SIL Proceedings, 1922-2010

ISSN: 0368-0770 (Print) (Online) Journal homepage: http://www.tandfonline.com/loi/tinw19

The use of aluminium sulphate to control algal blooms and chironomids in Jackadder Lake, Western Australia

M. A. Lund & E. T. Chester

To cite this article: M. A. Lund & E. T. Chester (1991) The use of aluminium sulphate to control algal blooms and chironomids in Jackadder Lake, Western Australia, SIL Proceedings, 1922-2010, 24:2, 1129-1133, DOI: 10.1080/03680770.1989.11898929

To link to this article: https://doi.org/10.1080/03680770.1989.11898929

Verh. Internat. Verein. Limnol.	24	1129–1133	Stuttgart, März 1991

III. Lakes. 5. Australasia and Antarctica

The use of aluminium sulphate to control algal blooms and chironomids in Jackadder Lake, Western Australia

M. A. Lund and E. T. Chester

Introduction

Jackadder Lake (area 7 ha) is situated in a 13.8 ha public park in Perth, Western Australia. The lake is shallow (1–2 m) and approximately 95 % of the fringing vegetation has been cleared for lawns.

Inputs of fertilizers entering the lake via surface runoff have elevated phosphorus concentrations to eutrophic levels ($> 10\,\mu g P \cdot l^{-1}$) (Wetzel 1975). Blooms of *Microcystis aeruginosa* or green algae are common throughout the year producing ideal conditions for the growth of the nuisance chironomid, *Polypedilum nubifer*. Adults emerge throughout the summer months in large numbers, restricting outdoor activities for local residents. In response to this problem, which is common in Perth, the local council treats the lake with the pesticide Abate (active ingredient Temephos). The treatment has become less effective due to increasing resistance in target species (Davis et al. 1988).

In response to this problem, this study attempted to reduce nutrient levels and thereby control chironomid abundance through food limitation rather than continued reliance on pesticides. The application of aluminium sulphate (alum) has proved an effective and economical method for improving water quality (Kennedy & Cooke 1982). The main disadvantage is that the treatment tends to only be effective for 2–3 years. In many previous aluminium sulphate treatments no controls have been used. Alum treatments have rarely been used in Australia to improve water quality and the only documented treatment is that of May (1974). The aim of this study was to conduct a controlled whole lake experiment into the use of aluminium sulphate as a tool for improving water quality in Australian lakes.

Methods

The guidelines of Kennedy & Cooke (1982) were used to determine the alum dose of $14.5\,mg\,Al^{3+} \cdot l^{-1}$ required to obtain a final pH of 6 in the lake, using an estimated lake volume of $93 \cdot 10^6\,l$, alkalinity of $120\,mg\,CaCO_3 \cdot l^{-1}$ and pH of 8.5. Application occurred over 2 days (days 0 and 1), the alum in liquid form ($33.5 \cdot 10^3\,kg$, 7.7 % Al_2O_3) was pumped from the shore via a floating hose and spraying was directed from a dingy.

A control enclosure was constructed approximately a week before treatment and utilized an island (0.12 ha) situated 40–50 m from the shore. Barriers of P.V.C. sheeting were weighted and suspended by chains between the island and the shore forming a 0.25 ha enclosure.

Samples were collected from 3 random sites in both the treated and control areas, over a 7 month period (November 1988 to May 1989). At each site, water-depth, temperature/oxygen profile (0.50 m intervals; YSI Oxygen electrode), a 0.5 m^3 plankton tow (53 μm mesh) and a surface water sample were collected. Conductivity (Activon Conductivity meter), pH (Hanna pH meter) and total alkalinity (Greenberg et al. 1985) were measured in the laboratory less than 4 hours after collection.

Chlorophyll *a* was analysed using a method adapted from Moran & Porath (1980) and Moran (1982). Total nitrogen and phosphorus were measured after perchloric acid digestion using the automated phenate method (Greenberg et al. 1985) and the single solution method (Murphy & Riley 1962) for nitrogen and phosphorus respectively. Ammonia and orthophosphate were measured in filtered water according to Greenberg et al. (1985) and Murphy & Riley (1962).

