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Use of a multi-proxy method to support the restoration of estuaries receiving inputs from industry

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ABSTRACT

In New South Wales (NSW), Australia, the availability of water from estuarine lakes combined with the use of coal as an energy source has resulted in coal-fired power stations on the margins of coastal lakes. The purpose of this study was to use a multi-proxy method to evaluate the extent and trends of historical metal inputs from a coal-fired power station to sediments in Lake Budgewoi. Metal concentrations in 15-cm sediment cores showed a uniform depth profile. The highest concentrations of zinc and copper were found close to the Munmorah Power Station outlet, while arsenic and lead were found in the deposition basin of sediments. Background values for metal concentrations of Zn < 80 mg/kg, As < 15 mg/kg, Se < 1 mg/kg, Cu < 16 mg/kg, Cd < 0.8 mg/kg and Pb < 20 mg/kg were used as the baseline for future studies in this lake. The history of sediment metal concentrations is consistent with power station activities in the lake. Maximum metal concentrations found in sediments of Lake Budgewoi were Zn 122 mg/kg, Cu 45 mg/kg, As 10 mg/kg, Se 1.8 mg/kg, Cd 0.2 mg/kg and Pb 41 mg/kg. The ratio of these values to the national interim sediment quality guidelines are Pb 0.8, Cu 0.7, Zn 0.6, As 0.5 and Cd 0.1. Although concentrations were below guideline values, the multi-proxy method applied in this study was sensitive enough to detect metal concentration changes over the 45 years of power station operation. The results of this study provide environmental regulators with a baseline of the past and current situation of power station metal contamination, and in the future will provide insights into how long it takes the environment to revert to background metal concentrations.

1. Introduction

Estuaries are among the most important coastal features, both ecologically and with respect to human settlement and use (Ryan, 2003). Along with tropical rainforests and coral reefs, estuaries are some of the world's most productive ecosystems (David et al., 1998). Estuaries are biologically and economically valuable natural resources, where fish, birds and other animals congregate to feed, find refuge, grow to adulthood, and stage migrations (David et al., 1998). Anthropogenic activities are, however, having an increasing and negative impact on estuarine environments, altering the physical and chemical processes which underpin ecological structure and function (Rabalais et al., 2009; Hooper et al., 2012).

By virtue of their nature and position between marine and terrestrial environments, estuaries have become sites of major ports, industrial, urban and recreational developments. They represent important zones of sediment transfer between fluvial and marine systems, and are natural archives of environmental contamination (Ridgway and Shimmield, 2002). In the eastern Australian state of New South Wales (NSW), there are approximately 154 large and medium-sized estuaries and embayments (West et al., 1985). Most of these are under intense urban development pressure with approximately 80% of the State's population living near an estuary (Morrisey, 1995). Some 60% of the State's estuaries

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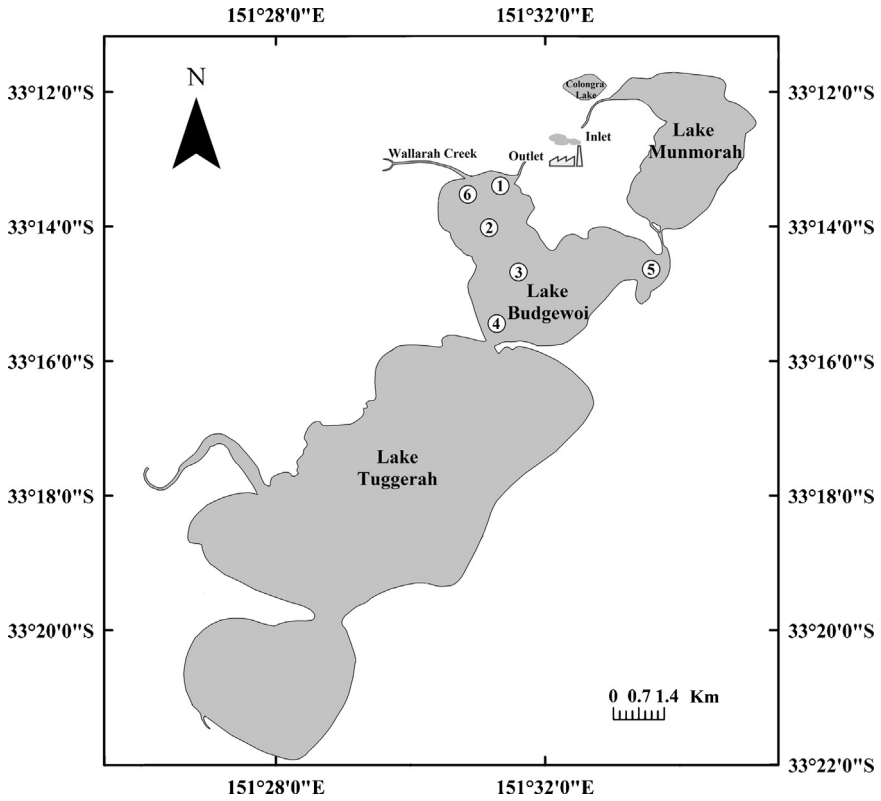

