as:

- the potential for increased fishing mortality through incidental capture;
- the potential to increase the impact of key threatening processes namely:
    - 'entanglement or ingestion of anthropogenic debris in marine and estuarine environments' (TSC/FM Act);
    - 'injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris' (EPBC Act);
    - the potential to increase the impact of a key threatening process (hook and line fishing in areas important to the survival of a threatened fish species).

The proposal was not considered to have a significant impact, such that a Species Impact Statement (SIS) would be necessary for any of the species identified above. In the case of the southern bluefin tuna and great white shark, this was mainly due to the transient nature of the species, whereby it is unlikely they would remain in the vicinity of the OARs long enough that they would be vulnerable to the potential impacts identified. The status of the green sawfish is 'presumed extinct' in NSW with the last documented sighting in 1972 from the Clarence River in Yamba. That considered, it would be highly unlikely for the species to occur in any of the proposed study areas. The grey nurse shark is known to aggregate at discreet locations within the wider study areas. This includes known critical habitats such as Magic Point (Maroubra) approximately 12.5 km from the Sydney OAR site and Bass Point approximately 8 km south of the Wollongong OAR site. Given the distance from known aggregation areas the proposal would not directly affect grey nurse shark habitat. It is possible, however, that individuals could occasionally forage within the direct OAR study areas. Although the species is most frequently sighted in or near sand-bottomed gutters or rocky caves, this shark is thought to be partly migratory and may forage outside of aggregation sites over open sandy habitat. This considered, it is possible that the grey nurse shark could be at risk of incidental capture as a result of the proposal. Even if sharks are returned to the water, capture related injuries (Section 2.4.3) can lead to early mortality or effect feeding efficiency.

Given that grey nurse sharks are only likely to forage within any of the direct study areas on occasion, it is considered unlikely that potential impacts of the proposal could affect the life cycle of a viable local population such that the species is placed at the risk of extinction. Furthermore, provided that fishing activities in the direct OAR study areas are properly managed and monitored, potential risks would be minimised or addressed before they become problematic.

Marine Turtles

Species of marine turtle (protected under State legislation) considered likely to occur within the wider Newcastle, Sydney and Wollongong study areas are:

- The *vulnerable* green turtle (*Chelonia mydas*);

- The *vulnerable* leatherback turtle (*Dermochelys coriacea*);
- The *endangered* loggerhead turtle (*Caretta caretta*).

The loggerhead turtle is only known to occur in the Newcastle and Sydney study regions.
Potential issues which could occur, or be exacerbated by the proposed OARs on marine turtles were identified as:

- increased risk of boat strike in the direct study areas; and
- the potential to increase the impact of key threatening processes namely;
    - 'entanglement or ingestion of anthropogenic debris in marine and estuarine environments' (TSC/FM Act); and
    - 'injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris' (EPBC Act) and;

For both species, the proposal was not considered to have a significant impact such that a Species Impact Statement (SIS) would be necessary. This was mainly due to the transient nature of the species and that no important nesting, mating or feeding areas are known to occur within any of the wider study areas.

Cetaceans

Species of cetacean (protected under State legislation) considered likely to occur within the wider Newcastle, Sydney and Wollongong study areas are:

- The *vulnerable* southern right whale (*Eubalaena australis*);
- The *vulnerable* humpback whale (*Megaptera novaeangliae*);
- The *vulnerable* sperm whale (*Physeter macrocephalus*);
- The *endangered* blue whale (*Balaenoptera musculus*).

Records show that the southern right whale and humpback whale were considered likely to occur in all study regions. The sperm whale was only known or likely to occur in the Sydney and Wollongong study areas and the blue whale only considered likely to occur in the Sydney study area. Potential issues which could occur, or be exacerbated by the proposed OARs on cetaceans were identified as:

- increased risk of acoustic disturbance (from boat noise) in the direct study areas;
- increased risk of boat strike in the direct study areas;
- the potential to increase the impact of key threatening processes namely;
    - 'entanglement or ingestion of anthropogenic debris in marine and estuarine environments' (*TSC/FM Act*); and
    - 'injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris' (*EPBC Act*).

The proposal was not considered to have a significant impact on any species of cetacean, such that a Species Impact Statement (SIS) would be necessary. This was mainly due to the transient nature of the species and that no important, mating, feeding or resting areas would be affected by the proposal.

Pinnipeds and Sirenians

Species of pinniped and sirenian (protected under State legislation) considered likely to occur within the wider Newcastle, Sydney and Wollongong study areas are:

- The *vulnerable* Australian fur-seal (*Arctocephalus pusillus doriferus*);
- The *vulnerable* New Zealand fur-seal (*Arctocephalus forsteri*);
- The *endangered* Dugong (*Dugong dugon*).

The Australian fur-seal and New Zealand fur-seal were considered likely to occur within all the wider study areas. Records suggest that the dugong is only known to occur in the wider Newcastle and Wollongong study areas. Potential issues which could occur, or be exacerbated by the proposed OARs on pinnipeds and sirenians were identified as:

- increased risk of boat strike in the direct study areas (only applicable to the dugong) and;
- the potential to increase the impact of key threatening processes namely;
    - 'entanglement or ingestion of anthropogenic debris in marine and estuarine environments' (*TSC/FM Act*); and
    - 'injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris' (*EPBC Act*).

Although pinnipeds and sirenians (particularly seals) could forage within the wider study areas, the proposal was not considered to have a significant impact, such that a Species Impact Statement (SIS) would be necessary.

Seabirds

Seabirds likely to forage offshore in the vicinity of the study areas were assessed collectively. Species protected under State legislation that are known to roost or breed on land nearby to the direct study areas include:

- The *vulnerable* sooty oyster catcher (*Haematopus fuliginosus*) - Moon Island (Newcastle study region) and Five Islands Nature Reserve (Wollongong study region);
- The *protected* wedge-tailed shearwater (*Puffinus pacificus*) - Moon Island (Newcastle study region) and Five Islands Nature Reserve (Wollongong study region);
- The *protected* short-tailed shearwater (*Puffinus tenuirostris*) - Five Islands Nature Reserve (Wollongong study region);
- The *protected* Kelp gull (*Larus dominicanus*) - Moon Island (Newcastle study region);
- The *protected* White bellied sea eagle (*Haliaeetus leucogaster*) - Five Islands Nature Reserve (Wollongong study region);
- The *endangered* wandering albatross (*Diomedea exulans*) - North Head (Sydney study region);
- The *endangered* southern giant petrel (*Macronectes giganteus*) - North Head (Sydney study region).

The Five Islands Nature Reserve, Moon Island Nature Reserve and North Head are located 2.4 km, 4 km and 1.7 km respectively from the proposed OAR locations. Potential issues which could occur, or be exacerbated by the proposed OARs on seabirds were identified as:

- Incidental capture by commercial or recreational fishing activity;
- the potential to increase the impact of key threatening processes namely;
    - 'entanglement or ingestion of anthropogenic debris in marine and estuarine environments' (TSC/FM Act); and
    - 'injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris' (EPBC Act).

The proposal was not considered to have a significant impact on any species of seabird, such that a Species Impact Statement (SIS) would be necessary, but it is recommended that suitable management measures are employed to minimise any potential harm from increased boating and recreational fishing activity (i.e. entanglement) in the vicinity of the OARs. The OARs should also be monitored for occurrence and/or interactions of the species with fishing activity.

Endangered Population – Little Penguins at Manly

An endangered population of the little penguin (*Eudyptula minor*) occurs within the wider Sydney study area. The proposal has the potential to increase the impact of key threatening processes on the little penguin population Manly, by:

- 'entanglement or ingestion of anthropogenic debris in marine and estuarine environments' (*TSC/FM Act*); and
- 'injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris' (*EPBC Act*).

The endangered population at Manly is the only 'mainland' breeding colony of little penguins and occurs approximately 3.7 km northwest of the proposed Sydney OAR site. Although the species could potentially forage in the direct study area, no area of critical habitat would be directly affected and the proposal was not considered to have a significant impact, such that a Species Impact Statement (SIS) would be necessary.

2.4.2 Assessment Under Commonwealth Legislation

In April 2008, the proposal was referred under the *EPBC Act* to the Minister for the Environment, Heritage and the Arts. It was subsequently determined that the proposal requires approval under the *EPBC Act,* as it is considered to have a significant impact on the following matters of national environmental significance (NES):

- Listed threatened species (sections 18 and 18A of the *EPBC Act*);
- Listed migratory species (sections 20 and 20 A of the *EPBC Act*);
- The Commonwealth marine environment (sections 23 and 24 A of the *EPBC Act*).

Listed Threatened and Migratory Species

The DEWHA environmental reporting tool (Web Reference 43) and the NSW government 'BioNet' database (Web Reference 10) were searched for listed threatened and migratory species, populations and communities listed in relevant Schedules of the *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*) that are likely or predicted to occur in the three study regions. Note that threatened species assessed under the *EPBC Act* include only those listed as 'extinct in the wild', 'critically endangered', 'endangered', 'vulnerable' or 'migratory'.

The search was carried out in February 2009 and included species of marine fish, marine mammals, marine reptiles, marine algae/vegetation, marine invertebrates and seabirds. Searches covered areas defined by CMA (Bionet) or by the relevant Natural Resource Management Region (NRMR) i.e. the Hunter/Central Rivers, Sydney Metro and Southern Rivers CMA's/NRMR's (DEWHA threatened species database). This allowed a broad-scale assessment of all threatened and protected species that could potentially occur in the study regions.

Species protected under the *EPBC Act* that may potentially occur in the Hunter/Central Rivers search area, included one 'critically endangered' species (the east coast population of the grey nurse shark, *Carcharias taurus*), four 'endangered' species (blue whale, *Balaenoptera musculus*, southern right whale *Eubalaena australis,* loggerhead turtle *Caretta caretta* and leatherback turtle *Dermochelys coriacea*), five 'vulnerable' species (whale shark *Rhincodon typus,* great white shark *Carcharodon carcharias*, humpback whale *Megaptera novaeangliae,* green turtle *Dermochelys coriacea* and flatback turtle *Natator depressus*), 27 'listed' species (including syngnathiformes, pinnipeds and marine reptiles) and two 'conservation dependent' species (eastern gemfish, *Rexea solandri* and school shark *Galeorhinus galeus)*. Thirty-one species were also identified as 'cetaceans' and 18 species identified as 'migratory' (Table 11). Note that a species may be classed as both a cetacean and migratory species in addition to its protected status, for example, the southern right whale (*Eubalaena australis*) which is listed as 'endangered', but is also protected as a migratory cetacean.

Species protected under the *EPBC Act* that may potentially occur in the Sydney Metro search area, included one 'critically endangered' species (the east coast population of the grey nurse shark, *Carcharias taurus*), four 'endangered' species (blue whale, *Balaenoptera musculus*, southern right whale *Eubalaena australis,* loggerhead turtle *Caretta caretta* and leatherback turtle *Dermochelys coriacea*), four 'vulnerable' species (whale shark *Rhincodon typus,* great white shark *Carcharodon carcharias*, humpback whale *Megaptera novaeangliae* and green turtle *Chelonia mydas*), 30 'listed' species (including syngnathiformes, pinnipeds and marine reptiles) and three 'conservation dependent' species (eastern gemfish *Rexea solandri,* orange roughy *Hoplostethus atlanticus* and the school shark *Galeorhinus galeus).* Fifteen migratory species, 21 species listed as 'cetaceans and 25 'listed' species were also identified in the Sydney Metro search area (Table 12).

Species protected under the *EPBC Act* that may potentially occur in the Southern Rivers search area, included one 'critically endangered' species (the east coast population of grey nurse shark, *Carcharias taurus*), three 'endangered' species (blue whale, *Balaenoptera musculus*, southern right whale *Eubalaena australis* and leatherback turtle *Dermochelys coriacea*), five 'vulnerable' species (whale shark *Rhincodon typus,* great white shark *Carcharodon carcharias*, humpback whale *Megaptera novaeangliae,* green turtle *Chelonia mydas* and flatback turtle *Natator depressus*), 37 'listed' species (including syngnathiformes, pinnipeds and marine reptiles) and three 'conservation dependent' species (eastern gemfish *Rexea solandri,* orange roughy *Hoplostethus atlanticus* and school shark *Galeorhinus galeus).* Fifteen migratory species and 34 species listed as 'cetaceans were also identified (Table 13).

Searches for seabirds occurring in the relevant CMAs/marine zone CMA sub-regions were carried out separately. Only seabirds likely to forage offshore and in the direct study areas were included in the database search. Intertidal and wading birds such as sandpipers, curlews and plovers (for example) were excluded from the assessment as they are unlikely to be affected by the proposal. The main groups of seabirds that were found to occur in the three study regions included albatrosses, petrels, shearwaters, terns, skuas, gulls, gannets and the endangered population of little penguins (*Eudyptula minor*) at Manly.

In the Hunter/Central Rivers CMA/NRMR, five species were listed as 'endangered', five listed as 'vulnerable', seven listed as 'migratory' and four just as 'listed' (Table 11).

In the Sydney Metro CMA/NRMR, five species were listed as 'endangered', 10 listed as 'vulnerable', five listed as 'migratory' and two just 'listed'(Table 12).

In the Southern Rivers CMA/NRMR, seven species were listed as 'endangered', 11 listed as 'vulnerable', seven as 'migratory' and one just 'listed'(Table 13).

No critically endangered or endangered ecological communities are known to occur within the proposed study areas.

2.4.3 Key Threatening Processes

The following Key Threatening Processes (KTPs) have been identified as relevant to the proposal:

- Hook and line fishing in areas important for the survival of threatened fish species (*FM Act*);
- Entanglement or ingestion of anthropogenic debris in marine and estuarine environments (*TSC Act*);
- Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris (*EPBC Act*).

Hook and line fishing in areas important for the survival of threatened fish species

Hook and line fishing refers to the activity that uses a combination of lines and hooks with the aim of catching fish. This includes, but is not restricted to, the use of lines composed of microfilament, wire and cord, with attached lures, hooks and jigs. Hand – lines, set lines, rod and reel fishing, trolling, lure fishing and fly fishing are all included in the activities identified as a key threatening process. This definition includes catch and release, not just the "taking" of fish (FSC 2003). Areas that are known to be used for feeding and breeding are considered important for the survival of a threatened species. Some of these areas may be declared as critical habitat, such as the grey nurse shark aggregation sites along the NSW coast. Species such as the critically endangered grey nurse shark, the endangered green sawfish and vulnerable black cod are considered particularly vulnerable to this KTP (Web Reference 11). Even when accidentally captured, hooks caught in fishes' mouths can result in damage that can impact on feeding behaviour and success. The effects of fish hooks can be more serious over a longer time if retained in the mouth, throat and stomach of fishes and sharks and ultimately can lead to death (FSC 2003). It is recognised that listing all hook and line fishing throughout NSW waters as a KTP would be unpractical and unwarranted. However, where known aggregation sites, spawning areas, important juvenile habitats and feeding areas are known, activities that could kill or adversely affect threatened fish species should be considered a threatening process and managed accordingly. A threat abatement plan is yet to be developed for this KTP.

Entanglement or ingestion of anthropogenic debris in marine and estuarine environments (TSC Act)

The NSW Scientific Committee has declared entanglement in or ingestion of anthropogenic debris in marine and estuarine environments to be a 'key threatening process' in NSW. Marine debris is mostly comprised of fishing gear, packaging materials, discarded convenience items and raw plastics. The major sources of marine debris are from ship waste, recreational activities, aquaculture industry and both urban and rural discharges into rivers, estuaries and coastal areas (Web Reference 12). Marine debris (particularly plastics) can become entangled around or ingested by marine animals. This can lead to a number of lethal or detrimental impacts for example:

- strangulation;
- increased drag;
- potential poisoning by polychlorinated biphenyls (PCBs);
- blockage and/or perforation of an individual's digestive system;
- wounds caused by line or net and subsequent infection;
- gastric impaction by plastic bodies.

Even sub-lethal effects of entanglement or ingestion of marine debris may reduce an individual's fitness and ability to successfully reproduce, catch prey and avoid predation. Records kept by the NSW National Parks & Wildlife Service and Taronga Zoo databases show that entanglement in monofilament line, presence of hooks in the mouth and/or gut, net/line wounds and gastric impaction of plastic bodies are the main reasons for injury or mortality in marine wildlife (Web Reference 12).

A number of threatened marine species have been found entangled in marine debris or to have ingested marine debris. This includes marine turtles, seals, cetaceans and a number of marine birds including the little penguin.

Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris' (EPBC Act)

This KTP is similar to the above KTP but applies to vertebrate marine life protected under Commonwealth legislation (Web Reference 13). The Commonwealth DEWHA has developed a draft Threat Abatement Plan to address the impacts of this KTP (DEWHA 2008).

2.4.4 Areas of Conservation Significance

For the purpose of this study, areas of conservation significance include areas declared as critical habitats under the *NSW FM and TSC Acts* and Marine Protected Areas (which includes Marine Parks, Aquatic Reserves and Nature Reserves).

Marine parks are areas of marine waters and lands permanently set aside to protect the biological diversity of our marine plants and animals, and to provide protection for unique and representative areas. Marine parks are zoned for multiple-uses such as fishing and recreation (Web Reference 14). Aquatic reserves have been established to protect biodiversity and provide representative samples of marine life and habitats. Aquatic reserves are generally small compared with marine parks, but play a significant role in by protecting important habitat, nursery areas and vulnerable and threatened species and have research and educational roles (Web Reference 15). Nature reserves are areas of predominantly untouched land in a natural condition and are considered to have high conservation value. Their primary purpose is to protect and conserve outstanding, unique or representative ecosystems, native plant and animal species or natural phenomena (Web Reference 16). Nature reserves are generally terrestrial, but may have associated marine components. Areas of conservation significance that occur within the wider study areas are summarised in Table 17.

The Port Stephens – Great Lakes Marine Park extends from Birubi Beach Surf Life Saving Club (North Stockton Beach), north, to Cape Hawke Surf Life saving Club (near Forster). As the Marine Park is located more than 45 km from the proposed Newcastle OAR site, the proposal is unlikely to cause any adverse impacts to species or habitats of the marine park and it is not considered further. Moon Island Nature Reserve (part of the Lake Macquarie State Conservation Area) is located off the coast at the entrance to Lake Macquarie (Swansea Heads) approximately 4 km south west of the proposed Newcastle OAR site. It is an important breeding and roosting habitat for seabirds including wedge tail shearwater (*Puffinus pacificus*), little penguins (*Eudyptula minor*), Dominican gull (*Larus dominicanus*), sooty oyster catcher (*Heamatopus unicolour*) and crested tern (*Sterna bergii*). The black backed gull is considered rare in Australia and the crested tern is an international migratory bird (Web Reference 17). There is thought to be one breeding pair of sooty oyster catchers and around 15 breeding pairs of little penguins (NSW NPWS 2005a) occurring within the reserve. According to the Pulbah Island and Moon Island Nature Reserve Plan of management (NSW NPWS 2005a) specific objectives for the Moon Island Nature Reserve include the protection of visual and aesthetic values; and conservation of biodiversity, with emphasis on protection of seabird nesting and roosting habitat.

In the Sydney study region, there are 10 Aquatic Reserves located between Barrenjoey Head (Broken Bay) and Shiprock (Port Hacking). Of these, three are considered relevant to the current proposal: these are the North Sydney Harbour Aquatic Reserve, Cabbage Tree Bay Aquatic Reserve and the Bronte-Coogee Aquatic Reserve. North (Sydney) Harbour Aquatic Reserve lies between an imaginary line from the headlands at North Head and Grotto Point and another line joining Little Manly Point, Manly Point and Forty Baskets Beach. The reserve extends from the seabed at these outer boundaries up to the mean high water mark between them and covers an area of approximately 260 ha (Web Reference 18). Within the reserve, line fishing is allowed only for fish with fins, although the collection or disturbance of marine life or habitat is prohibited. This includes collecting shellfish, pumping for worms, spearfishing and collecting dead or empty shells. The southern limit of North Harbour Aquatic reserve is located approximately 2 km from the proposed Sydney OAR site. The Cabbage Tree Bay Aquatic Reserve includes the whole foreshore of the bay from Manly Surf Life Saving Club to the northern end of Shelly Beach Headland, and encompasses all of Cabbage Tree Bay. The reserve is considered to be an important sanctuary for the weedy sea dragon, elegant wrasse, black rock cod and the blue groper amongst others (Web Reference 19) and is located approximately 4.2 km north of the direct study area.

Bronte-Coogee Aquatic Reserve on Sydney's eastern beaches includes the whole foreshore from the southern end of Bronte Beach to the rock baths at Coogee Beach, a distance of four kilometres. The reserve also extends 100 m seaward from mean low water. Line fishing is permitted in the reserve, together with the collection of rock lobster, sea lettuce and baitweed although recreational fishing competitions require a permit (Web Reference 20). The taking of groper by any fishing method is prohibited. The northern limit of the Bronte-Coogee Aquatic Reserve is approximately 7 km from the proposed Sydney OAR site.

Magic Point (south Maroubra) is a critical habitat for the grey nurse shark (*Carcharias taurus*). Grey nurse shark observations between 1998 and 2000 recorded by Otway and Parker (2000) and Otway *et al*. (2003), were mapped by the Natural Heritage Trust as part of the 'Broadscale Biodiversity Assessment of the Hawkesbury Shelf Marine Bioregion'. Maps showed that South Maroubra (Magic Point) was a significant aggregation site with sharks observed on 50 % of survey occasions in numbers representing 3.5 % of the total east coast population. The area of critical habitat includes a 200 m area off Magic Point with an 800 m buffer zone extending beyond the critical habitat. The Magic Point Critical habitat occurs approximately 12.5 km south of the proposed Sydney OAR site.

An endangered population of the Little Penguin (*Eudyptula minor*) is known to occur from just north of Smedley's Point to Cannae Point, North Sydney Harbour, Manly and is the only known breeding population on 'mainland' NSW (NSW NPWS 2000). The area has been declared a critical habitat and has a 50 m restriction zone extending outwards from the shoreline although it is unlikely to be an issue in relation to OARs. The proposed Sydney OAR is located approximately 3 km south of the southern boundary of the little penguin critical habitat.

Within the wider Wollongong study region, there is one nature reserve and one critical habitat which are considered relevant to the proposal. The Five Islands Nature Reserve is located approximately 2.4 km north of the proposed Wollongong OAR site and includes five small islands clustered off the coast of Port Kembla, immediately south of the city of Wollongong. The islands are clustered between approximately 0.5 km and 3.5 km off the coast (NSW NPWS 2005b). The five islands are Flinders Islet, Bass Islet, Martin Islet, Big Island and Rocky Islet, which together make up an area of approximately 26 ha. Rocky and Martin Islets and Big Island are tightly clustered to the mainland off Red Point while Flinders and Bass Islets are to the north and more distant. The reserve is a significant habitat for a number of migratory marine birds including the sooty oyster catcher (*Heamatopus unicolour*), wedge tailed shearwater (*Puffinus pacificus*), shorttailed shearwater (*Puffinus tenuirostris)* and white-bellied sea-eagle (*Haliaeetus leucogaster*). Two species of seal, the Australian fur-seal (*Arctocephalus pusillus doriferus)* and leopard seal (*Hydrurga leptonyx*), both of which are protected under NSW legislation also occur on the islands. According to the Five Islands Nature Reserve Plan of Management (NSW NPWS 2005b) specific objectives for the Reserve are that the islands remain important breeding sites for seabirds of conservation significance and to attain a more informed and better understanding of all terrestrial fauna within the reserve.

At Bass Point is a grey nurse shark critical habitat located within Bushrangers Bay Aquatic Reserve, approximately 4 km south of Shellharbour. The area is approximately 8 km south of the proposed Wollongong OAR site. Outside the critical habitat there is a 1 km buffer zone within which recreational fishing (apart from with wire trace line) is permitted. Distances of areas of conservation significance in relation to the proposed OARs are listed in Table 17.

2.5 Gaps in Information

Existing information relating to habitats and associated species assemblages that occur within the three study regions is mostly broad-scale or based on areas where other studies have been carried out.

In order to adequately assess potential impacts associated with the proposal, it is important that ecological investigations are carried out in the areas that would be directly affected by the proposal and will provide additional information to assist with risk and impact assessment.

Further investigations on species assemblages (fish and benthos), together with environmental conditions (sediment type, water quality and contaminants), have therefore been undertaken within the direct OAR study areas and are described in the following Section.

3 Field and Laboratory Methods

Benthos, BRUVS, sediment particle size distribution, water quality and heavy metals were sampled at the Newcastle study region on the 13, 14 and 19 of January 2009. Conditions during the sampling period were fine, with strong north - north easterly winds between 15 – 33 km p/h (Web Reference 41). Seas were choppy with 1 m – 2 m swell from the north east. Benthos was carried out on Tuesday the 14 January and all other sampling carried out on the 14 and 19 January. Sampling was carried out in the Sydney study region on Wednesday 21 January 2009. Conditions during the sampling period were fine, with moderate westerly winds up to 15 km/ph (Web Reference 41). Seas were choppy with around 1 m of swell from the south. Sampling was carried out in the Wollongong study region on Wednesday 23 January 2009. Conditions during sampling were fine, with light to moderate westerly winds up to 15 km/ph (Web Reference 41). Seas were slight to calm with around 1 m of swell from the south.

GPS positions of samples or readings taken during surveys of the study regions are listed in Appendix 2. Locations and sites sampled at each study regions are marked on Figures 1b and 1c.

3.1 Sampling Design

3.1.1 Benthos

The benthic survey provides information on the existing conditions at the three study regions (Figures 1b and c). At each study region (Newcastle, Sydney and Wollongong) the survey design was as follows:

- Locations;

(1 x impact location - the area of the proposed reef set)

(1 x control location - outside of the reef set in an area with similar sediment type and depth).

- Sites;

(4 x impact sites within the impact location)

(4 x control sites within the control location)

- Replicates;

(4 x replicate samples at each of the 4 impact sites)

(4 x replicate samples at each of the 4 control sites)

This design yields 32 samples at each study region, a total of 96 benthic samples for all three study regions (Figure 2).

3.1.2 Fish

BRUVS (Baited, Remote, Underwater, Video, Stations) were used to provide existing information on fish and mobile invertebrate assemblages at the three study regions (Figures 1b and c). The survey design was as follows:

- Locations;

(1 x impact location - the area of the proposed reef set)

(1 x control location - outside of the reef set in an area with similar sediment type and depth)

- Sites

(5 x impact sites within the impact location)

(5 x control sites within the control location)

- Replicates

(1 x BRUVS deployed at each of the 5 impact sites - spaced >200 m apart)

(1 x BRUVS deployed at each of the 5 control sites - spaced >200 m apart)

A fifth site was included to provide maximum coverage of the area. This yields 10 samples to be analysed for fish abundance and diversity per study region - a total of 30 BRUVS deployments for all three study regions (Figure 2).

3.1.3 Sediment Particle Size Distribution

Samples were also collected for analysis of particle grain size distribution. The design for collection of these samples was as for benthic samples, except two replicate samples (in addition to the benthos samples) were collected at each site, yielding 16 grain size samples at each location - a total of 48 grain size samples for all three study regions (Figure 3).

3.1.4 Water Quality

At each site where grain size and benthos samples were collected, the physico-chemical properties of water 1 m above the bottom and 1 m below the surface were recorded. Two replicate readings were taken at the surface and two at the bottom at each site. This yielded a total of 32 readings per study region - a total of 96 readings for all three study regions (Figure 4).

3.1.5 Heavy Metals

To estimate potential for the mobilisation of contaminants, further sediment samples were also collected. At each site where grain size, benthos and water quality samples were taken, one sediment sample was collected for analysis of heavy metal content. This yielded a total of eight samples per study region, four from the impact location and four from the control location - a total of 24 samples for all three study regions (Figure 3).

3.2 Sampling Sites

The three metropolitan regions proposed for artificial reef installation (Newcastle, Sydney and Wollongong) are referred to as ‘study regions’. At each study region, the proposal is for the installation of a ‘reef set’ consisting of four single ‘reef units’. Details of the structure design and potential configuration of the proposed reef units is outlined in the EA/draft PER. At each study region, an area of approximately 4 km^2 including the area occupied by each reef set, will be referred to as the ‘direct study area’. The area outside of this (within the study ‘region’) is referred to as the ‘wider study area’. A hand-held (accurate to < 5 m) was used to record positions of sample sites (Appendix 1). Depths were also recorded.

3.3 Sampling Methodology

3.3.1 Benthos

Samples collected for analysis of benthic assemblages (macroinvertebrates) were collected by deploying a Ponar benthic grab from a boat (Plate 1). The sampler collects approximately 2 L of sediment, with typical sample volumes of ~2 L. At each site, co-ordinates were recorded using GPS (accurate to < 5 m). Samples were sieved onboard through a 1 mm mesh sieve and the material fixed in a solution of 10% formalin in seawater with Rose Bengal dye. The Rose Bengal dye stains live animals pink, making them easier to sort from the sediment in the laboratory. The sieve was then examined after removal of sediment and any animals enmeshed in the sieve were removed using forceps and/or wash bottle and added to the main sample. After each sample, the sieve was inverted and rinsed with a jet of water to avoid cross-contamination of samples. Each sample was clearly labelled internally and externally, with the project details, time, date, location, site and replicate number. Each sample collected was checked off against a master list of samples and placed in a sealed labelled poly-drum for safe and leak-proof transport to the laboratory.

3.3.2 Fish

The BRUVS methodology is preferable to traditional fish survey techniques such as trawling and trapping, in that it is non-extractive and can therefore be used as a monitoring tool, or in no-take areas such as marine reserves. BRUVS surveys have been used to detect an increase in abundance and biomass of fish following implementation of a marine reserve (Denny *et al*. 2004) and as a sampling technique they provide higher and more reliable estimates of relative fish density than alternative techniques such as underwater visual census by SCUBA divers. Importantly, the BRUVS methodology is not limited by depth or allowable bottom time.

The BRUVS units each contained a high-definition (1080i) digital video camera, fitted with x0.6 wide angle conversion lens, and 60 minute MiniDV digital tapes (Plate 2). High-definition cameras provide suitable resolution in the low-light situations found at depths exceeding 20 m. Cameras were housed in custom–built underwater housings pressure tested to depths of 200 m. Cameras were set on manual focus at 'infinity' distance which prevents the cameras from going out of focus. Footage was captured from an area measuring approximately 1.8 m wide and 1.1 m high at a distance1.5 m from the camera lens.

BRUVS frames were made from solid aluminium, and deployed with ~2.7 kg of lead weight attached to each leg as ballast to provide stability in surge or current (Plate 2). The units were deployed via a length of silver rope attached to each corner of the frame, with a polystyrene float and fluorescent orange flag attached to the surface end of the rope to improve visibility from the surface, and allow location and retrieval of the unit.

Baits were housed in plastic sleeves made of robust, nylon mesh, to prevent fish from accessing the entire bait (Plate 2). The bait was fixed to a PVC pipe arm 1.5 m from the camera lens and elevated approximately 15 cm above the seafloor. Commercially available pilchards were used as bait and semi-frozen until placed in the bait sleeves. While onboard the vessel the bait was stored in an esky to keep them semi-frozen.

Each unit was be deployed for at least one hour before retrieval. The deployment process was repeated until at least five suitable samples of one hour duration had been recovered from each location. Video footage samples were deemed suitable when they met the following criteria:

- Visibility at least 4 m;
- Bait sleeve not more than 50 cm above the seafloor;
- Bait holder intact and visible;
- More than half the field of view unobscured;
- Bait remained in sleeve for at least 20 minutes;
- Footage in focus and clear enough to allow species level fish identification.

3.3.3 Sediment Particle Size Distribution

Additional sediment samples were collected by deploying a Ponar benthic grab from the boat. Samples collected for analysis of grain size were not sieved, but placed in 500 ml plastic containers and kept cool (< 5°C) until dispatched an NATA accredited laboratory for analysis, with a chain of custody.

3.3.4 Water Quality

At each site where grain size and benthos samples are taken, the physico-chemical properties of water at one metre above the bottom and one metre below the surface were recorded. Water quality was measured with a Yeokal 611 water quality probe and meter. Sampling locations were recorded from a hand held GPS unit accurate to < 5 m. The following variables were recorded:

- Salinity (ppt);
- Temperature (°C);
- Turbidity (ntu);
- DO (dissolved oxygen) (mg/L and % saturation;
- pH;
- ORP (mV).

3.3.5 Heavy Metals

Samples for analysis of heavy metals were taken from the remainder of sediment samples collected for grain size analysis collected by Ponar grab. The samples were sealed into 150 ml glass jars and immediately moved to an esky, to be stored at below 4°C until transfer to a freezer. Each jar was labelled with the projects details, date, time, location, site and replicate number. Samples were later delivered with a Chain of Custody to an NATA accredited laboratory for analysis.

3.4 Laboratory Methods

3.4.1 Benthos

Sieved sediment samples were processed in the laboratory (Plate 1). Excess formalin was drained from samples over a 1 mm mesh sieve and the formalin solution disposed of according to EPA guidelines. Samples were then rinsed in tap water and transferred to an alcohol solution for preservation.

Animals were then removed from sediment and elutriate under a binocular microscope, identified, counted and placed in separate vials for each taxon. Each vial was labelled with the project details and sample information (Plate 1).

Animals in major groups such polychaetes, molluscs and crustaceans were identified to family level. For groups where further identification would require a large expenditure of time (e.g. oligochaetes) or taxonomic status in Australia is insufficient to achieve a finer level of identification (e.g. anemones), identification was to a lower resolution such as Class or Sub Order. Data was entered into an Excel spreadsheet and checked by two staff against original data sheets.

3.4.2 Sediment Particle Size Analysis

Grain size samples were dispatched for analysis by an NATA accredited laboratory (ALS Laboratories) using the dry sieve method (AS 1289.3.6.11-1995), yielding the distribution of particles sizes greater than 0.063mm and median grain size.

3.4.3 Heavy Metals

Sediment samples were tested for trace metals arsenic (As), cadmium (Cd), cromium (Cr), copper (Cu), lead (Pb), mercury (Hg) and zinc (Zn) for NODG (National Ocean Disposal Guideline for Dredged Material 2002) guideline compliance. Sediment samples were prepared by 'Hot Block Digest' for metals in soils, sediments and sludges and tumbler extraction of solids/sample clean up. Moisture content was calculated by a gravimetric procedure based on weight loss over a 12 hour drying period at 103 - 105 ^{o}C. Total metals in sediments were calculated by the ICPMS (Inductively Coupled Plasma Mass Spectrometry) technique which uses argon plasma to ionise selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector. FIMS (Flow Injunction Mercury System) was used to test low level mercury content whereby an atomic absorption technique is used followed by an appropriate acid digestion.

3.5 Data Analyses

3.5.1 Benthos

The statistical analyses carried out included:

- A summary of general findings (mean number of individuals, mean number of species, comments on distribution of benthos);
- Analysis of assemblages using multivariate techniques including PERMANOVA, PERMDISP, non-metric Multi-dimensional scaling (nMDS) ordination and SIMPER analyses;
- Analysis of populations using descriptive and univariate techniques including PERMANOVA;
- Relationship of sediment characteristics to benthic assemblages using multivariate linear modelling (DISTLM);
- Comparison of assemblages at all sites including artificial reef locations and control locations

Sections 3.5.6 and 3.5.7 provide further details on the statistical routines carried out.

3.5.2 Fish

Video footage was analysed using the BRUVS Tape Reading Interface program developed at the Australian Institute of Marine Science (AIMS). This program runs as a Microsoft Access database which is specifically designed as a user-friendly interface for entering and storing data relating to fish abundance and diversity from baited underwater videos, and allows standardisation of data collected at different research agencies. The video footage was played back using a digital video camera connected simultaneously to a television set using an AV cable and a computer through a firewire (1394) port. The television display was used to observe and identify species, while the computer connection provided a link to the internal Microsoft Access database contained in the BRUVS Tape Reading Interface program.

Each video sample was given a unique identifying code, called an OPCODE. This code contains information defining survey period, site, replicate and camera number (1 - 5). The code was then used to create a unique record for each video sample in an Access database linked to the BRUVS Tape Reading Interface program. Each tape (sample) was reviewed for 45 minutes. During the tape reading, the following attributes were recorded in the database for each video sample:

- Tape reader;
- Time at which the unit reached the seafloor;
- Habitat/Habitats in view;
- Time at first appearance of each species;
- Activity (feeding/passing);
- Time at first feed of each species;
- Maximum number (MaxNum) of each species;
- Time at maximum number for each species.

In instances where large numbers of a species were present in a single frame, the video was paused and a still image used to count numbers of individuals in view at any one time (MaxNum).

As each new species was identified, a still screen image was captured from the video footage. These images were used as a quality control mechanism to ensure consistency of species identification between tape readers, and to build a reference image collection of species observed.

All data contained in the Access database linked to the BRUVS Tape Reading Interface program was checked by Cardno Ecology Lab staff prior to being extracted and analysed to ensure accurate data. This was done at several stages during the data entry and querying process.

Mean abundance (MaxNum), standard error of species abundance and the total number of species observed at each site was calculated.

3.5.3 Sediment Particle Size Distribution

Analysis of sediment particle size distribution included:

- General findings (percentage passing, mean and median grain size);
- Comparison of particle size distribution at all sites/locations;
- Relationships between grain size and benthic community composition.

Methods for multivariate statistical analyses were similar to that used for the analyses of benthic species assemblages.

3.5.4 Water Quality

Water quality data were compared with water quality guidelines for marine ecosystems in ANZECC & ARMCANZ (2000), which provides a schedule of trigger values for potential management response in marine waters of south-eastern Australia.

3.5.5 Heavy Metals

Levels of heavy metals found within sediment samples at all sites were compared to guideline levels recommended by the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000). The recommended guideline values are tabulated as interim sediment quality guidelines (ISQG) where low and high ISQG values correspond to low and medium effects ranges (ANZECC and ARMCANZ 2000).

3.5.6 Multivariate Analyses

Permanova+

Permanova+ in Primer v6, a permutation program for fitting linear analysis of variance models (Anderson *et al*. 2008), was used to examine differences between assemblages at sites across all locations. A matrix of differences in the types and relative abundance of the taxa between all possible pairs of samples was compiled by calculating their respective Bray-Curtis dissimilarity coefficients, after transforming abundance data to their square root. This transformation down-weights the importance of the most abundant groups of animals and thereby ensures that dissimilarities reflect groups of animals with large and moderate abundances (Warwick 1993). The underlying distribution of the data was determined by repeated randomisation of the samples in the dissimilarity 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. A nested statistical design was used with the following factors:

- Study Region (Newcastle, Sydney , Wollongong);
- Locations (nested in Study Region);
- Sites (nested in Study Region and Location).

Only two factors (Study region and location) were used for analyses of fish assemblages. *Post hoc* permutational t-tests using Permanova+ were performed to examine significant interactions or main effects. Monte Carlo permutations were used to obtain *P*-values when the number of unique permutations was less than 100 (Anderson *et al*. 2008).

MDS Ordinations

Spatial patterns in the composition of the assemblages were examined by means of non-metric Multi Dimensional Scaling (nMDS) ordinations (Warwick 1993). nMDS provides a graphical representation of the assemblages in the samples based on their similarity within and among places or times sampled. In nMDS plots, samples with similar sets of taxa (plant and animal groups) cluster closer together than those containing different sets. The stress value for each plot indicates how well the data fit the two dimensional representation. The lower the value, the better the fit of data, and values lower than 0.2 are considered acceptable (Clarke and Warwick 2001). The nMDS plots were based on the averages (centroids) of replicates from sites within each locality.

Linear Modelling

Multivariate relationships between assemblages and sediment grain size was examined using the Distance-based Linear Models (DISTLM) routine in Permanova+. This is a multiple regression procedure that provides quantitative measures and statistical tests of the variation in the data explained by one or more predictor variables (McArdle and Anderson 2001, Anderson *et al*. 2008), such as sediment grain size, metal concentrations, etc.

SIMPER

SIMPER analyses from the Primer v6 multivariate statistical package (Clarke and Gorley 2006) were used to identify taxa that contributed most to spatial dissimilarities.

3.5.7 Univariate Analyses

Analysis of variance was used to examine differences in taxa, species abundance and number that each contributed 5% or more to dissimilarities between sites as determined by SIMPER. Permanova+ was used to perform permutational analysis of variance as 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. The same design as in 3.5.6 was used in the univariate analyses.

4 Results of Field Investigations

4.1 Benthos

4.1.1 General Findings

General results are summarised in Appendix 3. Macrofaunal assemblages across all study regions were generally diverse with a total of 156 taxa from 17 phyla. Examples of some groups of organisms observed during field sampling are shown in Plate 3. In terms of number of taxa (an indication of biodiversity), the greatest mean number of taxa (32.3) was recorded at the Wollongong study region. The Sydney study region was the least diverse (total mean number of taxa 25.9).

The mean number of individuals was greatest in the Wollongong study region (148.5), while the lowest number of individuals was recorded in the Newcastle study region (121). Mean total number of taxa was similar in all regions (Figure 5). Crustaceans, followed by polycheates, were the most dominant phyla present at all study regions, in terms of both number of taxa and abundance (Figure 6). Molluscs were the next most dominant phylum at all study regions, with Echinodermata, other worm phyla (e.g. nematodes, nemerteans, oligochaetes and sipunculids) and other phyla (e.g. actinaria, bryozoa and fish larvae) represented by much fewer taxa and individuals (Figure 6).

4.1.2 Analyses of Assemblages

Differences in assemblages were evident at all spatial scales (Table 1). Estimates of components of variation indicate that the main component of variation among assemblages was among the replicates (Table 1). Pair-wise tests indicate that all regions were significantly different from each other with the greatest source of variation between Sydney and Newcastle. Variation at the level of location (i.e. between OAR and control locations) was due to significant differences in the Newcastle and Wollongong study regions ($P<0.05$) whereas locations within the Sydney study region were similar to each other. Differences among sites within locations in all study regions were also evident apart from the Newcastle control location.

The significant PERMDISP ($P<0.05$) indicates that significant differences among study regions are due partly to differences in multivariate dispersion (spatial variability). Samples within the Sydney study region showed the greatest dispersion (39.4 %) and samples within the Newcastle study region the least (34.1 %). The PERMDISP test for the term ‘sites’ was not significant, indicating that differences between sites are not the result of differences in spatial variability.

MDS ordination (Figure 7) illustrates the significant differences in assemblages between the three study regions and also variation within the Sydney study region evident from the greater dispersion of data points.

Results of SIMPER analyses (Table 2) show the families of macroinvertebrates characteristic of the three study regions. Amphipod crustaceans contributed most to the similarity within study regions and locations in all cases. Taxonomic groups contributing 5 % or more to dissimilarity between study regions were the aorid group (including Families Aoridae, Iseidae, Photidae and Unciolidae), polychaete worms (Family Onuphidae), an ostracod crustacean (Family Philomedidae), and an isopod crustacean (Family Apseudidae) (Plate 4).

4.1.3 Analyses of Populations

Figure 8 shows the relative abundances of taxonomic groups contributing 5 % or more to dissimilarity between study regions. Amphipod crustaceans in the aorid group were most dominant in the Sydney and Wollongong regions but not in Newcastle. Amphipods from the family Platyischnopidae were abundant in the Newcastle study region but not in others. Ostracod crustaceans from the family Philomedidae were prevalent at Sydney and Wollongong but absent from the Newcastle survey. Isopod crustaceans (family: Apseudidae), were found across all study regions. Polychaete worms (Family: Onuphidae) showed variability at the scale of location due to significant differences within the Newcastle and Wollongong study regions and were probably the most important taxa contributing to the overall variation at this level.

4.2 Fish

4.2.1 General Findings

BRUVS were deployed and retrieved without incident apart from two deployments at the Newcastle control on the 14 January where sea conditions had deteriorated and wind speed increased up to 33 km/ph. This resulted in the BRUVS being dragged by the current during deployment and sitting at an angle facing upwards. Sampling was therefore resumed on the 19 January and was completed without incident.

Video footage from all samples was clear, in focus, and allowed species level identification of most fishes observed. Visibility varied among samples, ranging between 3 m - 10 m. Even in situations of low light or poor visibility, the high-definition cameras captured clear footage which allowed species-level identification of fishes.

A total of 22 species and 14 families of fish were identified from the three study regions surveyed. Four of the families identified were cartilaginous fishes (Class: Chondrichthyes) and ten were bony fishes (Superclass: Osteichthyes). Two species of crustacean of the families Raninidae (spanner crabs) and Diogenidae (hermit crabs) were also observed on the seabed adjacent to the BRUV units at the Sydney and Wollongong study regions respectively. None of the species are strongly associated with rocky reef habitat. They are all either prevalent in sedimentary habitat or more loosely associated with reef.

The largest number of individuals (MeanMaxNum 133.4) was recorded at the Newcastle study region, a MeanMaxNum of 118.4 was recorded at the Sydney study region and the smallest number of individuals (MeanMaxNum 41.6) was recorded at the Wollongong study region (Table 3). Although the largest numbers of individuals were recorded at the Newcastle study region, this had the fewest species. Sydney was the most diverse of the three locations investigated (16 species in total). Mean total numbers of taxa and mean total abundances are given in Figure 9.

The most abundant species across the entire survey (MeanMaxNum 176) was the chinaman leatherjacket, *Nelusetta ayraudi* (Table 3, Plate 5). Long-spine flathead *(Platycephalus longispinus*), silver trevally (*Pseudocaranx dentex*) and clupeids (herrings, sardines and pilchards) were also abundant during the entire survey. Although chinaman leatherjacket, long-spine flathead and silver trevally were dominant at the Newcastle and Sydney study regions, only long-spine flathead was dominant in the Wollongong survey. Silver trevally were not recorded at any of the Wollongong sites. The fiddler ray, *Trygonorrhina fasciata* (Plate 5) and six-spine leatherjacket (*Meuschenia freycineti*) were the next most abundant species recorded at the Wollongong.

Still photographs extracted from the BRUVS footage indicated that habitat at the three study regions consisted predominantly of bare sand (Plates 6 - 8) with occasional sand waves and shell grit evident. As would be expected, many of the species, were typically demersal or benthic and commonly occur over sand e.g. the flatheads (*Platycephalus* spp.) rays, chinaman leatherjacket and flounder (*Pseudorhombus* spp.) Typically pelagic species including yellow-tail scad, *Trachurus novaezelandiae* (Plate 5), Australian bonito, *Sarda australis* (Plate 5), clupeids and some demersal species normally associated with reef e.g. six–spine leatherjacket *(Meuschenia* spp.) and samson fish (*Seriola hippos)* were also observed.

4.2.2 Analyses of Assemblages

Study region was a significant source of variation PERMANOVA (P<0.00 Table 4) which would be expected due to the broad geographical separation among regions. The significant PERMDISP result (P<0.001) also indicates that differences between study regions are mainly due to spatial variability within the Wollongong study region.

Pair-wise tests indicated that variation among study regions was due to the differences between Wollongong and Newcastle and Wollongong and Sydney.

Separation of these fish assemblages are presented in an MDS ordination (Figure 10).

Results of SIMPER analyses (Table 5), shows the species characteristic of each study region and location. Flatheads (*Platycephalus* spp.) were common at all locations. Long-spine flathead *Platycephalus longispinus* was recorded at all study regions although was considerably more abundant in the Wollongong region. Species contributing 5 % or more to dissimilarity between study regions were chinaman leatherjacket *(Nelusetta ayraudi*), yellow-tail scad *(Trachurus novaezelandiae*), silver trevally *(Pseudocaranx dentex*), six-spine leatherjacket *(M. freycenetti*) and the fiddler ray (*Trygonorrhina fasciata*), see Figure 11.

4.2.3 Analyses of Populations

The overall number of taxa differed significantly between the three study regions, which was consistent with the patterns observed in assemblages. Pair-wise tests indicate that this was due to significant differences in the number of taxa recorded in Wollongong compared with Newcastle and Sydney. The abundance of chinaman leatherjacket, silver trevally and six-spine leather were found to be a significant source of variation among the three study regions. Pair-wise tests indicated that the abundance of chinaman leatherjacket was a significant source of variation between Wollongong and the other study regions due to much fewer numbers recorded in Wollongong compared to in Newcastle and Sydney (Table 4, Figure 11). Abundance of silver trevally and six-spine leatherjacket was also a significant source of variation between Newcastle and Wollongong (Table 4). Silver trevally was most abundant in Newcastle and Sydney but not in Wollongong. Six-spine leatherjacket and the fiddler ray were found in all three study regions but were most abundant in the Wollongong study region (Figure 11).

4.3 Particle Size Distribution

Sediments collected at the three study regions were similar, consisting of a high percentage of sand (particle size between 0.06 mm – 2 mm) and a negligible percentage of gravel (particle size > 2 mm) (Appendix 4). Coarser fractions were due to shell grit and occasional large shell fragments observed during sample collection. Still photographs extracted from the BRUVS footage show the relatively barren habitat at all study regions consisting of fine sandy substratum with evidence of shell grit deposited between sand waves or in patches (Plates 6 – 8). Patches of macroalgae or reef habitat were not evident at any of the locations sampled with BRUVS. Sandy polychaete tubes were the only epibenthic structures observed on the seabed.

In the Newcastle study region, the sediment consisted of 95 % to 99 % fine, golden sand and (Table 6) with shell grit and polychaete tubes (Appendix 2, Plate 9).

Sediment at all Sydney sites consisted of 85 % to 99 % sand (Table 6). Slightly coarser sediments were recorded at site 2 at the proposed OAR (impact) location. Shell grit, shell fragments and polychaete tubes were observed during sample collection (Appendix 2, Plate 10).

Sediment samples collected from the Wollongong study region were noticeably darker than the two previous study regions (Plate 11), but were of similar composition, consisting on average between 95 % and 99 % sand at each site (Table 6). Occasional pockets of black, anoxic mud, shell grit, shell fragments and polychaete tubes were also observed.

Average median grain size was generally 0.15 mm larger at the Newcastle study region compared with the Sydney and Wollongong study regions (Figure 12). Control site 3 at Newcastle and control site 1 at the Sydney study region were relatively coarser than other sites sampled.

Particle grain size was differed among study regions and among study sites ($P<0.005$), but not between locations within study regions. Pair-wise tests indicate that this is likely to be due to the larger median grain size at the Newcastle region (Table 7). Some of the difference was due to small-scale spatial variability, particularly in the Sydney region PERMDISP ($P \leq 0.05$).

MDS ordination (Figure 13) indicates some separation between the Newcastle study region and the Sydney/Wollongong study regions and also shows the greater dispersion among samples in the Sydney region.

Results of DISTLM analysis (Table 10) also indicated a significant relationship between median grain size and macrofaunal assemblages ($P<0.001$), although this only accounts for approximately 15 % of the variability.

4.4 Water Quality

Water quality data collected *in situ* during site inspections were used to assess water quality within the study area by comparison with ANZECC/ARMCANZ (2000) guidelines for marine ecosystems in South–eastern Australia (Table 8). These data represent only a “snapshot” view of water quality on the day of sampling and should be extrapolated with caution (Table 8). Surface water temperatures at the three study regions varied between 17.4°C and 18.4 °C, while bottom temperature varied between 15.2 °C and 16.4 °C. In general, salinity varied between 36 and 38 ppt with surface salinity greater than nearer the seafloor. pH at all study regions was within the recommended ANZECC/ARMCANZ guidelines except at Sydney, control location, site 4 which was marginally above the upper recommended trigger value. Percentage saturation of dissolved oxygen (DO) was below the recommended ANZECC/ARMCANZ guidelines for marine ecosystems at all study regions sampled, with DO percentage saturation generally lower for bottom samples than at the surface. DO percentage saturation was lowest at the Sydney proposed OAR (impact) location (sites 3 and 4). Relatively low dissolved oxygen is indicative of a slight to moderately disturbed system, likely to be the result of anthropogenic activity as all sites are adjacent to significant metropolitan areas. Average turbidity was within recommended ANZECC/ARMCANZ guidelines at all sites except Sydney, impact site 2 and Sydney control sites 1, 2 and 3 which were marginally above the upper recommended ANZECC/ARMCANZ trigger value. This is likely to be a sampling error caused by the water quality probe making contact with the seabed and disturbing bottom sediment rather than an indication of impaired water quality.

4.5 Heavy Metals

Concentrations of metals analysed in sediment samples at all sites and study regions were well below the ANZECC/ARMCANZ ISQG lower trigger values, indicating that potential disturbance to surficial sediments would be very unlikely to mobilise heavy metal contaminants (Table 9).

5 Conclusions

The main conclusions drawn from existing information and the field work done for this study include the following:

- There is little existing information for the direct study areas although there are a number of studies which have been carried out along the mid-NSW coast.
- Habitat type was similar in all regions and consisted of relatively flat, sandy substratum with shell grit deposited between sand waves or in patches and evidence of polychaete tubes.
- Habitat mapping surveys carried out by DECCW as part of the EA/draft PER confirm that there are areas of natural reef in the vicinity of the proposed Sydney and Wollongong locations (see Technical Report E of the EA/draft PER). Dunbar Head is located approximately 400 m to the south-west of the proposed Sydney site. Extensive areas of reef were recorded approximately 870 m to the south, 60 m to the south-east and 30 m to the north-east of the proposed Wollongong location.
- Benthic assemblages in all study regions were diverse and characterised by large numbers of crustaceans and polychaetes with fewer representatives of other phyla. Analyses of macrofaunal communities showed evidence of large and small-scale variation among regions, locations and sites. These results were similar to earlier studies of benthic community composition of sandy habitats done at similar depths along the mid-NSW coast.
- Fish assemblages consisted predominantly of demersal species commonly associated with sandy habitat, although some partly pelagic and reef-associated species were also observed. Large-scale variation among study regions was evident.
- The Ocean fish trawl and ocean prawn trawl are the main commercial fisheries likely to be affected by the proposal. Subsequent to approval, it is likely the OARs would be targeted by commercial trap and line fisheries.
- Water quality was similar in all regions, with percentage saturation of DO below ANZECC/ARMCANZ recommended guidelines in all areas, indicative of a slight to moderate disturbance. Levels of heavy metals recorded in sediment samples were well within the recommended guideline levels.
- A number of threatened and or protected species are known or likely to occur within the three study regions. It was not however, considered that further assessment by means of a Species Impact Statement (SIS), would be necessary for any of the species identified. It was considered the proposal had potential to exacerbate Key Threatening Processes (KTPs) namely harm or injury from entanglement in discarded fishing gear or anthropogenic debris.

6 Risk Assessment

6.1 Introduction

Environmental or ecological risk assessment has become an important means for identifying the likelihood and relative consequence of potential hazards associated with human activities. It is also now being widely advocated as beneficial for fisheries management (Fletcher 2005).

Typically, assessment of risk entails the identification of a potential <u>hazard</u> (i.e. some aspect of the activity that could affect the environment), a judgment of the <u>likelihood</u> that the hazard has of occurring and a judgement of the <u>consequence</u> of that hazard, if it did result from the proposed activity. Frequently, scientists and managers also consider those aspects of the environment that might be subject to the hazard; such aspects are often referred to as <u>receptors</u>.

As part of a Preliminary Environmental Assessment, a risk analysis workshop was held on 17 January 2008 attended by representatives of I&I NSW, The Ecology Lab and Worley Parsons. The aim of the workshop was to identify potential issues/hazards associated with the Offshore Artificial Reefs program, to assess the likelihood of occurrence of these hazards and assess the consequence to key receptors if these hazards eventuated. This helped to focus on key issues related to marine ecology for further assessment. The current risk assessment (carried out by Cardno Ecology Lab) investigates these issues (related to the flora and fauna) in greater detail. The risk assessment consists firstly of a general assessment of the wider issues relating to the marine environment and secondly, concentrates on species likely to be affected by the proposal by means of productivity susceptibility analysis (PSA).

Key points that need to be recognised in relation to the general risk assessment:

- The risk assessment benefited greatly from the initial site selection and constraints mapping (The Ecology Lab 2008b) whereby major biological constraints such as areas of natural reef and areas of conservation significance were avoided.
- The risk assessment was done at a generic level, that is, without particular emphasis on any of the three study areas. Impacts on specific study areas are discussed in the following section.
- Risk is very often scale-dependent, therefore the risk assessment considered the potential effects of the artificial reefs at the direct and the wider study areas.
- The risk analysis methodology mainly deals with impacts on the environment, however, the methodology has also been interpreted to analyse relevant social issues (such as the effect on commercial fishing).
- The risk assessment takes into account potential effects from a single reef set and does not consider cumulative effects of the three reef sets along the coastline. This is considered further in the impact assessment.

Appendix 6 presents the rationale for scoring probability/likelihood of a hazard occurring and of the consequence if the hazard eventuated. Scores of likelihood and consequence may then be combined into a matrix to provide a subjective judgement of significance. Based on this, each hazard/risk is identified as low, medium or high significance. This does not mean that the project should not proceed (i.e. if the level of risk is high) or that an issue should be ignored if the level of risk is considered low, but rather that the issue may need greater or less effort in management/mitigation or that further research on the receiving environment is required.

6.2 Results

Risks were generally more significant within the direct study area (i.e. at small spatial scales) rather than at the scale of the wider study area (Table 14). The majority of issues identified (including issues of high significance) were related to the pelagic environment, recreationally and commercially important species and threatened species. In terms of social issues, loss of commercial fishing ground was considered to be significant. Environmental and social risks identified in the risk assessment are addressed in the Assessment of Impacts (Section 7) and where appropriate, measures to mitigate or manage these risks are discussed. Overall results of the risk assessment are summarised below:

Direct Study Area

Issues of High Significance:

- Increased mortality (from aggregation); and

- Drowning (spear fishing).

Issues of Moderate Significance:

- Sediment disturbance from unit emplacement (e.g. turbidity);
- Direct loss of habitat (soft sediment areas);
- Change to sedimentary characteristics (soft sediment areas);
- Sediment contamination;
- Changes to benthic assemblages (soft sediment areas and proximal natural reef);
- Increased predation by fishes from the OAR on benthos;
- Commercial trawling in areas not previously trawled;
- Change to fish assemblages (Proximal natural reef);
- Loss of habitat (benthic species);
- Attraction/aggregation of fish;
- Increased fishing effort;
- Contamination/pollution;
- Incidental capture (all groups of threatened and protected species);
- Aggregation of threatened or protected species (fish only);
- Harm from marine debris and pollution (all groups of threatened and protected species);
- Increased predation (threatened and protected fish);
- Loss of habitat (threatened and protected fish);
- Impacts on nature reserves;
- Loss of commercial fishing ground;
- Conflict between user groups;
- Gear hook up;
- Collision from crowding.

Wider Study Area

No issues of high significance were observed in the wider study area

Issues of Moderate Significance:

- Sediment disturbance from unit emplacement (e.g. turbidity);
- Change to sedimentary characteristics (soft sediment areas);
- Changes to benthic assemblages (proximal natural reef);
- Attraction/aggregation of fish;
- Increased mortality (from aggregation);
- Incidental capture (all groups of threatened and protected species);
- Aggregation of threatened or protected species (fish only);
- Harm from marine debris and pollution (all groups of threatened and protected species).

6.3 Productivity Susceptibility Analysis (PSA)

The risk assessment indicates that impacts of increased fishing mortality (from aggregation) on target species is an issue of high significance in relation to the proposal. This is, however, expected, as the aim of the proposal is to promote fishing opportunity. In order for the proposal to meet its objectives, fishing mortality must therefore occur. This is balanced by two mitigating factors:

- If the OAR increases production of fish, the additional mortality related to fishing would not reduce the population size at existing levels;
- Not all species are equally vulnerable to fishing mortality and different species are likely to be affected differently.

In fisheries management, productivity susceptibility analysis (PSA) is commonly used as part of a process to determine how vulnerable different species, communities or components of a habitat are to impacts from certain fisheries and for assessing the sustainability of a fishery. This approach has been adapted from Stobutzki *et al*. (2001) and Hobday *et al*. (2004) to provide a general assessment of the vulnerability of species likely to occur in the OAR study areas to fishing mortality.

The PSA approach assumes that vulnerability will depend on both the susceptibility of a species to capture on the OARs and the productivity of a species, which will determine the rate at which the population can recover from fishing mortality. Susceptibility to fishing mortality on the OARs is considered to depend upon behavioural factors such as:

- Attraction to artificial structures and habitat preference;
- Site fidelity (i.e. whether a species is resident or transient);
- Depth range (i.e. whether there is overlap of the species depth range with the OAR depth range).

For example, species that are attracted to the structure and occur within a narrow depth range for the proposed OAR units are likely to be more susceptible to fishing mortality than those that do not have a habitat preference for reef or structure and generally occur outside the OAR depth range. For the purpose of the assessment, it is also assumed that existing populations of resident (or territorial) reef species are less likely to occur on the OAR than transient species, if the units are positioned a sufficient distance away from the natural reefs to prevent overlap. Thus, territorial reef species are less likely to occur on the OARs and will be less susceptible to fishing mortality (on the OAR) compared to transient species. This does not apply to territorial reef species that recruit to the OAR as larvae, which would then become susceptible to fishing mortality. In this case, fishing mortality of resident reef species could potentially be mitigated by the increase in productivity from new recruits (if they were not prevented from recruiting to natural reefs).

In summary, site-attached species occurring on natural reef are less likely to move to the OAR than transient species. This hypothesis can be tested readily by monitoring the species and their size distribution in the period following deployment of the reef units. Larval fishes are typically much more abundant than post-settlement fishes. It would generally be expected that there would be an over supply of larval fishes and suitable settlement habitat would be limiting. On this basis, surplus larvae would be available to colonize the OARs, without limiting recruitment to natural reef.

Other factors related to susceptibility and species vulnerability are:

- The recreational or commercial importance of a species (i.e. a non-target species is more likely to be returned to the water after capture and avoid mortality than a targeted species).
- The species exploitation status (i.e. populations that are heavily exploited and suppressed from overfishing are likely to be more at risk than those that are moderately or lightly fished). The species exploitation status was classified according to the NSW DPI Status of Fisheries Resources (Scandol *et al.* 2008), see Appendix 8.

Productivity depends more on life history traits, whereby long lived, late maturing and slower growing species with low fecundity are likely to have relatively low productivity and therefore be more vulnerable to fishing mortality.

Table 15 lists the criteria used to assess productivity and susceptibility of species likely to be affected by the proposal and explains the rationale for ranking each attribute. The analysis was carried out on 48 species most likely to occur in the study areas based on the following:

- Surveys of line fishers and spearfishers carried out from March 2007 to February 2008 (Web Reference 21 - 23);
- Fisheries catch statistics (Web Reference 24);
- Results of BRUVS surveys carried out from the current OAR study.

The top ten recreational species (based on number of individuals observed) and top 20 commercially targeted species (based on reported gross tonnes) were extracted from the survey data. The ten most abundant species from the current survey also were included. In addition, species not represented but considered likely to occur on the OARs were included. The list of species included in the PSA is not exhaustive, but aims to represent a range of recreationally and commercially important species likely to be affected by the proposal.

Species information relating to the relevant criteria was collated from the NSW DPI Status of Fisheries Resources in NSW 2006/2007 (Scandol *et al*. 2008), Fishbase (Web Reference 26) and from the relevant literature (Appendix 7). For each species, criteria were ranked from 1 to 3, whereby 1 indicated low susceptibility and high productivity (low risk) and 3 indicated high susceptibility and low productivity (high risk). Rankings for each species are listed in Table 16. The average productivity and susceptibility scores for each of 48 species were plotted (Figure 14). Each data point is numbered (from 1- 48) and corresponds to an ID listed in Table 16.

