Report to:

Johnson Property Group

Concept Plan for Trinity Point Marina and Mixed Use Development

Aquatic Ecological Investigations

Revised Final

November 2008

The Ecology Lab Pty Ltd
Marine and Freshwater Studies

Concept Plan for Trinity Point Marina and Mixed Use Development

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Johnson Property Group

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DIRECTOR-GENERALS ENVIRONMENTAL ASSESSMENT REQUIREMENTS

The Director-Generals Environmental Assessment Requirements (DGRs - issued on 17 April 2008) that pertain to aquatic ecology, have been addressed within this report as indicated below.

DGR	Location within this report	How addressed
5 Water Cycle Management		
5.1 Water Cycle Management - potential impacts of elevated copper and zinc levels on water quality	Section 4.7	Review of Patterson Britton & Partners water quality data results, with particular emphasis on copper from anti-fouling paint and zinc from sacrificial anodes.
12 Flora and Fauna		
12.1 Assess potential impacts on threatened species, populations and endangered ecological communities in accordance with the draft *Guidelines for Threatened Species Assessment DEC & DPI July 2005.*	Section 1.3 Section 4.5 Appendix 3	Additional text on dugongs, turtles and Syngnathidae. Assessment of impacts on threatened and protected species and endangered communities. 7-Part Tests for threatened species listed under the *FM* and *TSC Act.*
	Section 3.1.3 Figure 1b Appendix 3.1.4	Listed dominant saltmarsh species observed. RPS Harper Somers O'Sullivan re-surveyed in October 2008 and their findings were incorporated into the mapping in Figure 1. 7-Part Test for endangered

		ecological community listed under the *TSC Act*.
12.2 Address measures for the conservation of flora and fauna and their habitats within the meaning of the *TSC Act 1995* and *FM Act*.	Section 3.1.4	There was no statement about whether or not the introduced species *Caulerpa taxifolia* was found within the seagrass beds at the site. Absence of *Caulerpa taxifolia* added to results.
12.3 Assess the impacts on flora and fauna in accordance with the *Lake Macquarie Flora and Fauna Survey Guidelines.*	Figure 1	Vegetation Mapping - there was a discrepancy in location of the saltmarsh community between terrestrial and aquatic ecological assessments. RPS Harper Somers O'Sullivan re-surveyed in October 2008 and their findings were incorporated into the mapping in Figure 1.
14 Marina Developments and Potential Impacts		
14.1 The breakwater running from the shoreline, seaward may cause seagrass wrack to build up along the shoreline to the east creating wrack accumulation zones.	Section 4.2.1	Assessment of impacts on seagrass wrack movement and accumulation.
14.1 There are no compensatory measures proposed to replace lost marine vegetation, i.e. seagrass.	Section 4.2.1	Due to the small area of direct damage to seagrass, it is considered that no mitigation is necessary. Ganassin and Gibbs (2008), show that seagrass

		restoration techniques in NSW have not been successful. However, if requested by NSW DPI (Fisheries), seagrass habitat compensation at a ratio of 2:1 (i.e. 12 m^2) could be undertaken.
14.1 There were no field data collected for fish within the seagrass beds in the proposed area of the marina development. The protected family Syngnathidae (seahorses, pipefish etc) will most likely be found in the seagrass beds.	Section 3.6 Section 4.2.2	Results of fish observations added. NSW DPI (Fisheries) requested that the proposal provide additional habitat for seahorses. This could be done by placing shark-netting, parallel to the shoreline, along the outer margin of a section of the existing seagrass bed.
14.1 There is no information on the potential impacts to the recreational fishers within this section of the lake.	Section 4.2.2	Given that artificial structures may attract many species of reef fish, sometimes in greater numbers than in similar natural habitats, it is considered that the proposed marina structures would benefit recreational fishers within this section of Lake Macquarie.

1.0 INTRODUCTION

1.1 Background and Aims

Johnson Property Group has commissioned The Ecology Lab Pty Ltd to provide advice, undertake ecological investigations and assist with the approvals process in relation to aquatic ecology issues for the Concept Plan for Trinity Point Marina and Mixed Use Development, on the shores of Lake Macquarie near Bardens Bay. Such developments have the potential to impact on the aquatic ecology of the area and these impacts require assessment as part of the approvals process. The current application is for a Concept Plan approval, which provides a broad overview of what is proposed at the development site. However, notwithstanding that, our aquatic ecology investigation was targeted at a greater level of assessment for the water-based component of the project.

The proposed Marina and Mixed Use Development at Trinity Point covers an area of 9.33 hectares. The aquatic structures proposed for the marina development (Figure 1) would include:

- a 20 m long aluminium mesh jetty that leads onto a 4-armed marina (constructed of floating walkways and supported by epoxy-coated steel tube piles) containing 308 berths that extends almost 300 m from the shoreline;
- a 25 m long aluminium mesh jetty that leads onto a timber slatted breakwater (supported by epoxy-coated steel tube piles) surrounding the southern and eastern sides of the marina to protect it from wave action in rough conditions;
- a steel pontoon helipad extending out from the south-eastern corner of the breakwater; and
- a travel lift platform with twin steel rails, extending approximately 50 m from the shoreline just north of the marina.

Potential impacts of the development centre around their impacts on seagrasses within the vicinity of the development site. Seagrass are protected under NSW legislation and subject to special consideration in the development approvals process. Also present adjacent to the site are small patches of protected saltmarsh and mangrove habitats that could be indirectly impacted by changes to land use in the resort complex. These vegetation types are also protected under NSW legislation.

RPS Harper Somers O'Sullivan has undertaken a terrestrial ecology report in relation to the Concept Plan for Trinity Point Marina and Mixed Use Development. This report also incorporated saltmarsh and mangrove communities, and their most recent mapping (October 2008) for these two vegetation communities is included in Figure 1.

The aims of the advice and ecological investigations undertaken by The Ecology Lab would be:

- to assess the current condition of the seagrass, saltmarsh, mangrove and benthic habitats adjacent to the development;
- suggest possible mitigative measures to minimise potential impacts on aquatic ecology, particularly with respect to sensitive and protected habitats;
- liaise with relevant agency representatives as required and under the direction of Johnson Property Group;

- assess the overall impact of the development on aquatic ecology in a technical Environmental Assessment document;
- assist in the preparation of permits relating to aquatic ecology (such as permit to dredge from NSW Fisheries, if required); and
- assist in responses to public submissions to issues relating to aquatic ecology.

This report provides:

- review existing relevant information relating to aquatic vegetation and fauna within Lake Macquarie, and more specifically Bardens Bay;
- results obtained from recent field investigations of the development site - including mapping of various aquatic vegetation types, seagrass density and morphology data, characterisation of unvegetated bottom (benthic) habitats and assessments of condition of mangroves and saltmarsh within the study area;
- an assessment of any potential impacts that may arise as a result of the proposed development which would help in the design of the marina complex and aid in the planning throughout the approvals process.

1.2 Review of Existing Information

1.2.1 Aquatic Vegetation Within Lake Macquarie

Aquatic vegetation, such as seagrasses, mangroves and saltmarsh, are ecologically important components of aquatic ecosystems as they are highly productive, stabilise sediments and provide food and habitat for many species of fish and invertebrates of commercial significance (Bell and Pollard 1989; Larkam *et al*. 1989; Smith and Pollard 1999).

Seagrass communities have been surveyed in Lake Macquarie for over 50 years (Wood 1959; West *et al*. 1985; King and Hodgson 1986; King and Barclay 1986; Robinson 1987; Wellington 2002; The Ecology Lab 2003; Gray and Wellington 2004). Initial studies were part of a response to a decline in fish stocks (Wood 1959) reflecting a growing awareness of the importance of seagrass habitat to various commercial and recreational fish species. Since then seagrass monitoring in Lake Macquarie has been a continuation of surveys by fisheries management agencies (West *et al*. 1985) or related to the potential effects of power plant operation (e.g. thermal pollution) on seagrass beds (King and Hodgson 1986; King and Barclay 1986; Robinson 1987; Wellington 2002; The Ecology Lab 2003; Gray and Wellington 2004).

Seagrass communities in Lake Macquarie appear to have declined since the earliest survey in 1953 (King and Barclay 1986; Poiner and Peterken 1995). Wood (1959) estimated the area of seagrass at 25.48 km^2, whereas surveys conducted in the 1980s calculated the total area to be 13.39 km^2 and 14.17 km^2 respectively (West *et al*., 1985; King and Barclay, 1986). This difference is much larger than the inaccuracy of earlier methods, believed to be approximately 10% and, therefore, has been interpreted as a real decline. Researchers attributed this decrease to a rise in turbidity caused by human activity (King and Hodgson 1986). However, from 2000–2004, there has been a general increase in the cover of seagrasses in Lake Macquarie, believed to be due to a reduction in light attenuation following a period of lower freshwater inputs (Gray and Wellington, 2004).

Lake Macquarie contains four species of seagrass; *Zostera capricorni* (eel grass), *Halophila ovalis* (paddle weed), *Ruppia* sp. and *Posidonia australis* (strap weed) (West *et al*., 1985) and is dominated by *Z. capricorni*, particularly in its southern half (The Ecology Lab, 2003). Surveys carried out in the late 1970's at Bluff Point (adjacent to the proposed Trinity Point Marina and Mixed Use Development site) describe *Z. capricorni* as abundant (King and Barclay 1986; Robinson 1987). *Z. capricorni* leaf cover was measured at ~70% and it co-existed with sparse beds of *H. ovalis* (King and Barclay 1986). The 1983 survey by West *et al*. (1985) covered the proposed marina site, where it identified beds of *Z. capricorni*, continuous to Bluff Point. Bardens Bay was home to significant beds of *Z. capricorni* and the intertidal area was ringed by a thin strip of mangroves (West *et al*. 1985). The bed composition of dense *Z. capricorni* and sparse *H. ovalis* at Bluff Point was still present during field surveys in the first half of 1980 (King and Hodgson, 1986). More recent surveys at Bluff Point have estimated percent leaf cover of inshore *Z. capricorni* beds at ~65% mixed with sparser *H. ovalis* (15%) (Wellington 2002; The Ecology Lab 2003). Further offshore, as depth increases, *H. ovalis* disappears entirely and *Z.capricorni* becomes increasingly sparse. These patterns are consistent with those observed 25 years previously by King and Barclay (1986).

The term mangrove is a description of an estuarine habitat but also refers to the trees that grow in these habitats. Mangrove trees are just like ordinary trees, with roots, stems and leaves, but they have adapted to live in saltwater. They live in soft muddy sediments in more sheltered areas. Because mud is generally low in oxygen, the roots of the mangrove trees are quite shallow and close to surface oxygen. This also means that the root system must be extensive to prove a stable base for the tree (Chapman and Underwood 1995). Large numbers of mangrove trees often occur together and are described as mangrove forests.

Mangroves grow along the shores of most NSW estuaries, with the general exception of those that are intermittently opened and closed (West *et al*. 1985). Mangroves often occur seaward of saltmarshes and are subject to regular tidal inundation. As well as stabilising shorelines, mangroves are thought to contribute significantly to estuarine productivity as well as trap sediment and pollutants (Burchmore *et al.* 1993). For this reason, mangroves are protected under the *Fisheries Management Act 1994* (Part 7).

Saltmarshes are estuarine habitats that occur high on the shore, typically just above the average high water mark. Saltmarshes are often found behind, or close to mangrove forests and occur in soft, water-logged sediments. Saltmarsh habitats consist of small succulent plants, grasses, rushes, sedges and herbaceous plants; including *Baumea juncea, Juncus krausii, Sarcocornia quinqueflora, Sporobolus virginicus* and *Suaeda australis* (Morrisey 1995). In general, the ecology of Australian saltmarshes is not well understood (McGuinness 1988). Like mangroves, saltmarshes are believed to have important physical and biological functions in estuarine ecosystems. Because of their close proximity to the land, saltmarshes are often threatened by human development. It has been estimated that 50% of the saltmarshes of NSW have been destroyed since 1788 (Morrisey 1995).

1.2.2 Aquatic Invertebrates Within Lake Macquarie

The most comprehensive study of the benthic invertebrate communities of Lake Macquarie was conducted by MacIntyre (1959) between 1953 and 1956 (Australian Water and Coastal Studies 1995). 400 sampling sites within Lake Macquarie were analysed. MacIntyre divided the bed into three zones: seagrass beds (occupying 23.5% in 1956), mud slopes around the lake perimeter (16%) and mud basins (60.5%). The majority of the marina development is located within the mud basin zone, and this is the zone that the benthic sediment samples were collected from in October 2007. MacIntyre found the zone was dominated by polychaetes (predominantly Lumbrineridae, Maldamidae and Sigalionidae), bivalve molluscs (Cardiidae and Myochamidae) and ophiuroids (brittle stars). A survey of fossil shell assemblages (Roy 1981) found that mussel and cockle shells were the dominant dead shell component of the muddy bed of Lake Macquarie. These same dead shells were seen in large numbers in the deep (5 m depth) sediment samples collected for this survey in October 2007.

The Ecology Lab (1991) undertook a study to describe the benthic communities in the vicinity of ash-dam discharge outlets in Lake Macquarie. Within this study, Lake Petite, north west of the proposed Trinity Point Marina development was sampled as a reference location. The most common taxa found were polychaetes (Opheliidae and Spionidae), along with dead bivalves (Tellinidae) and mud whelks (Batillariidae).

