Appendix 2.

AMBS CONSULTING

Biological Study of Myall Quays Lake

Crighton Properties Pty Ltd

Draft Report

2002009

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Executive Summary

AMBS carried out an ecological survey of the Myall Quays Lake to assess the aquatic habitats present and determine changes to the assemblages since the baseline survey in 1998. An evaluation of the health of the lake was carried out by comparing historical water quality parameters with those recommended in the ANZECC Guidelines with relevance to the seagrass, macroalgae, fish and macroinvertebrates present.

Myall Quays Lake is contained within the Myall Quays development which is located near Tea Gardens, north of New Castle. It was constructed as a detention basin to serve the needs of adjoining residential development.

Generally the ecological assemblages within the lake can still be considered to be maturing. The lake appears to be influenced more strongly by rainfall events than tidal inundation and as a result the salinity concentration within the large are variable. It can be concluded that the variable water parameters are influencing the species able to inhabit the lake and conditions are more favourable to those able to with stand extreme fluctuations in salinity levels. While some water quality parameters such as dissolved oxygen and faecal coliforms are not within the recommended guidelines further monitoring is required to determine the effects of these variations.

During the study seven species of fish were collected. The lake appears to be supporting a small number of resident fishes that are probably present year round and breed within the lake. These fishes include the flathead gudgeon, dwarf flathead gudgeon, blue-spot goby and southern blue-eye.

The aquatic flora of the lake is maturing and has become more widespread throughout the lake. Four species of aquatic plants (excluding riparian plants) were present in the lake during this survey, the dominant seagrass *Ruppia polycarpa* and three macroalagae; *Lamprothamnion papulosum*, *Chara spp* and *Ulvaria oxysperm*.

Contents

1 Introduction

Australian Museum Business Services (AMBS Consulting) carried out a baseline biological survey of the Myall Quays Lake for Crighton Properties in 1998. This survey of the ecological assemblages of the lake was conducted in September 2002 to determine changes to the lake environment that may have occurred since the baseline study. The Myall Quays Lake is located within the Myall Quays development near Tea Gardens, north of Newcastle. The lake was constructed as a detention basin to serve the needs of the surrounding residential development.

The scope of the study was an ecological survey of the lake to assess the current habitats present and determine changes to the assemblages since the previous survey. An evaluation of the health of the lake was carried out by comparing historical water quality parameters with those recommended in the ANZECC Guidelines.

2 Project objectives

This study aimed to;

- Survey the existing fish, seagrass, macrophyte, macroalgae and macroinvertebrates present in the Lakes;
- Compare current ecological assemblages with those present during the baseline survey;
- Map current lake vegetation;
- Analyse historical water quality data with relation to rainfall and tidal influence;
- Discuss water quality parameters with relevance to community assemblages and
- Provide advice for future lake management decisions.

3 Background Information

The baseline survey was conducted in 1998 when the lake was two years old and the communities within it were maturing. Previously 11 plants, nine fishes and one macroinvertebrate species were collected from the lake. The species were predominantly marine/estuarine species. The distribution of the species did not appear to be influenced by water quality parameters. The water quality of the lake was within the recommended ANZECC Guidelines.

4 Methodology

4.1 Review of Available Water Quality Data

Hunter Water Laboratories have collected water quality parameters from the lake since 1996 and the most recent available data was sampled in April 2002. AMBS reviewed and analysed the data collected since the previous report (02.04.98-11.4.02) and compared the results with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC Guidelines) and the previous water quality analyses. As only single water quality samples were taken at each site, no data was available to determine the vertical stratification of the lake or variation between replicate water samples.

Rainfall data for the lake was provided by Crighton Properties and was compared with the water quality results to determine any existing relationship between the two. Tidal information was sourced from the Department of Defence Australian National Tide Tables for Newcastle and was compared with the water quality results to determine any existing relationship between the two.

4.2 Site Locations

Sampling was undertaken at the sites previously surveyed. A map of the locations is included in Appendix A and site photographs are included in Appendix B;
Site 1a: North western end of lake
Site 1b: North western from the office
Site 2: In front of the office
Site 3: Eastern end of the lake near the drain entrance
Site 4: Near the drain

4.3 Seagrass and Macroalgae

4.3.1 Field

AMBS staff mapped five previously surveyed representative transects in the lake to determine the extent, pattern of cover and species composition of the seagrass, macrophyte and macroalgae communities. The abundance and distribution patterns of the vegetation were determined using the abundance/sociability scale (King and Barclay 1987) below, used previously to allow comparisons to be carried out. The plants were identified in the field and some macroalgae samples were transported to experts at the Royal Botanical Gardens for confirmation.

Table 1. Seagrass Abundance and Sociability Scale (based on King and Barclay 1986)

		Sociability	
Abundance	A	B	C
	Individuals	Patches	Beds relatively even distribution
1			
Sparse Growth (<15%)	A1	B1	C1
2			
Moderate Growth (15-50%)	A2	B2	C2
3			
Abundant Growth (>50%)	A3	B3	C3

4.3.2 Mapping

The seagrass beds were mapped using MapInfo.

4.4 Fishes

4.4.1 Field

AMBS staff used a variety of techniques to sample fish from the five sites. Based on habitat characteristics of the sites the techniques used included electrofishing, a 10m seine, Japanese seine and a fine mesh seine. These techniques are described below;

- **Electrofishing** was undertaken using a Model 12-A POW Smith Root Backpack
- **A 10 metre seine** was operated by two people walking towards the shore from about 1m depth, each holding a pole at either end of the net. This net was also operated using a row boat which allowed a greater water depth to be sampled.
- **A Japanese seine** is a small one-person collecting device which consists of two poles separated by a fine-meshed scooped net. The operator can effectively collect small fishes from stream banks and many areas that larger seines are ineffective.
- **A Fine mesh seine** is a two-person mesh net of about 2-3m in length and about 1m in height. This seine has very fine mesh and is therefore useful for collecting small fishes which may escape through the mesh of larger seines.

The fishes that were collected were identified in the field where possible and returned to the water. Any specimens unable to be identified in the field were preserved in 10% formalin and returned to the laboratory for identification. The fishes were transferred from 10% formalin to 70% alcohol after about one week.

4.4.2 Laboratory

Fishes collected that were less than 5cm could not be accurately identification in the field to species level. These were returned to the museum for identification under microscopes.

5 Results

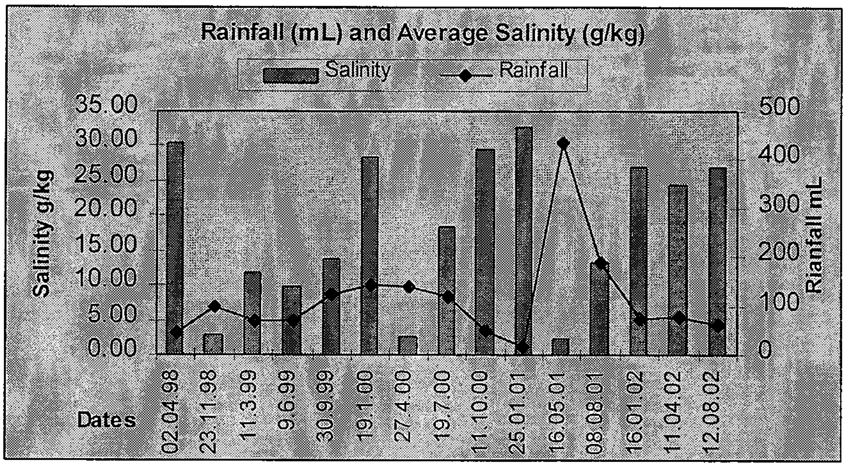
5.1 Water Quality

5.1.1 Salinity

The average salinity in the lake ranged from 2.22 to 32.81. On average salinity levels have remained similar to the previous survey, however, fluctuations and periods of low salinity have increasingly occurred.

