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Predicting wetland response to nutrient enrichment: modelling temperature, algal blooms and nuisance midge swarms

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Introduction

Lake Joondalup is one of the largest wetlands (504 ha) on the Swan Coastal Plain near Perth, Western Australia. However, the lake is shallow (mean depth 1.27 m) and undergoes large seasonal changes in volume in response to seasonal variation in rainfall and evaporation (CONGDON 1986). Many studies undertaken on the lake have found it to be eutrophic (CONGDON & MCCOMB 1976, CONGDON 1979, GORDON et al. 1981, CONGDON 1986, DAVIS et al. 1993, KINNEAR & GARNETT 1999). CONGDON (1979, 1986) and ROSE (1979) recorded the presence of metaphyton at the lake.

Recent problems (in 1996, 1998 and 1999) with large midge (Diptera: Chironomidae) swarms rising from the lake and reaching nuisance proportions in suburban areas along the north-eastern shore have resulted in local residents seeking management of lake water levels to ensure that deeper conditions are present over the summer. The perception of the local community is that nuisance midge problems are associated with shallow water.

The two major determinants of aquatic insect development are temperature and food availability. Studies of nuisance midge problems at other wetlands on the Swan Coastal Plain found that algal blooms form a rich food source for larval Chironomidae (PINDER et al. 1991). This study sought to develop conceptual models of the occurrence of nuisance midge swarms in relation to water depth, temperature, light climate, nutrient availability, sediment processes and algal biomass as a basis for further field investigations. In addition, a one-dimensional model for predicting the vertical distribution of temperature in lakes and reservoirs (DYRESM) was used to compare the relationship between water depth and water temperature in low and high rainfall years.

Methods

The reported association between low lake water levels and nuisance midge swarms was investigated by examining records of nuisance swarms held by the City of Wanneroo (ELIZABETH FRENCH personal communication) in conjunction with the hydrograph of lake water levels (from 1954 to present) provided by the Water and Rivers Commission. Changes in the nutrient status of the lake were examined by plotting concentrations of total phosphorus, total nitrogen and chlorophyll *a* recorded in a number of studies conducted at irregular intervals from 1985 to the present. Conceptual models and critical pathways in the development of nuisance midge swarms were formulated on the basis of information obtained in a number of previous studies on Perth wetlands (PINDER et al. 1991, DAVIS et al. 1993).

DYRESM, a one-dimensional model developed at the Centre for Water Research (CWR) at the University of Western Australia, was used to compare lake water temperatures under different depth scenarios. A water balance for Lake Joondalup was calculated for each test period using hypsographic curves provided by CONGDON (1985) and data from the Water and Rivers Commission and the Bureau of Meteorology, Western Australia. Water temperatures measured at mid-depth at two sites from 28 October 1999 to 29 February 2000, with HOBO H8 temperature loggers, were used to validate the model. Temperature outputs from DYRESM were visualised using *Modeller* software supplied by CWR.

Results

Midge–lake depth relationships

Nuisance midge problems severe enough to require the use of a larvicide (Temephos) occurred in the spring and summer months of 1981, 1985, 1986, 1991, 1996, 1998 and 1999 (Fig. 1). No records were available prior to 1981. Information provided by the hydrograph indicates that nuisance swarms occurred in years when the maximum depth was no greater than 17.5 m Australian Height Datum (AHD)

