

RESEARCH ARTICLE

Analysis of macrobenthic assemblages of lake Illawarra, New South Wales, Australia

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Abstract

- 1 - A survey of the macrobenthos community was carried out in Lake Illawarra, NSW, Australia, during April and May 2011.
- 2 - The aim of this study was to understand the current status of the characteristic macrobenthic fauna community, and the temporal changes over the past 30 years, as well as the impacts of anthropogenic activities on the benthic ecosystem.
- 3 - Fifteen stations were selected as representative of three main areas of the lake (the entrance channel, the central basin and the sublittoral fringe), which might be impacted by different kinds of human activities.
- 4 - A total of 45 macrobenthic species were identified. Mollusca represented the most abundant taxon with 17 species, followed by Crustacea with 16 species. Three species were dominant, i.e., the mollusk *Nassarius burchardi*, and the polychaeta *Lumbrineris* sp. and *Nephtys australiensis*.
- 5 - The abundance and biomass of the macrobenthos were variable between the three main areas. Based on Bray Curtis similarity of macrobenthos, the 15 sites also divided largely into three groups.
- 6 - M-AMBI index analysis indicated that eight stations (57.1%) had 'good' to 'high' ecological status (EcoQ), four stations (28.6%) 'moderate' EcoQ, and two stations (14.3%) with 'poor' to 'bad' EcoQ, which indicates the Lake Illawarra was in reasonably good condition, but evidence of disturbance and impact on benthic communities was obvious at several sites.

Keywords: macrobenthos; biodiversity; Lake Illawarra; ecological status; anthropogenic activity

Introduction

Lake Illawarra (LI) is a shallow coastal lagoon located approximately 80 km south of Sydney, New South Wales, Australia (Fig.1), with a surface of about 35 km² and a maximum depth of 3.8 m. The average depth of the Lake is approximately 1.9 m and about 25% of the lake is typically less than 1.2 m depth (LIA, 1995). Lake Illawarra has been an important natural asset for the Illawarra region, and is a complex natural system, which plays an

important role in the life of the people living in the Wollongong-Shellharbour region (Morrison and West, 2004). Due to the rapidly increasing population and human activities around the lake, including construction of seawalls, bridges, and tourism amenities, increasing inputs of sewage and other waste, the environmental condition of the lake has declined, including algal blooms and accumulations of trace metals (Morrison and West, 2004).

Macrobenthos play important roles in ecosystem processes of nutrient cycling, pollutant metabolism, dispersion and burial, etc. (Snelgrove, 1998). As macrobenthic species are relatively sedentary, their species composition and abundance can be used as a biological indicator to reflect changes in the marine environment, such as, the deterioration of water and sediment conditions (Pearson and Rosenberg, 1978; Borja and Tunberg, 2011). Much research and survey work has been conducted in LI, including sediment (Sloss *et al.*, 2004a; Chenhall *et al.*, 2004), geomorphological changes (Sloss *et al.*, 2004b; Treloar *et al.*, 2004), benthic microalgae (Wilson, 2004), macroalgae (Rutten *et al.*, 2004), jellyfish (Pitt *et al.*, 2004), seagrass (West, 2004; Howley *et al.*, 2004), commercial fishing and biodiversity (Gray, 2004; Chafer and Brandis, 2004), water quality (O'Donnell *et al.*, 2004), nutrient (Qu *et al.*, 2004) and health (Morrison and West, 2004), but little study of the macrobenthic fauna in Lake Illawarra has been conducted apart from the work of Gibbs (1986). The aims of this study were to clarify the current status of the characteristic macrobenthic fauna community, to assess if the ecological status and benthic habitat had suffered from disturbance, and to examine any temporal change of species composition since the 1980s.

Materials and methods

Sampling stations

Fifteen stations were selected to study the macrobenthos in LI; these were representative of the three main zones of the lake. i.e., the central basin (stations 1 to 7), the entrance channel (stations 9 and 10) and the sublittoral fringe (stations 8, 11, 12, 13, 14, 15) (Figure 1).

