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The spatial and temporal nature of changing acidity in a wetland: the case of Lake Jandabup on the Swan Coastal Plain, Western Australia

K. J. O'Neill, P. Horwitz and M. A. Lund

Introduction

Lake Jandabup is a large (330 ha), shallow (<1.5 m), seasonal wetland on the Swan Coastal Plain of Western Australia. It lies in a reserve managed for nature conservation (WAPC & WRC 1999).

The lake is a surface expression of the unconfined aquifer of the Gnangara groundwater mound. Groundwater inflow occurs along the north-eastern margins, where it is at a higher elevation than the lake bed. Discharge occurs through lake deposits on the relatively flat south-western margin (DAVIDSON 1995). The western half of the lake contains organic sediments (mainly diatomite) while the remainder is covered in fine quartz sands containing ilmenite ($FeTiO_3$) and goethite ($Fe(OH)_3$) (ALLEN 1979). Pyrite (iron sulfide) associated with palaeolake deposits is also found in the lake bed. However, the spatial nature of its distribution is unknown (DAVIDSON 1995).

In 1997, regular monitoring of the lake detected a decline in surface water pH from 6–8 to 4–5 pH units (SOMMER et al. 2000). This low pH persisted in some areas of the lake into 2000. This study aimed to describe the short-term spatial and temporal nature of changing acidity in the wetland and to briefly discuss the implications of this variation for managing wetlands.

Methods

The entire wetland was mapped at 200-m intervals for pH of surface waters, sediment type and vegetation coverage at the seasonal driest time of the year (March) and repeated at the seasonal wettest time of the year (November). Ten sites were then chosen in order to represent the full spatial variability at the lake (Fig. 1). Within each site, where a site occupied a 30 × 30 m^2 quadrat, five replicates were randomly selected. Between April and August 2000 (18 weeks) the pH and conductivity were measured (Wissenschaftliche Technische Werkstatten field meters) for the middle of the water column, at weekly intervals at each replicate in all of the sites. In June 2000, a bulked water sample was analysed for cations and anions (sodium, magnesium, potassium, calcium, chloride, sulfate, bicarbonate and carbonate) at each site (APHA 1998). Data on groundwater quality were obtained from the Water Corporation of Western Australia.

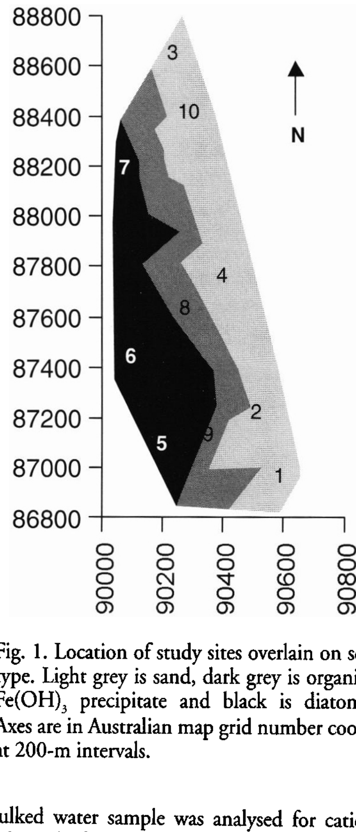

Fig. 1. Location of study sites overlain on sediment type. Light grey is sand, dark grey is organic under $Fe(OH)_3$ precipitate and black is diatomaceous. Axes are in Australian map grid number coordinates at 200-m intervals.

Results and discussion

Spatial mapping and monitoring showed that

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pH can vary within the lake by over 4 pH units on any one sampling day (Figs 2 and 3). In March there was an acidic area in the south-west corner of the wetland where diatomaceous sediment covered by a layer of $Fe(OH)_3$ precipitate was found. Generally areas with sandy sediment along the eastern edge of the lake did not have low pH. The cause of the acidity in the south-western corner was believed to be associated with the oxidation of pyrite (FeS_2) when the lake bed dries, as high concentrations of sulfates and $Fe(OH)_3$ precipitate (products of pyrite oxidation) were seen in conjunction with low pH. Acidification is unlikely to be from precipitation as pH and sulfate concentrations of rainwater collected near to the lake were ~7.0 and 6.0 mg L^{-1}, respectively.

Detailed monitoring of pH across the lake between April and August 2000 showed that the pH of the acidic area rose from 3–4 pH units to ~6.0 (Fig. 3). By November 2000, the pH at the lake further increased and became less spatially variable (Fig. 2). It is likely that the increase in pH is due to the seasonal effects of dilution, as explained below.

Over the 18 weeks of monitoring, the water depth increased from 44.23 mAHD (Australian Height Datum) to 44.87 mAHD in response to rainfall and rising groundwater levels (Fig. 2). On any one sampling day, conductivity values at the wetland could vary by over 1000 μS cm^{-1}. It decreased over the study period as water was diluted by rain and groundwater inflow (Fig. 3). While seasonal changes in conductivity are known for Swan Coastal Plain wetlands (see Davis & Rolls 1987, Davis et al. 1993), such spatial variability of conductivity for local wetlands has not been previously described.