The overall risk value (or measure of vulnerability) is the Euclidean distance from the origin of the graph (Hobday *et al*. 2004) to each respective point. The plot is divided into equal thirds representing three risk categories (high, medium and low). The cut–offs for each category are thirds of the total distribution of all possible risk values.

Limitations of this approach occur where there is uncertainty or missing data values (Hobday *et al*. 2004). In such circumstances, a more conservative rank was assigned (i.e. a high risk category was used). Units with missing scores therefore had a more conservative overall risk value than those species with fewer missing attributes. Stobutzski *et al*. (2001) recommends that in situations where attributes are strongly correlated only one of them should be included in the PSA. This is because two or more criteria explaining the same factor can over emphasize their effect. Correlations between the criteria indicated that there was little redundancy among the criteria suggesting that each criterion contributed unique information. The only exception was the correlation between maximum length (L_{max}) and length at maturity (L_{mat}) for which r = 0.87. The criterion maximum length was therefore removed from the analysis as length at maturity is likely to be more reliable than maximum length.

Of the 48 species assessed, 12 were considered to be at relatively high risk, five at low risk and the majority (17 species) at moderate risk to fishing mortality as a result of the proposal (Figure 14). The high risk group included wobbegong sharks (*Orectolobus* spp.), shovelnose ray (*Aptychotrema rostrata*), long-fin pike (*Dinolestes lewini*), sergeant baker (*Aulopus purpurissatus*), silver trevally (*Pseudocaranx dentex*), kingfish (*Seriola lalandi*), mulloway (*Argyrosomus japonicus*) and moray eel (*Gymnothorax prasinus*). The cartilaginous fishes (wobbegongs and shovelnose ray) were grouped as high risk mainly due to their life-history traits (i.e. they produce few offspring, are vivaporous and grow to a large size) which result in a low productivity ranking. Silver trevally, kingfish and mulloway are also in the higher risk group as they are targeted recreational species, are likely to occur on the reefs and are vulnerable to exploitation as they are 'growth overfished' or 'overfished' (Appendix 8). The blue grouper (*Achoerodus viridis*), also has a low productivity ranking. These species should therefore be considered a high priority within the impact assessment and for the future monitoring and management of the artificial reefs. It is, however, important to consider that existing populations of territorial reef species such as wobbegongs and blue grouper are only likely to be at high risk if they move away from natural reef and then became resident on the OAR. Provided that the OARs are located a sufficient distance away from natural reef, these species should not be affected significantly.

Long-fin pike, sergeant baker and moray eel are also potentially at high risk as they are target recreational species that are likely to occur on the OARs, however, gaps in life-history data may have resulted in an over-conservative productivity ranking for these species.

The moderate risk group included sawtail (*Prionurus microlepidotus*), tarwhine (*Rhabdosargus sarba*), (leatherjackets (Monacanthidae), snapper (*Pagrus auratus*), morwongs (Cheilodactylidae), nannygai (*Centroberyx affinis*), fiddler ray (*Trygonorrhina fasciata*), yellowfin bream (*Acanthopagrus australis*), Australian salmon (*Arripis trutta*) and silver sweep (*Scorpis lineolata*) among others.

Although this group is considered less vulnerable to fishing pressure, many of the species are of high commercial and recreational importance and are likely to be targeted on the OARs. Therefore consideration in the proposal's long-term management and monitoring strategy (particularly for target species) is also required for this group.

Species at low risk include those predominantly associated with sandy habitat with high productivity rankings such as flatheads (Platycephalidae) and species found further offshore, such as clupeids (herrings, sardines, pilchards) and mackerel (*scomber australasicus*). These species may be recorded as part of the ongoing monitoring but should be considered of low priority. There would be some loss of habitat for these sand dwelling species as a result of the unit placement, although this would be relatively insignificant in relation to the amount of similar habitat.

It should be noted that all species of fish that are threatened or protected should be considered to be of high vulnerability. The only exceptions to this would be most groups of syngnathiforms which are unlikely to be at risk of incidental capture even if occupying the proposed OARs.

7 Assessment of Impacts

7.1 Key Elements of the Proposal Relevant to Aquatic Ecology

A full description of the proposal is provided in the EA/draft PER. Those elements of the proposal relevant to the assessment of impacts on marine ecology include the following:

- At each region, four individual 'reef units' would be deployed in coastal waters at depths between 30 m – 40 m. Initially only one reef set would be deployed at one of the three regions for the pilot project. Subsequent deployments would depend on the success of the pilot.
- The combination of the four 'reef units' would collectively create a 'reef set' (i.e. the multi-component artificial reef) with units spaced between 200 m – 600 m apart either in a diamond or line configuration orientated into the prevailing swell direction. Each reef unit would occupy approximately 180 m^2 (720 m^2 for a reef set). The area of seabed occupied including bare sediment between the units would be approximately 0.39 km^2 for a diamond configuration and approximately 0.01 km^2 for a line configuration.
- Reef units would be fabricated from steel and sit directly on the seabed without requiring additional anchoring.
- The reefs have been designed to suit local conditions and to specifically target popular recreational species.
- The final design would be verified by a structural marine engineer to ensure the structures would remain stable even in extreme storm conditions.
- Units would be fabricated on land and transported by barge to the deployment site where they would be lowered by crane to their final position.
- The structures would not be physically marked with navigational aids as this is considered to be a hazard to small boats.
- The minimum design life of the reefs is 30 years and potentially longer, after which the units would be decommissioned. It is considered that a separate environmental assessment would be necessary prior to the time of decommissioning.

Additional studies were carried out to investigate the physical characteristics of the seabed at the proposed OAR locations including habitat mapping carried out by DECCW (Technical Report E) and assessment of impacts on the local seabed and nearshore coastal environment by Cardno Lawson Treloar (Technical Report C). In summary, it was found that:

- Habitat in the direct study areas consists mainly of bare fine to medium grained sand suitable for OAR deployment but there are areas of natural reef present in the vicinity of the proposed Sydney and Wollongong locations.
- Placement of the OARs would not have any measurable impact on nearshore coastal processes.
- Scouring, sediment infilling and deposition is likely to occur at the base of the OAR structures, but is likely to be minor and unlikely to compromise the stability of the units.

7.2 Impacts on Soft-Bottom Areas

Potential short-term impacts on soft sediment communities (including infauna and epifauna) are listed and discussed below:

- Sediment disturbance

Initial deployment of the OAR units would cause localised disturbance and re-suspension of sandy sediment in the area where the units are installed. This would result in a short-term and localised increase in turbidity, but there would be no immediate mobilisation of metals from surface sediments (Section 4.5). The deployment of units would result in a loss of benthic invertebrates at a very small scale and disturbance or displacement of fish and mobilise invertebrates.

Potential long-term impacts on soft sediments are listed and discussed below:

- Direct loss of habitat

Some loss or alteration to infaunal communities would occur directly below where the supporting legs and sections of the OAR are laid. The area of sandy habitat occupied by the OARs, is however, negligible when considered in context with the extensive areas of similar habitat in the direct and wider study areas. Area occupied as a result of the proposal is not considered unique in the wider study area and adjacent sandy habitat is likely to support very similar communities to those sampled in the current survey. Furthermore, the habitat will continue to support a wide variety of marine organisms found living on or over soft sandy substratum. It is expected that adjacent sandy habitat would support very similar communities to those sampled in the current survey.

- Change to sediment characteristics

Soft bottom habitats adjacent to artificial reefs may be affected by altered wave and current patterns that in turn can influence scouring, sand ripple patterns and grain size. Once established, detritus from dead organisms and waste materials produced by the reefs inhabitants will sink to the seafloor and may also alter the physical properties of the substratum. Changes to sediment characteristics would be investigated as part of the Monitoring Plan (Section 9) as this is likely to influence soft sediment assemblages (see below). Change to sediment characteristics alone is not considered to have a significant impact on the direct or wider study areas.

- Change in soft sediment benthic assemblages

It has been shown that macroinvertebrate assemblages are correlated with sediment properties (Connell and Gilanders 2007), in particular grain size (Section 4.3). It is therefore likely that there would be a change in soft sediment assemblages over time. This in turn, could have impacts at higher trophic levels (e.g. demersal fish that feed upon invertebrates – see below). Changes in macroinvertebrate communities would be investigated as part of the Monitoring Plan (Section 9).

- Increased predation by fishes and decapods on soft bottom species (infauna and epifauna)

It is possible that benthic assemblages in sandy habitat adjacent to the OARs may change as a result of increased predation by demersal fish attracted to the reef that feed on the adjacent sandy habitat. This effect is known as a 'feeding halo' (Section 2.1.5). Halo effects of reefs may be confined to areas very close to a reef (within a few metres) or extend over a much larger area and may depend on the size of the reef and/or the trophic structure of fish occupying it. Given the small relative scale of the reef units compared to the surrounding soft substratum, this effect is considered to be relatively small. Notwithstanding this prediction, methods to investigate this impact are discussed in Section 9.

- Sediment contamination

Artificial reefs in the marine environment tend to corrode over time, potentially affecting adjacent sediments and water quality. Many organisms can accumulate contaminants from surrounding waters, sediment or their food, which persist within their tissues for long periods of time or are transferred to consumers higher up the food chain i.e. bioaccumulation. Where these organisms also function as habitat, there is potential for accumulated contaminants to negatively affect associated epifauna.

Worley Parsons estimate the steel OAR structure would corrode at a rate of 0.01 mm per year over the 30 year design life. It is therefore likely to be some leaching of iron oxide over time and potentially elevated iron levels within sediments adjacent to the reef. Iron is not however, considered a significant contaminant in the sea (Clark 1997) and even at elevated levels, would be unlikely to have adverse effects on infaunal assemblages. Any leachate is likely to be quickly dispersed and diluted hence impacts would be of relatively small-scale and localised. Providing equivalent Australian standard guidelines are met and given the minimal rate of corrosion, contamination from leachate would not have a significant impact on sediments or water. As best practice, surrounding sediments should however, be investigated for contaminants as part of the Monitoring Plan (Section 9).

- Commercial

Given that commercial fishing would be permitted within the direct OAR study areas then trawling could occur in the vicinity of the units where there is good fishing potential. If this is the case, there would be disturbance of soft sediments and associated infauna in the sandy habitat adjacent to the reefs. Alternatively, trawling in the vicinity of the OARs may be discouraged due to the risks of gear hook up and obstruction. Monitoring of soft sediment assemblages and trawling activities would help determine the extent of this impact and whether mitigative action would be required.

7.3 Impacts on Proximal Natural Reef

Potential long-term impacts on nearby natural reefs are listed and discussed below:

- Change in natural reef benthic assemblages

Ecological impacts of artificial reefs on surrounding ecology are not well understood (Pears and Williams 2005) and it is possible that artificial reefs affect assemblages of nearby natural reefs. How adjacent natural reef is affected is likely to be dependent on factors such as distance from the artificial reef and the type of fish found on the artificial reef that are also likely to forage on adjacent natural reef. Hence overlap of predators, competitors or grazers from the artificial reef could lead to over-grazed or altered natural reef habitat or feeding haloes (Bortone *et al*. 1998).

The structure of natural reef habitat assemblages is largely dependent on larval settlement and recruitment that in turn depends on current and dispersal patterns. It is possible that the artificial reef structures could alter or interrupt dispersal patterns by:

- providing settlement substratum for recruits potentially occurring on natural rocky reef;
- increasing predation of planktivorous fishes on artificial reefs;
- providing a link between otherwise separate populations, or facilitating recruitment of invasive pest species (Pears and Williams 2005);
- altering local hydrology (Spieler *et al*. 2001).

The extent of impact on neighbouring natural reef may also be dependent on the size of the natural reef, that is impacts are likely to be greater for a smaller neighbouring reef than a larger one. Any change in benthic rocky reef assemblages (as a result of the proposal) would occur over a relatively long time period and would therefore require a suitably long period of monitoring to detect. Measures to minimise and monitor this potential impact are discussed in Section 9.

- Change in natural reef fish assemblages

Demersal species resident to adjacent natural reefs may be attracted to the proposed OARs if not sufficiently separated (this is referred to as ‘drawn-down’ effects). By being drawn away from the protection of their natural habitat and attracted to the OAR, fish may become more susceptible to capture if fishing effort there is greater. In turn, this could affect the dynamics of the adjacent natural reef assemblage. A minimum distance of approximately 500 m is considered sufficient distance to minimise the risk of interaction between natural and artificial reef populations, although this may vary according to species. Proximity to natural reef is not considered to be an issue for the proposed Newcastle OAR location as there is no natural reef within the direct study area, however, it is recommended that the proposed Sydney and Wollongong reef sets are separated a minimum of 500 m - 600 m from existing reef.

Potential impacts on nearby natural reef are not likely to be an issue at the proposed Newcastle OAR site due to the significant distance between the proposed OAR location and known natural reef. A relatively small outcrop of rocky reef (Dunbar Head) is located approximately 400 m south of the proposed Sydney OAR and extends out (500 m) sub-tidally from the shore. It is possible that impacts on benthic assemblages as a result of the OAR could occur at this distance.

More extensive natural reef is present in the Wollongong study area, directly to the east and to the south of the proposed OAR units. Potential impacts on adjacent reefs in this instance could be avoided by relocating the reef units to the west/north-west. Irrespective of mitigative measures, the effects on fish assemblages on proximal rocky reefs should be investigated as part of the Monitoring Plan (Section 9).

7.4 Impacts on the Pelagic Environment

Long-term Impacts on fish and plankton are listed and discussed below. Impacts on marine mammals, reptiles and seabirds are discussed in Section 7.5.

- Loss of habitat

Direct loss of sandy habitat (and associated infauna) where the artificial reef units are emplaced will result in a small direct loss of foraging habitat for demersal fish. These groups may relocate to similar alternative habitat within the study areas. Given the negligible area of sandy habitat occupied by the OAR within any direct study area and the relative area of similar habitat within any direct study area, this is not likely to have a significant impact in terms of habitat loss for these groups. Loss of sandy habitat is therefore not considered to have a significant impact on fish.

- Attraction and aggregation

Previous studies have indicated that after a relatively short period post-deployment, transient pelagic species will be found on the reefs. Initially this is due to the behaviour of certain types of fish whereby, they are attracted towards hard objects in an otherwise barren environment. Once the reefs are established, it is likely that fish will also be attracted to other biota inhabiting the reef which will provide a food source. According to Polovina (1990) attraction and aggregation of existing fish populations can have two effects:

  - redistribution of already exploited resources; and/or
  - availability of previously unexploited species or components of populations.

If the latter occurs, the OAR could result in an overall decrease in fish numbers within a given area. It is therefore important that impacts on fish abundance and diversity are investigated as part of the Monitoring Plan (Section 9). Wilson *et al*. (2001) suggest that both attraction and production are likely to interact in driving artificial-natural reef complexes.

- Increased production

The OAR is designed to increase fish abundance and diversity within a given area. The most favourable outcome, however, is that the increase in numbers of fish results from significant increases in biomass. The proposed OAR could contribute to increased production in the following ways:

  - Provision of additional habitat. Fish production results from fish growth (Jennings *et al*. 2001) and to grow, a fish must feed effectively to convert food into tissues. Given that once established, an OAR provides additional habitat and food for certain species of fish, then there is potential for increased production within a given area.
  - Habitat and substratum for recruitment. The OARs can provide refuge and food for recruitment of juvenile fish and a substratum for the settlement of planktonic larvae.
  - Reduction of harvesting pressure on natural reefs.

OARs are likely to be most effective if habitat is a limiting factor for population growth. It is considered likely that initial increases in fish numbers would be a result of attraction and aggregation, but that over time (once the reef has become established) the OARs would contribute to overall production. It is important that the potential contributions of aggregation, fishing mortality and fishing effort be measured against potential productivity as part of the environmental monitoring and management of the project (Sections 8 and 9).

- Increased fishing effort

Fishing 'effort' is a function of the number of participating fishers, number of fishing events (e.g. fishing trips) and time (days/hours) spent fishing. The convenience and likely popularity of an OAR should attract more recreational fishers, increase participation and length of time fishing and thus increase fishing effort rather than simply redistributing it. Commercial fishing in areas that were not previously fished may also occur. This issue would be addressed as part of the Monitoring Plan (Section 9) and management action taken as appropriate.

- Increased fishing mortality

The OARs have been specifically designed to attract species such as kingfish and snapper to enhance recreational fishing; it is also likely that some commercial operators would take advantage of the OARs. Increased fishing mortality could occur if there was a net increase in fishing effort (see above) or if species became more susceptible to fishing as a consequence of OARs. An expected increase in fishing mortality would therefore occur, but this would be balanced by an increased production of fish. Hence additional mortality related to fishing would be unlikely to reduce populations below existing levels. Notwithstanding this, regulation and management may be required to ensure acceptable levels of fishing mortality are not exceeded.

Not all species are equally vulnerable to fishing mortality and different types of species are likely to be affected differently. Productivity Susceptibility Analysis (PSA) identified which recreationally and commercially important species are likely to be affected by the proposal and their relative vulnerability to fishing mortality (Section 6.3). High risk species included mostly large, slow growing reef fish and sharks with low fecundity. The majority of species were considered to be at moderate risk to fishing mortality. This group included a number of recreationally and commercially important species that would be targeted for capture at the proposed artificial reefs. Targeted species at moderate or high risk should therefore be prioritised for monitoring and management.

- Concentration of plankton

The design of the OAR structures allows concentration of plankton in small eddies around the structures in the lee of ocean currents. Such concentrations would be localised and affect only a minute fraction of regional populations but would provide a source of food (and hence productivity) for planktivorous fishes and their predators. This would be beneficial for sustaining populations of target species on the OARs.

- Contamination/pollution

Increased boating traffic in the area could potentially lead to deterioration in water quality from fuel and/or oil leaks and gross pollution such as discarded fishing gear and litter. There is also a small risk that leaching of metal contaminants from the structure itself could affect the developmental stages of fish eggs attached to the surface of the structures (Kerr 1996). Korean designs ensure that reef materials must have a lower dissolved level of noxious compounds than the values specified in reef building guidelines. Providing equivalent Australian standard guidelines are met, this is not likely to be an issue.

7.5 Impacts on Threatened and Protected Species

Threatened species potentially affected by the proposal are identified in Section 2.4. The majority of impacts are relevant to threatened or protected species only if they move into the direct study areas.

Potential impacts on these species are listed and summarised below:

- Key threatening processes (KTPs) including:
  - Hook and line fishing in areas important for the survival of threatened fish species (*FM Act*);
  - Entanglement or ingestion of anthropogenic debris in marine and estuarine environments (*TSC Act*);
  - Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris (*EPBC Act*).

No areas important to the survival of a threatened fish species occur within any of the direct study areas. An unlikely exception to this is the green sawfish which occur over soft sediments but are unlikely to be affected by fishing activities associated with the OAR and have not been reported in any of the wider study areas for almost 30 years. It is therefore unlikely that the proposal would exacerbate the impacts of hook and line fishing in areas important to the survival of a threatened fish species. The proposed OARs could have a positive impact on threatened species by relieving fishing effort on areas where threatened species are susceptible to hook and line fishing.

The proposal is likely to result in the concentration of and increase in recreational fishing activity in the direct study areas. This potentially increases the risk of lost fishing gear and harmful marine debris entering the marine environment in the vicinity of the proposed OARs. Other studies have found that threatened marine species (particularly marine turtles, pinnipeds, small cetaceans and seabirds) can ingest or become entangled in marine debris (often plastics). This can lead to lethal or detrimental impacts such as strangulation, increased drag, poisoning, blockage and/or perforation of an individual's digestive system, wounds, consequent infection and gastric impaction. Sub-lethal effects of entanglement or ingestion of marine debris may reduce an individual's fitness and ability to successfully reproduce, catch prey and avoid predation.

Many of the threatened species vulnerable to this KTP could occur within the wider study areas although most would be transient within the direct study areas. Risk of harm to threatened species from this KTP is therefore considered relatively low, providing that the OARs are properly managed and monitored (Sections 8 and 9). For example, the units would require inspections to remove any fouled fishing gear or debris caught up on the units.

- Concentration/increase in recreational boating activity

In addition to impacts on KTPs, concentration of recreational boating within the direct study areas could also increase the risk of:

  - poor water quality;
  - boat strike (marine mammals and turtles);
  - acoustic disturbance (marine mammals).

As the artificial reefs are located in exposed offshore areas, leakage of fuel or oil would be quickly dispersed and would constitute a very small risk to habitat, flora or fauna within the direct or wider study areas.

Cetaceans and sirenians (dugongs) are vulnerable to boat strike as they can be slow moving and found swimming just below the water line. Risk to dugongs is considered negligible as the animals are rarely seen within the study regions and would only be transient through the direct study areas. Large cetaceans such as humpback and southern right whales would be most vulnerable during their annual migrations along the NSW coastline (May to November). During these periods it is possible the species would pass through or rest in any of the direct study areas. There are restrictions on the distance of approach to baleen whales and it is considered that risk to these species from boating activity to and from the proposed OAR would be minimal.

The effect on populations of these species, however, is likely to be negligible given their wide distribution in the wider study area and NSW waters.

- Incidental capture

Incidental capture from recreational fishing gear could potentially affect fish, marine turtles and seabirds that could forage in the surface waters. Incidental capture could lead to post-capture stress and in some cases, mortality. Species such as the critically endangered grey nurse shark and vulnerable black cod are considered potentially at risk. Even when returned to the water, hooks caught in fishes mouths can result in damage that can impact on feeding behaviour and success. Over a longer period of time, hooks retained in the mouth, throat and stomach of fishes and sharks can lead to early mortality (FSC 2003).

Grey nurse sharks often inhabit rocky reefs and islands, or near sandy-bottomed gutters and rocky caves (Otway and Parker 2000). Grey nurse sharks may be at risk to incidental capture if they reside on the OAR during their migratory movements and potentially if they ranged over large distances away from natural reefs. However, the sharks exhibit a high degree of site fidelity once a site (gutter or cave) has been occupied (Otway *et al*. 2003) and many of the sites where grey nurse sharks aggregate have been declared critical habitat. Given that the proposed OAR sites are located on bare sand, a significant distance from GNS critical habitat or known aggregation sites (Figures 15 a, b and c), the frequency of GNS occurring on the OAR and the likelihood of incidental capture is likely to be low. Moreover, monitoring would help to identify if grey nurse sharks are utilising the OAR and allow mitigative action to be taken as appropriate.

Black cod defend territories on natural reef and some artificial reef such as breakwaters. Post-settlement black cod are unlikely to move outside of their territories. Black cod settling on the OAR would be susceptible once they grew large enough to be caught. As noted above, it is unlikely that larval supply would be limiting to the extent that black cod would be 'deprived' of natural reef by settling on an OAR before or preferentially settling on natural reef.

- Interruption of movement corridors

It is possible that cetaceans and some species of fish (such as the grey nurse shark) that are known to undertake migrations along the NSW coastline could alter their migratory behaviour in response to the presence of the OARs. Most cetaceans are likely to simply avoid the structures. Sharks however, may occasionally forage on the OARs while moving between aggregation areas and become susceptible to incidental capture or harm from marine debris. Providing that threatened species in the vicinity of the OARs are properly monitored (Section 9) and mitigative action taken where necessary, it is unlikely that significant impacts on movement corridors would occur.

- Loss of habitat

No areas of habitat considered important to the survival of any threatened or protected species is found to be unique within the direct study areas. The area of sandy habitat lost through the proposal, is also negligible when considered in context with the extensive areas of similar habitat in the direct and wider OAR study areas. Therefore, it is considered highly unlikely that loss of sandy habitat would significantly affect any threatened species dependent on such habitat.

- Increased potential for disease and pest species harmful to threatened or protected species

The risk of increased potential for disease associated with biota at the OAR is considered to be extremely small. Similarly, the risk to threatened species from invasive marine pests associated with the OAR is considered very small. This is discussed further below.

7.6 Impacts from Invasive Marine Pests

The proposed OAR structures could provide a substratum or habitat suitable for invasive marine pests (also referred to as' introduced', 'alien' or 'non-indigenous'species). Invasive marine pests are defined as organisms (usually transported initially by humans) which successfully establish themselves and then compete with or displace otherwise intact, pre-existing native ecosystems (Connell and Gillanders 2007). Although a number of marine pests have been found in Australia only a few are known to occur in NSW. Of those species known to occur in NSW, the European fan worm (*Sabella spallanzani*, family: Sabellidae) could potentially occur on the units. The species can occur at depths to 30 m and colonise artificial structures such as marinas, submerged wrecks and pontoons. The species can compete with native species for food and space, thus inhibiting their settlement. Ship's ballast water is a major vector for introduced species. Fouling of ships hulls, aquaculture and the aquarium and bait industries are also considered vectors. Major ports and estuaries are therefore hotspots for invasive species. Whilst the proposed OAR sites are potentially at risk from colonisation by invasive marine pests, the scale of the potential impacts is small and unlikely to have any significant impact on the marine environment. It is, however, recommended that procedures to monitor and remove pest species are incorporated into the Monitoring Plan (Section 9).

7.7 Impacts on Areas of Conservation Significance

The proposal would not have any direct impacts on areas of conservation significance, although species associated with conservation areas and which forage in the vicinity of the proposed OARs may be indirectly affected (Table 17). The Moon Island Nature Reserve (part of the Lake Macquarie State Conservation Area) and the Five Islands Nature Reserve (near Port Kembla) are breeding and roosting habitats for several species of protected seabirds (Section 2.4.4). Diving seabirds and little penguins could be attracted to OAR sites as a foraging area, if suitable prey items were to aggregate there. They may also be attracted to discarded bait. This could increase the risk of interactions with fishing gear and/or harmful marine debris. Australian fur-seals and more rarely leopard seals, occur in and around the Five Islands Nature Reserve and although the species do not breed there, they may be vulnerable to interactions with fishing gear and/or harmful marine debris.

Critical habitat for the Little Manly population of little penguins is located approximately 3 km north of the proposed Sydney OAR. Little penguins forage significant distances on a daily basis and may also be vulnerable to interaction with fishing gear for reasons identified above. Grey nurse shark critical habitats are located in the wider Sydney and Wollongong study regions approximately 12.5 km and 8 km respectively from the proposed OAR sites. At these distances there would be no direct impacts on grey nurse shark critical habitat. Indirect impacts on individuals moving or foraging outside aggregation areas could be indirectly affected. The proposal is not considered to have any direct impacts on Aquatic Reserves located within the wider study areas. Indirect impacts on species associated with areas of conservation significance would be assessed as part of the Monitoring Plan.

7.8 Impacts on Commercial and Recreational Fishing

Long term impacts on commercial and recreational fishing are listed and discussed below:

- Loss of fishing ground

Fisheries likely to be affected by the proposal include the Ocean Trawl and the Ocean Trap and Line fisheries (Section 2.3.1). The proposed Newcastle OAR location is likely to conflict with the Ocean Trawl fishery, that operates offshore from Nine Mile Beach (between Swansea and Red Head). OAR units at the currently proposed location and configuration would result in the loss of a maximum of 0.39 km^2 of fishing ground but would also prevent trawling a further 100 m outside the area to prevent the risk of gear becoming hooked up on the units. Alternative options to minimise the loss of fishing ground are addressed in the following section. To minimise risk to trawl operators, the assessment process included consultation with local commercial operators. Based on consultation with local commercial fishers, loss of fishing area within the proposed Sydney and Wollongong study regions is not considered to be a significant issue. Issues have been raised for the proposed Newcastle OAR by one group that operate out of Sydney. Measures to minimise the loss or obstruction to fishing are discussed in the following sections.

- Conflict between user groups

Recreational fishing involves a variety of user groups including sportfishers, gamefishers, spearfishers and charter boat fishing (Section 2.3.2). The proposed OARs are aimed at the sport fishing public, but it is likely that charter fishing, spearfishing and commercial fishing would also take place. Some overlap between user groups is therefore likely and the potential for conflict would be addressed through a suitable monitoring and management strategy (Section 9).

- Safety Issues

Potential safety issues which could occur as a result of recreational or commercial fishing in the direct study areas include:

- Gear hook up;
- Collision;
- Increased risk of encounters with dangerous marine animals (spearfishing);
- Drowning (spearfishing).

The risk of gear hook up is considered relatively likely (particularly for recreational fishing gear) and could result in detrimental impacts to species vulnerable to entanglement or injury from fishing line and hooks (Section 7.5). Management and mitigation strategies that aim to minimise potential risks to the safety of commercial and recreational fishing groups are discussed in the following section. It is anticipated that free divers and spear fishers would utilise the reefs. The majority of spear fishers would benefit from accessing pelagic species aggregating above the units in the top 15 m – 20 m. There is however, risk that spear fishers/free divers would attempt to dive to depths beyond their limits. Recommendations in relation to safety are addressed in the following section.

- Impacts on commercial fish stocks

It is considered highly unlikely that the proposed OARs either individually or cumulatively across the three study regions would contribute to a reduction in commercially fished populations at a regional scale. It is possible that species most vulnerable to fishing mortality could be affected at a local scale, but this again is unlikely to have impacts at a population level. A main aim of the Monitoring Plan would be to investigate impacts of the proposed OARs on fish numbers within a suitable management area.

- Risk that the OAR project will not meet its objectives

The overall effectiveness and success of the reefs can be assessed only by monitoring of user satisfaction, structural integrity and impacts of the OARs on the surrounding environment. If the proposal were shown not to meet its objectives and/or to have significant adverse impacts on significant components of the marine environment, then appropriate mitigative action would be taken (Section 9) and deployment of future artificial reefs would need to be considered differently.

8 Recommendations and Mitigation

Recommendations for the minimisation, management or mitigation of impacts on flora and fauna are listed below.

- Re-positioning the OAR units in the Newcastle study region to an alternative location approximately 1.75 km southwest of the currently proposed location. This is considered the best possible alternative to minimise impacts on commercial fishing.

- Trawling groups should be notified of the exact OAR unit positions.

- It is recommended that the units are spaced 200 m (as opposed to 600 m) apart and configured in a line running parallel with depth contours (approximately north to south) where feasible. This is not considered to impact on the effectiveness of the OARs, but is likely to minimise impacts on commercial trawling by significantly reducing the area lost to trawling from 0.39 km^2 to 0.01 km^2 square kilometres (approximately 97 % less) and improve navigation around the OARs.

- Maximum separation of OAR units from existing natural reef should be achieved in order to minimise potential draw-down effects. It is therefore recommended that the Wollongong OAR units are relocated approximately 500 m to the west/north-west of the present location (but still within the direct study area).

- In order to minimise potential conflict between different user groups an OAR management area should be defined. A code of conduct should then be established for within the management area.

- It should be ensured that OAR user groups are informed of:
  - general salt water fishing rules and regulations, water traffic rules and boating safety;
  - the code of conduct and regulations within a defined management area;
  - mechanisms for reporting incidents of conflict;
  - safety recommendations for spear fishing/free diving and personal liabilities.

- Impacts on threatened and protected species should be minimised by:
  - ensuring there are mechanisms to report sightings or incidental capture of threatened and protected species.
  - education on threatened and protected species identification, best practice for returning incidentally captured fish, minimising risks to seabirds and boating restrictions in the vicinity of large cetaceans;
  - education on the potential impacts of harmful marine debris on marine life and the responsible disposal of litter and discarded fishing gear;
  - education on minimum approach distances to baleen whales.

- Species of recreational and commercial importance (and all threatened and protected species) that are of high to moderate significance occur on the OAR should be prioritised for monitoring and management. Species at moderate risk but considered target species should also be given priority in future management.

- Water quality and adjacent sediments would be monitored for contaminants over the long-term to determine any significant changes from baseline conditions.

An environmental management plan (EMP) detailing how maintenance, operation and management of the site (within a pre-determined management area) should be implemented. This is addressed in the EA/draft PER. Many of the potential impacts described would be addressed through implementation of a Monitoring Plan and appropriate mitigative action taken as and when appropriate. Recommendations for monitoring procedures are addressed in the following section.

9 Monitoring

9.1 Introduction

In order to better understand how the installation of OARs will impact upon significant components of the marine environment and evaluate their overall effectiveness in relation to the project objectives, a monitoring strategy is required. Spellerberg (2005) defines ecological monitoring as 'the systematic collection of data in a standardized manner at regular intervals over time' and assumes a specific reason for the collection of data such as meeting standards or objectives. Often, studies investigating impacts of artificial reefs have undertaken extensive multi-disciplinary research post-deployment and failed to gather sufficient pre-deployment data thereby reducing the value of subsequent research (Underwood 1996). A lack of replication of the reef systems has also resulted in less powerful statistical designs. Underwood (1997) quotes a series of papers on 'beyond BACI' (Before, After, Control, Impact) sampling designs which make use of multiple controls in space and time. This allows changes of the potential impact location to be evaluated against background variation measured at multiple control locations and is considered 'best practice' in environmental impact monitoring. This design requires that sampling is done in at least two external control locations in addition to the potential impact location. Sampling should also be carried out at least twice before deployment and at least twice post-deployment. This is particularly important as assessments of impacts are more reliable if data on prevailing conditions over a period of time before development are available for comparison. For this reason pre-deployment monitoring should begin as far ahead of deployment as possible. Although multiple control and impact locations have been sampled pre-deployment as part of the Marine Ecology study, further pre-deployment investigations are recommended. This is due to the broad spatial scale of the field studies and the significant amount of small-scale variation observed between sites within any given location. The results also suggest that further controls within each study region are required and that each study region should be investigated individually.

Replication in time is also crucial to the current proposal as biological variables such as abundance, biomass and diversity) in fish and macroinvertebrate assemblages are likely to be influenced by seasonal patterns (Kingsford and Battershill 1998). Many studies involving the census of fish in relation to artificial structures have been limited to periods of only a few years, often due to lack of resources and funding (Relini *et al*. 2002). To evaluate positive effects on fish assemblages, long-term seasonal variations and trends in relation to the age of the artificial reef are of crucial importance (Relini *et al* .1994). Stabilisation of fish assemblages is also likely to be a slow and long-term process, with changes likely to be observed even after 20-30 years. For this reason, the monitoring program should ideally continue throughout the operational lifespan of the artificial reef. As funding and resources for a monitoring period of this timescale cannot be guaranteed, an absolute minimum monitoring period of three years is recommended for the current proposal. Initial colonisation of the OARs by fish and epifauna is likely to occur rapidly post-deployment. Biological sampling events should therefore be more frequent in the initial post-deployment phase to record early stages of succession which can influence the long-term structure of the species assemblage. Studies of fish assemblages in relation to artificial reefs, benefit from simple sampling designs that allow for sufficient replicates to evaluate one or two variables rather than overly complex studies that are subject to large variance (Bortone *et al*. 2000). There has also been a focus of sampling effort on dependent variable parameters for a single species or a life-history stage of a species rather than attempting to address too many reef fish assemblage questions in one study. Non-parametric, multivariate, statistical packages (such as PRIMER-E), are also considered an important and useful tool in recent artificial reef research (Bortone 2006). In regard to the project objectives, the broad aims of the Monitoring Plan would be to:

1. *Evaluate usage of reefs by anglers, other members of the public and conflicts between users;*
2. *Evaluate effectiveness of reefs including catch rates, species catch composition and fish stocks;*
3. *Investigate impacts on significant components of the marine ecosystem;*
4. Investigate impacts and/or aggregation of threatened and protected species.

The assessment of impacts (Section 7) identified components of the marine environment and potential impacts/issues related to those components that require further investigation and monitoring. Table 18 lists each of the impacts/issues, the objectives of monitoring these and recommends suitable monitoring periods, locations and methods. Note that in many instances, the table makes provision for monitoring to begin *before* construction starts.

It should be noted that assessment of impacts on and monitoring the structural integrity of the unit structures themselves would also be carried out, but are not addressed in the current study.

9.2 Locations

It is considered that a separate Monitoring Plan would be implemented per study region (Newcastle, Sydney, Wollongong). The proposed Monitoring Plan (Table 18) is generic and could be applied to any of the three study regions. Sampling locations should include:

- The direct placement sites;
- impact sites (including adjacent soft sediment or natural reef);
- control sites (including soft sediments or natural reef).

The sampling design would vary according to the variables being monitored but will incorporate a combination of the above locations (Table 18). The location of control sites for the monitoring of soft sediment macroinvertebrate assemblages would be the same as those selected for the current field investigations. Location of impact sites will depend on the final location of the OAR units pending results of the EA/draft PER. Additional sites are required to assess effects on proximal natural reefs which have not been previously sampled. These would include areas of proximal natural reef as further 'impact' locations and natural reef sites outside the direct study area (but within the wider study region) as further control sites. It is important that control reef sites are of a similar depth and habitat type to the proximal (impact) reefs.

9.3 Timing

Six different monitoring periods (A – F) are recommended according to different components of the Monitoring Plan (Table 18). It should be noted that in order to investigate temporal seasonal patterns (e.g. between winter and summer) in biological components of the study, a minimum of two sampling events is required within each season investigated (Underwood 1994). As discussed in Section 9.1, the monitoring program should run for a minimum of 3 years, but a considerably longer term plan (preferably over the operational life of the OARs) is recommended if funding and resources allow. Pre-deployment monitoring should begin as soon as is practically feasible.

9.4 Methods

The Monitoring Plan should consist of three main components (biological, physical and socio-economic). It should be noted that standardisation and consistency in monitoring methods is essential to enable meaningful conclusions to be drawn from the data and to support appropriate management actions. Monitoring methods for each of these areas are discussed below.

1. Biological

Aims and methods to monitor impacts on biological components of the environment (including effectiveness of the proposed OARs) are summarised in Table 18. The biological monitoring section is further divided into three components (macrobenthos, fish and threatened species).

- Macrobenthos

Methodology for the macrobenthic monitoring of soft sediments (including field, laboratory and analyses) should be consistent with that used for the current field investigations (Sections 3.3.1 and 3.4.1). Monitoring for the occurrence and extent of feeding haloes would also be addressed.

It is recommended that monitoring of natural rocky reef sites be carried out by photo video quadrats deployed by boat. This method would be preferable to diver surveys for sampling at depths of 30 m or greater. The technique involves deployment of a rig (similar to that used in BRUVS) incorporating a square quadrat (0.5 m x 0.5 m) and high definition video cameras fitted in underwater housings. It is important that autofocussing cameras capable of recording high resolution footage at very low light levels are used. Information about species present, percent cover of each species and signs of disease or mortality would be recorded from each quadrat.

As it is possible the structures would be colonized by introduced species, a process for identifying pests and potentially removing them is required. This would be carried out by visual inspections of all reef units. Management of pest species would be carried out in accordance to NIMPIS (National Introduced Marine Pest Information System) rapid response control options (Web Reference 25). This database specifies the most appropriate management methods according to species and scale of the incursion. As it may be impractical to remove all species, consideration should be given to removing the most prolific or those considered to be a significant threat to species of commercial or recreational importance and to threatened or protected species.

- Fish

Methods for monitoring fish, including species of recreational and commercial importance and threatened species could include surveys of recreational and commercial fishers and/or charter boat log book data, deployment of BRUVS, stereo-videography, biotelemetry and visual diver surveys. Employing a combination of such techniques would provide a complete assessment of species occurring in the study areas. A single technique would be biased towards certain habitat groups or could fail to sample certain species/groups. Surveys of fishers and/or charter boat log book data would provide information on:

  - catch composition (including size and weight of fish to calculate biomass);
  - fishing effort in terms of number of anglers;
  - threatened and protected species (by providing information on incidental catch).

BRUVS surveys would provide qualitative information on species abundance and diversity and more importantly on species not sampled in the fisher surveys (i.e. accounting for species that may be avoiding capture). Detailed methodology for BRUVS is outlined in this report (Section 3.3.2). The limitation of the BRUVS technique is that the video stations can only be deployed directly adjacent to the structures and may therefore under-represent or miss species occurring within the void space of the structures. For this reason, additional diver surveys could be carried out to account for such species. Stereo-videography can be used to provide quantitative, size-frequency distribution data and habitat usage information for fish associated with the OAR and proximal reef and has proven an efficient method of monitoring in the estuarine artificial reef program.

Biotelemetry involves the deployment of acoustic listening stations and fish tagging which can be used to investigate movements and resident times of fish inhabiting the reef. Key recreational species would be prioritised for tagging, although this would also depend on the type and numbers of species found on the OARs. Monitoring would also work in conjunction with the Australian Acoustic Tagging and Monitoring System (AATAMS) enabling the movement of tagged fish to be tracked between the OARs and AATAMS arrays.

After the first year of post-deployment monitoring, these techniques would be reviewed and the most cost-effective and accurate techniques retained for long-term application. Methods for analyses of fish assemblages would be consistent with those used in the current marine ecology report. Analyses would focus on high priority species of recreational and/or commercial importance, for example those species identified in the Productivity Susceptibility Analysis.

- Threatened species

Investigations on threatened species would be incorporated into the fish surveys (above) using BRUVS, diver surveys, stereo-videography and survey information where feasible. In relation to the critically endangered grey nurse shark, ultrasonic telemetry studies as part of the monitoring program would be recommended. This would involve fitting remote, underwater receivers or 'listening stations' to the OAR units that could continuously detect sharks (and other species) tagged with internal ultrasonic transmitters. As tagging programs are run by different governmental departments and organisations (including CSIRO and I&I NSW) collaboration and coordination between relevant groups would be required to compile a register of tagged individuals.

2. Physical

Aims and methods to monitor impacts on the physical components of the environment (including the OARs themselves) are summarised in Table 18. In order to minimise potential impacts of discarded fishing gear and anthropogenic debris on vulnerable marine species, the structures should be regularly inspected for any lost gear or snagged debris. This should be carried out in conjunction with biological components of the monitoring program (Table 18).

- Sediments

Samples for analyses of particle size distribution would be collected by benthic grab from a boat using methodology consistent with that used for the current field study (Sections 3.3.3, 3.4.2 and 3.5.3). Sub-samples for analyses of heavy metals would be taken from the particle size samples using methodology consistent with that used for the current field investigation (Sections 3.3.5, 3.4.3 and 3.5.5).

- OAR structure

Regular inspections of the structures and maintenance to remove any entangled debris or fishing gear that could be harmful to marine animals would be carried out by diver inspections and could be incorporated into biological aspects of the monitoring program.

Procedures to monitor the structural integrity of the OARs are addressed in detail as part of the EA/draft PER. It is however, expected that the structures would be inspected by diver surveys and carried out at least once per year or in the foresight of any severe weather events.

3. Socio - economic

Aims and methods to monitor social and economic impacts of the proposal are summarised in Table 18. Effectiveness of the OARs should be monitored in terms of socio-economic consequences in addition to biological indicators. Sutton and Bushnell (2007) suggest that monitoring of use levels, users' perception of crowding, levels of conflict, users' attitudes, opinions, satisfaction and artificial reef-related expenditures are particularly important. Monitoring of public and stakeholder attitudes towards OARs is also important to evaluate the extent of negative social and economic impacts. It is recommended this would be carried out by questionnaires aimed at both user groups and stakeholders on an annual or twice yearly basis. Feedback from fishermen surveys would be incorporated into the annual assessment. Questionnaires could be filled out and submitted online via the I&I NSW website/fax, post or interview could be conducted by telephone.

9.5 Management

Table 18 identifies management options based on the dissemination and review of results over the given monitoring period i.e. an adaptive management approach. Results of the monitoring program should be disseminated and reviewed at appropriate stages (Table 18). Where no impact is detected, then monitoring would continue or be scaled down as appropriate. Should negative impacts be detected, then a series of relevant management options would be considered depending on the severity of the impact. Development of specific criteria to assess the severity of a potential impact may also be of benefit once the Monitoring Plan has been implemented. It should be noted that the Monitoring Plan outlined in this study would be considered a pilot. Experience from the initial Monitoring Plan is likely to result in the development of best practice methods for any subsequent reef deployments.

9.6 Monitoring Priorities

As best practise, it is recommended that all objectives outlined in the Monitoring Plan (Table 18) are met and appropriate monitoring carried out. It is, however, recognised that funding and resources may not be immediately available to cover all of the objectives outlined. To assist in the most appropriate allocation of funds and resources that are available, objectives in the Monitoring Plan have been prioritised as follows:

Priority 1 (Monitoring objectives strongly recommended):

Biological

A.2.1. Investigate movements of high priority species within the direct study area.

A.2.2. Assess effectiveness in terms of catch rates, species composition and fish stocks.

A.3. Investigate occurrence of threatened/protected species on the OARs.

Physical

B.3.1. Assess structural integrity.

B.3.2. Remove fouled gear and debris.

Socio-Economic

C.1.1. Assess effectiveness in terms of popularity with recreational fishing groups.

Priority 2 (Monitoring objectives to be addressed given availability of funds/resources):

Biological

A.1.1. Assess influence of OARs on benthic assemblages (soft sediments)including potential halo effects.

A.1.2. Assess influence of OARs on benthic assemblages of proximal natural reefs(benthos).

A.1.3. Document colonisation of the reef structures by macroinvertebrates including pest species.

Physical

B.1.1. Assess influence of OARs on sediment characteristics.

B.1.2. Assess concentrations of heavy metals in adjacent sediments to OARs.

B.2. Assess water quality.

Socio-Economic

C.1.2. Identify issues of conflict between user groups.

10 Conclusions

The current study has described the existing environment at the three locations identified as being potentially suitable for placement of an OAR. It has also identified a number of potential impacts that could occur within the direct or wider study areas. Many of these impacts can be addressed by the implementation of a long-term adaptive management approach supported by a rigorous monitoring plan. Provided that all recommendations to mitigate, monitor or manage potential impacts are followed, any adverse impacts occurring as a result of the proposed offshore artificial reef pilot are considered to be negligible. Furthermore, by successfully meeting the aims of the project (i.e. by providing a high quality fishing reef) there is potential for a number of benefits such as:

- Relief of fishing effort on existing natural reefs;
- Relief of fishing effort on areas of conservation significance or areas where threatened or protected species are vulnerable to recreational fishing activity;
- Contribution to local productivity in the long-term;
- Research and education opportunity.

The construction and long-term operation of the OARs is also likely to have local socio-economic benefits from employment and expenditure on fishing related items.

11 Acknowledgments

This report was written by Kate Reeds and Marcus Lincoln Smith and reviewed by Arthur Dye and Craig Blount. Kate Reeds, Bob Hunt, Chris Roberts and Martin Povea – Jiemenez undertook field work. Rick Johnson, Kate Reeds, Bob Hunt, Daniel Pygas, Greig Campbell, Rad Nair and Belinda Parkes sorted and identified samples. Kate Reeds undertook statistical analyses and prepared the figures and maps.

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13 Tables

Table 1: Permutational multivariate analysis of variance (PERMANOVA) comparing assemblages and taxa of macroinvertebrates in sandy habitats in the Newcastle, Sydney and Wollongong study regions. PERMDISP results are included for significant sources of variation. Significant factors are highlighted in bold. Data transformed to square root. SR - Study Region, Lo - Location, Si - Site, P(MC) - Monte Carlo *P*-value

Assemblage

Source of Variation	df	SS	MS	*Pseudo-F*	*P* (perm)	Unique perms	P (MC)
St	2	1524.30	762.15	3.56	0.073	15	**0.0002**
Lo(St)	3	642.13	214.04	2.27	**0.0024**	4964	**0.0004**
Si(Lo(St))	18	1695.00	94.17	2.55	**0.0002**	4930	**0.0002**
Res	72	2662.70	36.98				
Total	95	6524.10					

Estimates of components of variation		
S(St)	17.1280	4.1386
V(Lo(St))	7.4923	2.7372
V(Si(Lo(St)))	14.2970	3.7811
V(Res)	36.9810	6.0812

PERM DISP

Deviations from Centroid

F	9.1588		
P (permutational)	**0.0004**		
Group (Study Region)	Size	Average	S.E.
Newcastle	32	34.185	0.78859
Sydney	32	39.446	1.0318
Wollongong	32	37.508	0.79507

PERM DISP

Deviations from Centroid

F	F: 2.2639		
P (permutational)	0.1047		
Group (Site)	Size	Average	S.E.
New OAR S1	4	30.878	1.7765
New OAR S2	4	25.166	1.1147
New OAR S3	4	31.862	2.6115
New OAR S4	4	22.18	1.6674
New Con S1	4	27.965	1.751
New Con S2	4	30.917	1.2847
New Con S3	4	29.421	1.6647
New Con S4	4	28.268	2.3321
Syd OAR S1	4	33.884	1.7468
Syd OAR S2	4	25.118	0.53806

Continued

Table 1: Continued

Group (Site)	Size	Average	S.E.
Syd OAR S3	4	23.909	1.1421
Syd OAR S4	4	27.904	2.1962
Syd Con S1	4	22.456	1.9215
Syd Con S2	4	25.982	0.43042
Syd Con S3	4	28.126	3.5901
Syd Con S4	4	25.793	2.1218
Wol OAR S1	4	27.046	1.1531
Wol OAR S2	4	29.42	1.9043
Wol OAR S3	4	27.565	3.335
Wol OAR S4	4	30.124	1.2386
Wol Con S1	4	29.007	1.876
Wol Con S2	4	28.76	1.7361
Wol Con S3	4	25.223	1.8736
Wol Con S4	4	27.171	1.5186

PERMANOVA Pairwise Tests (Study Regions)

Groups	t	*P* (perm)	Unique perms	P (MC)
Newcastle, Sydney	2.5307	0.3256	3	**0.0004**
Newcastle, Wollongong	1.7219	0.3398	3	**0.0146**
Sydney, Wollongong	1.5449	0.336	3	**0.0318**

PERMANOVA Pairwise Tests (Locations within Study Regions)

Within level 'Newcastle' of factor 'Study Region'

Groups	t	P(perm)	Unique perms	P(MC)
OAR, Con	1.7982	0.0276	35	**0.0106**

Within level 'Sydney' of factor 'Study Region'

Groups	t	P(perm)	Unique perms	P(MC)
OAR, Con	1.037	0.3382	35	0.3558

Within level 'Wollongong' of factor 'Study Region'

Groups	t	P(perm)	Unique perms	P(MC)
OAR, Con	1.7741	0.0276	35	**0.0058**

PERMANOVA Pairwise Tests (Sites within Location)

Newcastle (OAR)

Groups	t	*P* (perm)	perms	P(MC)
1, 2	1.3004	0.1496	35	0.1804
1, 3	0.71926	0.7936	35	0.6694
1, 4	0.77188	0.7488	35	0.6652
2, 3	1.2171	0.1746	35	0.2286
2, 4	1.7857	**0.0256**	35	**0.033**
3, 4	1.0162	0.375	35	0.3864

Continued

Table 1: Continued

PERMANOVA Pairwise Tests (Sites within Location)

Newcastle (Con)

Groups	t	*P* (perm)	perms	P(MC)
1, 2	1.0534	0.311	35	0.366
1, 3	1.0973	0.2024	35	0.3174
1, 4	0.94384	0.5958	35	0.4956
2, 3	1.0174	0.3624	35	0.4146
2, 4	1.2453	0.058	35	0.1912
3, 4	1.3994	**0.0278**	35	0.1052

Sydney (OAR)

Groups	t	*P* (perm)	perms	P(MC)
1, 2	1.6188	**0.0286**	35	**0.0442**
1, 3	1.6479	**0.0248**	35	**0.0496**
1, 4	1.5428	**0.0302**	35	0.074
2, 3	1.9127	**0.0304**	35	**0.0138**
2, 4	2.1175	**0.0316**	35	**0.0076**
3, 4	1.9855	**0.0298**	35	**0.0148**

Sydney (Con)

Groups	t	*P* (perm)	perms	P(MC)
1, 2	1.523	**0.0292**	35	0.0718
1, 3	1.7838	**0.0292**	35	**0.0326**
1, 4	3.8735	**0.031**	35	**0.0006**
2, 3	1.101	0.1712	35	0.3208
2, 4	2.7682	**0.0228**	35	**0.0044**
3, 4	2.571	**0.0272**	35	**0.0046**

Wollongong (OAR)

Groups	t	*P* (perm)	perms	P(MC)
1, 2	1.6929	**0.03**	35	**0.0358**
1, 3	1.3127	**0.0278**	35	0.1364
1, 4	1.2977	0.0598	35	0.16
2, 3	1.6322	**0.029**	35	**0.0446**
2, 4	1.592	**0.031**	35	0.0552
3, 4	1.5691	**0.0288**	35	0.052

Wollongong (Con)

Groups	t	*P* (perm)	perms	P(MC)
1, 2	1.7308	**0.0284**	35	**0.0238**
1, 3	1.678	**0.0292**	35	**0.0356**
1, 4	1.1925	0.0854	35	0.231
2, 3	1.6065	**0.03**	35	0.063
2, 4	1.9206	**0.0274**	35	**0.0228**
3, 4	1.6278	**0.0326**	35	**0.0446**

Continued

Table 1: Continued

No. of taxa

Source of Variation	df	SS	MS	*Pseudo-F*	*P* (perm)	Unique perms	P (MC)
St	2	730.56	365.28	8.20	0.0656	15	0.056
Lo(St)	3	133.56	44.52	1.39	0.2798	4980	0.2774
Si(Lo(St))	18	577.38	32.08	1.47	0.1308	4982	0.1228
Res	72	1574.50	21.87				
Total	95	3016.00					

Aorid Group

Source of Variation	df	SS	MS	*Pseudo-F*	*P* (perm)	Unique perms	P (MC)
St	2	354.84	177.42	4.02	0.1348	15	0.14
Lo(St)	3	132.37	44.12	2.42	0.0944	4989	0.0934
Si(Lo(St))	18	327.70	18.21	8.07	**0.0002**	4966	**0.0002**
Res	72	162.43	2.26				
Total	95	977.34					

Platyischnopidae

Source of Variation	df	SS	MS	*Pseudo-F*	*P* (perm)	Unique perms	P (MC)
St	2	190.89	95.45	431.67	0.069	15	**0.0002**
Lo(St)	3	0.66	0.22	0.55	0.6504	4993	0.6618
Si(Lo(St))	18	7.30	0.41	0.93	0.5274	4973	0.5352
Res	72	31.23	0.43				
Total	95	230.09					

Apseudidae/Kalliapseudidae

Source of Variation	df	SS	MS	*Pseudo-F*	*P* (perm)	Unique perms	P (MC)
St	2	18.28	9.14	0.80	0.5324	15	0.5312
Lo(St)	3	34.08	11.36	2.10	0.1254	4989	0.1382
Si(Lo(St))	18	97.19	5.40	3.30	**0.0006**	4970	**0.0002**
Res	72	117.83	1.64				
Total	95	267.37					

Philomedidae

Source of Variation	df	SS	MS	*Pseudo-F*	*P* (perm)	Unique perms	P (MC)
St	2	155.78	77.89	20.85	0.0626	9	**0.0186**
Lo(St)	3	11.21	3.74	0.53	0.6606	4982	0.6648
Si(Lo(St))	18	125.97	7.00	17.10	**0.0002**	4982	**0.0002**
Res	72	29.47	0.41				
Total	95	322.43					

Continued

Table 1: Continued

Onuphidae

Source of Variation	df	SS	MS	*Pseudo-F*	*P* (perm)	Unique perms	P (MC)
St	2	148.62	74.31	0.97	0.4664	15	0.4746
Lo(St)	3	230.74	76.91	7.73	**0.0026**	4988	**0.0016**
Si(Lo(St))	18	179.13	9.95	2.26	**0.011**	4974	**0.0078**
Res	72	316.98	4.40				
Total	95	875.46					

PERMANOVA Pairwise Tests (Locations within Study Regions)

Within level 'Newcastle' of factor 'Study Region'

Groups	t	P(perm)	Unique perms	P(MC)
OAR, Con	4.2596	0.0312	35	**0.0038**

Within level 'Sydney' of factor 'Study Region'

Groups	t	P(perm)	Unique perms	P(MC)
OAR, Con	0.60494	0.4592	25	0.5814

Within level 'Wollongong' of factor 'Study Region'

Groups	t	P(perm)	Unique perms	P(MC)
OAR, Con	2.9264	0.028	35	**0.0228**

Table 2: Results of SIMPER analyses comparing assemblages of macroinvertebrates sampled during January 2009 in the three study regions (Newcastle, Sydney and Wollongong) and between locations (OAR and Control). Cut-off for cumulative contribution is 50%.

Newcastle study region

Average similarity: 51.02 %

Taxon	Ave. Abund	Ave. Diss	Diss/SD	Contrib. %	Cum %
Platyischnopidae	3.38	6.07	3.82	11.90	11.90
Onuphidae	4.31	4.98	1.95	9.76	21.66
Phoxocephalidae	2.42	4.20	3.90	8.24	29.90
Aoridae Group	2.15	2.73	1.78	5.36	35.25
Lysianassidae	1.86	2.73	1.96	5.34	40.60
Apseudidae/Kalliapseudidae	1.98	2.38	1.20	4.67	45.26
Ischyroceridae	1.50	2.07	1.19	4.07	49.33
Maldanidae	1.69	1.90	1.22	3.73	53.06

Sydney study region

Average similarity: 43.6%

Taxon	Ave. Abund	Ave. Diss	Diss/SD	Contrib. %	Cum %
Aoridae Group	6.85	10.84	2.17	24.86	24.86
Phoxocephalidae	2.63	5.15	2.29	11.80	36.66
Urothoidae	1.75	2.77	1.31	6.36	43.03
Veneridae	1.50	2.20	1.23	5.06	48.08
Spionidae	1.62	2.10	1.13	4.81	52.89

Wollongong study region

Average similarity: 46.22 %

Taxon	Ave. Abund	Ave. Diss	Diss/SD	Contrib. %	Cum %
Aoridae Group	4.37	5.51	2.06	11.91	11.91
Philomedidae	2.96	3.56	1.38	7.71	19.62
Onuphidae	3.79	3.38	1.00	7.31	26.93
Phoxocephalidae	2.17	3.02	2.21	6.54	33.47
Spionidae	2.09	2.72	2.09	5.88	39.35
Ampeliscidae	1.95	2.52	1.57	5.45	44.81
Bodotriidae/Nannastacidae	1.63	2.32	1.99	5.02	49.83
Diastylidae/Gynodiastylidae	1.47	2.12	2.46	4.59	54.42

Continued

Table 2: Continued

Newcastle & Wollongong study regions

Average dissimilarity: 65.32 %

Taxon	Newcastle Av.Abund	Wollongong Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Onuphidae	4.31	3.79	3.23	1.33	4.95	4.95
Platyischnopidae	3.38	0.18	3.09	3.33	4.74	9.68
Philomedidae	0	2.96	2.85	1.61	4.36	14.05
Aoridae Group	2.15	4.37	2.57	1.32	3.94	17.98
Apseudidae/Kalliapseudidae	1.98	2.19	1.71	1.26	2.61	20.6

Sydney & Wollongong study regions

Average dissimilarity: 63.82 %

Taxon	Sydney Av.Abund	Wollongong Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Aoridae Group	6.85	4.37	3.83	1.28	6	6
Onuphidae	1.45	3.79	3.19	1.17	5	11.01
Philomedidae	0.61	2.96	2.86	1.53	4.48	15.49
Apseudidae/Kalliapseudidae	1.18	2.19	2.02	1.18	3.17	18.65
Ampeliscidae	0.28	1.95	1.8	1.8	2.82	21.47

Newcastle & Sydney study regions

Average dissimilarity: 67.02 %

Taxon	Newcastle Av.Abund	Sydney Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Aoridae Group	2.15	6.85	5.2	1.41	7.76	7.76
Onuphidae	4.31	1.45	3.43	1.24	5.12	12.88
Platyischnopidae	3.38	0.64	2.99	2.42	4.47	17.35
Apseudidae/Kalliapseudidae	1.98	1.18	1.89	1.35	2.82	20.17
Atylidae	1.81	0.06	1.82	0.96	2.72	22.88

Table 3: Mean maximum number (MaxNum) and standard error (S.E.) of species recorded at the proposed OAR unit locations (OAR) and control (Con) sites at Newcastle, Sydney and Wollongong study regions in January 2009.

Family	Scientific Name	Common Name	Newcastle				Sydney				Wollongong			
			Impact		Control		Impact		Control		Impact		Control	
			Mean MaxNum (*n* =5)	S.E.	Mean MaxNum (*n* =5)	S.E.	Mean MaxNum (*n* =5)	S.E.	Mean MaxNum (*n* =5)	S.E.	Mean MaxNum (*n* =5)	S.E.	Mean MaxNum (*n* =5)	S.E.
INVERTEBRATES														
Raninidae	-	Spanner Crab	0	0.0	0	0.0	0	0.0	0.2	0.2	0	0.0	0	0.0
Diogenidae	-	Hemit Crab	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.2	0.2
CHONDRICHTHYES (CARTILAGINOUS FISHES)														
Heterodontidae	*portusjacksoni*	Port Jackson Shark	0.2	0.2	0	0.0	0.6	0.2	0.2	0.2	0	0.0	0	0.0
Rhinobatidae	*Aptychotrema sp.*	Shovelnose Ray	1	0.3	0.6	0.2	0	0.0	1.8	1.0	0	0.0	0	0.0
Rhinobatidae	*Trygonorrhina fasciata*	Fiddler Ray	0.8	0.4	0.8	0.2	1.2	0.5	2	0.7	4.2	1.6	0.8	0.2
Urolophidae	-	Stingaree	0	0.0	0	0.0	0.2	0.2	0	0.0	0.2	0.2	0.4	0.2
Myliobatidae	*Myliobatis australis*	Eagle Ray	0	0.0	0	0.0	0	0.0	0	0.0	0.4	0.2	0.2	0.2
OSTEICHTHYES (BONY FISHES)														
Clupeidae	-	Herrings, Sardines and Pilcharc	0	0.0	0	0.0	0	0.0	0	0.0	10	10.0	10	10.0
Platycephalidae	*caeruleopunctatus*	Blue-spotted Flathead	1.2	0.2	1.4	0.2	1.6	0.6	2.2	0.7	1	0.3	0.8	0.4
Platycephalidae	*longispinus*	Long-spine Flathead	6.2	1.5	2.8	0.9	4.6	1.0	3.2	0.8	5.2	1.0	3.2	1.2
Carangidae	*Pseudocaranx dentex*	Silvcr Trevally	7.4	4.5	5	2.9	5.8	1.7	2.6	1.4	0	0.0	0	0.0
Carangidae	*Seriola hippos*	Samson Fish	0	0.0	0	0.0	0.2	0.2	0	0.0	0	0.0	0	0.0
Carangidae	*novaezelandiae*	Yellow-tail Scac	4.8	2.1	12.8	7.3	1.2	1.2	0.2	0.2	0	0.0	0.4	0.4
Sparidae	*Pagrus auratus*	Snapper	0	0.0	0	0.0	1.4	1.0	0	0.0	0	0.0	0	0.0
Mullidae	*Upeneichthys lineatus*	Blue-lined Goatfish	0	0.0	0	0.0	0.4	0.2	0	0.0	0	0.0	0	0.0
Scombridae	*Sarda australis*	Australian Bonito	0	0.0	0.2	0.2	0	0.0	0	0.0	0	0.0	0	0.0
Paralichthyidae	*Pseudorhombus sp.*	Flounder	0	0.0	0	0.0	0	0.0	0	0.0	0.2	0.2	0	0.0
Monacanthidae	*Meuschenia freycineti*	Six-spine Leatherjacket	0	0.0	0.2	0.2	0	0.0	0.6	0.2	1.8	0.4	1.6	0.2
Monacanthidae	*Meuschenia trachylepis*	Yellow-finned Leatherjacket	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.2	0.2
Monacanthidae	*Nelusetta ayraudi*	Chinaman Leatherjacket	44	7.2	44	6.2	24.8	12.7	62.8	5.1	0	0.0	0.4	0.2
Aracanidae	*Anoplocapros inermis*	Eastern Smooth Boxfish	0	0.0	0	0.0	0.4	0.4	0	0.0	0.4	0.2	0	0.0
Diodontidae	*punctulatus*	Three-bar Porcupinefish	0	0.0	0	0.0	0.2	0.2	0	0.0	0	0.0	0	0.0
		Total number of species at site (all samples):	8		9		13		10		9		11	
		Total number of species (all sites):					22							
		Total number of individuals at Site (all sites):	65.6		67.8		42.6		75.8		23.4		18.2	
		Total number of individuals at Location (all sites):	133.4				118.4				41.6			

Table 4: Permutational multivariate analysis of variance (PERMANOVA) and pairwise tests comparing assemblages and taxa of fish recorded in the Newcastle, Sydney and Wollongong study regions. PERMDISP results are included for significant sources of variation. Significant factors are highlighted in bold. Data transformed to square root. SR - Study Region, Lo - Location, Si - Site. P(MC) - Monte Carlo *P*-value.