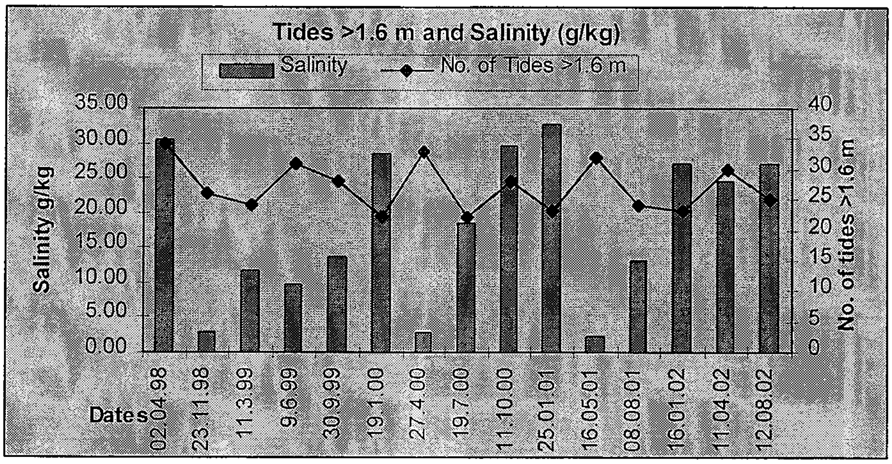
The salinity data was compared with rainfall totals for the month preceding the sampling to determine whether rainfall was influencing salinity levels in the lake. The lowest level of salinity occurred in 2001 following a period of high rainfall and the most saline sample was collected following a month of low rainfall. There would appear from the data to be a relationship between rainfall and salinity levels.

Figure 1 Salinity and Average Rainfall



The salinity data was compared with tidal influence by calculating salinity levels with the number of tides > than or equal to 1.6 metres in the month preceding the sampling event. There did not appear to be a relationship between the number of high tides and levels of salinity in the lake.

Figure 2 Tidal Influence and Salinity

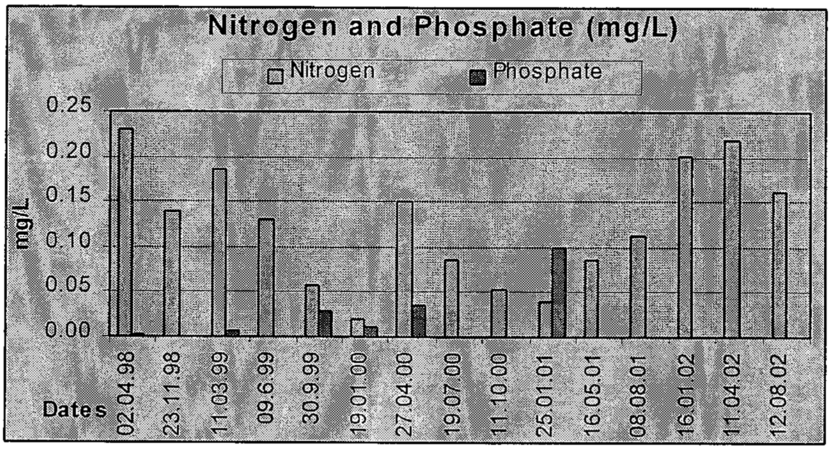


5.1.2 Nutrients

Nutrients in the environment are composed of phosphorus (P) and nitrogen (N). Levels of phosphorus and nitrogen in a water column are useful measures of the potential for nuisance plants to grow. Since the baseline survey phosphorus was measured as mg/L and the most bioavailable form of phosphorus, orthosphosphate was not analysed. Phosphate levels cannot be compared to the ANZECC Guidelines as the samples were filtered and do not include orthophosphate. Similarly, the oxidised nitrogen mg/L was measured without kjeldahl nitrogen so comparisons with the ANZECC Guidelines cannot be made.

General indications of trends relating to nutrient levels have been calculated using oxidised nitrogen, ammonia, and nitrates and phosphate (levels below .005 were considered as zero for nitrates and .01 for phosphate). On average levels of phosphate were low. The nitrogen levels on average reduced during 2000 but began increasing in 2001.

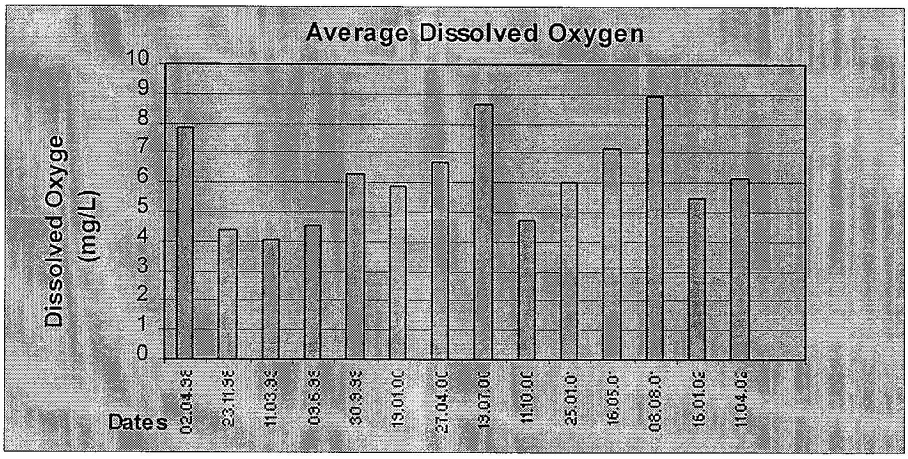
Figure 3 Average Nutrient Levels



5.1.3 Dissolved Oxygen

Average dissolved oxygen levels in the lake ranged from 4.4 -8.92 mg/L during the sampling period. The ANZECC Guidelines have set a default trigger range of 80-110% saturation levels for slightly disturbed estuarine environments. Levels of 6 mg/L and above will fall within the recommended guidelines. On average during half of the sampling events DO levels fell below the recommended guidelines. During the baseline survey all samples of DO fell within the recommended guidelines.

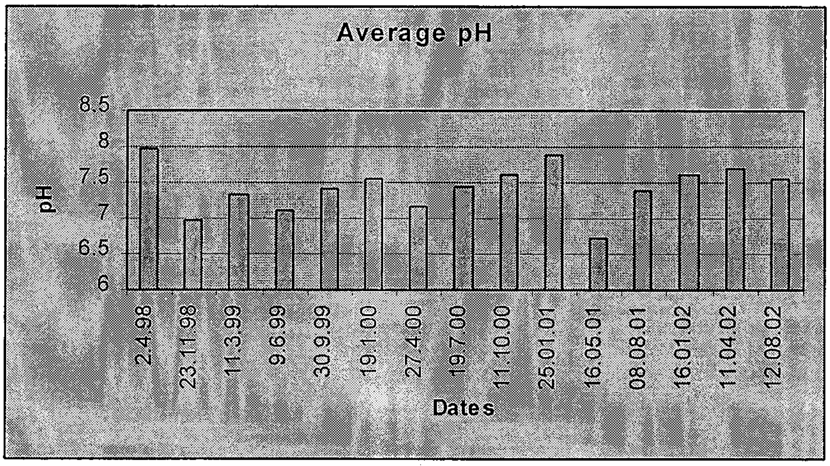
Figure 4 Average Dissolved Oxygen



5.1.4 pH

pH is the measure of the acidity or alkalinity of water on a scale of 0 (extremely acidic) to 7 neutral to 14 (extremely alkaline). The pH of natural fresh waters range from 6.5-8.0 and marine waters are commonly closer to 8.2. The average pH in the lake ranged from 6.72 -7.98, and values remained fairly consistent over the sampling period. On average the pH values of the lake were within the recommended guidelines for pH levels in estuarine environments.

