Nuisance midge (Chironomidae) plagues in urban wetlands: A catalyst for improved catchment management

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Abstract

Perth has over 450 shallow urban lakes of which many have problems with nuisance midge plagues. Midges (Chironomidae) have aquatic larvae with non-biting adults emerging from the lake in the millions during a plague. The sheer numbers severely impact on the quality of life for nearby residents. Lake Joondalup is a degraded urban lake that has experienced midge plagues over many years. Pesticide treatment is the only short-term solution currently available, however this is environmentally undesirable. Midge plagues galvanise, local communities, Politicians, Councillors and Agencies into dealing with the fundamental problem, as improved catchment management is the only long-term solution. Recent events at Lake Joondalup will be used as a case study of how plagues can result in improved catchment management.

Introduction

Aboriginal people have used Lake Joondalup for thousands of years, however it was colonisation by Europeans following the establishment of the Swan River Colony (now Perth) that has led to the current poor condition of the lake (O'Connor *et al*. 1989; Kennealy, 1994). Most of the European colonists were farmers, therefore a mixture of smallholdings and market gardens came to surround the lake. Gradually the farms have been replaced by urban development this process has accelerated with the growth of both Wanneroo and Joondalup townships. Changes to the hydrology of the lake, fertiliser usage in the catchment, infilling and clearing of fringing vegetation have led to a gradual decline in water quality (see Davis *et al*, 1993 and Kinnear *et al*, 1997).

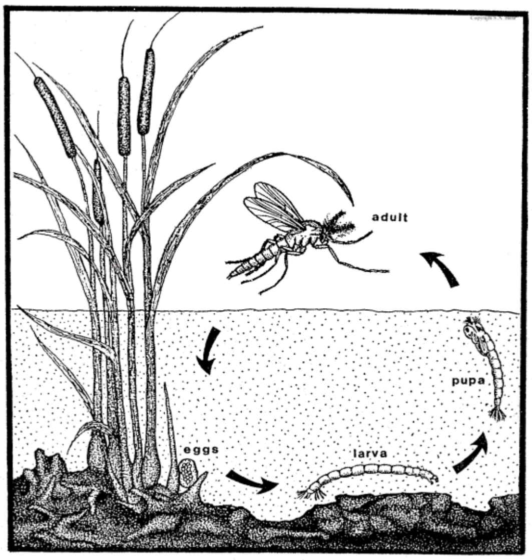

Figure 1: Lifecycle of a typical Perth midge (figure used with permission from S. Balla)

Chironomidae is the taxonomic insect family that consists of non-biting midges. These midges can occur in large numbers in nutrient enriched (eutrophic) lakes. The midge larvae live in the lake sediment and feed primarily on algae in the water (Figure 1). They turn into pupae after 2 weeks to 6 months and swim to the water surface and emerge as adult flies. Adult flies do not typically feed and their principle function is to breed and lay eggs in the water for the next generation. Adults survive for 2-3 weeks and as poor fliers are easily blown by the wind. They are also attracted to lights and so they tend to congregate around nearby resident's houses causing nuisance problems. Small species can pass through mosquito netting compounding the nuisance problem. During midge plagues several million individuals can emerge from a lake per night.

In the 1980's Lake Joondalup experienced nuisance midge problems which were controlled using the organophosphate pesticide Abate® (Active Ingredient: Temephos). Few problems were reported in the late 1980s and early 1990s. In the late 1990s a series of below average rainfall years has seen the lake dry for the first time in several decades. In 1998 after the lake had dried, nearby residents experienced severe midge plagues in the spring and summer. Public pressure led to the establishment of a Midge Steering Group made up of Council staff, community representatives, academics and representatives from a variety of Government Agencies. This group was instrumental in getting the Council to fund a research project into the midge problem. This paper reports on the results of the research project and how the Midge Steering Group evolved into the Yellagonga Catchment Group. The aims of the research project were to gain an understanding of the ecology and distribution of midge larvae and apply this to improved control strategies at Lake Joondalup.