Assemblage

Source of Variation	df	SS	MS	*Pseudo-F*	*P* (perm)	Unique perms	P (MC)
St	2	338.75	169.37	10.532	0.0678	15	**0.0006**
Lo(St)	3	48.247	16.082	1.5548	0.1514	4983	0.151
Res	24	248.24	10.343				
Total	29	635.24					

Source	Estimate	Sq.root
S(St)	15.329	3.9152
V(Lo(St))	1.1478	1.0713
V(Res)	10.343	3.2161

PERM DISP
Deviations from Centroid

F	13.172		
P (permutational)	**0.0004**		
Group (Study Region)	Size	Average	S.E.
Newcastle	10	17.034	1.5139
Sydney	10	25.449	2.1935
Wollongong	10	31.915	2.3616

PERM DISP
Deviations from Centroid

F	5.5002		
P (permutational)	**0.0135**		
Group (location)	Size	Average	S.E.
New Impact	5	15.915	2.4408
New Control	5	17.474	2.2236
Syd Impact	5	24.754	4.442
Syd Control	5	15.182	0.64775
Wol Impact	5	27.369	2.7099
Wol Control	5	32.444	3.9981

PERMANOVA Pairwise Tests (study region)

Groups	t	*P* (perm)	Unique perms	P (MC)
Newcastle, Sydney	1.1031	0.3332	3	0.3626
Newcastle, Wollongong	7.3433	0.344	3	**0.0002**
Sydney, Wollongong	3.1557	0.3246	3	**0.0068**

Continued

Table 4: Continued

No. of taxa

Source of Variation	df	SS	MS	*Pseudo-F*	*P* (perm)	Unique perms	P (MC)
St	2	11.467	5.7333	15.636	0.1992	9	**0.0262**
Lo(St)	3	1.1	0.36667	0.13253	0.9382	1767	0.9436
Res	24	66.4	2.7667				
Total	29	78.967					

PERMANOVA Pairwise Tests (study region)

Groups	t	*P* (perm)	Unique perms	P (MC)
Newcastle, Sydney	0.63246	1	2	0.5998
Newcastle, Wollongong	8.4853	0.3302	3	**0.0128**
Sydney, Wollongong	4.4272	0.3324	3	**0.0462**

Nelusetta ayraudi

Source of Variation	df	SS	MS	*Pseudo-F*	*P* (perm)	Unique perms	P (MC)
St	2	254.16	127.08	12.976	0.2098	15	**0.0304**
Lo(St)	3	29.38	9.7933	6.0559	**0.0038**	4982	**0.003**
Res	24	38.811	1.6171				
Total	29	322.35					

PERMANOVA Pairwise Tests (study region)

Groups	t	*P* (perm)	Unique perms	P (MC)
Newcastle, Sydney	0.20387	1	3	0.8566
Newcastle, Wollongong	31.52	0.3276	3	**0.002**
Sydney, Wollongong	3.497	0.335	3	**0.076**

Pseudocaranx dentex

Source of Variation	df	SS	MS	*Pseudo-F*	*P* (perm)	Unique perms	P (MC)
St	2	7.2216	3.6108	18.256	0.2074	9	**0.0208**
Lo(St)	3	0.59334	0.19778	0.38744	0.7576	4986	0.7634
Res	24	12.252	0.51048				
Total	29	20.066					

PERMANOVA Pairwise Tests (study region)

Groups	t	*P* (perm)	Unique perms	P (MC)
Newcastle, Sydney	0.2069	1	3	0.8576
Newcastle, Wollongong	21.647	0.332	2	**0.0014**
Sydney, Wollongong	4.4557	0.3336	2	0.0504

Continued

Table 4: Continued

Meuschenia freycineti

Source of Variation	df	SS	MS	*Pseudo-F*	*P* (perm)	Unique perms	P (MC)
St	2	7.9805	3.9902	11.851	0.1936	9	**0.0346**
Lo(St)	3	1.0101	0.3367	3.1105	**0.0482**	3102	**0.0468**
Res	24	2.5979	0.10825				
Total	29	11.589					

PERMANOVA Pairwise Tests (study region)

Groups	t	*P* (perm)	Unique perms	P (MC)
Newcastle, Sydney	0.63246	1	2	0.5894
Newcastle, Wollongong	11.249	0.331	3	**0.0058**
Sydney, Wollongong	3.2495	0.3498	3	0.0828

Clupeidae

Source of Variation	df	SS	MS	*Pseudo-F*	*P* (perm)	Unique perms	P (MC)
St	2	13.333	6.6667	Denom is 0			
Lo(St)	3	8.87E-15	2.96E-15	8.40E-16	1	3	1
Res	24	80	3.3333				
Total	29	93.333					

Table 5: Results of SIMPER analyses comparing assemblages of fish sampled during January 2009 in the three study regions (Newcastle, Sydney and Wollongong) and between locations (proposed OAR and Control). Cut-off for cumulative contribution is 50%.

Newcastle study region

Average similarity: 74.71 %

Taxon	Ave. Abund	Ave. Diss	Diss/SD	Contrib. %	Cum %
Nelusetta ayraudi	6.54	37.75	4.92	50.54	50.54
Platycephalus longispinus	2.02	10.61	2.96	14.21	64.74
Trachurus novaezelandiae	2.49	9.81	2.35	13.13	77.87
Platycephalus caeruleopunctatus	1.12	6.6	7.7	8.84	86.71
Pseudocaranx dentex	1.79	4.21	0.65	5.63	92.35

Sydney study region

Average similarity: 62.88%

Taxon	Ave. Abund	Ave. Diss	Diss/SD	Contrib. %	Cum %
Nelusetta ayraudi	6.19	32.05	2.52	50.98	50.98
Platycephalus longispinus	1.9	10.94	2.93	17.4	68.38
Platycephalus caeruleopunctatus	1.31	7.29	5.72	11.59	79.97
Pseudocaranx dentex	1.66	6.26	0.84	9.96	89.93
Trygonorrhina fasciata	1.04	4.01	0.9	6.37	96.3

Wollongong study region

Average similarity: 53.37 %

Taxon	Ave. Abund	Ave. Diss	Diss/SD	Contrib. %	Cum %
Platycephalus longispinus	1.96	21.93	2.43	41.1	41.1
Meuschenia freycineti	1.28	15.55	2.56	29.14	70.24
Trygonorrhina fasciata	1.27	8.08	1.1	15.15	85.38
Platycephalus caeruleopunctatus	0.78	4.9	0.89	9.18	94.57

Continued

Table 5: Continued.

Newcastle & Wollongong study regions

Average dissimilarity: 72.04 %

	Newcastle	Wollongong				
Taxon	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Nelusetta ayraudi	6.54	0.2	27.77	3.44	38.54	38.54
Trachurus novaezelandiae	2.49	0.14	9.87	1.66	13.7	52.24
Pseudocaranx dentex	1.79	0	7.21	1.02	10	62.25
Meuschenia freycineti	0.1	1.28	5.23	2.47	7.26	69.51
Clupeidae	0	1.41	4.87	0.49	6.76	76.27

Sydney & Wollongong study regions

Average dissimilarity: 68.97 %

	Sydney	Wollongong				
Taxon	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Nelusetta ayraudi	6.19	0.2	26.75	2.39	38.78	38.78
Pseudocaranx dentex	1.66	0	7.46	1.27	10.81	49.59
Clupeidae	0	1.41	5.02	0.5	7.28	56.88
Meuschenia freycineti	0.3	1.28	4.45	1.68	6.45	63.32
Trygonorrhina fasciata	1.04	1.27	4.4	1.37	6.38	69.71

Newcastle & Sydney study regions

Average dissimilarity: 35.41 %

	Newcastle	Sydney				
Taxon	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Nelusetta ayraudi	6.54	6.19	7.54	1.49	21.28	21.28
Trachurus novaezelandiae	2.49	0.34	7.29	1.57	20.59	41.87
Pseudocaranx dentex	1.79	1.66	5.67	1.36	16.01	57.88
Aptychotrema sp.	0.74	0.5	2.63	1.34	7.42	65.29
Trygonorrhina fasciata	0.74	1.04	2.49	1.35	7.04	72.34

Table 6: Sediment Particle Size Distribution summary table for samples collected at the Newcastle, Sydney and Wollongong study regions in January 2009. (OAR = proposed OAR location, Con = control location). See Appendix 2 for raw data.

	Location	Site	Rep	Date Collected	Median Grain Size	~% Gravel	~% Sand	~% Silt	~% Clay
					(mm)	(> 2 mm)	(0.060 - 2 mm)	(0.002 - 0.060 mm)	(< 0.002 mm)
NEWCASTLE	OAR	1	1	13/01/2009	0.300	0%	98%	NA	NA
	OAR	1	2	13/01/2009	0.300	0%	99%	NA	NA
	OAR	2	1	13/01/2009	0.300	0%	99%	NA	NA
	OAR	2	2	13/01/2009	0.300	1%	98%	NA	NA
	OAR	3	1	13/01/2009	0.300	0%	98%	NA	NA
	OAR	3	2	13/01/2009	0.300	0%	99%	NA	NA
	OAR	4	1	13/01/2009	0.300	0%	98%	NA	NA
	OAR	4	2	13/01/2009	0.300	1%	99%	NA	NA
	CON	1	1	13/01/2009	0.300	1%	99%	NA	NA
	CON	1	2	13/01/2009	0.300	2%	97%	NA	NA
	CON	2	1	13/01/2009	0.300	1%	98%	NA	NA
	CON	2	2	13/01/2009	0.300	0%	99%	NA	NA
	CON	3	1	13/01/2009	0.300	4%	95%	NA	NA
	CON	3	2	13/01/2009	0.425	0%	99%	NA	NA
	CON	4	1	13/01/2009	0.300	0%	98%	NA	NA
	CON	4	2	13/01/2009	0.300	1%	98%	NA	NA
SYDNEY	OAR	1	1	21/01/2009	0.150	0%	98%	NA	NA
	OAR	1	2	21/01/2009	0.150	0%	98%	NA	NA
	OAR	2	1	21/01/2009	0.150	3%	93%	NA	NA
	OAR	2	2	21/01/2009	0.300	12%	85%	NA	NA
	OAR	3	1	21/01/2009	0.150	0%	98%	NA	NA
	OAR	3	2	21/01/2009	0.150	0%	97%	NA	NA
	OAR	4	1	21/01/2009	0.150	0%	99%	NA	NA
	OAR	4	2	21/01/2009	0.150	0%	99%	NA	NA
	CON	1	1	21/01/2009	0.300	1%	98%	NA	NA
	CON	1	2	21/01/2009	0.300	0%	98%	NA	NA
	CON	2	1	21/01/2009	0.150	0%	97%	NA	NA
	CON	2	2	21/01/2009	0.150	0%	97%	NA	NA
	CON	3	1	21/01/2009	0.150	0%	98%	NA	NA
	CON	3	2	21/01/2009	0.150	0%	98%	NA	NA
	CON	4	1	21/01/2009	0.150	0%	98%	NA	NA
	CON	4	2	21/01/2009	0.150	0%	98%	NA	NA
WOLLONGONG	OAR	1	1	23/01/2009	0.150	0%	98%	NA	NA
	OAR	1	2	23/01/2009	0.150	0%	98%	NA	NA
	OAR	2	1	23/01/2009	0.150	0%	98%	NA	NA
	OAR	2	2	23/01/2009	0.150	0%	98%	NA	NA
	OAR	3	1	23/01/2009	0.150	0%	98%	NA	NA
	OAR	3	2	23/01/2009	0.150	0%	98%	NA	NA
	OAR	4	1	23/01/2009	0.150	0%	98%	NA	NA
	OAR	4	2	23/01/2009	0.150	0%	98%	NA	NA
	CON	1	1	23/01/2009	0.150	0%	98%	NA	NA
	CON	1	2	23/01/2009	0.150	0%	98%	NA	NA
	CON	2	1	23/01/2009	0.150	0%	99%	NA	NA
	CON	2	2	23/01/2009	0.150	0%	95%	NA	NA
	CON	3	1	23/01/2009	0.150	0%	98%	NA	NA
	CON	3	2	23/01/2009	0.150	0%	98%	NA	NA
	CON	4	1	23/01/2009	0.150	0%	98%	NA	NA
	CON	4	2	23/01/2009	0.150	0%	97%	NA	NA

Table 7: Permutational multivariate analysis of variance (PERMANOVA) and pairwise tests comparing the median grain size of sediments collected at the Newcastle, Sydney and Wollongong study regions. PERMDISP results are included for significant sources of variation. Significant factors are highlighted in bold. Data was normalised. SR - Study Region, Lo - Location, Si - Site, P(MC) - Monte Carlo *P*-value.

Source of Variation	df	SS	MS	*Pseudo-F*	*P* (perm)	Unique perms	P (MC)
St	2	0.22674	0.11337	142.74	**0.0682**	9	**0.0004**
Lo(St)	3	2.38E-03	7.94E-04	0.29756	0.8138	530	0.8284
Si(Lo(St))	18	4.80E-02	2.67E-03	3.3607	**0.004**	594	**0.0036**
Res	24	1.91E-02	7.94E-04				
Total	47	0.29624					

Estimates of components of variation

Source	Estimate	Sq. Root
Fixed(SR)	1.1084	1.0528
Fixed(Lo)	-1.48E-04	-1.21E-02
Fixed(SRxLo)	-2.37E-02	-0.15389
Random(Res)	0.25351	0.5035

PERM DISP

Deviations from Centroid

F	12.014		
P (permutational)	**0.0264**		
Group (Study Region)	Size	Average	S.E.
Newcastle	16	0.18451	8.61E-02
Sydney	16	0.57567	0.11901
Wollongong	16	9.85E-16	3.75E-16

PERMANOVA Pairwise Tests (study region)

	t	*P* (perm)	Unique perms	P (MC)
Groups				
Newcastle, Sydney	10.627	0.3398	3	**0.011**
Newcastle, Wollongong	20.2	0.3328	2	**0.004**
Sydney, Wollongong	3	0.3354	2	0.093

PERMANOVA Pairwise Tests (Sites within Location)

Newcastle (OAR)

Groups	t	*P* (perm)	perms	P(MC)
S1, S2	Denom 0			
S1, S3	Denom 0			
S1, S4	Denom 0			
S2, S3	Denom 0			
S2, S4	Denom 0			
S3, S4	Denom 0			

Continued

Table 7: Continued

PERMANOVA Pairwise Tests (Sites within Location)

Newcastle (Con)

Groups	t	*P* (perm)	perms	P(MC)
S1, S2	Denom 0			
S1, S3	1	1	1	0.4212
S1, S4	Denom 0			
S2, S3	1	1	1	0.4158
S2, S4	Denom 0			
S3, S4	1	1	1	0.43

Sydney (OAR)

Groups	t	*P* (perm)	perms	P(MC)
S1, S2	1	1	1	0.4292
S1, S3	Denom 0			
S1, S4	Denom 0			
S2, S3	1	1	1	0.4252
S2, S4	1	1	1	0.4164
S3, S4	Denom 0			

Sydney (Con)

Groups	t	*P* (perm)	perms	P(MC)
S1, S2	Denom 0			
S1, S3	Denom 0			
S1, S4	Denom 0			
S2, S3	Denom 0			
S2, S4	Denom 0			
S3, S4	Denom 0			

Wollongong (OAR)

Groups	t	*P* (perm)	perms	P(MC)
S1, S2	Denom 0			
S1, S3	Denom 0			
S1, S4	Denom 0			
S2, S3	Denom 0			
S2, S4	Denom 0			
S3, S4	Denom 0			

Wollongong (Con)

Groups	t	*P* (perm)	perms	P(MC)
S1, S2	Denom 0			
S1, S3	Denom 0			
S1, S4	Denom 0			
S2, S3	Denom 0			
S2, S4	Denom 0			
S3, S4	Denom 0			

Table 8: Water quality data collected at the Newcastle, Sydney and Wollongong study regions in January 2009 (OAR = proposed OAR location, CON =control location). Results were obtained using a Yeo-Kal 611 probe. Mean values highlighted in bold indicate that variable is outside of ANZECC guidelines for marine ecosystems. GPS Positions were recorded in WGS84. (*) Indicates an anomalus reading.

Region	Location	Site	Depth	Variable	Temperature (^{0}C)	Conductivity (mS/cm)	Salinity (ppt)	pH	ORP (mV)	DO (%sat'n)	DO (mg/L)				Ave Turbidity
				ANZECC (2000) guidelines for				8.0 - 8.4		90 -110		T1	T2	T3	0.5 - 10
NEWCASTLE	OAR	Site 1 33°03.514' S 151°43.270' E	Surface	Rep 1	18.84	57.77	38.60	8.17	434.00	83.00	6.20	0.00	0.00	0.00	0.00
				Rep 2	18.85	57.49	38.29	8.17	434.00	83.60	6.20	0.00	0.00	0.00	0.00
				Mean	18.85	57.63	38.45	8.17	434.00	83.30	6.20	0.00	0.00	0.00	0.00
				SE	0.01	0.14	0.15	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00
			Bottom	Rep 1	15.94	55.26	33.61	8.14	434.00	59.10	4.70	3.70	3.60	3.40	3.57
				Rep 2	16.76	55.90	37.17	8.18	434.00	67.80	5.30	0.70	0.60	0.50	0.60
				Mean	16.35	55.58	35.39	8.16	434.00	63.45	5.00	2.20	2.10	1.95	2.08
				SE	0.41	0.32	1.78	0.02	0.00	4.35	0.30	1.50	1.50	1.45	1.48
		Site 2 33°03.700' S 151°43.354' E	Surface	Rep 1	18.65	57.59	38.37	8.20	441.00	81.20	6.00	0.00	0.00	0.00	0.00
				Rep 2	18.67	57.68	38.40	8.20	441.00	82.40	6.10	0.00	0.00	0.00	0.00
				Mean	18.66	57.64	38.39	8.20	441.00	81.80	6.05	0.00	0.00	0.00	0.00
				SE	0.01	0.04	0.02	0.00	0.00	0.60	0.05	0.00	0.00	0.00	0.00
			Bottom	Rep 1	15.85	55.19	36.54	8.16	443.00	64.90	5.10	3.70	3.80	3.80	3.77
				Rep 2	15.84	55.12	36.53	8.16	443.00	58.10	4.60	4.80	4.70	4.60	4.70
				Mean	15.85	55.16	36.54	8.16	443.00	61.50	4.85	4.25	4.25	4.20	4.23
				SE	0.00	0.04	0.00	0.00	0.00	3.40	0.25	0.55	0.45	0.40	0.47
		Site 3 33°03.764' S 151°43.013' E	Surface	Rep 1	18.83	57.77	38.33	8.22	4.25	81.70	6.00	0.00	0.00	0.00	0.00
				Rep 2	18.86	57.74	38.44	8.22	4.26	82.20	6.10	0.00	0.00	0.00	0.00
				Mean	18.85	57.76	38.39	8.22	4.26	81.95	6.05	0.00	0.00	0.00	0.00
				SE	0.02	0.02	0.05	0.00	0.00	0.25	0.05	0.00	0.00	0.00	0.00
			Bottom	Rep 1	15.90	55.20	36.65	8.18	4.25	65.00	5.00	0.20	0.10	0.20	0.17
				Rep 2	15.96	55.28	36.60	8.18	4.26	58.90	4.60	0.70	0.70	0.70	0.70
				Mean	15.93	55.24	36.63	8.18	4.26	61.95	4.80	0.45	0.40	0.45	0.43
				SE	0.03	0.04	0.02	0.00	0.00	3.05	0.20	0.25	0.30	0.25	0.27
		Site 4 33°03.911' S 151°43.168' E	Surface	Rep 1	18.69	57.45	38.32	8.25	427.00	80.70	6.00	0.00	0.00	0.00	0.00
				Rep 2	18.69	57.82	38.31	8.25	428.00	81.80	6.10	0.00	0.00	0.00	0.00
				Mean	18.69	57.64	38.32	8.25	427.50	81.25	6.05	0.00	0.00	0.00	0.00
				SE	0.00	0.18	0.00	0.00	0.50	0.55	0.05	0.00	0.00	0.00	0.00
			Bottom	Rep 1	15.87	54.59	36.55	8.19	429.00	62.10	4.80	0.00	0.00	0.00	0.00
				Rep 2	15.99	55.74	36.93	8.24	429.00	58.20	4.60	0.00	0.00	0.00	0.00
				Mean	15.93	55.17	36.74	8.22	429.00	60.15	4.70	0.00	0.00	0.00	0.00
				SE	0.06	0.57	0.19	0.03	0.00	1.95	0.10	0.00	0.00	0.00	0.00

Continued

Table 8: Continued

Variable						Temperature (^{0}C)	Conductivity (mS/cm)	Salinity (ppt)	pH	ORP (mV)	DO (%sat'n)	DO (mg/L)				Turbidity (ntu)
ANZECC (2000) guidelines for									8.0 - 8.4		90 -110		T1	T2	T3	0.5 - 10
NEWCASTLE	CON	Site 1	33°06.610' S 151°42.005' E	Surface	Rep 1	18.59	57.51	38.24	8.27	449.00	82.40	6.10	0.00	0.00	0.00	0.00
					Rep 2	18.60	57.24	38.17	8.27	448.00	83.00	6.20	0.00	0.00	0.00	0.00
					Mean	18.60	57.38	38.21	8.27	448.50	82.70	6.15	0.00	0.00	0.00	0.00
					SE	0.01	0.13	0.04	0.00	0.50	0.30	0.05	0.00	0.00	0.00	0.00
				Bottom	Rep 1	15.94	54.94	36.74	8.23	452.00	66.10	5.10	0.00	0.00	0.00	0.00
					Rep 2	16.74	56.42	37.34	8.29	451.00	70.30	5.50	0.00	0.00	0.00	0.00
					Mean	16.34	55.68	37.04	8.26	451.50	68.20	5.30	0.00	0.00	0.00	0.00
					SE	0.40	0.74	0.30	0.03	0.50	2.10	0.20	0.00	0.00	0.00	0.00
		Site 2	33°06.476' S 151°42.488' E	Surface	Rep 1	18.43	57.44	38.42	8.29	440.00	84.30	6.20	0.00	0.00	0.00	0.00
					Rep 2	18.43	57.66	38.42	8.29	440.00	85.30	6.30	0.00	0.00	0.00	0.00
					Mean	18.43	57.55	38.42	8.29	440.00	84.80	6.25	0.00	0.00	0.00	0.00
					SE	0.00	0.11	0.00	0.00	0.00	0.50	0.05	0.00	0.00	0.00	0.00
				Bottom	Rep 1	15.76	55.30	36.65	8.24	443.00	62.80	5.10	1.30	1.40	1.80	1.50
					Rep 2	16.05	55.57	36.99	8.27	443.00	61.80	4.70	0.10	0.00	0.00	0.03
					Mean	15.91	55.44	36.82	8.26	443.00	62.30	4.90	0.70	0.70	0.90	0.77
					SE	0.14	0.14	0.17	0.01	0.00	0.50	0.20	0.60	0.70	0.90	0.73
		Site 3	33°06.720' S 151°42.198' E	Surface	Rep 1	18.54	57.45	38.29	8.28	443.00	85.90	6.40	0.00	0.00	0.00	0.00
					Rep 2	18.54	57.66	38.32	8.28	443.00	84.20	6.40	0.00	0.00	0.00	0.00
					Mean	18.54	57.56	38.31	8.28	443.00	85.05	6.40	0.00	0.00	0.00	0.00
					SE	0.00	0.10	0.02	0.00	0.00	0.85	0.00	0.00	0.00	0.00	0.00
				Bottom	Rep 1	15.99	55.08	36.54	8.22	445.00	72.20	5.50	0.00	0.00	0.00	0.00
					Rep 2	16.86	56.31	37.52	8.30	445.00	72.60	5.70	0.00	0.00	0.00	0.00
					Mean	16.43	55.70	37.03	8.26	445.00	72.40	5.60	0.00	0.00	0.00	0.00
					SE	0.43	0.62	0.49	0.04	0.00	0.20	0.10	0.00	0.00	0.00	0.00
		Site 4	33°06.346' S 151°42.256' E	Surface	Rep 1	18.47	57.79	38.45	8.30	440.00	82.90	6.20	0.00	0.00	0.00	0.00
					Rep 2	18.48	57.64	38.31	8.30	440.00	83.90	6.30	0.00	0.00	0.00	0.00
					Mean	18.48	57.72	38.38	8.30	440.00	83.40	6.25	0.00	0.00	0.00	0.00
					SE	0.01	0.07	0.07	0.00	0.00	0.50	0.05	0.00	0.00	0.00	0.00
				Bottom	Rep 1	15.80	55.52	36.02	8.27	441.00	60.70	4.80	0.00	0.00	0.00	0.00
					Rep 2	16.99	57.02	38.00	8.34	439.00	69.80	5.40	0.00	0.00	0.00	0.00
					Mean	16.40	56.27	37.01	8.31	440.00	65.25	5.10	0.00	0.00	0.00	0.00
					SE	0.59	0.75	0.99	0.04	1.00	4.55	0.30	0.00	0.00	0.00	0.00

Continued

Table 8: Continued

Variable				Temperature (^{0}C)	Conductivity (mS/cm)	Salinity (ppt)	pH	ORP (mV)	DO (%sat'n)	DO (mg/L)				Turbidity (ntu)
ANZECC (2000) guidelines for							8.0 - 8.4		90 -110		T1	T2	T3	0.5 - 10
SYDNEY OAR	Site 1 33°50.350' S 151°17.763' E	Surface	Rep 1	17.70	59.96	37.59	8.26	379.00	76.50	5.80	0.00	0.00	0.00	0.00
			Rep 2	17.74	57.06	37.90	8.26	384.00	77.80	5.90	0.00	0.00	0.00	0.00
			Mean	17.72	58.51	37.75	8.26	381.50	77.15	5.85	0.00	0.00	0.00	0.00
			SE	0.02	1.45	0.15	0.00	2.50	0.65	0.05	0.00	0.00	0.00	0.00
		Bottom	Rep 1	15.79	55.40	36.20	8.25	356.00	65.10	5.20	9.40	3.80	2.90	5.37
			Rep 2	15.17	55.69	36.84	8.26	364.00	65.90	5.20	15.60	1.10	4.40	7.03
			Mean	15.48	55.55	36.52	8.26	360.00	65.50	5.20	12.50	2.45	3.65	6.20
			SE	0.31	0.15	0.32	0.00	4.00	0.40	0.00	3.10	1.35	0.75	0.83
	Site 2 33°50.546' S 151°17.923' E	Surface	Rep 1	17.76	59.98	37.94	8.28	383.00	79.10	6.00	0.00	0.00	0.00	0.00
			Rep 2	17.66	57.08	37.95	8.28	386.00	79.20	6.00	0.00	0.00	0.00	0.00
			Mean	17.71	58.53	37.95	8.28	384.50	79.15	6.00	0.00	0.00	0.00	0.00
			SE	0.05	1.45	0.01	0.00	1.50	0.05	0.00	0.00	0.00	0.00	0.00
		Bottom	Rep 1	15.76	55.44	36.48	8.28	391.00	66.60	5.30	32.10	55.90	8.80	0.00
			Rep 2	15.75	54.71	36.56	8.29	393.00	55.60	5.20	46.30	41.70	31.10	39.70
			Mean	15.76	55.08	36.52	8.29	392.00	61.10	5.25	39.20	48.80	19.95	19.85
			SE	0.00	0.36	0.04	0.00	1.00	5.50	0.05	7.10	7.10	11.15	19.85
	Site 3 33°50.688' S 151°17.721' E	Surface	Rep 1	17.64	57.00	37.84	8.29	391.00	78.50	6.00	0.00	0.00	0.00	0.00
			Rep 2	17.61	56.98	57.91	8.29	393.00	78.40	6.00	0.00	0.00	0.00	0.00
			Mean	17.63	56.99	47.88	8.29	392.00	78.45	6.00	0.00	0.00	0.00	0.00
			SE	0.02	0.01	10.04	0.00	1.00	0.05	0.00	0.00	0.00	0.00	0.00
		Bottom	Rep 1	15.93	55.69	36.93	8.30	397.00	65.30	5.50	0.00	0.00	0.00	0.00
			Rep 2	15.93	55.65	36.94	8.30	398.00	37.90	5.30	0.00	0.00	0.00	0.00
			Mean	15.93	55.67	36.94	8.30	397.50	51.60	5.40	0.00	0.00	0.00	0.00
			SE	0.00	0.02	0.00	0.00	0.50	13.70	0.10	0.00	0.00	0.00	0.00
	Site 4 33°50.573' S 151°17.550' E	Surface	Rep 1	17.42	56.71	37.77	8.29	365.00	76.70	5.90	0.00	0.00	0.00	0.00
			Rep 2	17.42	56.72	37.70	8.29	362.00	77.10	5.90	0.00	0.00	0.00	0.00
			Mean	17.42	56.72	37.74	8.29	363.50	76.90	5.90	0.00	0.00	0.00	0.00
			SE	0.00	0.00	0.04	0.00	1.50	0.20	0.00	0.00	0.00	0.00	0.00
		Bottom	Rep 1	15.85	56.07	37.26	8.29	367.00	37.40	5.30	0.00	0.00	0.00	0.00
			Rep 2	15.55	57.07	37.19	8.30	371.00	65.70	5.20	0.00	0.00	0.00	0.00
			Mean	15.70	56.57	37.23	8.30	369.00	51.55	5.25	0.00	0.00	0.00	0.00
			SE	0.15	0.50	0.04	0.01	2.00	14.15	0.05	0.00	0.00	0.00	0.00

Continued

Table 8: Continued

Location	Site	Coordinates	Depth	Variable	Temperature (°C)	Conductivity (mS/cm)	Salinity (ppt)	pH	ORP (mV)	DO (%sat'n)	DO (mg/L)	T1	T2	T3	Turbidity (ntu)
ANZECC (2000) guidelines for								8.0 - 8.4		90 -110		T1	T2	T3	0.5 - 10
SYDNEY CON	Site 1	33°52.517' S 151°17.530' E	Surface	Rep 1	15.85	55.39	36.80	8.32	339.00	74.70	5.90	19.10	19.20	19.20	19.17
				Rep 2	15.90	55.09	36.70	8.33	343.00	71.50	5.70	18.40	18.50	18.40	18.43
				Mean	15.88	55.24	36.75	8.33	341.00	73.10	5.80	18.75	18.85	18.80	18.80
				SE	0.03	0.15	0.05	0.00	2.00	1.60	0.10	0.35	0.35	0.40	0.37
			Bottom	Rep 1	18.15	57.34	38.16	8.34	350.00	82.10	6.10	9.80	9.80	9.60	9.73
				Rep 2	18.25	57.43	38.26	8.33	354.00	83.70	6.30	7.90	7.80	7.80	7.83
				Mean	18.20	57.39	38.21	8.34	352.00	82.90	6.20	8.85	8.80	8.70	8.78
				SE	0.05	0.04	0.05	0.00	2.00	0.80	0.10	0.95	1.00	0.90	0.95
	Site 2	33°52.722' S 151°17.650' E	Surface	Rep 1	18.30	57.48	38.15	8.33	360.00	82.80	6.20	8.60	5.00	8.60	7.40
				Rep 2	18.20	57.43	38.21	8.32	365.00	85.00	6.20	6.40	6.30	6.10	6.27
				Mean	18.25	57.46	38.18	8.33	362.50	83.90	6.20	7.50	5.65	7.35	6.83
				SE	0.05	0.02	0.03	0.00	2.50	1.10	0.00	1.10	0.65	1.25	0.57
			Bottom	Rep 1	16.08	55.93	37.06	8.32	345.00	74.10	7.30	11.80	11.90	12.10	11.93
				Rep 2	16.42	55.81	37.07	8.34	351.00	76.60	7.50	13.50	13.80	13.70	13.67
				Mean	16.25	55.87	37.07	8.33	348.00	75.35	7.40	12.65	12.85	12.90	12.80
				SE	0.17	0.06	0.00	0.01	3.00	1.25	0.10	0.85	0.95	0.80	0.87
	Site 3	33°52.889' S 151°17.487' E	Surface	Rep 1	17.97	57.18	38.11	8.35	371.00	77.40	5.90	4.20	4.10	4.00	4.10
				Rep 2	18.20	57.45	38.27	8.34	373.00	80.20	6.00	1.70	1.70	1.60	1.67
				Mean	18.09	57.32	38.19	8.35	372.00	78.80	5.95	2.95	2.90	2.80	2.88
				SE	0.11	0.14	0.08	0.00	1.00	1.40	0.05	1.25	1.20	1.20	1.22
			Bottom	Rep 1	15.71	55.20	36.61	8.34	360.00	66.50	5.30	7.80	10.80	10.90	9.83
				Rep 2	15.64	55.29	36.65	8.34	367.00	65.10	5.20	11.50	11.40	11.60	11.50
				Mean	15.68	55.25	36.63	8.34	363.50	65.80	5.25	9.65	11.10	11.25	10.67
				SE	0.04	0.04	0.02	0.00	3.50	0.70	0.05	1.85	0.30	0.35	0.83
	Site 4	33°52.758' S 151°17.346' E	Surface	Rep 1	17.80	57.20	38.05	8.54	391.00	76.30	5.80	5.60	5.80	5.80	5.73
				Rep 2	17.95	57.26	38.09	8.53	392.00	78.80	6.00	4.60	4.50	4.50	4.53
				Mean	17.88	57.23	38.07	8.54	391.50	77.55	5.90	5.10	5.15	5.15	5.13
				SE	0.07	0.03	0.02	0.00	0.50	1.25	0.10	0.50	0.65	0.65	0.60
			Bottom	Rep 1	15.80	54.34	35.94	8.50	386.00	70.60	56.00	9.10	9.80	9.20	9.37
				Rep 2	15.77	54.26	35.91	8.49	387.00	66.10	53.00	10.30	10.30	10.40	10.33
				Mean	15.79	54.30	35.93	8.50	386.50	68.35	54.50	9.70	10.05	9.80	9.85
				SE	0.02	0.04	0.02	0.00	0.50	2.25	1.50	0.60	0.25	0.60	0.48

Continued

Table 8: Continued

			Variable	Temperature (^{0}C)	Conductivity (mS/cm)	Salinity (ppt)	pH	ORP (mV)	DO (%sat'n)	DO (mg/L)				Turbidity (ntu)
ANZECC (2000) guidelines for							8.0 - 8.4		90 -110		T1	T2	T3	0.5 - 10
WOLLONGONG OAR	Site 1 34°31.064' S 151°55.289' E	Surface	Rep 1	17.68	56.69	37.76	8.31	436.00	74.90	5.70	0.00	0.00	0.00	0.00
			Rep 2	17.68	56.83	37.40	8.31	436.00	75.50	5.70	0.00	0.00	0.00	0.00
			Mean	17.68	56.76	37.58	8.31	436.00	75.20	5.70	0.00	0.00	0.00	0.00
			SE	0.00	0.07	0.18	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00
		Bottom	Rep 1	15.21	54.49	36.15	8.30	439.00	75.30	5.20	0.00	0.00	0.00	0.00
			Rep 2	15.19	54.69	36.16	8.31	439.00	60.50	4.90	0.00	0.00	0.00	0.00
			Mean	15.20	54.59	36.16	8.31	439.00	67.90	5.05	0.00	0.00	0.00	0.00
			SE	0.01	0.10	0.00	0.00	0.00	7.40	0.15	0.00	0.00	0.00	0.00
	Site 2 34°31.224' S 151°55.504' E	Surface	Rep 1	17.69	56.50	37.68	8.33	432.00	71.20	5.60	0.00	0.00	0.00	0.00
			Rep 2	17.69	56.77	37.72	8.32	432.00	74.90	5.70	0.00	0.00	0.00	0.00
			Mean	17.69	56.64	37.70	8.33	432.00	73.05	5.65	0.00	0.00	0.00	0.00
			SE	0.00	0.14	0.02	0.00	0.00	1.85	0.05	0.00	0.00	0.00	0.00
		Bottom	Rep 1	15.16	54.27	36.30	8.31	436.00	53.10	5.10	0.00	0.00	0.00	0.00
			Rep 2	15.14	54.33	36.10	8.32	436.00	55.80	4.80	0.00	0.00	0.00	0.00
			Mean	15.15	54.30	36.20	8.32	436.00	54.45	4.95	0.00	0.00	0.00	0.00
			SE	0.01	0.03	0.10	0.00	0.00	1.35	0.15	0.00	0.00	0.00	0.00
	Site 3 34°31.263' S 150°55.380' E	Surface	Rep 1	17.60	56.39	37.57	8.31	440.00	78.00	5.90	0.00	0.00	0.00	0.00
			Rep 2	17.61	56.48	37.26	8.31	440.00	76.50	5.80	0.00	0.00	0.00	0.00
			Mean	17.61	56.44	37.42	8.31	440.00	77.25	5.85	0.00	0.00	0.00	0.00
			SE	0.00	0.04	0.16	0.00	0.00	0.75	0.05	0.00	0.00	0.00	0.00
		Bottom	Rep 1	15.17	54.67	35.90	8.32	443.00	65.00	5.20	0.00	0.00	0.00	0.00
			Rep 2	15.20	54.31	35.94	8.32	443.00	63.30	5.10	0.00	0.00	0.00	0.00
			Mean	15.19	54.49	35.92	8.32	443.00	64.15	5.15	0.00	0.00	0.00	0.00
			SE	0.01	0.18	0.02	0.00	0.00	0.85	0.05	0.00	0.00	0.00	0.00
	Site 4 34°31.216' S 151°55.074' E	Surface	Rep 1	17.64	66.21	37.37	8.34	433.00	75.50	5.80	0.00	0.00	0.00	0.00
			Rep 2	17.63	66.44	37.12	8.34	434.00	76.00	5.80	0.00	0.00	0.00	0.00
			Mean	17.64	66.33	37.25	8.34	433.50	75.75	5.80	0.00	0.00	0.00	0.00
			SE	0.01	0.12	0.13	0.00	0.50	0.25	0.00	0.00	0.00	0.00	0.00
		Bottom	Rep 1	15.23	54.61	36.02	8.32	436.00	65.30	5.20	0.00	0.00	0.00	0.00
			Rep 2	15.24	54.50	35.40	8.32	437.00	61.10	4.90	0.00	0.00	0.00	0.00
			Mean	15.24	54.56	35.71	8.32	436.50	63.20	5.05	0.00	0.00	0.00	0.00
			SE	0.00	0.05	0.31	0.00	0.50	2.10	0.15	0.00	0.00	0.00	0.00

Continued

Table 8: Continued

Location	Site	Depth	Variable	Temperature (^0C)	Conductivity (mS/cm)	Salinity (ppt)	pH	ORP (mV)	DO (%sat'n)	DO (mg/L)	T1	T2	T3	Turbidity (ntu)
ANZECC (2000) guidelines for							8.0 - 8.4		90 -110		T1	T2	T3	0.5 - 10
WOLLONGONG CON	Site 1 34°27.144' S 150°57.592' E	Surface	Rep 1	18.19	56.79	37.82	8.31	374.00	81.30	6.10	0.00	0.00	0.00	0.00
			Rep 2	18.16	56.79	37.62	8.32	370.00	80.80	6.10	0.00	0.00	0.00	0.00
			Mean	18.18	56.79	37.72	8.32	372.00	81.05	6.10	0.00	0.00	0.00	0.00
			SE	0.02	0.00	0.10	0.00	2.00	0.25	0.00	0.00	0.00	0.00	0.00
		Bottom	Rep 1	15.65	53.37	36.20	8.32	383.00	72.20	5.70	0.00	0.00	0.00	0.00
			Rep 2	15.50	54.81	36.17	8.33	384.00	65.70	5.30	0.00	0.00	0.00	0.00
			Mean	15.58	54.09	36.19	8.33	383.50	68.95	5.50	0.00	0.00	0.00	0.00
			SE	0.08	0.72	0.02	0.00	0.50	3.25	0.20	0.00	0.00	0.00	0.00
	Site 2 34°27.059' S 150°57.389' E	Surface	Rep 1	18.42	56.65	37.64	8.29	363.00	85.60	6.40	7.20	7.30	7.20	7.23
			Rep 2	18.40	56.72	37.71	8.30	366.00	84.90	6.40	6.90	6.80	6.90	6.87
			Mean	18.41	56.69	37.68	8.30	364.50	85.25	6.40	7.05	7.05	7.05	7.05
			SE	0.01	0.04	0.04	0.01	1.50	0.35	0.00	0.15	0.25	0.15	0.18
		Bottom	Rep 1	15.56	54.49	36.25	8.31	372.00	74.90	5.90	7.80	7.90	7.80	7.83
			Rep 2	15.60	54.78	36.14	8.32	373.00	69.80	5.60	7.90	8.00	7.90	7.93
			Mean	15.58	54.64	36.20	8.32	372.50	72.35	5.75	7.85	7.95	7.85	7.88
			SE	0.02	0.15	0.05	0.00	0.50	2.55	0.15	0.05	0.05	0.05	0.05
	Site 3 34°26.876' S 150°57.535' E	Surface	Rep 1	18.23	57.00	37.90	8.31	331.00	78.90	5.90	0.00	0.00	0.00	0.00
			Rep 2	18.18	56.90	37.94	8.32	337.00	79.50	6.00	0.00	0.00	0.00	0.00
			Mean	18.21	56.95	37.92	8.32	334.00	79.20	5.95	0.00	0.00	0.00	0.00
			SE	0.03	0.05	0.02	0.00	3.00	0.30	0.05	0.00	0.00	0.00	0.00
		Bottom	Rep 1	15.53	54.65	36.25	8.32	349.00	69.20	5.50	1.00	1.10	1.00	1.03
			Rep 2	15.70	54.87	36.33	8.33	352.00	65.40	5.20	1.60	1.60	1.70	1.63
			Mean	15.62	54.76	36.29	8.33	350.50	67.30	5.35	1.30	1.35	1.35	1.33
			SE	0.09	0.11	0.04	0.00	1.50	1.90	0.15	0.30	0.25	0.35	0.30
	Site 4 34°27.010' S 150°57.736' E	Surface	Rep 1	18.18	56.68	37.65	8.32	368.00	77.50	5.80	0.00	0.00	0.00	0.00
			Rep 2	18.16	56.55	37.64	8.32	371.00	78.00	5.90	0.00	0.00	0.00	0.00
			Mean	18.17	56.62	37.65	8.32	369.50	77.75	5.85	0.00	0.00	0.00	0.00
			SE	0.01	0.07	0.00	0.00	1.50	0.25	0.05	0.00	0.00	0.00	0.00
		Bottom	Rep 1	15.54	54.65	36.16	8.32	327.00	75.50	5.20	0.10	0.10	1.00	0.40
			Rep 2	15.60	54.90	36.39	8.33	380.00	63.80	5.10	1.30	1.40	1.30	1.33
			Mean	15.57	54.78	36.28	8.33	353.50	69.65	5.15	0.70	0.75	1.15	0.87
			SE	0.03	0.13	0.12	0.00	26.50	5.85	0.05	0.60	0.65	0.15	0.47

Table 9: Heavy metal concentrations recorded in sediment samples collected at the Newcastle, Sydney and Wollongong study regions in January 2009. Samples with heavy metal concentrations exceeding ISQG low and/or high trigger values are highlighted.

Region	Sample ID	Date	Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Mercury (mg/kg)
	ISQG low and high trigger		*20 - 70*	*1.5 - 10*	*80 - 370*	*65 - 270*	*50 - 220*	*200 - 410*	*0.15 - 1*
NEWCASTLE	NEW OAR S1	13/01/2009	2.85	<0.1	2.5	<1.0	<1.0	1.5	<0.01
	NEW OAR S2	13/01/2009	2.58	<0.1	2	<1.0	<1.0	1.4	<0.01
	NEW OAR S3	13/01/2009	3.61	<0.1	2.6	<1.0	1	1.6	<0.01
	NEW OAR S4	13/01/2009	2.72	<0.1	2.3	<1.0	<1.0	1.4	<0.01
	NEW CON S1	13/01/2009	2.8	<0.1	2.2	<1.0	<1.0	1.3	<0.01
	NEW CON S2	13/01/2009	3.26	<0.1	2.4	<1.0	<1.0	1.4	<0.01
	NEW CON S3	13/01/2009	2.91	<0.1	2.2	<1.0	<1.0	1.4	<0.01
	NEW CON S4	13/01/2009	2.78	<0.1	2.2	<1.0	<1.0	1.6	<0.01
SYDNEY	SYD OAR S1	21/01/2009	6.09	<0.1	6.1	1.8	10.7	14	0.06
	SYD OAR S2	21/01/2009	5.7	<0.1	5	3.7	10.2	12.1	0.04
	SYD OAR S3	21/01/2009	3.92	<0.1	5.9	<1.0	5.7	7.9	0.04
	SYD OAR S4	21/01/2009	4.67	<0.1	5.3	<1.0	6.1	8.4	0.03
	SYD CON S1	21/01/2009	2.01	<0.1	2.8	<1.0	2.3	3	0.01
	SYD CON S2	21/01/2009	2.73	<0.1	4.9	<1.0	3.7	4.8	0.03
	SYD CON S3	21/01/2009	2.64	<0.1	5.2	<1.0	5.3	6.1	0.04
	SYD CON S4	21/01/2009	2.96	<0.1	6	1.2	4.8	7	0.06
WOLLONGONG	WOL OAR S1	23/01/2009	7.4	<0.1	9.5	1.2	3.7	10.1	<0.01
	WOL OAR S2	23/01/2009	11.1	<0.1	12.6	1.4	4.8	14.1	<0.01
	WOL OAR S3	23/01/2009	6.83	<0.1	10	1.5	3.6	11	<0.01
	WOL OAR S4	23/01/2009	5.77	<0.1	8	1	2.9	8.3	<0.01
	WOL CON S1	23/01/2009	9.8	<0.1	7.9	1.2	4.5	10.6	<0.01
	WOL CON S2	23/01/2009	5.06	<0.1	7.1	1.1	4.4	11.8	<0.01
	WOL CON S3	23/01/2009	4.99	<0.1	7.3	1	4.2	11.2	<0.01
	WOL CON S4	23/01/2009	12.6	<0.1	11.2	1.5	6.1	14.7	<0.01

Table 10: Distance-based linear model (DISTLM) of the relationship between multivariate macrofauna assemblages and median grain size (mm). Macrofauna data were transformed by square root.

Marginal Tests

Variable	SS(trace)	Pseudo-F	P	Prop.
Median Grain Size	13402	7.9914	**0.0001**	0.14801

res.df: 46

Sequential Tests

Variable	R^2	SS(trace)	Pseudo-F	P	Prop.	Cumul.	res.df
Median Grain Size	0.14801	13402	7.9914	**0.0001**	0.14801	0.14801	46

Specified solution

R^2	RSS	No.Vars	Selections
0.14801	77147	1	All

Table 11: Species known or predicted to occur in the Hunter/Central Rivers CMA/NRMR (Newcastle study region) as listed under the NSW *Fisheries Management Act* (FM Act), the NSW *Threatened Species Conservation Act* (TSC Act) and the *Environment Protection and Biodiversity Conservation Act* (EPBC Act). PE = presumed extinct, CE = critically endangered, E = endangered, V = vulnerable, CD= Conservation Dependant, M = migratory, L = listed, Cet = cetacean and P = protected. Source: NSW 'Bionet' database and the EPBC Database environmental reporting tool (accessed February 2009). Note: All native birds, reptiles, amphibians and mammals in NSW are protected by the *National Parks and Wildlife Act* (NP&W Act).

Scheduled Species	Common Name	Status under *TSC/FM Act*	Status under *EPBC Act*	Species known (✓) or likely (~) to occur in the direct or wider study area
1. Marine Mammals:				
Cetaceans				
Balaenoptera acutorostrata	Dwarf minke whale	P	Cet	~
Balaenoptera musculus	Blue whale	E	Cet, E, M	
Balaenoptera bonaerensis	Antarctic minke whale	P	Cet, M	
Balaenoptera edeni	Bryde's whale	P	Cet, M	~
Caperea marginata	Pygmy right whale	P	Cet, M	~
Delphinus delphis	Common dolphin	P	Cet	✓
Dugong dugon	Dugong	E	Cet, M	✓
Eubalaena australis	Southern right whale	V	Cet, E, M	✓
Feresa attenuata	Pygmy killer whale		Cet	
Globicephala melas	Short-finned pilot whale	P	Cet	
Globicephala macrorhyncus	Long-finned pilot whale	P	Cet	
Grampus griseus	Risso's dolphin	P	Cet	~
Kogia breviceps	Pygmy sperm whale	P	Cet	
Lagenorrhycus obscurus	Dusky dolphin		Cet, M	~
Lissodelphis peronii	Southern right whale dolphin		Cet	
Mesoplodon bowdoini	Andrews beaked whale		Cet	
Megaptera novaeangliae	Humpback whale	V	Cet, V, M	✓
Mesoplodon grayi	Gray's beaked whale	P	Cet	✓
Mesoplodon layardii	Strap-toothed beaked whale	P	Cet	
Mesoplodon mirus	True's beaked whale		Cet	
Orcinus orca	Killer whale		Cet, M	~
Peponocephala electra	Melon-headed whale	P	Cet	
Pseudorca crassidens	False killer whale	P	Cet	
Physeter macrocephalus	Sperm whale	V	Cet, M	
Stenella coeruleoalba	Striped dolphin	P	Cet	
Stenella attenuata	Spotted dolphin	P	Cet	✓
Stenella longirostris	Long snouted spinner dolphin		Cet, M	
Steno bredanensis	Rough toothed dolphin	P	Cet	
Tursiops aduncus	Long-beaked bottle nosed dolphi	P	Cet, M	✓
Tursiops truncatus	Bottlenose dolphin	P	Cet	~
Ziphius cavirostris	Cuvier's beaked whale		Cet	
Pinnipeds				
Arctocephalus pusillus doriferus	Australian fur-seal	V	L	~
Arctocephalus forsteri	New Zealand fur-seal	V	L	~
Arctocephalus tropicalis	Sub-Antarctic fur seal	P		
Hydrurga leptonyx	Leopard seal	P		✓

Continued

Table 11: Continued

Scheduled Species	Common Name	Status under *TSC/FM Act*	Status under *EPBC Act*	Species known (✓) or likely (~) to occur in the direct or wider study area
Pinnipeds				
Neophoca cinerea	Australian sea lion	P		
2. Fish				
Carcharodon carcharias	Great white shark	V	V, M	✓
Carcharias taurus (East Coast)	Grey nurse shark	CE	CE	✓
Epinephelus coioides	Estuary cod	P		
Epinephelus daemelii	Black cod	V		
Epinephelus lanceolatus	Giant Queensland groper	P		
Girella cyanea	Bluefish	P		
Galeorhinus galeus	School shark		CD	~
Paraplesiops bleekeri	Bleekers devil fish	P		✓
Pristis zijsron	Green sawfish	PE		✓
Rexea solandri	Eastern gemfish		CD	
Thunnus maccoyii	Southern bluefin tuna	E		
Rhincodon typus	Whale shark		M, V	~
Pipefish (Sygnathiformes)				
Phyllopteryx taeniolatus	Weedy seadragon	P	L	✓
Acentronura tentaculata	Hairy pygmy pipehorse	P	L	~
Festucalex cinctus	Girdled pipefish	P	L	~
Filicampus tigris	Tiger pipefish	P	L	~
Heraldia nocturna	Upside-down pipefish	P	L	~
Hippichthys heptagonus	Madura pipefish	P	L	
Hippichthys penicillus	Beady pipefish	P	L	~
Hippocampus abdominalis	Eastern potbelly seahorse	P	L	~
Hippocampus whitei	White's seahorse	P	L	~
Histiogamphelus briggsii	Briggs' crested pipefish	P	L	~
Lissocampus runa	Javelin pipefish	P	L	~
Maroubra perserrata	Sawtooth pipefish	P	L	~
Notiocampus ruber	Red pipefish	P	L	~
Solegnathus dunckeri	Duncker's pipehorse	P	L	
Solegnathus spinosissimus	Spiny pipehorse	P	L	~
Solenostomus cyanopterus	Blue-finned ghost pipefish	P	L	~
Solenostomus paradoxus	Harlequin Ghost pipefish	P	L	~
Stigmatopora argus	Spotted pipefish	P	L	~
Stigmatopora nigra	Wide-bodied pipefish	P	L	~
Syngnathoides biaculeatus	Double-ended pipehorse	P	L	~
Trachyrhamphus bicoarctatus	Short-tailed pipefish	P	L	~
Urocampus carinirostris	Hairy pipefish	P	L	~
Vanacampus margaritifer	Mother-of-pearl pipefish	P	L	~

Continued

Table 11: Continued

Scheduled Species	Common Name	Status under *TSC/FM Act*	Status under *EPBC Act*	Species known (✓) or likely (~) to occur in the direct or wider study area
3. Marine Reptiles				
Marine Turtles				
Caretta caretta	Loggerhead turtle	E	E,M	✓
Chelonia mydas	Green Turtle	V		✓
Eretmochelys imbricata	Hawksbill turtle	P		✓
Dermochelys coriacea	Leatherback turtle	V	E, M	~
Natator depressus	Flatback turtle	P	V, M	✓
Seasnakes				
Hydrophis elegans	Elegant seasnake		L	
Pelamis platurus	Yellow-bellied seasnake		L	
4. Seabirds				
Apus pacificus	Fork-tailed swift	P		~
Calonectris leucomelas	Streaked shearwater	P	M	~
Catharacta skua	Great skua		L	~
Chlidonias hybridus	Whiskered tern	P		~
Chlidonias leucopterus	White-winged black tern	P		~
Diomedea exulans	Wandering albatross	E	V, M	~
Diomedea exulans amsterdamensis	Amsterdam albatross		E, M	~
Diomedea exulans antipodensis	Antipodean albatross	V	V, M	~
Diomedea exulans exulans	Tristan albatross		E, M	~
Diomedea exulans gibsoni	Gibsons albatross	V	V, M	~
Fregata ariel	Lesser frigatebird	P		~
Fregetta grallaria grallaria	White-bellied storm-petrel	V	V	~
Gygis alba	White tern	V		~
Haematopus fuliginosus	Sooty oystercatcher	V		✓
Haematopus longirostris	Pied oystercatcher	V		~
Haliaeetus leucogaster	White-bellied sea-eagle	P	M	~
Larus dominicanus	Kelp gull	P		✓
Larus novaehollandiae	Silver gull	P	L	✓
Macronectes giganteus	Southern giant petrel	E	E, M	~
Macronectes halli	Northern giant petrel	V	V, M	~
Morus serrator	Australasian gannet	P		~
Pachyptila turtur	Fairy prion	P	V, M	~
Pelecanus conspicillatus	Australian pelican	P		✓
Pelagodroma marina	White-faced storm petrel		L	~
Phalacrocorax carbo	Great cormorant	P		~
Phalacrocorax melanoleucos	Little pied cormorant	P		~
Phalacrocorax sulcirostris	Little black cormorant	P		~
Phalacrocorax varius	Pied cormorant	P		~
Phoebtria fusca	Sooty albatross	V	V,M	~
Pterodroma externa	Juan fernandez petrel	P		~
Pterodroma leucoptera leucoptera	Gould's petrel	E	E, M	~
Pterodroma neglecta neglecta	Kermadec petrel	V	V	~
Pterodroma nigripennis	Black-winged petrel	V		~

Continued

Table 11: Continued

Scheduled Species	Common Name	Status under *TSC/FM Act*	Status under *EPBC Act*	Species known (✓) or likely (~) to occur in the direct or wider study area
4. Seabirds				
Pterodroma solandri	Providence petrel	V		~
Puffinus assimilis	Little shearwater	V		~
Puffinus carneipes	Flesh-footed shearwater	V		~
Puffinus gavia	Fluttering shearwater	P		~
Puffinus griseus	Sooty shearwater	P	M	~
Puffinus pacificus	Wedge-tailed shearwater	P	M	✓
Puffinus tenuirostris	Short-tailed shearwater	P	M	~
Sterna albifrons	Little tern	E	M	~
Stercorarius parasiticus	Arctic jaeger	P		~
Stercorarius pomarinus	Pomarine jaeger	P		~
Sterna bergii	Crested tern	P	L	~
Sterna caspia	Caspian tern	P		~
Sterna fuscata	Sooty tern	V		~
Sterna hirundo	Common tern	P		~
Sterna nilotica	Gull-billed tern	P		~
Sterna paradisaea	Arctic tern	P		~
Sterna striata	White-fronted tern	P		~
Sula dactylatra	Masked booby	V		~
Thalassarche cauta	Shy albatross	V	V, M	~
Thalassarche chlororhynchos	Yellow-nosed albatross	P	M	~
Thalassarche chrysostoma	Grey-headed albatross	P		~
Thalassarche melanophris	Black-browed albatross	V	V, M	~
Thalassarche bulleri	Bullers albatross		V, M	~
Thalassarche cauta salvini	Salvins albatross		V, M	~
Thalassarche cauta steadi	White-capped albatross		V, M	~
Thalassarche cauta eremita	Chatham albatross		E, M	~
Thalassarche melanophris impavida	Campbell albatross		V, M	~

Table 12: Species known or predicted to occur in the Sydney Metro CMA/NRMR (Sydney study region) as listed under the NSW *Fisheries Management Act* (FM Act), the NSW *Threatened Species Conservation Act* (TSC Act) and the *Environment Protection and Biodiversity Conservation Act* (EPBC Act). PE = presumed extinct, CE = critically endangered, E = endangered, V = vulnerable, CD= Conservation Dependant, M = migratory, L = listed, Cet = cetacean and P = protected. Source NSW 'Bionet' database and the EPBC Database environmental reporting tool (accessed February 2009). Note: All native birds, reptiles, amphibians and mammals in NSW are protected by the *National Parks and Wildlife Act* (NP&W Act).