Figure 5 Average pH Levels



5.1.5 Faecal Coliforms

Based on the ANZECC Guidelines for recreational water quality for primary contact the median bacterial content of fresh or marine waters should not exceed 150 faecal coliform organisms/100mL and 1000 organisms for secondary contact. Generally the levels were within the recommended guidelines but during five sampling events the faecal coliforms exceeded levels considered safe for primary contact such as swimming (Figure 6). It appears that the spikes in faecal coliform levels in the lake followed periods of rainfall. On average the lake did not exceed the recommended guidelines. Site 2 most commonly had the highest levels of coliforms. (Figure 7)

Figure 6 Faecal Coliforms

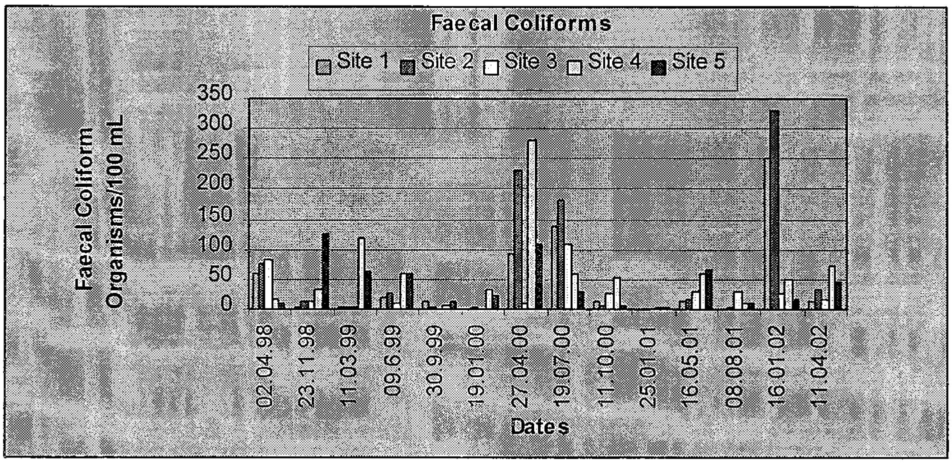
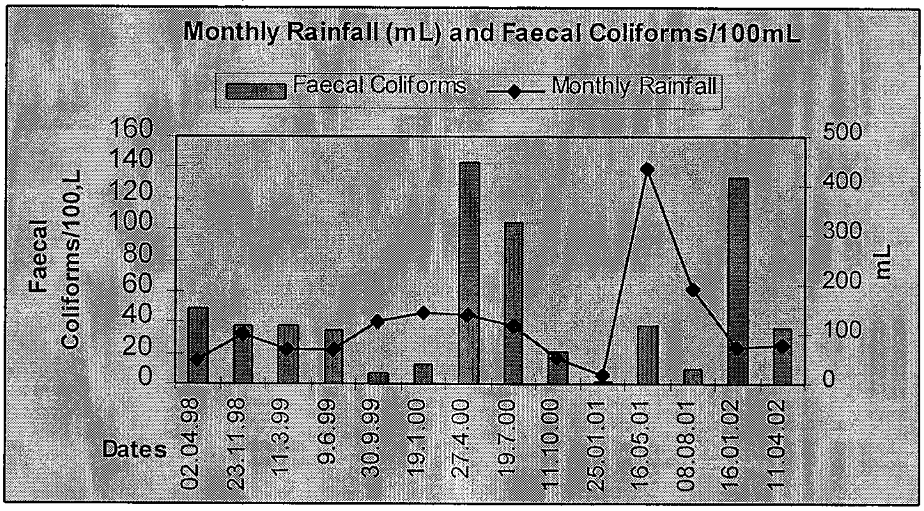


Figure 7 Monthly Rainfall and Faecal Coliforms



5.2 Seagrass and Macroalgae

The following aquatic flora were present in the lake:

5.2.1 Seagrass

Ruppia polycarpia (Sea Tassel)
Commonly grows in coastal lakes and lagoons at similar or lower salinities than seawater. *Ruppia polycarpa* is the most dominant species in Myall Quays Lake.

5.2.2 Aquatic Angiosperms

Triglochlin striata (Streaked Arrow Grass)
This is a useful stabilising species growing in tidal and freshwater swamps (Sainty & Jacobs, 1994). *Triglochlin striata* was found growing around the banks of the lake particularly in the north western end of the lake.

Family Caryophyllaceae
Paronychia brasiliana
Polycarpon tetraphyllum (Four leaved Allseed)
These plants were considered riparian and will not be discussed. *P. tetraphyllum* is a native to Europe.

Juncus spp. (Rushes)
These rushes surround the lake along the shoreline. They were not identified further as they were not growing in the lake.

5.2.3 Macroalgae

Chlorophyta (Green Alagae)
Ulvaria oxysperma

No information regarding this species could be sourced from the Royal Botanic Gardens. *U. oxysperma* was present in the shallows along the north western shoreline of the lake.

Charophytes (Stoneworts)
Chara spp
Is a native algae is found in lakes or slow moving water where calcium levels are high. *Chara* spp is present from the middle of the lake to the eastern end.

Lamprothamnion papulosum (Foxtail stonewort)
This stonewort is commonly associated with saline lakes in Australia in conditions ranging from relatively fresh to brine salt water salinities. This species is noted for its tolerance to salt water. *L. papulosum* was present only in the north western end of the lake in the shallows.

5.2.4 Distribution

A map of the distribution of the aquatic flora is presented in Appendix C. The vegetation of Myall Quays Lake was dominated by the seagrass *Ruppia polycarpa* in beds that included the charophytes; *Lamprothamnion papulosum* in the west and *Chara* spp in the middle and eastern ends of the lake. The beds were almost continuous across most of the lake thinning to the lake edges towards the eastern end of the lake. At the western end *Ulvaria oxysperma* was present in a shallow band around the lakes edge. The *L. papulosum* at the western end of the lake was present as sparse individual plants in the *R. polycarpa* bed extending to 25 metres from shore. The rest of the lake was dominated by *Chara* spp and *R. polycarpa* that formed beds covering the width of the lake. The seagrass beds were generally continuous ranging in densities from individual plants to very thick beds. Towards the eastern end of the lake the beds gradually became closer to shore. These eastern beds were dominated by gradually thinning *R. polycarpa.*

5.3 Fishes and Invertebrates

Fishes were collected at each of the five sites (1a, 1b, 2, 5 and 6). No fishes were returned to the water as all fishes were less than 5 cm and could not be accurately identified in the field to species level. The techniques carried out included electrofishing (no fishes caught), 10m seine (few gudgeons caught), Japanese seine (few gudgeons and gobies caught) and a fine mesh seine (most fishes were collected using this net). A small school of mullet (family Mugilidae) was seen, but not collected at site 6. All specimens are registered in the Australian Museum Fish Collection, under the station numbers, I. 41538 - I. 41542
Seven species of fishes representing six families were recorded from the lake. A total of 304 fishes were collected. The dominant fish species in the lake in terms of numbers collected was the blue-spot goby *Pseudogobius* sp., with 203 specimens collected (approx. two-thirds of all fish collected). The blue-spot goby was present at all sites. The next most dominant fish species in terms of numbers collected were the dwarf flathead gudgeon *Philypnodon* sp. (39 specimens from 4 sites), southern blue-eye *Pseudomugil signifer* (30 specimens from 3 sites) and flathead gudgeon *Philypnodon grandiceps* (24 specimens from 4 sites). The two other fish species

collected (Mosquitofish *Gambusia holbrooki* and Common jollytail *Galaxias maculatus*) were represented by 4 or less specimens and were only present at one site each.
The following fishes were collected from the lake;

Family Galaxiidae (Galaxiids)
Galaxias maculatus (Common jollytail)
Site 2: 1 specimen 33mm standard length
The common jollytail is very common in the coastal drainages of mainland south-eastern Australia (southern Qld to Adelaide, SA), Tasmania and southern WA (Denmark to Esperance). It is also known from Lord Howe Island, the Chatham Island, New Zealand, Argentina, Chile and the Falkland Islands. It is found in a variety of habitats, but most commonly occurs in still or gently flowing water of streams, rivers and lakes at low elevations. It has a high salinity tolerance and can live in fresh or seawater. This species is an important component of whitebait fisheries throughout the Southern Hemisphere. Adults typically migrate downstream into estuaries during high spring tides in autumn to spawn on fringing vegetation.