Methods

The research program had two components, the first was to examine the distribution of midge larvae within the lake and try and determine what factors were responsible for any patterns seen. Secondly an experiment was conducted to observe the effectiveness of Abate in controlling midge densities. Full details of the research can be found in Lund *et al* (2000).

The distribution of midge larvae was assessed by sampling on a grid (200 x 300 m). Sampling was conducted between 21/7/99 and 10/9/99. At each site, a sediment and surface water sample were collected. The sediment sample was later analysed for organic matter content (Loss on Ignition), water content and Total Phosphorus (Total P). The water sample was later analysed for Total P, Total Nitrogen (Total N), Nitrate/nitrite (NOx), ammonia (NH_3), filterable reactive P (FRP) and chlorophyll *a*. Nutrient and chlorophyll *a* samples were analysed at the Edith Cowan University Nutrient Laboratory (as per APHA, 1998). In addition, at each site WTW™ handheld meters were used to measure pH, conductivity and water temperature. Water depth was also measured. An assessment was made on the coverage of the site by plants and algae. At each site, 3 random cores of sediment were collected. Cores were taken by inserting a 1 m perspex tube (dia. 44 mm) approximately 0.1 m into the sediment. The top of the tube was sealed with a bung. The tube was extracted and sealed at the bottom. The sediment and 50 mm of overlying water were transferred to a plastic bag.

An experiment to test the effectiveness of spraying with Abate® was conducted between 12/10/99 and 13/12/99. Two hot spot areas identified from the above experiment were sampled at 3-4 day intervals (Figure 2). During the course of the experiment the northern (treatment) area was sprayed on two occasions with Abate®, the southern area (control) was not treated. A total of 30 random core sediment samples were taken in each area.

Midge larval samples were not preserved, but were kept cool until they were sorted. All midges were removed from the sediment, counted and identified. Identification was made down to species level, using the Voucher Collection of Dr Mark Lund (held at Edith Cowan University) and Davis and Christidis (1997).

Figure 2: Maps of Lake Joondalup showing a) the experimental areas (left) and b) the areas sprayed with Abate® (right) (Map adapted from the 1997 Streetsmart Road Directory).

Results

Distribution of Midges in Lake Joondalup

Two major midge ‘hotspots’ were identified that are likely to be major contributors to midge plaques (Figure 3) these are located directly opposite the areas on the north-eastern shore where most resident complaints are recorded. A maximum density of 17095 larvae m^{-2} was recorded and conservatively there were at least 5.6 billion larvae in the lake at this time.

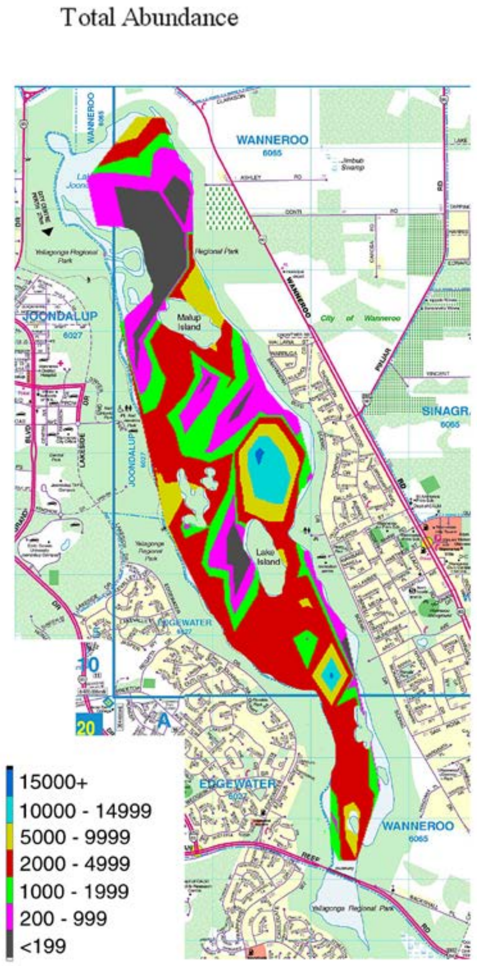

Figure 3: Midge larval densities (larvae m^{-2}) in Lake Joondalup, it should be noted that samples were collected over 7 weeks with the samples collected from North to South (Map adapted from the 1997 Streetsmart Road Directory).