Scheduled Species	Common Name	Status under *TSC/FM Act*	Status under *EPBC Act*	Species known (✓) or likely (~) to occur in the direct or wider study area
1. Marine Mammals:				
Cetaceans				
Balaenoptera acutorostrata	Dwarf minke whale	P	Cet	✓
Balaenoptera musculus	Blue whale	E	Cet, E, M	~
Balaenoptera bonaerensis	Antarctic minke whale	P	Cet, M	~
Balaenoptera edeni	Bryde’s whale	P	Cet, M	~
Berardius arnuxii	Arnoux's beaked whale		Cet	~
Caperea marginata	Pygmy right whale	P	Cet, M	~
Delphinus delphis	Common dolphin	P	Cet	✓
Dugong dugon	Dugong	E	Cet, M	✓
Eubalaena australis	Southern right whale	V	Cet, E, M	✓
Grampus griseus	Risso's dolphin	P	Cet	✓
Kogia breviceps	Pygmy sperm whale	P	Cet	✓
Kogia simus	Dwarf sperm whale	P	Cet	✓
Lagenorrhycus obscurus	Dusky dolphin		Cet, M	~
Lobodon carcinophagus	Crab-eater seal	P		✓
Megaptera novaeangliae	Humpback whale	V	Cet, V, M	✓
Mesoplodon layardii	Strap-toothed beaked whale	P	Cet	~
Mirounga leonina	Southern elephant seal	P		✓
Orcinus orca	Killer whale		Cet, M	✓
Pseudorca crassidens	False killer whale	P	Cet	✓
Physeter macrocephalus	Sperm whale	V	Cet, M	✓
Stenella coeruleoalba	Striped dolphin	P	Cet	✓
Stenella attenuata	Spotted dolphin	P	Cet	✓
Tursiops truncatus	Bottlenose dolphin	P	Cet	✓
Pinnipeds				
Arctocephalus pusillus doriferus	Australian fur-seal	V	L	✓
Arctocephalus forsteri	New Zealand fur-seal	V	L	✓
Arctocephalus tropicalis	Sub-Antarctic fur seal	P		✓
Hydrurga leptonyx	Leopard seal	P		✓
Neophoca cinerea	Australian sea lion	P		✓
2. Fish				
Anampses elegans	Elegant wrasse	P		✓
Carcharodon carcharias	Great white shark	V	V, M	✓
Carcharias taurus (East Coast)	Grey nurse shark	CE	CE	✓
Epinephelus daemelii	Black cod	V		✓

Continued

Table 12: Continued

Scheduled Species	Common Name	Status under *TSC/FM Act*	Status under *EPBC Act*	Species known (✓) or likely (~) to occur in the direct or wider study area
2. Fish				
Galeorhinus galeus	School shark		CD	~
Girella cyanea	Bluefish	P		~
Hoplostethus atlanticus	Orange roughy		CD	~
Paraplesiops bleekeri	Bleekers devil fish	P		✓
Pristis zijsron	Green sawfish	PE		✓
Rexea solandri	Eastern gemfish		CD	~
Thunnus maccoyii	Southern bluefin tuna	E		~
Rhincodon typus	Whale shark		M, V	~
Pipefish (Sygnathiformes)				
Phyllopteryx taeniolatus	Weedy seadragon	P	L	~
Acentronura tentaculata	Hairy pygmy pipehorse	P	L	~
Festucalex cinctus	Girdled pipefish	P	L	~
Filicampus tigris	Tiger pipefish	P	L	~
Heraldia nocturna	Upside-down pipefish	P	L	~
Hippichthys penicillus	Beady pipefish	P	L	~
Hippocampus abdominalis	Eastern potbelly seahorse	P	L	~
Hippocampus whitei	White's seahorse	P	L	~
Histiogamphelus briggsii	Briggs' crested pipefish	P	L	~
Lissocampus runa	Javelin pipefish	P	L	~
Maroubra perserrata	Sawtooth pipefish	P	L	~
Notiocampus ruber	Red pipefish	P	L	~
Solegnathus spinosissimus	Spiny pipehorse	P	L	~
Solenostomus cyanopterus	Blue-finned ghost pipefish	P	L	~
Solenostomus paradoxus	Harlequin Ghost pipefish	P	L	~
Stigmatopora argus	Spotted pipefish	P	L	~
Stigmatopora nigra	Wide-bodied pipefish	P	L	~
Syngnathoides biaculeatus	Double-ended pipehorse	P	L	~
Trachyrhamphus bicoarctatus	Short-tailed pipefish	P	L	~
Urocampus carinirostris	Hairy pipefish	P	L	~
Vanacampus margaritifer	Mother-of-pearl pipefish	P	L	~
3. Marine Reptiles				
Caretta caretta	Loggerhead turtle	E	E, M	✓
Chelonia mydas	Green turtle	V	M, V	✓
Dermochelys coriacea	Leatherback turtle	V	E, M	✓
Seasnakes				
Pelamis platurus	Yellow-bellied seasnake		L	✓
Hydrophis elegans	Elegant seasnake		L	✓

Continued

Table 12: Continued

Scheduled Species	Common Name	Status under *TSC/FM Act*	Status under *EPBC Act*	Species known (✓) or likely (~) to occur in the direct or wider study area
4. Seabirds				
Eudypula minor	Little penguin	Endangered Population	L	✓
Anous minutus	Black noddy		L	~
Anous stolidus	Common noddy		M	~
Apus pacificus	Fork-tailed swift	P		~
Calonectris leucomelas	Streaked shearwater	P	M	~
Catharacta skua	Great skua		L	~
Chlidonias hybridus	Whiskered tern	P		~
Chlidonias leucopterus	White-winged black tern	P		~
Daption capense	Cape petrel	P		~
Diomedea exulans	Wandering albatross	E	V, M	~
Diomedea exulans amsterdamensis	Amsterdam albatross		E, M	~
Diomedea exulans antipodensis	Antipodean albatross	V	V, M	~
Diomedea exulans exulans	Tristan albatross		E, M	~
Diomedea gibsoni	Gibsons albatross	V	V,M	✓
Fregata ariel	Lesser frigatebird	P		~
Fregatta grallaria grallaria	White-bellied storm-petrel	V	V, M	~
Fulmarus glacialoides	Southern fulmar	P		~
Garrodia nereis	Grey-backed storm-petrel	P		~
Gygis alba	White tern	V		~
Haematopus fuliginosus	Sooty oystercatcher	V		~
Haematopus longirostris	Pied oystercatcher	V		~
Haliaeetus leucogaster	White-bellied sea-eagle	P	M	~
Larus dominicanus	Kelp gull	P		~
Larus novaehollandiae	Silver gull	P		~
Larus pacificus	Pacific gull	P		~
Larus pipixcan	Franklin's gull	P		~
Macronectes giganteus	Southern giant petrel	E	E, M	~
Macronectes halli	Northern giant petrel	V	V, M	~
Morus serrator	Australasian gannet	P		~
Pachyptila belcheri	Slender-billed prion	P		~
Pachyptila desolata	Antarctic prion	P		~
Pachyptila turtur	Fairy prion	P	V, M	~
Pelagodroma marina	White-faced storm-petrel	P		~
Pelecanoides urinatrix	Common diving-petrel	P		~
Pelecanus conspicillatus	Australian pelican	P		✓
Phalacrocorax carbo	Great cormorant	P		~
Phalacrocorax melanoleucos	Little pied cormorant	P		~
Phalacrocorax sulcirostris	Little black cormorant	P		~

continued

Table 12: Continued

Scheduled Species	Common Name	Status under *TSC/FM Act*	Status under *EPBC Act*	Species known (✓) or likely (~) to occur in the direct or wider study area
4. Seabirds				
Phalacrocorax varius	Pied cormorant	P		~
Phoebetria fusca	Sooty albatross	V	V,M	✓
Procelsterna cerulea	Grey ternlet	V		~
Pseudobulweria rostrata	Tahiti petrel	P		~
Pterodroma inexpecta	Mottled petrel	P		~
Pterodroma lessonii	White-headed petrel	P		~
Pterodroma leucoptera leucoptera	Gould's petrel	E	E, M	✓
Pterodroma macroptera	Great-winged petrel	P		~
Pterodroma mollis	Soft-plumaged petrel	P		~
Pterodroma neglecta neglecta	Kermadec petrel	V	V	✓
Pterodroma nigripennis	Black-winged petrel	V		✓
Pterodroma solandri	Providence petrel	V		✓
Puffinus assimilis	Little shearwater	V		✓
Puffinus carneipes	Flesh-footed shearwater	V		✓
Puffinus gavia	Fluttering shearwater	P		~
Puffinus griseus	Sooty shearwater	P	M	~
Puffinus huttoni	Hutton's shearwater	P		~
Stercorarius longicaudus	Long-tailed jaeger	P		~
Stercorarius parasiticus	Arctic jaeger	P		~
Stercorarius pomarinus	Pomarine jaeger	P		~
Sterna albifrons	Little tern	E	M	✓
Sterna bergii	Crested tern	P	L	~
Sterna caspia	Caspian tern	P		✓
Sterna fuscata	Sooty tern	V		~
Sterna hirundo	Common tern	P		~
Sterna nereis	Fairy tern	P		~
Sterna nilotica	Gull-billed tern	P		~
Sterna paradisaea	Arctic tern	P		~
Sterna striata	White-fronted tern	P		~
Sula leucogaster	Brown booby	P		~
Thalassarche bulleri	Bullers albatross		V, M	~
Thalassarche cauta	Shy albatross	V	V, M	✓
Thalassarche cauta eremita	Chatham albatross		E, M	~
Thalassarche cauta salvini	Salvins albatross		V, M	~
Thalassarche cauta steadi	White-capped albatross		V, M	~
Thalassarche chlororhynchos	Yellow-nosed albatross	P	M	~
Thalassarche chrysostoma	Grey-headed albatross	P		~
Thalassarche melanophris	Black-browed albatross	V	V, M	✓
Thalassarche melanophris impavida	Campbell albatross		V, M	~

Table 13: Species known or predicted to occur in the Southern Rivers (Wollongong study region) as listed under the NSW *Fisheries Management Act* (*FM Act*), the NSW *Threatened Species Conservation Act* (*TSC Act*) and the *Environment Protection and Biodiversity Conservation Act* (*EPBC Act*). PE = presumed extinct, CE = critically endangered, E = endangered, V = vulnerable, CD= Conservation Dependant, M = migratory, L = listed, Cet = cetacean and P = protected. Source: NSW 'Bionet' database and the EPBC Database environmental reporting tool (accessed February 2009). Note: All native birds, reptiles, amphibians and mammals in NSW are protected by the National Parks and Wildlife Act (NP&W Act).

Scheduled Species	Common Name	Status under *TSC/FM Act*	Status under *EPBC Act*	Species known (✓) or likely (~) to occur in the direct or wider study area
1. Marine Mammals				
Cetaceans				
Balaenoptera acutorostrata	Dwarf minke whale	P	Cet	✓
Balaenoptera musculus	Blue whale	E	Cet, E, M	✓
Balaenoptera bonaerensis	Antarctic minke whale	P	Cet, M	
Balaenoptera edeni	Bryde’s whale	P	Cet, M	✓
Berardius arnuxii	Arnoux's beaked whale		Cet	
Caperea marginata	Pygmy right whale	P	Cet, M	~
Delphinus delphis	Common dolphin	P	Cet	✓
Dugong dugon	Dugong	E	Cet, M	✓
Eubalaena australis	Southern right whale	V	Cet, E, M	✓
Globicephala melas	Short-finned pilot whale	P	Cet	✓
Globicephala macrorhyncus	Long-finned pilot whale	P	Cet	
Grampus griseus	Risso's dolphin	P	Cet	~
Hyperooodon planifrons	Southern bottlenose whale	P	Cet	
Kogia breviceps	Pygmy sperm whale	P	Cet	✓
Kogia simus	Dwarf sperm whale	P	Cet	
Lagenorrhycus obscurus	Dusky dolphin		Cet, M	~
Lissodelphis peronii	Southern right whale dolphin		Cet	
Megaptera novaeangliae	Humpback whale	V	Cet, V, M	✓
Mesoplodon bowdoini	Andrews beaked whale		Cet	✓
Mesoplodan densirostris	Blainvilles beaked whale	P	Cet	✓
Mesoplodon gingodens	Ginko-toothed whale	P	Cet	
Mesoplodon grayi	Gray's beaked whale	P	Cet	✓
Mesoplodon hectori	Hectors beaked whale		Cet	
Mesoplodon layardii	Strap-toothed beaked whale	P	Cet	✓
Mesoplodon mirus	True's beaked whale		Cet	
Orcinus orca	Killer whale		Cet, M	~
Pseudorca crassidens	False killer whale	P	Cet	✓
Physeter macrocephalus	Sperm whale	V	Cet, M	✓
Stenella attenuata	Spotted dolphin	P	Cet	✓
Stenella coeruleoalba	Striped dolphin	P	Cet	✓
Steno bredanensis	Rough toothed dolphin	P	Cet	✓
Tursiops aduncus	Long-beaked bottle nosed dolphin	P	Cet, M	~
Tursiops truncatus	Bottlenose dolphin	P	Cet	✓
Ziphius cavirostris	Cuvier's beaked whale		Cet	

Continued

Table 13: Continued

Scheduled Species	Common Name	Status under *TSC/FM Act*	Status under *EPBC Act*	Species known (✓) or likely (~) to occur in the direct or wider study area
Pinnipeds				
Arctocephalus pusillus doriferus	Australian fur-seal	V	L	✓
Arctocephalus forsteri	New Zealand fur-seal	V	L	✓
Arctocephalus tropicalis	Sub-Antarctic fur seal	P		✓
Hydrurga leptonyx	Leopard seal	P		✓
2. Fish				
Carcharodon carcharias	Great white shark	V	V, M	~
Carcharias taurus (East Coast)	Grey nurse shark	CE	CE	~
Epinephelus coioides	Estuary cod	P		
Epinephelus daemelii	Black cod	V		
Epinephelus lanceolatus	Giant Queensland groper	P		✓
Galeorhinus galeus	School shark		CD	~
Girella cyanea	Bluefish	P		
Hoplostethus atlanticus	Orange roughy		CD	
Paraplesiops bleekeri	Bleekers devil fish	P		✓
Pristis zijsron	Green sawfish	PE		~
Rexea solandri	Eastern gemfish		CD	
Thunnus maccoyii	Southern bluefin tuna	E		
Rhincodon typus	Whale shark		M, V	~
Pipefish (Sygnathiformes)				
Phyllopteryx taeniolatus	Weedy seadragon	P	L	✓
Acentronura tentaculata	Hairy pygmy pipehorse	P	L	~
Cosmocampus howensis	Lord Howe pipefish	P	L	
Festucalex cinctus	Girdled pipefish	P	L	~
Filicampus tigris	Tiger pipefish	P	L	~
Heraldia nocturna	Upside-down pipefish	P	L	~
Hippichthys penicillus	Beady pipefish	P	L	~
Hippocampus abdominalis	Eastern potbelly seahorse	P	L	~
Hippocampus breviceps	Short-head seahorse	P	L	
Hippocampus minotaur	Bullneck seahorse	P	L	
Hippocampus whitei	White's seahorse	P	L	~
Histiogamphelus briggsii	Briggs' crested pipefish	P	L	~
Histiogamphelus cristatus	Rhino pipefish	P	L	
Hypselognathus rostratus	Knife-snouted pipefish	P	L	
Kaupus costatus	Deep-bodied pipefish	P	L	
Kimblaeus bassensis	Trawl pipefish	P	L	
Leptoichthys fistularius	Brushtail pipefish	P	L	
Lissocampus runa	Javelin pipefish	P	L	~
Maroubra perserrata	Sawtooth pipefish	P	L	~
Mitotichthys semistriatus	Half-banded pipefish	P	L	
Mitotichthys tuckeri	Tucker's pipefish	P	L	
Notiocampus ruber	Red pipefish	P	L	~
Solegnathus robustus	Robust spiny pipehorse	P	L	

Continued

Table 13: Continued

Scheduled Species	Common Name	Status under *TSC/FM Act*	Status under *EPBC Act*	Species known (✓) or likely (~) to occur in the direct or wider study area
2. Fish				
Solegnathus spinosissimus	Spiny pipehorse	P	L	~
Solenostomus cyanopterus	Blue-finned ghost pipefish	P	L	~
Solenostomus paradoxus	Harlequin Ghost pipefish	P	L	~
Stigmatopora argus	Spotted pipefish	P	L	~
Stigmatopora nigra	Wide-bodied pipefish	P	L	~
Stipecampus cristatus	Ring-backed pipefish	P	L	
Syngnathoides biaculeatus	Double-ended pipehorse	P	L	~
Trachyrhamphus bicoarctatus	Short-tailed pipefish	P	L	~
Urocampus carinirostris	Hairy pipefish	P	L	~
Vanacampus margaritifer	Mother-of-pearl pipefish	P	L	~
Vanacampus phillipi	Port Phillip pipefish	P	L	
Vanacampus poecilolaemus	Long-snouted pipefish	P	L	
3. Marine Reptiles				
Marine Turtles				
Chelonia mydas	Green turtle	V	M, V	~
Eretmochelys imbricata	Hawksbill turtle	P		✓
Natator depressus	Flatback turtle	P	V, M	
Dermochelys coriacea	Leatherback turtle	V	E, M	~
4. Seabirds				
Eudypula minor	Little penguin	Endangered Population	L	✓
Apus pacificus	Fork-tailed swift	P		~
Calonectris leucomelas	Streaked shearwater	P	M	~
Chlidonias hybridus	Whiskered tern	P		~
Chlidonias leucopterus	White-winged black tern	P		~
Daption capense	Cape petrel	P		~
Diomedea epomophora	Southern royal albatross		V, M	~
Diomedea epomophora sanfordi	Northern royal albatross		E, M	~
Diomedea exulans	Wandering albatross	E	V, M	~
Diomedea exulans amsterdamensis	Amsterdam albatross		E, M	~
Diomedea exulans antipodensis	Antipodean albatross	V	V, M	~
Diomedea exulans exulans	Tristan albatross		E, M	~
Diomedea exulans gibsoni	Gibsons albatross	V	V, M	~
Eudyptes pachyrynchus	Fjordland penguin	P		~
Fregata ariel	Lesser frigatebird	P		~
Fregatta grallaria grallaria	White-bellied storm-petrel	V	V	✓
Fregetta tropica	Black bellied storm petrel	P		~
Fulmarus glacialoides	Southern fulmar	P		~
Gygis alba	White tern	V		~
Haematopus fuliginosus	Sooty oystercatcher	V		✓
Haematopus longirostris	Pied oystercatcher	V		~
Haliaeetus leucogaster	White-bellied sea-eagle	P	M	✓
Halobaena caerulea	Blue petrel		V	~

Continued

Table 13: Continued

Scheduled Species	Common Name	Status under *TSC/FM Act*	Status under *EPBC Act*	Species known (✓) or likely (~) to occur in the direct or wider study area
4. Seabirds				
Larus dominicanus	Kelp gull	P		✓
Larus novaehollandiae	Silver gull	P		✓
Larus pacificus	Pacific gull	P		~
Macronectes giganteus	Southern giant petrel	E	E, M	~
Macronectes halli	Northern giant petrel	V	V, M	~
Pachyptila belcheri	Slender-billed prion	P		~
Pachyptila desolata	Antarctic prion	P		~
Pachyptila turtur	Fairy prion	P	V, M	~
Pelagodroma marina	White-faced storm-petrel	P		✓
Pelecanoides urinatrix	Common diving-petrel	P		~
Pelecanus conspicillatus	Australian pelican	P		✓
Phalacrocorax carbo	Great cormorant	P		~
Phalacrocorax fuscesans	Black-faced cormorant	P		~
Phalacrocorax melanoleucos	Little pied cormorant	P		~
Phalacrocorax sulcirostris	Little black cormorant	P		~
Phalacrocorax varius	Pied cormorant	P		~
Phoebetria fusca	Sooty albatross	V		~
Procellaria aequinoctialis	White chinned petrel	P		~
Procellaria parkinsoni	Black petrel	P		~
Pterodroma inexpecta	Mottled petrel	P		~
Pterodroma lessonii	White-headed petrel	P		~
Pterodroma leucoptera leucoptera	Gould's petrel	E	E, M	~
Pterodroma macroptera	Great-winged petrel	P		~
Pterodroma neglecta neglecta	Kermadec petrel	V	V	~
Pterodroma nigripennis	Black-winged petrel	V		~
Pterodroma solandri	Providence petrel	V		~
Puffinus assimilis	Little shearwater	V		~
Puffinus carneipes	Flesh-footed shearwater	V		~
Puffinus gavia	Fluttering shearwater	P		~
Puffinus griseus	Sooty shearwater	P	M	~
Puffinus huttoni	Hutton's shearwater	P		~
Puffinus pacificus	Wedge-tailed shearwater	P	M	✓
Puffinus tenuirostris	Short-tailed shearwater	P	M	✓
Sterna albifrons	Little tern	E	M	~
Sterna bergii	Crested tern	P	L	✓
Sterna caspia	Caspian tern	P		~
Sterna fuscata	Sooty tern	V		~
Sterna hirundo	Common tern	P		~
Sterna nereis	Fairy tern	P		~
Sterna nilotica	Gull-billed tern	P		~
Sterna paradisaea	Arctic tern	P		~
Sterna striata	White-fronted tern	P		~
Thalassarche cauta cauta	Shy albatross	V	V, M	~
Thalassarche cauta eremita	Chatham albatross		E, M	~
Thalassarche cauta salvini	Salvins albatross		V, M	~

Continued

Table 13: Continued

Scheduled Species	Common Name	Status under *TSC/FM Act*	Status under *EPBC Act*	Species known (✓) or likely (~) to occur in the direct or wider study area
4. Seabirds				
Thalassarche cauta steadi	White-capped albatross		V, M	~
Thalassarche chlororhynchos	Yellow-nosed albatross	P	M	~
Thalassarche chrysostoma	Grey-headed albatross	P		~
Thalassarche melanophris	Black-browed albatross	V	V, M	~
Thalassarche melanophris impavida	Campbell albatross		V, M	~

Table 14: Risk analysis matrix. L = Likelihood of risk occurring, C = Consequence of risk occurring. See Appendix 6. for methods and rational for the risk assessment criteria.

High significance = (orange)
Moderate significance = (yellow)
Low significance = (green)

Receptor	Hazard/Negative Impact	Study Area Direct L	Direct C	Wider L	Wider C
1. Soft sediment areas					
	Sediment disturbance from unit emplacement (e.g.	A	4	A	4
	Direct loss of habitat	A	4	E	4
	Change to sedimentary characteristics	A	4	B	4
	Sediment contamination	B	3	E	4
	Changes to benthic assemblages	A	4	C	4
	Increased predation by fishes from the OAR on benthos	A	4	C	4
	Commercial trawling in areas not previously trawled	B	5	E	4
2. Proximal natural reef					
	Changes to benthic assemblages	C	3	B	3
	Change to fish assemblages	B	3	D	3
3. Pelagic environment					
Plankton	Concentration of Plankton	B	5	E	5
Fish	Loss of habitat (benthic species)	A	5	E	5
	Attraction/aggregation	A	4	B	4
	Increased fishing effort	B	4	C	4
	Increased mortality (from aggregation)	A	3	B	3
	Capture of undersized fish	C	4	C	4
	Contamination/pollution	C	3	E	3
4. Threatened and protected species					
Fish	Incidental capture	B	2	C	2
	Aggregation of threatened or protected species	B	2	C	2
	Harm from marine debris and pollution (KTPs)	C	2	C	2
	Interruption of movement corridors (e.g. GNS)	D	3	D	3
	Increased predation	C	4	D	4
	Loss of habitat	A	5	E	5
	Introduction of pest species	D	3	D	3
Marine Turtles	Harm from marine debris and pollution (KTPs)	C	2	C	2
	Incidental capture	C	2	C	2
	Boat strike	C	2	C	2
	Acoustic disturbance	C	5	E	5
	Interruption of movement corridors	D	3	D	3
	Loss of habitat	D	4	E	4
	Introduction of pest species	E	2	E	2
Cetaceans	Harm from marine debris and pollution (KTPs)	C	2	C	2
	Incidental capture	C	2	C	2
	Boat strike	C	2	C	2
	Acoustic disturbance	B	4	B	4
	Interruption of movement corridors	C	4	C	4
	Loss of habitat	E	2	E	2
	Introduction of pest species	E	2	E	2

Continued

Table 14: Continued

Pinnipeds and Sirenians	Harm from marine debris and pollution (KTPs)	C	2	C	2
	Incidental capture	D	2	D	2
	Boat strike (sirenians only)	D	2	D	2
	Acoustic disturbance	D	4	E	4
	Interruption of movement corridors	E	2	E	2
	Loss of habitat	E	2	E	2
	Introduction of pest species	E	2	E	2
Seabirds	Harm from marine debris and pollution (KTPs)	C	2	C	2
	Incidental capture	C	2	C	2
5. Invasive Marine Pests					
	Introduction of invasive marine pests	C	4	E	3
6. Areas of Conservation Significance					
	Impacts on Nature Reserves	C	2	C	2
	Impacts on Aquatic Reserves	E	2	E	2
	Impacts on Critical Habitats	E	2	E	2
7. Recreational and Commercial fishing					
General	Loss of commercial fishing ground	A	4	N/A	N/A
	Conflict between user groups	A	4	A	4
	Risk OAR does not achieve goals	D	3	D	3
Safety	Gear hook-up	A	4	N/A	N/A
	Collision from crowding	C	3	E	3
	Increased encounters with dangerous marine animals	C	5	E	5
	Drowning (spear fishing)	C	1	N/A	N/A
	Impacts on commercial fish stocks	D	3	D	3

Table 15: Attributes used to provide an index of the productivity and susceptibility of target recreational and commercial species. Methodology for the PSA sourced from Hobday *et al*. 2004.

1. Productivity attributes

			Productivity Ranking		
Productivity attribute	Rationale for attribute	Action in the case of multiple values	High (1)	Moderate (2)	Low (3)
Age at maturity	Later maturing species tend to have lower natural mortality, they are threrefore less productive and tend to show a greater decrease in abundance with fishing.	Average of male, female and no-gender minimum age at maturity.	< 3 yrs	3 yrs - 4 yrs	> 4
Approx. lifespan	Longer lived species tend to be slow growing, later maturing and have lower natural mortality, they are therefore less productive and tend to show a greater decrease in abundance with fishing.	Average of male, female and no-gender maximum longevity.	< 10 yrs	10 yrs - 20 yrs	> 20 yrs
Fecundity (estimated as geometric mean)	Species with fewer offspring are less productive.	N/a	> 500, 000	200 - 500,000 or unknown for broadcast spawners	< 200
Max size (L_{max})	Larger species tend to be slow growing and have lower natural mortality, they are therefore less productive and tend to show a greater decrease in abundance with fishing.	Average of male, female and no-gender upper limit of maximum size.	< 50 cm	50 cm - 99 cm	100 cm and greater
Length at maturity (L_m)	Late maturing species tend to be slow growing and have lower natural mortality, they are therefore less productive and tend to show a greater decrease in abundance with fishing.	Average of male, female and no-gender upper limit of maximum size.	< 25 cm	25 - 45 cm	> 45 cm
Reproductive strategy	Species with fewer offspring are considered less productive.	N/a	Broadcast spawner	Demersal spawner, brood or guard young	Live bearer

Continued

Table 15: Continued

2. Susceptibility attributes

		Susceptibility Ranking		
Susceptibility attribute	Rationale for attribute	Low (1)	Moderate (2)	High (3)
Target Group	Target group indicates the relative likelihood of surviving capture. Target species ar retained, thus non-target species are likely to be returned to the water. Recreationally targeted species will be most vulnerable. Species targeted only by commercial fishing are considered less vulnerable.	Commercially targeted species	Recreationally targeted species	Recreationally and commercially targeted species
Habitat Preference	Species prefering reef habitat are more likely to aggregate at the OARs and therefore be more vulnerable to fishing.	Sand	Reef and/or sand	On or near reef
Site fidelity	Existing populations of transient or transient/territorial species are likely to be more susceptible than territorial reef species.	Territorial	Transient	Both
Exploitation Status	Species that are 'overfished' are more vulnerable to overexploitation. (The exploitation status of species is taken from the Status of Fisheries Resources in NSW, 2006/2007).	Lightly - moderately fished	Fully fished	Recruitment overfished, overfished, growth overfished or status uncertain/undefined
Depth Range	Species with a narrow depth range are more likely to occur on the OARs than species with a broad depth range.	Outside 20 m - 40 m OAR range	Broad depth range 0 m - 500 m	Narrow depth range 0 m - 100 m

Table 16: Ranking of species with respect to criteria that reflect their susceptibility to fishing and productivity.

1. Productivity Attributes

ID	Family	Common Name	Scientific Name	Age at maturity	Length at maturity (Lmat)	Approx. lifespan	Fecundity	Reproductive strategy	Ave. Productivity
1	Rhinobatidae	Shovelnose ray*	*Aptychotrema rostrata*	1	3	2	3	3	**2.4**
2	Rhinobatidae	Fiddler ray*♦	*Trygonorrhina fasciata*	1	3	2	3	3	**2.4**
3	Orectolobidae	Spotted wobbegong♥	*Orectolobus maculatus*	3	3	3	3	3	**3.0**
4	Orectolobidae	Banded wobbegong♥	*Orectolobus halei*	3	3	3	3	3	**3.0**
5	Orectolobidae	Ornate wobbegong♥	*Orectolobus ornatus*	3	3	3	3	3	**3.0**
6	Clupeidae	Herrings, sardines, pilchards*♦	*Clupeidae*	2	1	1	2	1	**1.4**
7	Muraenidae	Moray eel♥	*Gymnothorax prasinus*	3	3	3	2	1	**2.4**
8	Aulopidae	Sargeant baker♥	*Aulopus purpurissatus*	3	2	3	2	1	**2.2**
9	Berycidae	Nannygai †	*Centroberyx affinis*	3	2	3	2	1	**2.2**
10	Zeidae	John dory♥	*Zeus faber*	2	2	2	2	1	**1.8**
11	Scorpaenidae	Red rock cod♥	*Scorpaena cardinalis*	3	1	2	2	1	**1.8**
12	Platycephalidae	Eastern blue-spotted flathead*†	*Platycephalus caeruleopunctatus*	2	2	2	1	1	**1.6**
13	Platycephalidae	Long-spine flathead*†	*Platycephalus longispinus*	1	1	1	1	1	**1.0**
14	Platycephalidae	Dusky flathead♦	*Platycephalus fuscus*	1	3	2	1	1	**1.6**
15	Platycephalidae	Tiger flathead♦	*Platycephalus richardsoni*	1	2	1	1	1	**1.2**
16	Dinolestidae	long-fin pike♥	*Dinolestes lewini*	3	3	3	2	1	**2.4**
17	Sillaginidae	School whiting♦	*Sillago bassensis*	1	1	2	2	1	**1.4**
18	Pomatomidae	Tailor †	*Pomatomus saltatrix*	2	3	2	1	1	**1.8**
19	Rachycentridae	Cobia♥	*Rachycentron canadum*	1	3	2	2	1	**1.8**
20	Carangidae	Silver trevally*♦	*Pseudocaranx dentex*	3	2	3	2	1	**2.2**
21	Carangidae	Yellow-tail scad*♦	*Trachurus novaezelandiae*	2	1	3	2	1	**1.8**
22	Carangidae	Kingfish †♦	*Seriola lalandi*	3	3	3	1	1	**2.2**
23	Coryphaenidae	Common dolphinfish♥	*Corypheana hippurus*	1	3	1	2	1	**1.6**
24	Arripidae	Australian salmon♦	*Arripis trutta*	2	2	1	2	1	**1.6**
25	Sparidae	Snapper*♦	*Pagrus auratus*	3	3	3	1	1	**2.2**

Continued

Table 16: Continued

ID	Family	Common Name	Scientific Name	Age at maturity	Length at maturity (Lmat)	Approx. lifespan	Fecundity	Reproductive strategy	Ave. Productivity
26	Sparidae	Tarwhine♦	*Rhabdosargus sarba*	3	1	3	2	1	**2.0**
27	Sparidae	Yellow-fin bream †♦	*Acanthopagrus australis*	2	1	2	1	1	**1.4**
28	Gerreidae	Silver biddy♦	*Gerres subfasciatus*	1	1	1	2	1	**1.2**
29	Sciaenidae	Mulloway♥	*Argyrosomus japonicus*	3	3	3	1	1	**2.2**
30	Girellidae	Luderick♦	*Girella tricuspidata*	2	2	2	2	1	**1.8**
31	Girellidae	Black drummer♥	*Girella elevata*	3	2	2	2	1	**2.0**
32	Scorpididae	Silver sweep †	*Scorpis lineolata*	1	1	3	2	1	**1.6**
33	Cheilodactylidae	Blue morwong †	*Nemadactylus douglasii*	2	1	3	2	1	**1.8**
34	Cheilodactylidae	Red morwong♥	*Cheilodactylus fuscus*	3	2	3	2	1	**2.2**
35	Latrididae	Bastard trumpeter♥	*Latridopsis forsteri*	1	2	2	2	1	**1.6**
36	Mugilidae	Sand mullet♦	*Myxus elongatus*	1	1	2	2	1	**1.4**
37	Sphyraenidae	Striped sea pike♥	*Sphyraena obtusata*	1	1	1	2	1	**1.2**
38	Labridae	Maori wrasse †	*Opthalmolepis lineolata*	1	1	2	2	1	**1.4**
39	Labridae	Blue grouper♥	*Achoerodus viridis*	3	3	3	2	1	**2.4**
40	Scombridae	Blue mackerel♦	*Scomber australasicus*	1	2	1	2	1	**1.4**
41	Scombridae	Australian bonito♦	*Sarda australis*	2	3	2	1	1	**1.8**
42	Istiophoridae	Striped marlin♥	*Tetrapturus audax*	1	3	1	1	1	**1.4**
43	Acanthuridae	Sawtail♥	*Prionurus microlepidotus*	2	2	2	2	1	**1.8**
44	Monocanthidae	Yellow-finned leatherjacket*	*Meuschenia trachylepis*	2	1	2	1	1	**1.4**
45	Monocanthidae	Chinaman leatherjacket*♦	*Nelusetta ayraudi*	2	3	2	1	1	**1.8**
46	Monocanthidae	Six-spined leatherjacket†	*Meuschenia freycineti*	3	2	3	1	1	**2.0**
47	Loliginidae (Cephlapoda)	Southern calamari♥	*Sepioteuthis australis*	1	1	1	2	2	**1.4**
48	Teuthida (Cephlapoda)	Arrow squid♥	*Nototodarus gouldi*	3	2	1	2	2	**2.0**

Continued

Table 16: Continued

2. Susceptibility Attributes

ID	Family	Common Name	Scientific Name	Target Group	Habitat preference (adults)	Site fidelity	NSW DPI Exploitation status	Depth range	Ave Susceptibility
1	Rhinobatidae	Shovelnose ray*	*Aptychotrema sp.*	3	1	2	3	3	**2.4**
2	Rhinobatidae	Fiddler ray*♦	*Trygonorrhina fasciata*	1	1	2	3	3	**2.0**
3	Orectolobidae	Spotted wobbegong♥	*Orectolobus maculatus*	3	2	1	3	3	**2.4**
4	Orectolobidae	Banded wobbegong♥	*Orectolobus halei*	3	3	1	3	3	**2.6**
5	Orectolobidae	Ornate wobbegong♥	*Orectolobus ornatus*	3	3	1	3	3	**2.6**
6	Clupeidae	Herrings, sardines, pilchards*♦	Clupeidae	1	2	2	1	2	**1.6**
7	Muraenidae	Moray eel♥	*Gymnothorax prasinus*	2	3	1	3	3	**2.4**
8	Aulopidae	Sargeant baker♥	*Aulopus purpurissatus*	2	3	3	3	3	**2.8**
9	Berycidae	Nannygai †	*Centroberyx affinis*	2	3	1	3	2	**2.2**
10	Zeidae	John dory♥	*Zeus faber*	2	2	2	2	2	**2.0**
11	Scorpaenidae	Red rock cod♥	*Scorpaena cardinalis*	2	3	1	3	3	**2.4**
12	Platycephalidae	Eastern blue-spotted flathead*†	*Platycephalus caeruleopunctatus*	3	1	1	2	2	**1.8**
13	Platycephalidae	Long-spine flathead*†	*Platycephalus longispinus*	2	1	1	3	3	**2.0**
14	Platycephalidae	Dusky flathead♦	*Platycephalus fuscus*	3	1	1	2	3	**2.0**
15	Platycephalidae	Tiger flathead♦	*Platycephalus richardsoni*	3	1	1	2	2	**1.8**
16	Dinolestidae	Long-fin pike♥	*Dinolestes lewini*	2	3	3	3	3	**2.8**
17	Sillaginidae	School whiting♦	*Sillago bassensis*	3	1	1	2	3	**2.0**
18	Pomatomidae	Tailor †	*Pomatomus saltatrix*	2	2	1	3	3	**2.2**
19	Rachycentridae	Cobia♥	*Rachycentron canadum*	2	2	2	3	2	**2.2**
20	Carangidae	Silver trevally*♦	*Pseudocaranx dentex*	3	1	3	3	3	**2.6**
21	Carangidae	Yellow-tail scad*♦	*Trachurus novaezelandiae*	3	3	1	2	2	**2.2**
22	Carangidae	Kingfish †♦	*Seriola lalandi*	3	3	2	3	2	**2.6**
23	Coryphaenidae	Common dolphinfish	*Corypheana hippurus*	3	2	2	3	3	**2.6**
24	Arripidae	Australian salmon♦	*Arripis trutta*	3	2	1	3	3	**2.4**
25	Sparidae	Snapper*♦	*Pagrus auratus*	3	2	2	3	2	**2.4**

Continued

Table 16: Continued

ID	Family	Common Name	Scientific Name	Target Group	Habitat preference (adults)	Site fidelity	NSW DPI Exploitation status	Depth range	Ave Susceptibility
26	Sparidae	Tarwhine♦	*Rhabdosargus sarba*	3	2	3	2	3	**2.6**
27	Sparidae	Yellow-fin bream †♦	*Acanthopagrus australis*	3	2	3	2	3	**2.6**
28	Gerreidae	Silver biddy♦	*Gerres subfasciatus*	1	1	3	1	3	**1.8**
29	Sciaenidae	Mulloway♥	*Argyrosomus japonicus*	3	2	3	3	3	**2.8**
30	Girellidae	Luderick♦	*Girella tricuspidata*	3	3	1	1	1	**1.8**
31	Girellidae	Black drummer♥	*Girella elevata*	2	3	1	3	1	**2.0**
32	Scorpididae	Silver sweep †	*Scorpis lineolata*	3	3	1	2	3	**2.4**
33	Cheilodactylidae	Blue morwong †	*Nemadactylus douglasii*	2	3	1	2	3	**2.2**
34	Cheilodactylidae	Red morwong♥	*Cheilodactylus fuscus*	2	3	1	3	3	**2.4**
35	Latridae	Bastard trumpeter♥	*Latridopsis forsteri*	3	1	2	3	2	**2.2**
36	Mugilidae	Sand mullet♦	*Myxus elongatus*	1	1	1	3	3	**1.8**
37	Sphyraenidae	Striped sea pike♥	*Sphyraena obtusata*	2	3	3	3	2	**2.6**
38	Labridae	Maori wrasse †	*Opthalmolepis lineolata*	2	3	1	3	1	**2.0**
39	Labridae	Blue grouper♥	*Achoerodus viridis*	2	3	1	3	3	**2.4**
40	Scombridae	Blue mackerel †	*Scomber australasicus*	3	2	2	1	1	**1.8**
41	Scombridae	Australian bonito♦	*Sarda australis*	3	1	2	3	1	**2.0**
42	Istiophoridae	Striped marlin♥	*Tetrapturus audax*	3	1	2	3	2	**2.2**
43	Acanthuridae	Sawtail♥	*Prionurus microlepidotus*	2	3	3	3	3	**2.8**
44	Monocanthidae	Yellow-finned leatherjacket*	*Meuschenia trachylepis*	3	2	2	2	3	**2.4**
45	Monocanthidae	Chinaman leatherjacket*♦	*Nelusetta ayraudi*	3	2	2	2	2	**2.2**
46	Monocanthidae	Six-spined leatherjacket†	*Meuschenia freycineti*	2	3	3	2	3	**2.6**
47	Loliginidae (Cephlapoda)	Southern calamari♥	*Sepioteuthis australis*	3	1	3	3	2	**2.4**
48	Teuthida (Cephlapoda)	Arrow squid♥	*Nototodarus gouldi*	3	1	3	3	1	**2.2**

(*) = recorded in January 2009 fish survey

(†) = recorded in top ten observed recreational and spearfishing catches 2007/2008 (Web Reference 23)

(♦) = recorded in top 20 commercially caught species (estimated by weight in tonnes) 2006/2007 (Web Reference 24)

(♥) = Other species considered likely to occur

Table 17: Distances of OARs to areas of conservation significance

Area of Conservation Significance	Designation	Nearest OAR site	Distance to nearest OAR site (km)
Port Stephens Great Lakes	Marine Park	Newcastle (Swansea)	45.0
Moon Island	Nature Reserve	Newcastle (Swansea)	4.0
North Sydney Harbour	Aquatic Reserve	Sydney (South)	2.0
Cabbage Tree Bay	Aquatic Reserve	Sydney (South)	4.2
Bronte-Coogee	Aquatic Reserve	Sydney (South)	7.0
Magic Point	GNS Critical Habitat	Sydney (South)	12.5
Little Manly	Little Penguin Critical Habitat	Sydney (South)	3.0
Five Islands Nature Reserve	Nature Reserve	Wollongong (Port Kembla)	2.4
Bass Point	Critical Habitat	Wollongong (Port Kembla)	8.0

Table 18: Recommended OAR Monitoring Plan. (*) Details of each monitoring program (A - F) is given at the end of the Table.

Factor to Monitor	Objectives	Monitoring Program	Location	Method	Review Period	Management Procedures	
						A. Impact not detected	**B.** Negative impact detected and/ or failure to meet objectives
A. Biological							
A.1 Macrobenthos	**A.1.1** Assess influence of OARs on benthic assemblages (soft sediments) including potential halo effects.	A or C*	Impact sites (soft sediment habitat adjacent to OARs) and control sites	Benthic grab deployed by boat	Annual	■Continue monitoring	■Determine acceptable level of impact in context with other cumulative impacts
	A.1.2 Assess influence of OARs on benthic assemblages of proximal natural reefs (benthos)	A*	OAR sites, proximal natural reef sites (impact sites), and natural reef sites (controls)	Photo video quadrats	Annual	■Continue monitoring	■Determine acceptable level of impact**:** ■Continue monitoring ■Consider temporary closure and/or further monitoring ■Limit to seasonal operation ■Removal of structures
	A.1.3 Document colonisation of the reef structures by macroinvertebrates including pest species	D*	OAR Structures only	Photo video quadrats and visual diver inspections	As for monitoring period	■Continue monitoring	■Verify species identification ■Determine threat of pest species if observed: ■Continue monitoring ■Removal of pest species according to appropriate NIMPIS method

Continued

Table 18: Continued

Factor to Monitor	Objectives	Monitoring Program	Location	Method	Review Period	Management Procedures	
						A. Impact not detected	**B.** Negative impact detected and/ or failure to meet objectives
A. Biological							
A.2 Fish	**A.2.1** Investigate movements of high priority species within the wider study area	A or C*	OAR sites, proximal natural reef sites (impact sites), and natural reef sites (controls)	BRUVS, biotelemetry and visual diver census	Annual	■Continue monitoring	■Determine acceptable level of impact**:** ■Continue monitoring ■Consider temporary closure and/or further monitoring ■Limit to seasonal operation ■Removal of structures
	A.2.2 Assess effectiveness in terms of catch rates, species composition and fish stocks	A or C*	OAR wider study area	Stereo-videography, BRUVS and/or visual diver surveys, on-site surveys and/or charter boat log book data	Annual	■Continue monitoring	■Determine acceptable level of impact**:** ■Continue monitoring ■Consider temporary closure and/or further monitoring ■Limit to seasonal operation ■Removal of structures
A.3 Threatened/ protected Species	Investigate occurrence of threatened and/or protected species on the OAR	C and F*	OAR sites	BRUVS or stereo-videography, visual diver census and/or listening stations if feasible	As for the monitoring period and on an 'ad hoc' basis	■Continue monitoring	■Determine acceptable level of impact**:** ■Continue monitoring ■Consider temporary closure and/or further monitoring ■Limit to seasonal operation ■Removal of structures

Continued

Table 18: Continued

Factor to Monitor	Objectives	Monitoring Program	Location	Method	Review Period	Management Procedures	
						A. Impact not detected	**B.** Negative impact detected and/ or failure to meet objectives
B. Physical							
B.1 Sediments	**B.1.1** Assess the influence of OARs on sediment characteristics (sediment particle size composition)	A or C*	Impact sites (soft sediment habitat adjacent to OARs) and control sites (Note that control sites should be of similar particle size composition and depth to impact sites	Benthic grab deployed by boat	Annual	■Continue monitoring	■Determine acceptable level of impact in context with other cumulative impacts
	B.1.2 Assess concentrations of heavy metals in adjacent sediments	B*	Impact sites (soft sediment habitat adjacent to OARs) and control sites (Note that control sites should be of similar particle size composition and depth to impact sites	Benthic grab deployed by boat	Annual	■Continue monitoring and compare against ANZECC guidelines.	■Determine acceptable level of impact in context with other cumulative impacts
B.2 Water Quality	Assess water quality	A*	Impact and control sites	Water quality probe	Annual	■Continue monitoring and compare against ANZECC guidelines	■Determine acceptable level of impact in context with other cumulative impacts

Continued

Table 18: Continued

Factor to Monitor	Objectives	Monitoring Program	Location	Method	Review Period	Management Procedures	
						A. Impact not detected	**B.** Negative impact detected and/ or failure to meet objectives
B.3 OAR Structure	**B.3.1** Assess structural integrity	E*	OAR units only	Diver survey	Every two years	■Continue monitoring	■Consider need for maintenance
	B.3.2 Remove fouled gear and debris	E*	OAR Structures only	Diver survey	Every two years	■Continue monitoring	■Continue monitoring and/or; ■Removal of entangled fishing gear and debris
C. Social and Economic							
C.1 Recreational and Commercial fishermen	**C.1.1** Assess effectiveness in terms of popularity with recreational fishing groups	E*	N/a	Stakeholder questionaires	Annual	■Continue monitoring until project objectives are met	■Analyse feedback from user groups against project objectives: ■Implement necessary changes ■Consider temporary closure and/or further monitoring ■Limit to seasonal operation ■Removal of structures
	C.1.2. Identify issues of conflict between user groups (e.g. from crowding)	F*	N/a	Mechanism for incident reporting	Annually and on an 'ad hoc' basis	■Continue monitoring	■Analyse feedback from user groups against project objectives: ■Continue monitoring or; ■Resolve issues within a forum between user groups

Continued

Table 18: Continued

Monitoring Program					
A*	B*	C*	D*	E*	F*
Pre-deployment	Pre-deployment	Pre-deployment	Pre-deployment	Pre-deployment	Pre-deployment
winter x1 summer x1	x1	winter x2 summer x2	N/A	N/A	N/A
Post-deployment	Post-deployment	Post-deployment	Post-deployment	Post-deployment	Post-deployment
3 months 6 months 12 months Every year thereafter (winter x1 and summer x1) for a minimum of 3 years	12 months Every year thereafter (x1) for a minimum 3 years	3 months 6 months 12 months Every year thereafter (winter x2 and summer x2) for a minimum of 3 years. Note this option allows temporal seasonal comparisons.	3 months 6 months 12 months Every year thereafter (winter x1 and summer x1) for a minimum of 3 years	12 months Every 1-2 years thereafter	Continuous mechanism for feedback e.g. reporting incidents or remote data transfer

14 Figures

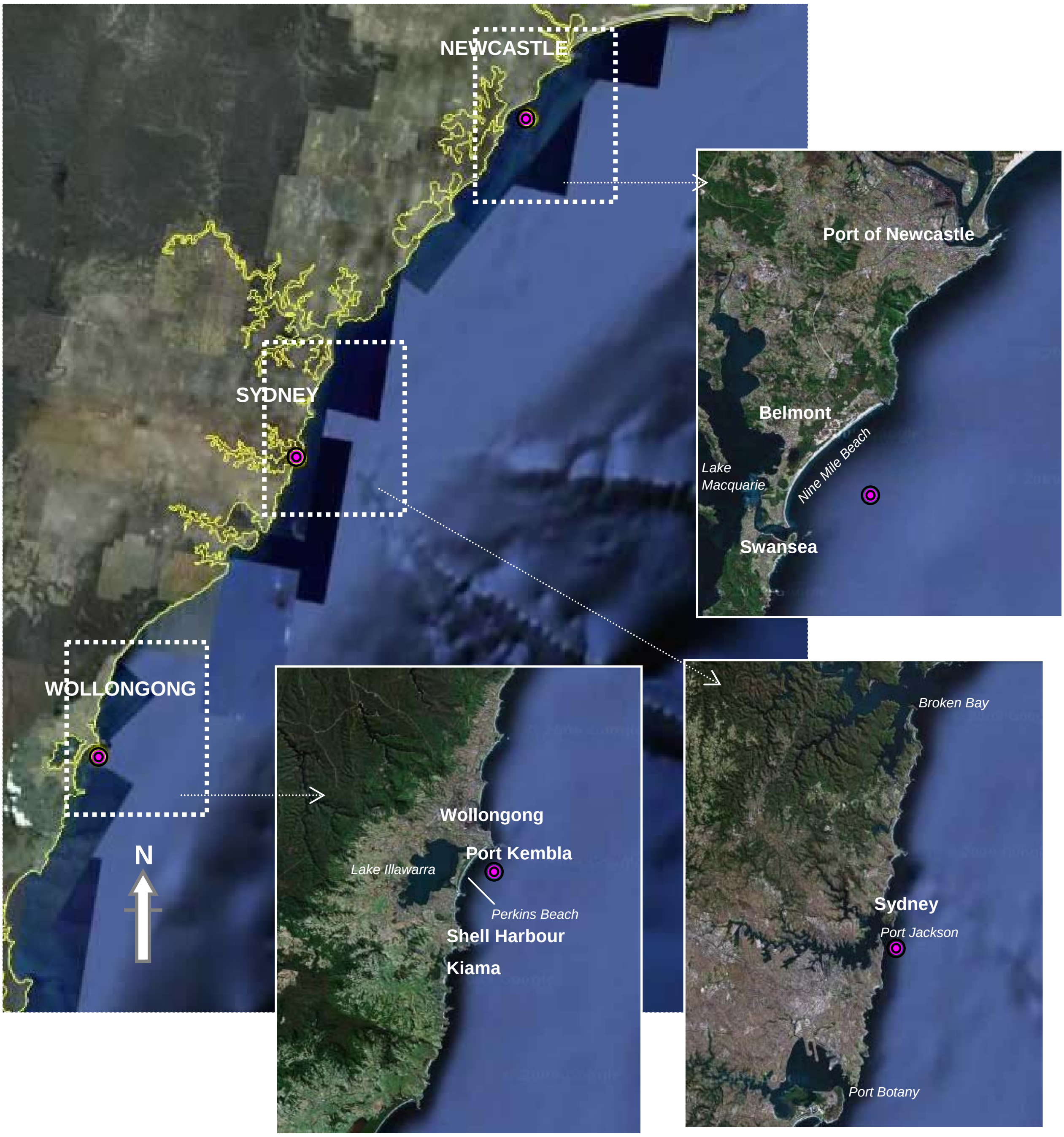
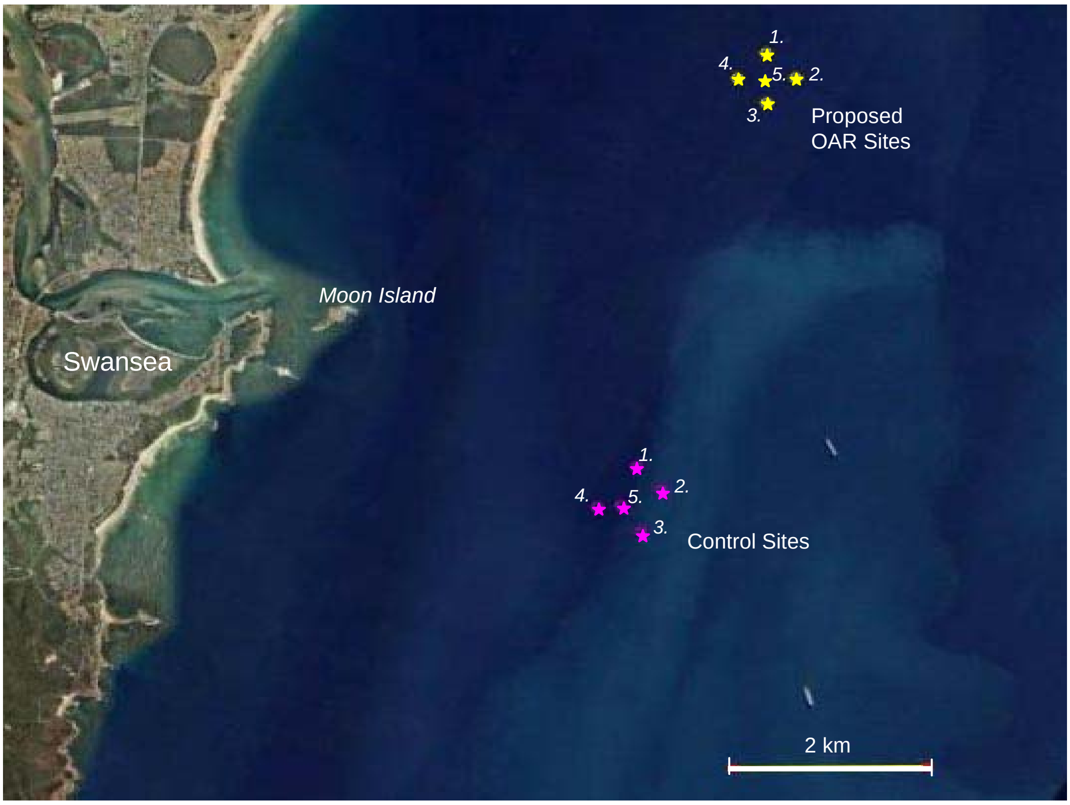


Figure 1a: Overview map of metropolitan regions (Newcastle, Sydney and Wollongong) and the proposed offshore artificial reef sites (Swansea, South Sydney and Port Kembla) within each region.

a)



b)

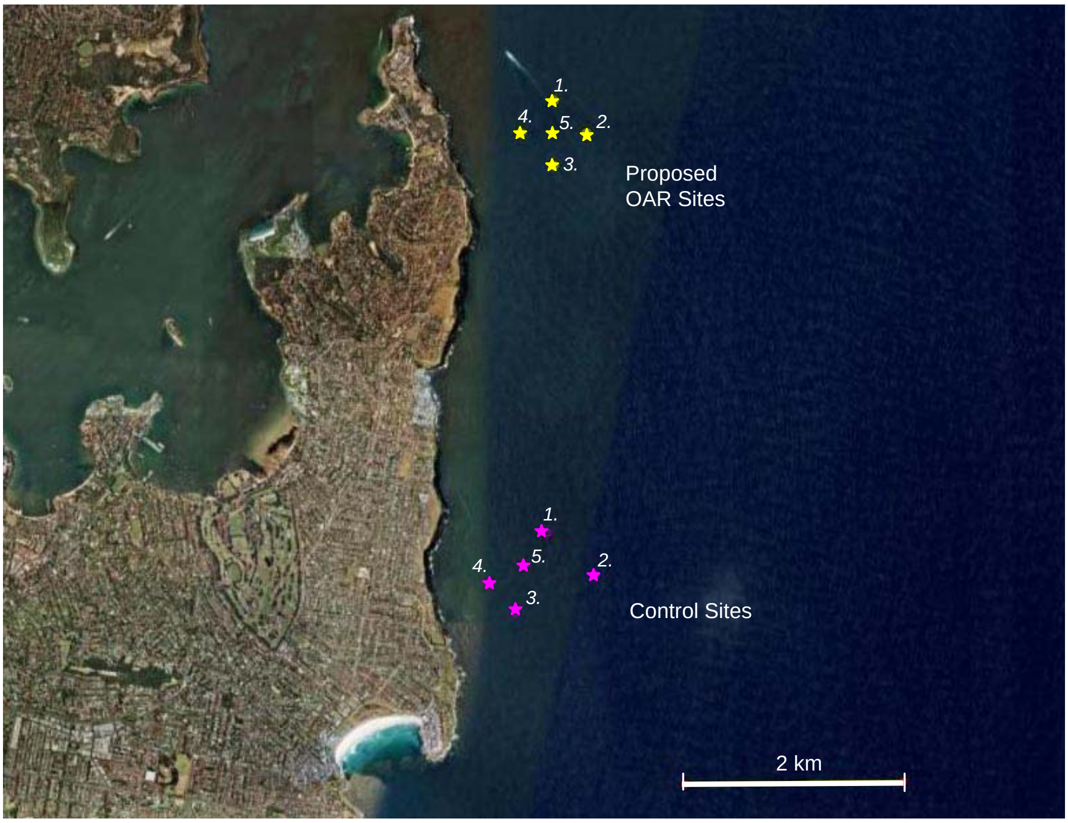


Figure 1b: Location of proposed OAR (impact) and control sites at the a) Newcastle (Swansea) and b) Sydney (South) and study regions sampled during January 2009.

Figure 1c: Location of proposed OAR (impact) and control sampling sites at the Wollongong (Port Kembla) study region.

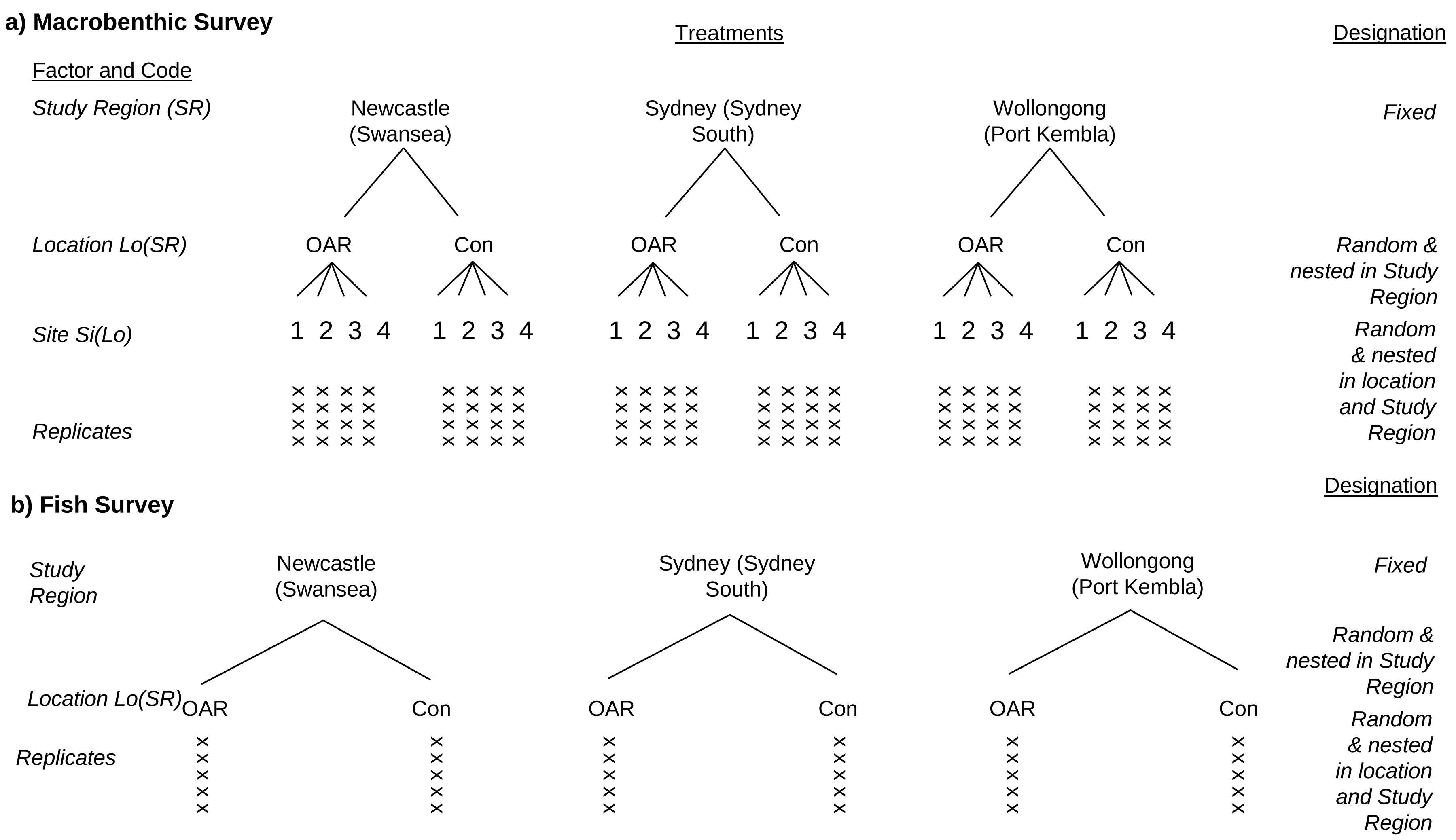


Figure 2: Sampling design for surveys of macroinvertebrate communities and fish at the Newcastle, Sydney and Wollongong study regions in January 2009. (OAR = proposed OAR location, Con = control location).

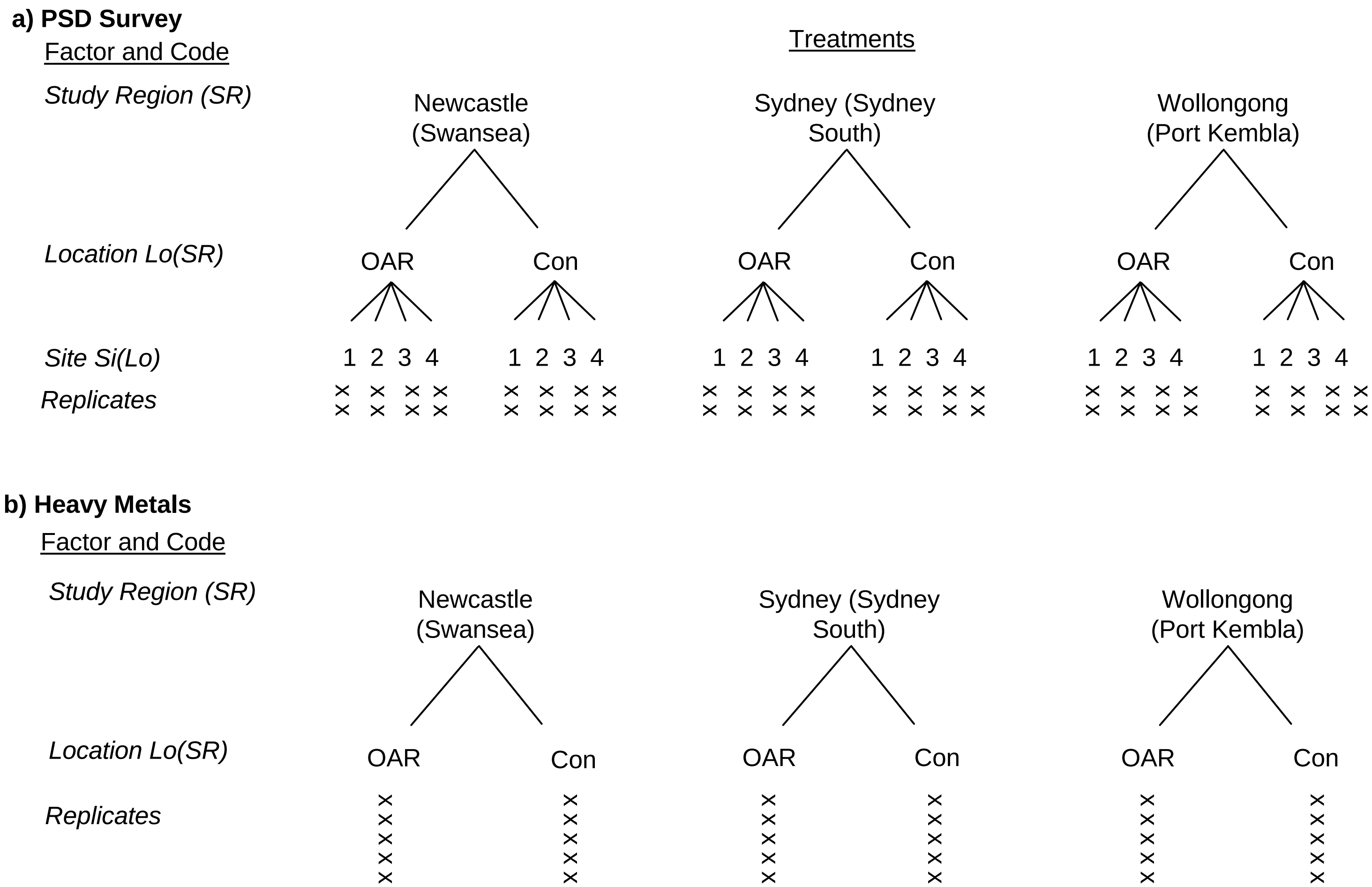
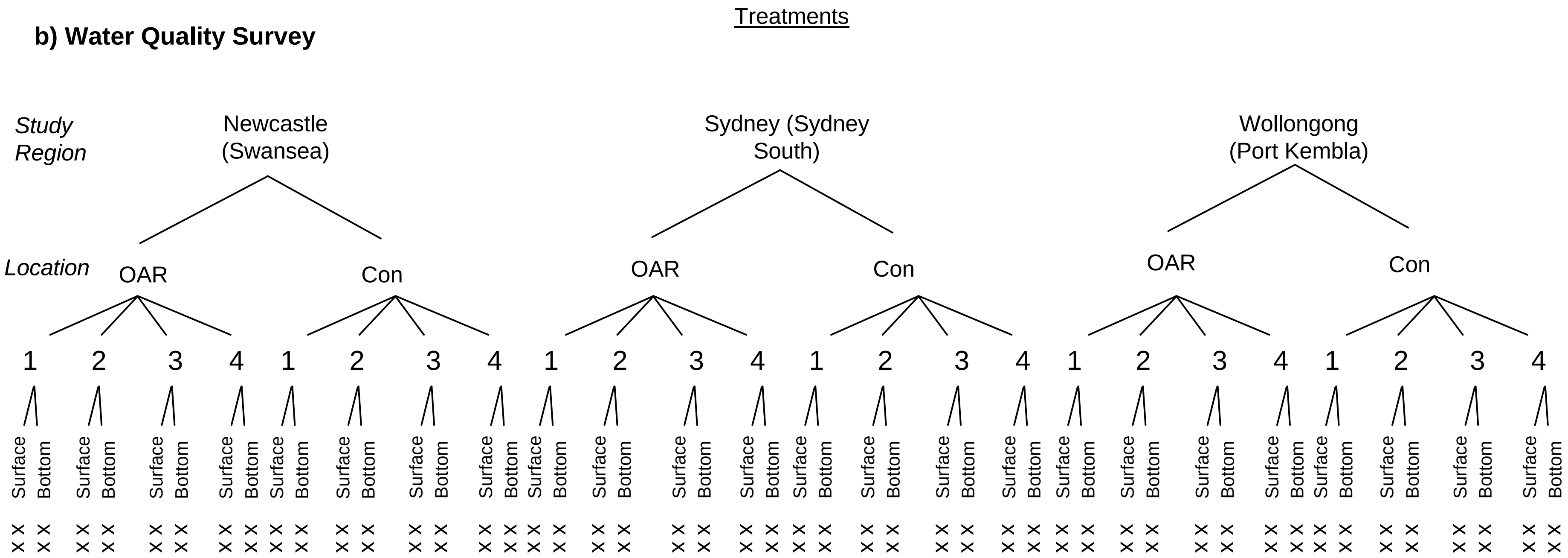


Figure 3: Sampling design for surveys of particle size distribution (PSD) and heavy metal concentrations at the Newcastle, Sydney and Wollongong study regions in January 2009. (OAR = proposed OAR location, Con = control location).

b) Water Quality Survey



(1- 4 = Sites)

(x = Replicates)

Figure 4: Sampling design for water quality surveys at the Newcastle, Sydney and Wollongong study regions in January 2009. (OAR = proposed OAR location, Con = control location).