Family Poeciliidae (Livebearers)
Gambusia holbrooki (Mosquito Fish)
Site 6: 4 specimens: size range 19-22mm standard length
The mosquito fish is an exotic species, introduced into Australia from the USA in the 1920's. It is widespread and abundant throughout NSW, SA and Vic. in both inland and coastal drainages, and coastal Qld. It is also known from parts of WA. Mosquito fish tolerate a wide range of salinities from pure fresh water to full marine salinities. It is most abundant in warm and gently flowing or still waters, mainly around margins and along the edges of aquatic vegetation beds. It feeds on a wide array of both terrestrial and aquatic organisms. It is an adaptable generalist predator that may be a threat to other small fish species into whose habitat it has been introduced or spread. It has also been implicated in the reduction of green and golden bell frogs, presumably by feeding on the tadpoles.

Family Pseudomugilidae (Blue eyes)
Pseudomugil signifer (Southern Blue eye)
Site 2: 7 specimens: size range 12-25mm standard length
Site 5: 2 specimens: size range 24mm standard length (both specimens)
Site 6: 21 specimens: size range 12-17mm standard length
The southern blue-eye is widespread throughout eastern drainages, from Cooktown (northern Qld) southwards to Narooma, NSW. It is abundant in fresh or brackish coastal waters, but does not penetrate far inland and is usually found within 15-20km of the sea. It has been found in water temperatures of 15-28°C and pH values of 5.5-7.8.

Family Mugilidae (Mullets)
Mugil cephalus (Sea Mullet)
Site 2: 4 specimens: size range 19-28mm standard length
Sea mullet occur worldwide in tropical and temperate seas. It occurs along the entire Australian mainland coastline and northern Tasmania. It is primarily a coastal marine fish but frequently enters the lower reaches of large rivers. Large schools migrate along ocean beaches, leaving the estuaries to spawn offshore. Small schools of

juveniles enter rivers, as do adults occasionally. The species can survive for more than one year in freshwater. It is an important commercial species.

Family Gobiidae (Gobies)
Pseudogobius sp. (Blue spot goby)
Site 1a: 47 specimens: size range 9-22mm standard length
Site 1b: 31 specimens: size range 13-19mm standard length
Site 2: 58 specimens: size range 12-28mm standard length
Site 5: 28 specimens: size range 16-28mm standard length
Site 6: 39 specimens: size range 13-37mm standard length
Although this species is undescribed it is not uncommon. It is distributed from Bundaberg (southern Qld) southwards to the Victoria/SA border and is also in northern Tasmania. It occurs in coastal estuaries, coastal lagoons and swamps near the sea and usually inhabits aquatic vegetation over sand or mud.

Family Eleotrididae (Gudgeons)
Philypnodon grandiceps (Flathead gudgeon)
Site 1b: 2 specimens: size range 22-33mm standard length
Site 2: 3 specimens: size range 17-48mm standard length
Site 5: 11 specimens: size range 21-40mm standard length
Site 6: 8 specimens: size range 18-31mm standard length
The flathead gudgeon is widespread and common in the Southeast Coast Drainage Division between the Burdekin R. (Qld) and the Murray River mouth (SA), extending inland throughout the Murray Darling system. It is also found at Kangaroo Island (SA) and occasionally on Tasmania's northern coast. Adults feed on small fishes, crustaceans, insects and tadpoles. It attains a maximum size of 12cm and commonly occurs to 8cm.

Philypnodon sp. (Dwarf flathead gudgeon)
Site 1b: 5 specimens: size range 14-23mm standard length
Site 2: 4 specimens: size range 20-30mm standard length
Site 5: 24 specimens: size range 14-27mm standard length
Site 6: 6 specimens: size range 17-22mm standard length
This species is undescribed, but has been known to scientists for many years. It occurs in coastal streams of southern Qld, NSW, Victoria and SA. It is found in brackish waters in estuaries to altitudes of a few hundred metres and is common in coastal northern areas of its range. It prefers relatively calm waters and lives over mud, rocks, woody debris or in weedy areas. This species is carnivorous, feeding on a wide variety of insects, larvae and micro-crustaceans. It attains a maximum size of about 5cm and commonly occurs to 3.5-4 cm.

PHYLUM MOLLUSCA

Family Amphibolidae
site 1a: 14 specimens collected by fine mesh seine
site 6: 3 specimens collected by fine mesh seine
Salinator fragilis is a small snail (maximum size of about 1cm)
Salinator fragilis is a small snail restricted to estuaries and coastal lagoons. It has a thin, fragile shell with a narrow band around the edge and is an air-breather. It is often abundant on sand and mudflats and occurs in all Australian states (Ponder et al. 2000).

<u>Family Hydrobiidae</u>
site 1b: 1 specimen collected by fine mesh seine
site 2: 1 specimen collected by fine mesh seine
site 6: 16 specimens collected by fine mesh seine
Tatea rufilabrus is a small gastropod shell (maximum size about 5mm) that is restricted to estuaries and coastal lagoons, being found in association with algae and other plants, in leaf litter, under logs and rocks. It has a tall spire with many whorls. It is distributed from southern Qld to southern WA and Tasmania (Ponder et al. 2000).

6 Conclusions

Myall Quays Lake is now six years old and changes to the water quality parameters, ecological communities and habitats have occurred as it has matured.

6.1 Water Quality

Water quality parameters have been sampled from five sites within the lake since 1996. As previously, the lack of replication at each sampling site makes it difficult to assess variability at each site or vertical stratification of the lake environment. Vertical stratification, especially saline or dissolved oxygen levels, can significantly affect the composition and distribution of the biological assemblages.

The salinity levels of the lake are similar to those collected during the baseline survey and are typical of an estuarine environment. The salinity levels fluctuate more widely than previously and the lake experiences periods of almost freshwater conditions. The lake is influenced by runoff, groundwater, stormwater, saline river water inputs and vertical stratification of salt and freshwater after heavy rainfall. It would appear from the data analyses that rainfall levels have a greater influence on levels of salinity in the lake than tidal influences. It is unknown wether the low levels of salinity during certain sampling events are a result of flushing by rainfall events or increased stratification of the water column. The fluctuations in saline concentrations of the lake would effect the ecological assemblages of the lake by making the environment favourable only to species adapted to survive in highly variable saline conditions.

The nutrient samples collected could not be compared to the baseline survey or the ANZECC Guidelines due to the omission of certain components necessary for comparisons. Nitrogen levels deceased during 2000 but started increasing towards 2002. Generally it is known that nitrogen is the nutrient that limits plant growth in marine environments and sometimes in estuarine environments where salinity is low or variable.

Dissolved oxygen levels in the lake are considered depressed when compared with the baseline survey and the recommended Guidelines for estuarine environments. During the baseline survey dissolved oxygen levels were within the recommended guidelines but levels collected during subsequent sampling events were below the recommended levels and generally the dissolved oxygen levels have decreased over time. Dissolved oxygen concentrations measured in the lake reflect the equilibrium between the oxygen consuming processes (respiration) and oxygen-releasing process (eg. photosynthesis). The dissolved oxygen levels sampled indicate that there is a disturbance to these processes. Dissolved oxygen levels are highly dependent on temperature, salinity, biological activity and rate of transfer with the atmosphere. It is common in highly productive systems such as estuaries to have periods of oxygen depletion particularly where stratification occurs. Dissolved oxygen levels are highly influenced by diurnal variety particularly where significant levels of nutrient enrichment occurs. Low levels of dissolved oxygen have the potential to adversely effect fishes. While DO levels are depressed on average in the lake, this could be caused by a variety of reasons such as nutrient enrichment of the lake, stratification, atmospheric absorption and diurnal variation relating to sampling timing. Generally average DO levels are below those recommended in the ANZECC guidelines.