Seven species were collected, all the species were common in Perth although the high abundance of *Kiefferulus martini* was unusual. Davis and Christidis (1997) lists only four species from Lake Joondalup (*Procladius villosimanus*, *Chironomus alternans*, *Cladopelma curtivalva* and *Polypedilum nubifer*) of which *C. curtivalva* was not recorded in this study. The apparent absence of *C. curtivalva* could be due to sampling technique/location or seasonal differences and should not be taken as indicative of changes in water quality within the lake. The three most dominant species were *P. nubifer*, *C. alternans* and *Chironomus occidentalis* (Figure 4).

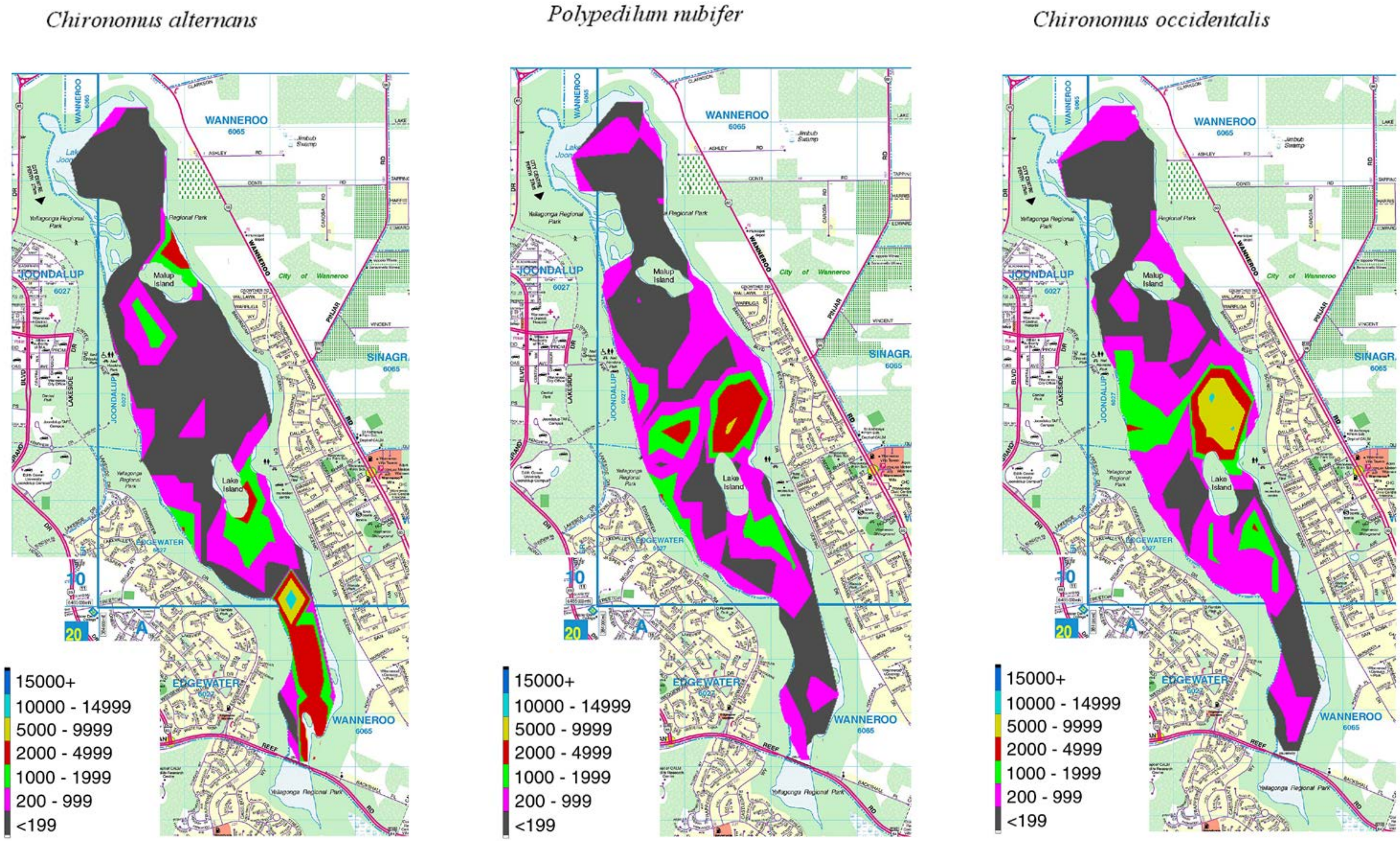

Figure 4: Midge larval densities (larvae m^{-2}) in Lake Joondalup, it should be noted that samples were collected over 7 weeks with the samples collected from North to South (Map adapted from the 1997 Streetsmart Road Directory).

Individual species have different spatial distributions within the lake, in particular *C. alternans* was found mainly in the southern end of the lake and on the eastern side of the two islands (Figure 4). *Polypedilum nubifer* and *C. occidentalis* had a similar distribution concentrated in a band from Neil Hawkins Park to a hotspot close to the northern end of Scenic Drive.

No strong correlations ($r>\pm0.5$; $P<0.05$) were found between any species and any physico-chemical parameter. There is a strong conductivity gradient running from north to south with progressively fresher water towards the south. This difference in conductivity north to south is still relatively minor and is unlikely to influence the distribution of midge larvae. Water temperature has often been suggested as a possible predictor of midge densities. Two species were weakly correlated with water temperature (negatively *K. martini* and positively *C. alternans*). It is not surprising that no strong correlations were found as the temperature at the time of egg laying is probably ultimately responsible for larval density, rather than the temperature at the time of sampling. Water temperature was poorly correlated ($r = 0.282$) with water depth. A stronger correlation would be expected, as shallower water should be warmer than deeper water. However, this may be accounted for by mixing patterns and variability introduced by the long sampling period.