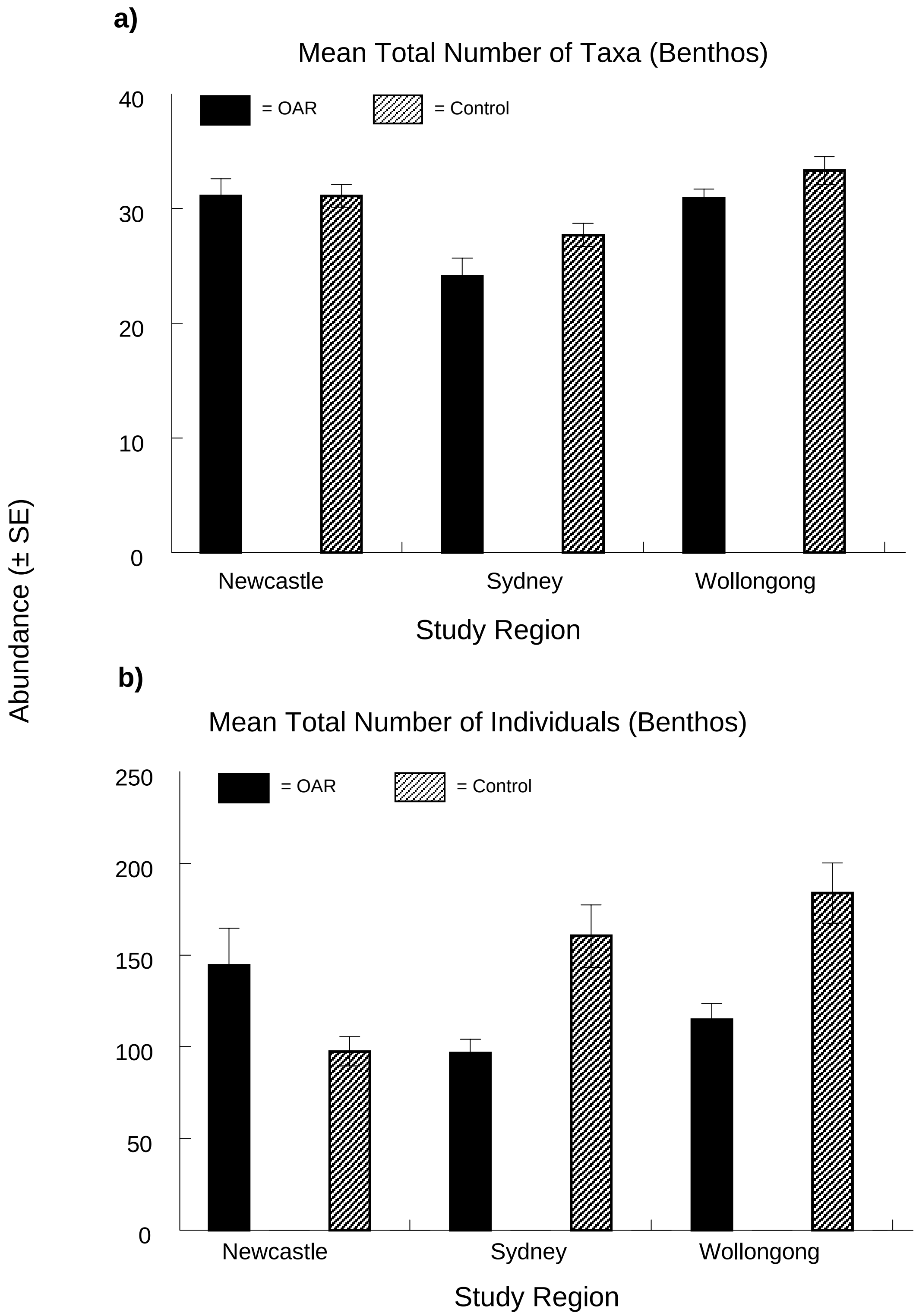


Figure 5: Mean total abundance of taxa and mean total abundance of individuals (± SE) identified in benthic grab samples collected from the Newcastle, Sydney and Wollongong study regions in January 2009. Significant differences between locations are denoted by asterisks (PERMANOVA, * = p< 0.05, ** = p< 0.01, n = 16).

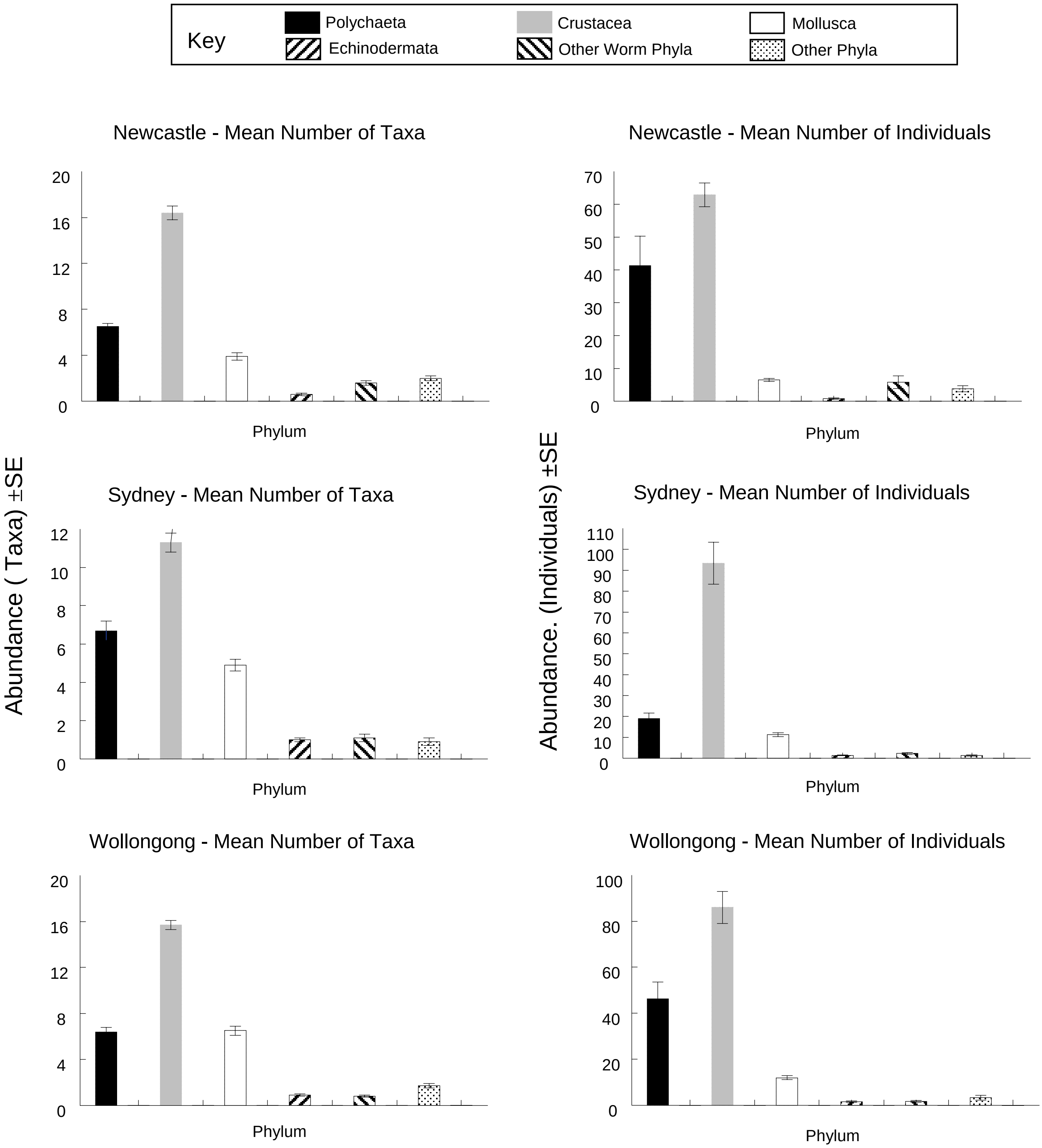


Figure 6: Mean abundance of taxa and mean abundance of individuals grouped by phyla in benthic grab samples collected from the Newcastle, Sydney and Wollongong study regions in January 2009.

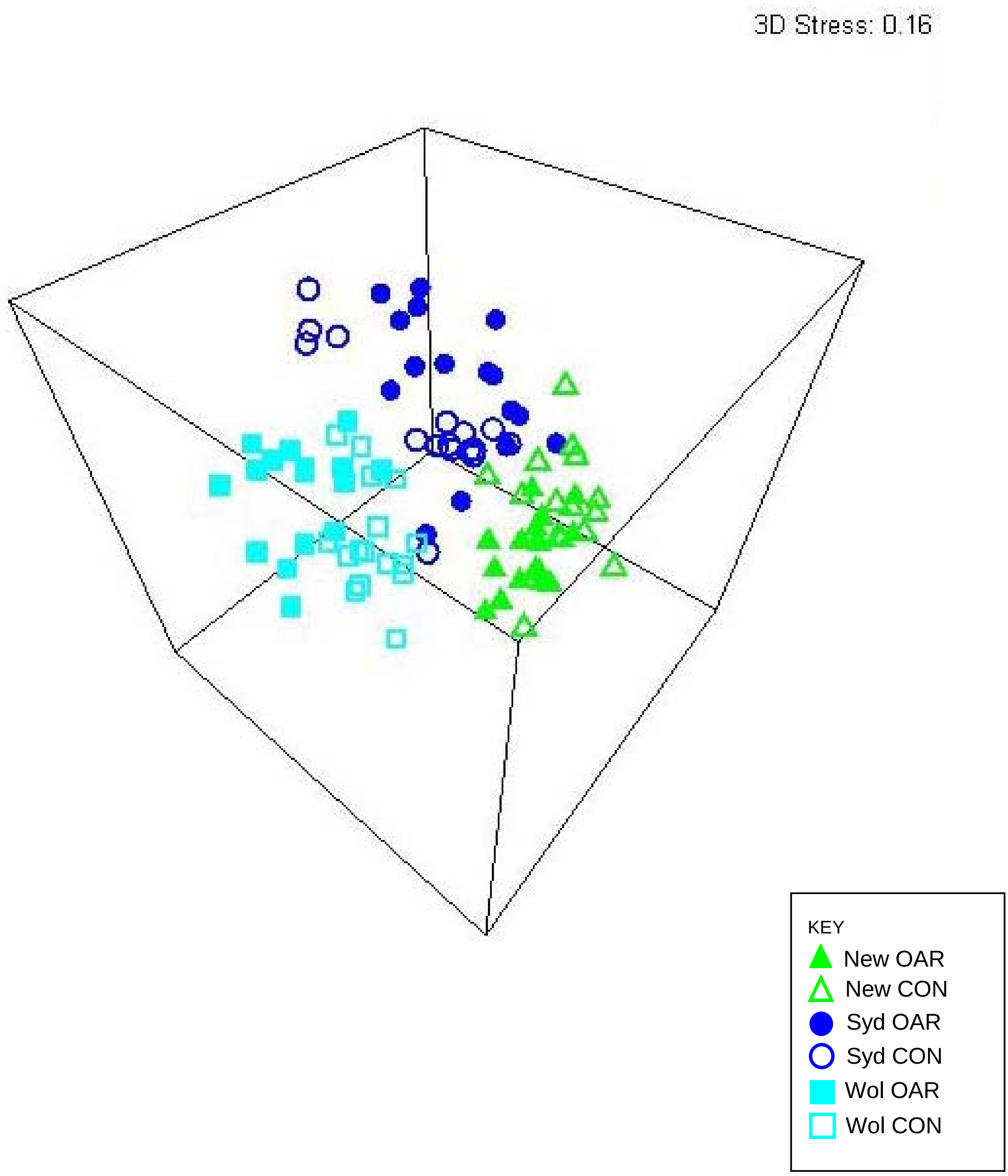


Figure 7: Non – metric multi-dimensional scaling (nMDS) ordination of benthic assemblages present in the Newcastle, Sydney and Wollongong study regions in January 2009. Square root transformation. OAR = proposed OAR (impact location), CON = Control location.

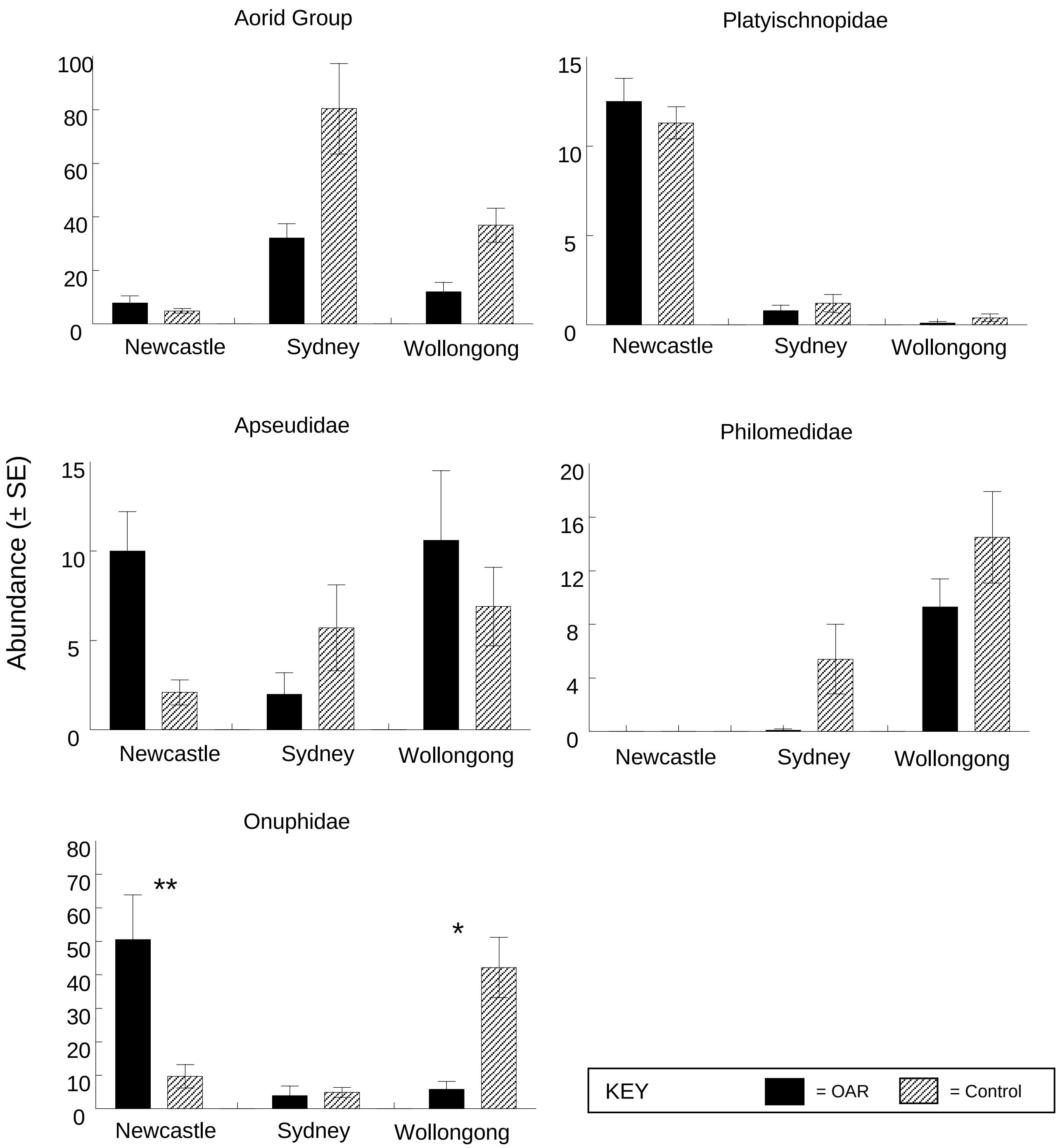


Figure 8: Abundances of macrobenthic taxa contributing approx. 5% or more to dissimilarities between assemblages at the Newcastle, Sydney and Wollongong study regions. Significant differences between locations are denoted by asterisks (PERMANOVA, * = $p < 0.05$, ** = $p < 0.01$, n = 16).

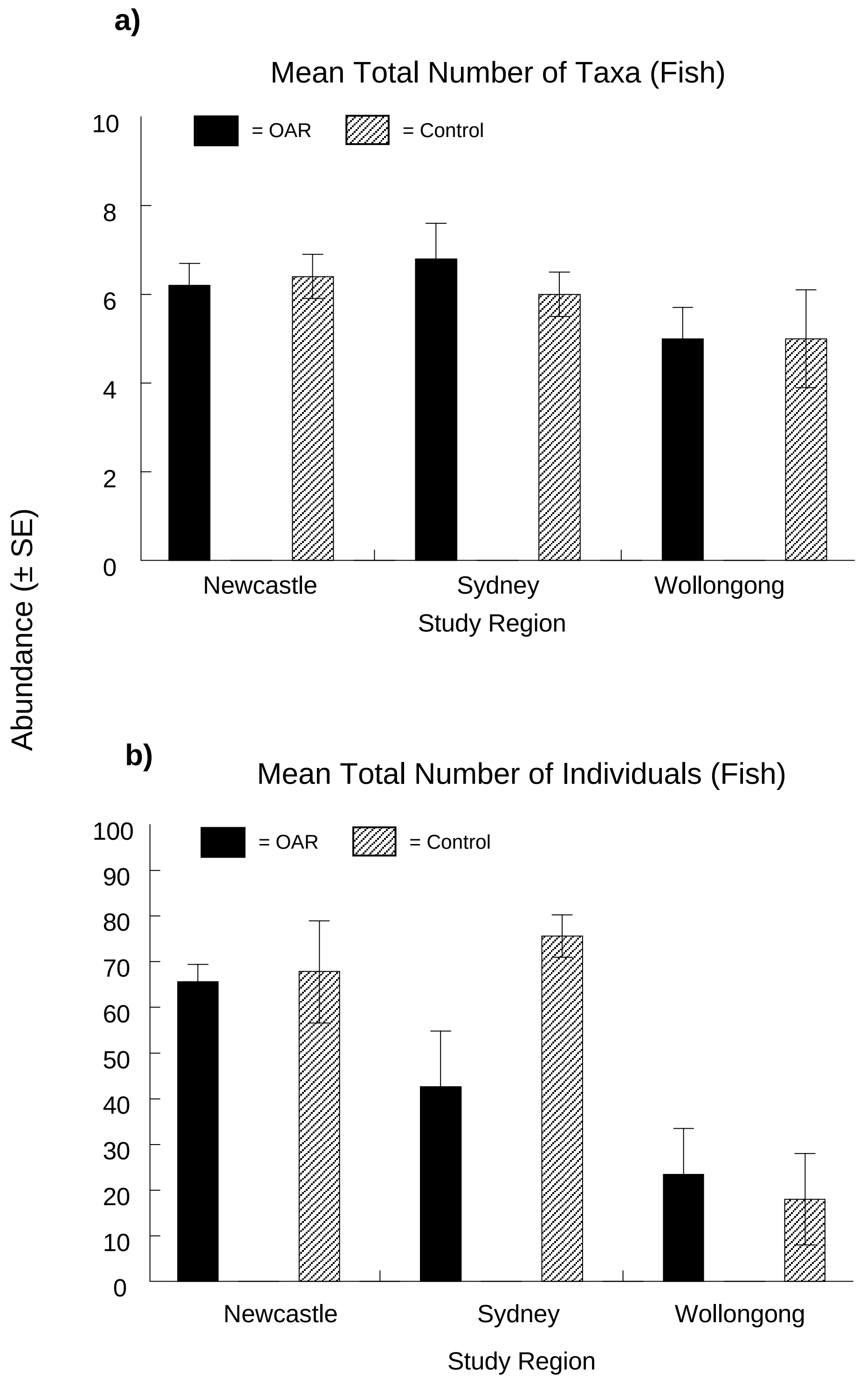


Figure 9: Mean total abundance of taxa and mean total abundance of individuals (± SE) identified from BRUVS deployed at the Newcastle, Sydney and Wollongong study regions in January 2009. Significant differences between locations are denoted by asterisks (PERMANOVA, * = p < 0.05, ** = p < 0.01, n = 5).

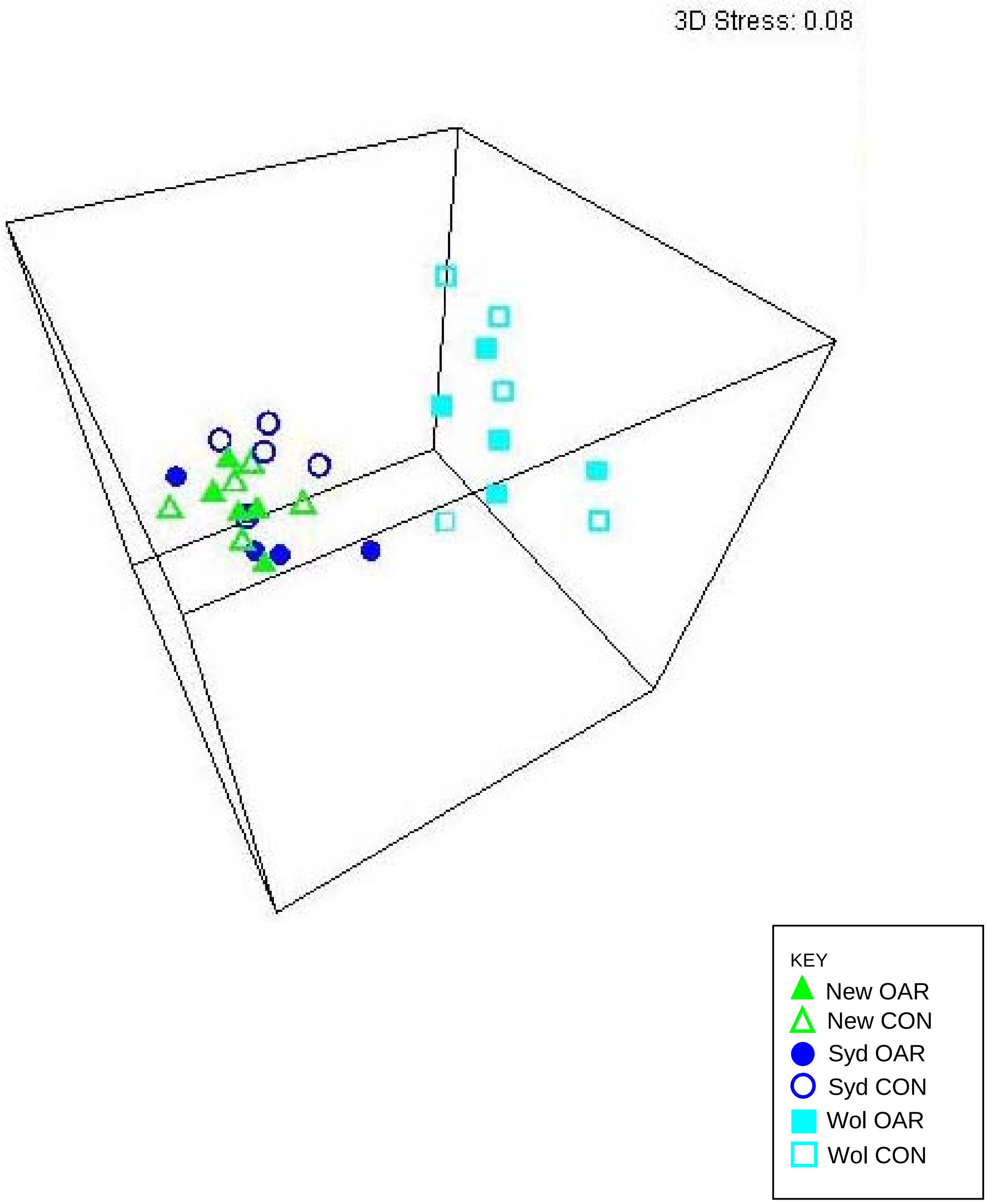


Figure 10: Non – metric multi-dimensional scaling (nMDS) ordination of fish assemblages present in the Newcastle, Sydney and Wollongong study regions in January 2009. Square root transformation. OAR = proposed OAR (impact location), CON = Control location.

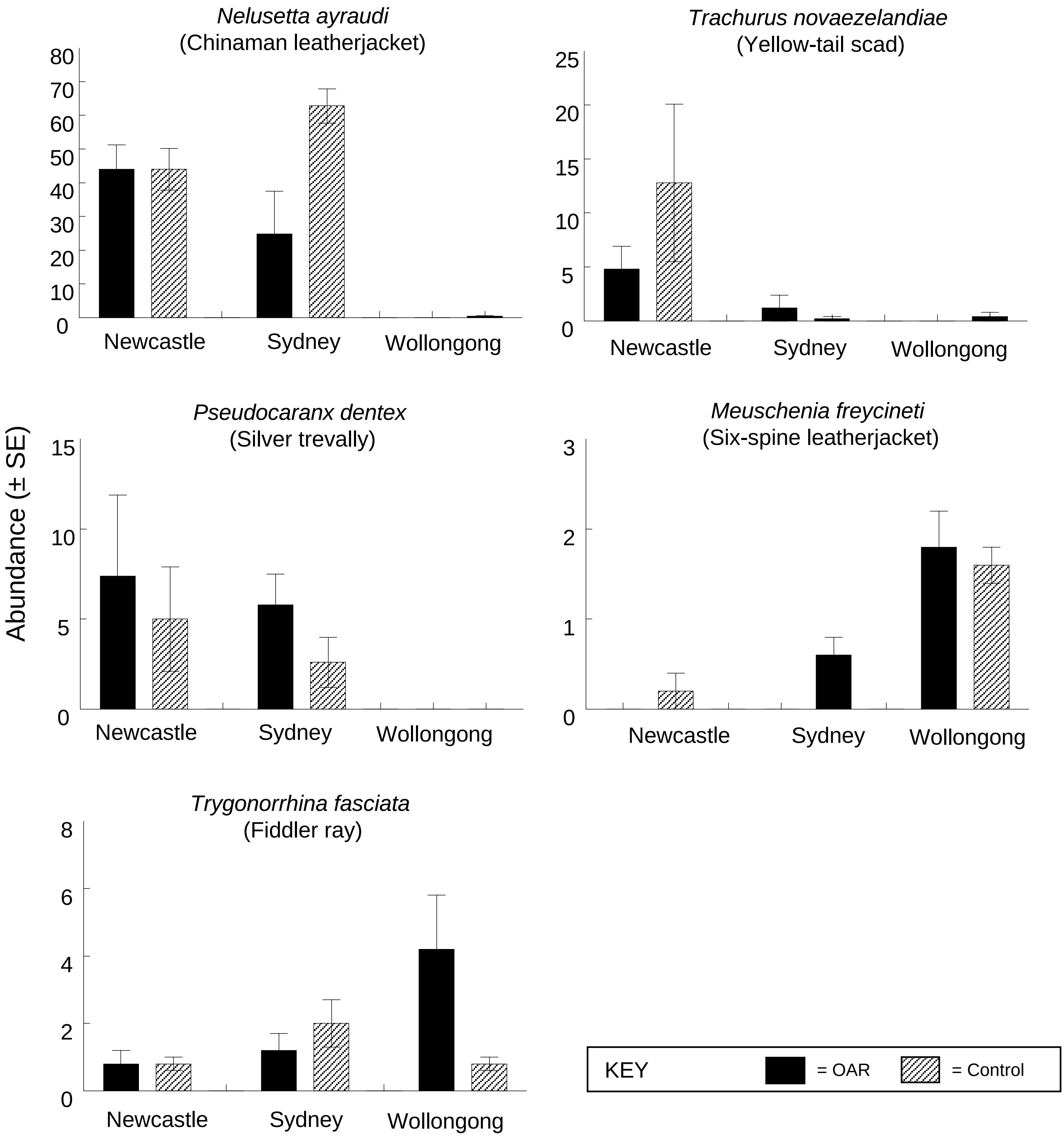


Figure 11: Abundances of fish species contributing approx. 5% or more to dissimilarities between assemblages at the Newcastle, Sydney and Wollongong study regions.

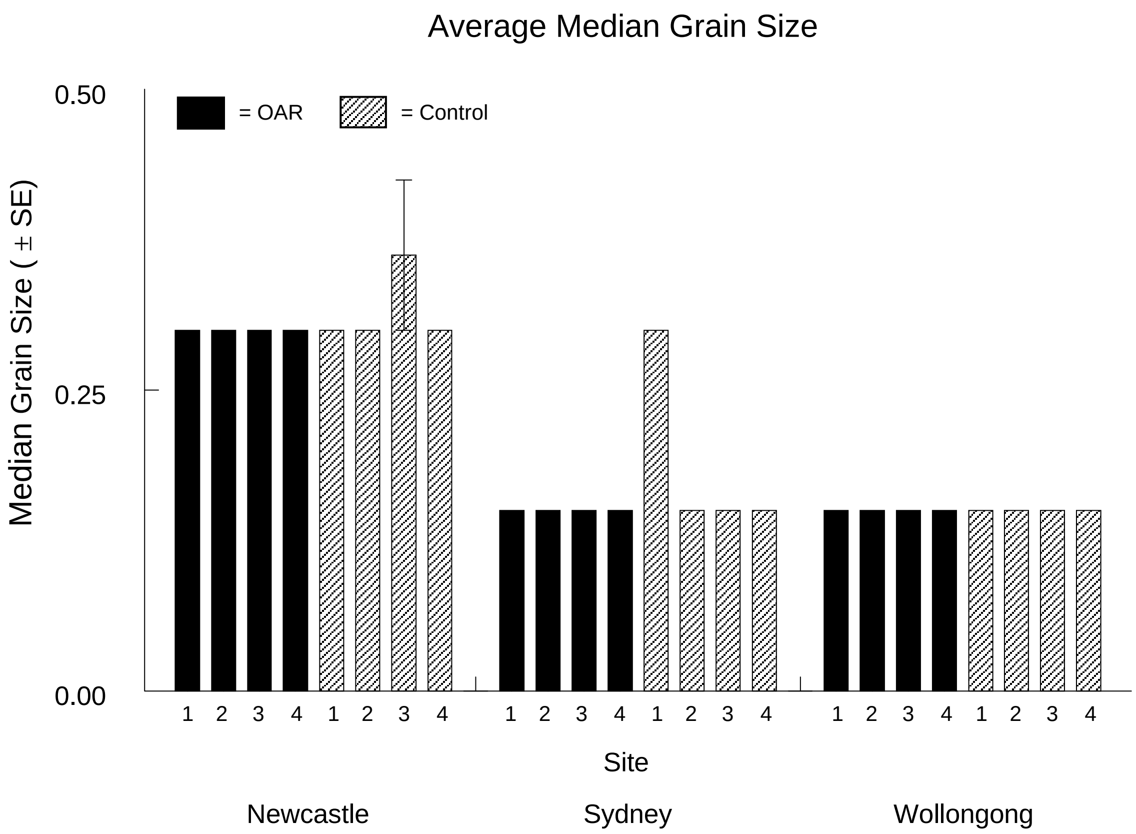


Figure 12: Average median grain size recorded at sites within the Newcastle, Sydney and Wollongong study regions. Significant differences between locations are denoted by asterisks (PERMANOVA, *= p<0.05; **= p<0.01, n = 2).

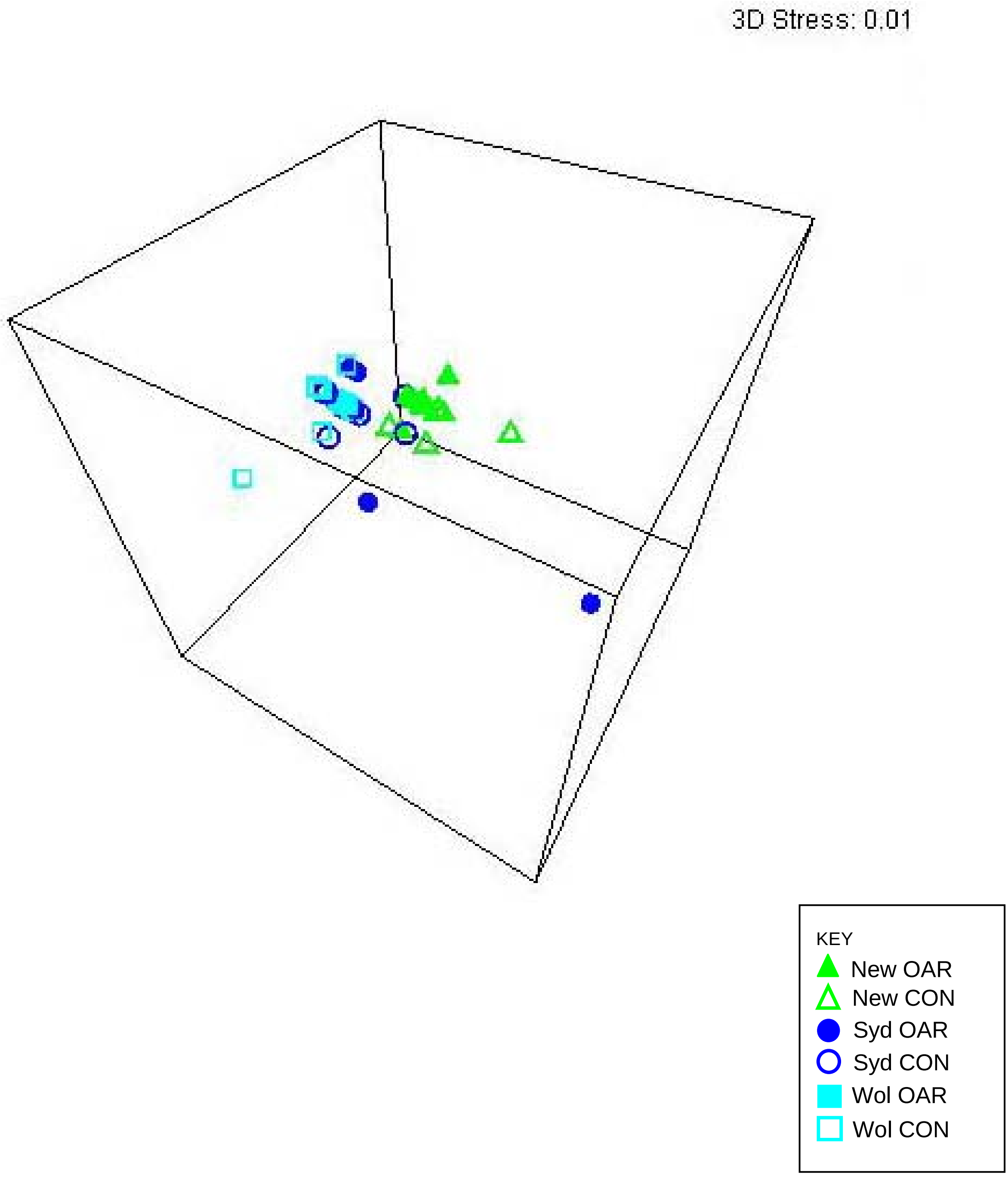
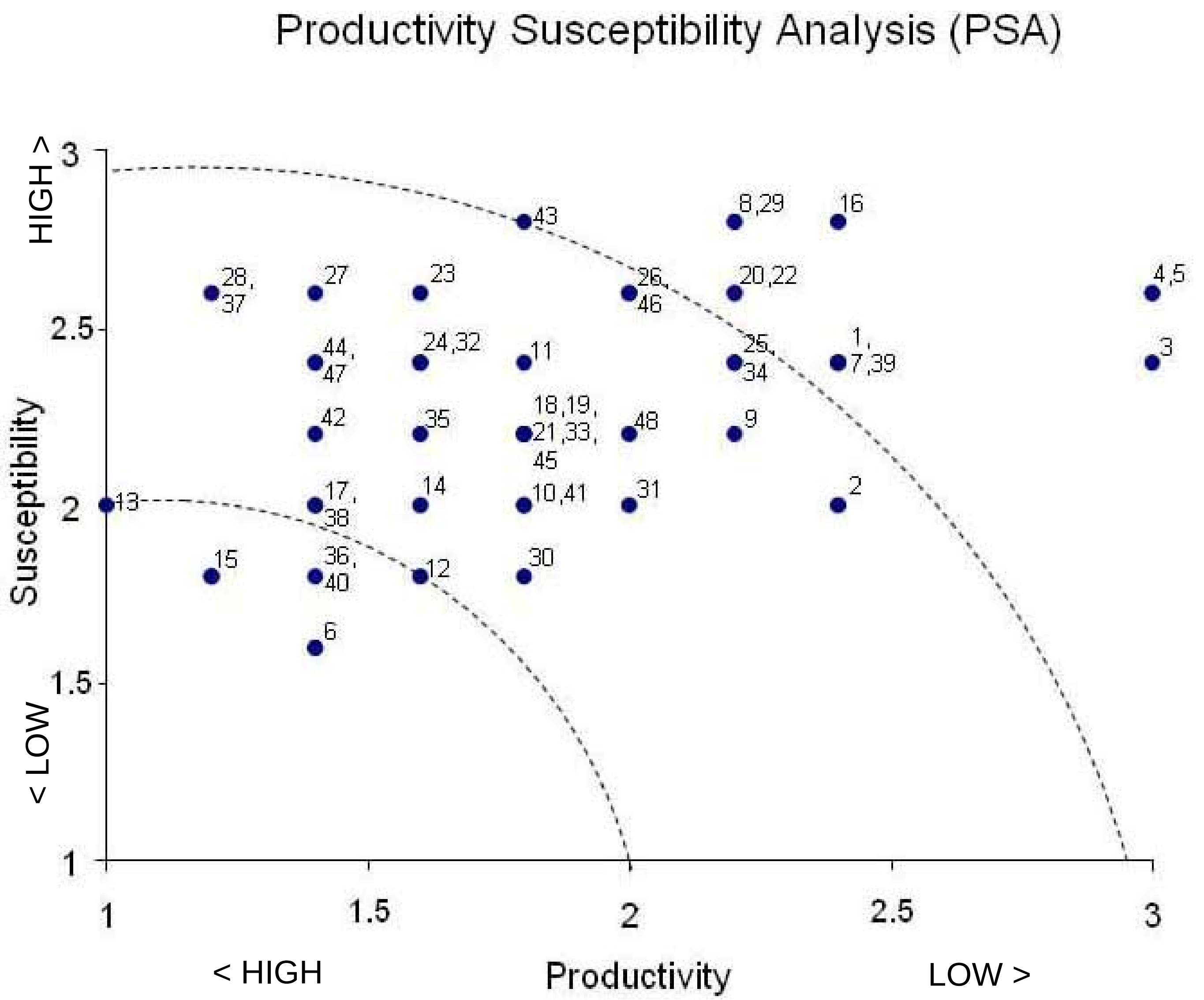


Figure 13: Non – metric multi-dimensional scaling (nMDS) ordination of median grain sizes recorded at the Newcastle, Sydney and Wollongong study regions in January 2009. Square root transformation. OAR = proposed OAR (impact location), CON = Control location.



1 Shovelnose ray
2 Fiddler ray
3 Spotted wobbegong
4 Banded wobbegong
5 Ornate wobbegong
6 Herrings, sardines, pilchards
7 Moray eel
8 Sargeant baker
9 Nannygai
10 John dory
11 Red rock cod
12 Eastern blue-spotted flathead
13 Long-spine flathead
14 Dusky flathead
15 Tiger flathead
16 long-fin pike
17 School whiting
18 Tailor
19 Cobia
20 Silver trevally
21 Yellow-tail scad
22 Kingfish
23 Common dolphinfish
24 Australian salmon
25 Snapper
26 Tarwhine
27 Yellow-fin bream
28 Silver biddy
29 Mulloway
30 Luderick
31 Black drummer
32 Silver sweep
33 Blue morwong
34 Red morwong
35 Bastard trumpeter
36 Sand mullet
37 Striped sea pike
38 Maori wrasse
39 Blue grouper
40 Blue mackerel
41 Australian bonito
42 Striped marlin
43 Sawtail
44 Yellow-finned leatherjacket
45 Chinaman leatherjacket
46 Six-spined leatherjacket
47 Southern calamari
48 Arrow squid

Figure 14: Productivity Susceptibility Analysis (PSA) of recreationally and commercially important species likely to occur at the proposed OAR study regions.

Figure 15a: Location of grey nurse shark critical habitat and aggregation sites in relation to the proposed Newcastle OAR site.

Figure 15b: Location of grey nurse shark critical habitat and aggregation sites in relation to the proposed Sydney OAR site.

Figure 15c: Location of grey nurse shark critical habitat and aggregation sites in relation to the proposed Wollongong OAR site.

15 Plates

Plate 1: Sampling for macroinvertebrates with a Ponar Grab on the vessel 'Krista' in January 2009.

Plate 2: Fish sampling using Baited Remote Underwater Video Stations (BRUVS) on the vessel 'Krista' in January 2009.

Plate 3: Species observed during the field sampling in January 2009.

Plate 4: Dominant groups of macrofauna comtributing to 5 % or more dissimilarity between study regions.

Plate 5: Fish species observed during BRUVS surveys in January 2009.

Plate 6: Still photographs taken from BRUVS deployed in the Newcastle study region in January 2009.

Plate 7: Still photographs taken from BRUVS deployed in the Sydney study region in January 2009.

Plate 8: Still photographs taken from BRUVS deployed in the Wollongong study region in January 2009.

Plate 9: Sediment samples collected by Ponar grab in the Newcastle study region during January 2009.

Plate 10: Sediment samples collected by Ponar grab in the Sydney study region during January 2009.

Plate 11: Sediment samples collected by Ponar grab in the Wollongong study region during January 2009.

a)

b)

c)

d)

e)

f)

Plate 1: Sampling for macroinvertebrates with a Ponar Grab on the vessel 'Krista' in January 2009. **a)** retrieving the Ponar grab **b)** sieving the sample (1 mm sieve) **c)** transferring the sample **d)** adding 10 % formalin solution **e)** sample sorting and identification of macroinvertebrates at the laboratory **f)** final samples.

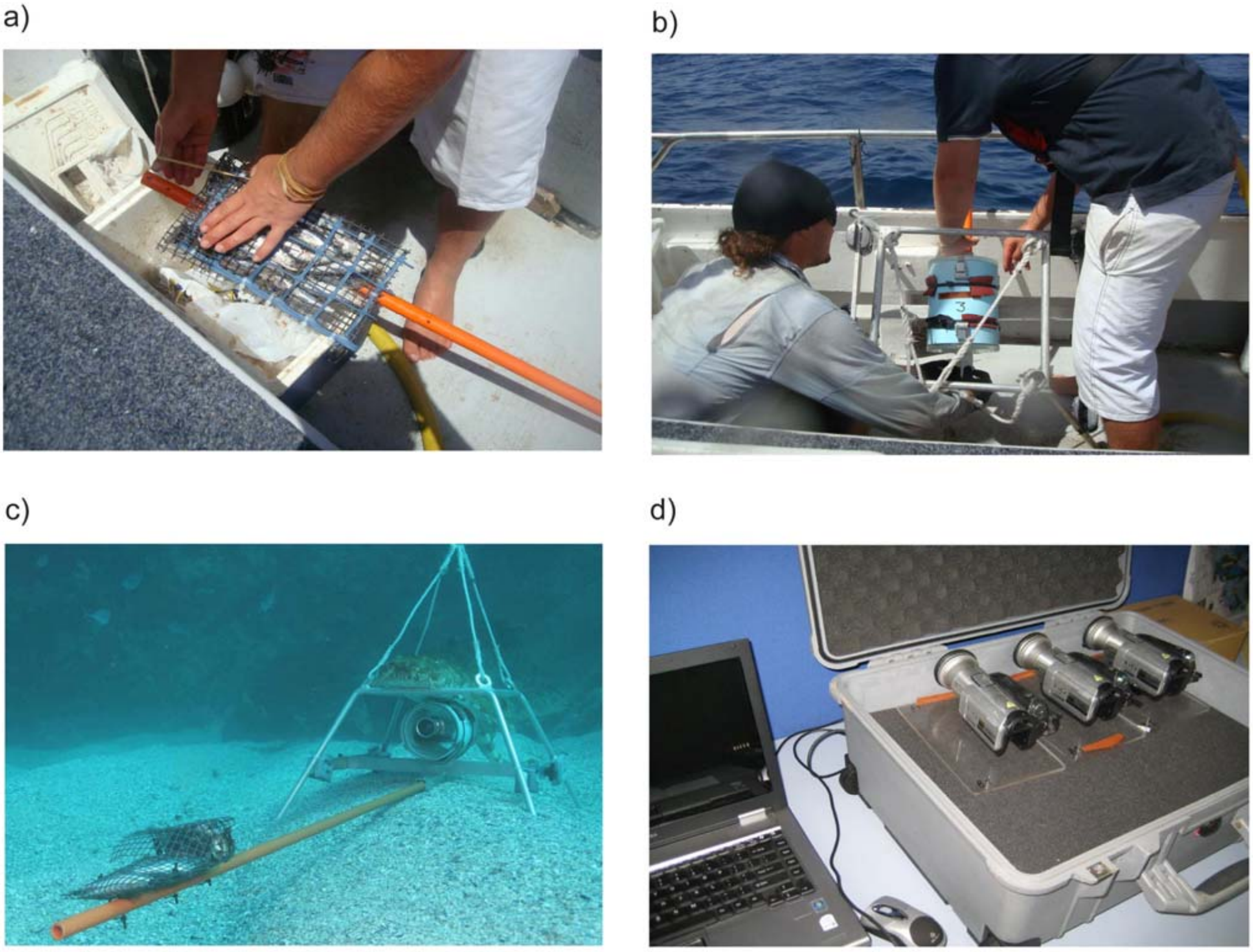
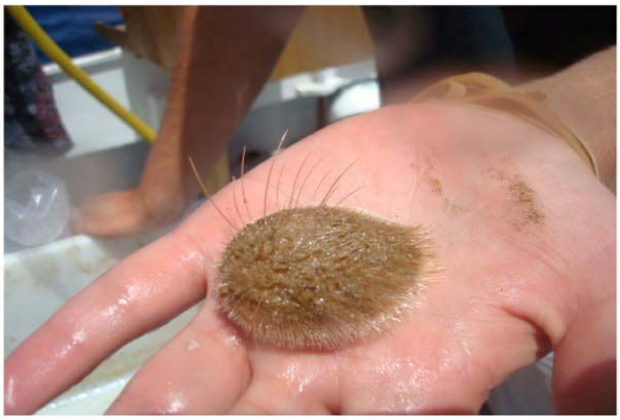


Plate 2: Fish sampling using Baited Remote Underwater Video Stations (BRUVS) on the vessel ‘Krista’ in January 2009. **a)** deploying the BRUVS **b)** preparing the bait sleeve with pilchards **c)** the BRUVS unit positioned on the seabed **d)** high-definition (1080i) digital video cameras housed in the BRUVS.

a)

b)



c)

d)

e)

f)

Plate 3: Species observed during the field sampling in January 2009. a) eel (Family: Anguilidae) b) sea urchin (*Echinocardium cordatum*) c) bivalve mollusc (Family: Trigonidae) d) Purse Crab (Family: Leucosiidae) e) scorpion fish (Family: Scorpaenidae) f) Common dolphins (*Delphinus delphis*).

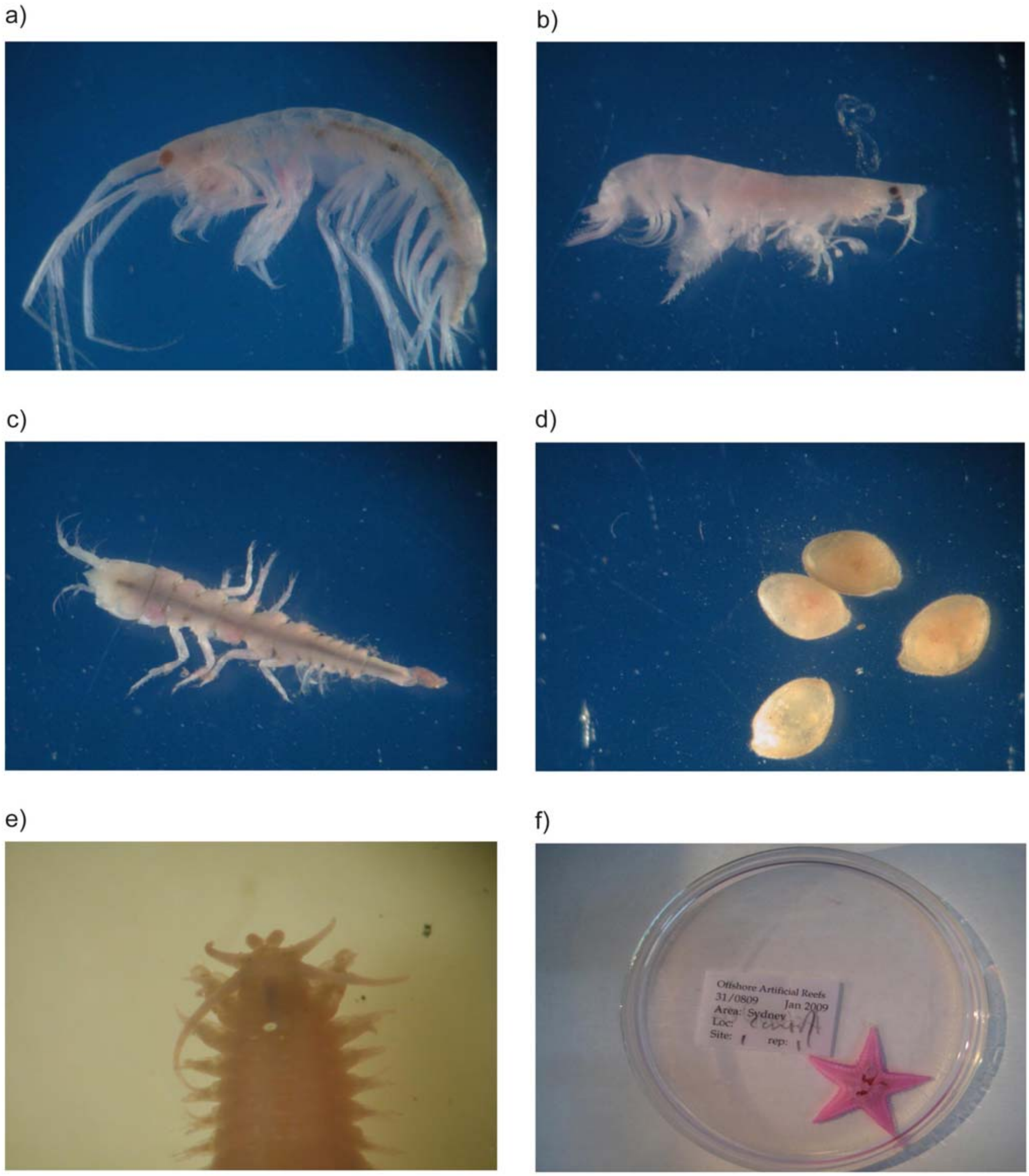


Plate 4: Dominant groups of macrofauna comtributing to 5 % or more dissimilarity between study regions. a) Amphipod crustacean from the Aoridae Group (including families aoridae, iseidae, photidae and unciolidae b) amphipod crustacean - family: platyischnopidae c) isopod crustacean - family: apseudidae d) ostracod crustacean - family: philomedidae and e) polychaete worm - family: onuphidae and f) less dominant groups - family asteroidea (Echinodermata).

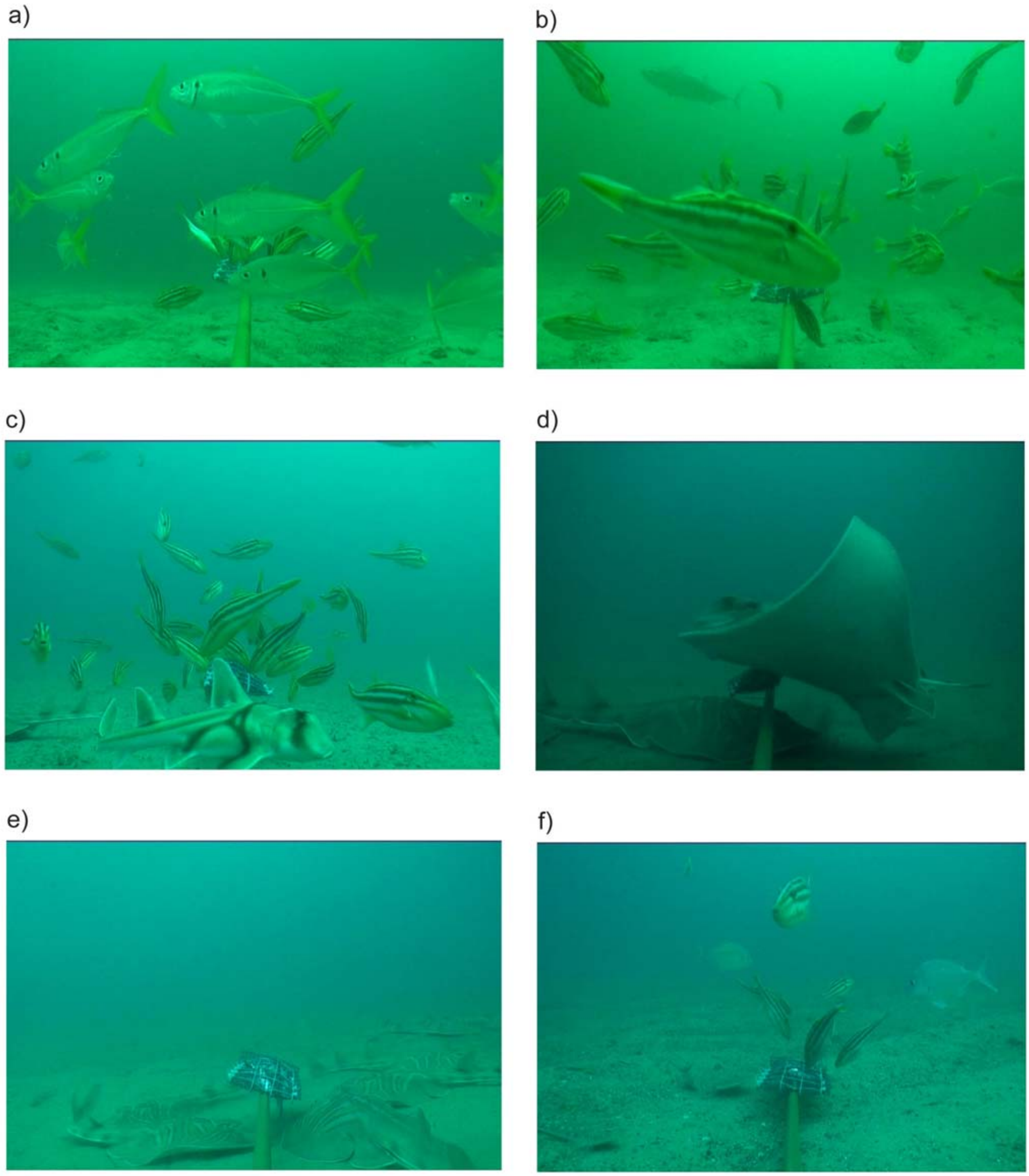
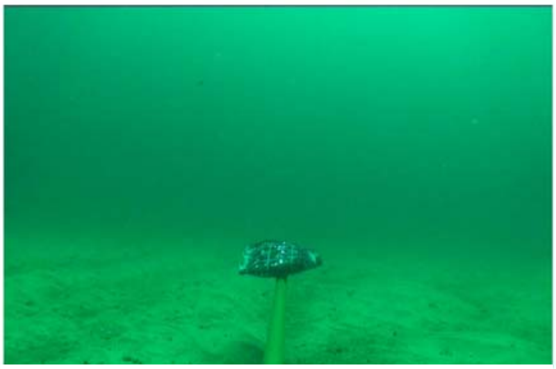
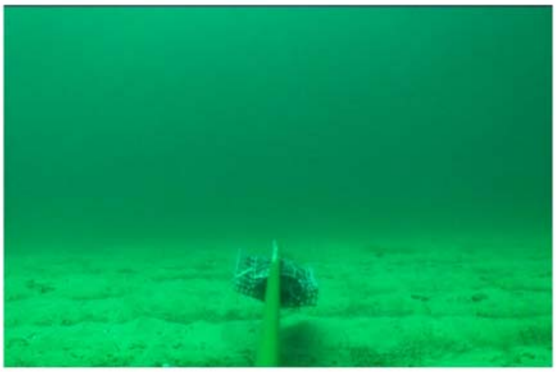


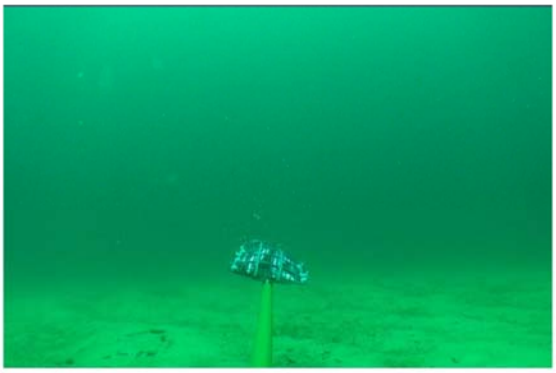
Plate 5: Fish species observed during BRUVS surveys in January 2009. **a)** yellow-tail scad (*Trachurus novaezelandiae)* **b)** chinaman leatherjacket (*Nelusetta ayraudi)* in foreground and Australian bonito *(Sarda australis)* **c)** Port Jackson shark (*Heterodontus portusjacksoni)* **d)** eagle ray (*Myliobatus australis)* **e)** fiddler rays (*Trygonorrhina fasciata)* **f)** snapper (*Pagrus auratus*).



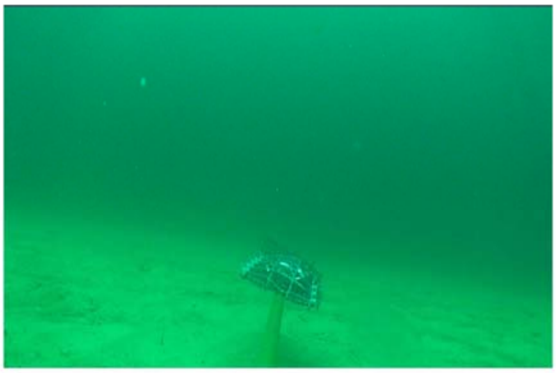
Newcastle, OAR location, site 1



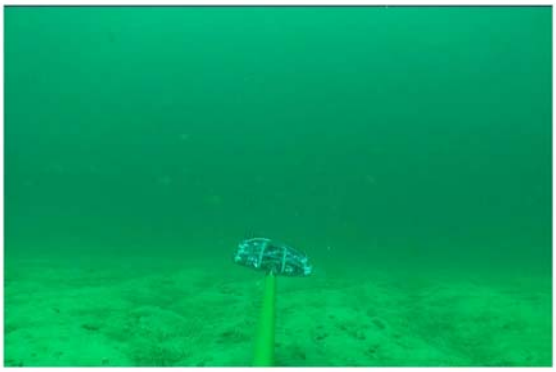
Newcastle, OAR location, site 2



Newcastle, OAR location, site 3

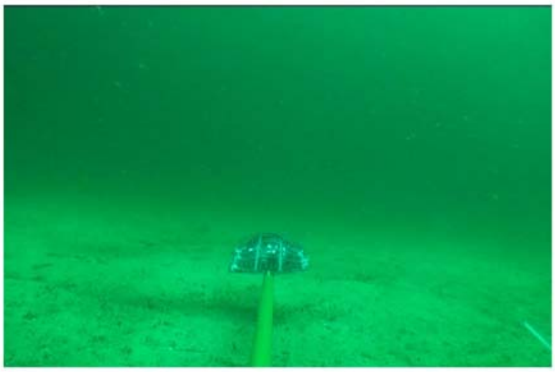


Newcastle, OAR location, site 4

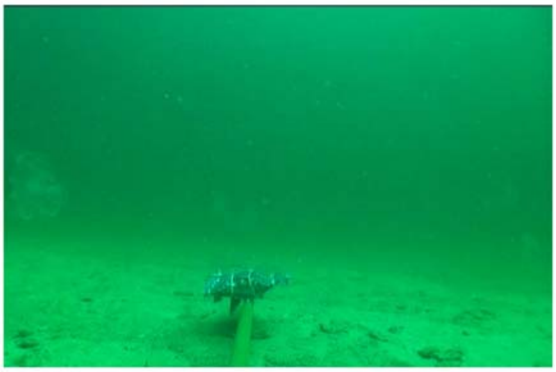


Newcastle, OAR control location, site 1

Newcastle, OAR control location, site 2



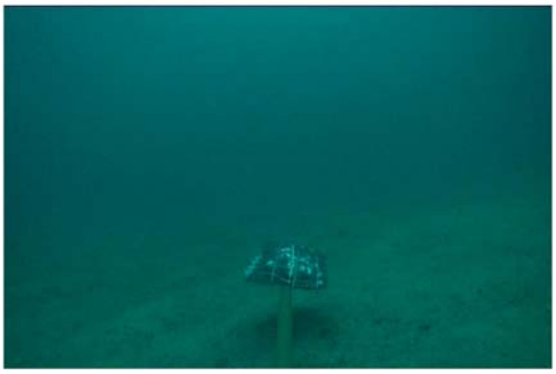
Newcastle, OAR control location, site 3



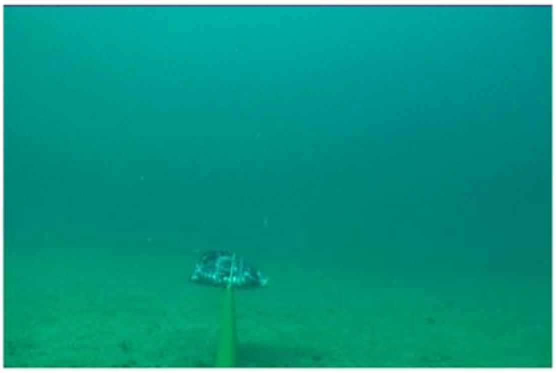
Newcastle, OAR control location, site 4

Plate 6: Still photographs taken from BRUVS deployed in the Newcastle study region in January 2009.