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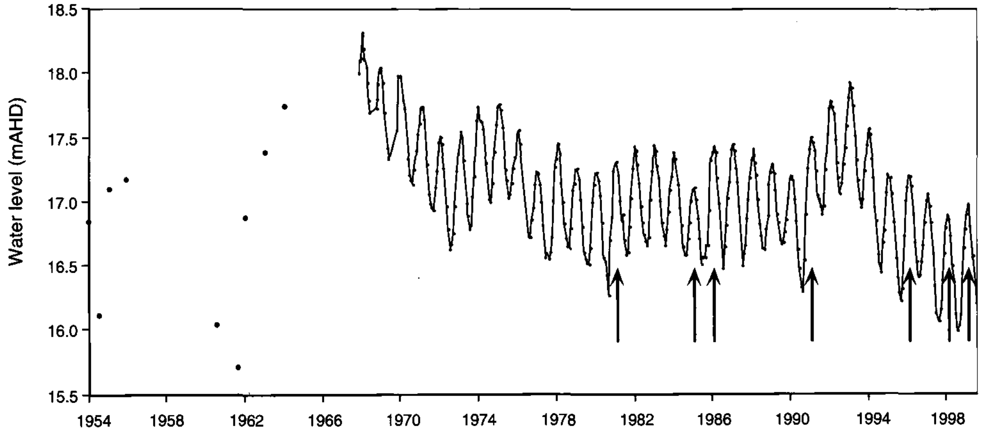

Fig. 1. Water level recorded at Lake Joondalup from 1954 to 1999. Arrows indicate years in which midge outbreaks occurred. Hydrograph supplied by Water and Rivers Commission, Western Australia.

and minimum depth ranged from 16 to 16.6 m AHD. Approximately 80% of the lakebed is exposed at a depth of 16.4 m AHD. These results suggested that midge problems were associated with conditions in which less than 1 m of water was present over most of the lake at maximum depth (September/October) and extensive drying occurred before the end of summer.

Midge problems were also associated with years in which the previous summer water level had been very low (mean = 16.5 m AHD), i.e. summers in which approximately three-quarters of the lakebed was dry.

Lake nutrient status

Compilation of the total phosphorus, total nitrogen and chlorophyll *a* concentrations recorded at the lake over the period from 1985 to present confirmed that the lake is enriched but did not provide any clear evidence that enrichment was increasing.

Midge–temperature relationships

PINDER et al. (1991) found that the most constant predictor of larval midge density (mainly *Polypedilum nubifer*) at North Lake was maximum temperature. Densities of 8000 larvae/m^2 occurred 3–7 weeks after the maximum weekly temperature reached 20 °C. At Forrestdale Lake a rapid rise in the density of larval *P. nubifer* occurred within 4–6 weeks of the median water temperature rising above 22 °C.

Midge–algal–nutrient relationships

Previous investigations into chironomid problems at Perth wetlands found that the density of larval midges increased in response to nutrient enrichment and algal blooms (DAVIS et al. 1988). KIRBY (1991) demonstrated experimentally that significantly higher abundances of larval midges and phytoplankton occurred in enriched ponds than in non-enriched control ponds. The maximum density of larval chironomids in enriched ponds was 11200 ± 2852 larvae/m^2 compared with 287 ± 197 larvae/m^2 in non-enriched control ponds. The maximum chlorophyll *a* concentration recorded in the enriched ponds was 169 ± 115 µg/L in contrast to 8 ± 6 µg/L in the control ponds.

PINDER et al. (1991) found that interannual variation in the abundance of larval *P. nubifer* at North Lake was related to chlorophyll *a* concentration. In the 2 years in which high densities of *P. nubifer* were recorded, the mean spring/summer concentration of chlorophyll *a* was over 130 µg/L whereas in the years with lower larval densities the mean spring/summer concentration was less than 80 µg/L. DAVIS et al (1993) found that non-coloured wetlands with concentrations of total P of <165 µg/L displayed attributes of low to moderate nutrient enrichment. These workers suggested that this may be a reasonable criterion for total P to avoid excessive algal growth.