Due to the patterns of groundwater inflow from north-east to south-west, the pH and conductivity of sites located in sandy sediment on the eastern side (1, 3, 4, and 10) could be attributed to that of the ground water. The pH and conductivity of the ground water and surface water were around 6.0 pH units and 500 μS cm^{-1}, respectively. Sites on the western side (6, 7, 8 and 9), and especially in the far south-western corner (5), had a much higher conduc-

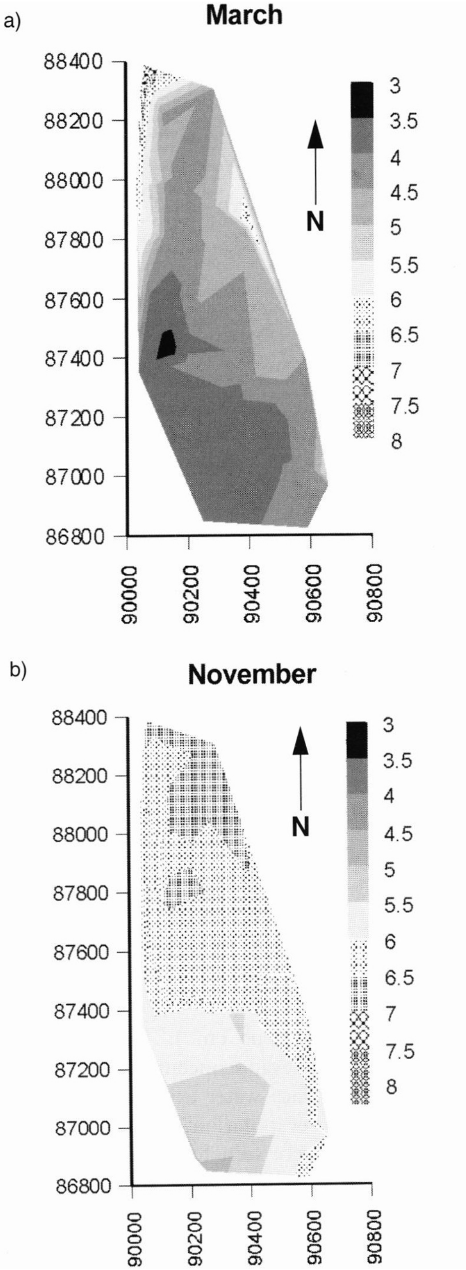

Fig. 2. Spatial map of surface water pH at Lake Jandabup in (a) March and (b) November showing how the spatial distribution of pH changes over time. Axes are in Australian map grid number coordinates at 200-m intervals.

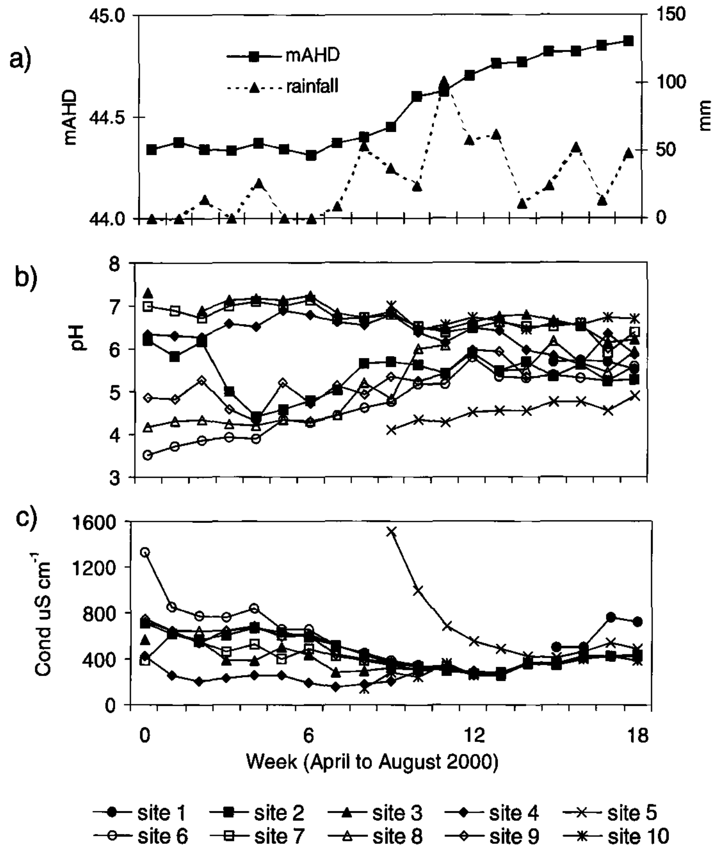

Fig. 3. (a) Water depth and total rainfall, (b) mean pH, and (c) mean conductivity for surface water at each site at Lake Jandabup between April and August 2000. Standard error is not shown for clarity. It shows a general pH increase and conductivity decrease with increasing water depth.

tivity (up to 1000 µS cm^{-1}). This increase is probably due to evapoconcentration effects as ground and surface water exits the wetland as discharge and evaporation, respectively. The same patterns were seen for cation and anion concentrations, which were highest in the south-western corner of the lake (Fig. 4). Figure 5 describes this situation, and gives an indication of the seasonal variations at the lake.