1.2.3 Recreational and Commercial Fishing within Lake Macquarie

After many years of public discussion and consultation with various interest groups, commercial fishing ended in Lake Macquarie on 1 May 2002, with the lake being declared a Recreational Fishing Haven (Steffe *et al.* 2005). The commercial fishing annual catch in 2001 was approximately 300 tonnes. Recreational fishing is improving as fish stocks respond to the recent removal of commercial fishing (Steffe *et al.* 2005) and the significant increase in water quality that has come from a concerted environmental program undertaken by the state government and council (Web Ref 2).

NSW DPI (Fisheries) undertook two daytime recreational fishing surveys – one before the Recreational Fishing Haven zoning (pre-RFH) between March 1999 and February 2000 and one survey after (post-RFH) between December 2003 and November 2004 (Steffe *et al.* 2005). The two recreational fishing surveys provide evidence of a relatively productive recreational fishery in Lake Macquarie, indicated that that the post-RFH recreational fishery was very different to the fishery that had existed prior to the implementation of the RFH. The recreational harvest of dusky flathead, tailor, sand whiting, trumpeter whiting and large-toothed flounder (by number and weight) had increased significantly during the post-RFH survey year; however, the recreational harvest of common squid, yellow-finned leatherjacket and sand mullet (by number and weight) had decreased significantly during the post-RFH survey year.

Recreational angling effort in Lake Macquarie was lower in winter and spring compared to that of summer and autumn, and overall was greatest in the northern part of the lake where greater angling effort occurs from boats (Virgona 1983). As Lake Macquarie has little tidal movement, there are few places where fish naturally gather on the tides to feed (Ross 1995). For this reason the fast flowing Swansea Channel is a popular recreational fishing location. The fish caught by recreational fishers in Lake Macquarie are similar to other estuaries in NSW and are dominated by eight species (NSW DPI 2001). These are yellowfin bream, dusky flathead, luderick, snapper, tailor, tarwhine, whiting and leatherjackets. The first four species have life-history stages generally dependent on estuaries for all their main ecological requirements, and the latter four species are dependant on estuarine habitats as juveniles but adults generally inhabit areas outside the estuary. Three of these dominant species were observed during the seagrass surveys undertaken for this study (see Section 3.1.1). Ross (1995) indicates that bream, flathead and whiting are the most common fish off Bluff Point.

1.2.4 Shorebirds Utilising Lake Macquarie

Shorebirds (otherwise called waders) are typically birds of wetlands and include stints, stilts, sandpipers, curlews, snipes and godwits. Most species occurring in Australia are only temporary residents during spring and summer, with the majority of adults departing for distant breeding grounds in the Northern Hemisphere in autumn (Geering *et al.* 2007). A total of 55 species of shorebirds regularly occur in Australia (Geering *et al.* 2007), including 18 resident species and 37 migratory species. The Hunter Estuary has six species which are considered to occur in internationally significant numbers: bar-tailed godwit, black-tailed godwit, curlew sandpiper, eastern curlew, terek sandpiper and ruddy turnstone. All of these are migratory species and are found predominantly on exposed intertidal mudflats; a habitat not found in the vicinity of the proposed marina. The terek sandpiper is also found on exposed seagrass beds.

There is one endangered and five vulnerable shorebird species recorded from Lake Macquarie which are listed in the NSW *Threatened Species Conservation Act 1995* (source: Lake Macquarie City Council 2007), see Section 1.3 below for more detail.

Although not surveyed specifically for this proposal in 2007, several fishing bird species were observed by terrestrial ecologists (RPS Harper Somers O'Sullivan) in 2007. The observed species included black swan, pelican, egret, cormorant, royal spoonbill, silver gull, crested tern, masked lapwing, chestnut teal, pacific black duck, wood duck, white-faced heron, sacred ibis, white-bellied sea-eagle and osprey (not observed by RPS HSO, but via residents records). These birds use boats and marina structures, along with mangrove trees, shoaling sand and mud flats for roosting. The numbers of theses fishing birds are likely to increase in the Bardens Bay area as a result of the increase in boats and structures for them to utilise at the proposed marina.

1.2.5 Impacts on Aquatic Vegetation from Marinas

The construction and operation of marinas can impact on aquatic ecosystems (Smith and Pollard, 1999). Reclamation can directly remove habitat and can reduce both the tidal prism and flushing capacity of an estuary. Dredging can destroy seagrass beds by removing substratum or by increasing turbidity and sedimentation (Smith and Pollard 1999). Marina facilities with tall stand dry berth capacities and repair workshops represent a potential source for contaminants to be introduced into the waterway. However, not all marina developments are equivalent and, therefore, neither are the potential threats they pose.

Marina development may cause changes to sedimentation, which can occur as a result of the mobilization of sediments during construction (e.g. from land-based earthworks or insertion of pylons) or if water flow reduces upon encountering the marina structure, depositing suspended sediments. Light attenuation may increase (reducing photosynthetically available light and primary productivity) as a result of potential increased turbidity during construction or as structures such as jetties, pontoons and walkways shade various habitats below. Any increase in boat activity could see a concomitant increase in disturbance from boat wash, propeller and anchor damage and the transfer of invasive species, such as *Caulerpa taxifolia*.

It is possible that marina developments can become a source of chemical pollution. If contaminants are present and bound to sediments, it is possible they could be resuspended during construction and become bioavailable. Changes to (or the introduction of) storm water drainage could create an ongoing point source pollution and increase turbidity. There is also the possibility of periodic sullage spills or hydrocarbons associated with re-fuelling.

The physical structure of the marina provides hard surfaces for the colonization of marine invertebrates and alga and protection for other organisms, such as demersal and benthic fish. This is often represented as a 'positive' or 'good' side-effect of development, yet it represents an impact or change to pre-marina communities. It is not a form of environmental compensation, as this is not the type of habitat that may be lost during the development, and assemblages found on structures such as pontoons are different to those found on rocky reefs (Glasby and Connell 2001; Connell and Glasby 1999). Further more, it is possible that these new assemblages will impact on adjacent habitats (Barros 2001).

Physical disturbance or increased sedimentation can seriously degrade seagrass beds by direct removal, smothering and/or reduced light intensity (Poiner and Peterken 1995; Smith and Pollard, 1999). Damage to beds can be long term as species such as *Posidonia* are not considered good re-colonisers due to low seedling survival and slow growth of their rhizomes (Shepherd *et al*., 1989). The effects on *Zostera* and *Halophila* beds may not be as severe, as re-colonisation of disturbed habitats has been recorded within 12 months in some parts of NSW (Clarke and Kirkman 1989). Experimental studies have also revealed that some mangrove species can suffer significant mortality following partial burial in sediments (Tharnpanya *et al*. 2002).

Light attenuation is the principle limiting factor of primary productivity (Struck et al. 2004). An increase in attenuation may have adverse effects on aquatic vegetation with potential flow-on effects for other trophic groups within the community. Shading experiments using *Posidonia* and *Zostera* have shown that reduced light levels can have significant adverse effects on seagrass morphology, growth and biomass (Fitzpatrick and Kirkman 1995; Philippart 1995). Affected *Posidonia* beds had shown no sign of recovery 17 months after the removal of the shading treatment (Fitzpatrick and Kirkman 1995). Studies in North America have found reduced shoot densities and canopy structure for seagrasses occurring beneath, and immediately adjacent to boat docks (Burdick and Short 1999). Iannuzzi *et al*. (1996) demonstrated that marina construction may not necessarily cause a reduction in primary productivity; as loss through shading was compensated by creation of new habitat for macroalgae on pylons. If net primary production is maintained by macroalgae, it doesn't change the fact that a completely different assemblage (seagrass beds) has been lost or reduced.

Physical damage to seagrass caused by boat propellers (and to a lesser degree anchors) has similar long term effects to those described above. Recovery of seagrass in propeller scars can be a slow process and fragmentation can result from continued impacts (Dawes *et al*., 1997). Boat wash can erode shorelines and high levels of boat traffic could possibly effect nearby seagrass communities. A study by Moran *et al*., (2003) found that the effect of large wind-driven waves on seagrass communities could cause secondary planktonic dispersal of some fish species. Increase in boat activity is also more likely to result in the local introduction of invasive species, such as *Caulerpa taxifolia*.

Soft-bottom infaunal communities have been shown to be affected by hydrocarbon pollution (Gray *et al*. 1988; Warwick *et al*. 1990; Peterson *et al.* 1996) and similarly, the mortality of seagrass has resulted from oil spills (Zieman and Zieman 1989). Increases of bioavailable nutrients into the water may increase the epiphytic load on seagrass blade, thereby reducing their capacity to photosynthesise (Poiner and Peterken 1995).

Marinas may have effects on fish assemblages as well. It is possible that marinas attract fish from surrounding areas rather than enhancing recruitment. Aggregating populations may make them more vulnerable to exploitation, i.e. resulting in more effective effort of fishers who use the jetty. Reef-associated fish and crustaceans inhabiting the marina may also forage over adjacent soft-sediment and/or seagrass habitat. A study by Barros *et al*., (2001) found differences in soft-sediment macroinvertebrate fauna between sites close to, and far away, from rocky reefs. One explanation is predation by reef associated fauna on sediments near to the reef. Alternatively the pattern could also be caused by the reefs effect on larval dispersal or sediment sorting.

1.3 Threatened Species, Populations and Ecological Communities

There are provisions in both State and Commonwealth legislation to ensure that threatened species, populations and communities and threatening processes are considered in relation to proposed developments. Threatened species legislation examined included the *Threatened Species Conservation Act 1995*, the *Environment Protection and Biodiversity Conservation Act 1999* and the *Fisheries Management Act 1994*, as required in both the *Threatened Species Assessment Guidelines* (DECC 2007) and the *Draft Guidelines for Threatened Species Assessment* (DECC 2005) for development applications assessed under Part 3A of the Environmental Planning and Assessment Act 1979. The objective of the latter assessment process is to provide information to enable decision makers to ensure that developments deliver the following environmental outcomes:

1. Maintain or improve biodiversity values;
2. Conserve biological diversity and promote ecologically sustainable development;
3. Protect areas of high conservation value (including areas of critical habitat);
4. Prevent the extinction of threatened species;
5. Protect the long-term viability of local populations of a species, population or ecological community;
6. Protect aspects of the environment that are matters of national environmental significance.

For the *FM Act*, *TSC Act* and *EPBC Act* to have relevance there must be likelihood that one or more threatened species occur in or encroach upon the study area which could then be impacted upon by the proposed works. A review was made of the existing literature and database records on aquatic species to confirm the threatened species, populations or communities identified as likely to occur in Lake Macquarie. These included The Ecology Lab library of scientific journals on aquatic species, Register of the National Estate, Environment Australia's EPBC Act database, the NSW Fisheries database and "BioNet" NSW Wildlife database maintained by DEC. From these searches, the only listed aquatic threatened and protected aquatic species known to occur within the Lake Macquarie were:

- 2 threatened fish species (grey nurse shark and green sawfish);
- 4 endangered fish species (weedy sea dragon, Australian grayling, eastern blue devil fish and estuary cod);
- 1 endangered marine mammals (dugong);
- 1 vulnerable marine mammal (southern right whale);
- 1 endangered turtle (loggerhead turtle); and
- 1 vulnerable turtle (green turtle).

The study area is dominated by soft silty sediments within a protected embayment of Lake Macquarie. The Australian grayling is primarily a freshwater fish, and highly unlikely to have a remaining population in this area of NSW. The other five species of fish inhabit coastal waters with rocky habitats, and if they were present in Lake Macquarie, would not extend beyond Swansea Channel.

The three recorded sightings of dugongs occurred in Swansea Channel and offshore, which is over 15 km away from the study site. Similarly, the single record of the southern right whale was in offshore waters near Redhead in the Pacific Ocean. Dugongs are highly migratory, which means Australia shares populations with other neighbouring countries. In Australia, dugongs inhabit the warm shallow coastal waters of northern Australia from the Qld/NSW border in the east to Shark Bay on the WA coast, and are usually found in shallow waters protected from large waves and storms where they graze on seagrass meadows. Dugongs are subject to a range of human threats in Australia, including entanglement in nets, loss and degradation of important habitat such as seagrass meadows, and collisions with boats (also known as boat strikes).

The loggerhead turtle has two recorded sightings within Lake Macquarie, and both located within 5 km of the study site. Adult and large juvenile loggerhead turtles (> 70 cm carapace length) are known to feed in seagrass meadows, and undertake reproductive migrations to subtropical beaches in southern Qld and WA from October, and nest until February (Web Ref 3). The green turtle has 82 recorded sightings within Lake Macquarie – with approximately 12 within 5 km of the study site. This species is typically found in tropical and subtropical waters of Australia (Great Barrier Reed, Gulf of Carpentaria and NW Shelf in WA), however, individuals do stray into temperate waters such as Lake Macquarie. Juvenile green turtles (30 – 40 cm carapace length) are known to feed in seagrass meadows, and undertake Qld reproductive migrations to subtropical beaches from October, and nest until March (Web Ref 4). Both of these turtle species take approximately 30 years to reach sexual maturity. All marine turtle species are experiencing serious threats to their survival. The main threats are pollution and changes to important turtle habitats, especially coral reefs, seagrass beds, mangrove forests and nesting beaches. Other threats include accidental drowning in fishing gear, over-harvesting of turtles and eggs, and predation of eggs and hatchlings by foxes, feral pigs, dogs and goannas.