Sampling methods and procedure

Three separate replicate sediment samples were collected by a 0.059 m² Van Veen grab

at stations 1 to 10 (with the water depth over 0.4 m) and by shovelling 0.16 m² samples at the sublittoral fringe stations 11 to 15 (with the water depth about 0.2 to 0.4 m); the sediments were then sieved through a mesh with 1.0 mm aperture to obtain the macrobenthic organisms.

The macrobenthic samples were preserved in 80% ethanol until laboratory identification to the lowest possible taxonomic level, then counted and weighted using a 0.01g precision electric balance to get the number and wet weight. Sediment samples were also collected to measure the particle size (measured on undried samples) using a Malvern mastersizer.

Statistical analysis

The Plymouth routines in multivariate ecological research (PRIMER 6.0) software and SPSS 15.0 were used for statistical analysis. The biological properties included the total biomass (B), abundance (A), number of species (S), Shannon-Wiener diversity index (H'), Margalef richness index (d), and the dominant index (Y).

The Azti Marine Biotic Index (AMBI) was calculated by means of AMBI 4.0 (www.azti.es), using the species-list of February 2010, on the basis of the AMBI guidelines (Borja and Muxika, 2005). Based upon Borja and Tunberg (2011), the threshold values for the M-AMBI are as follows: 'high' quality, >0.77; 'good', 0.53-0.77; 'moderate', 0.38-0.53; 'poor', 0.20-0.38; and 'bad', <0.20. Because the reference conditions are difficult to define in the LI, we adopted the method of Borja *et al.* (2008), e.g., the highest richness and diversity values found in all sites were used, and increased them by 10-15%. Further, according to the guidelines for the use of AMBI (Borja and Muxika, 2005), we removed all the non-benthic invertebrate taxa (fish and crabs), and the site with one number of taxa (station 10).

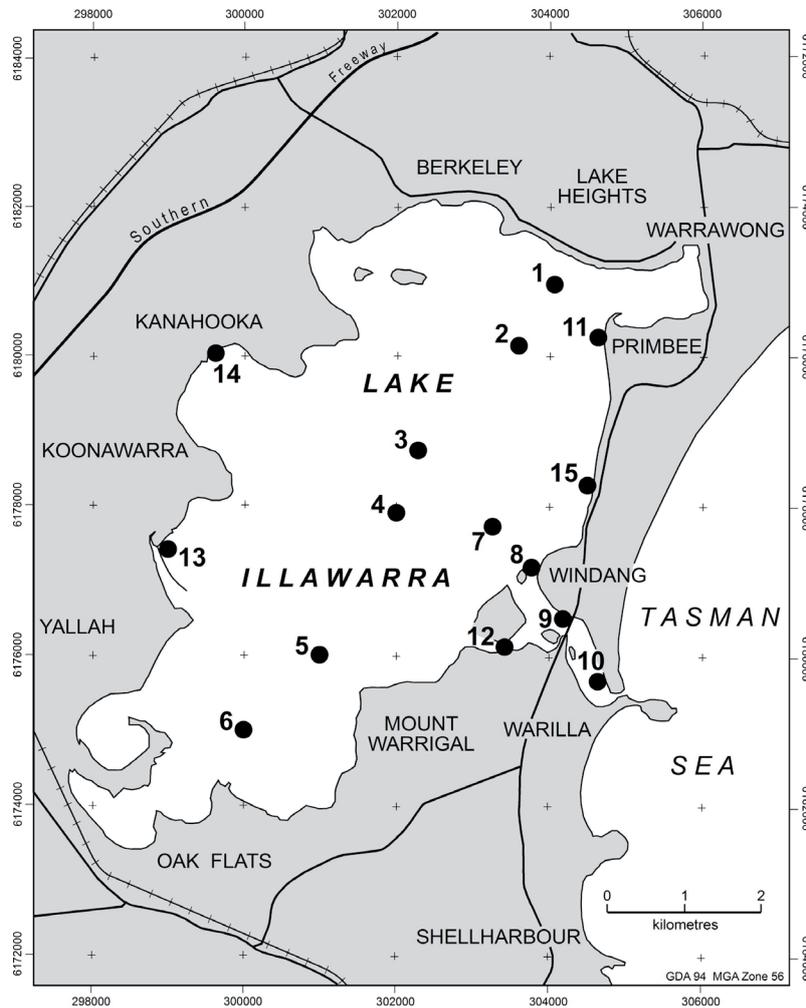


Figure 1. Study area and locations of sampling stations in Lake Illawarra.