Three sites were chosen in each area for the collection of macroinvertebrates. A 1 m · 0.5 m area of the lake's edge was sampled for 20 s using a sweep net (250 μm mesh). A corer was used to sample chironomids in the littoral zone. Nine samples were taken in the control area and 15 samples in the treated area. Macroinvertebrates and zooplankton ($> 250\,\mu m$) were identified using available keys and a reference collection held at Murdoch University.

Results and discussion

Water quality and physical parameters

No changes were recorded in water-depth and conductivity that could be attributed to the treatment, although conductivity increased as a result of evapoconcentration occurring in the warmer summer months. Levels are similar to those recorded by Davis et al. (1988) in a study undertaken at the lake in the summer of 1987/88.

0368-0770/91/0024-1129 $ 1.25

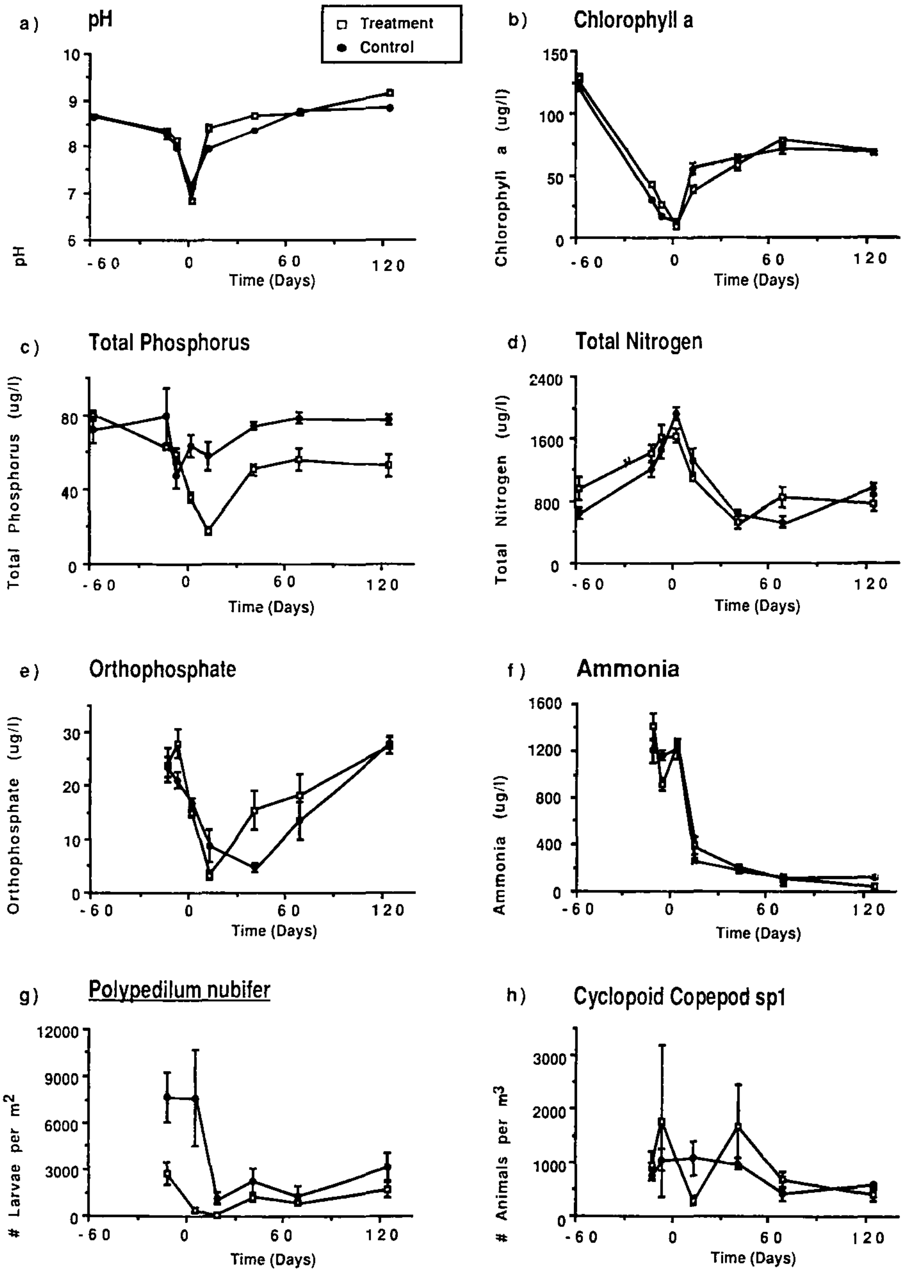

Fig. 1. Mean values for selected parameters before and after treatment and between the control (untreated) and treated areas; a) pH, b) chlorophyll-*a*, c) total phosphorus, d) total nitrogen, e) orthophosphate, f) ammonia, g) chironomid larvae (*Polypedilum nubifer*) and h) zooplankton (Cyclopoid copepod sp1). (Control (●), treated area (□), day 0 is the day of alum application.)

Dissolved oxygen concentrations at 0.1 m and 0.5 m deep were not significantly different ($P < 0.05$) between the control and treated areas or before and after treatment. As no significant difference was found between control and treated areas, the enclosure appeared to have little effect on the natural mixing patterns within the island/shore channel. GASPERINO et al. (1979) found that alum treatment had no significant effects on dissolved oxygen levels. In contrast MORENCY & BELNICK (1984) found dissolved oxygen levels declined markedly, the difference can probably be attributed to the amount of algae removed to the bottom by the alum floc.