In addition to the Threatened Species Schedules, Part 2 (19) of the *FM Act* allows for the declaration of 'protected species'. Syngnathiformes (seahorses, seadragons, pipefish, pipehorses, ghost pipefishes and sea moths) are a group of fish protected under this part of the *FM Act*. It is likely that seahorses and pipefish (Family Syngnathidae) occur in the fringing seagrass bed in the vicinity of the proposed marina.

Shorebirds known to occur in Lake Macquarie which are listed under Schedules 1 and 2 of the *Threatened Species Conservation Act 1995* (source: LMCC 2007) include:

- Schedule 1 (endangered) Australian painted snipe.
- Schedule 2 (vulnerable) comb-crested jacana, lesser sand plover, greater sand plover, pied oystercatcher and sooty oystercatcher.

The only endangered shorebird species recorded from Lake Macquarie, Australian painted snipe, occurs in freshwater marshes - this habitat is not present in Bardens Bay. The two plovers occur on intertidal sand and mudflats, the comb-crested jacana on freshwater wetlands, the pied oystercatcher on ocean beaches and the sooty oystercatcher on rocky coastline. None of these habitats occur in the Bardens Bay area either. Due to the absence of differing habitats used by the listed threatened shorebirds recorded from Lake Macquarie, it is considered very unlikely that any would occur in the vicinity of the propose marina.

Over the last three decades, Australia has played an important role in international efforts to conserve migratory birds of the East Asian - Australasian Flyway (the Flyway). This work includes bilateral migratory bird agreements, which provide a formal framework for cooperation between two countries relating to the conservation of migratory birds. Two pertinent agreements are the Japan-Australia Migratory Bird Agreement (JAMBA) and China-Australia Migratory Bird Agreement (CAMBA). Species of conservation significance previously recorded in Lake Macquarie (Australian Water and Coastal Studies 1995) that are likely to utilise the Bardens Bay area include the Eastern Curlew (listed on both CAMBA and JAMBA) and the greater sand plover (CAMBA). These agreements oblige the Australian government, as a signatory to these agreements, to undertake a range of actions on behalf of the species listed. These include the preservation and enhancement of important habitats, establishment of sanctuaries and other facilities for the protection and management of migratory birds and their habitats, and preventing damage to migratory birds and their habitats.

Coastal saltmarsh in the NSW North Coast, Sydney Basin and South East Corner Bioregions is considered an endangered ecological community under an amendment to the *Threatened Species Conservation Act* in 2004. Some of the threats to saltmarsh include: in-filling for development, physical damage from human disturbance and alteration of salinity and increased nutrient levels resulting from the discharge of stormwater. The Department of Environment and Climate Change identified 12 priority actions needed to recover saltmarsh (Web Ref 1). These included protection from high nutrient runoff, reduce sedimentation, protection from clearing, minimise human vehicle impact, undertake weed control programs and restore tidal flows.

Coastal saltmarsh was observed around the small lake on the north-western side of the Trinity Point Marina and Mixed Use Development (hereafter referred to as Unnamed Inlet).

2.0 METHODS

2.1 Aquatic Vegetation Mapping

During the development approvals process, it is important to know the distribution of aquatic vegetation due to their protected status under NSW legislation. Mapping of aquatic vegetation was based on geo-referenced, ortho-rectified aerial photographs taken on 10 December 2006 by Geo-Spectrum (Australia). The aerial photographs of the development site were examined and polygons were drawn around areas interpreted to contain seagrasses, saltmarsh and mangroves. The boundaries of these vegetation types were later adjusted to accommodate the findings of field-based ground truthing.

Ground truthing was done on 16 and 17 January 2007 and 10 October 2007. Observers accessed the three vegetation types from a small boat and by foot, and mapped their distribution by following the outer perimeter of each vegetation type. GPS coordinates were recorded at regular intervals around these perimeters using a Digital Global Positioning System (DGPS).

Estimates of relative abundance of various seagrass species were also made by using three categories: low density (<15% cover), medium density (15-50% cover) or high density (>50% cover) as per King and Barclay (1986). During the iterative process of mapping, additional points were also ground truthed where required to resolve differences perceived in the aerial photographs.

GPS coordinates were later plotted onto the aerial photograph using MapInfo Professional (version 8.5) and the boundaries of each vegetation type were drawn as mentioned above. The area of each vegetation type within the study area was calculated and recorded on a spreadsheet.

2.2 Seagrass Density and Morphology

To accurately assess potential impacts it is essential not only to know where seagrasses are present, but also their abundance and current condition. Seagrass beds are dynamic habitats and can change due to both natural and man-induced activities. As part of the site inspection conducted on 16 and 17 January 2007, data on various parameters of seagrass density and morphology were taken to characterise seagrasses within the study area.

2.2.1 Field Work

Divers recorded quantitative data on the density of the dominant seagrass *Zostera capricorni* as well as *Zostera* leaf length and width and the number of leaves per *Zostera* shoot at a number of sites at Trinity Point. Similar data was also taken at two reference locations (Frying Pan Point and Wyee Point) to provide a comparison with that taken at Trinity Point. Although present within the study area, no data was collected for *Halophila ovalis* as it did not occur at each site within Trinity Point and was considered to not contribute as much to the overall ecological value of the area compared to *Zostera*.

At each location (Trinity Point and the two reference locations), five sites were randomly selected to encompass the study area and to examine smaller spatial scale variability. At each of the five sites per location, the following data was recorded:

- Density of *Zostera* shoots recorded within 4 random 30 cm x 30 cm quadrats placed within *Zostera* habitat.
- The length and width of *Zostera* leaves by randomly selecting 5 leaves per quadrat and measuring their length (to the nearest cm) and width (to the nearest mm)
- Number of leaves per *Zostera* shoot recorded by randomly selecting 5 shoots per quadrat and counting the number of leaves per shoot.

In total, the number of density estimates at Trinity Point was 20 and the number of estimates of leaf lengths, widths and the number of leaves per shoot was 100.

It was also envisaged that the percent cover of seagrass was to be measured by noting the occurrence of seagrass at fixed points along replicate transect lines that extended from shore to the seaward extent of the seagrass bed. However, after an initial inspection of the seagrass within the vicinity of Trinity Point, it was considered that this would not provide any useful data for analysis due to the uniform extent of the seagrass from shore (i.e. 100%) around the whole of the study area. Therefore, the percent cover of seagrasses was not recorded.

In conjunction with the seagrass surveys, any fish observed were recorded. A more extensive fish survey was not undertaken as the likelihood of threatened or endangered fish species occurring at Trinity Point was very low (see Section 1.3), and the construction of the marina would only have a temporary impact on fish populations in the area.

In October 2007, following more detailed plans for the proposed marina, seagrass density was recorded along three transects by snorkelling out from the shoreline at the positions of the travel lift platform, marina access jetty and the breakwater accessway. Distance of the seagrass away from the edge of the grassy shoreline was measured using a tape measure. Seagrass species were given the following codes:

Hal – *Halophila ovalis*

Pos – *Posidonia australis*

Zos – *Zostera capricorni*

The level of patchiness was also estimated using three categories as per King and Barclay (1986):

A – Individual strands or small clumps (< 2 m diameter),

B – Medium sized patches 2 - 10 m diameter, or

C – Beds of relatively even distribution (> 10 m diameter).

Estimates of seagrass density were made by ranking each observation point using three categories as per King and Barclay (1986):

1 – low density (< 15% cover),

2 – medium density (15% - 50% cover), or

3 – high density (> 50% cover).

Leaf length of seagrass was also categorised as follows:

Halophila – S (short < 1 cm), M (medium 1 cm – 3 cm), L (long > 3 cm),

Posidonia – S (short < 15 cm), M (medium 15 cm – 30 cm), L (long > 30 cm), or

Zostera – S (short < 5 cm), M (medium 5 cm – 15 cm), L (long > 15 cm).

These codes provide a description of the seagrasses within an area and are useful in determining the nature and ecological value of any seagrasses likely to be affected by the proposed works. For example, seagrass with shorter leaves and a lower density (e.g. ZosC1S) may have less ecological value compared with seagrass with longer leaves and a higher density (ZosC3L).

2.2.2 Statistical Methods

Asymmetrical analysis of variance (ANOVA) was used to examine the spatial differences in the density of *Zostera* and the morphology of *Zostera* leaves at Trinity Point and the two reference locations (Frying Pan Point and Wyee Point) to determine whether the seagrasses at Trinity Point are somehow unique to the area (see Winer 1971; Underwood 1981 for further details of ANOVA and Underwood 1993; Glasby 1997 for details on asymmetrical ANOVA). These asymmetrical analyses allow for unbalanced data to be analysed, as is the case within this study (1 impact location (Trinity Point) vs 2 reference locations (Frying Pan Point and Wyee Point)).

The significance level (α) for each ANOVA test was set at 0.05. Prior to analysis, data were tested for homogeneity of variance using Cochran's C test and transformed where necessary (Underwood 1981). If these transformations failed to remove heteroscedasticity, analysis was done on transformed data that provided the lowest Cochran's C value, but the significance level (α) was reduced from 0.05 to 0.01 to guard against the increased likelihood of Type I error (Underwood, 1981). Where the test for differences between sampling units was non-significant at *p* /0.25, the test was made more powerful by post-hoc pooling procedures (Winer 1971). Figures were prepared as a graphical representation of the data and were used to verify the results of the statistical tests for determination of whether or not Trinity Point was different from the two reference locations. This was especially important where statistical tests were perceived to be of low power i.e. having small denominator degrees of freedom (e.g. df = 1).

A two-factor asymmetrical ANOVA was used to test for differences in the density of *Zostera* shoots, the length and width of *Zostera* leaves and the number of leaves per Zostera shoot among Locations and Sites. Location was considered a random, orthogonal factor with three levels: Trinity Point, Frying Pan Point and Wyee Point, while Site was also a random factor, although consisted of 5 levels: 1 - 5, and was nested within Location. With respect to the analysis of *Zostera* density, data from four replicate quadrats per Site were analysed, whereas morphological data of *Zostera* from the four quadrats was combined and analysed to give a total of 20 replicates per Site.

2.3 Seagrass, Mangrove and Saltmarsh Condition

In addition to the above data taken on aquatic vegetation, the condition of each vegetation type (i.e. seagrasses, mangroves and saltmarsh) was assessed qualitatively during the site inspection. For each vegetation type, the species present was recorded and their overall 'health' was estimated by inspecting the level of various parameters for each vegetation type. Such parameters included the amount of rubbish, the level of stress (i.e. leaves wilting or dead) and the epiphytic load that had accumulated in each vegetation type. Photographic records were also taken to help describe their overall 'health'.

These data, and those collected from the mapping and seagrass density and morphology studies, will provide a thorough determination of the condition of each vegetation type that is present within the vicinity of the proposed development.

2.4 Soft Sediment Infauna

Installation of piling to support the floating marina arms and breakwater in the soft sediments of Bardens Bay has potential to disturb animals living in unvegetated bottom sediments (benthos) and reduce the amount of benthic habitat. Therefore, it is important to find out what benthic invertebrate communities live in the soft sediment seabed at both the shallow (2 – 3 m depth) and deep (5 – 5.5 m depth) areas within the marina footprint area.

2.4.1 Fieldwork

Soft sediments within the proposed area of the marina in Bardens Bay were sampled on 10 October 2007. At each location (Arms A – D), two separate sites (shallow inner and deep outer) were sampled (Figure 1). At each site, three replicate 2.4 L samples of sediment for analysis of benthic infauna were taken using a van veen grab. Sediment samples for analysis of grain size were collected at each site by taking an additional grab sample.

Samples used for the analysis of infauna were sieved on site through a 1 mm mesh and the material retained was preserved in 10% formaldehyde with Rose Bengal stain (making the invertebrates easier to identify). In the laboratory, samples were sorted under a dissecting microscope and taxa identified to the lowest taxonomic level practicable (generally to family). Samples for grain size analysis were sent to a NATA-registered laboratory.

2.4.2 Statistical Methods

<u>Multivariate Analyses</u>

A suite of multivariate techniques included in the computer program, PRIMER (Plymouth Routines In Multivariate Ecological Research), were used to detect spatial patterns in the biotic communities. Similarities between each pair of samples were calculated using the Bray-Curtis similarity measure (Bray and Curtis, 1957) and ranked to form a triangular matrix of association. The relative distances between paired samples are proportional to relative similarity in species composition (Clarke, 1993). Prior to construction of the matrix, the data were transformed using the square root transformation to reduce the influence of very abundant species and therefore increase the contribution of rarer species to the community structure.

The one-way 'analysis of similarities' permutation test (ANOSIM, Clarke and Green, 1988), was used to assess differences in fauna between the four marina arms.

Bray-Curtis dissimilarities were used to construct two-dimensional MDS (multi-dimensional scaling) plots. The plots locate each sample in two dimensional space, on the basis of ranked similarity with other samples. Samples grouped close together are more similar to each other than samples that are widely separated on the plot. The stress value is a measure of how well the data have been reduced to two dimensions (Kruskal and Wish 1978), with values between 0 and 0.1 providing accurate information and values between 0.1 and 0.2 considered adequate. Values above 0.2 should be interpreted with caution, as the latter may not provide an adequate representation of the relationship among samples (Clarke 1993).