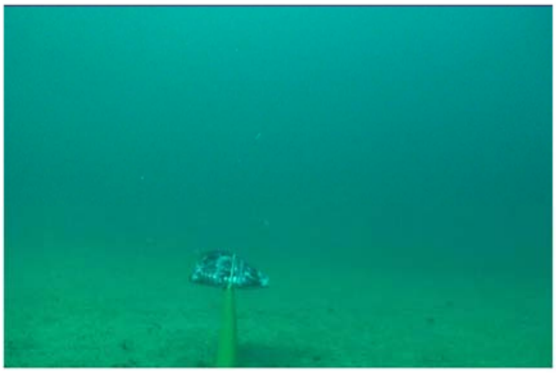
Sydney, OAR location, site 1



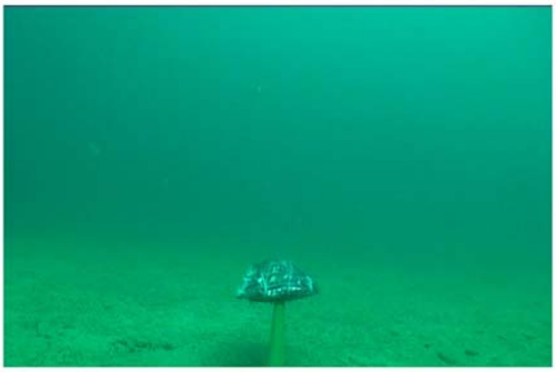
Sydney, OAR location, site 2



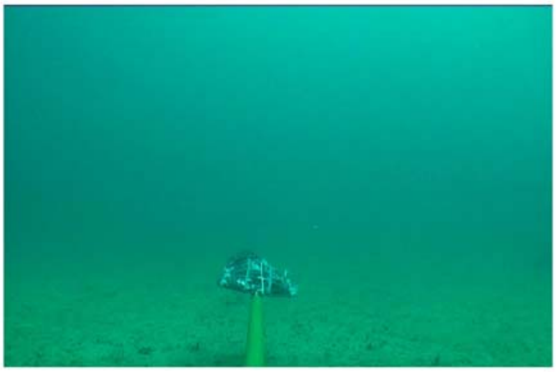
Sydney, OAR location, site 3



Sydney, OAR location, site 4

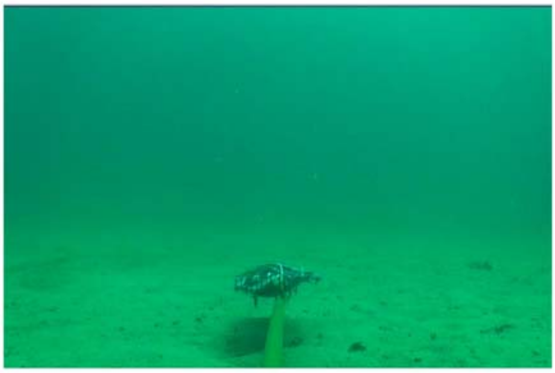


Sydney, OAR control location, site 1



Sydney, OAR control location, site 2

Sydney, OAR control location, site 3

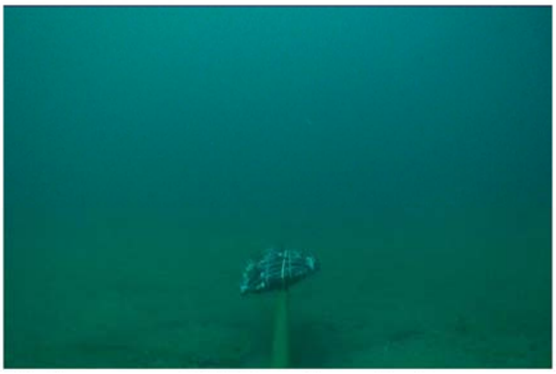


Sydney, OAR control location, site 4

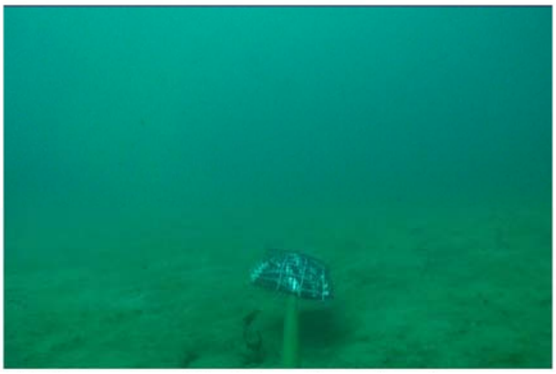
Plate 7: Still photographs taken from BRUVS deployed in the Sydney study region in January 2009.

Wollongong, OAR location, site 1

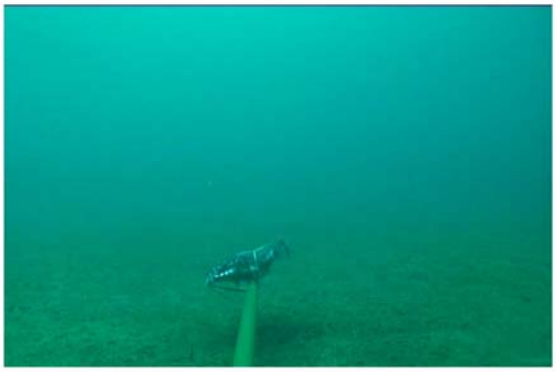
Wollongong, OAR location, site 2



Wollongong, OAR location, site 3

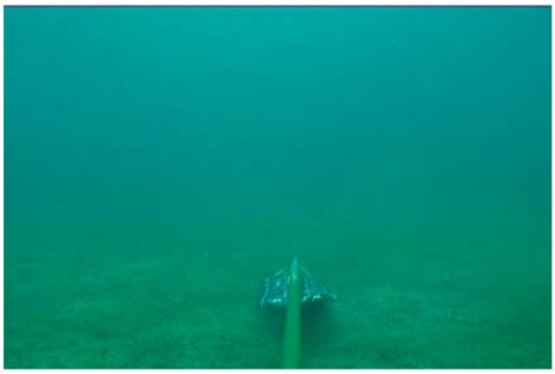


Wollongong, OAR location, site 4

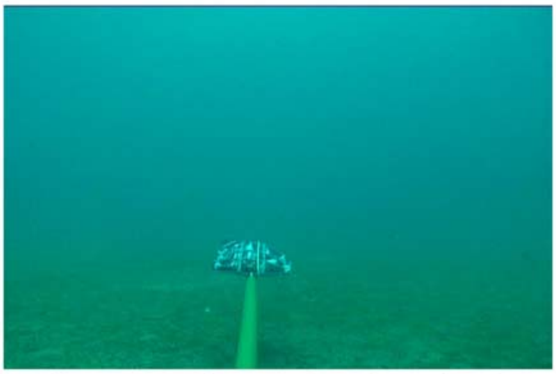


Wollongong, OAR control location, site 1

Wollongong, OAR control location, site 2



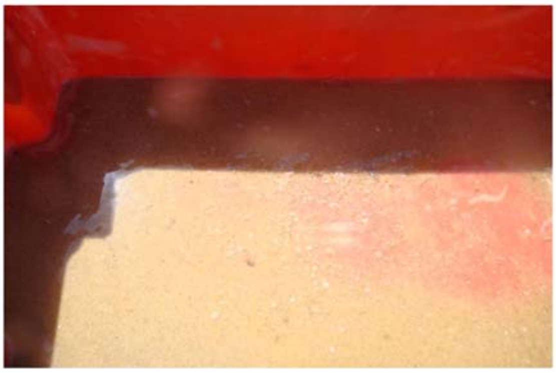
Wollongong, OAR control location, site 3



Wollongong, OAR control location, site 4

Plate 8: Still photographs taken from BRUVS deployed in the Wollongong study region in January 2009.

Newcastle, OAR location, site 1



Newcastle, OAR location, site 2

Newcastle, OAR location, site 3

Newcastle, OAR location, site 4

Newcastle, OAR control location, site 1

Newcastle, OAR control location, site 2

Newcastle, OAR control location, site 3

Newcastle, OAR control location, site 4

Plate 9: Sediment samples collected by Ponar grab in the Newcastle study region during January 2009.

Sydney, OAR location, site 1

Sydney, OAR location, site 2

Sydney, OAR location, site 3

Sydney, OAR location, site 4

Sydney, OAR control location, site 1

Sydney, OAR control location, site 2

Sydney, OAR control location, site 3

Sydney, OAR control location, site 4

Plate 10: Sediment samples collected by Ponar grab in the Sydney study region during January 2009.


Wollongong, OAR location, site 1


Wollongong, OAR location, site 2


Wollongong, OAR location, site 3


Wollongong, OAR location, site 4


Wollongong, OAR control location, site 1


Wollongong, OAR control location, site 2


Wollongong, OAR control location, site 3


Wollongong, OAR control location, site 4

Plate 11: Sediment samples collected by Ponar grab in the Wollongong study region during January 2009.

16 Appendices

Appendix 1: GPS positions (WGS84) of sampling sites and locations for benthos, fish, particle size distribution, water quality and heavy metals taken in January 2009.

Appendix 2: GPS Positions (WGS84) of samples collected for analysis of benthic assemblages, sediment particle size distribution and BRUVS (Baited Remote Underwater Video Stations) deployed at the three study regions (Newcastle, Sydney and Wollongong) in January 2009.

Appendix 3: Summary data for assemblages of benthic macrofauna collected from the Newcastle, Sydney and Wollongong study regions in January 2009.

Appendix 4: Sediment particle size distribution raw data for samples collected from the Newcastle, Sydney and Wollongong study regions in January 2009.

Appendix 5: Assessment of Significance' for threatened species, populations and communities protected under the *TSC* and *FM Act.*

Appendix 6: Risk assessment methodology.

Appendix 7: Raw species data used to determine ranks for the Productivity Susceptibility Analyses (PSA)

Appendix 8: Classification of species exploitation status.

Appendix 1: GPS positions (WGS84) of sampling sites and locations for benthos, fish, particle size distribution, water quality and heavy metals taken in January 2009. (*) indicates location of a Baited Under Water Video Station (BRUVS) only. Exact position fixes for all benthos, fish and particle size distribution samples taken are listed in Table 2.

Study Region	Location	GPS Position (WGS84)	
Newcastle	Potential OAR Unit	Latitude (S)	Longitude (E)
	Site 1 (North)	33°03.543' S	151°43.227' E
	Site 2 (East)	33°03.703' S	151°43.424' E
	Site 3 (South)	33°03.866' S	151°43.230' E
	Site 4 (West)	33°03.706' S	151°43.038' E
	Site 5* (Centre)	33°03.726' S	151°43.208' E
Newcastle	Control Locations	Latitude (S)	Longitude (E)
	Site 1 (North)	33°06.235' S	151°42.355' E
	Site 2 (East)	33°06.366' S	151°42.539' E
	Site 3 (South)	33°06.646' S	151°42.411' E
	Site 4 (West)	33°06.484' S	151°42.119' E
	Site 5* (Centre)	33°06.476' S	151°42.280' E
Sydney	Potential OAR Unit	Latitude (S)	Longitude (E)
	Site 1 (North)	33°50.368' S	151°17.735' E
	Site 2 (East)	33°50.529' S	151°17.929' E
	Site 3 (South)	33°50.692' S	151°17.733' E
	Site 4 (West)	33°50.532' S	151°17.535' E
	Site 5* (Centre)	33°50.510' S	151°17.736' E
Sydney	Control Locations	Latitude (S)	Longitude (E)
	Site 1 (North)	33°52.527' S	151°17.503' E
	Site 2 (East)	33°52.714' S	151°17.658' E
	Site 3 (South)	33°52.903' S	151°17.475' E
	Site 4 (West)	33°52.681' S	151°17.312' E
	Site 5* (Centre)	33°52.673' S	151°17.551' E
Wollongong	Potential OAR Unit	Latitude (S)	Longitude (E)
	Site 1 (North)	34°31.037' S	150°55.308' E
	Site 2 (East)	34°31.200' S	150°55.500' E
	Site 3 (South)	34°31.361' S	150°55.308' E
	Site 4 (West)	34°31.199' S	150°55.110' E
	Site 5* (Centre)	34°31.216' S	150°55.200' E
Wollongong	Control Locations	Latitude (S)	Longitude (E)
	Site 1 (South)	34°27.188' S	150°57.626' E
	Site 2 (West)	34°27.055' S	150°57.415' E
	Site 3 (North)	34°26.920' S	150°57.582' E
	Site 4 (East)	34°27.041' S	150°57.748' E
	Site 5* (Centre)	34°27.029' S	150°57.561' E

Appendix 2: GPS Positions (WGS84) of samples collected for analysis of benthic assemblages, sediment particle size distribution and BRUVS (Baited Remote Underwater Video Stations) deployed at the three study regions (Newcastle, Sydney and Wollongong) in January 2009.

Benthos

Study Area	Location	Site	Rep	Date	GPS Position (WGS84) Latitude (S)	GPS Position (WGS84) Longitude (E)	Comments
Newcastle	OAR	S1	1	13/01/2009	33°03.509	151°43.304	Fine sand,shell grit,polychaete tubes
Newcastle	OAR	S1	2	13/01/2009	33°03.560	151°43.228	Fine sand,shell grit,polychaete tubes
Newcastle	OAR	S1	3	13/01/2009	33°03.544	151°43.230	Fine sand,shell grit,polychaete tubes
Newcastle	OAR	S1	4	13/01/2009	33°03.545	151°43.228	Fine sand,shell grit,polychaete tubes
Newcastle	OAR	S2	1	13/01/2009	33°03.675	151°43.456	Coarser sand and shell grit
Newcastle	OAR	S2	2	13/01/2009	33°03.701	151°43.425	Coarser sand,shell fragments,whole shells
Newcastle	OAR	S2	3	13/01/2009	33°03.758	151°43.361	Coarser sand,shell fragments,whole shells
Newcastle	OAR	S2	4	13/01/2009	33°03.682	151°43.450	Coarser sand,shell fragments,whole shells
Newcastle	OAR	S3	1	13/01/2009	33°03.849	151°43.201	Fine sand,shell grit,polychaete tubes
Newcastle	OAR	S3	2	13/01/2009	33°03.926	151°43.098	Fine sand,shell grit,polychaete tubes
Newcastle	OAR	S3	3	13/01/2009	33°03.814	151°43.302	Fine sand,shell grit,polychaete tubes
Newcastle	OAR	S3	4	13/01/2009	33°03.850	151°43.239	Fine sand,shell grit,polychaete tubes
Newcastle	OAR	S4	1	13/01/2009	33°03.665	151°43.092	Fine sand,shell grit,polychaete tubes
Newcastle	OAR	S4	2	13/01/2009	33°03.692	151°43.054	Fine sand,shell grit,polychaete tubes
Newcastle	OAR	S4	3	13/01/2009	33°03.776	151°42.935	Fine sand,shell grit,polychaete tubes
Newcastle	OAR	S4	4	13/01/2009	33°03.691	151°43.061	Fine sand,shell grit,polychaete tubes
Newcastle	Control	S1	1	13/01/2009	33°06.235	151°42.355	Fine sand,shell grit,polychaete tubes
Newcastle	Control	S1	2	13/01/2009	33°06.293	151°42.318	Fine sand,shell grit,polychaete tubes
Newcastle	Control	S1	3	13/01/2009	33°06.260	151°42.250	Fine sand,shell grit,polychaete tubes
Newcastle	Control	S1	4	13/01/2009	33°06.271	151°42.199	Fine sand,shell grit,polychaete tubes
Newcastle	Control	S2	1	13/01/2009	33°06.366	151°42.539	Fine sand,shell grit,polychaete tubes
Newcastle	Control	S2	2	13/01/2009	33°06.377	151°42.503	Coarser sand and shell grit
Newcastle	Control	S2	3	13/01/2009	33°06.388	151°42.468	Fine sand,shell grit,polychaete tubes
Newcastle	Control	S2	4	13/01/2009	33°06.397	151°42.438	Fine sand,shell grit,polychaete tubes
Newcastle	Control	S3	1	13/01/2009	33°06.646	151°42.411	Fine sand,shell grit,polychaete tubes
Newcastle	Control	S3	2	13/01/2009	33°06.651	151°42.383	Fine sand,shell grit,polychaete tubes
Newcastle	Control	S3	3	13/01/2009	33°06.674	151°42.308	Fine sand,shell grit,polychaete tubes
Newcastle	Control	S3	4	13/01/2009	33°06.680	151°42.290	Fine sand,shell grit,polychaete tubes

Continued

Appendix 2: Continued

Benthos

Study Area	Location	Site	Rep	Date	GPS Position (WGS84) Latitude (S)	Longitude (E)	Comments
Newcastle	Control	S4	1	13/01/2009	33°06.484	151°42.119	Fine sand,shell grit,polychaete tubes
Newcastle	Control	S4	2	13/01/2009	33°06.495	151°42.083	Fine sand,shell grit,polychaete tubes
Newcastle	Control	S4	3	13/01/2009	33°06.513	151°42.025	Fine sand,shell grit,polychaete tubes
Newcastle	Control	S4	4	13/01/2009	33°06.525	151°42.982	Fine sand,shell grit,polychaete tubes

Sediment Particle Size Distribution

Study Region	Location	Site	Rep	Date	GPS Position (WGS84) Latitude (S)	Longitude (E)	Comments
Newcastle	OAR	S1	1	13/01/2009	33°03.568	151°43.221	fine golden sand and shell grit
Newcastle	OAR	S1	2	13/01/2009	33°03.554	151°43.218	fine golden sand and shell grit
Newcastle	OAR	S2	1	13/01/2009	33°03.732	151°43.390	fine golden sand and shell grit
Newcastle	OAR	S2	2	13/01/2009	33°03.714	151°43.408	fine golden sand and shell grit
Newcastle	OAR	S3	1	13/01/2009	33°03.819	151°43.271	fine golden sand and shell grit
Newcastle	OAR	S3	2	13/01/2009	33°03.891	151°43.173	fine golden sand and shell grit
Newcastle	OAR	S4	1	13/01/2009	33°03.726	151°43.007	fine golden sand and shell grit
Newcastle	OAR	S4	2	13/01/2009	33°03.772	151°42.935	fine golden sand and shell grit
Newcastle	Control	S1	1	13/01/2009	33°06.245	151°42.306	fine golden sand and shell grit
Newcastle	Control	S1	2	13/01/2009	33°06.275	151°42.181	fine golden sand and shell grit
Newcastle	Control	S2	1	13/01/2009	33°06.381	151°42.497	fine golden sand and shell grit
Newcastle	Control	S2	2	13/01/2009	33°06.398	151°42.435	fine golden sand and shell grit
Newcastle	Control	S3	1	13/01/2009	33°06.661	151°42.352	fine golden sand and shell grit
Newcastle	Control	S3	2	13/01/2009	33°06.684	151°42.274	fine golden sand and shell grit
Newcastle	Control	S4	1	13/01/2009	33°06.504	151°42.055	fine golden sand and shell grit
Newcastle	Control	S4	2	13/01/2009	33°06.528	151°42.971	fine golden sand and shell grit

Continued

Appendix 2: Continued

Baited Underwater Video Camera Stations (BRUVS)

Study Region	Location	Site	Rep		GPS Position (WGS84)		Comments
					Latitude (S)	Longitude (E)	
Newcastle	OAR	S1	n/a	14/01/2009	33°03.539	151°43.233	Deployed for 2 hrs 13 mins
Newcastle	OAR	S2	n/a	14/01/2009	33°03.706	151°43.432	Deployed for 1 hrs 52 mins
Newcastle	OAR	S3	n/a	14/01/2009	33°03.870	151°43.214	Deployed for 1hr
Newcastle	OAR	S4	n/a	14/01/2009	33°03.712	151°43.035	Deployed for 1 hr 30 mins
Newcastle	OAR	S5	n/a	19/01/2009	33°03.726	151°43.208	Deployed for 1 hr
Newcastle	Control	S1	n/a	14/01/2009	33°06.223	151°42.278	Deployed for 1 hr 5 mins
Newcastle	Control	S2	n/a	14/01/2009	33°06.412	151°42.487	Deployed for 1 hr 5 mins
Newcastle	Control	S3	n/a	19/01/2009	33°06.698	151°42.292	Deployed for 1 hr 5 mins
Newcastle	Control	S4	n/a	19/01/2009	33°06.535	151°42.029	Deployed for 1 hr 5 mins
Newcastle	Control	S5	n/a	19/01/2009	33°06.476	151°42.280	Deployed for 1 hr 3 mins

Benthos

Study Region	Location	Site	Rep	Date	GPS Position (WGS84)		Comments
					Latitude (S)	Longitude (E)	
Sydney	OAR	S1	1	21/01/2009	33°50.328	151°17.751	Fine sand with shell grit and polychaete tubes, slightly muddy
Sydney	OAR	S1	2	21/01/2009	33°50.341	151°17.779	Fine sand with shell grit and polychaete tubes, slightly muddy
Sydney	OAR	S1	3	21/01/2009	33°50.343	151°17.778	Fine sand with shell grit and polychaete tubes, slightly muddy
Sydney	OAR	S1	4	21/01/2009	33°50.353	151°17.787	Fine sand with shell grit and polychaete tubes, slightly muddy
Sydney	OAR	S2	1	21/01/2009	33°50.465	151°17.882	Fine sand with shell grit and shell fragments (small sand eel observed)
Sydney	OAR	S2	2	21/01/2009	33°50.479	151°17.917	Fine sand with shell grit, shell fragments and polychaete tubes
Sydney	OAR	S2	3	21/01/2009	33°50.486	151°17.956	Fine sand with shell grit, shell fragments and polychaete tubes
Sydney	OAR	S2	4	21/01/2009	33°50.491	151°17.989	Fine sand with shell grit, shell fragments and polychaete tubes
Sydney	OAR	S3	1	21/01/2009	33°50.669	151°17.700	Fine sand with polychaete tubes
Sydney	OAR	S3	2	21/01/2009	33°50.680	151°17.702	Fine sand with polychaete tubes
Sydney	OAR	S3	3	21/01/2009	33°50.681	151°17.716	Fine sand with polychaete tubes
Sydney	OAR	S3	4	21/01/2009	33°50.687	151°17.722	Fine sand with polychaete tubes
Sydney	OAR	S4	1	21/01/2009	33°50.514	151°17.998	Fine sand with polychaete tubes
Sydney	OAR	S4	2	21/01/2009	33°50.513	151°17.506	Fine sand with polychaete tubes
Sydney	OAR	S4	3	21/01/2009	33°50.513	151°17.504	Fine sand with shell grit and polychaete tubes

Continued

Appendix 2: Continued

Benthos							
Study Region	Location	Site	Rep	Date	GPS Position (WGS84)		Comments
					Latitude (S)	Longitude (E)	
Sydney	OAR	S4	4	21/01/2009	33°50.515	151°17.504	Fine sand with shell grit and polychaete tubes
Sydney	Control	S1	1	21/01/2009	33°52.527	151°17.503	Fine sand with shell grit and polychaete tubes
Sydney	Control	S1	2	21/01/2009	33°52.543	151°17.502	Fine sand with shell grit and polychaete tubes
Sydney	Control	S1	3	21/01/2009	33°52.555	151°17.501	Fine sand with shell grit and polychaete tubes
Sydney	Control	S1	4	21/01/2009	33°52.562	151°17.501	Fine sand with shell grit and polychaete tubes
Sydney	Control	S2	1	21/01/2009	33°52.714	151°17.658	Fine sand with shell grit and polychaete tubes
Sydney	Control	S2	2	21/01/2009	33°52.730	151°17.661	Fine sand with shell grit and polychaete tubes
Sydney	Control	S2	3	21/01/2009	33°52.748	151°17.664	Fine sand with shell grit and polychaete tubes
Sydney	Control	S2	4	21/01/2009	33°52.786	151°17.694	Fine sand with shell grit and polychaete tubes
Sydney	Control	S3	1	21/01/2009	33°52.903	151°17.475	Fine sand, some mud, and polychaete tubes, *Caulerpa* sp. observed
Sydney	Control	S3	2	21/01/2009	33°52.917	151°17.482	Fine sand, some mud, and polychaete tubes
Sydney	Control	S3	3	21/01/2009	33°52.930	151°17.490	Fine sand, some mud, and polychaete tubes
Sydney	Control	S3	4	21/01/2009	33°52.953	151°17.509	Fine sand, some mud, and polychaete tubes
Sydney	Control	S4	1	21/01/2009	33°52.681	151°17.312	Fine sand occasional polychaete tubes
Sydney	Control	S4	2	21/01/2009	33°52.693	151°17.313	Fine sand occasional polychaete tubes
Sydney	Control	S4	3	21/01/2009	33°52.714	151°17.317	Fine sand occasional polychaete tubes
Sydney	Control	S4	4	21/01/2009	33°52.736	151°17.326	Fine sand occasional polychaete tubes

Sediment Particle Size Distribution							
Study Region	Location	Site	Rep	Date	GPS Position (WGS84)		Comments
					Latitude (S)	Longitude (E)	
Sydney	OAR	S1	1	21/01/2009	33°50.354	151°17.797	fine sand, shell grit, some large shell fragments
Sydney	OAR	S1	2	21/01/2009	33°50.356	151°17.798	fine sand, shell grit, some large shell fragments
Sydney	OAR	S2	1	21/01/2009	33°50.497	151°18.027	fine sand and shell grit
Sydney	OAR	S2	2	21/01/2009	33°50.498	151°18.032	fine sand and shell grit
Sydney	OAR	S3	1	21/01/2009	33°50.691	151°17.730	fine sand and shell grit
Sydney	OAR	S3	2	21/01/2009	33°50.695	151°17.736	fine sand and shell grit
Sydney	OAR	S4	1	21/01/2009	33°50.695	151°17.739	fine sand, shell grit, polychaete worms observed
Sydney	OAR	S4	2	21/01/2009	33°50.524	151°17.511	ophiuroids, sipunculids, polychatetes, egg mass observed
Sydney	Control	S1	1	21/01/2009	33°52.564	151°17.503	fine sand, some shell grit, ophiuoroids, polychaete tubes

Continued

Appendix 2: Continued

Sediment Particle Size Distribution

Study Region	Location	Site	Rep	Date	GPS Position (WGS84) Latitude (S)	Longitude (E)	Comments
Sydney	Control	S1	2	21/01/2009	33°52.566	151°17.563	fine sand, some shell grit, polychaete tubes
Sydney	Control	S2	1	21/01/2009	33°52.789	151°17.695	fine sand, some shell grit, polychaete tubes
Sydney	Control	S2	2	21/01/2009	33°52.802	151°17.704	fine sand, some shell grit, polychaete tubes
Sydney	Control	S3	1	21/01/2009	33°52.992	151°17.545	fine sand, occasional polychaete tubes
Sydney	Control	S3	2	21/01/2009	33°52.996	151°17.546	fine sand, occasional polychaete tubes
Sydney	Control	S4	1	21/01/2009	33°52.752	151°17.333	fine sand, occasional polychaete tubes
Sydney	Control	S4	2	21/01/2009	33°52.758	151°17.337	fine sand

Baited Underwater Video Camera Stations (BRUVS)

Study Region	Location	Site	Rep	Date	GPS Position (WGS84) Latitude (S)	Longitude (E)	Comments
Sydney	OAR	S1	n/a	21/01/2009	33°50.335	151°17.715	Deployed for 1 hr 44 mins
Sydney	OAR	S2	n/a	21/01/2009	33°50.522	151°17.930	Deployed for 1 hr 25 mins
Sydney	OAR	S3	n/a	21/01/2009	33°50.698	151°17.741	Deployed for 1 hr 09 mins
Sydney	OAR	S4	n/a	21/01/2009	33°50.534	151°17.551	Deployed for 1 hr
Sydney	OAR	S5	n/a	21/01/2009	33°50.510	151°17.736	Deployed for 1 hr 10 mins
Sydney	Control	S1	n/a	21/01/2009	33°52.509	151°17.533	Deployed for 1 hr 31 mins
Sydney	Control	S2	n/a	21/01/2009	33°52.751	151°17.650	Deployed for 1 hr 15 mins
Sydney	Control	S3	n/a	21/01/2009	33°52.926	151°17.484	Deployed for 1 hr 38 mins
Sydney	Control	S4	n/a	21/01/2009	33°52.758	151°17.346	Deployed for 1 hr 20 mins
Sydney	Control	S5	n/a	21/01/2009	33°52.673	151°17.551	Deployed for 1 hr 6 mins

Continued

Appendix 2: Continued

Benthos							
Study Region	Location	Site	Rep	Date	GPS Position (WGS84)		Comments
					Latitude (S)	Longitude (E)	
Wollongong	OAR	S1	1	23/01/2009	34°31.032	150°55.305	Fine brown sand, occasional pockets of anoxic mud, polychaete tubes
Wollongong	OAR	S1	2	23/01/2009	34°31.009	150°55.297	Fine brown sand, occasional pockets of anoxic mud, polychaete tubes
Wollongong	OAR	S1	3	23/01/2009	34°31.012	150°55.294	Fine brown sand, occasional pockets of anoxic mud, polychaete tubes
Wollongong	OAR	S1	4	23/01/2009	34°30.982	150°55.315	Fine brown sand
Wollongong	OAR	S2	1	23/01/2009	34°31.224	150°55.551	Fine - slightly coarse brown sand
Wollongong	OAR	S2	2	23/01/2009	34°31.198	150°55.559	Fine - slightly coarse brown sand
Wollongong	OAR	S2	3	23/01/2009	34°31.177	150°55.565	Fine - slightly coarse brown sand
Wollongong	OAR	S2	4	23/01/2009	34°31.150	150°55.573	Fine - slightly coarse brown sand

Benthos							
Study Region	Location	Site	Rep	Date	GPS Position (WGS84)		Comments
					Latitude (S)	Longitude (E)	
Wollongong	OAR	S3	1	23/01/2009	34°31.374	150°55.295	V. fine sand, some silt, polychaete tubes
Wollongong	OAR	S3	2	23/01/2009	34°31.346	150°55.303	V. fine sand, some silt, polychaete tubes
Wollongong	OAR	S3	3	23/01/2009	34°31.303	150°55.313	Fine - slightly coarse brown sand, occasional pockets of anoxic mud
Wollongong	OAR	S3	4	23/01/2009	34°31.371	150°55.312	Fine - slightly coarse brown sand, occasional pockets of anoxic mud
Wollongong	OAR	S4	1	23/01/2009	34°31.223	150°55.068	Fine - slightly coarse brown sand, occasional pockets of anoxic mud
Wollongong	OAR	S4	2	23/01/2009	34°31.216	150°55.070	Fine brown sand, some shell grit. Ophiuroids and nut crabs observed
Wollongong	OAR	S4	3	23/01/2009	34°31.170	150°55.092	Fine brown sand, some shell grit.
Wollongong	OAR	S4	4	23/01/2009	34°31.145	150°55.101	Fine brown sand, some shell grit.
Wollongong	Control	S1	1	23/01/2009	34°27.188	150°57.626	Fine brown sand, polychaete tubes, some shell grit
Wollongong	Control	S1	2	23/01/2009	34°27.185	150°57.626	Fine brown sand, some silt, polychaete tubes
Wollongong	Control	S1	3	23/01/2009	34°27.148	150°57.610	Fine - slightly coarse brown sand
Wollongong	Control	S1	4	23/01/2009	34°27.144	150°57.610	Fine - slightly coarse brown sand
Wollongong	Control	S2	1	23/01/2009	34°27.055	150°57.415	Fine brown sand
Wollongong	Control	S2	2	23/01/2009	34°27.045	150°57.407	Fine brown sand
Wollongong	Control	S2	3	23/01/2009	34°27.029	150°57.400	Fine brown sand, polychaete tubes
Wollongong	Control	S2	4	23/01/2009	34°27.002	150°57.389	Fine brown sand
Wollongong	Control	S3	1	23/01/2009	34°26.920	150°57.582	Fine brown sand, some silt, polychaete tubes
Wollongong	Control	S3	2	23/01/2009	34°26.917	150°57.580	Fine brown sand, some silt, polychaete tubes

Continued

Appendix 2: Continued

Benthos							
Study Region	Location	Site	Rep	Date	GPS Position (WGS84)		Comments
					Latitude (S)	Longitude (E)	
Wollongong	Control	S3	3	23/01/2009	34°26.906	150°57.571	Fine brown sand, some silt, polychaete tubes and ophiuriods
Wollongong	Control	S3	4	23/01/2009	34°26.889	150°57.562	Fine brown sand, some silt, polychaete tubes and ophiuriods
Wollongong	Control	S4	1	23/01/2009	34°27.041	150°57.748	Fine - slightly coarse brown sand, polychaetes and tubes
Wollongong	Control	S4	2	23/01/2009	34°27.032	150°57.740	Fine - slightly coarse brown sand
Wollongong	Control	S4	3	23/01/2009	34°27.017	150°57.729	Fine - slightly coarse brown sand, heart urchin
Wollongong	Control	S4	4	23/01/2009	34°27.006	150°57.719	Fine - slightly coarse brown sand

Sediment Particle Size Distribution							
Study Region	Location	Site	Rep	Date	GPS Position (WGS84)		Comments
					Latitude (S)	Longitude (E)	
Wollongong	OAR	S1	1	23/01/2009	34°31.000	150°55.313	Fine brown sand, some shell grit
Wollongong	OAR	S1	2	23/01/2009	34°30.907	150°55.329	Fine brown sand, some shell grit, hermit crabs
Wollongong	OAR	S2	1	23/01/2009	34°31.232	150°55.467	Fine brown sand
Wollongong	OAR	S2	2	23/01/2009	34°31.191	150°55.478	Fine brown sand
Wollongong	OAR	S3	1	23/01/2009	34°31.285	150°55.365	Fine brown sand
Wollongong	OAR	S3	2	23/01/2009	34°31.179	150°55.413	Fine brown sand
Wollongong	OAR	S4	1	23/01/2009	34°31.070	150°55.117	Fine brown sand, occasional pockets of anoxic mud
Wollongong	OAR	S4	2	23/01/2009	34°27.067	150°55.117	Fine brown sand
Wollongong	Control	S1	1	23/01/2009	34°27.142	150°57.606	Fine - slightly coarse brown sand, polychaete tubes
Wollongong	Control	S1	2	23/01/2009	34°27.136	150°57.604	Fine - slightly coarse brown sand, polychaete tubes
Wollongong	Control	S2	1	23/01/2009	34°26.991	150°57.387	Fine - slightly coarse brown sand, polychaete tubes
Wollongong	Control	S2	2	23/01/2009	34°26.982	150°57.381	Fine - slightly coarse brown sand, polychaete tubes
Wollongong	Control	S3	1	23/01/2009	34°26.877	150°57.550	Fine brown sand, polychaete tubes
Wollongong	Control	S3	2	23/01/2009	34°26.862	150°57.536	Fine brown sand, polychaete tubes
Wollongong	Control	S4	1	23/01/2009	34°26.995	150°57.711	Fine - slightly coarse brown sand
Wollongong	Control	S4	2	23/01/2009	34°26.975	150°57.693	Fine - slightly coarse brown sand, heart urchin

Continued

Appendix 2: Continued

Baited Underwater Video Camera Stations (BRUVS)							
Study Region	Location	Site	Rep	Date	GPS Position (WGS84) Latitude (S)	GPS Position (WGS84) Longitude (E)	Comments
Wollongong	OAR	S1	n/a	23/01/2009	34°31.050	150°55.300	Deployed for 1 hr 52 mins
Wollongong	OAR	S2	n/a	23/01/2009	34°31.214	150°55.519	Deployed for 1 hr 36 mins
Wollongong	OAR	S3	n/a	23/01/2009	34°31.354	150°55.331	Deployed for 1 hr 04 mins
Wollongong	OAR	S4	n/a	23/01/2009	34°31.182	150°55.119	Deployed for 1 hr 11 mins
Wollongong	OAR	S5	n/a	23/01/2009	34°31.216	150°55.200	Deployed for 1 hr 05 mins
Wollongong	Control	S1	n/a	23/01/2009	34°27.151	150°57.591	Deployed for 1 hr 47 mins
Wollongong	Control	S2	n/a	23/01/2009	34°27.089	150°57.382	Deployed for 1 hr 17 mins
Wollongong	Control	S3	n/a	23/01/2009	34°26.906	150°57.573	Deployed for 1 hr 14 mins
Wollongong	Control	S4	n/a	23/01/2009	34°27.017	150°57.737	Deployed for 1 hr 07 mins
Wollongong	Control	S5	n/a	23/01/2009	34°27.029	150°57.561	Deployed for 1 hr 05 mins

Appendix 3: Summary data for assemblages of benthic macrofauna collected from the Newcastle, Sydney and Wollongong study regions in January 2009. (OAR = proposed OAR location, CON = control location).

Newcastle study region	OAR		CON		Total /OAR & CON	
Summary statistics based on taxa	Total	Ave	Total	Ave	Total	Ave
Total number of taxa	498.0	31.1	497.0	31.1	**31.1**	**0.9**
Polychaeta	112.0	7.0	97.0	6.1	6.5	0.3
Crustacea	260.0	16.3	264.0	16.5	16.4	0.6
Mollusca	63.0	3.9	63.0	3.9	3.9	0.3
Echinoderma	11.0	0.7	9.0	0.6	0.6	0.1
Other worm phyla	21.0	1.3	30.0	1.9	1.6	0.2
Other phlya	31.0	1.9	34.0	2.1	2.0	0.2
Summary statistics based on abundance	Total	Ave	Total	Ave	Total	Ave
Total number of individuals	2312.0	144.5	1561.0	97.6	**121.0**	**11.5**
Polychaeta	1022.0	63.9	298.0	18.6	41.3	9.0
Crustacea	1114.0	69.6	898.0	56.1	62.9	3.6
Mollusca	95.0	5.9	113.0	7.1	6.5	0.5
Echinoderma	15.0	0.9	11.0	0.7	0.8	0.2
Other worm phyla	24.0	1.5	162.0	10.1	5.8	1.9
Other phlya	42.0	2.6	79.0	4.9	3.8	0.9

Sydney study region	OAR		CON		Total /OAR & CON	
Summary statistics based on taxa	Total	Ave	Total	Ave	Total	Ave
Total number of taxa	386.0	24.1	443.0	27.7	**25.9**	**1.0**
Polychaeta	105.0	6.6	108.0	6.8	6.7	0.5
Crustacea	164.0	10.3	198.0	12.4	11.3	0.5
Mollusca	73.0	4.6	83.0	5.2	4.9	0.3
Echinoderma	15.0	0.9	18.0	1.1	1.0	0.1
Other worm phyla	15.0	0.9	20.0	1.3	1.1	0.2
Other phlya	14.0	0.9	16.0	1.0	0.9	0.2
Summary statistics based on abundance	Total	Ave	Total	Ave	Total	Ave
Total number of individuals	1546.0	96.6	2568.0	160.5	**128.6**	**10.8**
Polychaeta	312.0	19.5	295.0	18.4	19.0	2.7
Crustacea	974.0	60.9	2016.0	126.0	93.4	10.1
Mollusca	181.0	11.3	179.0	11.2	11.3	0.9
Echinoderma	18.0	1.1	28.0	1.8	1.4	0.2
Other worm phyla	40.0	2.5	31.0	1.9	2.2	0.4
Other phlya	21.0	1.3	19.0	1.2	1.3	0.3

Continued

Appendix 3: Continued

Wollongong study region	OAR		CON		Total /OAR & CON	
Summary statistics based on taxa	Total	Ave	Total	Ave	Total	Ave
Total number of taxa	463.0	30.9	532.0	33.3	**32.3**	**0.8**
Polychaeta	86.0	5.7	111.0	6.9	6.4	0.4
Crustacea	229.0	15.3	258.0	16.1	15.7	0.4
Mollusca	91.0	6.1	107.0	6.7	6.5	0.4
Echinoderma	13.0	0.9	17.0	1.1	0.9	0.1
Other worm phyla	9.0	0.6	14.0	0.9	0.8	0.1
Other phlya	26.0	1.7	25.0	1.6	1.7	0.2
Summary statistics based on abundance	Total	Ave	Total	Ave	Total	Ave
Total number of individuals	1720.0	114.7	2943.0	183.9	**148.5**	**11.2**
Polychaeta	326.0	21.7	1125.0	70.3	46.2	7.4
Crustacea	1216.0	81.1	1502.0	93.9	86.0	7.0
Mollusca	165.0	11.0	196.0	12.3	11.9	0.9
Echinoderma	20.0	1.3	27.0	1.7	1.5	0.3
Other worm phyla	16.0	1.1	33.0	2.1	1.6	0.4
Other phlya	36.0	2.4	60.0	3.8	3.2	1.0

Appendix 4:

Sediment particle size distribution raw data for samples collected from the Newcastle, Sydney and Wollongong study regions in January 2009.

Certificate of Analysis

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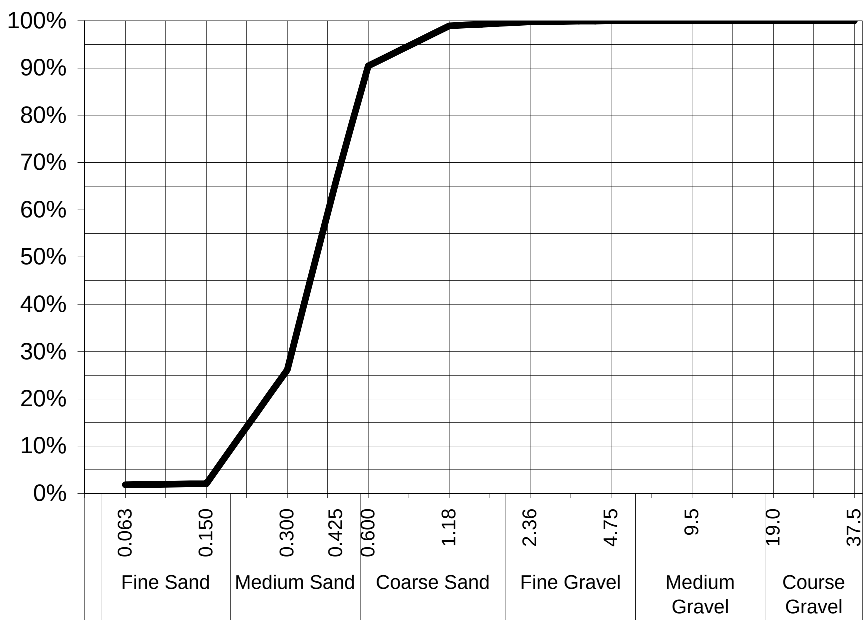
ALS Environmental

Newcastle, NSW

CLIENT:	Kate Reeds	**DATE REPORTED:**	29-Jan-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	15-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0900610-009 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	N IMP S1 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	99%
0.600	90%
0.425	66%
0.300	26%
0.150	2%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 27-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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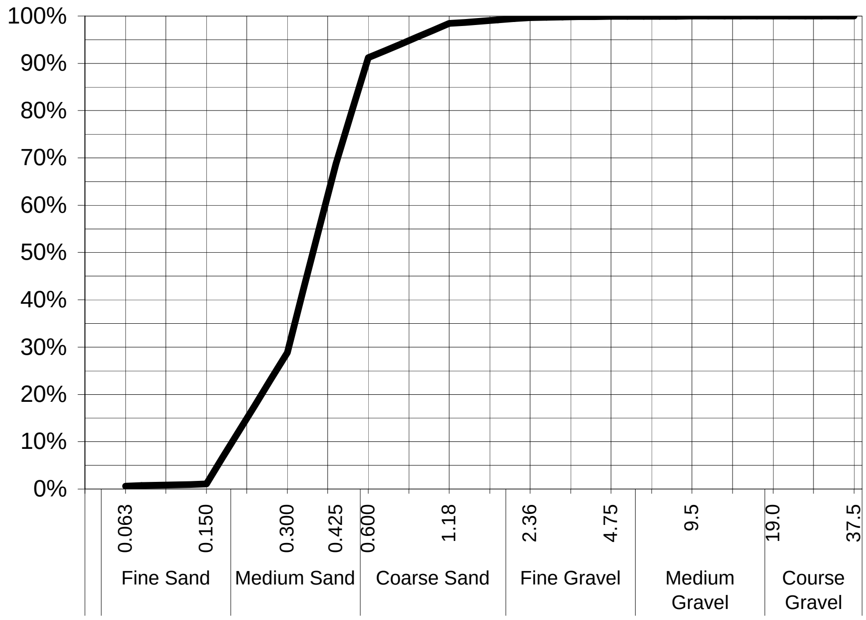
CLIENT:	Kate Reeds	**DATE REPORTED:**	29-Jan-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	15-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0900610-010 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	N IMP S1 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	98%
0.600	91%
0.425	69%
0.300	29%
0.150	1%
0.063	1%

Samples analysed as received.

Sample Comments:

Analysed: 27-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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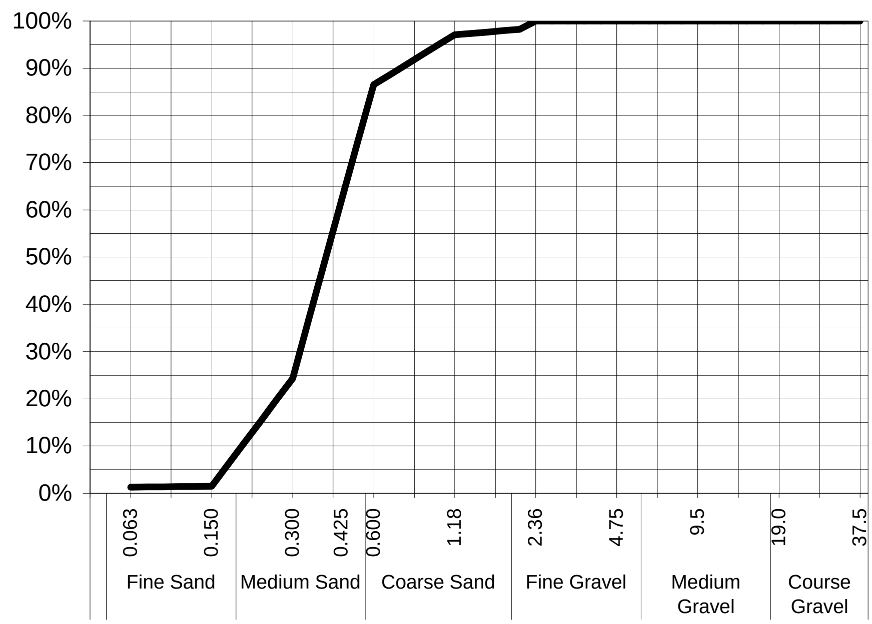
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0900610-011 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	N IMP S2 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	97%
0.600	87%
0.425	62%
0.300	24%
0.150	1%
0.063	1%

Samples analysed as received.

Sample Comments:

Analysed: 27-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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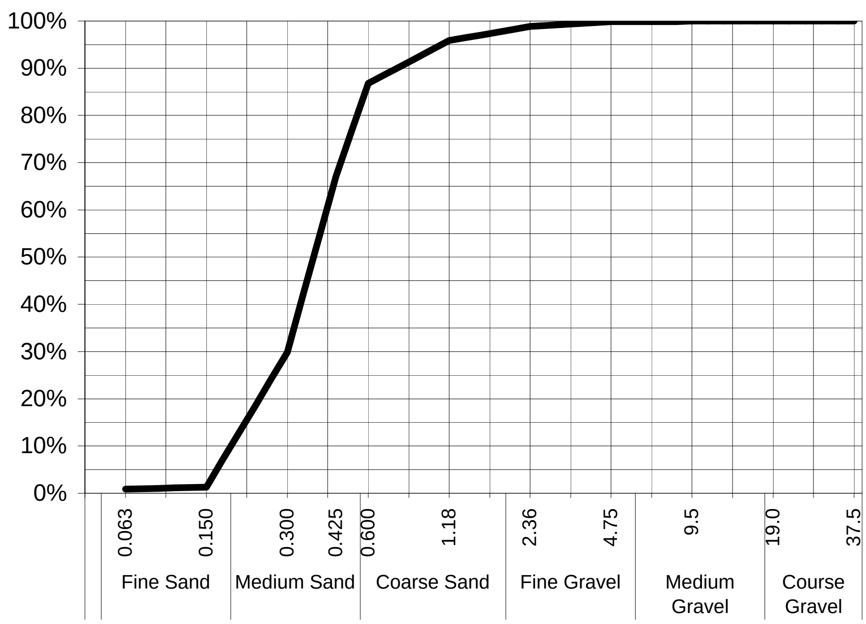
CLIENT:	Kate Reeds	**DATE REPORTED:**	29-Jan-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	15-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0900610-012 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	N IMP S2 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	99%
1.18	96%
0.600	87%
0.425	67%
0.300	30%
0.150	1%
0.063	1%

Samples analysed as received.

Sample Comments:

Analysed: 27-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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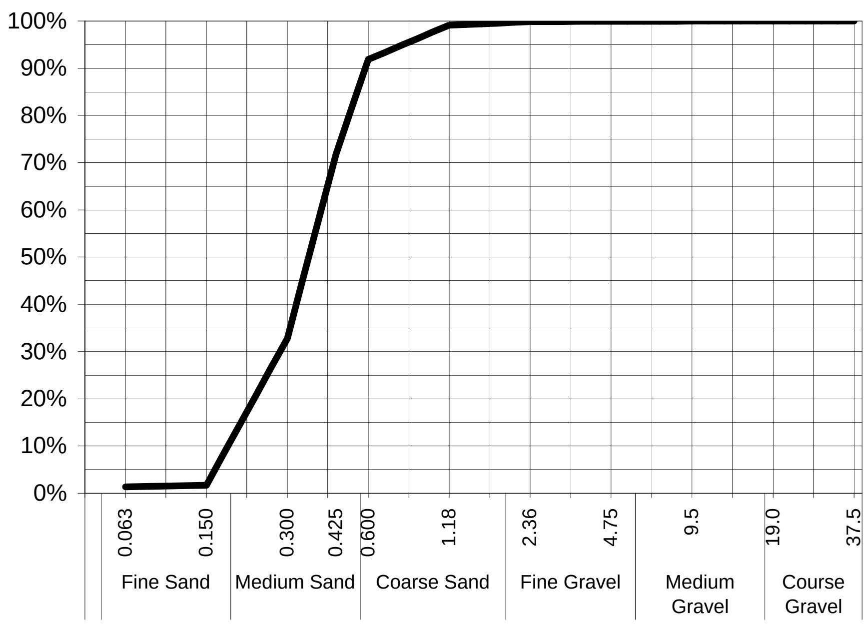
CLIENT:	Kate Reeds	**DATE REPORTED:**	29-Jan-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	15-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0900610-013 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	N IMP S3 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	99%
0.600	92%
0.425	72%
0.300	33%
0.150	2%
0.063	1%

Samples analysed as received.

Sample Comments:

Analysed: 27-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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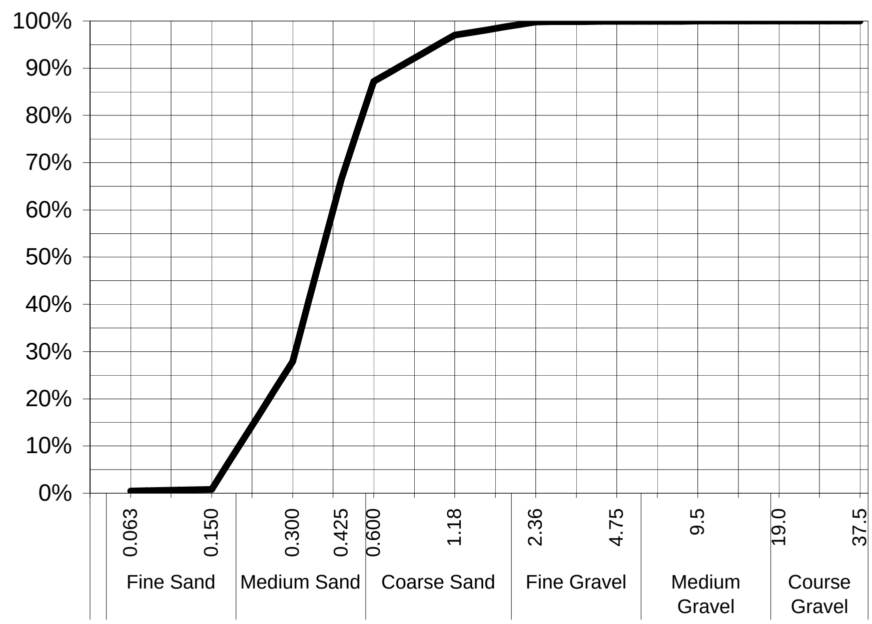
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	15-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0900610-014 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	N IMP S3 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	97%
0.600	87%
0.425	66%
0.300	28%
0.150	1%
0.063	1%

Samples analysed as received.

Sample Comments:

Analysed: 27-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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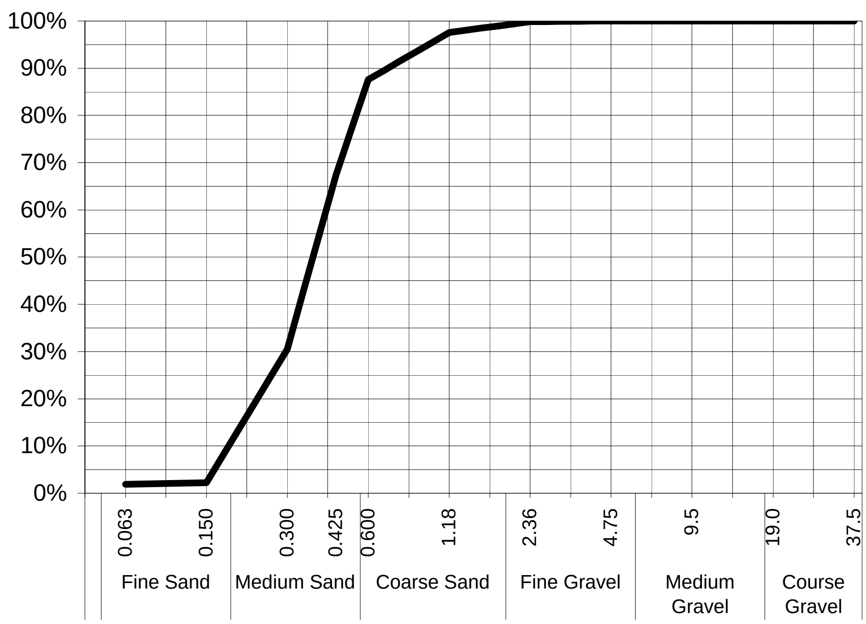
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	15-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0900610-015 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	N IMP S4 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	98%
0.600	88%
0.425	67%
0.300	31%
0.150	2%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 27-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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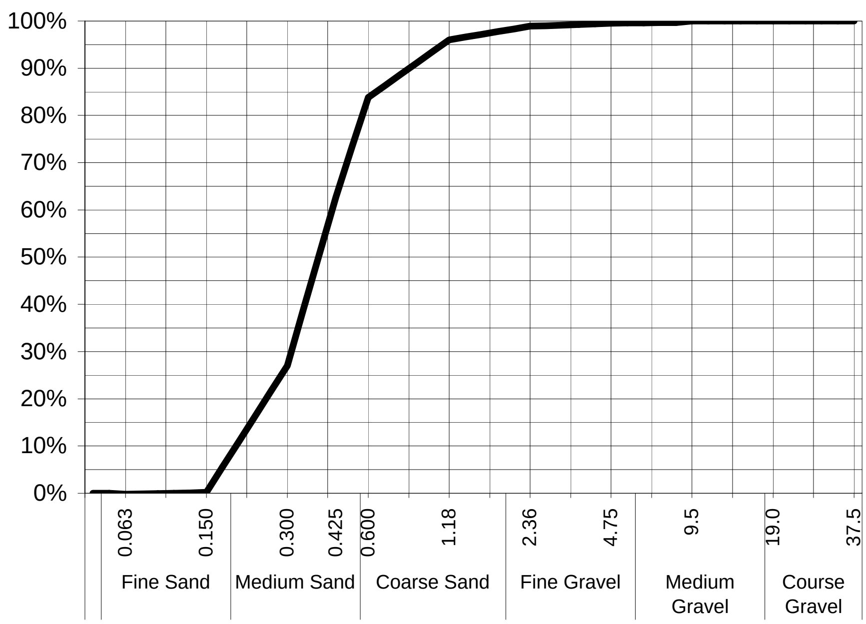
ALS Environmental

Newcastle, NSW

CLIENT:	Kate Reeds	**DATE REPORTED:**	29-Jan-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	15-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0900610-016 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	N IMP S4 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	99%
1.18	96%
0.600	84%
0.425	63%
0.300	27%
0.150	0%
0.063	0%

Samples analysed as received.

Sample Comments:	0	**Analysed:**	27-Jan-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & shell		
Test Method:	AS1289.3.6.1		

NATA Accreditation: 825 Site: Newcastle
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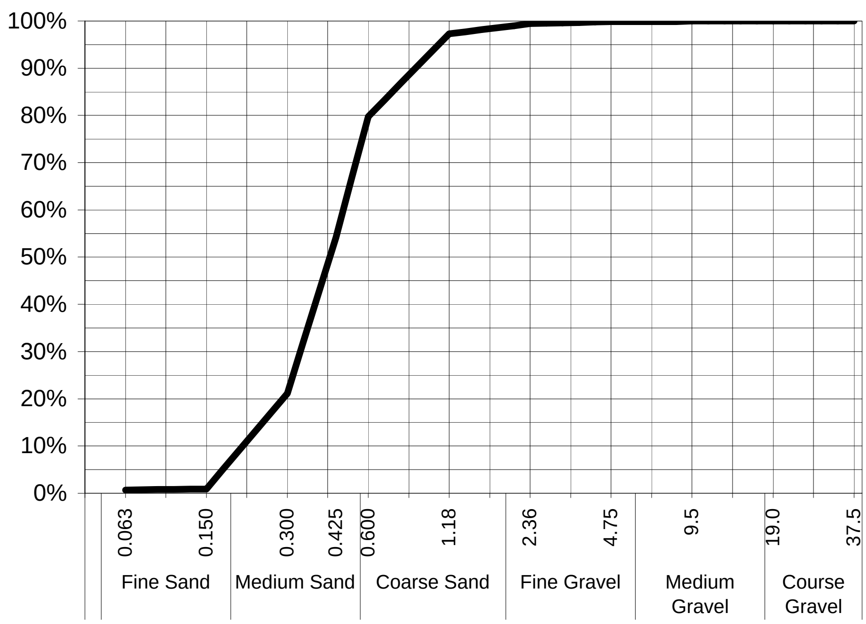
Newcastle, NSW

CLIENT:	Kate Reeds	**DATE REPORTED:**	29-Jan-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	15-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0900610-017 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	N CON S1 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	99%
1.18	97%
0.600	80%
0.425	54%
0.300	21%
0.150	1%
0.063	1%

Samples analysed as received.

Sample Comments:

Analysed: 27-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand & shell

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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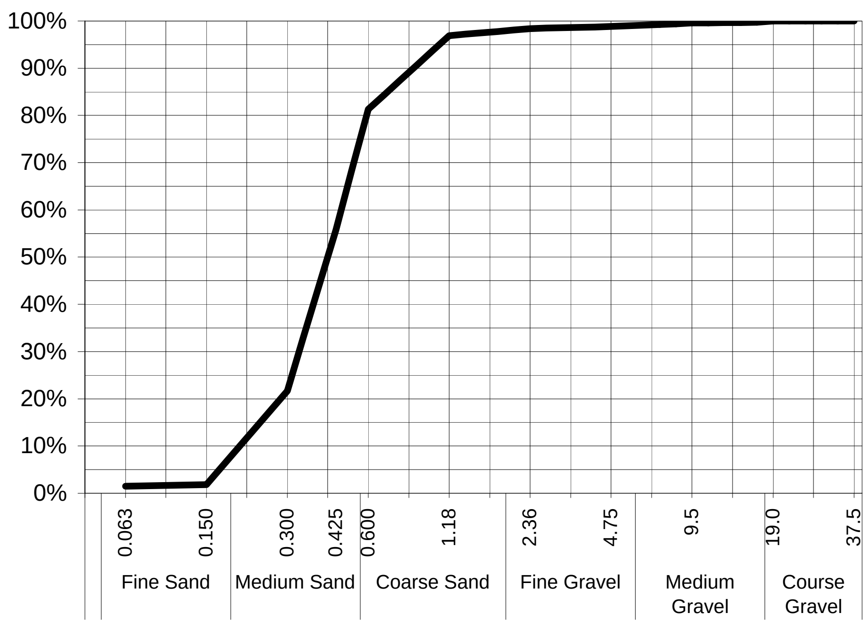
CLIENT:	Kate Reeds	**DATE REPORTED:**	29-Jan-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	15-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0900610-018 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	N CON S1 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	99%
2.36	98%
1.18	97%
0.600	81%
0.425	56%
0.300	22%
0.150	2%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 27-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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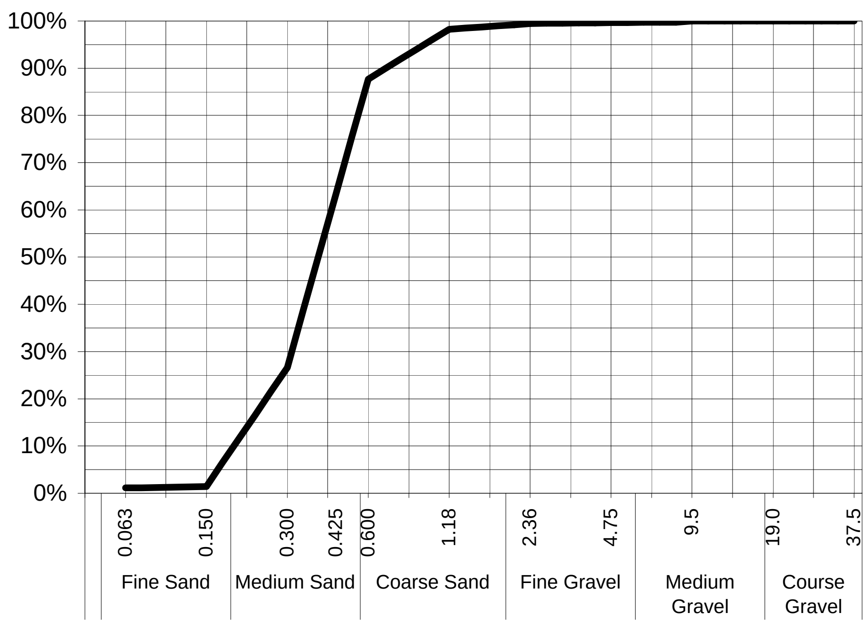
CLIENT:	Kate Reeds	**DATE REPORTED:**	29-Jan-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	15-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0900610-019 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	N CON S2 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	99%
1.18	98%
0.600	88%
0.425	63%
0.300	27%
0.150	1%
0.063	1%

Samples analysed as received.

Sample Comments:

Analysed: 27-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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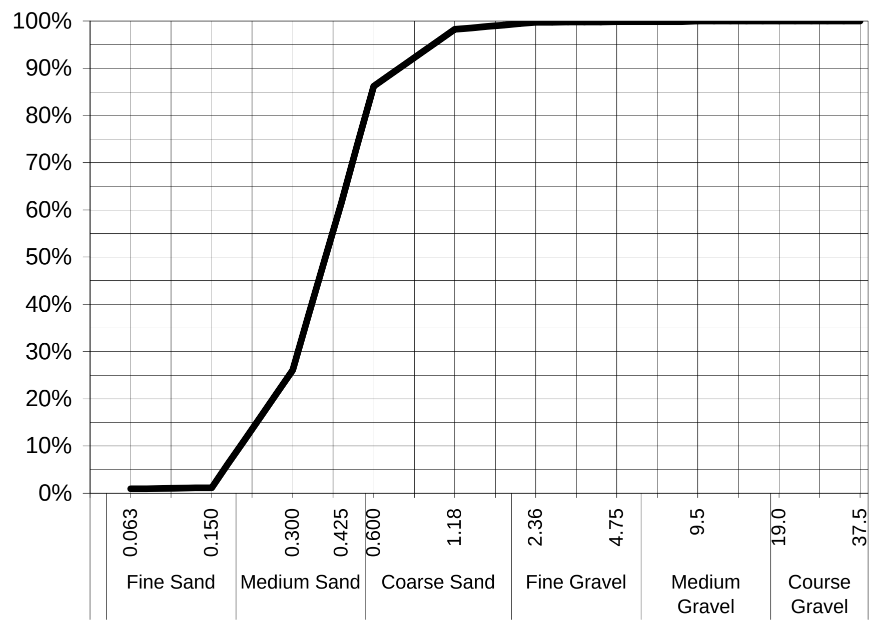
CLIENT:	Kate Reeds	**DATE REPORTED:**	29-Jan-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	15-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0900610-020 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	N CON S2 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	98%
0.600	86%
0.425	62%
0.300	26%
0.150	1%
0.063	1%

Samples analysed as received.