pH was strongly correlated ($r=0.71$) to dissolved oxygen, both of which were correlated to the presence of *Chara* sp. (submerged plant). The most likely explanation is that photosynthesis by the *Chara*, raised pH during the day and released oxygen in the process. *Chara* was typically found in areas without metaphyton, as it prefers solid ground to grow on. The western edge of the lake tended to have areas without metaphyton. Areas with metaphyton also had the highest percentage of water in the sediment and the highest Loss on Ignition (LOI). There is significant correlation between LOI and percentage of water ($r = 0.671$). It is difficult in the field to distinguish between the true lake bed and the metaphyton, so in this study metaphyton was considered to be the lake bed.

The Total P in the sediment correlates with the percentage of water in the sediment ($r = 0.672$) and is highest along the north-eastern edge of the lake (Figure 5). Total P in the sediments indicates that there are two probable sources of P one at the northern end of the lake and direct runoff from the lawns/drains on the eastern side. Sediment Total P concentrations range from the low values recorded by Davis *et al.* (1993) in the Lake to levels found in some of the most eutrophic wetlands they measured. As in areas of metaphyton (a benthic algal ‘soup’), this was considered sediment, the high water content will tend to give an overly high P concentration when consider on a load per area basis. Interestingly the distribution of Total P in the sediment suggests that park lawns (or the landfill under some of them) are probably the main culprits for elevated levels as enriched areas all lie alongside lawn areas. Surprisingly there appears to be little evidence that unsewered areas are a major source of P into the lake. Furthermore the contention of Kinnear *et al* (1997) that the northerly flow from Beenyup Swamp is a major source of nutrients does not appear to be substantiated by the sediment P loads.