Results

Analysis of sediment grain size

The sediment particle sizes are shown in Figure 2; stations 2, 3, 4, 5, 6 in the central basin had silt dominated sediment, while the other 10 stations in the entrance channel and the sublittoral fringe of LI had sand dominated sediment.

Species composition

In total, 45 species of macrobenthos were identified by this survey (see Appendix). Mollusca represented as the most abundant taxon with 17 species (38%), followed by

Polychaeta with 16 species (36%), Crustacea with 9 (20%), Pisces with 1 (2%) and other groups with 2 (4%). Of these, three species were found over 9 stations, and could be considered as the dominant species in the study area, i.e., mollusca *Nassarius burchardi* and polychaeta, *Lumbrineris* sp., *Nephtys australiensis*. The distributions of the macrobenthic species numbers at the 15 stations were variable (Figure 3); the highest value was found at station 8, and the lowest at station 10. The average species numbers in the three main zones were different, the sublittoral fringe with

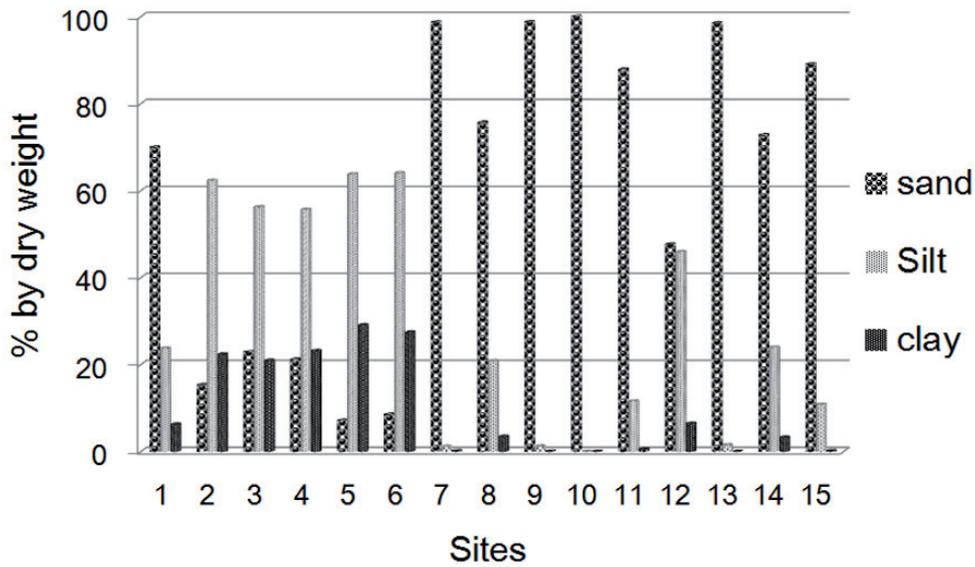


Figure 2. Sediment grain size of the 15 sampling sites.

8.5 ± 5.5 ind., central basin with 5.9 ± 2.5 ind. and the entrance channel with 3.5 ± 2.1 ind..

Biomass and abundance

The distribution patterns of macrobenthic biomass for the 15 stations were similar to those of the species numbers, with the largest value found in the sublittoral fringe (52.93 ± 56.60 g m⁻²), followed by the central basin (27.80 ± 45.27 g m⁻²), and the entrance channel area (1.30 ± 1.68 g m⁻²). The average biomass of macrobenthos at four areas was 34.32 ± 48.46 g m⁻² (Figure 4).