Sample Comments:

Analysed: 27-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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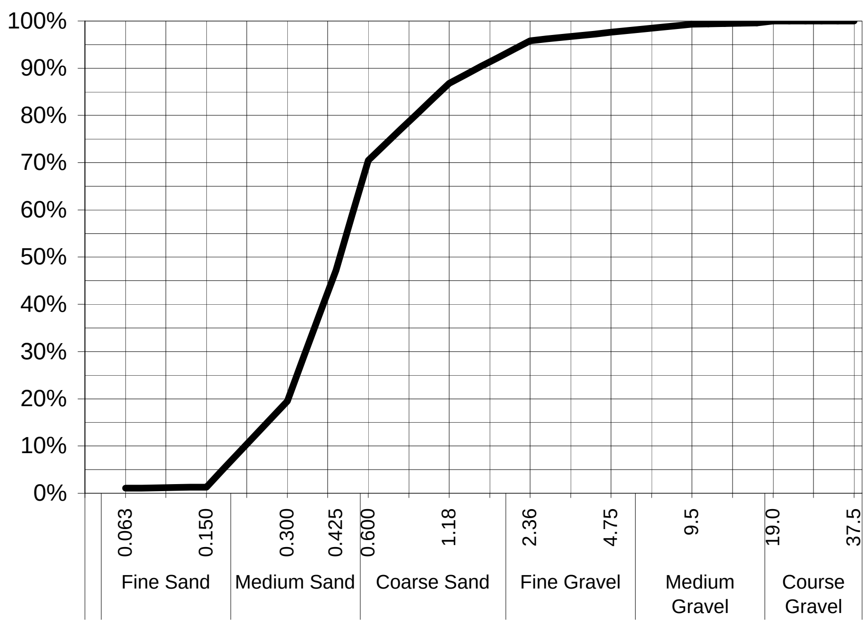
CLIENT:	Kate Reeds	**DATE REPORTED:**	29-Jan-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	15-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0900610-021 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	N CON S3 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	99%
4.75	98%
2.36	96%
1.18	87%
0.600	71%
0.425	47%
0.300	19%
0.150	1%
0.063	1%

Samples analysed as received.

Sample Comments:

Analysed: 27-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand & shell

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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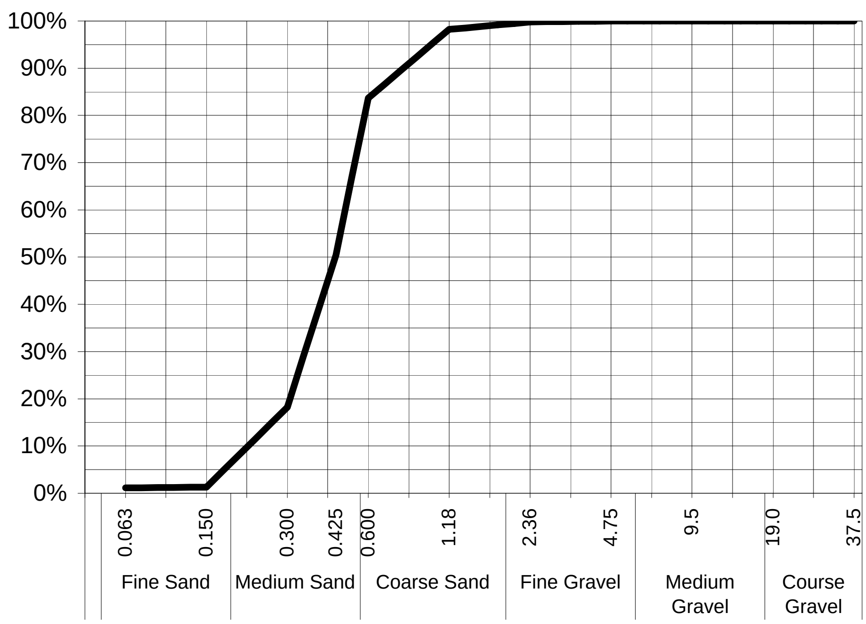
CLIENT:	Kate Reeds	**DATE REPORTED:**	29-Jan-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	15-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0900610-022 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	N CON S3 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	98%
0.600	84%
0.425	50%
0.300	18%
0.150	1%
0.063	1%

Samples analysed as received.

Sample Comments:

Analysed: 27-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand & shell

Test Method: AS1289.3.6.1

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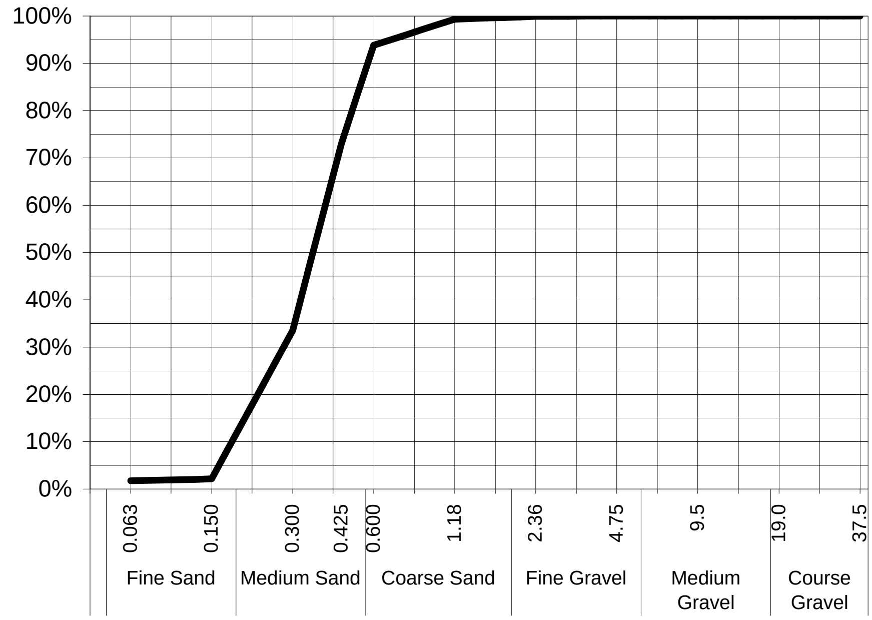
CLIENT:	Kate Reeds	**DATE REPORTED:**	29-Jan-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	15-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0900610-023 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	N CON S4 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	99%
0.600	94%
0.425	73%
0.300	34%
0.150	2%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 27-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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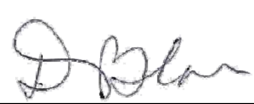

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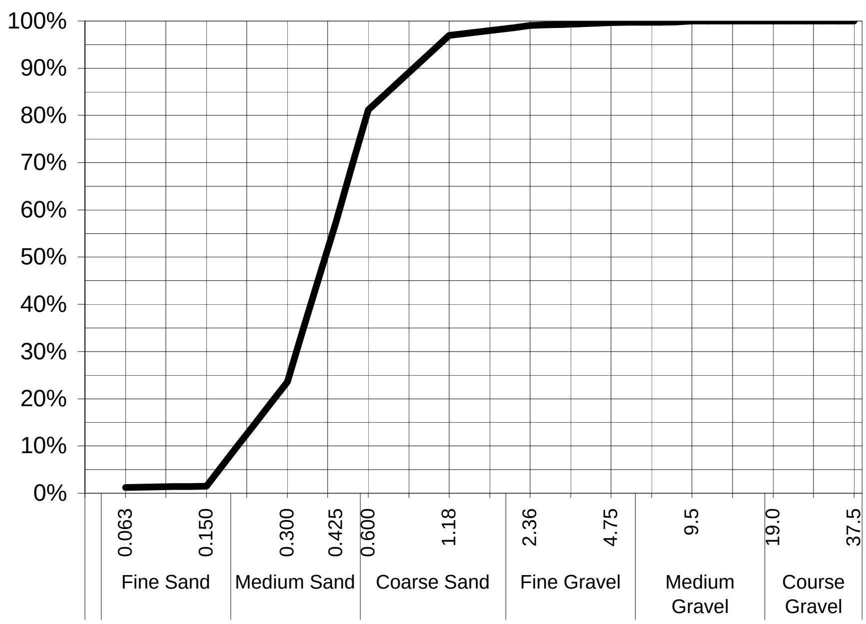
CLIENT:	Kate Reeds	**DATE REPORTED:**	29-Jan-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	15-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0900610-024 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	N CON S4 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	99%
1.18	97%
0.600	81%
0.425	57%
0.300	24%
0.150	1%
0.063	1%

Samples analysed as received.

Sample Comments:

Analysed: 27-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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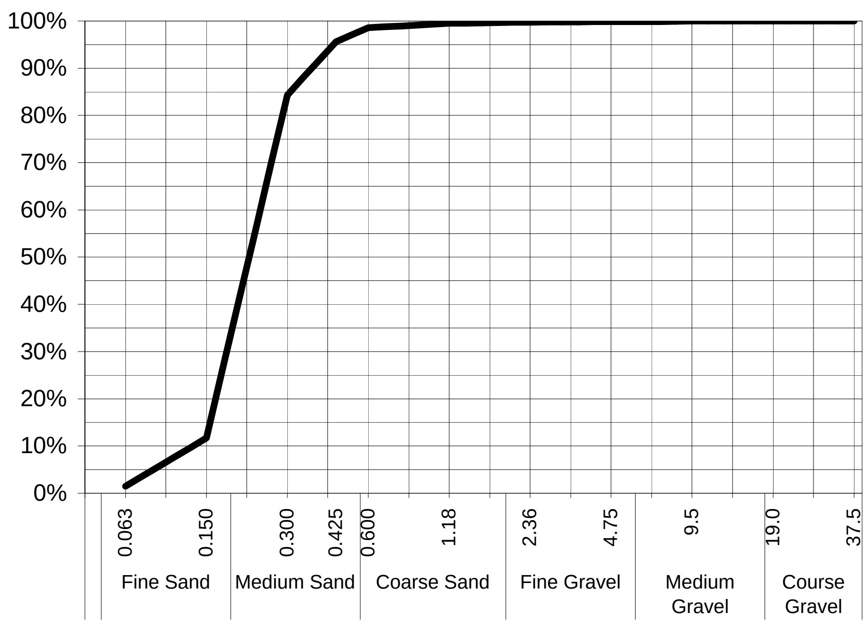
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-017 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	S IMP S1 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	99%
0.600	99%
0.425	96%
0.300	84%
0.150	12%
0.063	1%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle

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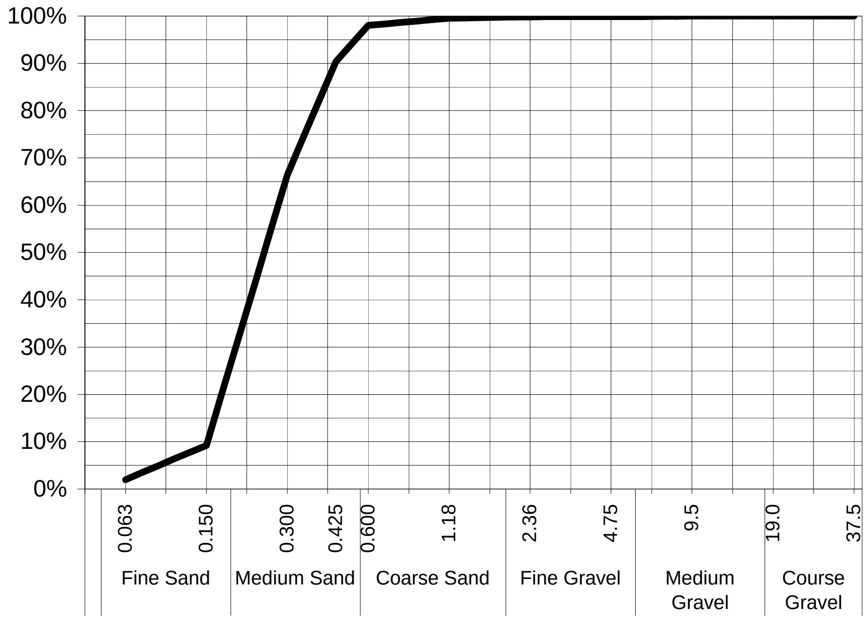
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-018 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	S IMP S1 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	98%
0.425	90%
0.300	66%
0.150	9%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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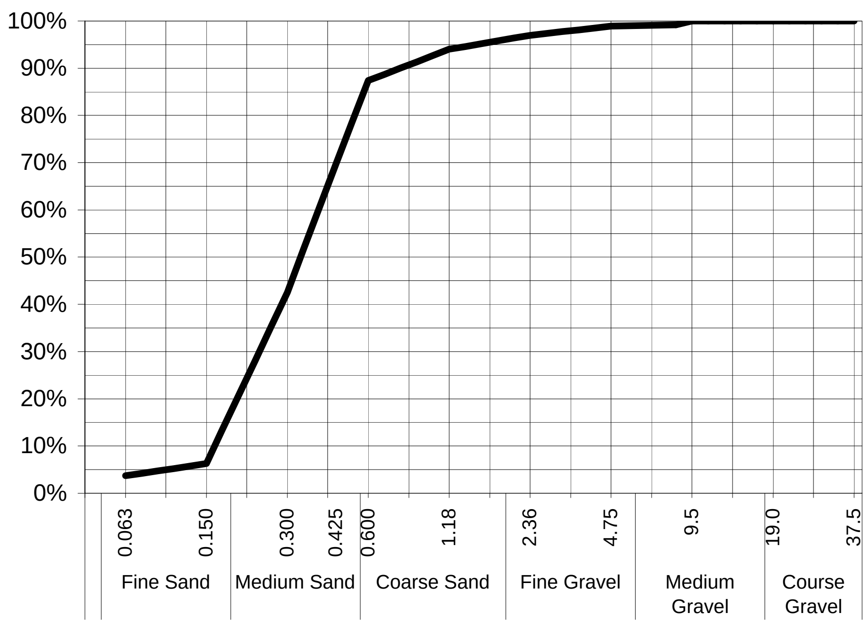
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-019 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	S IMP S2 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	99%
2.36	97%
1.18	94%
0.600	87%
0.425	70%
0.300	43%
0.150	6%
0.063	4%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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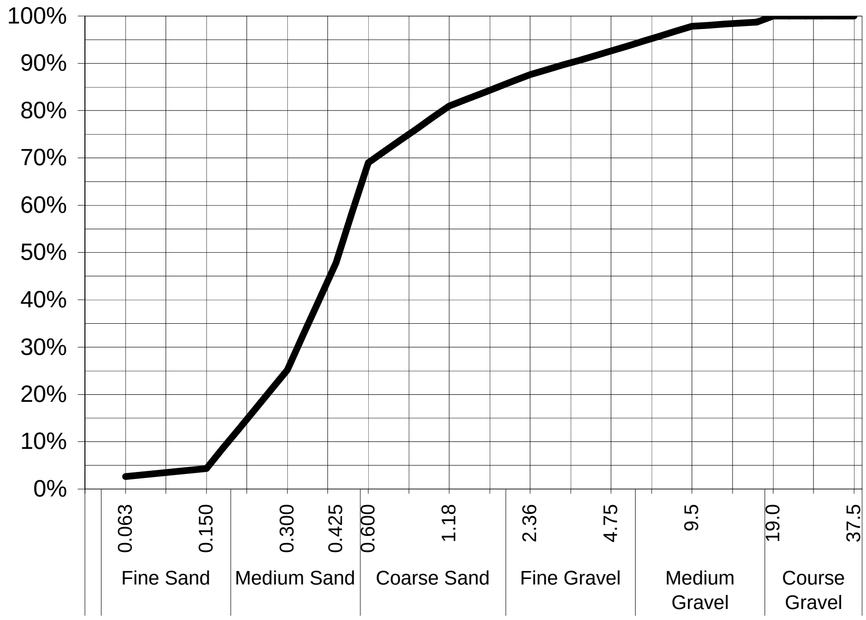
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-020 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	S IMP S2 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	98%
4.75	93%
2.36	88%
1.18	81%
0.600	69%
0.425	48%
0.300	25%
0.150	4%
0.063	3%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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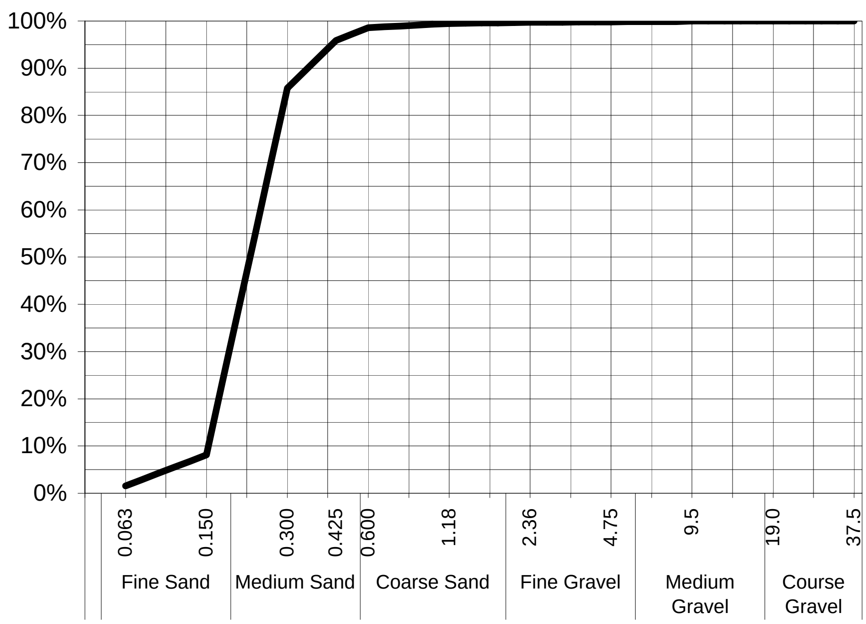
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-021 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	S IMP S3 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	99%
0.600	99%
0.425	96%
0.300	86%
0.150	8%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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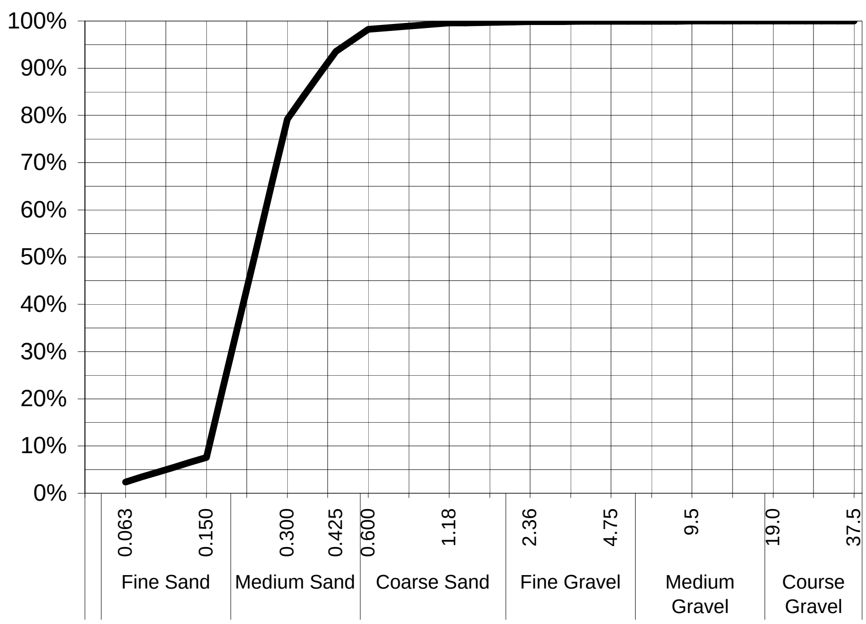
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-022 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	S IMP S3 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	98%
0.425	94%
0.300	79%
0.150	8%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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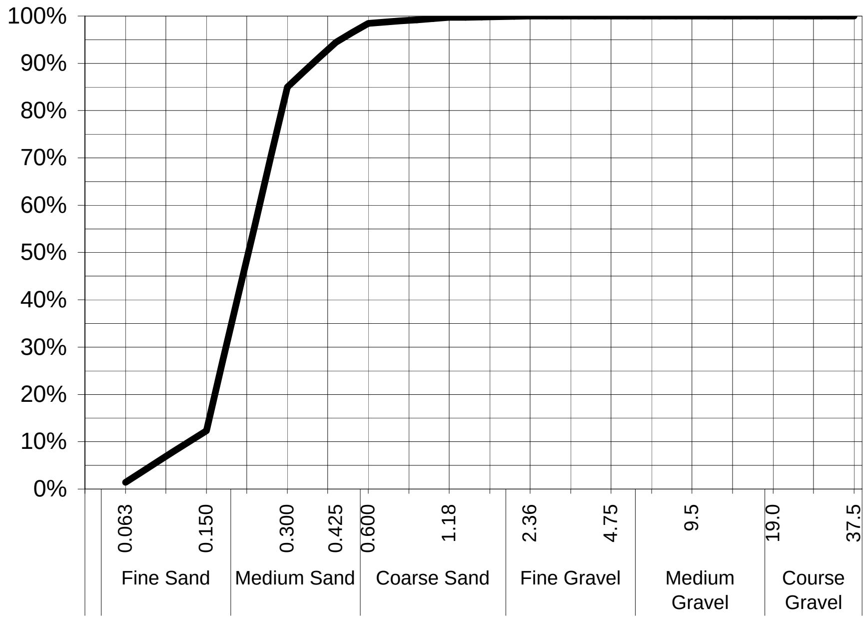
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-023 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	S IMP S4 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	98%
0.425	94%
0.300	85%
0.150	12%
0.063	1%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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ALS Environmental

Newcastle, NSW

CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-024 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	S IMP S4 R2

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	99%
0.425	97%
0.300	90%
0.150	14%
0.063	1%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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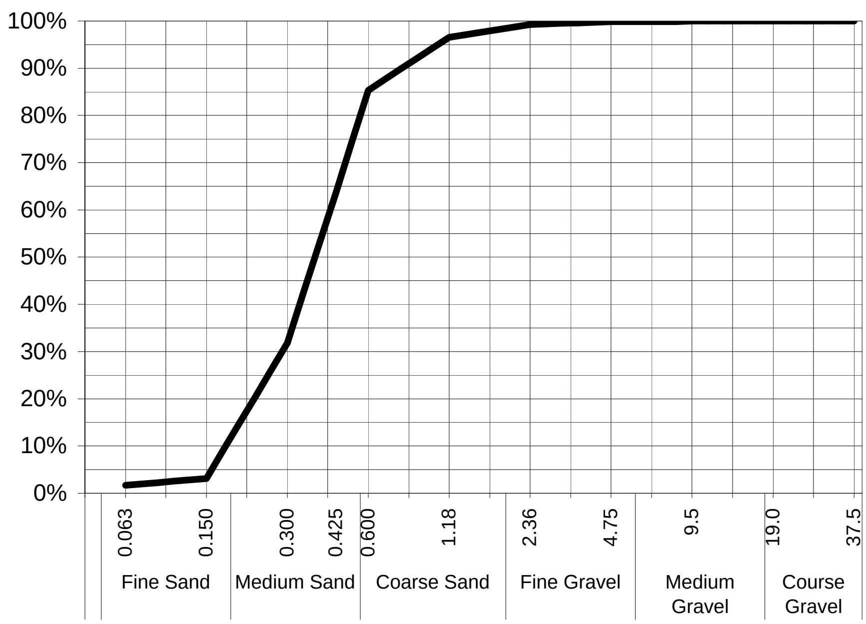
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-025 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	S CON S1 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	99%
1.18	97%
0.600	85%
0.425	64%
0.300	32%
0.150	3%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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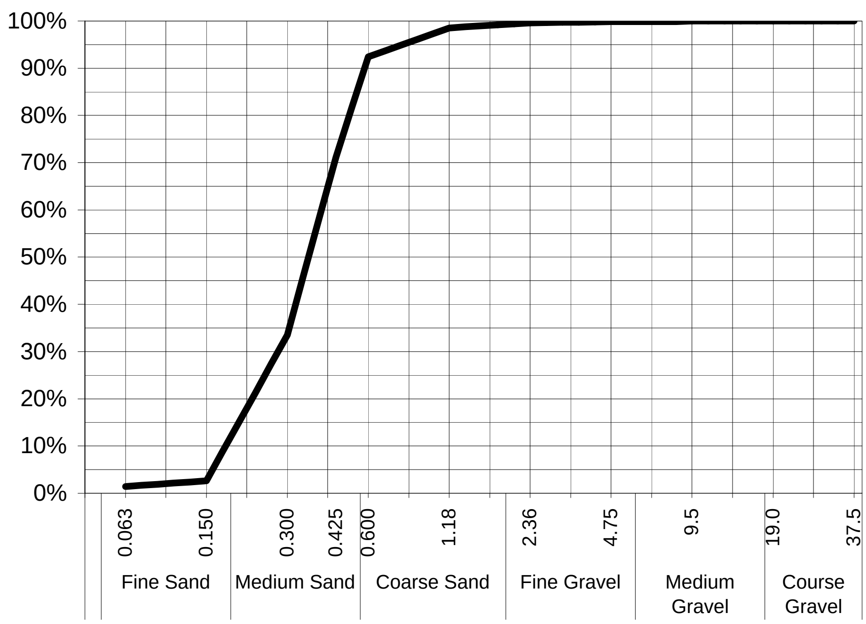
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-026 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	S CON S1 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	99%
0.600	92%
0.425	71%
0.300	33%
0.150	3%
0.063	1%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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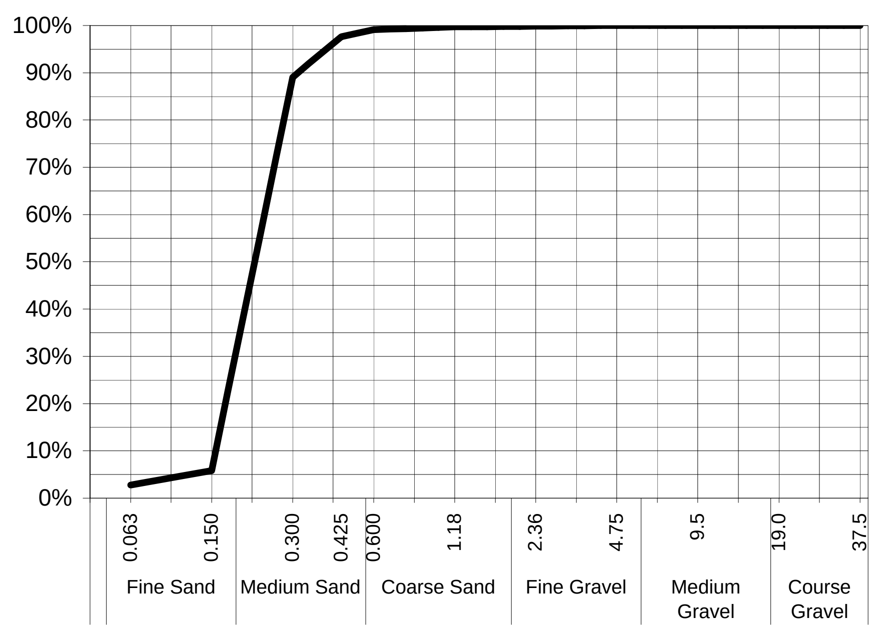
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-027 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	S CON S2 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	99%
0.425	98%
0.300	89%
0.150	6%
0.063	3%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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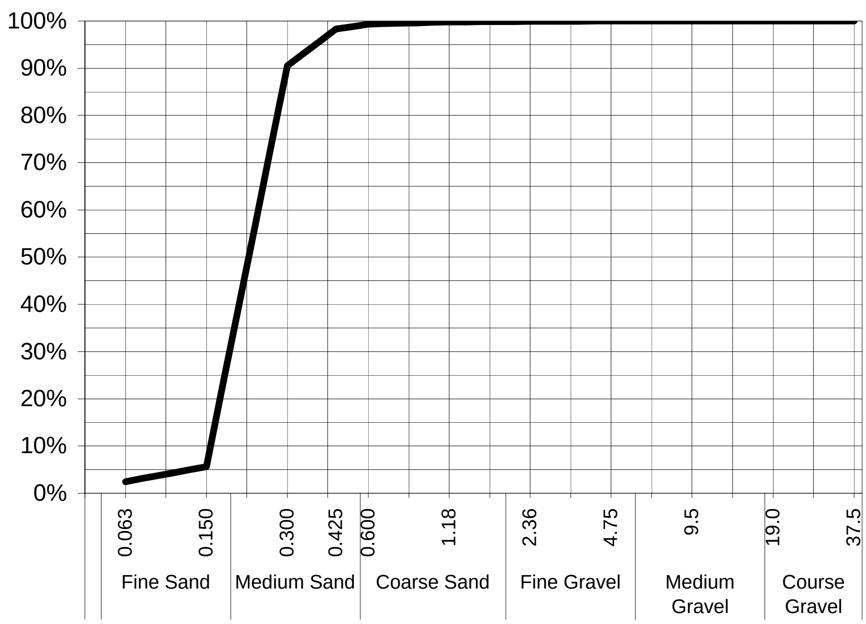
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-028 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	S CON S2 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	99%
0.425	98%
0.300	91%
0.150	6%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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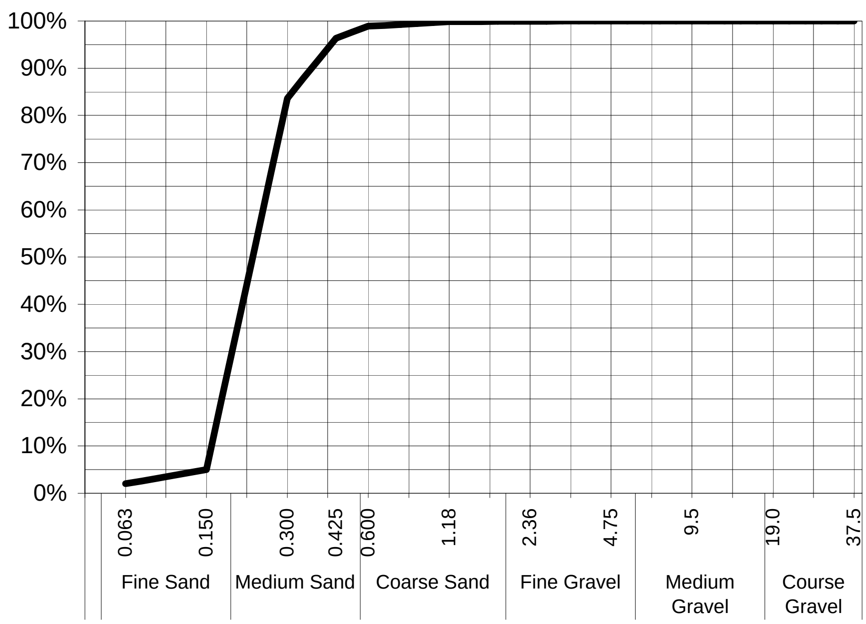
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-029 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	S CON S3 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	99%
0.425	96%
0.300	84%
0.150	5%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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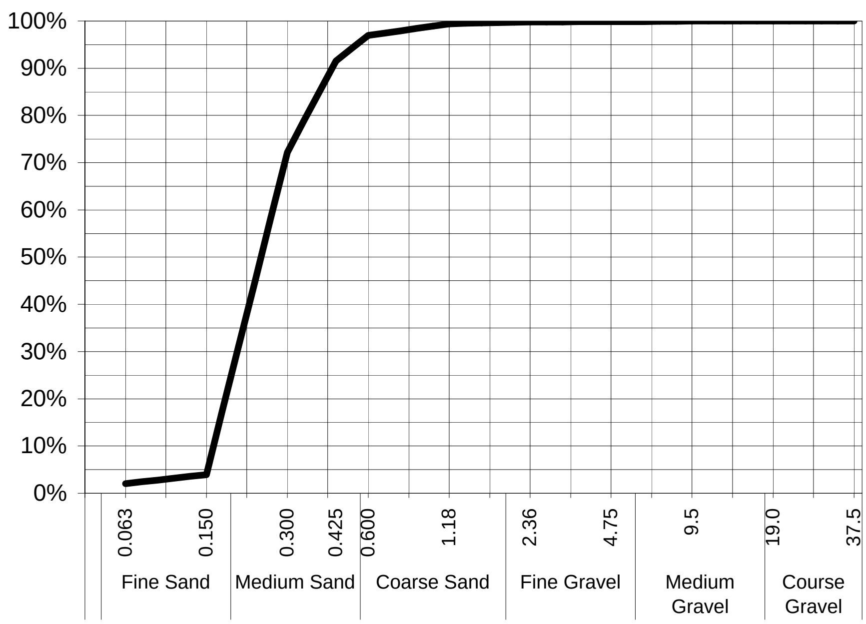
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-030 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	S CON S3 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	99%
0.600	97%
0.425	92%
0.300	72%
0.150	4%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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CLIENT: Kate Reeds

DATE REPORTED: 3-Feb-2009

COMPANY: Cardno Ecology Lab

DATE RECEIVED: 27-Jan-2009

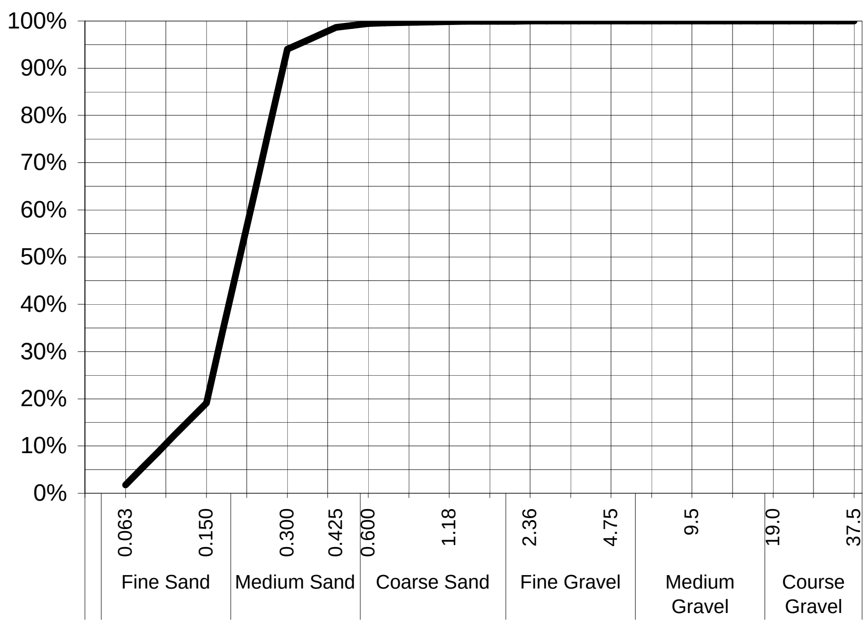
ADDRESS: 4 Green Street
Brookvale, NSW Australia 2100

REPORT NO: ES0901076-031 / PSD

PROJECT: 31-0809 OARS

SAMPLE ID: S CON S4 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	99%
0.425	99%
0.300	94%
0.150	19%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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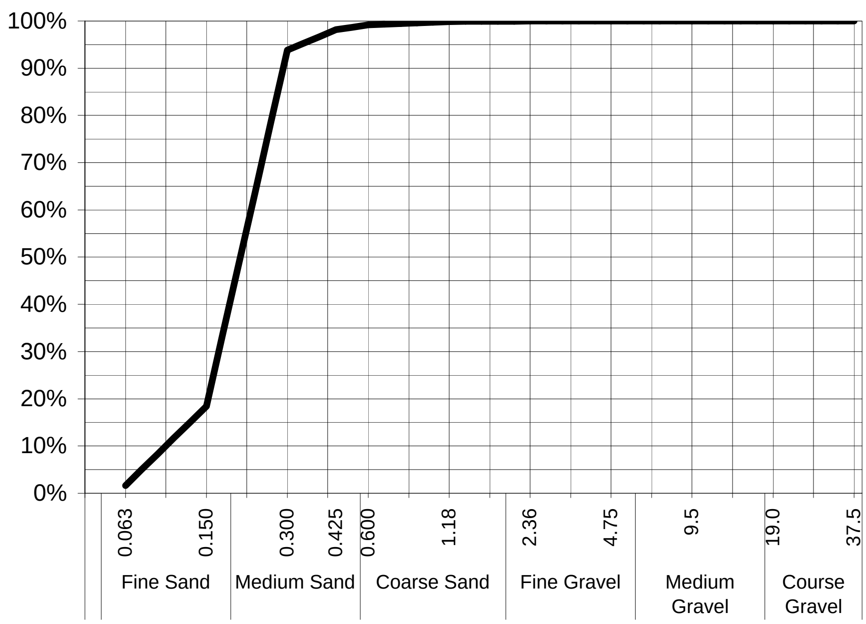
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-032 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	S CON S4 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	99%
0.425	98%
0.300	94%
0.150	18%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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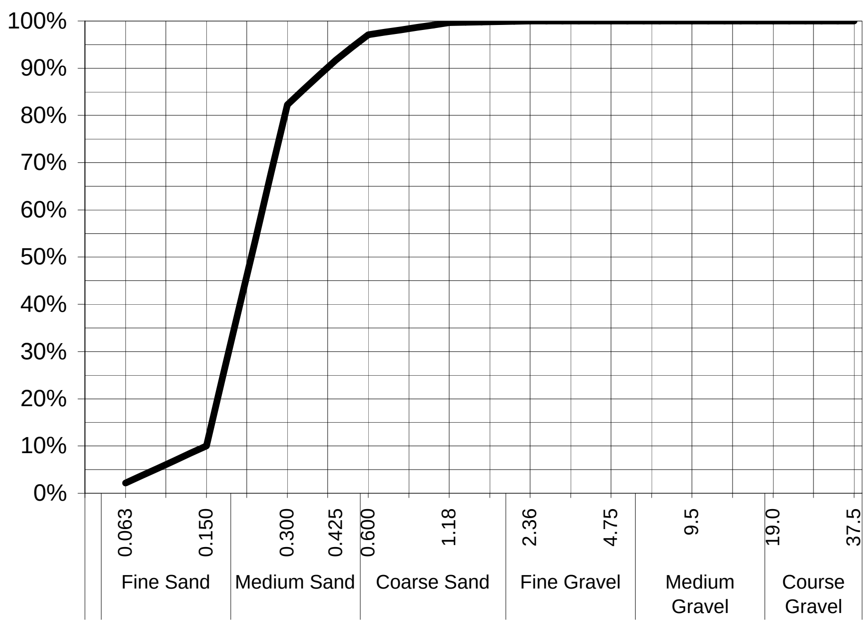
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-033 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	W IMP S1 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	97%
0.425	92%
0.300	82%
0.150	10%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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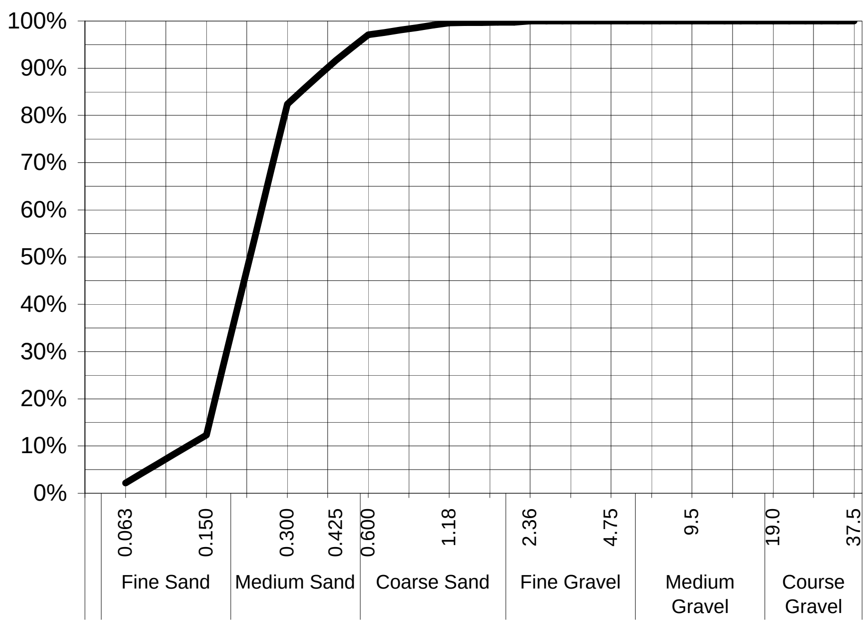
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-034 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	W IMP S1 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	97%
0.425	92%
0.300	82%
0.150	12%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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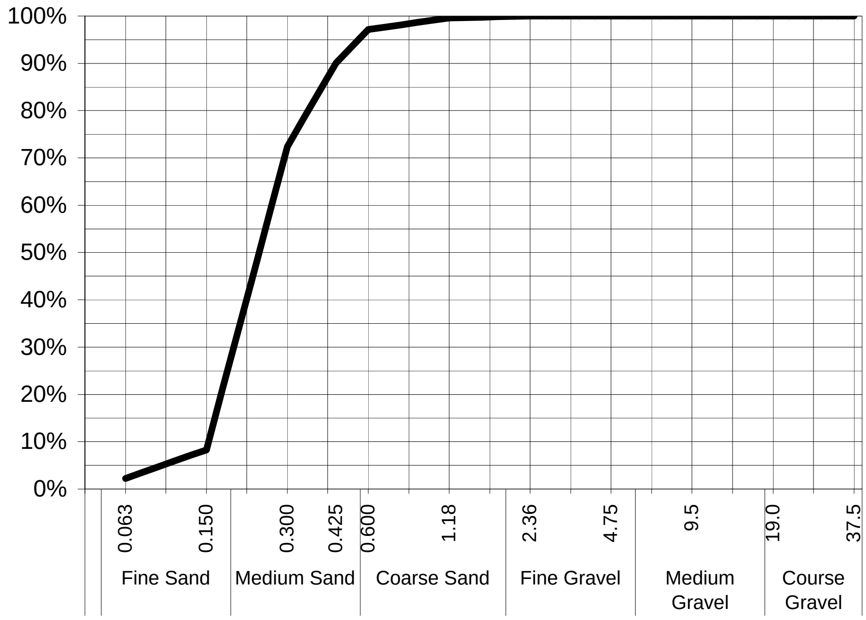
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-035 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	W IMP S2 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	97%
0.425	90%
0.300	72%
0.150	8%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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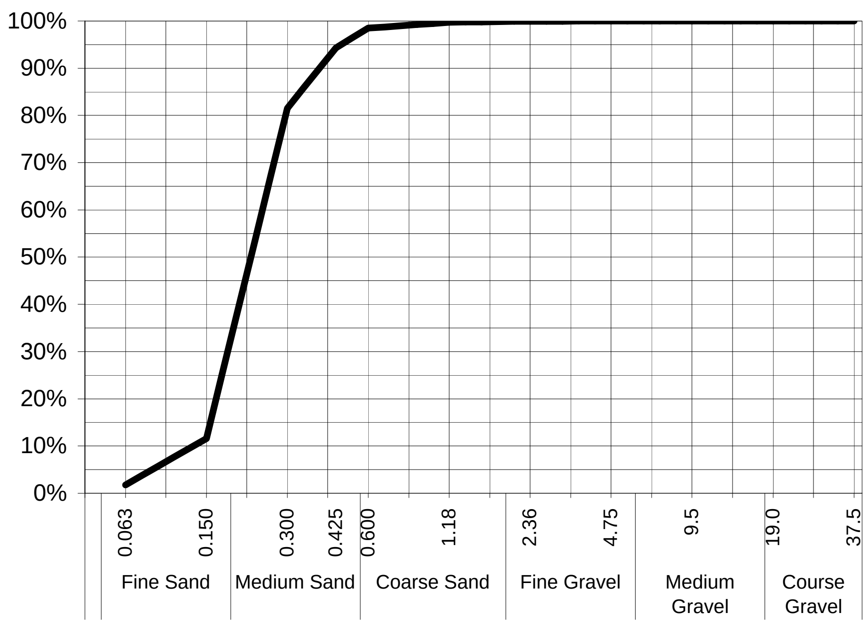
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-036 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	W IMP S2 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	98%
0.425	94%
0.300	82%
0.150	12%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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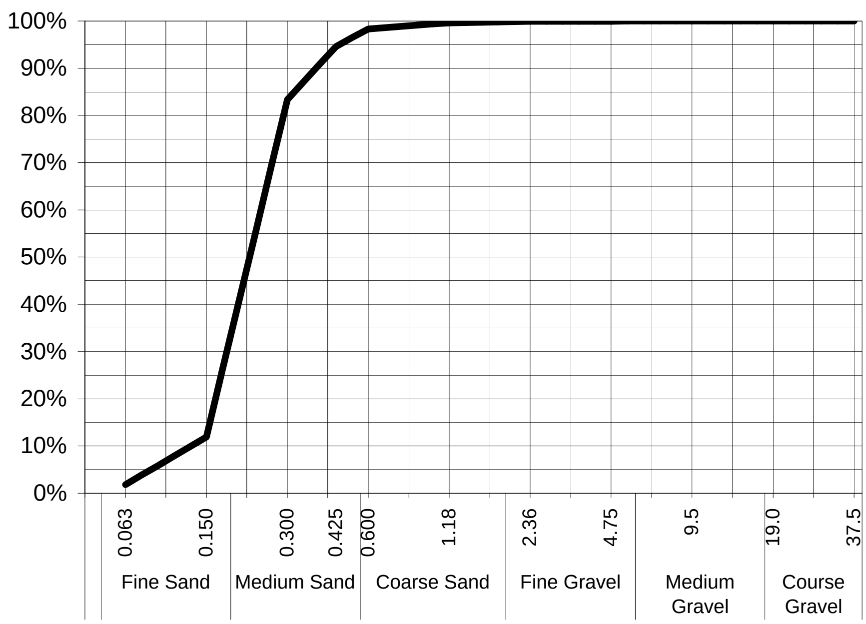
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-037 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	W IMP S3 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	98%
0.425	95%
0.300	83%
0.150	12%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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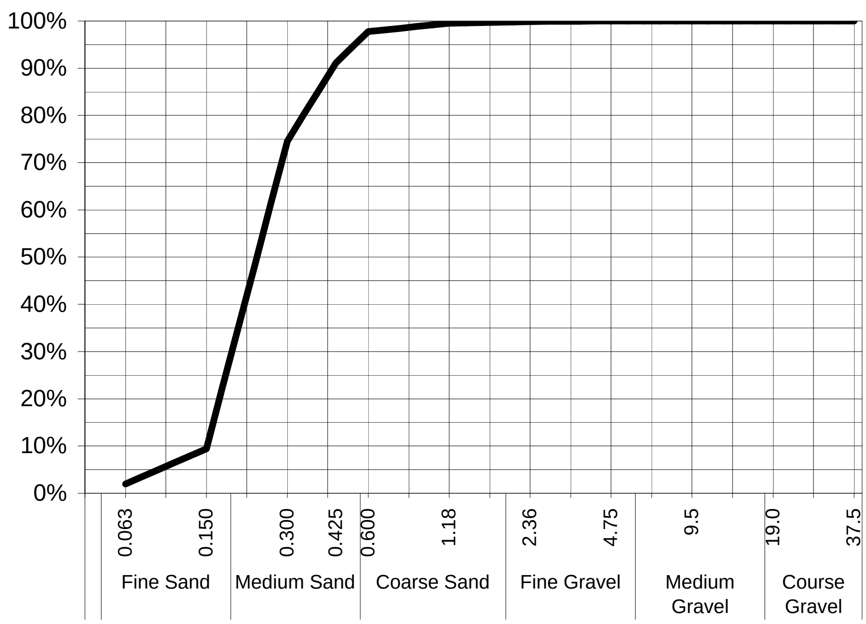
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-038 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	W IMP S3 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	98%
0.425	91%
0.300	75%
0.150	9%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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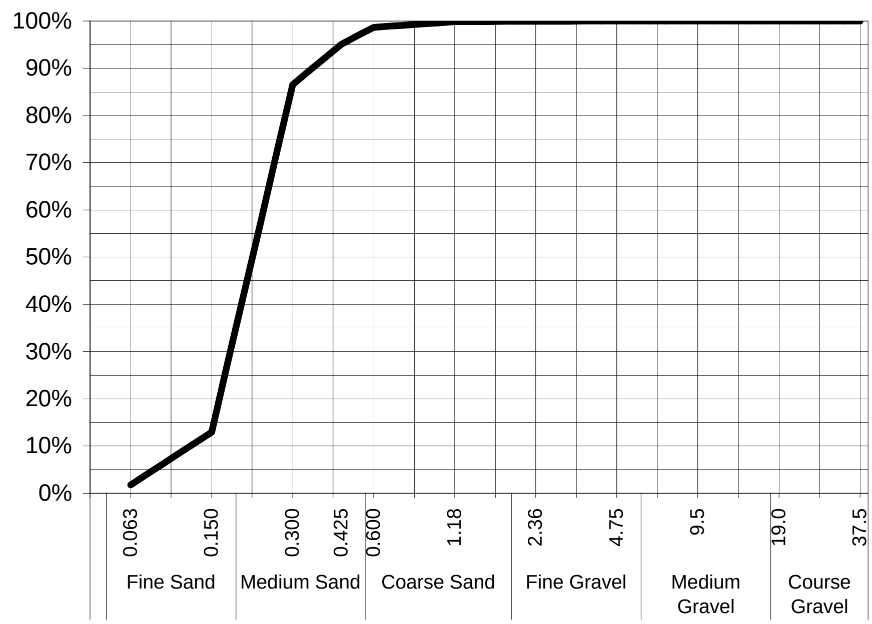
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-039 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	W IMP S4 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	99%
0.425	95%
0.300	87%
0.150	13%
0.063	2%

Samples analysed as received.

Sample Comments:		**Analysed:**	29-Jan-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand		
Test Method:	AS1289.3.6.1		

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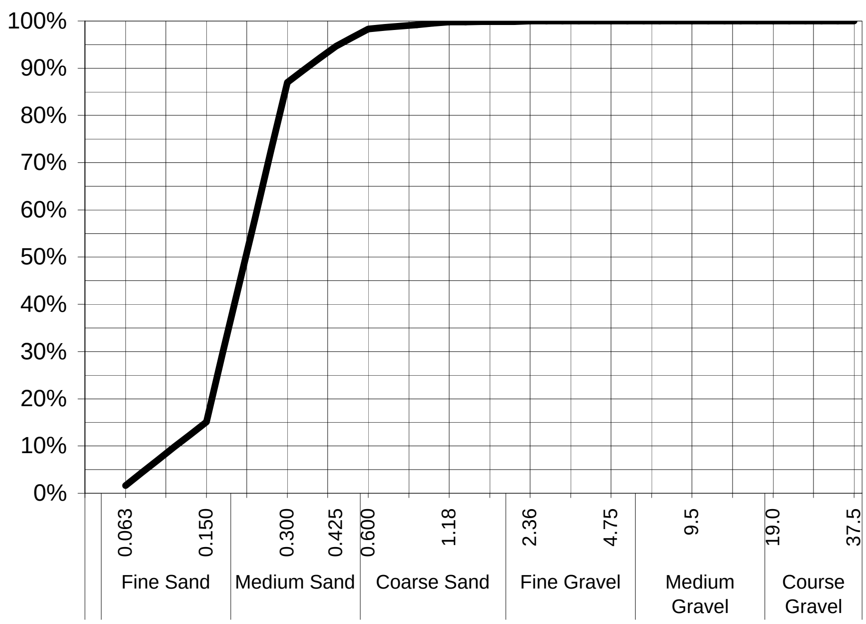
ALS Environmental

Newcastle, NSW

CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-040 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	W IMP S4 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	98%
0.425	95%
0.300	87%
0.150	15%
0.063	2%

Samples analysed as received.

Sample Comments:		**Analysed:**	29-Jan-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand		
Test Method:	AS1289.3.6.1		

NATA Accreditation: 825 Site: Newcastle
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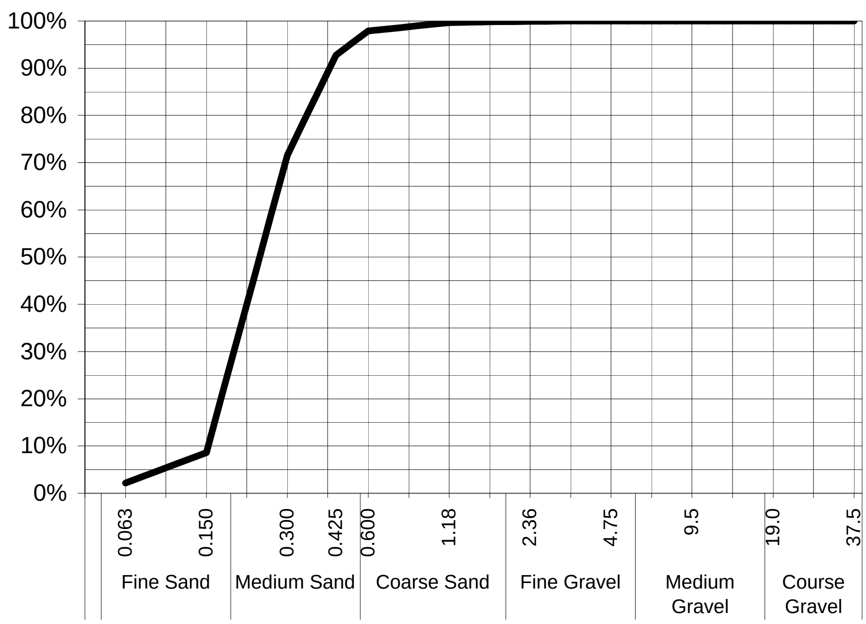
ALS Environmental

Newcastle, NSW

CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-041 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	W CON S1 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	98%
0.425	93%
0.300	72%
0.150	9%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

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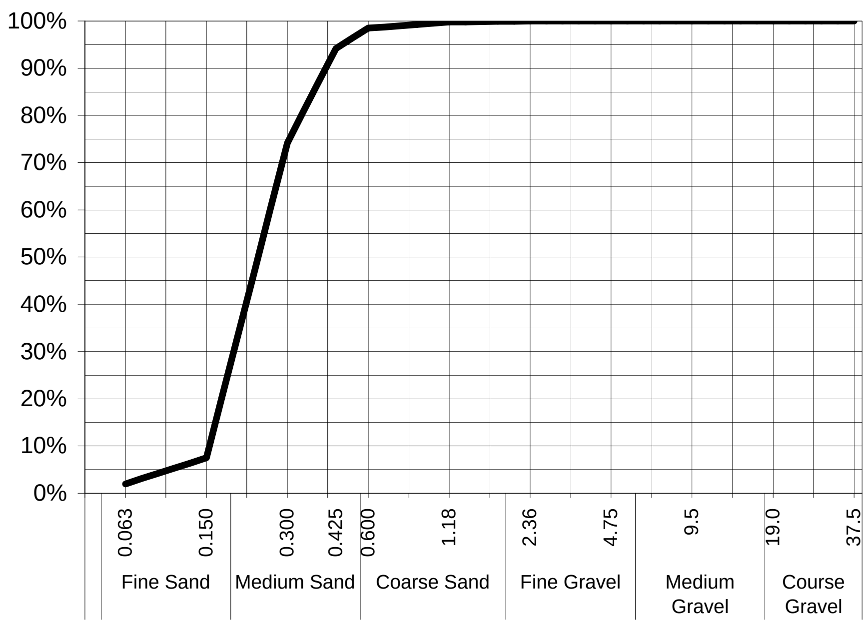
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-042 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	W CON S1 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	98%
0.425	94%
0.300	74%
0.150	7%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-043 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	W CON S2 R1

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	99%
0.425	97%
0.300	92%
0.150	16%
0.063	1%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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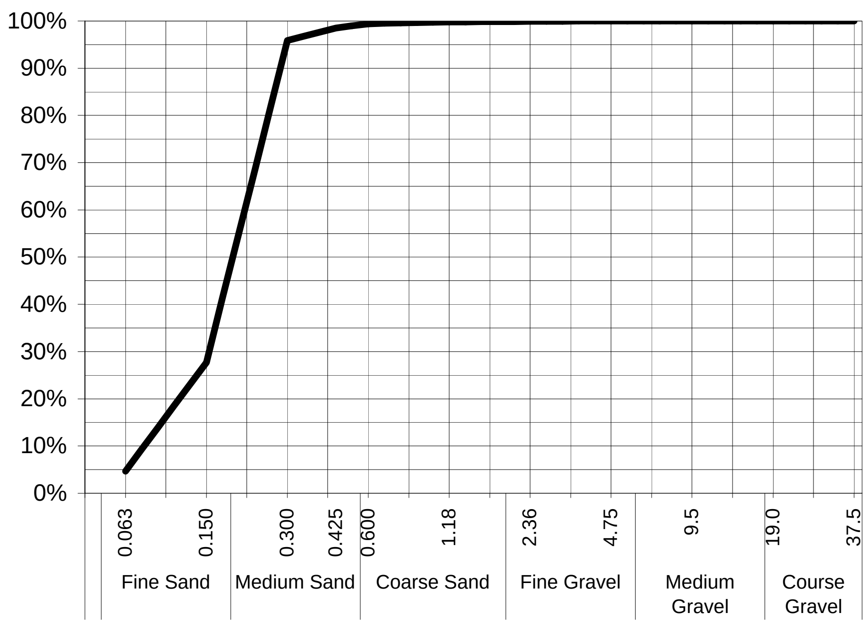
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-044 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	W CON S2 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	99%
0.425	99%
0.300	96%
0.150	28%
0.063	5%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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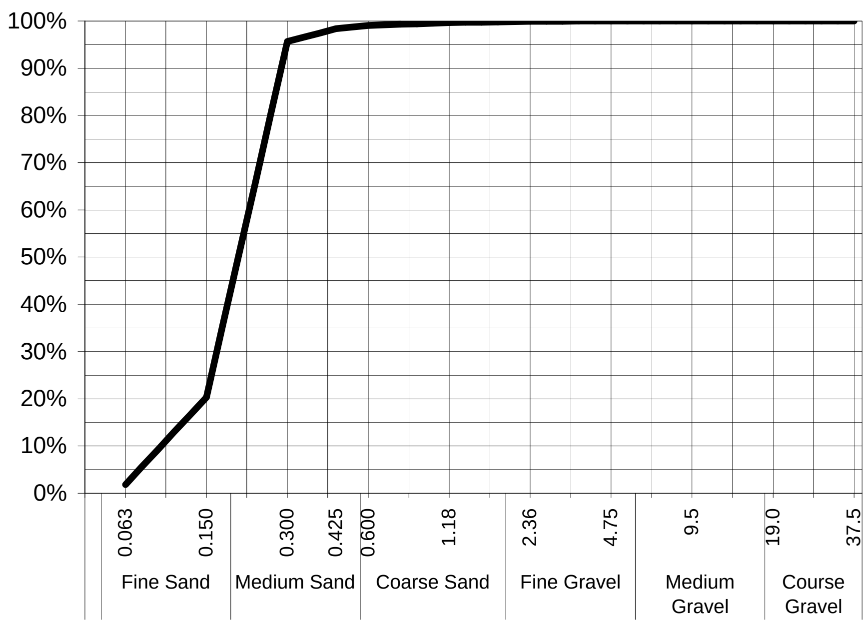
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-045 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	W CON S3 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	99%
0.425	98%
0.300	96%
0.150	20%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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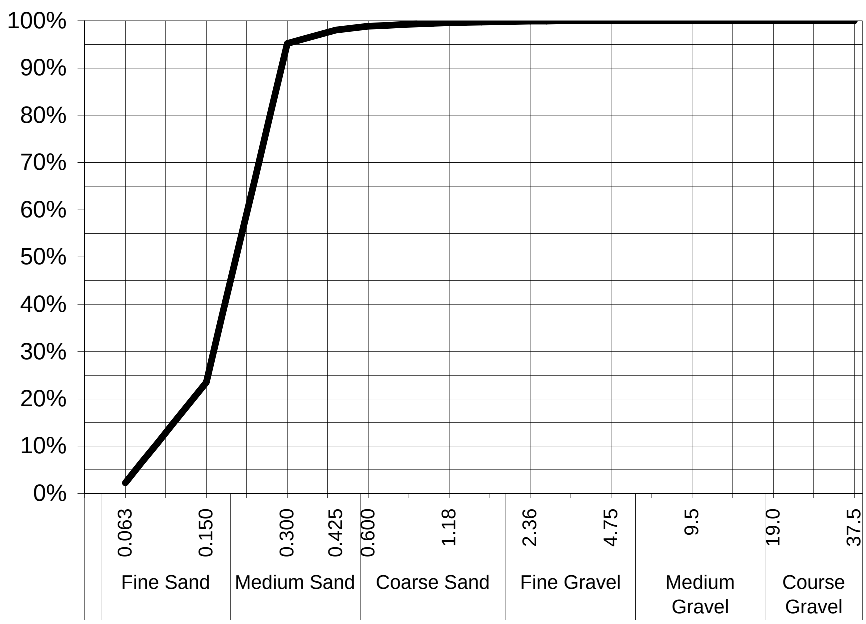
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-046 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	W CON S3 R3

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	99%
0.425	98%
0.300	95%
0.150	23%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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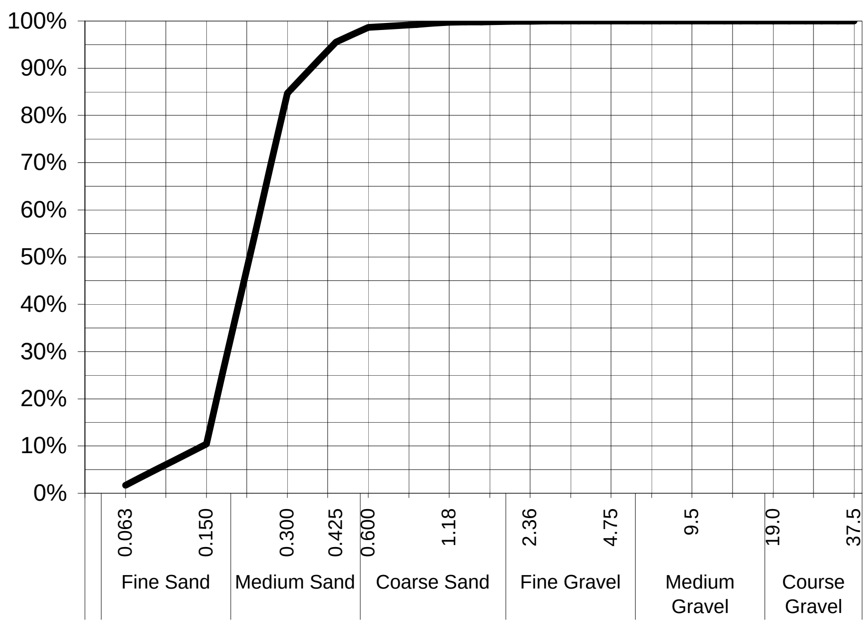
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-047 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	W CON S4 R1

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	99%
0.425	96%
0.300	85%
0.150	10%
0.063	2%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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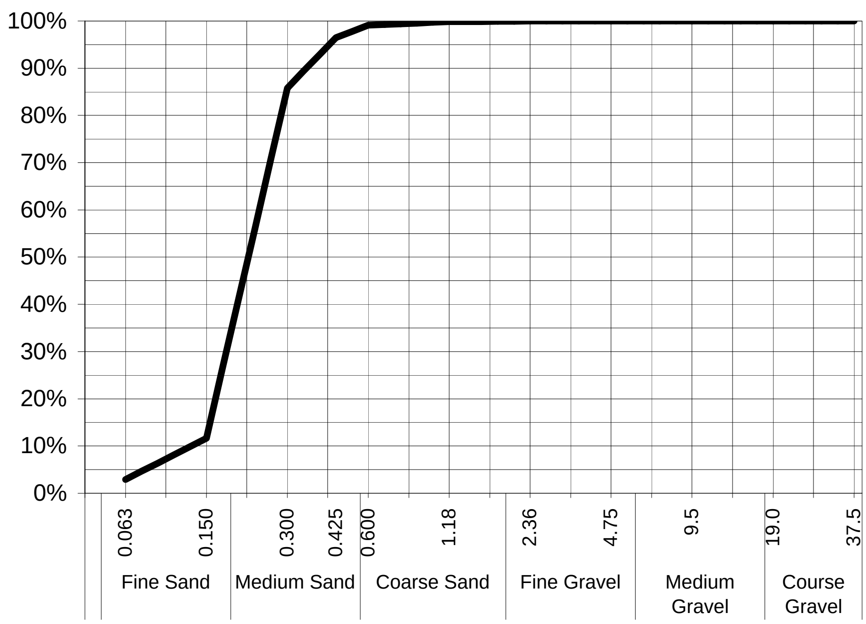
CLIENT:	Kate Reeds	**DATE REPORTED:**	3-Feb-2009
COMPANY:	Cardno Ecology Lab	**DATE RECEIVED:**	27-Jan-2009
ADDRESS:	4 Green Street Brookvale, NSW Australia 2100	**REPORT NO:**	ES0901076-048 / PSD
PROJECT:	31-0809 OARS	**SAMPLE ID:**	W CON S4 R2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	100%
0.600	99%
0.425	96%
0.300	86%
0.150	12%
0.063	3%

Samples analysed as received.