The SIMPER (similarity analyses) routine was used to determine which families of macroinvertebrates were responsible for discriminating between the dredge and disposal sites.

<u>Univariate Methods</u>

Analysis of variance (ANOVA) was used to examine differences in total number of animals sampled, total number of families and abundances of major discriminating families between sites (see Winer 1971 and Underwood 1981 for further details). Prior to analysis, data were tested for homogeneity of variance by Cochran's test and transformed where necessary (Underwood 1981). If these transformations failed to remove heteroscedasticity, raw data were analysed, but critical probabilities were reduced from 0.05 to 0.01 to guard against the increased likelihood of Type I error (Underwood 1981). A two-way ANOVA with the model: location (2 levels, fixed, orthogonal) and treatment i.e. dredge versus disposal, (2 levels, fixed, orthogonal), with 9 replicates for each treatment was used. When ANOVA was significant, Student Newman Keuls (SNK) tests were used to identify which means differed (Winer 1971, Underwood 1981).

Families whose abundance contributed greatly to the total number of individuals or which contributed greatly to differences between sites (as identified by SIMPER) were tested with ANOVA.

3.0 RESULTS AND DISCUSSION

3.1 Aquatic Vegetation

The distribution of aquatic vegetation within the vicinity of the development site is shown in Figure 1. All three vegetation types of aquatic vegetation (i.e. seagrasses, mangroves and saltmarsh) were present within the study area. In addition, a number of species of algae were also observed within seagrass habitat.

3.1.1 Seagrasses

Two species of seagrasses were observed within the study area, eel grass (*Zostera capricorni*) and paddle weed (*Halophila ovalis*) (Plate1).

Along the southern shoreline, medium to high density *Zostera* dominated the seabed, with small scattered patches of high density *Halophila* also observed. The length of *Zostera* throughout much of the bed was considered long, while *Halophila*, although quite dense in some areas, was short. This pattern of distribution continued towards Bluff Point and further north. The bed of *Zostera* to the north of Bluff Point widened considerably, although decreased in width further north. The density of *Zostera* within this portion of the bed was still medium to high density and small patches of *Halophila* were still observed. Within the vicinity of the proposed marina, the *Zostera* bed narrowed considerably and could be best described as a fringing bed of medium to high density *Zostera*. At this point very little *Halophila* was observed. This distribution continued similarly, terminating near Unnamed Inlet west of the development.

The three transects surveyed in the area of the proposed marina in October 2007 indicated the following morphology and distribution of seagrass:

- travel lift platform - ZosC3M, heavy epiphytic load, 9.5 m wide (4 - 13.5 m from bank/0.0 m AHD)
- marina access jetty - ZosC3M, heavy epiphytic load, 14 m wide (2.5 - 16.5 m from bank/0.0 m AHD)
- breakwater accessway - ZosC3M, heavy epiphytic load, 16 m wide (3.5 - 19.5 m from bank/0.0 m AHD)

Seagrasses within Unnamed Inlet were dominated by high density *Zostera,* with a fringing bed of high density *Halophila* along the northern shoreline of the inlet. *Zostera* covered most areas of the inlet and in general was incredibly dense (Plate 2). Possibly due to very shallow water depths and being exposed to the sun for prolonged periods, the *Zostera* within the inlet was light brown in colour in comparison to its usual dark brown/green colour (compare Plate 1 to Plate 2). In a number of areas, small bare patches could be seen within the thick bed of *Zostera* and these can be seen as dark patches within the lighter coloured *Zostera* in Figure 1a.

Sediments within the inlet were varied with more sandy sediments prevalent near the shoreline, and more muddy sediments dominating further out making access to some areas within the inlet problematic.

3.1.2 Mangroves

One species of mangrove was observed within the study area, the grey mangrove (*Avicennia marina*). This occurred around the shoreline of Unnamed Inlet to the west of the proposed marina development, and was mapped by The Ecology Lab in January 2007, and updated by RPS Harper Somers O'Sullivan in October 2008 (Figure 1; Plate 3). The distribution of mangroves around the inlet was generally continuous with a general stand width of 1-2 trees and approximately 5 m high.

3.1.3 Saltmarsh

The boundary of the saltmarsh community was mapped by The Ecology Lab in January 2007, and updated by RPS Harper Somers O'Sullivan in October 2008 (Figure 1). However, due to the size and scale of the saltmarsh community, individual species mapping was not done.

There were five dominant species of saltmarsh plants observed within the study area during the site inspection. These were samphire (*Sarcocornia quinqueflora*), salt couch (*Sporobolus virginicus*), seablite (*Sueada australis*), creeping brookweed (*Samolus repens*) and sea rush (*Juncus kraussi)*. Of these species, the dominant species was samphire.

Saltmarsh was generally found on the landward side of the mangroves, with some overlap in several areas (Figure 1; Plate 3). Similarly, there was some areas of overlap with swamp oak (*Casuarina glauca*) community. The saltmarsh distribution was continuous around the entire Unnamed Inlet to the west of the marina development site (Figure 1). At its widest point the saltmarsh community was approximately 35 m, while at its narrowest point was only a couple of metres.

3.1.4 Macroalgae

Species of macroalgae observed within the study area included brown alga (bubble weed *Sargassum* sp.), green algae (*Codium fragile, Microdictyon* sp. and sea lettuce *Ulva* sp) and red algae (*Hypnea* sp. and unidentified filamentous).

The invasive green alga species, *Caulerpa taxifolia,* was not observed in the study area.

3.2 Seagrass Density and Morphology

3.2.1 Seagrass Density

Results from the asymmetrical ANOVA revealed that significant spatial variability occurred with respect to the density of *Zostera*. Not only were Locations (i.e. Trinity Point, Frying Pan Point and Wyee Point) significantly different from one another, Sites within Locations were significantly different from one another, the latter indicating smaller scale variation. However, results suggest that the differences among Locations comes from differences in *Zostera* density between the two reference locations (Frying Pan Point and Wyee Bay) and not from a difference between *Zostera* density at Trinity Point compared with that at the two reference locations (Table 1). This suggests that the density of *Zostera* at Trinity Point is in no way unique to the area and is comparable to that in other parts of Lake Macquarie.

3.2.2 Seagrass Morphology

Leaf length showed both significant large-scale (Locations) and small-scale (Sites) variability, whilst leaf width and the number of leaves per *Zostera* shoot only showed significant small-scale (Sites) variation (Table 2). Leaf length showed significant differences among Locations, but this appeared to come from differences between the two reference Locations and not from differences between Trinity Point and the reference locations (Table 2). These results, as for *Zostera* density, suggest that the length, width and the number of leaves per shoot of *Zostera* at Trinity Point are not unique and are comparable to other parts of Lake Macquarie.

3.3 Seagrass, Mangrove and Saltmarsh Condition

The overall health of the aquatic vegetation within the vicinity of Trinity Point was considered to be very good. Although there were some areas that were under some form of stress, most areas were regarded as healthy.

The amount of rubbish within each vegetation type was minimal, although some general rubbish (i.e. cans, bottles) had accumulated within the saltmarsh habitat on the eastern tip of Unnamed Inlet to the west of the marina development. No other rubbish was observed in other areas of saltmarsh, nor was there any observed within the other vegetation types.

The level of stress (i.e. condition of leaves – wilting or dead) for each vegetation type was considered low. Both mangrove and saltmarsh habitat were considered to be very healthy with little evidence of dead or wilting foliage. Seagrasses also were considered healthy in most areas, although, within the Unnamed Inlet, *Zostera* colouration appeared very pale (light brown). This is possibly due to these seagrasses becoming exposed to the sun in the shallow waters within the inlet (possibly caused by periodic build-up of sediment). However, given its very dense nature within the inlet and the observation of many small juvenile fish utilising this habitat, seagrasses within the inlet were considered to be healthy.

The epiphytic load on seagrass leaves was also assessed and in most areas was considered to be minimal. However, in some areas, mainly close to shore along the eastern and northern shorelines within the vicinity of the proposed marina, some substantial epiphytic loading was observed (Plate 4). This can sometimes be attributable to excess nutrients within the water column which can be utilised more effectively by the epiphytic algae than the seagrass, thus promoting the growth of the epiphytic algae. This could also be verified by the presence of the fast growing green alga, *Ulva* sp., also along the eastern shoreline (Plate 4). As for the epiphytic algae, this green alga can utilise nutrients within the water column more effectively than seagrasses, thus its presence can be an indicator of excess nutrients within the area.

3.4 Soft Sediment Infauna

3.4.1 Assemblages

The structure of the infaunal assemblages differed between inner and outer sites, but not among the four arms of the proposed marina (Table 4). The symbols representing the samples collected at these positions also form two distinct clusters in the MDS plot (Figure 4). The cluster on the right-hand side of the plot represents all the samples collected from the inner sites while that on the left-hand side represents all the samples collected from the outer sites, except for two outliers from Arm A. This pattern also implies that the structure of infaunal assemblages differed between inner and outer sites. The two outliers also imply that the structure of the assemblage in the outer site of Arm A is more variable than that at the other sites. This site also had a more sandy sediment composition than the other three outer sites (see Section 3.4 below), which could explain the variability in the assemblage.

Fourteen taxa contributed to 90% of the average dissimilarity between the assemblages in the inner and outer sites (Table 5). The average abundances of eight of these taxa were greater in inner than outer sites. Two taxa, magelonid and pilargid polychaete worms, were found only in inner sites and one taxon, sigalionid worms, was present only in the outer sites. The three principal discriminator taxa (capitellid and cirratulid polychaete worms, and semelid bivalve molluscs) together accounted for > 50% of the average dissimilarity.

3.4.2 Populations

The variation in total number of taxa and number of terebellid polychaete worms among arms depended on the site considered (Table 6). In the inner sites, samples collected from Arm B contained significantly more taxa than those collected from Arm C, however, in the outer sites there were significantly more taxa in Arm A than in any of the other arms (Figure 5a). Significant differences in number of terebellids among Arms were restricted to outer sites and were due to the absence of these worms from Arms C and D and their low abundance at Arm B relative to Arm A (Figure 5b).

Significant differences in total numbers of animals, numbers of capitellids, cirratulids and semelids were detected between inner and outer sites (Table 6). The total numbers of animals, capitellids and cirratulids were greater in the inner sites, whereas semelids were more abundant in the outer sites (Figure 6).

3.5 Sediment Characteristics

The percentage of each sediment sample passing through sieves of various mesh sizes, median grain size of the sediment and general description collected at each of the four Arms in the inner and outer positions are presented in Appendix 2. Median grain size and % sand content of the sediment varied among positions, but not between Arms. Median grain size was significantly greater at the inner (shallow) positions, and more sand particles were found in the sediment at the inner (shallow) positions also. The sediment descriptions at the inner positions varied between sand and clayey sand, whereas at the outer positions it was clayey silt, except for Arm A.

Overall, the findings from the sampling of unvegetated soft sediment fauna revealed healthy, but variable, benthic communities that are likely to be strongly influenced by sediment type, depth or a combination of these and other factors. The taxa found were similar to those present in similar habitats in other parts of Lake Macquarie.

3.6 Fish Populations

Abundant fish populations were observed in the vicinity of the seagrass beds in the study area and within Unnamed Inlet. Species of fish observed included yellowfin bream (*Acanthopagrus australis*), luderick (*Girella tricuspidata*), whiting (*Sillago* sp.) and mullet (Family Mugilidae). Many small juveniles of these and other species were observed associated with the seagrass beds.

Pipefish commonly occur within seagrass beds and seahorses are often attached to algae, however no pipefish or seahorses were observed in this survey.

4.0 ASSESSMENT OF IMPACTS

4.1 Description of the Proposal With Respect to Aquatic Ecological Issues

From information presented to The Ecology Lab, it is proposed that a marina and mixed use development be developed at Bardens Bay. The marina development, on the northern shoreline of the development site, would consist of:

- an aluminium mesh jetty that leads onto a 4-armed floating marina that extends almost 300 m from the shoreline;
- an aluminium mesh jetty that leads onto a timber slatted breakwater to protect the marina from wave action in rough conditions;
- a steel pontoon helipad extending out from the south-eastern corner of the breakwater; and
- a travel lift platform with twin steel rails just north of the marina.

The current application is for a Concept Plan approval, which provides a broad overview of what is proposed at the development site. However, notwithstanding that, our aquatic ecology investigation was targeted at a greater level of assessment for the water-based component of the project. With respect to aquatic ecology, the proposed development of the marina has the potential to impact on protected estuarine habitats in the following ways:

- Direct disturbance to aquatic vegetation during marina construction and subsequent use,
- Indirect disturbance to aquatic vegetation via shading,
- Impacts from boat movements on seagrasses when the marina is in operation,
- Impacts on water quality that could affect seagrass and other estuarine habitat during marina operation,
- Impacts from stormwater run-off from the resort complex on water quality that could affect aquatic vegetation during the operation of the resort.
- Impacts from the alteration of run-off on saltmarsh and mangrove habitats in Bardens Bay.

All these impacts could also ultimately affect fish and other aquatic faunal assemblages within the area due to the impacts that may occur to their habitats.