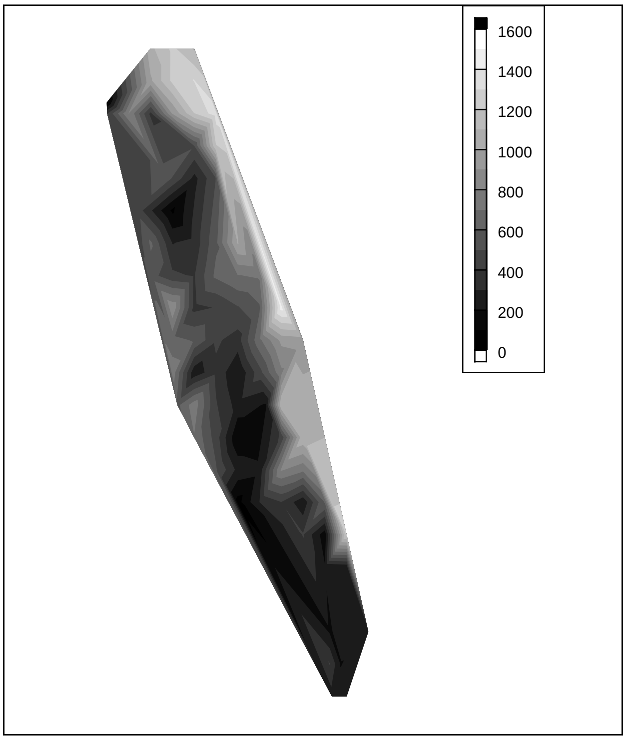

Figure 5: Sediment P concentrations (mg P kg^{-1}) in Lake Joondalup.

Water concentrations of Total P and Total N were highest opposite Neville Drive and Ariti Avenue (Figure 6). These concentrations correspond with clusters of stormwater drains entering the lake from the nearby roads (Ove Arup Partners, 1994).