The pH was not significantly different between areas and before or after treatment (Fig. 1 a). The alum addition reduced the pH to a minimum of 6.83 in the treated area and 7.13 in the control 2 days after treatment. However after 13 days the pH had returned to pre-treatment values. The pH levels, except after treatment were similar to those found by DAVIS et al. (1988). The target pH of 6 was not achieved, probably due to an underestimation of lake volume, however an estimated Al/P molar ratio of 138 (based on peak P levels) was achieved, indicating that long term P control should be possible. Although some leakage of water was observed around the edge of the enclosure, little alum was believed to have entered the control. Water exchange between the two areas may account for the similarity in dissolved oxygen and pH levels between areas after treatment.

Alkalinity decreased by 42% (148 to 87 mg $CaCO_3 \cdot l^{-1}$) immediatealy after treatment, but by day 13 had returned to pretreatment levels. Similar results were reported by MORENCY & BELNICK (1984).

In the 8 weeks prior to treatment concentrations of chlorophyll *a* had declined from 129 to 26 $\mu g \cdot l^{-1}$ (Fig. 1 b). A similar decline was found by DAVIS et al. (1988) in 1987/88. Chlorophyll *a* concentrations reached a minimum of 9 $\mu g \cdot l^{-1}$ on day 2, however by day 13 chlorophyll *a* returned to a level of 38 $\mu g \cdot l^{-1}$. Secchi depth was closely inversely correlated with chlorophyll *a* and in the 8 weeks prior to treatment increased from 0.26 to 0.73 m. A maximum Secchi depth of 1.4 m was recorded on day 2, though by day 41 Secchi depth had decreased to 0.67 m. The improvement in Secchi depth on day 2 was larger than the equivalent decrease in chlorophyll *a*, probably due to precipitation of seston rather than algae by the alum.