Fig. 1. Map of the Tuggerah Lakes complex. White circles are the core sample locations in Lake Budgewoi. Colongra Lake is the ash dam for Munmorah Power Station.

are intermittently closed and open lakes and lagoons which are sensitive to changes in the estuary and also in the catchment (Morrisey, 1995).

Large coal deposits close to the major population centres of Sydney and Newcastle (NSW) and a number of large estuaries have led to significant coal mining activity and power generation in their catchments. The availability of water from estuarine lakes combined with the use of coal as an energy source, has resulted in coal-fired power stations on the margins of coastal lakes. In Lake Budgewoi, NSW (Fig. 1), water has been extracted for use in steam turbines and to remove heat from the Munmorah Power Station (Batley et al., 1990).

Coal combustion waste released to aquatic basins through runoff can be a significant source of metal and metalloid inputs to adjacent water bodies (Batley et al., 1990; Rowe et al., 2002). Hereon, metals and metalloids are collectively referred to as metals. The ecological effects of metal discharges from coal-fired power stations include species extinctions, population declines, decreased growth rates, and diminished offspring viability in fish and amphibians (Crutchfield, 2000; Hopkins et al., 2006, 2000; Lemly, 2002a,b).

In places where coal-fired power stations release metals, a monitoring programme is necessary to provide data on the contaminant status and understand any present or future effects on toxicity to aquatic organisms and humans (Lemly, 2002a,b). In areas where no routine monitoring programme is conducted, such as Lake Budgewoi, a multi-proxy approach using different techniques to assess the history of contamination in sediments is useful for the on-going ecological management of the lake (Schneider et al., 2014, 2015).

When the protection of estuaries has failed, another course of action is to restore them. This study was designed to deliver an assessment of metal contamination in sediments of Lake Budgewoi and provide information to assist in the restoration of estuarine lakes. We applied a multi-proxy approach using ^{210}Pb, ^{137}Cs and metal concentration profiles to determine the history of metal inputs to sediments of Lake Budgewoi over the past 60 years. This period predates the time when Munmorah Power Station first commenced activities in 1969 and lasts until its decommissioning in 2010. The metals assessed in this study were copper, arsenic, selenium, zinc, cadmium and lead, all of which are known to be the primary metal contaminants released from coal-fired power stations (Batley, 1987). We also compared metal concentrations by sites in order to identify metal hot spots in Lake Budgewoi and assess whether metal concentrations exceeded the national interim sediment quality guidelines (ANZECC/ARMCANZ, 2000).

2. Materials and methods

2.1. Historical setting

Lake Budgewoi, part of the Tuggerah Lakes system, is located within the Wyong Shire local government area on the Central Coast of New South Wales, Australia (Fig. 1). The lake is located near the settlement of Budgewoi approximately 100 km north of Sydney.

The lake is relatively shallow, with an average depth of 1.9 m (Scott, 1999). The system has only limited water exchange between lakes and the sea. Water exchange with the Tasman Sea occurs through a narrow channel at the Entrance, and hence tides in the main body of the lakes are negligible. Daily tidal exchange has been estimated at approximately 2% by volume (IDC, 1979; Scott, 1998).

Urban development commenced in the 1960s with the construction of the Munmorah Power Station and the associated coal mines. The social structure of the coastal communities started to change, with the holiday-makers being replaced by a permanent residential population living in the urban centres (Scott, 1998).

Urban development continued through the 1980s, largely due to the extension of the Sydney–Newcastle freeway and the electrification of the Gosford–Newcastle railway. This enabled people to live in the Wyong Shire and commute to Sydney for work.