4.2 Direct Disturbance

4.2.1 Seagrass Habitats

The marina, breakwater, helipad and travel lift will be supported by a large number of 457 mm diameter, epoxy-coated, hollow steel tube piles with a total footprint of 29.77 m^2. However, none of these structures (except for a section of the travel lift – see below) would pass over any seagrass beds, and any disturbance to the unvegetated, soft sediment seabed would be minimal due to the hollow design of the piles. The inner section of the travel lift platform would pass over 9.5 m of seagrass (*Zostera*). Following consultation with Patterson Britton & Partners, as many of the hollow steel tube piles, as is structurally possible, will be located outside the seagrass bed. A proportion of the marina access jetty and breakwater accessway will be located over seagrass beds. The piles to be used for both of these jetties would be hardwood timber with a 250 mm diameter at the toe, up to 300 mm diameter nominal. These piles would be vibrated or driven into position, and as such would limit the area of direct disturbance to roughly the same area as the 457 mm diameter hollow steel piles. The total footprint area of these piles is approximately 6 m^2. Considering the extent of the *Zostera* along the area of this northern shoreline, the impacts on seagrass from direct disturbance as a result of piling are considered to be minimal. No seagrass beds will be fragmented and the area of direct disturbance is a very small proportion of the total seagrass bed.

Due to the small area of direct damage to seagrass (approximately 6 m^2) which will not result in any fragmentation of the seagrass bed, it is considered that no mitigation is necessary. Ganassin and Gibbs (2008), following a review of seagrass restoration projects in NSW estuaries since 2000, believe that seagrass restoration techniques in NSW are a costly process that are still somewhat developmental, and have only been successful sometimes in replacing small areas of habitat. However, if requested by NSW DPI (Fisheries), seagrass habitat compensation at a ratio of 2:1 (i.e. 12 m^2) could be undertaken at an appropriate location at the proposed site after construction works have been completed.

The marina has been designed with minimal structures on the foreshore – with only two jetties, supported by hardwood timber piles, passing over the foreshore. There would be little or no change to seagrass wrack in the study area due to the proposed marina and associated piles. The natural movement, accumulation and degradation of seagrass wrack will be unaffected, as the jetty and breakwater structures will not interfere with the free movement of seagrass wrack along the foreshore. In addition, it is unlikely that there would be any additional accumulation of seagrass wrack to the east of the marina as a result of the breakwater. Similarly, the potential for these foreshore structures to impact on wave energy and the risk of deflection or refraction to seagrass beds is very unlikely.

Care should taken when anchoring barges or work platforms, as anchor lines and chains can scour areas of seagrass and in some cases, can remove large areas of seagrass habitat.

As there is adequate depth along this part of Bardens Bay, no dredging needs to be undertaken prior to construction of the marina. As a result there will be minimal disturbance to the soft sediment bottom, and minimal siltation to impact the seagrass.

Other aquatic vegetation, such as mangroves and saltmarsh habitat, are also at risk during the construction phase. The building of temporary roads and areas designated for stock piling should avoid damage to these habitats during this phase.

4.2.2 Fish Habitats

It is likely that seahorses and pipefish (Family Syngnathidae) occur in the seagrass bed in the vicinity of the proposed marina, although none were observed during the survey. As no seagrass beds will be fragmented and the area of direct disturbance is a very small proportion of the seagrass bed, it is unlikely that any seahorses or pipefish will be impacted. Due to the likelihood of seahorses being present in the seagrass beds in the vicinity of the marina, it has been recommended by NSW Department of Primary Industries, Fisheries (Scott Carter *pers. comm.*, 2 May 2008) that the proposal provide additional preferred habitat for them to colonise. This could be done by placing shark-netting, parallel to the shoreline, along the outer margin of a section of the existing seagrass bed. The preferred location would be on the eastern section of the marina – attached to the inside of the breakwater arm.

Given that artificial structures such as piles, pontoons and breakwaters may attract many species of reef fish, sometimes in greater numbers than in similar natural habitats, it is considered that the proposed marina structures would benefit recreational fishers within this section of Lake Macquarie. Although questions persist as to whether artificial structures produce new biomass or simply attract the natural fish population (e.g. Liston *et al*. 1986 and Clynick *et al*. 2007) it appears as though many sought after recreational species could be caught in and around the marina, some of which that may not have been present before its construction.

4.3 Shading Impacts

Shading from marina structures such as the marina access jetty, breakwater accessway and the travel lift platform can affect the growth of aquatic vegetation, such as seagrasses, by blocking vital photosynthetic processes. The design of such structures would take into account shading issues and minimise this impact to help prevent any damage to seagrass due to shading. Materials, such as aluminium mesh decking, can be substituted for more traditional timber structures over areas that contain seagrasses, which allow adequate levels of sunlight to reach the underlying seagrass.

Structures that would be constructed with 'seagrass-friendly' aluminium mesh decking make up approximately 135 m^2 - this equates to just over 0.5 % of the total marina footprint. These structures to be constructed with aluminium mesh decking (see Figure 1) include:

- the marina access jetty – the entire length, extending from the shoreline (0.0 m AHD) out to its end (20.6 m in length);
- the breakwater accessway - the entire length, from the shoreline (0.0 m AHD) out to its end (24.8 m in length).

Due to the structural strength required by the travel lift, the slipway would need to be constructed of steel and would create a shading footprint of approximately 50 -75 m^2 over the seagrass.

In conclusion, any impacts due to shading from the proposed marina would be fairly minor given the majority of the marina structures are located beyond the area of seagrass beds. Nonetheless, all efforts should be made to minimise this impact.

4.4 Boat Movements

Boat movements within the vicinity of aquatic vegetation have the potential to impact on their distribution and abundance. Boat wake can scour and erode areas such as seagrasses, mangroves and saltmarsh. When this occurs, it is possible that affected areas destabilise other areas within the vicinity and thus a chain reaction can occur. It is not uncommon for 'blowouts' or bare areas within healthy seagrass beds to grow in size in very short periods of time due to the scouring effect that can erode the margins of the 'blowout'. It is not envisaged, however, that boat movements within the vicinity of the proposed marina would be great enough to cause any substantial boat wake as boat wake would be limited by navigational controls within and around the marina.

Damage by boat propellers is another potential impact. Not only can propellers impact on seagrasses by physically removing or damaging the seagrass, they can also cause or start a potential 'blowout', which can increase in size as mentioned above. Due to the location of the seagrass in shallow water (down to a depth of approximately 1.8 m), it is considered unlikely that boats within the marina would be approaching this close to shore.

Section 4.5 and Appendix 3 considers the impacts to threatened and protected species as a result of the proposal, including boat movements.

The Acoustic Assessment Report (Arup 2008) for the development site assessed that underwater noise levels resulting from boating movements and helicopter movements are not considered likely to cause adverse noise impact to fish.

4.5 Threatened and Protected Species and Endangered Ecological Communities

4.5.1 Listed Species of Conservation Significance

Threatened species legislation examined included the *Threatened Species Conservation Act 1995,* the *Environment Protection and Biodiversity Conservation Act 1999* and the *Fisheries Management Act 1994,* as required in both the *Threatened Species Assessment Guidelines* (DECC 2007) and the *Draft Guidelines for Threatened Species Assessment* (DECC 2005) for development applications assessed under Part 3A of the Environmental Planning and Assessment Act 1979.

No individual aquatic species listed in the schedules of the three relevant acts were observed in the survey area.

The proposed marina works are unlikely to affect listed threatened and protected species of fish, marine mammals and reptiles that occur in, or encroach upon, the study area. Hence, there is no need to prepare any Species Impact Statements under state legislation or refer the Proposal to the Minister for the Environment for further consideration and approval.

Individual and generic (group) assessments for species listed under the *TSC* and *FM* Acts against the assessments of significance, and assessments for species listed under the *EPBC* Act against the 'Administrative Guidelines on Significance' can be found in Appendix 3.

4.5.2 Separate Considerations

In addition to the species considered in the sections above, there are a number of other species listed for consideration in the legislation. These species are not considered to be at risk because of the proposed works. The reasons for this are specified in this section.

4.5.2.1 Other Listed Marine Species (*EPBC* Act)

Listed Marine Species constitute a diverse group of marine animals. Many of them occur rarely in the study area. Whilst they are reported from time to time their rarity in the study area suggests that any disturbance from the proposal would be highly unlikely to affect populations of these species.

One group that does require some consideration includes the seahorses, pipefish and sea dragons (Syngnathidae). Pipefish and seahorses occur in seagrass beds (Kuiter 2000). Despite this, it is unlikely that the proposed works would affect populations of these species, as no seagrass beds will be fragmented and the area of direct disturbance is a very small proportion of the total seagrass bed. In addition, should any seagrass habitat be disturbed or damaged there would be adequate undisturbed seagrass habitat for these species to assimilate into in the near vicinity. However, it is recommended by NSW Department of Primary Industries (Fisheries) that an additional preferred seahorse habitat, in the form of shark-netting, is provided in the proposal.

4.5.2.2 Protected Species (*FM* Act)

Under the Fisheries Management (General) Regulations 2002, provision is made for listing of species as protected (eastern blue devil fish, estuary cod and all Syngnathiformes). The protected status reflects more a susceptibility of the species to capture (for food, sport or display in aquariums) rather than known susceptibility to other types of disturbance or known rarity. There is no requirement that Assessments of Significance are done for these species. Although no protected species were observed during the site inspection, some individuals may occur there. Despite this, it is unlikely that the proposed marina works would affect populations of these species as there would be adequate undisturbed seagrass and soft sediment habitats for these species to assimilate into if there were to be damage or harm to these habitats.

4.5.2.3 Endangered Ecological Communities

The proposed marina works are unlikely to affect the endangered coastal saltmarsh community listed located to the west of the marina location. Notwithstanding this, care should be taken to avoid accidental damage to the saltmarsh habitat by people or equipment. Hence, there is no need to prepare Species Impact Statements, but an assessment of significance under the *TSC* Act can be found in Appendix 3.

4.6 Run-off

4.6.1 Background

Given the high sensitivity of aquatic ecosystems in the immediate receiving water, management of stormwater quality is an essential element of the environmental objectives for the proposed development. The quality of run-off from land is of particular importance to the local seagrass populations, some of which are located immediately adjacent to the proposed development site. Seagrass is typically highly sensitive to increased levels of suspended sediment and nutrients, which are commonly observed in high levels in runoff from urbanised catchments.

Run-off can also mobilise nutrients, such as nitrogen and phosphorus, from the surrounding area and displace them into the water column. This can lead to algal blooms if nutrients within the water column are found to be in excess. As mentioned in Section 3.3, there already was an indication that nutrients within area may be in excess due to the substantial epiphytic load and the presence of various indicator algae within the seagrass habitat near the location of the proposed marina. Algal blooms have the potential to smother seagrasses, limiting their light resources used for photosynthesis. After rapid growth, they can deplete local resources and, as they begin to die and decay, strip the water column and surrounding sediment of oxygen. This can then impact upon aquatic fauna, such as fish, that utilise these habitats since sediments and, in extreme circumstances, the water column can become anoxic.

A range of stormwater control measures are proposed to achieve levels of water quality that are higher than currently occur, mitigating any degradation of the water quality in Lake Macquarie resulting from the proposed development.

Historically, marina workshop and vessel repair areas have been a source of a large array of toxic pollutants, which are typically the by-products of vessel hull repair and maintenance operations occurring over a hardstand within or adjacent to the tidal zone of the receiving water. A range of preventative, containment and treatment measures would be adopted to manage stormwater runoff quality from the workshop/hardstand area.

4.6.2 Proposed Stormwater Management Plan

A multi-objective approach would be adopted to achieve the stormwater management objectives for the Trinity Point site. These would include a range of preventative measures and source controls which would collectively provide a high level of water quality control for all runoff generated on-site. Additionally, opportunities exist to implement a stormwater harvesting scheme, which would reduce the volume of runoff and mains water demands for the proposed development.

Due to the proposed construction of buildings and an increase in hard surfaces at the Trinity Point site, as compared to the site at present, it is understood that stormwater runoff will increase. However, due to the depth profile of the existing seagrass and the expected water quality of runoff, mixing of runoff with the lake water will occur quickly close to the shoreline. Therefore, it is unlikely to decrease salinity or increase nutrient levels; both factors important to the health of seagrass habitats.

Proposed stormwater control measures for both the marina and the residential tourism developments are outlined as follows.

4.6.2.1 Preventative Measures

The following preventative measures would be adopted as development controls to reduce the generation of pollutants under normal conditions as well as provide contingency in the event of an accidental spill of potentially polluting substances: -

- Minimising areas of impervious surfaces - by reduced road and carparking areas (the majority of carparking on the site is to be provided underground) and increased landscaping around dwellings;
- Implement drought tolerant native plant species into the landscape, which would reduce the need for irrigation and fertiliser application;
- Establishment of a fertiliser management plan which would ensure fertiliser application is undertaken in a controlled manner using best practice methods;
- Provide bunded storage around potentially polluting liquid storage areas to prevent any accidental spills entering Lake Macquarie;
- Provide double lining for any fuel or sewage line extending over water to minimise the chance of a line puncture;
- Provide adequate rubbish bins and waste disposal services to encourage responsible disposal of waste and rubbish;
- Establish measures to reduce pet droppings in the development area; and
- Establish a public education system, which informs residents and guests of the stormwater management issues and encourages environmentally responsible actions.