The greatest effects on nutrient levels were observed 13 days after treatment. Total phosphorus was significantly ($P < 0.05$) different between areas and following treatment, however there was no significance difference in total nitrogen concentrations (Figs. 1 c and 1 d). On day 13 total phosphorus concentrations were 70% lower in the treated area (18 $\mu g \cdot l^{-1}$) compared to the control (58 $\mu g \cdot l^{-1}$). The difference between control and treated area after day 41 has remained constant at 30%. Orthophosphate and ammonia concentrations were not significantly ($P < 0.05$) different between treatment and control but were significantly different ($P < 0.05$) before and after treatment. Orthophosphate concentrations by day 13 were reduced by 90% (compared to pre-treatment levels) from 26 to 3 $\mu g \cdot l^{-1}$, though by day 125 levels had returned to 28 $\mu g \cdot l^{-1}$ (Fig. 1 e). Ammonia concentrations by day 13 had declined by 65% from 902 to 389 $\mu g \cdot l^{-1}$ and continued to decrease up to day 125 to 40 $\mu g \cdot l^{-1}$ (Fig. 1 f). GASPERINO et al. (1979) found that alum treatment had little effect on total nitrogen or ammonia. An additional benefit of the alum dosing is that the selective removal of phosphorus and not nitrogen should increase the N/P ratio favouring the growth of green algae over blue-green algae.

Alum treatment is very effective against inorganic forms of phosphorus, but poorly binds organic forms (FRANCKO & HEATH 1981, COOKE et al. 1986). Alum additions are therefore recommended in spring when inorganic phosphorus concentrations are high (KENNEDY & COOKE 1982). A spring addition at Jackadder Lake was not possible, however, the summer treatment reduced total phosphorus and orthophosphate concentrations, although orthophosphate concentrations returned to pre-treatment levels. In summer phosphorus tends to be organically boundand so the high rate of removal observed in this study is encouraging. GASPERINO et al. (1979) found that following a summer alum application most water quality improvements occurred during autumn and winter. The same effect may occur in Jackadder Lake where further removal of inorganic phosphorus during winter should lead to an improvement in chlorophyll *a* concentrations. A reduction in chlorophyll *a* was necessary to deplete the algal food resource for chironomids, which was one of the objectives of this project.

The main change in Jackadder Lakes water quality was the reduction in total phosphorus, with the potential for further removal during winter. All other parameters measured returned to pre-treatment levels 5 months after treatment, with the exception of ammonia concentrations which have remained very low.

Macroinvertebrates

Zooplankton species richness was not significantly ($P < 0.05$) affected by the treatment either before or after treatment or between control and treatment. No significant difference was found in the abundance of the 4 dominant zooplankton groups (2 species of cyclopoid copepods, a calanoid copepod and rotifers), between control and treated areas. On day 13 there was a noticeable decrease in numbers of rotifers and cyclopoid sp1. This corresponds with the findings of SONNICHSEN (1978) and GIBBONS et al. (1984), who found an initial decrease in abundance followed by recovery in all groups, except cladocerans.

The approximate percentage composition of chironomid larvae in the benthos is *P. nubifer* (85 %), *Chironomus grisedorsum* (10 %), *Procladius villosomanus* (2 %), *Chironomus australis* (1 %) and rare species (2 %). Only *P. nubifer* and *C. grisedorsum* appeared to show any response to the alum treatment. Levels of *C. grisedorsum* which were similar at the start were reduced in the treated area compared to the control after treatment, however the difference was not significant ($P < 0.05$). The numbers of *P. nubifer* were initially 2 – 3 times higher in the control than in the treated area. Numbers dropped in the treated area by approximately 85 % on day 5, this was mirrored by an equivalent drop in the control on day 19. In 1987/88, the larval population declined by 74 % in two stages over 41 days (DAVIS et al. 1988). A natural decrease in larval numbers occurs at this time of year probably due to synchronized adult emergence. The time displacement between the declines in the control and treated area indicate that the alum treatment induced a premature decline. LAMB & BAILEY (1983) found that a chironomid (a Tanytarsini) suffered no acute effects from alum addition. It is possible that rather than the alum being toxic, the chironomids were stressed prompting an early emergence.

Macroinvertebrate species richness was not found to differ significantly ($P < 0.05$) before or after treatment or between control and treated area. It appears that macroinvertebrates abundances were generally unaffected by the treatment.

The alum treatment appeared to have no long-term detrimental effects on macroinvertebrates or zooplankton. Although an initial decline in numbers appeared to occur following treatment this was followed by subsequent recovery.