Depth–temperature relationships

Comparison of the model output against water temperatures recorded from 28 October 1999 to 29 February 2000 (Fig. 2) indicated that model output closely followed measured temperatures. Comparison of the DYRESM output for a period when lake water levels were high and no midge problems were recorded (July–December 1992, Fig. 3) with a similar period when water levels were low and midge problems were present (July–December 1998, Fig. 4) revealed that stratification was not present during either period. Using the criterion of a median temperature of 22 °C for 4 weeks as representing favourable conditions for the development and emergence of *P. nubifer*, it is evident that this was not reached in 1992 until the end of December. This threshold was reached almost a month earlier in 1998. Running the same model for 1992, but with depth reduced by 50% (Fig. 5) to simulate a low water level year, indicated that conditions conducive to midge development and emergence may have been present by the end of October. More interesting, however, was the warm water period in July when conditions were also suitable for midge emergence. Midge problems do occur at the lake in this period (winter) in the years when water levels are low.

Discussion

Many studies (JÓNASSON 1972, DAVIES 1980, AAGAARD 1982, FAIRCHILD & LOWE 1984, RASMUSSEN 1984, WELCH et al. 1988, FAIRCHILD et al. 1989, WINTERBOURN 1990) have documented the relationship between nutrient enrichment, algal abundance and elevated midge populations. However, the relationship between algal abundance and chironomid density is not necessarily a simple one. Chironomids are considered to feed on both live and decaying algae. An algal bloom provides a food source that can support large populations and also provides protection from predators by reducing visibility (FAIRCHILD et al. 1989). However, many larvae potentially gain their nutrition from the bacteria that colonise dying

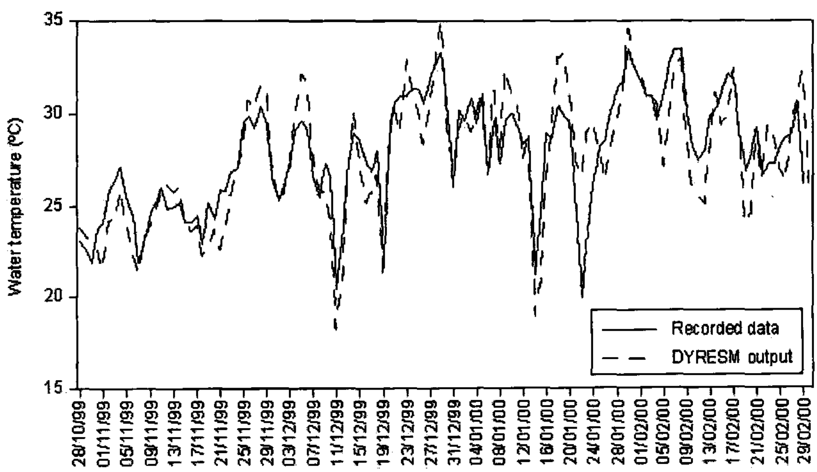

Fig. 2. Model and actual water temperatures recorded at Lake Joondalup from 28 October 1999 to 29 February 2000, at 18:00 h each day.

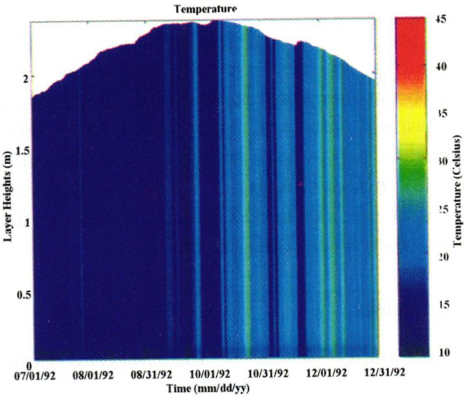

Fig. 3. DYRESM output of temperature for Lake Joondalup from 1 June 1992 to 31 December 1992, at 18:00 h each day.