4.6.2.2 Source Controls

The following source controls measures are considered for the Trinity Point Development: -

- Rooftop Gardens – rooftops would be entirely vegetated with drought tolerant, non-fertilised gardens, which would provide water quality, thermal efficiency and aesthetic benefits. Water quality benefits would be achieved through a reduction in runoff volume and treatment of runoff by infiltration into the soil media;
- Stormwater Harvesting - would capture roof and some hardstand runoff for reuse within the establishment for non-potable purposes. This would allow for a reduction in mains water demand as well as mitigate against any increase in runoff volume as a result of the introduction of impervious areas on the site;
- Permeable Pavements - can be implemented into any uncovered walkways or parking bays. The pavers allow stormwater to infiltrate into the sub-base, where stormwater retention and treatment is provided. As permeable pavements can be integrated into the landscape, they generally have no net land take;
- Bio-filtration swales – All site runoff is to be treated by bio-retention areas which are to be integrated into the lakeside walkway. Bio-filtration areas would consist of vegetated areas with an enhanced filtration media. Stormwater attenuation is provided within the filter media as well as ponding within the swale. Runoff is slowly infiltrated through the enhanced filter media, where physical and bio-chemical processes provide removal of suspended sediments and nutrients. Filtered stormwater would be collected in an underlying subsurface drainage system and discharged into the lake in a "low impact" distribution system.

4.6.3 Workshop and Hardstand Management Plan

The workshop/hardstand area is a potential source of toxic pollutants. Hence, strict stormwater controls will be required, these are outlined as follows.

4.6.3.1 Preventative Measures

The following preventative measures would be adopted to minimise generation of pollutants from the vessel repair operations:-

- Mist shrouds would be used in the wash down bay to minimise the spread of any wash down waters;
- Abrasive blasting would be undertaken within tarp enclosures and would be closely monitored on windy days to prevent drifting dust;
- Where practical, vacuum sanders would be used to remove paint from hulls and collect paint dust;
- Sacrificial anodes would be removed or covered before water blasting;
- The majority of solid contaminants (e.g. paint shavings, marine growths, etc) which can accumulate on the hardstand would be regularly swept up and stored in solid waste bins for collection by a commercial waste contractor;
- Tributyltin (an antifouling paint which is highly toxic) would not be used onsite; and

- The hardstand area would be above the 5 year ARI Lake Macquarie still flood level to prevent frequent inundation.

4.6.3.2 Containment and Treatment Controls

A first flush tank would be provided to capture the initial 15 mm of runoff from the hardstand/workshop area (as well as any water used for the vessel repair operations). Captured stormwater would be treated using a proprietary treatment package and reused for vessel repair/wash down purposes. Excess water would be discharged to the sewer under a trade waste agreement.

4.7 Water Quality

Water quality has the potential to be affected during the ongoing use of the marina complex. Areas such as fuelling docks, pump-out facilities, hardstands and repair workshops can all impact on the water quality within the area. Chemicals from such operations can often become trapped within sediment and be transported to other areas via currents or through the water column itself. Many aquatic organisms have the ability to accumulate such toxins, which can cause health issues later on.

4.7.1 Copper Leaching and Zinc Dissolution

An assessment of the extent and nature of potential copper leachate from antifouling paints and zinc dissolution from sacrificial anodes on vessels moored within the marina has recently been undertaken by Patterson Britton & Partners to determine the potential effects on the aquatic ecosystem, and incorporated in detail in their Trinity Point Environmental Assessment Report. Sampling for dissolved and total copper and for zinc was conducted within and outside of a number of marinas in Lake Macquarie and at the proposed Trinity Pointy marina site over a period of six months since November 2007 to establish background levels within the lake and assess typical levels found within marinas

ANZECC (2000) established default trigger values for the protection of aquatic ecosystems. These are:

- Copper - trigger value 3.0 µg/L protects 90% of aquatic species;
  - trigger value 1.3 µg/L protects 95% of aquatic species.
- Zinc - trigger value 23 µg/L protects 90% of aquatic species;
  - trigger value 15 µg/L protects 95% of aquatic species.

Copper sampling indicated that Lake Macquarie is a highly modified water body with respect to copper concentrations. Moderate to high background levels were recorded with 90% and 95% ANZECC trigger values being exceeded depending on the location. The Trinity Point sampling site was typical of these results. Because of the existing background copper levels, it would be expected that the existing marine biota have adapted to the existing levels of copper and, as a result, be relatively tolerant to the existing levels of copper in the lake. The proposed Trinity Point Marina is expected to have similar flushing properties, copper levels and colonisation by marine flora and fauna as the other marinas tested. With the proposed layout design features (see Section 4.7.2 below) it is expected that copper levels within the Trinity Point Marina would not differ significantly to those near existing marinas in Lake Macquarie. The predicted copper levels are not expected to elevate the impact on biota beyond the 90% to 95% species protected range.

Zinc dissolution from sacrificial anodes used to protect vessels moored within the marina from corrosion is another potential source of heavy metal impacting on water quality. In Lake Macquarie, naturally occurring zinc levels in the water column and in the sediments are generally higher than copper levels. Zinc is also less toxic than copper to marine biota as is reflected in the ANZECC exceedance guideline values. Based on sampling undertaken by Patterson Britton & Partners, Trinity Point appears to be typical with respect to the levels of zinc released to the water. Given the relatively lower toxicity, lower release rates and high naturally occurring levels of zinc compared to copper, it is considered that elevated zinc levels at the proposed Trinity Point Marina are of lesser concern that that posed by copper. Design features of the marina to minimise the impact of copper levels, as discussed above and in Section 4.7.2, would be of similar benefit in relation to zinc.

4.7.2 Marina Design Features to Assist in Dilution and Flushing

Design features already incorporated would assist in dilution and flushing to ensure that the marina will not elevate water quality levels significantly, or exceed the existing trigger value percentile ranges. Design features include a timber slatted breakwater which has been designed to be totally pervious, unlike traditional rocky rubble breakwaters. This will allow the movement of water through the breakwater, and minimise the entrapment of sediments on the southern side of the breakwater. A partial depth wave screen and open foreshore section on the breakwater will assist in minimising restrictions to flushing.

The proposed location of the fuel and sewer pump-out berths is at the T-head end of Arm A of the marina berths, in deep water (greater than 5 m depth). This location would minimise the impact a spill would have on the seagrass habitat located over 200 m away inshore, and mangroves and saltmarsh located over 250 m to the north-west. The repair workshops and hardstands have been designed so that very little untreated run-off and chemicals can enter the waterway (see Section 4.6.3 above).

5.0 CONCLUSIONS

During the surveys of the development site, it was concluded that the condition of the three main aquatic vegetation types was generally very good. Although some areas of seagrasses had large epiphytic loads, the overall health of each vegetation type was good. This was reflected in the numbers of benthic invertebrates and juvenile fish, many of which are of economic importance, which were observed within and around the proposed development site.

From information gathered during the assessment of impacts, the proposed location of the marina is considered to be in the most suitable position to minimise damage to aquatic vegetation within the area. The marina and breakwater jetties will have aluminium mesh decking which will minimise any shading issues. The steel slipway of the travel lift will create a shading footprint of approximately 50 -75 m^2. The installation of wooden jetty piles (250 - 300 mm diameter) and hollow steel travel lift piles (457 mm diameter) will result in the loss of no greater than 10 m^2 of seagrass (*Zostera*). Considering the extent of the *Zostera* along the area of this northern shoreline, the impacts on seagrass from direct disturbance as a result of piling and shading are considered to be minimal. No seagrass beds will be fragmented and the area of direct disturbance is a very small proportion of the seagrass bed. The construction and operation of the marina development is unlikely to have any long term impacts upon the seagrass habitats.

The proposed marina works are unlikely to affect listed threatened and protected species of fish, marine mammals and reptiles that occur in, or encroach upon, the study area.

Data collected and presented within this report can be used throughout the approvals process and can form a baseline of information on the aquatic vegetation within the area. This data can be compared with that recorded after construction of the marina has taken place as part of any monitoring programs if required.

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TABLES

Table 1. Results of asymmetrical ANOVA for the density of *Zostera* sampled within 5 sites at Trinity Point and two reference locations (*n* = 4). Significant terms are in bold print. TP = Trinity Point, Ref = Reference.

a) *Zostera* Density — Transform: Ln(X+1), Cochran's Test: C = 0.2328 (Not Significant)

	df	MS	F	*p*	F versus
Location	2	0.864	4.543	**0.034**	Site(Lo)
TPvsRef	1	0.9534	1.230	0.467	C
Ref	1	0.775	36.976	**0.000**	Site(C)
Site(Lo)	12	0.190	7.090	**0.000**	Residual
Site(TP)	4	0.5288	19.708	**0.000**	Residual
Site(Ref)	8	0.021	0.781	0.621	Residual
Residual	45	0.027			

Table 2. Results of asymmetrical ANOVA for various morphological characteristics of *Zostera* sampled within 5 sites at Trinity Point and two reference locations (n = 20). Significant terms are in bold print. TP = Trinity Point, Ref = Reference.

a) Leaf Length — Transform: Sqrt(X+1), Cochran's Test: C = 0.1314 (Not Significant)

	df		MS		F	*p*	F versus
Location	2		127.053		15.448	**0.000**	Site(Lo)
TPvsRef		1		141.8789	1.264	0.463	C
Ref		1		112.227	15.988	**0.004**	Site(C)
Site(Lo)	12		8.224		48.798	**0.000**	Residual
Site(TP)		4		10.6342	63.097	**0.000**	Residual
Site(Ref)		8		7.019	41.649	**0.000**	Residual
Residual	285		0.169				

b) Leaf Width — Transform: None, Cochran's Test: C = 0.1056 (Not Significant)

	df		MS		F	*p*	F versus
Location	2		5.590		3.033	0.086	Site(Lo)
TPvsRef		1		4.335	0.633	0.572	C
Ref		1		6.845	5.286	0.051	Site(C)
Site(Lo)	12		1.843		5.066	**0.000**	Residual
Site(TP)		4		2.94	8.080	**0.000**	Residual
Site(Ref)		8		1.295	3.559	**0.001**	Residual
Residual	285		0.364				

c) No. of Leaves per Shoot — Transform: Ln(X+1), Cochran's Test: C = 0.1150 (Not Significant)

	df		MS		F	*p*	F versus
Location	2		0.245		3.744	0.055	Site(Lo)
TPvsRef		1		0.2282	0.869	0.522	C
Ref		1		0.263	3.989	0.081	Site(C)
Site(Lo)	12		0.066		1.689	**0.069**	Residual
Site(TP)		4		0.065	1.674	**0.156**	Residual
Site(Ref)		8		0.066	1.696	**0.099**	Residual
Residual	285		0.039				

Table 3. GPS coordinates of benthic sampling sites for the proposed marina in Bardens Bay sampled in October 2007 (WGS 84 datum).

Location	Site	Easting	Northing
Arm A	Inner	0363936	6334199
	Outer	0364030	6334218
Arm B	Inner	0363888	6334234
	Outer	0364000	6334278
Arm C	Inner	0363859	6334228
	Outer	0363965	6334304
Arm D	Inner	0363834	6334236
	Outer	0363934	6334355

Table 4. Results of 1-way ANOSIM tests comparing infaunal assemblages across the location of the arms and between inner and outer sites at the proposed marina.

Global tests

Factor	*R*	*P*
Arm	-0.016	0.483
Site	0.882	**0.001**

Table 5. Results of SIMPER analysis showing the contribution of the principal taxa to the dissimilarity between infaunal assemblages in the inner and outer positions.

Average dissimilarity = 90.7%

Taxon	Average Abundance		Diss	Diss/SD	Contrib%	Cum.%
	Inner	Outer				
Cirratulidae	28.67	0.17	26.68	3.14	29.41	29.41
Semelidae	2.08	10.75	9.59	1.25	10.57	39.98
Capitellidae	10.00	0.08	9.21	1.94	10.15	50.13
Oweniidae	7.08	0.25	7.33	1.23	8.07	58.21
Magelonidae	6.42	0.00	5.82	1.63	6.42	64.62
Maldanidae	5.00	1.25	4.95	1.46	5.45	70.08
Lucinidae	3.17	0.00	3.31	1.98	3.65	73.72
Terebellidae	1.42	2.67	3.17	0.82	3.49	77.21
Pilargidae	3.17	0.00	3.13	2.04	3.45	80.66
Lumbrineridae	3.08	0.33	2.78	0.95	3.07	83.73
Mactridae	2.58	0.83	2.40	1.25	2.64	86.37
Sigalionidae	0.00	1.67	1.85	1.15	2.04	88.41
Nemertea	1.00	0.08	1.16	0.67	1.28	89.69
Syllidae	1.25	0.17	1.09	0.66	1.20	90.89

Table 6. Results of 2-way ANOVAs comparing numbers of taxa and abundances of selected infaunal groups across the location of the proposed arms of the marina and between inner and outer sites on each arm.