Conclusions

The treatment of Jackadder Lake with alum appears to have enhanced water quality with no detrimental effects on the biota. Total phosphorus concentrations were reduced and the onset of winter should bring additional benefits as it will allow the further binding of phosphorus by the alum. At present however the reduction in total phosphorus has not been sufficient to eliminate the algal blooms. Unless the algal blooms are reduced the effects of the treatment on nuisance chironomid levels will be minor. Monitoring of the lake is continuing to assess long-term effects of the alum treatment.

Acknowledgements

The technical support and funding for the study was provided by the Stirling City Council. In addition the help of colleagues in the Wetland Ecology Group and Midge Study Team at Murdoch University is gratefully acknowledged. Criticism of the manuscript by Dr. J. A. DAVIS and Mr. T. WRIGLEY were invaluable and appreciated.

References

COOKE, G. D., WELCH, E. B., PETERSON, S. A. & NEWROTH, P. R., 1986: *Lake and Reservoir restoration.* – Butterworths, Stoneham MA.

DAVIS, J. A., HARRINGTON, S. A. & PINDER, A. M., 1988: Investigations into more effective control of nuisance chironomids (midges) in metropolitan wetlands. – Murdoch University, Perth, Western Australia (unpubl.).

FRANCKO, D. A. & HEATH, R. T., 1981: Aluminium sulphate treatment: short-term effect on complex phosphorus compounds in a eutrophic lake. – *Hydrobiologia* **78:** 125 – 128.

GASPERINO, A. F., KEIZUR, G. R. & SOLTERO, R. A., 1979: Preliminary findings of Medical lake restoration. – In: Anon.: *Lake Restoration*: 209 – 214. – US Environmental Protection Agency, EPA 440/5-79-001, Washington D.C.

GIBBONS, M. V., WODDWICK, F. D., FUNK, W. H. & GIBBONS, H. L., 1984: Effects of multiphase restoration particularly aluminium sulphate application on the zooplankton community of a eutrophic lake in Eastern Washington. – *J. Freshw. Ecol.* **2:** 393 – 404.

GREENBERG, A. E., TRUSSELL, R. R. & CLESCERI, L. S. (Eds.), 1985: *Standard Methods for the examination of water and wastewater.* – 16th edition, A.P.H.A., Washington D.C.

KENNEDY, R. H. & COOKE, G. D., 1982: Control of lake phosphorus with aluminium sulphate dose determination and application techniques. – *Water Res. Bull.* **18:** 389–395.

LAMB, D. S. & BAILEY, G. C., 1983: Effects of aluminium sulphate to midge larvae (Diptera: Chironomidae) and rainbow trout (*Salmo gairdneri*). – In: Anon.: *Lake Restoration, Protection and Management.* – North American Lake Management Society, Washington D.C.

MAY, V., 1974: Suppression of blue-green algal blooms in Braidwood Lagoon with alum. – *J. Aust. Inst. Agric. Sci.* **40:** 54–57.

MORAN, R., 1982: Formulae for determination of chlorophyllon pigments extracted with N, N-Dimethylformamide. – *Plant Physiol.* **69:** 1376–1381.

MORAN, R. & PORATH, D., 1980: Chlorophyll determination in intact tissues using N, N-Dimethylformamide. – *Plant Physiol.* **65:** 478–479.

MORENCY, D. A. & BELNICK, T. J., 1984: Control of internal phosphorus loading in two shallow lakes by alum and aquatic plant harvesting. – In: Anon.: *Lake and Reservoir Management.* – North American Lake Management Society, Washington D.C.

MURPHY, J. & RILEY, J., 1962: A modified single solution method for the determination of phosphate in natural waters. – *Anal Chim. Acta* **27:** 31.

SONNICHSEN, T., 1978: Toxicity of a phosphate-reducing agent (aluminium sulphate) on the zooplankton in the Lake Lyngby So. – *Verh. Internat. Verein. Limnol.* **20:** 709–713.

WETZEL, R. G., 1975: *Limnology.* – Saunders, Philadelphia.

Author's address:

M. A. LUND, School of Biological and Environmental Science, Murdoch University, Perth WA 6150, Australia.