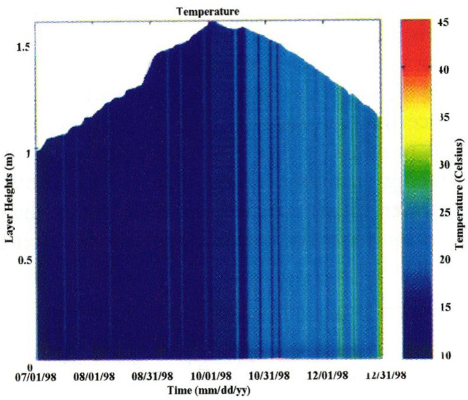

Fig. 4. DYRESM output of temperature for Lake Joondalup from 1 June 1998 to 31 December 1998, at 18:00 h each day.

cells, rather than directly from algal cells (JOHANNSSON & BEAVER 1983). Regardless of whether algae provide a direct or indirect food source, abundant algal growth appears to result in larger populations of larval midges.

Certainly the enriched state of Lake Joondalup suggests that sufficient nutrients are present to fuel large algal blooms. However, the exact form in which algae are available to midges still needs to be determined. In particular, the role of metaphyton in lake nutrient dynamics and as

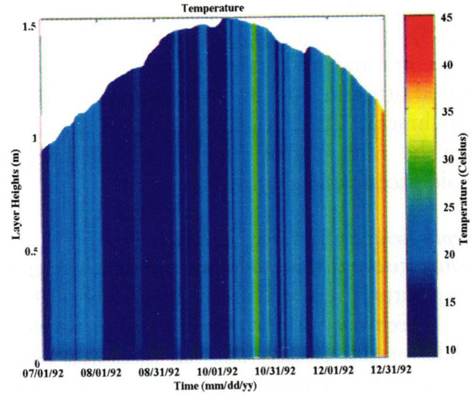

Fig. 5. DYRESM output of temperature for Lake Joondalup from 1 June 1992 to 31 December 1992, at 18:00 h each day, with water level at 50% of actual depth.

a potential food source for larval midges needs to be investigated more fully.

Several alternative conceptual models are proposed to act as a basis for further modelling and the collection of field data.

In the first model it is hypothesised that water temperatures favourable to midge growth occur when the maximum lake depth is <1 m and high evaporation rates result in shallow water occurring over approximately 80% of the lake. Abundant nutrients and high temperatures result in phytoplankton blooms that provide an abundant food source for midges. High water temperatures also directly favour midge growth.

The second model proposes that drying of most of the lake bed in the previous summer combined with the presence of shallow warm water the following spring promotes the release of nutrients from the sediments that in turn drive large algal blooms. High water temperatures directly favour midge development in addition to indirectly promoting a large food source by facilitating the development of cyanobacterial blooms.

The third model proposes that drying of most of the lakebed in the previous summer combined with the presence of warm, shallow water the following spring promotes the release of nutrients from the metaphyton on rewetting.

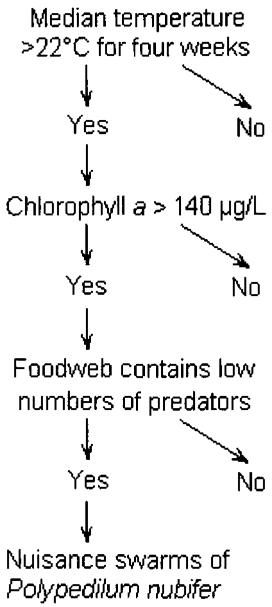

Fig. 6. Critical pathway in the development of nuisance midge swarms.

This process in turn promotes development of a richer micro-layer of benthic algae in the upper metaphyton, which provides an abundant food source for larval midges. Shallow water overlying the metaphyton may also result in a greater oxygenation of the benthic algal layer than when deeper water is present.

Sufficient data now exist to formulate a critical pathway (Fig. 6) for the development of nuisance midge problems in Perth wetlands. However, the critical pathway illustrated still requires refinement for the specific problems occurring at Lake Joondalup. In particular, the nuisance midge species is often *Chironomus alternans* and the major food source may be benthic algae rather than phytoplankton. Further research will use the ecological model CAEDYM to investigate the relative influence of water depth, temperature and nutrients on the development of phytoplankton and benthic algae. Field sampling will be undertaken to more fully determine the food sources driving the development of midge populations to nuisance levels.