The abundances from the study zones were similar to those of the biomass, the sequence from large to small values being, the sublittoral fringe (304.61 ± 383.97 g m⁻²), followed by the central basin (127.78 ± 104.85 g m⁻²), and the entrance channel area (48.02 ± 51.93 g m⁻²) (Figure 5). The average abundance was 187.88 ± 260.76 g m⁻². The standard deviations both in abundance and biomass were high in three zones suggesting that the distribution pattern of macrobenthos is not continuous or uniform, more likely to be clustered or random

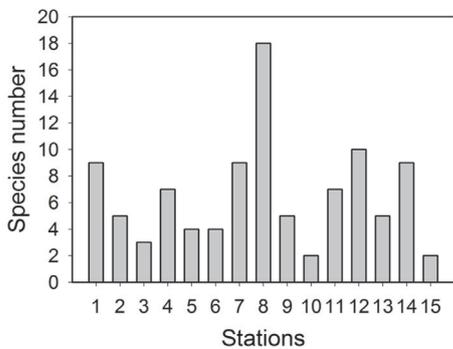


Figure 3. Distribution of the species number of macrobenthos in Lake Illawarra.

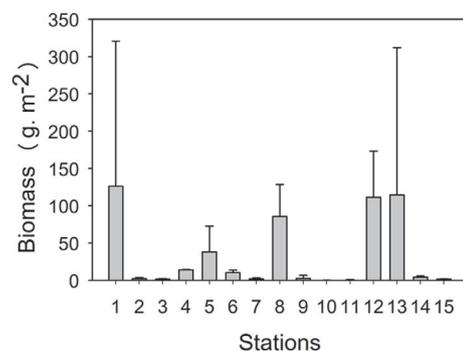


Figure 4. Distribution of biomasses (g m⁻²) of macrobenthos in Lake Illawarra.

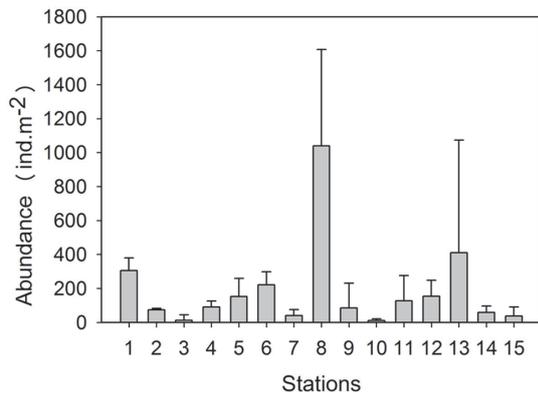


Figure 5. Distribution of the abundances (ind m⁻²) (g m⁻²) of macrobenthos in Lake Illawarra.

distribution according to different small area habitats, especially with the patchy presence of the seagrass *Zostera capricorni*.

Biodiversity

The Shannon-Wiener index H' at the 15 stations varied among the 44 samples tested (3 replicate samples from each station except station 15) from 0.00 to 2.71, and the highest mean value was found at station 12 (2.29 ± 0.37) followed by station 8 (2.28 ± 0.15). Margalef richness index d and Evenness index J' also showed similar patterns, with the highest values at sites 8 and 12.

Community structure

The cluster analysis of the macrobenthos was based on the species and their abundances in the study area. The results showed that the similarity of macrobenthic structures among the stations was low, mostly in 50-70% similarity range; the highest value of over 70%, occurred in stations B7-B8 (Figure 6). The cluster results show three groups on the whole.

AMBI

Station 8 (7.1%) had 'high' ecological status (EcoQ), and stations 1, 2, 4, 5, 7, 12, 14 (50%) had 'good' EcoQ, while stations

6, 9, 11, 13 (28.6%) had 'moderate' EcoQ, and stations 3 and 15 (14.3%) had 'poor' to 'bad' EcoQ. Station 3 was in the central basin, while 15 was on the sublittoral fringe of Lake Illawarra, which had suffered some disturbance from human activities (Figure 7).

Discussion

Biological characteristics of the LI macrobenthic assemblage and its temporal and spatial changes

Forty five macrobenthic species were found in this survey, with Polychaeta and Mollusca as the two dominant taxonomic groups. Comparison with the work of Gibbs (1986) showed an increase from 20 species to 45 species at nearly the same sampling stations. No immediate explanation is available as to why the species numbers have increased in this 30 year period due to the lack of a serial temporal data. One factor may be the noted improvement in water quality in LI from the 1980s to 2011 (Lake Illawarra Authority, unpublished data). The quantitative biomass and abundance distribution of macrobenthos surveyed and calculated in this study form, therefore, the basis for further study on macrobenthos in this area.