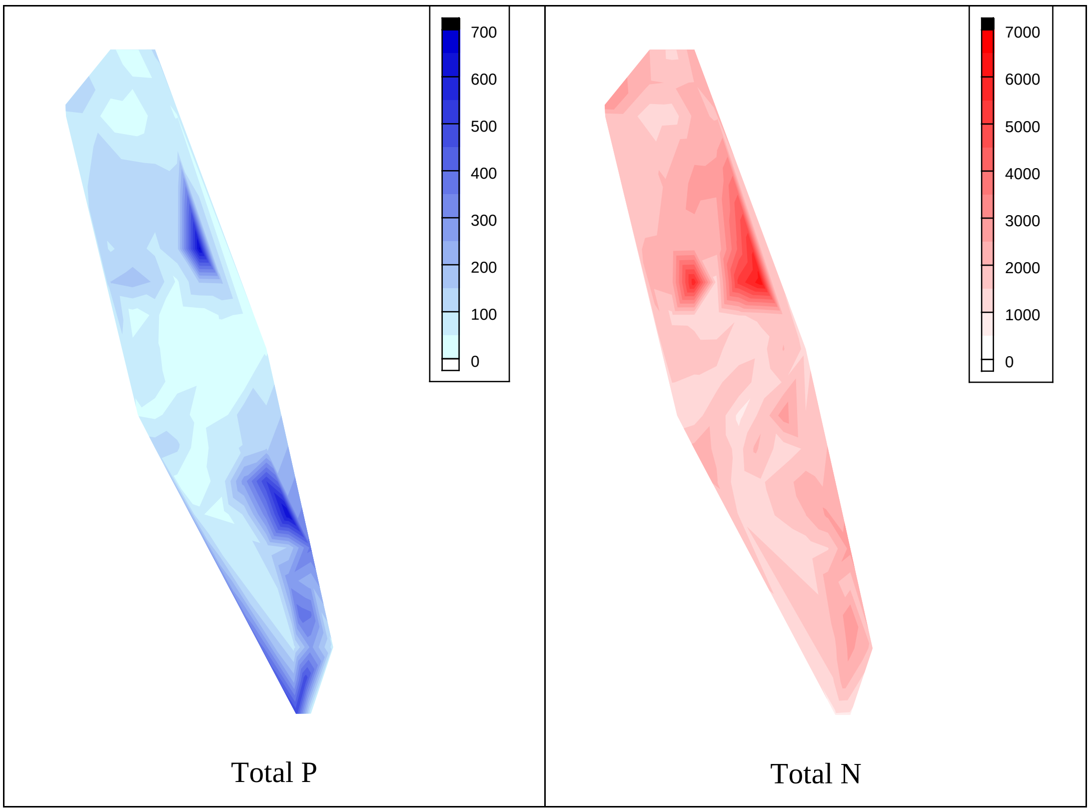

Figure 6: Concentrations of Total P and N in the water of Lake Joondalup

The highest levels of FRP were recorded opposite Ariti Avenue and in the northwestern edge of the wetland (Figure 7). The northwestern site has no obvious sources of FRP and so the reason for the high concentrations here deserves further study. The high FRP around Ariti Avenue is probably entering through the drains (drain 12 in Ove Arup Partners, 1994). The other drains do not at this time of the year appear to be a major source of FRP. Although FRP concentrations over most of the wetland were relatively low they were sufficient to promote algal growth. This algal growth does not appear to be expressed as an algal bloom as chlorophyll *a* concentrations were very low (<20 µg l^{-1}) suggesting that most of this P is being used to support the growth of metaphyton. No significant correlations were found between Chlorophyll *a* and Total P or FRP.

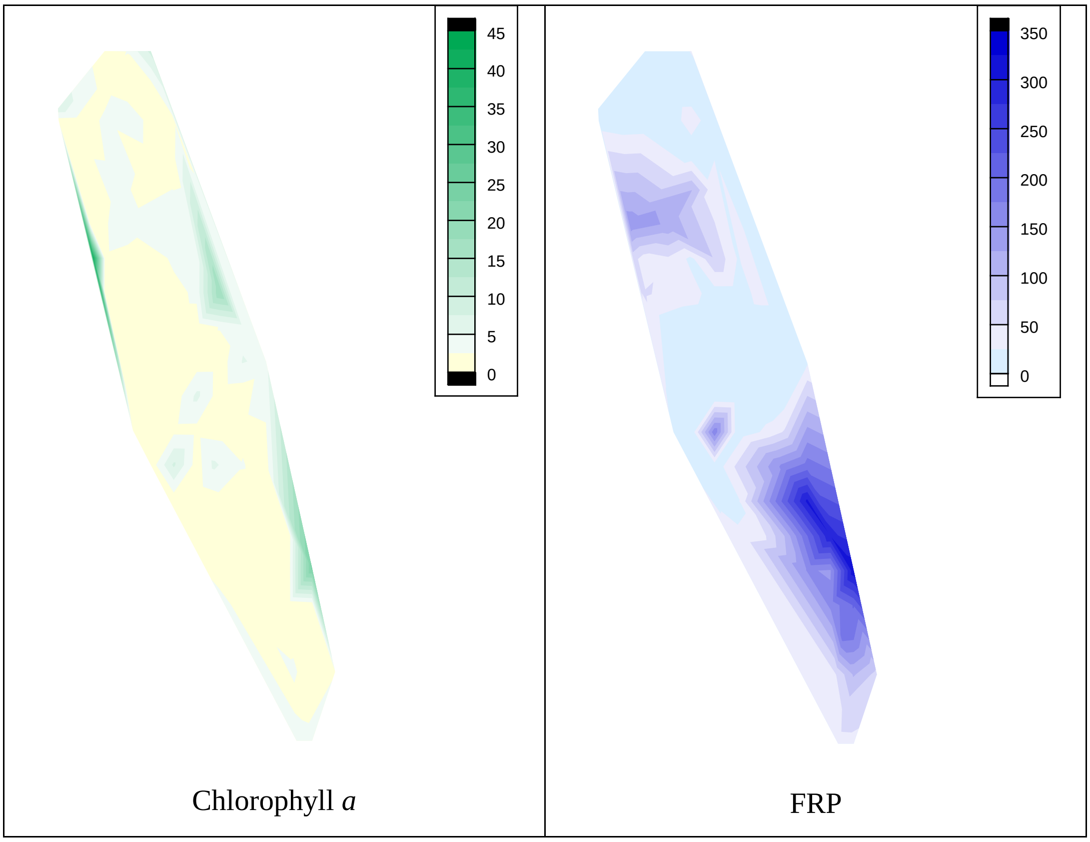

Figure 7: Distribution of FRP (µg l^{-1}) and Chlorophyll *a* (µg l^{-1}) in Lake Joondalup.