Generally, diatomaceous areas of the wetland had low pH. However, one site (7) had diatomaceous sediment, but did not have low pH. It was located in the north of the wetland whereas the other low pH sites with diatomaceous sediment were located in the south-west corner. It is possible that this site was not acidic due to its location near the inflow of neutral ground water which would dilute the water faster compared to sites located at the southern end of the wetland.

Seasonality of refilling also impacts on acidity. Although the pH in the wetland generally increased, at site 5 it did not. In November 2000 it had a pH of around 4.5. This site was located in the far south-west section of the wetland, which had organic/diatomaceous sediment in a vegetated area. It was the last to become wet and the first to become dry due to

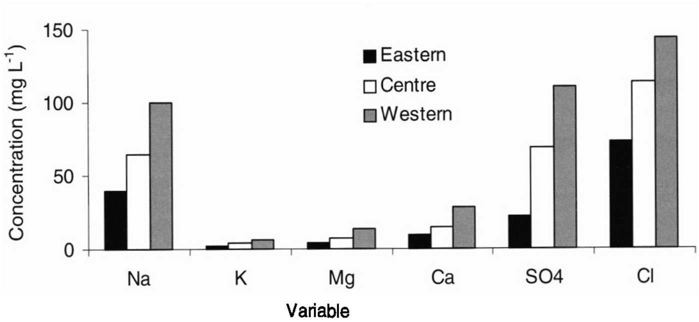

Fig. 4. Average anion and cation concentrations for groups of sites in the east, centre and west of the wetland for June 2000. It shows a general increase over an east to west gradient.

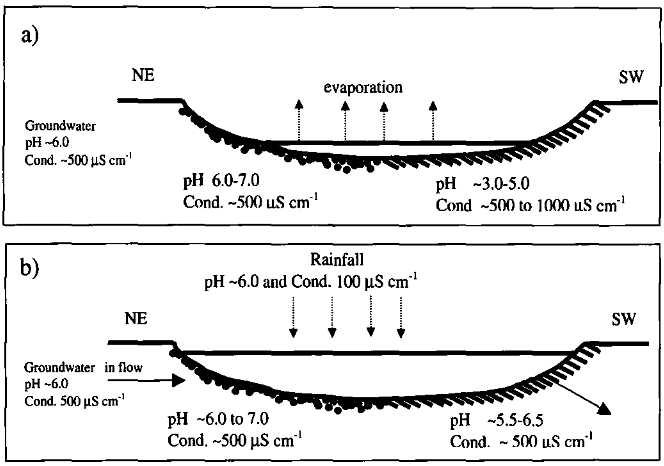

Fig. 5. Cross-section of Lake Jandabup showing pH and conductivity (Cond.) of surface waters during conditions of (a) shallow water depth during summer (<30 cm) and (b) after refilling (>30 cm, <150 cm). Note movement and quality of ground water and two distinct sediment types, sand (•) and diatomaceous (\). NOTE: This figure does not take into account spatial variability within sediment types as described for site 7 in the text.

seasonal water fluctuations. These examples indicate that seasonality of refilling, in addition to sediment type and location, affect the short-term temporal and spatial nature of pH at Lake Jandabup.

Detailed spatial and temporal sampling, as undertaken in this study, is usually not feasible for most monitoring programmes, as it is both time consuming and costly. Despite this, managers should be aware that high spatial and short-term temporal variability can occur for some physico–chemical parameters in some wetlands. Choosing sites based on location, sediment type or vegetation coverage alone cannot always represent processes in the system and could mask changes if certain areas were neglected. To solve this problem, managers could map entire waterbodies before choosing sites for monitoring programmes, as this should enable the full spatial variability to be detected.

As was found in this study, short-term temporal variability can also mask spatial variability; therefore, pre-monitoring/mapping needs to adequately describe this, so that monitoring programmes can take it into account.

Conclusions

The findings of this study, that pH and conductivity can have high spatial and short-term temporal variability, have important implications for wetland managers and researchers. While these variations may be common in some aquatic ecosystems and occur without any detrimental effects, for some lakes, such as Jandabup, it may be an indication of a more serious problem such as anthropogenically induced acidification of the system. If monitoring is irregular and/or the lake is under-sampled, it will be difficult to detect water quality changes and effectively manage the wetland for conservation purposes.

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