(a) Number of taxa - Ln(X+1) transformed
Cochran's *C = 0.409, ns*

Source	SS	DF	MS	F	P	F versus
Arm	1.195	3	0.399	10.60	R	Residual
Site	8.789	1	8.789	233.80	R	Residual
Arm x Site	0.708	3	0.236	6.28	**0.005**	Residual
Residual	0.602	16	0.038			
Total	11.294	23				

(b) Number of animals - untransformed
Cochran's *C = 0.340, ns*

Source	SS	DF	MS	F	P	F versus
Arm	743.167	3	247.722	0.45	0.722	Residual
Site	23064.000	1	23064.000	41.74	**<0.001**	Residual
Arm x Site	1072.667	3	357.556	0.65	0.596	Residual
Residual	8842.000	16	552.625			
Total	33721.833	23				

(c) Number of capitellids - Ln(X+1) transformed
Cochran's *C = 0.365, ns*

Source	SS	DF	MS	F	P	F versus
Arm	1.729	3	0.576	2.79	0.075	Residual
Site	26.797	1	26.797	129.51	**<0.001**	Residual
Arm x Site	1.668	3	0.556	2.69	0.081	Residual
Residual	3.311	16	0.207			
Total	33.504	23				

(d) Number of cirratulids - Ln(X+1) transformed
Cochran's *C = 0.328, ns*

Source	SS	DF	MS	F	P	F versus
Arm	0.086	3	0.029	0.13	0.941	Residual
Site	59.233	1	59.233	269.23	**<0.001**	Residual
Arm x Site	0.427	3	0.142	0.65	0.596	Residual
Residual	3.520	16	0.220			
Total	63.267	23				

Table 6. (cont.)

(e) Number of semelids - untransformed
Cochran's *C = 0.441, ns*

Source	SS	DF	MS	F	P	F versus
Arm	27.500	3	9.167	0.27	0.847	Residual
Site	450.667	1	450.667	13.22	**<0.001**	Residual
Arm x Site	66.333	3	22.111	0.65	0.595	Residual
Residual	545.333	16	34.083			
Total	1089.833	23				

(f) Number of terebellids - Ln (X+1) transformed
Cochran's *C = 0.242, ns*

Source	SS	DF	MS	F	P	F versus
Arm	6.855	3	2.285	6.54	R	Residual
Site	0.002	1	0.002	0.01	R	Residual
Arm x Site	4.821	3	1.607	4.60	**0.017**	Residual
Residual	5.586	16	0.349			
Total	17.263	23				

FIGURES

Figure 1a. Aquatic vegetation at Trinity Point in Lake Macquarie. Seagrass mapped by The Ecology Lab in January 2007; all other vegetation mapped by RPS Harper Somers O'Sullivan in October 2008.

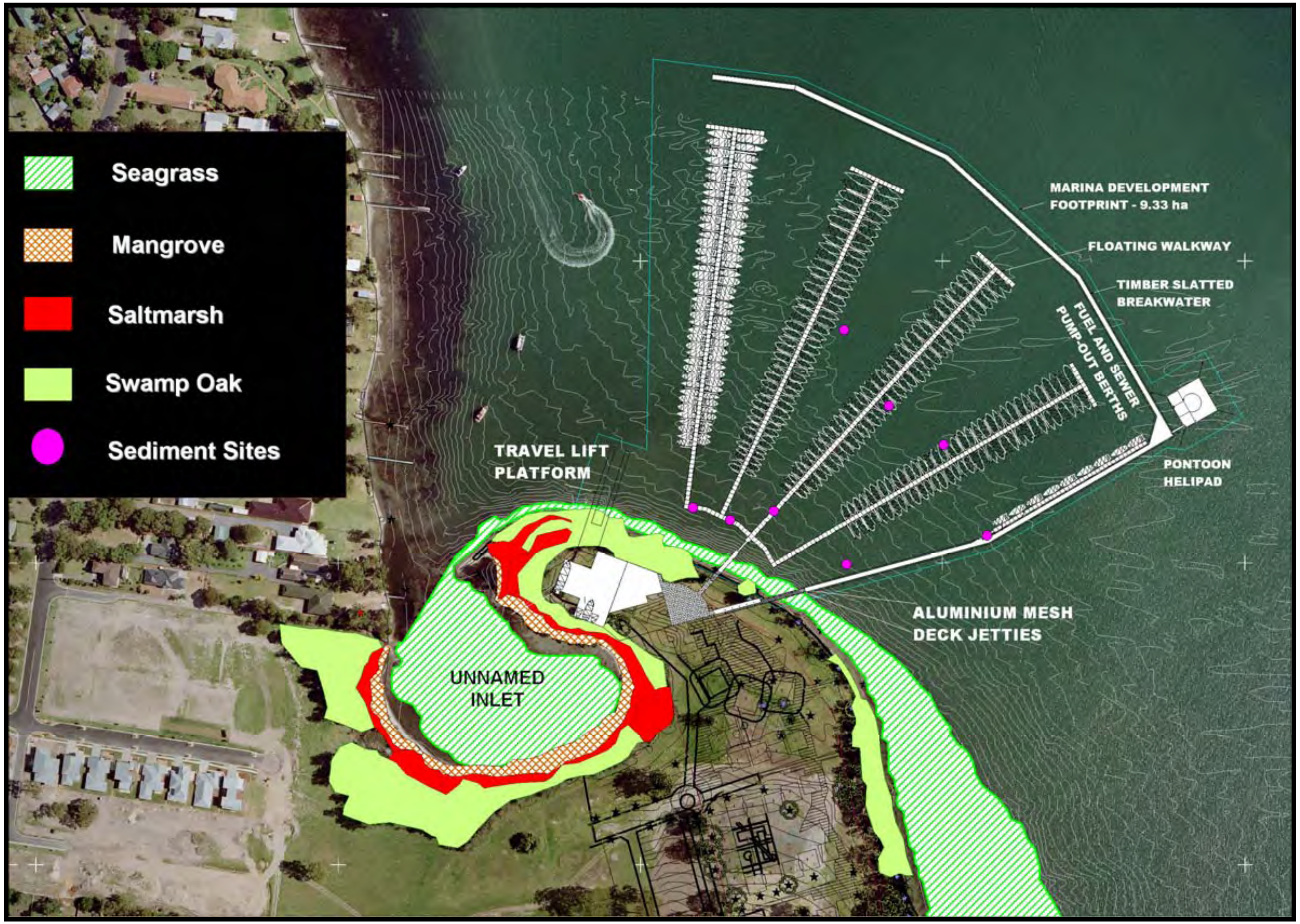

Figure 1b. Aquatic vegetation at Trinity Point in the vicinity of the proposed marina footprint, and positions of sediment samples (collected in October 2007). The saltmarsh area includes a community of species (as indicated in the text). Seagrass mapped by The Ecology Lab in January 2007; all other vegetation mapped by RPS Harper Somers O'Sullivan in October 2008.

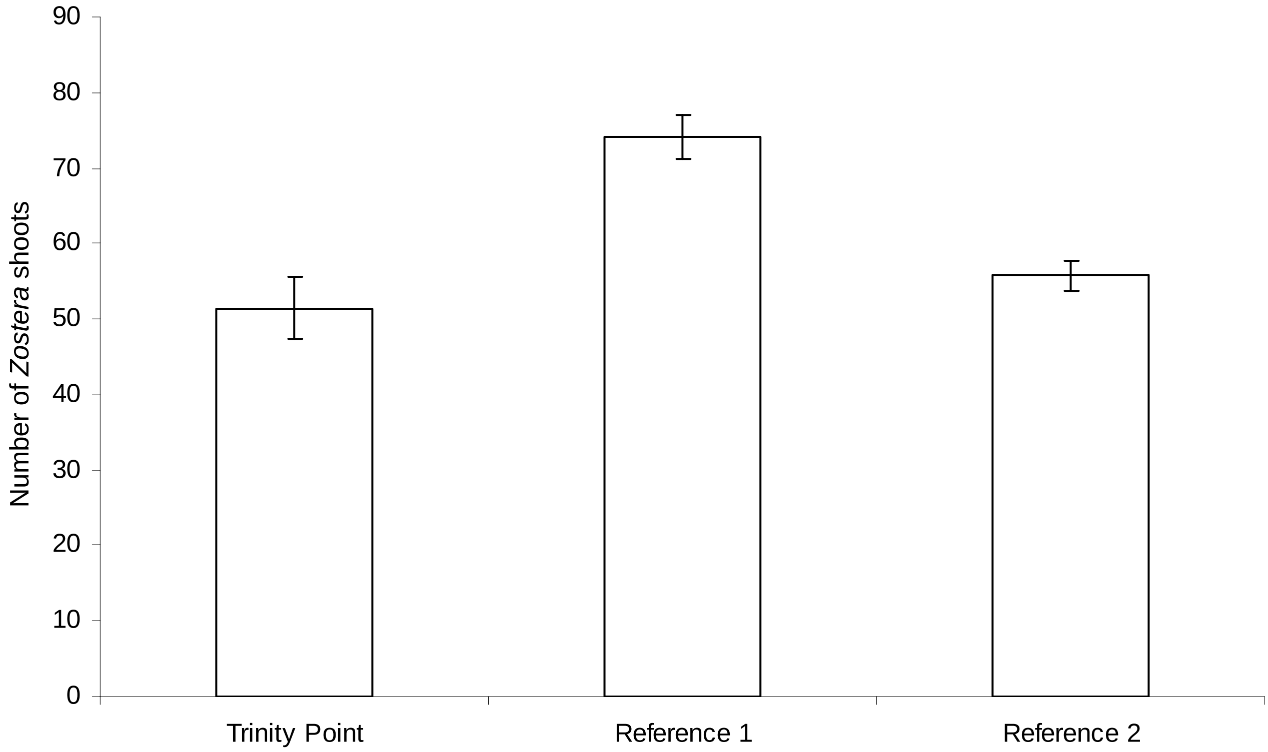

Figure 2. Mean density of *Zostera* shoots per 30 cm x 30 cm at Trinity Point and two reference locations (*n* = 20). Ref 1 = Frying Pan Point, Ref 2 = Wyee Point.

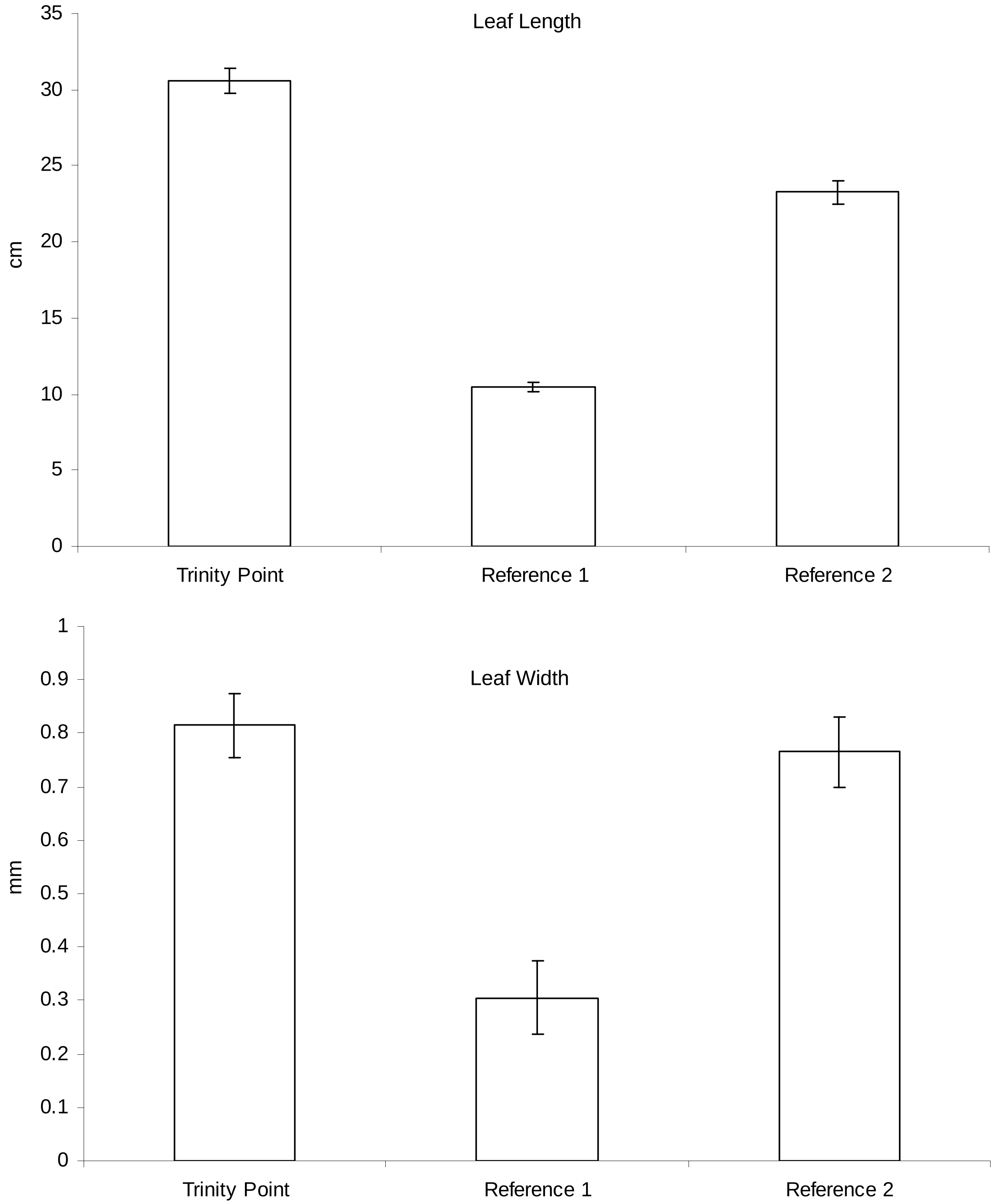

Figure 3. Mean leaf length, width and number of leaves per *Zostera* shoot at Trinity Point and two reference locations (n = 100). Ref 1 = Frying Pan Point, Ref 2 = Wyee Point.