Nitrate and ammonia have high concentrations opposite Neville Drive, Ariti Avenue and opposite the causeway under Ocean Reef Rd. The source of these nutrients remains unclear, as peak levels do not correspond with drains.

Abate® Experiment in Lake Joondalup

Three Abate® treatments were made to the Lake during this experiment (15/10/99, 10/11/99 and 10/12/99), the first treatment had little effect on larval abundances. The first treatment failed to deliver the full application rate (estimated application rate was about half that recommended by the manufacturer) to the lake due to the helicopter crashing. The second treatment resulted in a 5 fold reduction (>10000 m^{-2} to ~2000 m^{-2}) in the total larval abundance after a week compared to pre-treatment levels and a 3 fold reduction compared to the control. Abundances were slightly lower in the control than found in the experimental area prior to spraying. The third treatment was a blanket treatment over the entire lake (including control). After 3 days this had reduced control abundances to ~3000 larvae m^{-2} and brought experimental levels back down to ~2000 larvae m^{-2} as they had increased up to ~3000 larvae m^{-2} over the month between spraying.

A total of 8 species of midge were collected, of these only two occurred in high enough numbers to cause problems these were *P. nubifer* and *C. occidentalis* (Figure 8). Both these species are common nuisances in Perth wetlands with *P. nubifer* being a particular problem as the adults are small enough to pass through some flyscreens. The second application of Abate® significantly reduced the abundance of *P. nubifer* from ~4000 to <1000 larvae m-2. Numbers in the subsequent month increased marginally but did not exceed 2000 larvae m^{-2}. The third treatment substantially reduced *P. nubifer* levels in both areas to <1000 larvae m^{-2}. There appears to be a general natural decline in the abundance of *C. occidentalis* throughout the experiment, with little impact seen in response to Abate® treatments.