The pH levels in the lake on average fell within the recommended guidelines for marine and aquatic assemblages.

Levels of faecal coliforms present in the lake were above the recommended guidelines for recreation and primary contact on a number of occasions during water quality sampling. A number of reasons for the high levels of coliforms present in the lake were suggested by NSW Health including; rainfall events, septic tank seepage into the environment, stormwater input and urban runoff. Rainfall did appear to influence the average levels of coliforms present in samples. Levels were highest at site 2 near the office while site 1 near the stormwater drain did not experience levels as consistently high. So conclusions as to the exact entry of coliforms into the lake could not be established.

NSW Health indicated that levels such as those recorded are not unusual and are common following rainfall events. It is recommended that following rainfall events primary contact with lake water is avoided for 48 hours. (pers comm NSW Health). The commonly high levels of coliforms in the lake have the potential to increase nutrient levels in the water column and result in blooms of nuisance algae species.

6.2 Seagrasses and Macroalgae

Four species of aquatic plants (excluding riparian plants) were present in the lake during this survey, the seagrass *Ruppia polycarpa* and three macroalagae; *Lamprothamnion papulosum*, *Chara spp* and *Ulvaria oxysperm*. The baseline survey identified seven aquatic species (excluding riparian plants) present including *R. polycarpa and L. papulosum*. The number and type of species present and their distribution and densities have changed since the baseline survey. The seagrass *R. polycarpa* is the dominant plant throughout the lake forming continuos beds across the lake. The previously dominant *L. papulosum* has become restricted to sparse beds in the western end of the lake and has been replaced by the similar charophyte, *Chara spp* in the middle and eastern end of the lake. During the baseline survey the beds were restricted to the shallows along the shoreline but now plants are present throughout much of the lake only narrowing to the lake edges in the eastern end.

The increased colonisation of *R. polycarpa* may be related to the salinty fluctuations experienced within the lake. This seagrass is adapted to wide ranges in freshwater and saline conditions enabling it to thrive in variable saline conditions.

The Charophytes, *L. papulosum* and *Chara spp* prefer nutrient poor, calcium rich environments and are highly sensitive to nutrient enrichment. While *Nitella subtilissima* is no longer present in the lake *Chara spp* appears to be flourishing. Charophytes are now present throughout the lake and their increased colonisation may be the best indication that faecal coliforms influxes have not significantly increased nutrient levels in the lake. Likewise, no blooms of nuisance macroalgae species such as *Cladophora sp* have occurred that would indicate nutrient enrichment, rather this species is no longer present in the lake.

6.3 Fishes and Invertebrates

Seven species representing 6 families were recorded from the lake as compared to nine species during the baseline study. A total of 304 fishes were collected compared to 839 during the baseline study. This difference could be partly related to the use of slightly differing sampling techniques or differing abundances of fish species in different seasons (the baseline survey was completed in January and this survey was undertaken in September). As was outlined in the baseline survey, the lake is still young and changes in the faunal composition of the lake are not surprising. The physical (eg habitat) and chemical (eg salinity, pH) variables controlling fish occurrences and abundances appear to be still changing in the lake.

Two species collected in the most recent survey that were not collected in the baseline survey were the flathead gudgeon *Philypnodon grandiceps* and the saline tolerant common jollytail *Galaxias maculatus*. Three species of goby and the common silver belly were collected during the baseline survey but were not collected during the most recent survey. The wide range of salinities recorded in the lake would favour estuarine species that can tolerate such changing conditions. It is expected that if fish sampling were undertaken on a more regular basis, more species would be recorded than have been on the previous two occasions. It is likely that some fishes are not permanent residents of the lake and only enter it when conditions are favourable to their needs.

The Myall Quays Estate Lake appears to be supporting a small number of resident fishes that are probably present year round and breed within the lake. These fishes include the flathead gudgeon, dwarf flathead gudgeon, blue-spot goby and southern blue-eye. Sea mullet may only be present in considerable numbers at specific times of the year and probably migrate out of the lake to spawn at sea.

6.4 Summary

The ecosystem within the lake is now six years old and the water quality and ecological communities within it have changed in composition, abundance and distribution over time. The species present in the lake are adapted to a changing physical environment, with fluctuations in salinity, nutrients and dissolved oxygen occurring as a complex result of freshwater influxes (rainfall and stormwater), tidal flows and other causes.

The physical characteristics of the lake appear to have changed since the baseline survey. The lake appears to be less effected by tidal influence and increasingly by rainfall events. While salinity levels within the lake have remained similar in general to the baseline survey, the lake experiences extreme fluctuations in concentrations following rainfall events. At times the lake experiences conditions of almost freshwater ranges. This will effect the species able to live in the lake. pH levels fall within the recommended ANZECC Guidelines, however the dissolved oxygen levels appear to be becoming depressed over time. On average levels of faecal coliforms within the lake have been within the guidelines, however on a number of occasions during sampling events total levels have been above those recommended for primary contact.

During the study seven species of fish were collected. The lake appears to be supporting a small number of resident fishes that are probably present year round and breed within the lake. These fishes include the flathead gudgeon, dwarf flathead gudgeon, blue-spot goby and southern blue-eye.

The aquatic flora of the lake is maturing and has become more widespread throughout the lake. Four species of aquatic plants (excluding riparian plants) were present in the lake during this survey, the dominant seagrass *Ruppia polycarpa* and three macroalagae; *Lamprothamnion papulosum*, *Chara spp* and *Ulvaria oxysperm*.

7 Recommendations

AMBS suggest that water quality sampling of the lake continue and that future samples be replicated within the sites to allow more stringent statistical analysis. The sampling should include orthophosphate and kjeldahl nitrogen so that nutrient levels can be compared to the ANZECC guidelines. The monitoring of nutrient levels could prove important in the future to monitor the effects of runoff of faecal coliforms into the lake.

Based on the ANZECC guidelines for recreational water quality on a number of occasions in the last few years the faecal coliform levels in the lake were above the recommended levels for primary contact (swimming). These guidelines direct that a minimum of five samples are taken at regular intervals not exceeding a month and four out the five samples must contain less than 600 organisms/100mL. AMBS suggest that Crighton Properties regularly monitoring the lake for faecal coliforms following rainfall events following the sampling frequency above.

AMBS suggest that monitoring of the ecological assemblages of the lake continue to be carried every few years. Assessments of fish habitat in the lake and inflowing waters may help to provide information on the suitability of any necessary habitat changes.

Further fish surveys at more regular intervals would confirm or deny whether the above mentioned fishes are permanent residents. As the lake currently only has a small number of habitats (i.e. mainly sand, mud, algae), the introduction of new habitat such as growing mangroves at the seaward end may encourage more fishes into the lake. There is currently little protection for larger fishes (ie over 10cm) within the lake from bird predation. The introduction of additional native aquatic vegetation (eg. mangroves) or artificial habitat (eg woody debris or artificial structures) may encourage the growth and survival of fishes by providing shelter and food.

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Appendix A Site Locations

Appendix B Site Photograph

Appendix C Maps of Aquatic Vegetation

Appendix 3.

Appendix 3.

HARRIS RESEARCH Pty Ltd

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Freshwater ecology and fisheries

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10 August 2002

ECOLOGICAL PRINCIPLES AND DEVELOPMENT OPTIONS FOR THE MYALL QUAYS WATERWAY

Background

The success of the Myall Quays development will be judged by the natural values that it supports and these values can be optimised by integrating environmental, social and commercial principles. Planning for the development should be based on an understanding of the principles that govern the ecology of comparable brackish lagoon systems, as well as the engineering, town planning and other considerations. The following notes aim to outline the aquatic ecological principles that should be considered and planning options that may be available. They are underpinned by the assumption that water is the key resource to be managed for best usage, rather than a waste product of development or a problem to be dealt with. Key objectives include biological diversity, fisheries-based recreational opportunities and environmental amenity for residents.