Sample Comments:

Analysed: 29-Jan-09

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: Sand

Test Method: AS1289.3.6.1

NATA Accreditation: 825 Site: Newcastle
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Appendix 5. 'Assessment of Significance' for threatened species, populations and communities protected under the *TSC* and *FM Act.*

FISH

East Coast Population of Grey Nurse Sharks

Species Name: Grey Nurse Shark (*Carcharias taurus*) - East Coast Population
Status: Critically endangered
a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction. Grey nurse sharks typically occur on shallow rocky reefs along the NSW coast (Last and Stevens 1994). Young are born live and also occur on shallow rocky reefs, often segregated from the adults. Grey nurse sharks can be observed at day hovering or slowly swimming around high-relief reefs. It is thought that the species becomes more active at night where it hunts over rocky reef and over soft substrata (Smale 2005). There is also evidence to suggest that grey nurse sharks migrate along the NSW coast (northwards in autumn/winter and southwards in summer (Pollard *et al.*1996, Otway and Parker 1999). Hence, they could occasionally occur around any of the artificial reefs once installed and may potentially use the area for foraging. If this was the case, then it would be possible for individuals to be susceptible to incidental catch from recreational or commercial fishing (considered a threat to the species). Under State and Commonwealth law it is illegal to catch or harm grey nurse sharks, so those that are accidentally caught should be returned to the water unharmed. It is however, possible that damage caused by accidental catch could contribute to early mortality. While there is potential for grey nurse sharks to utilise the artificial reef habitat on occasion, and be at risk to incidental hooking or catch, it is considered unlikely that this would have adverse impact such that a viable local population would be placed at risk of extinction. This is based on the assumption that the OARs would be monitored for the occurrence of GNS and that appropriate mitigative action would be taken if the species was found to occur near the OARs.
b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction. Under the *FM Act*, the whole NSW population of grey nurse sharks may be considered to be endangered. Notwithstanding this, the impacts of the proposal to grey nurse sharks would be the same as for a) and considered unlikely to have adverse impacts such that a viable local population would be placed at risk of extinction.
c) In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: *i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction; or* *ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.* Not applicable
d) In relation to the habitat of a threatened species, population or ecological community: *i) the extent to which habitat is likely to be removed or modified as a result of the action proposed; and* *ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action; and* *the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality.* The major habitat utilised by grey nurse sharks comprises rocky reefs, with small sandy gutters within the reef

matrix being often preferred microhabitat. There is some likelihood that the species ranges away from reefs to feed at night, but the extent of this range is unknown (Smale 2005). The proposal would not modify any core reef habitat of grey nurse sharks. The proposal would not isolate any reef from other habitat used by the species. There would, however, be a small loss of soft bottom habitat which grey nurse sharks may forage over on occasion. The lost soft bottom foraging area would amount to only a relatively small proportion of the total foraging area for the species.
e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly). Many of the known aggregation sites for grey nurse sharks in the eastern Australian population have been declared critical habitat for the species and are protected by legislation administered by I&I NSW. Areas declared critical habitat for the species include Little Broughton Island and The Pinnacle, north of Newcastle (within Port Stephens Marine Park), Magic Point (Maroubra) and Bass Point in the south. The Magic Point critical habitat occurs approximately 12.5 km from the proposed Sydney OAR site. The Bass Point critical habitat occurs approximately 8 km from the proposed Wollongong OAR site. Therefore no critical habitat would be directly or indirectly affected by the proposal.
f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan. Grey nurse sharks are protected from all forms of fishing. Given their movement patterns, it is unlikely that grey nurse populations are confined to the relatively small spatial scale of their reserves (see section 'e'). It is therefore possible that grey nurse sharks occurring at known aggregation sites within the wider study areas could interact with the proposed OARs and be vulnerable to incidental capture. This could contravene objectives of the State and Commonwealth Recovery Plans for the species (Environment Australia 2002, NSW Fisheries 2002) which aim to reduce the impact of commercial and recreational fishing on the species. Conversely, creation of new recreational fishing areas may assist in the species recovery (consistent with recovery plans) by providing alternative fishing locations away from known aggregation areas.
g) Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process. 'Hook and line fishing in areas important for the survival of threatened fish species' is listed as a key threatening process. Grey nurse sharks are known to forage in sandy habitats characteristic of the proposed artificial reef sites. These sites are not however, considered to be important to the survival of the species or to constitute a significant percentage of total foraging area. The proposal is therefore not considered to constitute part of this, or any key threatening process.

Conclusion:
The proposal would not have any direct or indirect impacts on the habitat critical to the survival of the grey nurse shark. It is possible that the proposed artificial reefs could occasionally draw in migrating or foraging individuals, making them susceptible to incidental capture and consequent injury by commercial and/or recreational fishing. This is considered a threat to the species and contravenes State and Commonwealth recovery plans. Given that the OARs are properly monitored and appropriate mitigative action taken if GNS were found to occur on the reefs, it is not considered that the proposal would place a local viable population at risk of extinction.

Great White Shark

Species Name: Great White Shark (*Carcharodon carcharias*)
Status: Vulnerable
a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction. Great white sharks are large, highly predatory animals whose life cycle is poorly understood. They occur from cold temperate to tropical waters worldwide and generally frequent coastal waters, often close to shore. They also swim into bays and estuaries. Great white sharks are live bearers that do not appear to frequent specific habitats. The exception is when they take up residence adjacent to rocky shores, particularly where seals or sea

lions are present. Emerging evidence suggests that both juveniles and adults can range widely, with one tagged individual recorded from Tasmania along the NSW coast into southern Queensland. There is also anecdotal evidence that the species follows large schools of migrating fish (e.g. sea mullet, Australian salmon) and migrating whales, particularly those with calves. The sharks' prey also includes wide array of teleost fishes (Pogonowski 2002), it is therefore possible the predator would be attracted to fish aggregating around the OARs and become susceptible to incidental capture. Incidental hooking or capture could lead to mortality or capture induced sub-lethal stress. It is however, unlikely that the proposal would affect the life cycle of the species such that a viable local population would be placed at risk of extinction.
b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction. There are no endangered populations of great white sharks listed under the TSC or FM Acts. Under these definitions, no endangered population of great white sharks would be disrupted by the proposal. Stockton Bight is considered an important area for the occurrence of the great white shark. However, given the significant distance from the proposed Newcastle OAR (over 25 km) it is not considered that there would be any adverse effect such that the local occurrence of the species was placed at risk of extinction.
c) In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: *i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction; or* *ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.* Not applicable.
d) In relation to the habitat of a threatened species, population or ecological community: *i) the extent to which habitat is likely to be removed or modified as a result of the action proposed; and* *ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action; and* *iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality.* If great white sharks do prefer a particular habitat, it is likely to be rocky shores with seals or sea lions. They may also follow schools of fish along the coast, hence it is possible that OARs may affect the 'temporary' habitat of great white sharks. In that case, the proposed OAR locations are not considered to be significant known habitat, as the sharks are likely to simply follow the schools elsewhere. Since the proposed OAR locations are not known habitat, or likely to be significant habitat for great white sharks, it would not become isolated from other habitat used by the species.
e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly). No critical habitat would be affected for great white sharks.
f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan. There is an approved Great White Shark Recovery Plan (Web Reference 27). Prior to the implementation of protective legislation, commercial and recreational fishing were some of the most prominent threats to the great white shark. Although protected from all commercial or recreational fishing, the species is still susceptible to incidental by-catch despite management measures. The recovery plan aims to 'monitor and reduce impacts of commercial fishing' and further 'investigate and evaluate the impacts of recreational fishing' on the species. As such, the proposal would not contravene the aims of the recovery plan.
g) Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process. 'Hook and line fishing in areas important for the survival of threatened fish species' is listed as a key threatening

process. Great white sharks are known to occur in the wider study areas of the proposed artificial reef sites on occasion. These sites are not however, considered to be habitat important to the survival of the species. The proposal is therefore not considered to constitute part of this, or any key threatening process.

Conclusion:
The proposal is not considered to have adverse affects on habitat important for the long term survival of the great white shark. It is possible that the proposal could lead to incidental hooking or capture, although it is considered unlikely that the species would be affected to the extent that a viable local population would be placed at risk of extinction. Hence, the proposal is not considered to represent a significant threat to the great white shark and no SIS is recommended. Suitable management measures should be employed to minimise any potential harm from incidental capture

Black Cod

Species Name: Black Cod (*Epinephelus daemelii*)
Status: Vulnerable
a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction. Black cod, also known as black rockcod and saddled rockcod, occur from southern Queensland to Kangaroo Island (South Australia) and are found at Lord Howe Island, Norfolk Island, Kermadec Islands and the North Island of New Zealand (Heemstra and Randall 1993). They are protogynous hermaphrodites (i.e. change sex from female to male) and occur on relatively shallow coastal and estuarine rocky reefs. Juveniles may recruit to rock pools; adults are highly territorial, usually adopting a cave as a core territory. The life cycle of the species revolves around rocky reefs and possibly rock pools with pelagic dispersal of eggs and larvae. Black cod are not known to occur over the sandy habitat of the proposed OAR sites and due to their territorial nature it is unlikely that adults would utilise the new artificial habitat. It is however, possible that juveniles or vagrants could recruit to the new artificial reefs and become susceptible to incidental capture and hooking injuries. The likelihood of this occurring to the extent that a viable population is placed at risk of extinction is considered unlikely.
b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction. No known endangered population of black cod exists within the proposed study area.
c) In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: *i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction; or* *ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.* Not applicable
d) In relation to the habitat of a threatened species, population or ecological community: *i) the extent to which habitat is likely to be removed or modified as a result of the action proposed; and* *ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action; and* *iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality.* As indicated in (a), black cod are usually found in caves or rocky reefs and no such areas would be directly affected by the proposal.
e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly). No critical habitat for black cod would be affected by the proposal.

f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan. There is no approved recovery plan for this species
g) Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process. 'Hook and line fishing in areas important for the survival of threatened fish species' is listed as a key threatening process. The proposed OAR sites are not considered to be habitat important to the survival of the species and therefore the proposal is not considered to constitute part of this, or any key threatening process.

Conclusion: The proposal is not considered to represent a significant threat to black cod, hence no SIS is recommended. Suitable management measures should be employed to minimise any potential harm from incidental capture.

Southern Bluefin Tuna

Species Name: Southern Bluefin Tuna (*Thunnus maccoyii*)
Status: Endangered
a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction. Southern bluefin tuna are a pelagic species mainly occurring seaward of the continental shelf in waters between 50 m – 2743 m (Web Reference 28). The occurrence of the species within the 3 nm limit of State waters is considered rare although their distribution in Australian waters is known to extend from northern NSW around the south of the continent to northern Western Australia (Pogonowski *et al*. 2002). The species is highly migratory, moving to tropical seas off the west coast of Australia to spawn. Over harvesting is considered the main threat to the species. That considered, it is highly unlikely that the deployment and operation of the proposed OARs would have any adverse effect such that it would place local populations of the species at risk of extinction.
b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction. Not Applicable
c) In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: *i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction; or* *ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.* Not Applicable
d) In relation to the habitat of a threatened species, population or ecological community: *i) the extent to which habitat is likely to be removed or modified as a result of the action proposed; and* *ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action; and* *iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality.* Habitat in the direct and wider study areas consists predominantly of fine to medium bare sandy seabed and is not considered unique or important in relation to the southern bluefin tuna. The installation of the OARs at the three proposed locations is not considered to fragment or isolate areas of habitat important to the southern bluefin tuna.

e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly). No critical habitat for this species exists in the study areas
f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan. There is no approved recovery plan for the species although the international Commission for the Conservation of the Southern Bluefin Tuna (CCSBT) aim to attain the 1980 spawning stock level by 2020.
g) Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process. 'Hook and line fishing in areas important for the survival of threatened fish species' is listed as a key threatening process. However, the proposed study areas are not considered important to the survival of the species and this KTP is therefore not considered relevant.

Conclusion:
Given the rarity of southern bluefin tuna inshore, it is considered unlikely that the proposal would have any adverse affect on the population or have any effect on habitat important to the population.

Green Sawfish

Species Name: Green Sawfish (*Pristis zijsron*)
Status: Presumed extinct
a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction. In 2000, the green sawfish was listed as an endangered species. In 2007 the listing was reviewed and the conservation status changed to 'presumed extinct' in NSW. The population decline of the green sawfish has mostly been attributed to fishing and incidental capture in commercial prawn and gill nets (Web Reference 29), although deliberate capture for sale and degradation of soft bottom areas important for feeding and breeding are also reasons. The last confirmed sighting of the Green sawfish was in 1972 from the Clarence River in Yamba. Green sawfish habitat includes muddy or sandy mud, soft sediment in inshore areas (Web Reference 29) where they mostly feed on shoaling fish such as mullet, molluscs and small crustaceans. Although it is possible that a small portion of soft bottom habitat would be lost through emplacement of artificial reef structures, this would not be significant due to the abundance of similar habitat and more favourable muddy substratum in the wider study area. Furthermore, the rarity of the species in the wider study areas in all regions suggests that the proposal would be very unlikely to have any adverse impact on the population which is already presumed extinct.
b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction. Not applicable
c) In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: *i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction; or* *ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.* Not applicable
d) In relation to the habitat of a threatened species, population or ecological community: *i) the extent to which habitat is likely to be removed or modified as a result of the action proposed; and* *ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action; and* *iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the*

species, population or ecological community in the locality. Habitat in the direct and wider study areas consists predominantly of fine to medium bare sandy seabed. A total of 400 m^2 (consisting of four, 10 m x 10 m areas) of seabed would be occupied by the artificial reef structures, although only the footprint of the actual steel supports would result in the loss of soft bottom habitat. It is possible that potential green sawfish habitat could be modified as a result of the proposal, although the habitat is not considered important to the long term survival of the species. The proposal is not considered to fragment or isolate areas of potential habitat.
e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly). No critical habitat for this species exists in the study areas although inshore soft bottom areas are considered important to the species (Pogonowski *et al*. 2002).
f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan. There is no approved recovery plan for the green sawfish.
g) Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process. 'Hook and line fishing in areas important for the survival of threatened fish species' is listed as a key threatening process under the *FM Act*. Green sawfish are listed as one of the species likely to be vulnerable to this KTP. In the highly unlikely event that green sawfish were present in any of the direct study areas, it is possible the species could be subject to this KTP.

Conclusion:
Given the rarity of the green sawfish occurring in any of the three study areas, it is considered unlikely that the proposal would have any adverse affect on the long-term survival of the population or adversely affect habitat important to the population.

MARINE REPTILES

Species Group: Marine Turtles
Status: Vulnerable green turtle (*Chelonia mydas),* vulnerable leatherback turtle (*Dermochelys coriacea*) and endangered loggerhead turtle (*Caretta caretta*).
a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction. Most of the listed marine turtles tend to prefer warmer waters, ranging from tropical to warm temperate seas (Marquez 1990). For a large part of their life cycle, marine turtles are pelagic, particularly leatherbacks, although green turtles tend to stay in coastal waters and may even take up residence in some areas. All the marine turtles scheduled under the legislation are vulnerable to hunting through much of their range, particularly in developing countries. The species are probably most vulnerable when they come ashore to nest – at this time adults, eggs and hatchlings are subject to direct harvesting, predation by native fauna, feral animals and pets and various forms of human disturbance. By-catch of marine turtles in fisheries, marine debris, coastal development, loss of habitat and deterioration of water quality is also a significant threat to the species. The leatherback has a wide distribution and may be observed all around Australia. The green turtle is generally found in more northern latitudes of Australia although resident groups of green turtles have been found in northern New South Wales, in Jervis Bay and in more southerly estuaries. Loggerheads occur in coral reefs, bays and estuaries in tropical and warm temperate waters off the coast of Queensland, Northern Territory, Western Australia and New South Wales. Although these species may occasionally occur within the entire study region (from Newcastle, south to Wollongong) this is outside the range of known nesting, mating or feeding areas. Moreover, although marine

turtles are not uncommon within the study region during summer, there is no known breeding population within or near the proposed OAR sites. On this basis, it is unlikely that a viable local population of any marine turtles would be placed at risk of extinction by the proposal.
b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction. No endangered populations of marine turtles are identified in the legislation
c) In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: *i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction; or* *ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction*. Not applicable
d) In relation to the habitat of a threatened species, population or ecological community: *i) the extent to which habitat is likely to be removed or modified as a result of the action proposed; and* *ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action; and* *iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality.* In theory, the proposed study areas could potentially provide foraging habitat for marine turtles but it is unlikely that the small amount of soft bottom loss would constitute a significant area of known foraging habitat. The lost soft bottom foraging area would amount to only a very small proportion of the total foraging area. In addition, it is most unlikely that any area of marine turtle habitat would become isolated by the proposal.
e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly). This would not occur for marine turtles in relation to the proposal.
f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan. There is an approved Recovery Plan for Marine Turtles in Australia (Web Reference 30). The proposal is unlikely to affect any of the recovery actions proposed under the plan.
g) Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process. 'Entanglement or ingestion of anthropogenic debris in marine and estuarine environments' is listed as a key threatening process under the the NSW *TSC Act.* 'Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris (such as discarded fishing gear)' is also listed as a key threatening process under the Australian Government's *EPBC Act*. The leatherback and green turtles are considered particularly vulnerable to this KTP. It is possible that increased boating activity in the vicinity of the proposed artificial reefs may exacerbate this KTP by increasing the risk of harmful marine debris being released into the marine environment. However, providing that boating activity in the vicinity of the OARs is properly monitored and regulated, then impacts of this KTP are unlikely to increase the impact of this KTP.

Conclusion:

The proposal is not considered to represent a significant threat to marine turtles, hence no SIS is recommended. Suitable management measures should be employed to monitor and regulate boating activities in the vicinity of the OARs so that the risk of boat strike and release of harmful marine debris is minimised or prevented.

CETACEANS

Southern Right Whale

Species Name: Southern Right Whale (*Eubalaena australis*)

Status: Vulnerable

a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

Southern right whales migrate between summer feeding grounds in Antarctica and winter breeding grounds around the coasts of southern Australia, New Zealand, South Africa and South America. They are thought to feed in the open ocean in summer and known to move inshore in winter for calving and mating. Calving females and females with young usually remain very close to the coast, often in the 5-10 m watermark (Web Reference 31). Their population has increased rapidly since they became protected from hunting. They are slow moving and there is some evidence that they are susceptible to vessel strike. Females travel to temperate waters to give birth and mother and calf sightings are becoming more common in the Sydney region as the species' population increases. Southern rights are known to be present along the east coast of Australia between May and November. During this period it is possible that the proposed OAR structures could impact upon habitat availability, increase acoustic pollution (from increased boating activity) or increase the risk of boat strike. However, given that few transient individuals are likely to occur in the study areas and the relatively small proportion of habitat affected by the proposal (in terms of available habitat), it is most unlikely that the 'local' population of the species (which would extend from Sydney to the Southern Ocean) would be placed at risk of extinction due to the possible impacts listed above.

b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Under the *TSC Act*, no endangered population of southern right whales has been scheduled

c) In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:
i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction; or
ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.

Not applicable

d) In relation to the habitat of a threatened species, population or ecological community:
i) the extent to which habitat is likely to be removed or modified as a result of the action proposed; and
ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action; and
iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality.

The major habitats of southern right whales are the feeding areas of the Southern Ocean, the mating and birthing areas of southern Australia (e.g. Great Australian Bight) and some birthing areas along the east and west coasts, principally adjacent to coastal sandy beaches.

Southern right whales migrate along the NSW coast and may move into sandy embayments. Whilst southern right whales may, from time to time occur within wider study areas of the proposed OARs, these areas would be most unlikely to provide a significant area of habitat. The proposed OAR study areas do not constitute a habitat for southern right whales that would become isolated from any other currently interconnecting or proximate areas of habitat.

e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

No critical habitat for southern right whales would be affected as a result of the proposal

f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan. There is an approved Southern Right Whale Recovery Plan 2005 - 2010 (Web Reference 32). Potential threats identified in the plan such as physical injury from boat strike, entanglement in marine debris and acoustic disturbance are relevant to all study regions as they are located in significant metropolitan areas. It is possible that the proposed OAR installment may exacerbate such threats if not properly managed. However, providing that appropriate management measures are implemented to reduce or prevent potential threats from increased boating activity, the proposal would not be considered to affect any of the recovery actions proposed under the plan.
g) Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process. 'Entanglement or ingestion of anthropogenic debris in marine and estuarine environments' is listed as a key threatening process under the NSW *TSC Act.* 'Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris (such as discarded fishing gear)' is also listed as a key threatening process under the Australian Government's *EPBC Act*. The Southern Right Whale is considered particularly vulnerable to this KTP. It is possible, that increased boating activity in the vicinity of the proposed artificial reefs may exacerbate this KTP by increasing the risk of harmful marine debris being released into the marine environment. However, providing that boating activity in the vicinity of the OARs is properly monitored and regulated, then impacts of this and other potential threats from increased boating activity such as risk of boat strike or acoustic disturbance are unlikely to increase the impact of this KTP.

Conclusion:
The proposal is not considered to represent a significant threat to southern right whales, hence no SIS is recommended. Suitable management measures should be employed to minimise any potential harm from increased boating activity in the vicinity of the OARs.

Humpback Whale

Species Name: Humpback Whale (*Megaptera novaeangliae*)
Status: Vulnerable
a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction. The life cycle of humpback whales in the southern hemisphere involves feeding and advancement to maturity in the Southern Ocean during the summer months, followed by northward migration during winter to mate and give birth in subtropical and tropical waters (Jefferson *et al*. 1993). The east coast population of humpbacks migrates along the Victorian, NSW and Queensland coasts to the Coral Sea from late autumn to winter and back along the coast in spring and early summer. Often on the return trip, adults swim close to the shore and are accompanied by new-born calves. Pairs may rest in large embayments such as Jervis Bay and Twofold Bay. During the annual migration, humpbacks swim past the Newcastle, Sydney and Wollongong study areas. During this period it is possible that the proposed OAR structures could impact upon habitat availability, or increase the risk of acoustic disturbance or boat strike due to increased boating activity in the vicinity of the installations. There is also potential entanglement in discarded fishing gear. However, given that no significant aggregation areas (important for either feeding, breeding, resting or calving) occur in the study areas and that individuals are likely to be transient the risk of these factors having an adverse effect on the life cycle of the species such that it would have an affect on a viable local population is considered highly unlikely.
b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction. There are no listed endangered populations of humpback whales in either the TSC Act or EPBC Act, although

both Acts list this species as Vulnerable. Under these definitions, no endangered population of humpback whales could be disrupted by the proposal.
c) In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: *i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction; or* *ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.* Not applicable.
d) In relation to the habitat of a threatened species, population or ecological community: *i) the extent to which habitat is likely to be removed or modified as a result of the action proposed; and* *ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action; and* *iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality.* Major habitats for humpback whales include the feeding/growth and breeding/mating areas in the south and north of their range, respectively, and the migration corridors which extend at least the width of the continental shelf. In addition, some large embayments such as Jervis Bay and Twofold Bay may be used for resting during migration. Given the location, size and present uses of the proposed artificial reefs, it is most unlikely that a significant area of known humpback habitat would be affected by the proposal. It is possible that the OARs could provide a minor obstacle to migrating whales but not to the extent that it could fragment or isolate habitat.
e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly). No habitat critical for humpback whales would be affected as a result of the proposal
f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan. There is an approved Humpback Whale Recovery Plan 2005 - 2010 (Web Reference 33). The proposal would not, however, affect any of the recovery actions proposed under the plan. Potential threats identified in the plan such as physical injury from boat strike, entanglement in marine debris and acoustic disturbance are relevant to all study regions as they are located in significant metropolitan areas. It is possible that the proposed OAR installment may exacerbate such threats if not properly managed. However, providing that appropriate management measures are implemented to reduce or prevent potential threats from increased boating activity, the proposal would not be considered to affect any of the recovery actions proposed under the plan.
g) Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process. Entanglement or ingestion of anthropogenic debris in marine and estuarine environments' is listed as a key threatening process under the NSW *TSC Act.* 'Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris (such as discarded fishing gear)' is also listed as a key threatening process under the Australian Government's *EPBC Act*. The humpback whale is considered particularly vulnerable to this KTP. It is possible, that increased boating activity in the vicinity of the proposed artificial reefs may exacerbate this KTP by increasing the risk of harmful marine debris being released into the marine environment. However, providing that boating activity in the vicinity of the OARs is properly monitored and regulated, then impacts of this and other potential threats from increased boating activity such as risk of boat strike or acoustic disturbance are unlikely to increase the impact of this KTP.

Conclusion:

The proposal is not considered to represent a significant threat to humpback whales, hence no SIS is recommended. Suitable management measures should be employed to minimise any potential harm from increased boating activity in the vicinity of the OARs, particularly during peak migration periods.

Sperm Whale

Species Name: Sperm whale (*Physeter macrocephalus*)
Status: Vulnerable
a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction. Sperm Whales are very large marine mammals with a huge box-like head and underslung lower jaw. Males can grow 18m in length. Distribution is wide, but patchy, from the tropics to the edge of the polar pack-ice in both hemispheres. Concentrations of sperm whales tend to occur where the seabed rises steeply from a greater depth, beyond the continental shelf. It is likely they feed on squid, octopus and fish (Web Reference 34). Main threats to the species are collision with boats and other marine traffic, accidental entanglement in nets, traps, longlines and other fishing gear and rubbish, particularly plastic, which can cause suffocation, abrasion, infection or blockages in the whale's system when swallowed. There have been occasional records of sperm whales occurring inshore in the wider study regions of the proposed OARs. It would be highly unlikely that a viable population of the sperm whale would be placed at risk of extinction as a result of the proposal.
b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction. The proposal is not considered to have an adverse effect such that a local population of the species is put at risk of extinction.
c) In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: *i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction; or* *ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.* Not applicable
d) In relation to the habitat of a threatened species, population or ecological community: *i) the extent to which habitat is likely to be removed or modified as a result of the action proposed; and* *ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action; and* *iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality*. Habitat in the proposed study areas is not considered important to the sperm whale
e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly). No habitat critical to the survival of the sperm whale occurs in any of the wider study areas.
f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan. There is no approved recovery plan for the species, however, collision with boats and other marine traffic, accidental entanglement in nets, traps, longlines and other fishing gear and harmful marine debris are considered potential threats to the species.
g) Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process. Entanglement or ingestion of anthropogenic debris in marine and estuarine environments' is listed as a key threatening process under the NSW *TSC Act.* 'Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris (such as discarded fishing gear)' is also listed as a key threatening process under the Australian Government's

EPBC Act. The sperm whale is considered particularly vulnerable to this KTP. It is possible, that increased boating and fishing activity in the vicinity of the proposed artificial reefs may exacerbate this KTP by increasing the risk of harmful marine debris being released into the marine environment. However, providing that boating activity in the vicinity of the OARs is properly monitored and regulated, then impacts of this KTP and other threats such as boat strike are unlikely to be increased.

Conclusion:

The proposal is not considered to represent a significant threat to sperm whales, hence no SIS is recommended. Suitable management measures should be employed to minimise any potential harm from increased boating activity in the vicinity of the OARs.

Blue Whale

Species Name: Blue Whale (*Balaenoptera musculus*)
Status: Endangered
a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction. Blue whales are the largest living animals and are found in all oceans of the world. Records indicate that the species may occur right around Australia including the coast of NSW (Web Reference 35). Observations in south-east Australia (and other parts of the world) indicate that aggregations of blue whales are mostly associated with feeding areas. There are however, no known feeding or aggregation areas in the wider study region of any of the proposed OAR locations and no known migration routes in Australasian waters. It is therefore considered unlikely that the proposed action would adversely effect the life cycle of the species such that a viable population is likely to be placed at risk of extinction.
b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction. Not applicable
c) In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: *i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction; or* *ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.* Not applicable
d) In relation to the habitat of a threatened species, population or ecological community: *i) the extent to which habitat is likely to be removed or modified as a result of the action proposed; and* *ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action; and* *iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality.* Little is known about the location and characteristics of habitat utilised by blue whales. The best information relates to feeding areas which are known to occur in the south-east of Southern Australia and off Rottnest Island (Western Australia) but is mainly thought to occur in the Antarctic. These areas are considered important as they seasonally support significant aggregations of whales and the ecosystem processes upon which they rely. The habitat affected by the proposal is not considered important to the long-term survival of the species.
e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly). No critical habitat for the blue whale has been declared in NSW.
f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat

abatement plan. There is a recovery plan for the species (Web Reference 36). The proposal would not affect the recovery plan for this species.
g) Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process. Entanglement or ingestion of anthropogenic debris in marine and estuarine environments' is listed as a key threatening process under the NSW *TSC Act.* 'Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris (such as discarded fishing gear)' is also listed as a key threatening process under the Australian Government's *EPBC Act*. The blue whale is considered particularly vulnerable to this KTP. It is possible, that increased boating activity in the vicinity of the proposed artificial reefs may exacerbate this KTP by increasing the risk of harmful marine debris being released into the marine environment. However, providing that boating activity in the vicinity of the OARs is properly monitored and regulated, then impacts of this and other potential threats from increased boating activity such as risk of boat strike or acoustic disturbance are unlikely to increase the impact of this KTP.

Conclusion:
The proposal is not likely to have any affect on habitat important to the blue whale or on the life cycle of the species so that viable populations are put at risk of extinction. The action does not contravene the objectives of a species recovery or threat abatement plan. Provided that suitable management measures should be employed to minimise any potential harm from increased boating activity in the vicinity of the OARs, no SIS is recommended.

PINNIPEDS AND SIRENIANS

Australian Fur-Seal

Species Name: Australian Fur-Seal (*Arctocephalus pusillus doriferus*)
Status: Vulnerable
a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction. Australian fur seals (*Arctocephalus pusillus doriferus*) are coastal mammals that range over the continental slope and shelf waters of Victoria, Tasmania and NSW (Web Reference 37). They may also move into bays occasionally. Australian fur seals eat pelagic and mid-water fish and cephalopods and can dive to approximately 200 m whilst chasing food. They breed on 10 islands in the Bass Strait. Pregnant females return to colonies in late October /early November to give birth to a single pup (Menkhorst and Knight 2001). Pregnant females feed intensively at sea in early spring before returning to give birth. Australian fur seals are reported to have bred in the past in NSW (prior to commercial sealing) at Seal Rocks and Montague Island but they no longer do so. There are other non-breeding colonies between Kangaroo Island in South Australia and Jervis Bay in NSW. These are Green Cape, Montague Isand and Steamers Beach near Jervis Bay. In addition, other various locations along the NSW coast are used irregularly as haul-out sites. Australian fur-seals are known to be found in and around The Five Islands Nature Reserve in the Wollongong study region. Although the species no longer breeds in NSW, habitat and resources within the state remain important to non-breeding individuals. Human activities in the ocean can affect seals by competing with them for prey, by entanglement (i.e. with fishing gear) and through noise (Shaughnessy 1999). The threat to seals from the proposal comes from the expected increase in boating activity in the study areas whereby there is potential for collision, entanglement in discarded fishing gear and increased noise disturbance. It is also possible that seals would be attracted to aggregating prey or traps which could be set around the reefs. It is likely that Australian fur-seals may use the proposed study area for occasional foraging, although the disturbance to the seals is considered to be relatively minor and unlikely to disrupt the life cycle of this species

such that a viable local population of the species is placed at risk of extinction.
b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction. No endangered population of Australian fur seals is listed in NSW.
c) In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: *i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction; or* *ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.* Not applicable.
d) In relation to the habitat of a threatened species, population or ecological community: *i) the extent to which habitat is likely to be removed or modified as a result of the action proposed; and* *ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action; and* *iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality.* Although a small area of foraging habitat of seals would be potentially affected during emplacement of the structures, this would be temporary and not considered to be significant in terms of the regional distribution of the habitat.
e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly). No critical habitat for the Australian fur seal has been declared in NSW.
f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan. There is no approved recovery plan for this species.
g) Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process. Entanglement or ingestion of anthropogenic debris in marine and estuarine environments' is listed as a key threatening process under the NSW *TSC Act.* 'Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris (such as discarded fishing gear)' is also listed as a key threatening process under the Australian Government's *EPBC Act*. The Australian fur-seal is considered particularly vulnerable to this KTP. It is possible, that increased boating activity in the vicinity of the proposed artificial reefs may exacerbate this KTP by increasing the risk of harmful marine debris being released into the marine environment. However, providing that boating activity in the vicinity of the OARs is properly monitored and regulated, then impacts of this KTP are unlikely to be increased as a result of the proposal.

Conclusion:

The proposal is not considered to represent a significant threat to the Australian fur-seal as there are no significant seal colonies in any of the wider study areas and provided that suitable management measures should be employed to minimise any potential harm from increased boating and recreational fishing activity in the vicinity of the OARs.

New Zealand Fur-Seal

Species Name: New Zealand Fur-Seal (Arctocephalus forsteri)
Status: Vulnerable

a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

New Zealand fur seals (*Arctocephalus forsteri*) are coastal mammals that occur in Australian and New Zealand waters. In Australian waters, New Zealand fur-seals have been recorded in all of the southern states as well as in Queensland (south of Fraser Island). They eat fish and cephalopods and to a lesser extent birds such as penguins, both in shallow waters and around the margins of the continental shelf. In Australia, breeding colonies are known from islands off WA, SA and Tasmania, including Macquarie Island. Although the species does not breed in NSW, habitat and resources within the state remain important to non-breeding individuals. Montague Island is a regular haul-out site in NSW (Shaughnessy 1999), although other infrequently used sites have been recorded along the NSW coast. New Zealand fur seals may range into coastal bays.

Human activities in the ocean can affect seals by competing with them for prey, by entanglement (i.e. fishing gear) and through noise (Shaughnessy 1999). The threat to seals from the proposal comes from the expected increase in boating activity in the study areas whereby there is potential for collision, entanglement in discarded fishing gear and increased noise disturbance. It is also possible that seals would be attracted to aggregating prey or traps which could be set around the reefs.

It is likely that Australian fur-seals may use the proposed study area for occasional foraging, although the disturbance to the seals is considered to be relatively minor and unlikely to disrupt the life cycle of this species such that a viable local population of the species is likely to be placed at risk of extinction.

b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

No endangered population of New Zealand fur seals is listed in NSW.

c) In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction; or

ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.

Not applicable.

d) In relation to the habitat of a threatened species, population or ecological community:

i) the extent to which habitat is likely to be removed or modified as a result of the action proposed; and

ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action; and

iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality.

Although a small area of potential foraging habitat for seals would be affected during emplacement of the OAR this would be temporary and not considered to be significant in terms of the regional distribution of the habitat. The proposal would not cause any area of fur seal habitat to become isolated

e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

No critical habitat for the New Zealand fur seal has been declared in NSW

f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

There is no approved recovery plan for this species

g) Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

Entanglement or ingestion of anthropogenic debris in marine and estuarine environments' is listed as a key threatening process under the NSW *TSC Act.*

'Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris (such as discarded fishing gear)' is also listed as a key threatening process under the Australian Government's *EPBC Act*. The New Zealand fur-seal is considered particularly vulnerable to this KTP. It is possible, that increased boating activity in the vicinity of the proposed artificial reefs may exacerbate this KTP by increasing the risk of harmful marine debris being released into the marine environment. However, providing that boating activity in the vicinity of the OARs is properly monitored and regulated, then impacts of this KTP are unlikely to be increased

Conclusion:
The proposal is not considered to represent a significant threat to the Australian fur-seal as there are no significant seal colonies in any of the wider study areas. Provided that suitable management measures are employed to minimise any potential harm from increased boating and recreational fishing activity (i.e. entanglement) in the vicinity of the OARs it is not considered that a SIS would be required.

Dugong

Species Name: Dugong (*Dugong dugon*)
Status: Endangered
a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction. In Australia, dugongs (*Dugong dugon*) swim in the shallow coastal waters of northern Australia where they find protection from large waves and storms. Dugongs surface only to breathe, and never come on to land. They like to live in large herds, but due to declining numbers are often now found in smaller "family" groups of between one to three dugongs. The largest remaining dugong population in the world, in 1991 was the northern Australian population, which was estimated at approximately 70,000 with 12,500 in the Torres Straits and 1,700 in the northern Great Barrier Reef (Web Reference 38). Although they only live where there is seagrass, on which they feed, they may migrate between areas. No seagrass is found within any of the direct study areas as it is too deep. Dugongs that have been observed in NSW including the wider study areas of the proposed Newcastle and Sydney OARs are thought to be non-breeding vagrants. Hence, if they were to occur in the study area they would presumably be passing through. Risks from the proposal would be potential for entanglement in fishing gear and injury from boat strike due to increased boating activity in the OAR study areas. This is, however, considered unlikely and the proposal is not considered to have an adverse effect on the life cycle of the species such that a viable local population of the species is placed at risk of extinction.
b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction. No endangered population of dugongs has been listed in NSW
c) In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: *i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction; or* *ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.* Not applicable
d) In relation to the habitat of a threatened species, population or ecological community: *i) the extent to which habitat is likely to be removed or modified as a result of the action proposed; and* *ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action; and* *iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the*

species, population or ecological community in the locality. Dugongs have been reported feeding in seagrass beds of the North Coast of NSW and vagrants may occur further south. Mating and birthing areas are normally in northern Australian waters between Shark Bay in Western Australia and Moreton Bay in Queensland. The artificial reefs would not be located on seagrass beds and no area of the dugong habitat would be modified or removed through the proposal. The proposal would not lead to any habitat becoming isolated
e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly). No critical habitat for dugongs has been declared in NSW
f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan. There is currently no recovery plan for this species in NSW.
g) Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process. Entanglement or ingestion of anthropogenic debris in marine and estuarine environments' is listed as a key threatening process under the NSW *TSC Act.* 'Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris (such as discarded fishing gear)' is also listed as a key threatening process under the Australian Government's *EPBC Act*. The dugong is considered particularly vulnerable to this KTP. It is possible, that increased boating activity in the vicinity of the proposed artificial reefs may exacerbate this KTP by increasing the risk of harmful marine debris being released into the marine environment. However, likelihood of this occurring is considered low and providing that boating activity in the vicinity of the OARs is properly monitored and regulated, then impacts of this KTP and other threats such as boat strike are unlikely to be increased.

Conclusion:
The proposal is not considered to represent a significant threat to the dugong as there is no important habitat (such as seagrass beds) in the direct study area and no known aggregations in the wider study areas. Provided that suitable management measures are employed to minimise any potential harm from increased boating and recreational fishing activity (i.e. entanglement or boat strike) in the vicinity of the OARs it is not considered that a SIS would be required.

MARINE BIRDS

Little Penguin

Species Name: Little Penguin (*Eudyptula minor*)
Status: Endangered Population (Little Manly Point)
a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction. A critical habitat has been declared for the little penguin population in the Manly Point area that extends from the area on and near the shoreline from Cannae Point generally northward to the point near the intersection of Stuart Street and Oyama Cove Avenue, including 100 m offshore from that shoreline. The endangered population of little penguins at Manly are the only known breeding population on the mainland in NSW (Web Reference 39). The population utilises a range of nest sites, including under rocks on the foreshore, under seaside houses and structures, such as stairs, in wood piles and under overhanging vegetation. The penguins appear to be opportunistic feeders foraging in relatively shallow waters preying on small schooling fish such as anchovy and pilchards and squid. The daily foraging range for adult penguins is between 10 km and 30 km. Immature birds however, are known to disperse hundreds of kilometres from their colonies. The foraging range and breeding success is considered to be very much dependant on the availability and abundance of food

(NSW NPWS 2000). The Manly population of little penguins is located approximately 3.7 km north west from the proposed Sydney OAR site and may therefore utilise the direct and wider study area for foraging. The species commonly dives to depths between 2 m and 10 m but may occasionally forage much deeper than this i.e. > 25 m (Ropert-Couldert et al 2006). The species could therefore potentially forage within the OAR depth range. The major threat to the Manly population is the loss of suitable habitat for breeding nesting and moulting (Web Reference 39), while predation from dogs and foxes is also a significant threat. As the colony is located in an urbanised area, disturbance from noise, light and movement is also a problem. The species may also be put at risk from injury due to harmful marine debris such as discarded fishing gear as a result of increased fishing activity at the proposed Sydney OAR location. However, providing that OARs are suitably managed and carefully monitored for interactions of fishing with the species, then it is considered unlikely the proposal would disrupt the life cycle of this species such that a viable local population of the species is likely to be placed at risk of extinction.
b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction. It is considered unlikely that the proposal would have an adverse effect on the Manly population of little penguins such that the viable local population was put at risk of extinction.
c) In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: *i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction; or* *ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.* Not Applicable
d) In relation to the habitat of a threatened species, population or ecological community: *i) the extent to which habitat is likely to be removed or modified as a result of the action proposed; and* *ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action; and* *iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality.* The proposal would not affect the habitat important to the survival of the species in any of the ways outlined above.
e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly). The proposal would not have any direct or indirect adverse effect on the manly little penguin critical habitat.
f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan. The proposal does not directly contravene the objectives of the recovery plan, it is however, possible that potential entanglement due to increased recreational fishing activity could be a threat if the species were to regularly forage in the area.
g) Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process. Entanglement or ingestion of anthropogenic debris in marine and estuarine environments' is listed as a key threatening process under the NSW *TSC Act.* 'Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris (such as discarded fishing gear)' is also listed as a key threatening process under the Australian Government's *EPBC Act*. The little penguin is considered vulnerable to this KTP. It is possible, that increased boating activity in the vicinity of the proposed artificial reefs may exacerbate this KTP by increasing the risk of harmful marine debris being released into the marine environment. However,

providing that boating activity in the vicinity of the OARs is properly monitored and regulated, then impacts of this KTP are unlikely to be increased.

Conclusion:
The proposal is not considered to represent a significant threat to the little penguin but it is recommended that suitable management measures are employed to minimise any potential harm from increased boating and recreational fishing activity (i.e. entanglement or boat strike) in the vicinity of the OARs. The OARs should also be carefully monitored for occurrence and/or interactions of the species with fishing activity it is not considered that a SIS would be required.

Seabirds

Species Group: Seabirds (not including penguins)
Status: (protected, vulnerable and endangered)
a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction. Commercial long-lining is considered a significant threat to seabirds (particularly albatross and giant petrels) this however, mainly takes place in Commonwealth waters and is not relevant to the current proposal. Other types of line fishing (such as set-lining) do take place within State waters and could potentially affect seabirds if these practices were to increase within the study areas. The recreational practice of trolling a fishing line at or near the surface also has the potential to cause mortality if seabirds are caught on hooks. This risk can be eliminated by setting troll lines at least 2m below the surface of the water. It is possible that discarded bait from recreational fishing boats could also attract seabirds to feed in the area thus, increasing the risk of becoming injured or entangled. Seabirds may also be put at risk from injury due to harmful marine debris such as discarded fishing gear as a result of increased fishing activity within the study areas. Such entanglement can constrict growth and circulation, leading to asphyxiation. Entanglement may also increase the bird's drag coefficient through the water, causing the animal to die due to its reduced ability to catch prey or avoid predators. Species most at risk to these potential threats are those known to roost or breed on land nearby to the direct study areas. This includes the sooty oyster catcher, wedge-tailed shearwater, short-tailed shearwater, silver gull, kelp gull and white bellied sea eagle. These species are known to inhabit the Five Islands Nature Reserve (Wollongong) and/or the Moon Island Nature Reserve (Newcastle) which are located 2.4 km and 4 km from the respective OAR locations. However, providing that OARs are suitably managed and carefully monitored for impacts on such species, then it is considered unlikely the proposal would disrupt the life cycle of this species such that a viable local population of the species is likely to be placed at risk of extinction
b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction. It is considered unlikely that the proposal would have an adverse effect on seabirds such that a viable local population was put at risk of extinction.
c) In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: *i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction; or* *ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.* Not Applicable
d) In relation to the habitat of a threatened species, population or ecological community: *i) the extent to which habitat is likely to be removed or modified as a result of the action proposed; and* *ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action; and* *iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the*

species, population or ecological community in the locality. The proposal would not affect the habitat important to the survival of the species in any of the ways outlined above.
e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly). The proposal would not have any direct or indirect adverse effect on the critical habitat of a species of seabird.
f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan. A recovery plan for albatrosses and giant petrels is available (Web Reference 40). One aim of the recovery plan is to minimise all human induced threats to albatrosses and giant-petrels. The proposal is not considered to directly contravene the objectives of the recovery plan, it is however, possible that indirect impacts from recreational fishing activity (e.g. entanglement in fishing line, increase in harmful marine debris) could be potential threats to seabirds. The proposal would however aim to educate fishers and promote public awareness of the threats to albatrosses and giant-petrels which would be consistent with objectives of the recovery plan. A recovery plan for 10 species of seabirds is also available. This incudes the protected soft-plumaged petrel (*Pterodroma molis*) likely to occur in the Sydney study region. The proposal is considered to be consistent with the objectives of this recovery plan.
g) Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process. Entanglement or ingestion of anthropogenic debris in marine and estuarine environments' is listed as a key threatening process under the NSW *TSC Act.* 'Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris (such as discarded fishing gear)' is also listed as a key threatening process under the Australian Government's *EPBC Act*. Seabirds are considered vulnerable to this KTP. It is possible, that increased boating activity in the vicinity of the proposed artificial reefs may exacerbate this KTP by increasing the risk of harmful marine debris being released into the marine environment. However, providing that boating activity in the vicinity of the OARs is properly monitored and managed, then impacts of this KTP are unlikely to be increased.

Conclusion:

The proposal is not considered to represent a significant threat to seabirds but it is recommended that suitable management measures are employed to minimise any potential harm from increased boating and recreational fishing activity (i.e. entanglement or boat strike) in the vicinity of the OARs. The OARs should also be carefully monitored for occurrence and/or interactions of the species with fishing activity it is not considered that a SIS would be required.

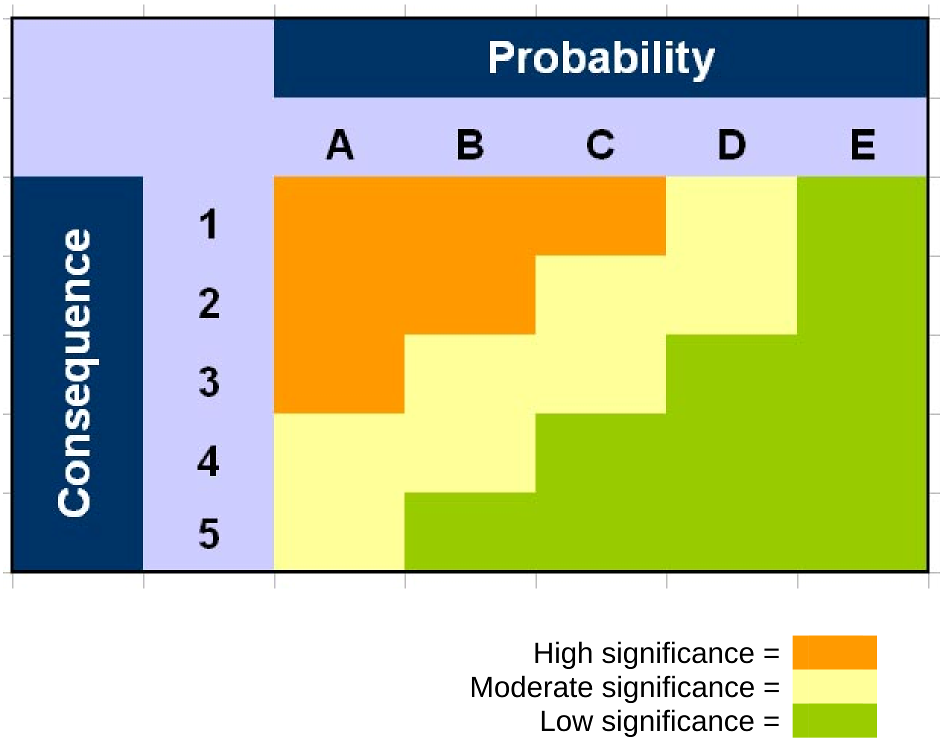
Appendix 6: Risk assessment methodology. a) rationale for likelihood and consequence b) significance assessment matrix.

a)

Probability/Likelihood		
A	Almost certain	> 1 month
B	Could readily happen	> 1 year
C	Could happen and has occurred elsewhere	1 to 10 years
D	has not happened but could	10 - 100 years
E	Concievable in extreme circumstances	<1/100 years

Consequence	
1	Extreme environmental harm (e.g. widespread catastrophic impact)
2	Major environmental harm (widespread substantial impact)
3	Serious environmental harm (widespread significant impact)
4	Moderate environmental harm (localised and significant harm)
5	Minimal environmental harm (interference or likely interferance)

b)



Appendix 7: Raw species data used to determine ranks for the Productivity Susceptibility Analyses (PSA). Data was compiled from the NSW Status of Fisheries Resources (Scandol *et al*. 2008), Fishbase (Web Reference 26) and relevant literature.

1. Productivity Attributes

Common Name	Scientific Name	Age at maturity	Length at maturity (L_m)	Approx. lifespan	Fecundity	Reproductive strategy
Shovelnose ray*	*Aptychotrema rostrata*	2.9	60	13	18	live bearer
Fiddler ray*♦	*Trygonorrhina fasciata*	2.8	65.7	13.7	3	live bearer
Spotted wobbegong♥	*Orectolobus maculatus*	unknown	130	unknown	30	live bearer
Banded wobbegong♥	*Orectolobus halei*	unknown	170	unknown	53	live bearer
Ornate wobbegong♥	*Orectolobus ornatus*	unknown	80	unknown	7 - 10	live bearer
Herrings, sardines, pilchards*♦	*Clupeidae*	3	15	8	10,000 - 45, 000	broadcast spawners
Moray eel♥	*Gymnothorax prasinus*	unknown	49.5	unknown	unknown	broadcast spawners
Sargeant baker♥	*Aulopus purpurissatus*	unknown	34.1	unknown	unknown	broadcast spawners
Nannygai †	*Centroberyx affinis*	4.1	29.5	30	unknown	broadcast spawners
John dory♥	*Zeus faber*	3	30	12	unknown	broadcast spawners
Red rock cod♥	*Scorpaena cardinalis*	4.8	23.8	18.9	unknown	broadcast spawners
Eastern blue-spotted flathead*†	*Platycephalus caeruleopunctatus*	3.9	30	15.8	300,000 - 1,500,000	broadcast spawners
Long-spine flathead*†	*Platycephalus longispinus*	2.1	22.8	8.4	assumed 2,000,000	broadcast spawners
Dusky flathead♦	*Platycephalus fuscus*	2.9	45.1	13.1	294,000 - 3,948,000	broadcast spawners
Tiger flathead♦	*Platycephalus richardsoni*	1.8	29	7.5	1,936,492	broadcast spawners
long-fin pike♥	*Dinolestes lewini*	unknown	45.9	unknown	unknown	broadcast spawners
School whiting♦	*Sillago bassensis*	2	15	10.9	unknown	broadcast spawners
Tailor †	*Pomatomus saltatrix*	3.3	64.6	16	400,000 to 2,000,000	broadcast spawners
Cobia♥	*Rachycentron canadum*	2.1	66.3	10	unknown	broadcast spawners
Silver trevally*♦	*Pseudocaranx georgianus*	10	25	30	50,000 - 200,000	broadcast spawners
Yellow-tail scad*♦	*Trachurus novaezelandiae*	3	23.9	28	unknown	broadcast spawners
Kingfish †♦	*Seriola lalandi*	4.5	74.3	22.2	assumed >1,000,000	broadcast spawners
Common dolphinfish♥	*Corypheana hippurus*	<1	87.2	4	58,000 - 1,548,685	broadcast spawners
Australian salmon♦	*Arripis trutta*	4	39	9.9	unknown	broadcast spawners
Snapper*♦	*Pagrus auratus*	8.8	50.7	35	519,616	broadcast spawners

Continued

Appendix 7: Continued

1. Productivity Attributes

Common Name	Scientific Name	Age at maturity	Length at maturity (L_m)	Approx. lifespan	Fecundity	Reproductive strategy
Tarwhine♦	*Rhabdosargus sarba*	5.7	21	26.1	unknown	broadcast spawners
Yellow-fin bream †♦	*Acanthopagrus australis*	3.9	22	17	948,684	broadcast spawners
Silver biddy♦	*Gerres subfasciatus*	0.9	12.9	3.4	unknown	broadcast spawners
Mulloway♥	*Argyrosomus japonicus*	5.8	68	24	968,401	broadcast spawners
Luderick♦	*Girella tricuspidata*	3.8	26.7	15.8	346,411	broadcast spawners
Black drummer♥	*Girella elevata*	4.3	35.1	19.1	unknown	broadcast spawners
Silver sweep †	*Scorpis lineolata*	2.5	17.2	54	unknown	broadcast spawners
Blue morwong †	*Nemadactylus douglasii*	3	23	22	unknown	broadcast spawners
Red morwong♥	*Cheilodactylus fuscus*	4.6	36.6	20.4	unknown	broadcast spawners
Bastard trumpeter♥	*Latridopsis forsteri*	2.7	36.6	11.9	unknown	broadcast spawners
Sand mullet♦	*Myxus elongatus*	2.6	23.8	10.5	unknown	broadcast spawners
Striped sea pike♥	*Sphyraena obtusata*	1.1	22.7	4.5	unknown	broadcast spawners
Maori wrasse †	*Opthalmolepis lineolata*	2	18.4	14.2	unknown	broadcast spawners
Blue grouper♥	*Achoerodus viridis*	7.6	62.9	36.2	unknown	broadcast spawners
Blue mackerel♦	*Scomber australasicus*	2.9	25	7	unknown	broadcast spawners
Australian bonito♦	*Sarda australis*	3.6	90	18.1	assumed >1,000,000	broadcast spawners
Striped marlin♥	*Tetrapturus audax*	1.3	140.1	7.1	>2,000,000	broadcast spawners
Sawtail♥	*Prionurus microlepidotus*	3.2	39.1	14.3	unknown	broadcast spawners
Yellow-finned leatherjacket*	*Meuschenia trachylepis*	3.5	23.8	14.2	2,000,000 max	broadcast spawners
Chinaman leatherjacket*♦	*Nelusetta ayraudi*	3	53.5	13.8	2,000,000 max	broadcast spawners
Six-spined leatherjacket†	*Meuschenia freycineti*	4.7	34.1	20.4	2,000,000 max	broadcast spawners
Southern calamari♥	*Sepioteuthis australis*	7 - 8 months	15-20	1	thousands	demersal egg layer
Arrow squid♥	*Nototodarus gouldi*	unknown	30	1 ?	thousands	demersal egg layer

Continued

Appendix 7: Continued

2. Susceptibility Attributes

Common Name	Scientific Name	Target group	Habitat preference	Site fidelity	NSW DPI Exploitation status	Depth range
Shovelnose ray*	*Aptychotrema sp.*	CR	soft substratum	transient	Undefined	0 - 100
Fiddler ray*♦	*Trygonorrhina fasciata*	C	soft substratum	transient	Undefined	0 - 100
Spotted wobbegong♥	*Orectolobus maculatus*	CR	both	territorial	Undefined	0 - 100
Banded wobbegong♥	*Orectolobus halei*	CR	reef	territorial	Undefined	0 - 50
Ornate wobbegong♥	*Orectolobus ornatus*	CR	reef	territorial	Undefined	0 - 50
Herrings, sardines, pilchards*♦	*Clupeidae*	C	both	transient	Moderately fished	0 - 200
Moray eel♥	*Gymnothorax prasinus*	R	reef	territorial	Undefined	0 - 50
Sargeant baker♥	*Aulopus purpurissatus*	R	reef	both	Undefined	0 - 100
Nannygai †	*Centroberyx affinis*	R	reef	territorial	Growth overfished	10 - 450
John dory♥	*Zeus faber*	R	both	transient	fully fished	5 - 400
Red rock cod♥	*Scorpaena cardinalis*	R	reef	territorial	Undefined	5 - 50
Eastern blue-spotted flathead*†	*Platycephalus caeruleopunctatus*	RC	soft substratum	territorial	Fully fished	40 -100
Long-spine flathead*†	*Platycephalus longispinus*	R	soft substratum	territorial	Undefined	10 - 75
Dusky flathead♦	*Platycephalus fuscus*	CR	soft substratum	territorial	Fully fished	0 - 30
Tiger flathead♦	*Platycephalus richardsoni*	CR	soft substratum	territorial	Fully fished	40 - 300
long-fin pike♥	*Dinolestes lewini*	R	reef	both	Undefined	5 - 65
School whiting♦	*Sillago bassensis*	CR	sand	territorial	Fully fished	0 - 100
Tailor †	*Pomatomus saltatrix*	R	both	territorial	Undefined	0 - 50
Cobia♥	*Rachycentron canadum*	R	both	transient	Undefined	0 - 1200
Silver trevally*♦	*Pseudocaranx dentex*	RC	sand	both	Growth overfished	10 - 25
Yellow-tail scad*♦	*Trachurus novaezelandiae*	RC	reef	territorial	Fully fished	22 - 150
Kingfish †♦	*Seriola lalandi*	RC	reefs	transient	Growth overfished	3 - 825
Common dolphinfish♥	*Corypheana hippurus*	RC	both	transient	Undefined	0-85
Australian salmon♦	*Arripis trutta*	CR	both	territorial	Undefined	30 - 39
Snapper*♦	*Pagrus auratus*	RC	both	transient	Growth overfished	0 - 200
Tarwhine♦	*Rhabdosargus sarba*	CR	both	both	fully fished	0 - 70
Yellow-fin bream †♦	*Acanthopagrus australis*	RC	both	both	Fully fished	0- 55
Silver biddy♦	*Gerres subfasciatus*	C	soft substratum	both	Moderately fished	3 - 40

Continued

Appendix 7: Continued

2. Susceptibility Attributes

Common Name	Scientific Name	Target group	Habitat preference	Site fidelity	NSW DPI Exploitation status	Depth range
Mulloway♥	*Argyrosomus japonicus*	RC	both	both	overfished	0 - 100
Luderick♦	*Girella tricuspidata*	CR	reef	territorial	Moderately fished	0 - 20
Black drummer♥	*Girella elevata*	R	reef	territorial	Undefined	0 - 25
Silver sweep †	*Scorpis lineolata*	RC	reef	territorial	Fully fished	1 - 30
Blue morwong †	*Nemadactylus douglasii*	R	reef	territorial	Fully fished	10 -100
Red morwong♥	*Cheilodactylus fuscus*	R	reef	territorial	Undefined	0 - 30
Bastard trumpeter♥	*Latridopsis forsteri*	CR	soft substratum	transient	Undefined	20 - 160
Sand mullet♦	*Myxus elongatus*	C	soft substratum	territorial	Undefined	0 - 50
Striped sea pike♥	*Sphyraena obtusata*	R	reef	both	Undefined	20 - 120
Maori wrasse †	*Opthalmolepis lineolata*	R	reef	territorial	Undefined	60 - ?
Blue grouper♥	*Achoerodus viridis*	R	reef	territorial	growth overfished	0 - 40
Blue mackerel♦	*Scomber australasicus*	CR	both	transient	Moderately fished	87 - 200
Australian bonito♦	*Sarda australis*	CR	soft substratum	transient	Undefined	deep
Striped marlin♥	*Tetrapturus audax*	RC	soft substratum	transient	Undefined	0-200
Sawtail♥	*Prionurus microlepidotus*	R	reef	both	Undefined	0 - 50
Yellow-finned leatherjacket*	*Meuschenia trachylepis*	CR	both	transient	Fully fished	10 - 40
Chinaman leatherjacket*♦	*Nelusetta ayraudi*	RC	both	transient	Fully fished	0 - 200
Six-spined leatherjacket†	*Meuschenia freycineti*	R	reef	both	Fully fished	0 - 100
Southern calamari♥	*Sepioteuthis australis*	CR	soft substratum	both	Undefined	10 - 500
Arrow squid♥	*Nototodarus gouldi*	CR	soft substratum	both	Undefined	50 - 400

(*) = recorded in January 2009 fish survey
(†) = recorded in top ten observed recreational and spearfishing catches 2007/2008 (Web Reference 23)
(♦) = recorded in top 20 commercially caught species (estimated by weight in tonnes) 2006/2007 (Web Reference 24)
(♥) = Other species considered likely to occur

Appendix 8: Classification of species exploitation status. Source: Scandol *et al*. 2008.

CATEGORY	CHARACTERISTIC
RECRUITMENT OVERFISHED	• Recruitment is being significantly or measurably suppressed as a result of a small spawning biomass • Other characteristics of an 'overfished' stock (see below) are likely to be evident • Unequivocal determination will require a well-calibrated population model or stock-recruitment relationship
OVERFISHED	• Fishing mortality rates are more than double natural mortality rates • Estimates of biomass are less than 30% of the estimated unfished stock • Catch rates are less than 30% of the initial catch rates • Length and age distributions unstable (excessively affected by recruitment, too few age or size classes in the exploitable population given a species' life history) • Trends in length/age compositions are evident which indicate increasing (and/or excessive) fishing mortality • The 'Spawning Potential Ratio' is less than 20%
GROWTH OVERFISHED	• Yield per recruit would increase if length at first capture was increased or fishing mortality decreased
FULLY FISHED	• Fishing mortality is approximately the same as natural mortality • Estimates of the biomass are greater than 30% of the estimated unfished biomass • Catch rates have been steady for 5-10 years and/or catch rates are greater than 30% of initial catch rates. • Length and age distributions are stable • Species are fished throughout their entire geographic range
MODERATELY FISHED	• Fishing mortality is less than half of natural mortality • Estimates of the biomass are greater than 70% of the estimated unfished biomass • Catch rates are greater than 70% of initial catch rates • Species are fished in most of their geographic range but non-fishing areas are known to exist
LIGHTLY FISHED	• Fishing mortality less than 25% of natural mortality • Estimates of the biomass are greater than 90% of the estimated unfished biomass • Catch rates are greater than 90% of initial catch rates • Only small proportions of the geographic range are fished • Markets would likely limit catch and effort
UNCERTAIN	• A significant amount of evidence has been collected and considered, but there are inconsistent or contradictory signals in the data that preclude determination of exploitation status
UNDEFINED	• Commercial catch data are available but no reasonable attempt has been made to determine exploitation status