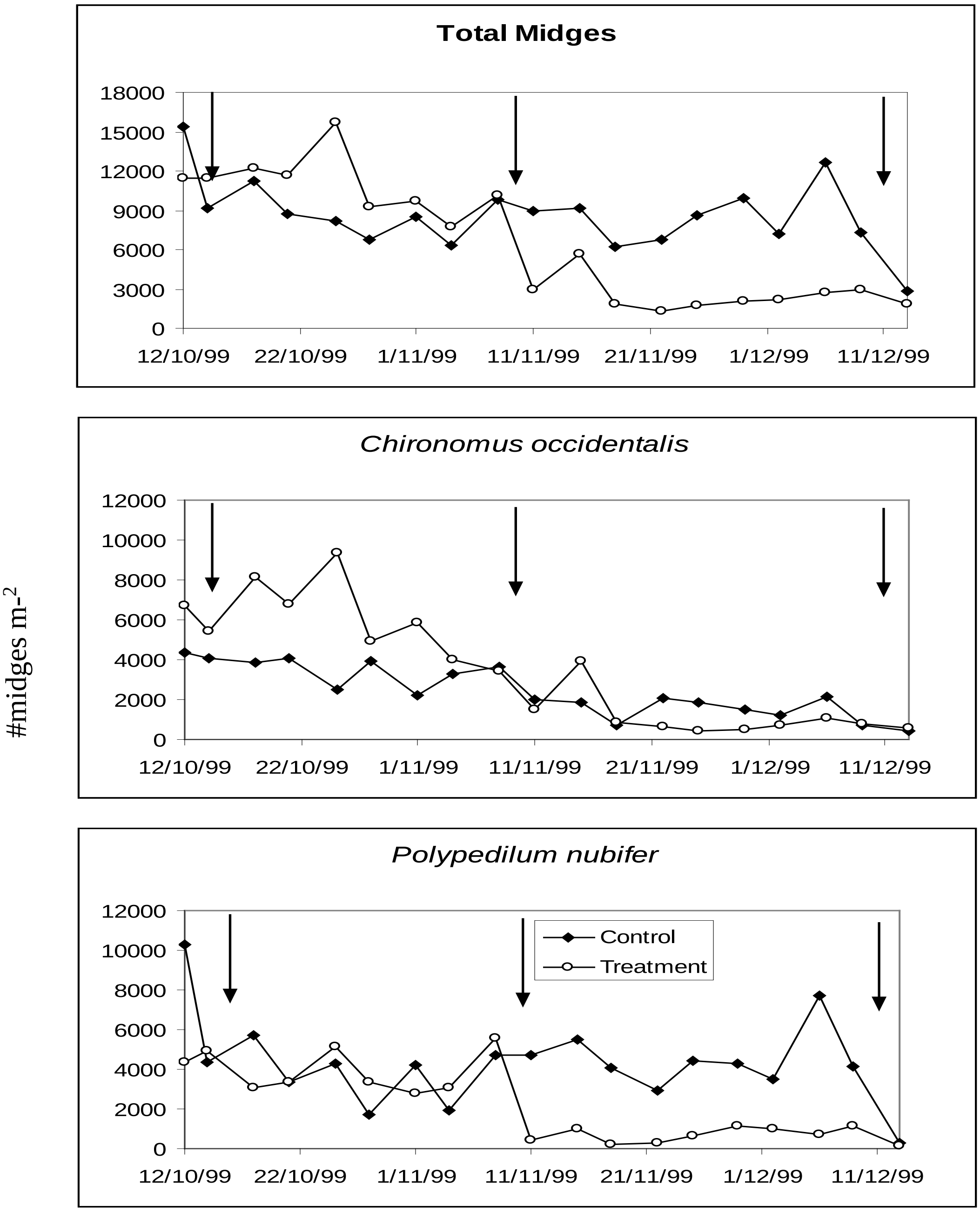

Figure 8: Abundance of midge species in both the control (south) and treatment (north) experimental areas of the Abate® Experiment (arrows indicate when the site was sprayed with Abate®)

Discussion

Two distinct 'hotspot' areas were found within the lake, although it was not possible to determine why midge densities were highest there. In addition, the effectiveness of Abate® as a short-term treatment was demonstrated, although its effectiveness varied between species. One of the outcomes of the research was a recommended monitoring program and a spraying protocol. The protocol was designed to provide refuges for non-target fauna and to find a balance between environmental and public health concerns. The essence of the protocol is that spraying is restricted to the minimum area required and the justification for spraying is based on monitoring data.

In 2000, the Councils adopted this protocol and became responsible for all the monitoring. Unfortunately, the midge problem was very severe despite monitoring data showing that larval numbers should have been acceptable. As I was being consulted on the meaning of the results, I eventually came to the conclusion that it was the Council monitoring program that was inadequate. The Council workers collecting the data were using sites they had previously used rather than those recommended by this study. Once this was corrected, it was obvious that spraying was needed. Spraying was initiated and then everyone waited for the midge problem to ease (it can take a while for the existing adults to die). After two weeks it was obvious that the spraying had not been effective. It was decided that the dosage, which was at the bottom end of the manufacturer recommended rate was inadequate as the lake was marginally deeper than in previous years. The dosage was increased to the upper end of the range and the lake re-sprayed. The midge problem was now over for the rest of the year.

In 2000, the midge problems mobilised the affected residents into a powerful lobby group, which were able to attract media coverage and political interest. The Yellagonga Catchment Group initially attracted considerable criticism for being 'ineffective and unrepresentative' in its response to the midge problem. However, a couple of public meetings changed public opinion and while many of the public are still committed to short-term midge control, most now accept that long-term rehabilitation of the lake is essential for a long-term solution.

The midge crisis has resulted in a joint Agency and Council research fund to examine how the lake can be rehabilitated. It has seen the Yellagonga Catchment Group become the major driver for rehabilitation of the lake, by coordinating public education campaigns, some water quality monitoring and on-ground rehabilitation works. There is no doubt that without the midge problem, water quality within the lake would have been allowed to decline still further. In this sense the midges have truly acted as a catalyst to begin the process of rehabilitation which will have far reaching environmental benefits above those of just controlling midges.

Acknowledgments

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