The biomass and abundance of macrobenthos found in 15 sampling sites from the three areas are spatially different, with the distribution patterns of sublittoral fringe highest, followed by central basin, and the entrance channel area lowest. The results of CLUSTER analysis show that the structures of the macrobenthic community in the three areas of LI are relatively different, as seen through the low similarity values among them, due to the variable habitats in the local region, which are direct or indirect ecological effects resulting from human activities. Some stations (station 8, 11) in the sublittoral fringe have seagrasses present, which provide food and refuge for macrobenthos, while in shallow sandy areas, some factors also affect the macrobenthos, e.g., people

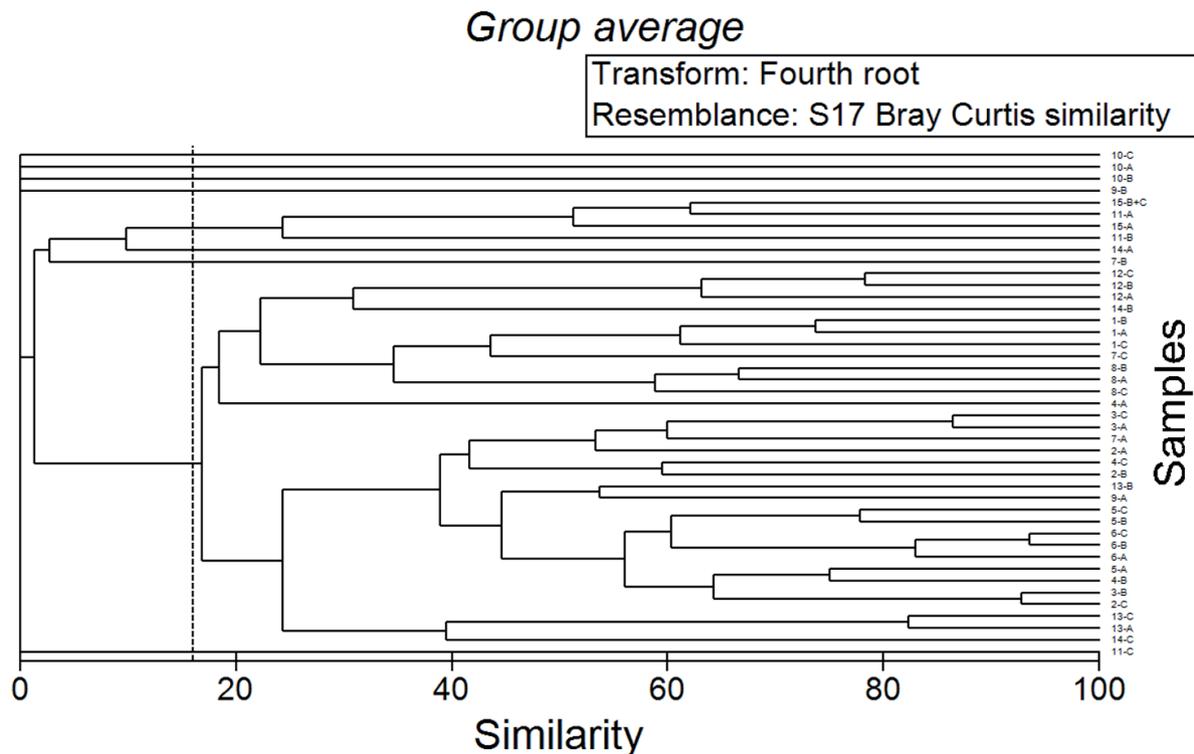


Figure 6. Dendrogram of the similarity of macrobenthic structures among the 15 stations in Lake Illawarra. (Using the group-average linking on Bray-Curtis species similarities calculated on the standardized samples by total and square root transformations of abundance data).