The tidal and saline regimes will drive ecology

The most basic planning issue for the aquatic system relates to the levels of salinity and tidal flushing, and their variations. Clearly, these attributes will be dynamic and result from the interaction of freshwater runoff, groundwater and incursions from the Myall River estuary via the small connecting drains from the lake.

The tidal and saline regimes will drive the waterway's ecology, determining the types of plants and animals that can be supported, and their patterns of diversity and abundance. If it were possible to create full tidal ventilation, the system would come to mimic that seen in the adjacent estuary. At the other extreme, if tidal incursion were prevented, a freshwater system similar to the existing runoff detention ponds would result. For several reasons, a saline regime intermediate between these two extremes seems desirable. Other regional brackish systems such as Smiths Lake or the Mall Lakes provide potential models. It is important to recognise that, in practice, the saline regime will vary substantially as the various controlling inputs change with the weather and tides. Reflecting this variation, the waterway's ecology will also be dynamic, with only a limited range of plant and animal species able to cope with these fluctuating conditions.

Towards the saline end of the water-quality spectrum, those fish that are 'euryhaline' – meaning they can tolerate changing salinities - will dominate the wetlands fish community. Typically they might include two or three mullet species, estuarine herring, two eels, bream, silver biddies, blue-eyes, gobies and perhaps flathead and a few other infrequent species. Alternatively, a predominantly freshwater system would occasionally support some of these species plus two or three gudgeons, smelt, eels and Australian bass. The level and stability of the saline regime would similarly determine the composition of aquatic vegetation and the invertebrate fauna.

A desirable management objective would be to represent a variety of aquatic systems. This could be achieved by maintaining tidal, saline conditions in the lagoon while promoting a freshwater 'riverine' regime in the in-flowing tributary sections. Such a combination would enhance biological diversity, visual amenity and recreational opportunities for Myall Quays residents.

Options for managing saline and tidal regimes

Each of the key inputs – runoff, groundwater and tidal incursion – are more or less amenable to planned manipulation to achieve an optimal outcome. Runoff can potentially be detained or diverted to some degree, groundwater could (in theory at least) be raised or lowered, and tidal incursion through the drains can be restricted or enhanced. These possibilities suggest some useful management and design options.

1. Tidal control

It appears highly desirable to install facilities to control the extent of tidal incursion through the lagoon's drains. This would allow the lagoon's water levels and water quality to be manipulated. If it were appropriate, salinity could be regulated closer to that of the adjacent Myall River. Potential problems such as nuisance blooms of algae or low dissolved oxygen could be managed directly by tidal flushing should they occur.

A simple 'drop-log' control structure would be needed to control tidal incursion. These are simple concrete 'U'-shaped structures, slotted to carry timber or concrete drop-logs, and sized to conform to the drain. Manually adding or removing drop-logs can either increase or reduce the amount of tidal incursion. The maximum height needed would be the median high-tide level, so that visual impact would be slight. It might be desirable to control both the main drains from the lagoon.

To optimise control over water quality, it would be desirable to deepen the drains slightly so that greater tidal flow can be available if needed. Deepening by 300mm – 400mm would probably be sufficient.

2. Limiting upstream salinity

To produce stable freshwater conditions in the tributary riverine reaches of the waterway it will be necessary both to design appropriately sized channels and also to control saline inputs to these upstream areas. The number and surface area of these riverine areas may need to be modelled in order to balance them against the frequency and volume of runoff events and to maintain water quality by continued through-flow. But it seems clear that only a small number (one, two or three) should be created, perhaps with a long, sinuous path to enhance their individual area. A uniform, low gradient is needed to ensure outflow, and this could resemble the upper Myall River reaches above Bulahdelah.

In the diverse, freshwater/brackish waterway system suggested, salt intrusion into the riverine areas from the lagoon would need to be prevented. This would arise from gravity-driven saline stratification in the lagoon, and could be prevented by creating a shallow sill at the junction of each riverine tributary with the lagoon. A narrow rocky sill across the stream, perhaps built with rip-rap material over a clay core, should limit depth to about 300mm at this point. This would prevent deep saline layers from intruding upstream and help maintain freshwater conditions. Similar sills might also be desirable upstream to retain stable freshwater pools.

Aquatic habitats should be optimised

The diversity of aquatic habitats will determine the biological diversity that can be supported by the waterway. Similarly, the quantity of habitat will control the abundance, diversity and resilience of biological populations. Of course, both these quantity and quality relationships depend on the assumption that water quality will be maintained at suitable levels of dissolved oxygen, pH, nutrients, toxicants and salinity and these conditions should be encouraged by enhancing tidal flushing of the lagoon. Continuing effective operation of the small runoff-treatment ponds is also clearly important.

In the suggested freshwater/brackish system, habitat quality can be predicted from several key attributes: depth, physical structure (including macrophyte growth), the nature of substrates, and the extent of the littoral zone (i.e. the near-shore areas where the land and water meet). Flow velocity is unlikely to be a significant factor except in and adjacent to the drains or during extreme-runoff periods. Creating diversity should be a guiding principle in planning the design of the key attributes.

Options for enhancing the amount and quality of habitat

Depth profiles should be varied as much as practicable while bearing in mind the need to ensure adequate flows and mixing. The littoral zone is a critical area for food-web production, mainly based on the growth of algae and macrophytes, so that extensive areas with low-gradient batters are valuable within the upper one metre of the water column.

Physical structure is a critical aspect of habitat and can be derived from several sources. Submerged logs and mounds of rockwork would both provide valuable structure, especially when distributed in the upper two metres of the water column. Within practical limits, the more structure, the better.

Beds of macrophytes and algae can also contribute greatly as structural habitat and food-web source areas. Their growth will be determined by the stability of water quality and other factors. In creating the waterway it would be important to introduce desirable aquatic plants early in the process to pre-empt weed growth. Desirable plants in the brackish zone could include Ruppia and Zostera, with Phragmites and Vallisneria in freshwater areas. Emergent littoral rushes and reeds should also be experimentally planted. It could be productive to engage a botanical consultant to provide detailed advice on these aspects.

Options to incorporate diverse substrates seem limited, given the sandy character of the area, other than for the rockwork mounds suggested earlier. But this aspect deserves consideration in any underwater structural works such as culverts. Rip-rap and other rock-based construction methods will contribute far more habitat value than formed concrete.

The size of the littoral zone can be increased in the lagoon by creating a complex, strongly curved shoreline, with many small bays and inlets. A sinuous stream path would have the same effect in the riverine section. These simple options can produce substantial habitat benefits and will also enhance visual amenity.

Fringing terrestrial native plants, including trees, shrubs, rushes and grasses, contribute to food resources for many fish. They also reduce temperature fluctuations, control excessive wind effects and contribute greatly to amenity. Landscaping options should be investigated, using local native plant communities as a guide.

The network of small runoff-treatment ponds also has potential habitat value. Enabling fish passage over their small control weirs could activate this. A suitable device would be a small-scale rock-ramp fishway on a slope of 1:20.

Recruitment processes control fish populations

Recruitment involves the addition of new individuals to the populations. These counteract population losses from emigration and mortality. Three sources of recruitment are possible in the Myall Quays development.

1. Immigration from the Myall River

Estuarine fish species will enter and leave the waterway via the drains. Fish of many species will enter as juveniles, grow for a period in the lagoon, and then emigrate, often to spawn elsewhere. Mullets, bream, eels and herring are examples.

2. Local spawning

Some species, especially the smaller ones like gobies, smelt and gudgeons, are likely to spawn and recruit within the waterway. The extent of this local recruitment will depend on availability of suitable habitat, especially plant beds and rocky substrates, together with an appropriate water quality.

3. Fish stocking

Some success has already been reported with the stocking of hatchery-propagated Australian bass, and this is a way of maintaining numbers of this popular species. Wild bass may colonise the waterway naturally, but local populations are in severe decline and it would be useful to boost numbers artificially. Bass will tend to move towards the freshwater habitats.