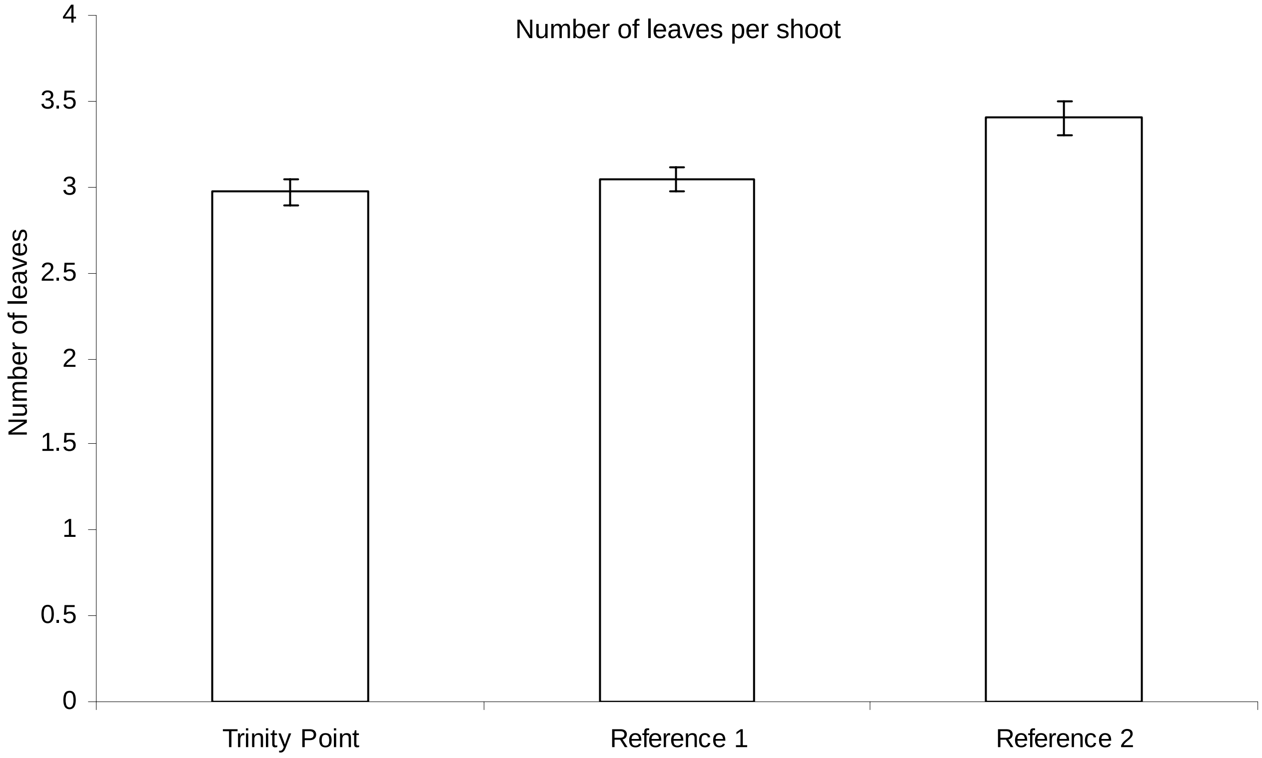

Figure 3. Continued.

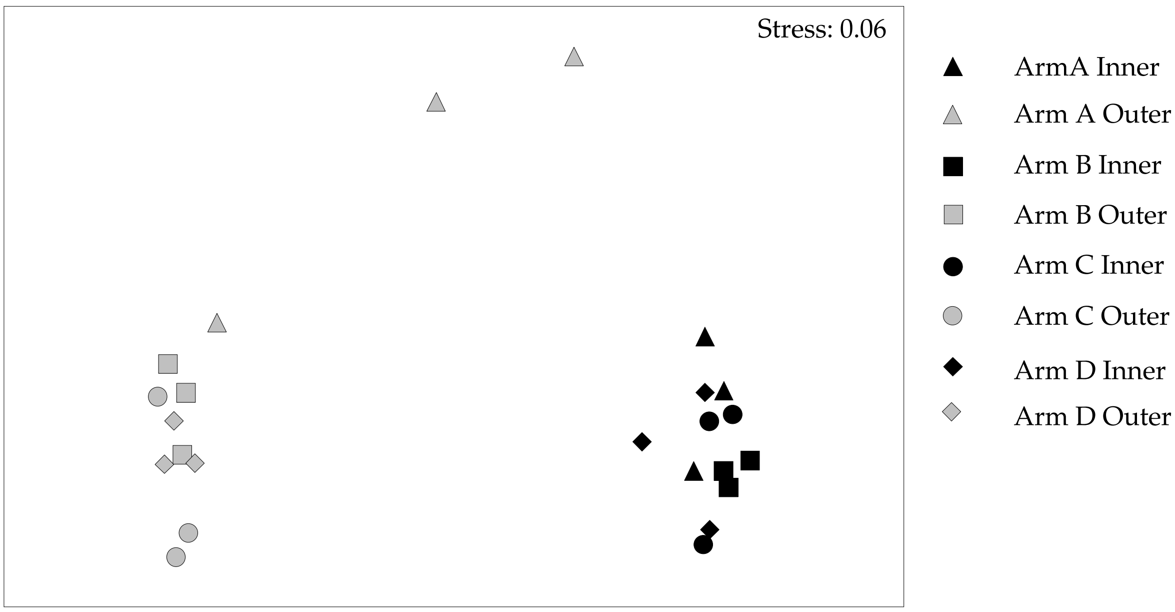

Figure 4. MDS plot comparing infaunal assemblages in the inner and outer sites at each of the four arms (A - D) of the proposed marina.

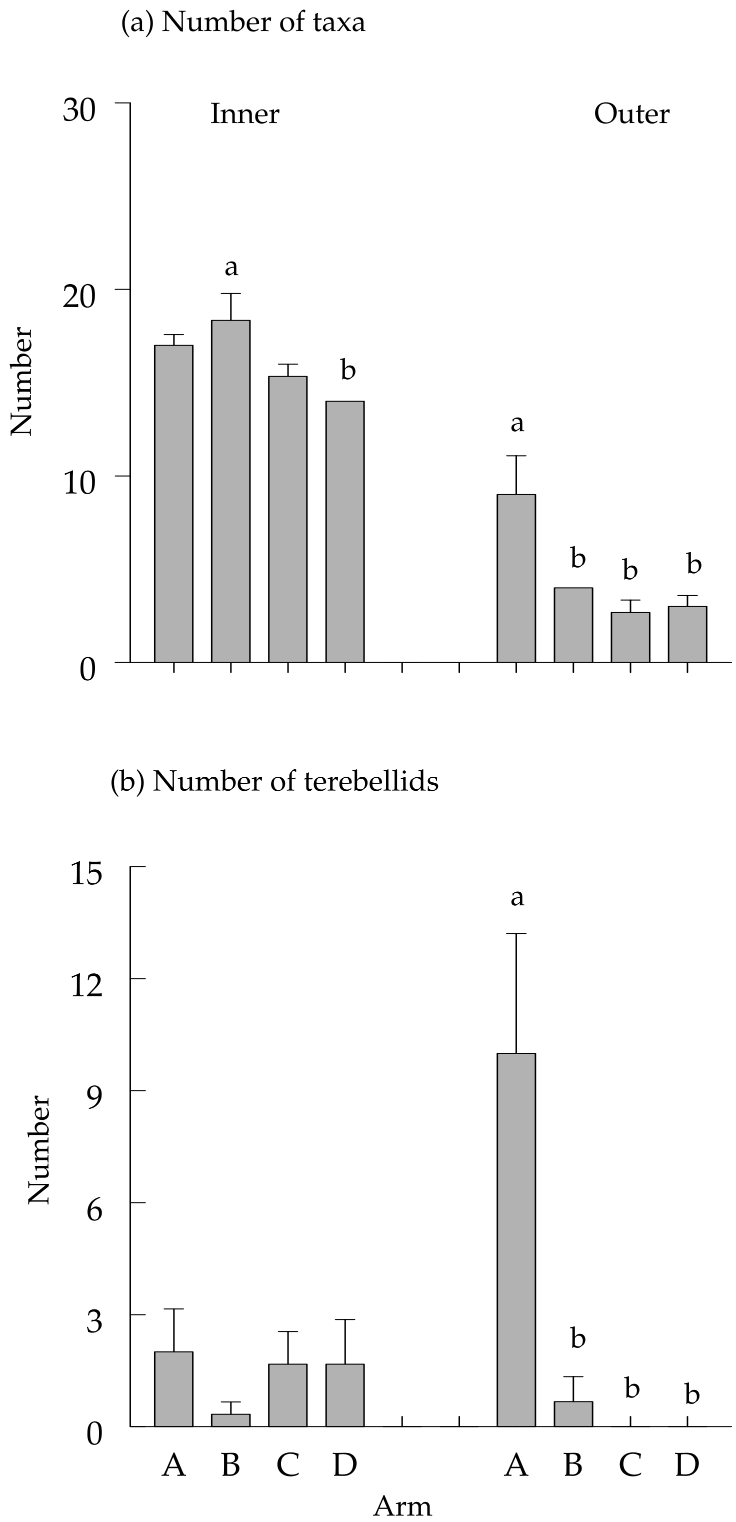

Figure 5. Mean (± S.E) number of (a) taxa and (b) terebellids in the inner and outer position of each of the arms (A - D) of the proposed marina. Different letters (a or b) indicate that numbers differ significantly between arms.

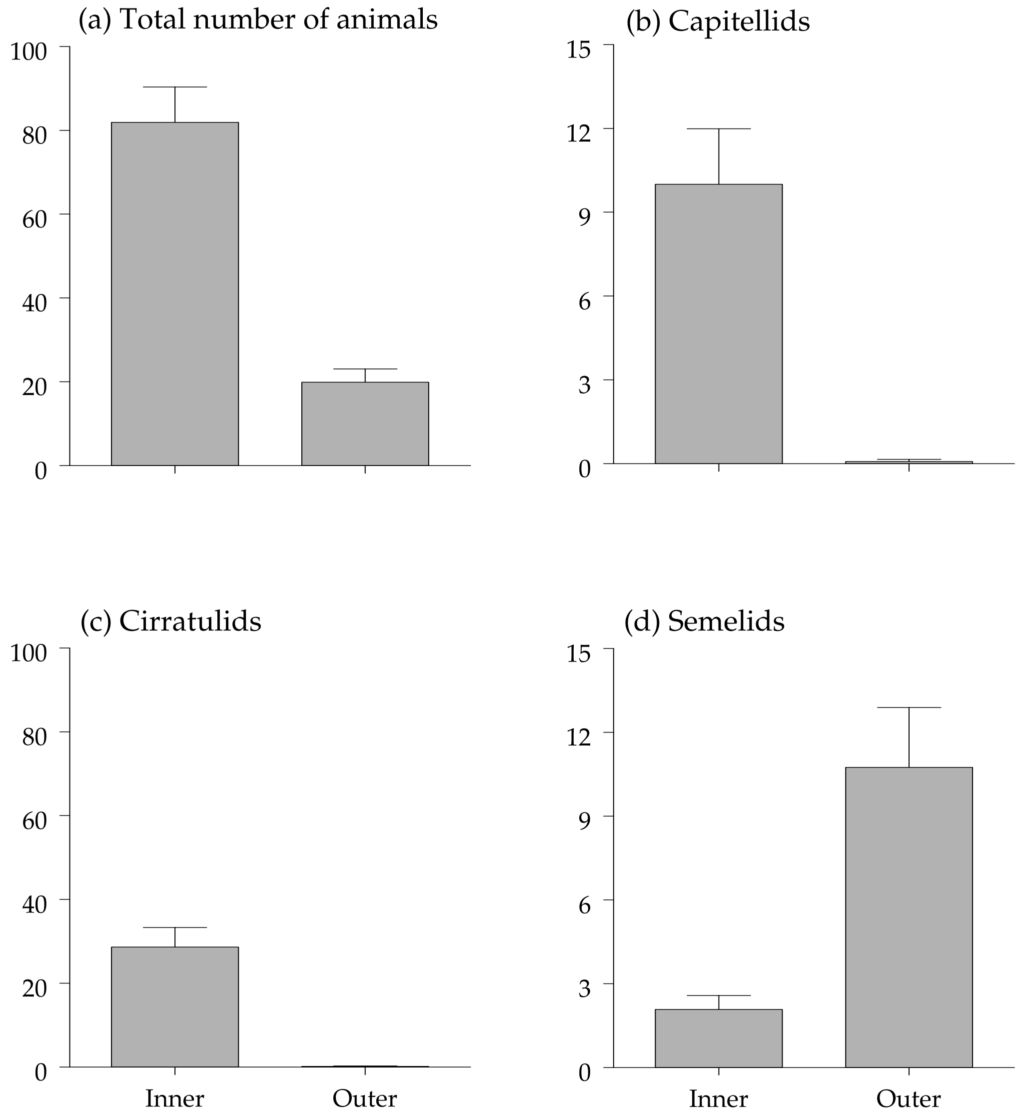

Figure 6. Mean (± S.E) number of (a) animals, (b) capitellids, (c) cirratulids and (d) semelids in the inner and outer position averaged across the four arms of the proposed marina.