trampling, “harvester” collecting floating material, seabirds preying on macrobenthos (especially at station 15, where many seabirds were observed). The entrance channel area has changed much since 2000 due to extensive channel dredging, which destroyed and/or changed the benthic habitat. Coastal marine benthic communities are threatened by anthropogenic activities, and the present rate of habitat degradation is alarming (Grey, 1997; Snelgrove *et al.*, 1997). Several studies have also proved that anthropogenic activities and environmental factors would influence the spatial and temporal distributions of macrofaunal abundance and biomass (Drake and Mrias, 1997; DelValls *et al.*, 1998; Magni *et al.*, 2005, 2006). Pollution also causes changes in community composition with dramatic

reductions in diversity (Snelgrove, 1998). Magni *et al.*, (2005) concluded that an excess of sedimentary organic matter may strongly affect the composition, structure and distribution of macrofaunal communities of a lagoon. In the study area, due to the narrow entrance of Lake (approximately 50-80 m in breadth), the water exchange with the open sea is limited; also some human derived pollutants might easily be deposited in the sediment. Song et al (2011) found matrix-bound phosphine (MBP) in LI sediments, with some values being amongst the highest ever measured, indicating the Lake is quite phosphorus eutrophic.

Relationship with the seagrass in Lake Illawarra

Most shallow water areas of LI are densely

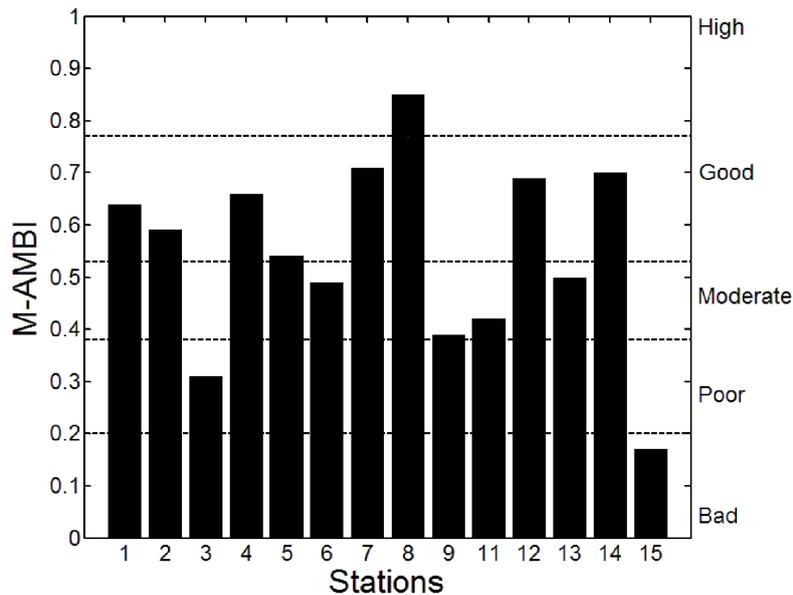


Figure 7. M-AMBI index values for Lake Illawarra.

populated with seagrasses and macroalgae (Rutten *et al.*, 2004). Based on WBM Oceanics (2000), the seagrasses covered approximately 7.86 km², occupying about 22 % of the total Lake surface area. The dominant seagrass is *Zostera capricorni*, followed by *Ruppia megacarpa* and small patches of *Halophila ovalis* and *Halophila decipiens* (Rutten *et al.*, 2004).

Algae and seagrass beds can provide food and refuge for animals to live and breed. In the present study, the macrofaunal abundance and biomass seemed to be directly influenced by the presence of seagrass even within the same station with patchy seagrass, i.e., more seagrass, more macrobenthos, which can be confirmed by the macrobenthos abundance collected inside seagrass (293 ind m⁻²), near seagrass (81 ind m⁻²) and no seagrass (6 ind m⁻²) found at station 11. Station 8, which is densely populated with *Zostera capricorni*, had species numbers, biomass and abundance obviously higher than at the other 14 stations (Figures 3, 4, 5).