Options for enhancing recruitment

An extra benefit from deepening the drains as suggested earlier would be the enhancement of fish recruitment from the Myall estuary. Increasing depth and flow through the drains should result in significantly greater fish immigration.

The various options suggested for enhancing habitat attributes could all be expected to aid local recruitment of fish through increased spawning and nursery areas, as well as a stronger, more diverse food web.

The bass-stocking option is worthwhile. Hatcheries should be asked to provide juvenile fish bred from local broodstock. It may be best to stock small numbers annually.

Continuing growth of knowledge is critical

The ecology of aquatic systems such as the Myall Quays waterway is dynamic and it is not possible to predict the composition of biological communities with certainty. Furthermore, such communities undergo substantial fluctuations driven by weather, conditions in the estuary and other poorly predictable influences. And, in addition, it must be expected that an artificially created waterway will go through a long process of ecological development, with large trends in its physical, water-quality and biological attributes over a period of years or decades.

Options to improve knowledge

To manage such a dynamic system effectively and minimise the various inherent risks, it is essential that knowledge of the system should be as comprehensive and thorough as possible. This shows the need to utilise existing knowledge about comparable systems, such as that gathered at the University of New South Wales' Smiths Lake field station.

It is also necessary to have effective ongoing monitoring to understand how the hydrological, water-quality, physical and biological components of the system are responding through time. Various consultancy reports already achieve some of these objectives. It seems desirable to complement this process through an association with a suitable university, and an ongoing series of student scholarships would be an effective means of achieving this at relatively low cost. It should be stressed that the value of such knowledge would increase exponentially through time, regular observations over a long period are far more valuable for most of the important topics. A sequence of student projects on the waterway's biology, hydrology, water quality and ecological processes would be an extremely useful tool for management.

Appendix 4.

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MEMORANDUM

3 May 2007

John Harris [John.h.harris@bigpond.com]

Peter Childs [peter@crighton.com.au]

To: Dr John Harris, Peter Childs

From: Dr Peggy O'Donnell

Re: Results of Fish Survey, Myall Quay Lakes

John and Peter,

Sampling in Myall Quay Lake was completed as requested on 26 and 27 April, 2007.

Methodology used was as described in our proposal of 24 April 2007, and subsequent conversation with John Harris regarding recording information on the relative abundance of aquatic macrophytes. Data are attached as an Excel file with 3 worksheets, and a pdf file containing site photographs. Additional sampling details are provided below:

Seine netting

Seine netting was conducted along the shoreline at 8 locations. GPS coordinates for sampling locations at given in Table 1 (Excel spreadsheet attached). The seine used measured 25 m long x 2 m deep, with a mesh size of 5mm. The net was run out from the shore in a U-shape using a boat and then hauled up on to the bank. Fish were collected in the cod end and placed in a tub with water, in order to minimise handling and stress. Identification, measurements and enumeration were done and all native fish were then released. Those species not readily recognisable were preserved in formalin and returned to the laboratory for identification checks.

Gill netting

This technique was used to capture fish in deeper areas of the water body. Nets were made of a rectangular panel measuring 30m (50mm mesh x 0.25mm diameter) x 1.8m deep. Four gill nets were deployed along the middle of the lake with GPS points taken at the start and end of each panel. GPS coordinates for sampling locations at given in Table 2 (Excel spreadsheet attached). Gill nets were placed either perpendicular or horizontal to the shore. Deployment times were 90 minutes, with times deployed listed in Table 2. Captured fish were identified to species, measured and released. Those fish species not readily identifiable in the field were preserved in 10% formalin and checked in the laboratory.

Macrophytes

Aquatic plants and algae were identified using a visual assessment of percentage cover based on King and Barclay (1986):

1 – present - low density (< 15% cover),

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

3 – abundant - high density (> 50% cover).

Macrophytes present in the sampling area along the bank were inspected and ranked using this classification. Algae and seagrass were inspected along the shoreline, and were also categorised based on species and amounts collected in the seine and gill nets. The seagrass *Ruppia* spp. was recorded at only one of the sampling sites.

Additional Information

Photos of several of the sampling sites were taken, including macrophytes. These are found in the attached pdf file. Note that photographs of algae and seagrass were limited due to poor instream visibility.

I would be happy to provide any further detail you may require.

Regards,

Peggy O'Donnell

Dr Peggy O'Donnell

Senior Environmental Scientist, Manager

Table 1 - Field sampling locations and time of each seine net shot. Datum: WGS84 - Zone 56H.

Sample	Easting	Northing	Date	Time
SEINE 1	420583	6155610	26/04/2007	13:15
SEINE 2	420571	6386708	26/04/2007	13:45
SEINE 3	420978	6386366	26/04/2007	14:50
SEINE 4	421001	6386403	26/04/2007	15:15
SEINE 5	420599	6386606	27/04/2007	8:40
SEINE 6	420793	6386419	27/04/2007	9:10
SEINE 7	420969	6386597	27/04/2007	9:40
SEINE 8	420678	6386536	27/04/2007	10:15

Table 2 - Field sampling locations, depths and time for the start and end of each gill net set. Datum: WGS84 - Zone 56H.

	Start					End			
Sample	Date	Time	Easting	Northing	Depth (m)	Time	Easting	Northing	Depth (m)
GILL 1	26/04/2007	12:55	420973	6386428	3.4	14:25	420970	6386399	3.3
GILL 2	26/04/2007	13:05	420829	6386389	3.5	14:35	420814	6386373	3.4
GILL 3	27/04/2007	8:15	420586	6386780	2.1	9:45	420563	6386763	3
GILL 4	27/04/2007	8:18	420642	6386597	3.1	9:48	420629	6386572	3.5

Data entered by:HLS 30/04/2007
Data checked by:HLS & MP 02/05/2007
Data corrections entered by:MP 02/05/2007

Myall Quays Lake Fish Study 2007

Table 3 - Survey data for seine and gill net fish samples. Caudal fin legth was measured for up to 10 individuals of larger species. # denotes an exotic species.

			Seine shot 1		Seine shot 2		Seine shot 3		Seine shot 4		Seine shot 5		Seine shot 6		Seine shot 7		Seine sh
Family Name	**Species Name**	**Common Name**	**Caudal Fin Lengths (mm)**	**No. Individuals**	**Caudal Fin Lengths (mm)**	**No. Individuals**	**Caudal Fin Lengths (mm)**	**No. Individuals**	**Caudal Fin Lengths (mm)**	**No. Individuals**	**Caudal Fin Lengths (mm)**	**No. Individuals**	**Caudal Fin Lengths (mm)**	**No. Individuals**	**Caudal Fin Lengths (mm)**	**No. Individuals**	**Caudal Fin Lengths (mm)**
FISH																	
Poeciliidae	*Gambusia holbrooki*	Mosquito fish#								3				1			
Psuedomugilidae	*Psuedomugil signifer*	Pacific blue-eye								9				2			
Mugilidae	*Mugil cephalus*	Sea mullet		40	1				115	1	65, 80, 80, 75, 60, 70, 50, 65, 70, 70	65	125, 155, 80, 50, 50, 70, 50, 45, 45.	9			50, 50, 50, 60, 50, 40, 60, 45, 50, 80
Mugilidae	*Myxus elongatus*	Sand mullet															
Sparidae	*Acanthopagrus australis*	Yellow-finned Bream	329	1	130	1							150	1			
Gerreidae	*Gerres subfasciatus*	Silver Biddy	105, 110, 140, 130, 155, 120, 135, 110.	8	165, 138, 125, 125, 85, 110.	6	130	1	170	1	125, 140.	2	130, 120, 120.	3	145	1	
Gobiidae	*Philypnodon grandiceps/* sp.	Flathead gudgeon/Dwarf flathead gudgeon		90		83		3		78		95		130		18	
Gobiidae	*Psueudogobius sp.*	Blue spot goby		1										8		1	
Gobiidae	*Afurcagobius tamarensis*	Tamar River goby				10		4				1				2	
Gobiidae	*Amoya bifrenatus*	Bridled goby												2			
Gobiidae	*Favonigobius exquisitus*	Exquisite sand goby		6		3		17		1		4		7		1	
MACROINVERTEBRATES																	
Palaemonidae		Estuary Shrimp						2				2		11			
Gastropoda	Unidentified species																
Notes			2 large mullet observed jumped out of net.														