Water quality and benthic environmental quality

As the most commonly used biotic index within the European Water Framework Directive (WFD) (Borja *et al.*, 2000, 2007; Bioge *et al.*, 2008), AMBI has proved efficient in detecting degradation of habitat quality. Corresponding to different sensitivity levels, the macrobenthic species were classified into five ecological groups (EG) (Bioge *et al.*, 2008). AMBI does not take diversity into account and uses a single scale to infer ecological status (EcoQ). M-AMBI has been recently introduced to overcome this potential weakness (Muxika *et al.*, 2007).

Morrison and West (2004) reviewed the health of LI and pointed out that the LI was in reasonably good condition in the early 2000s. They noted, however, that LI has been dramatically influenced by human activities, and still suffers some stress and exhibits some health problems, such as higher concentrations of certain metals, decreased fish catches since the 1980s, and macroalgal and jellyfish blooms.

The M-AMBI index of macrobenthos found in this study approximately coincides with the Morrison and West (2004) report. While 86 % of the sampling stations have achieved the EcoQ from 'moderate' to 'high', only less than 14 % of stations with 'bad' to 'poor' status. Station 10 was in the entrance channel with only one polychaeta species found there which most possibly due to the unsuitable habits for macrobenthos resulting from the pressure of physic-chemical variables, e.g., current, coarser sand sediment. The stations 3 and 15 with 'bad' to 'poor' EcoQ as well as the relatively low biodiversity index show macrobenthic assemblages have suffered some disturbance from human activities.

Conclusions

A macrobenthos study of Lake Illawarra has shown an increase in species numbers from 20 to 45 between the early 1980s and 2011. Using a biotic index, many of the sites examined showed a moderate to good ecological status, but evidence of disturbance and impact on benthic communities was obvious at several sites. It is recommended that this type of study be repeated on a more frequent time scale to provide indications of the changing environmental condition of the lake.

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Appendix A - Name list of macrobenthos found in Lake Illawarra in 2011.

Group	species
Crustacea	<i>Amphipoda</i> sp.1
Crustacea	<i>Amphipoda</i> sp.2
Crustacea	<i>Alpheus richardsoni</i>
Crustacea	<i>Metapenaeus</i> sp.
Crustacea	crab
Crustacea	<i>Metapenaeus bennettiae</i>
Crustacea	<i>Paragrapsus</i> sp.
Crustacea	<i>Urohaustonius</i> sp.
Crustacea	<i>Urohaustorius metungi</i>
Mollusca	<i>Anadara trapezia</i>
Mollusca	<i>Austrocochlea porcata</i>
Mollusca	<i>Batillaria australis</i>
Mollusca	<i>Bentharca</i> sp.
Mollusca	<i>kellia</i> sp.
Mollusca	<i>Laternula marilina</i>
Mollusca	<i>Mactra</i> sp.
Mollusca	<i>Mysella</i> sp.
Mollusca	<i>Mysella vitrea</i>
Mollusca	<i>Nassarius burchardi</i>
Mollusca	<i>Nitidotellina</i> sp.
Mollusca	<i>Potiarca pilula</i>
Mollusca	<i>Pseudoliotia micans</i>
Mollusca	<i>Pyrazus ebeninus</i>
Mollusca	<i>Salinator fragilis</i>
Mollusca	<i>Spisula trigonella</i>
Mollusca	<i>Theora lata</i>
Nemertean	<i>Nemertean</i> spp.
Oligochaeta	
Polychaeta	<i>Armandia</i> sp.
Polychaeta	<i>Australoneris ehlersi</i>
Polychaeta	<i>Australoneris</i> sp.
Polychaeta	<i>Barantolla lepte</i>
Polychaeta	<i>Capitella</i> sp.
Polychaeta	<i>Chaetopterus</i> sp.
Polychaeta	<i>Lumbrineris</i> sp.
Polychaeta	<i>Magelona</i> sp.
Polychaeta	<i>Nephtys australiensis</i>
Polychaeta	<i>Nephtys longipes</i>
Polychaeta	Orbiniidae
Polychaeta	<i>Paralepidonotus ampulliferus</i>
Polychaeta	<i>Polydora</i> sp.
Polychaeta	<i>Simpliseta</i> sp.
Polychaeta	<i>Simplisetia aequiselis</i>
Polychaeta	Spionidae
Fish	<i>Centropogon australis</i>