Data entered by:HLS
Date data entered:30/04/2007
Data checked by:HLS & MP
Date data checked:02/05/2007
Data corrections entered by:MP
Date corrections entered:02/05/2007

Myall Quays Lake Fish Study 2007

Table 3 - Survey data for seine and gill net fish samples. Caudal fin legth was measured for up to 10 individu

			ot 8	Gill Net rep 1		Gill Net rep 2		Gill Net rep 3		Gill Net rep 4	
Family Name	**Species Name**	**Common Name**	**No. Individuals**	**Caudal Fin Lengths (mm)**	**No. Individuals**	**Caudal Fin Lengths (mm)**	**No. Individuals**	**Caudal Fin Lengths (mm)**	**No. Individuals**	**Caudal Fin Lengths (mm)**	**No. Individuals**
FISH											
Poeciliidae	*Gambusia holbrooki*	Mosquito fish#									
Psuedomugilidae	*Psuedomugil signifer*	Pacific blue-eye	20								
Mugilidae	*Mugil cephalus*	Sea mullet	22			420	1				
Mugilidae	*Myxus elongatus*	Sand mullet		290	1	290	1				
Sparidae	*Acanthopagrus australis*	Yellow-finned Bream									
Gerreidae	*Gerres subfasciatus*	Silver Biddy									
Gobiidae	*Philypnodon grandiceps*/ sp.	Flathead gudgeon/Dwarf flathead gudgeon	112								
Gobiidae	*Psueudogobius sp.*	Blue spot goby	1								
Gobiidae	*Afurcagobius tamarensis*	Tamar River goby									
Gobiidae	*Amoya bifrenatus*	Bridled goby									
Gobiidae	*Favonigobius exquisitus*	Exquisite sand goby	4								
MACROINVERTEBRATES											
Palaemonidae		Estuary Shrimp	1								
Gastropoda	Unidentified species		1								
Notes								No fish found		No fish found	
Data entered by:HLS											
Date data entered:30/04/2007											
Data checked by:HLS & MP											
Date data checked:02/05/2007											
Data corrections entered by:MP											
Date corrections entered:02/05/2007											

Table 4 - Relative abundance of macrophytes recorded at each sampling site in Myall Quays Lake. 1 = Present; 2 = Common; 3 = Abundant. Blank cells indicate absence from sampling site. Growth forms: 1 = Floating attached; 2 = Submerged; 3 = Emergent.

Type	Scientific name	Common name	Growth Form	Seine shot 1	Seine shot 2	Seine shot 3	Seine shot 4	Seine shot 5	Seine shot 6	Seine shot 7	Seine shot 8	Gill net rep 1	Gill net rep 2	Gill net rep 3	Gill net rep 4
Algae															
Chlorophyta (Green Algae)															
	Cladophora sp., *Spirogyra* sp., *Rhizoclonium* sp.		2		3		1	2	2	1	3				
Cyanobacteria/Rhodophyta															
	Unid. filamentous Blue-Green/Red algae														1
Seagrass															
	Zostera capricorni	Eel grass	2	1		1	2			1	1				
	Ruppia polycarpa	Sea tassel	2								2				
Saltmarsh															
	Sarcocornia quinqueflora		2							2					
Macrophyte															
	Juncus sp.	Common rush	3	2	3	3	2	3	3	1					
	Triglochin striata	Streaked arrow-grass	3						1		1				
	Ceratophyllum demersum	Hornwort	2	1			2								
	Phragmites australis	Common reed					1								
Bed description				Mostly bare muddy sands	bare sands with silt/muds	Mostly bare sand with silt detritus			Sand and mud with fine detritus	Muddy sands					Black algae sample taken

Data entered by:HLS 30/04/2007
Data checked by:HLS & MP 02/05/2007
Data corrections entered by:MP 02/05/2007

Plate 1. Upper: tidal inlet.

Plate 1. Lower: looking North with tidal inlet near right.

Plate 2. Upper: sand mullet from seine net shot 4.

Plate 2. Lower: Seine net shot at site 5. Photo looking North, away from tidal inlet.

Plate 3. Upper: seine net shot Site 7 including *Juncus* sp. and *Sarcocornia quinqueflora.*

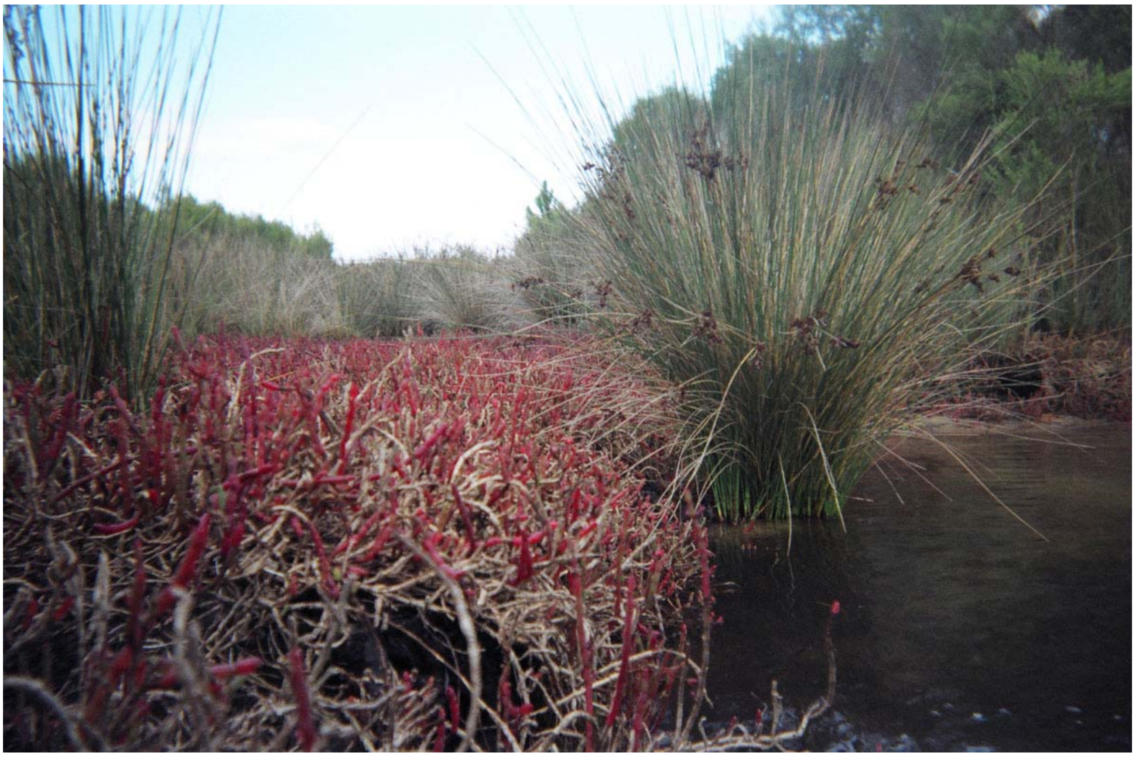

Plate 3. Lower: *Sarcocornia quinqueflora* at seine Site 8.

Plate 4. Upper: Medium density *Juncus* sp. on embankment located at seine net shot 1.

Plate 4. Lower: High density *Juncus* sp. instream and on embankment at seine net shot 6.

Plate 5. Upper: Setting gill net from boat.

Plate 5. Lower: Seine net shot 8 site looking towards tidal inlet. *Ruppia* spp. growing on shallow sand sandbars around the enclosures.

Appendix 5.

Map of sampling sites in Myall Quays Lake, 26 and 27 April 2007. S = Seine shot, G = gill net set.