References

Aagaard, K., 1982: Profundal chironomid populations during a fertilization experiment in Lanvatn, Norway. – *Holarctic Ecol.* 5: 325–331.

Congdon, R. A., 1979: *Hydrology, Nutrient Loading and Phytoplankton in Lake Joondalup: A Feasibility Study.* Bulletin No. 67. – Department of Conservation and Environment. Perth, Western Australia.

Congdon, R. A., 1985: *The Water Balance of Lake Joondalup.* Bulletin No. 183 – Department of Conservation and Environment. Perth, Western Australia.

Congdon, R. A., 1986: *Nutrient Loading and Phytoplankton Blooms in Lake Joondalup, Wanneroo, Western Australia.* Technical Series 6. – Department of Conservation and Environment. Perth, Western Australia. 99pp.

Congdon, R. A. & McComb, A. J., 1976: The nutrients and plants of Lake Joondalup, a mildly eutrophic lake experiencing large seasonal changes in volume. – *J. R. Soc. Western Aust.* 59: 14–23.

Davies, I. J., 1980: Relationships between dipteran emergence and phytoplankton production in the Experimental Lakes Area, North-western Ontario, – *Can. J. Fish. Aquat. Sci.* 37: 523–533.

Davis, J. A. & Rolls, S. W., 1987: *A Baseline Biological Monitoring Programme for the Urban Wetlands of the Swan Coastal Plain, Western Australia.* – Environmental Protection Authority, Perth Western Australia, Bulletin 265, March 1987.

Davis, J. A., Harrington, S. A. & Pinder, A. M., 1988: *Investigations into more Effective Control of Nuisance Chironomids (midges) in Metropolitan Wetlands.* – Report prepared for the Midge Research Steering Committee, Perth, Western Australia, 116 pp.

Davis, J. A., Rosich, R. S., Bradley, J. S., Growns, J. E., Schmidt, L. G. & Cheal, F., 1993: Wetland classification on the basis of water quality and invertebrate community data. In: *Wetlands of the Swan Coastal Plain* (6) – Water Authority of Western Australia and the Environmental Protection Authority. 242 pp.

Fairchild, G. W. & Lowe, R. L., 1984: Artificial substrates which release nutrients: effects of periphyton and invertebrate succession. – *Hydrobiologia* 114: 29–37.

Fairchild, G. W., Cambell, J. M. & Lowe, R. L., 1989: Numerical response of chydorids (Cladocera) and chironomids (Chironomidae) to nutrient-enhanced periphyton growth – *Arch. Hydrobiol.* 114: 369–382.

Gordon, D. M., Finlayson, C. M. & McComb, A. J., 1981: Nutrients and phytoplankton in three shallow lakes of different trophic status in Western Australia. – *Aust. J. Mar. Freshw. Res.* 32: 541–543.

Johannsson, O. E. & Beaver, J. L., 1983: Role of algae in the diet of *Chironomus plumosus* f. *semireductus* from the Bay of Quinte, Lake Ontario. – *Hydrobiologia* 107: 237–247.

Jonasson, P. H., 1972: Ecology and production of the profundal benthos in relation to phytoplankton in Lake Esrom. *Oikos Supplements* 14: 1–148.

KINNEAR, A. & GARNETT, P., 1999: Water chemistry of the wetlands of the Yellagonga Regional Park, Western Australia. – *J. R. Soc. Western Aust.* **82**: 79–85.

KIRBY, D., 1991: *The Relationship between Nutrient Enrichment and Midge Production in Perth Wetlands.* Murdoch University Honours Thesis, School of Biological Sciences.

PINDER, A. M., TRAYLER, K. M. & DAVIS, J. A., 1991: *Chironomid Control in Perth Wetlands: Final report and recommendations.* – Report to the Midge Research Steering Committee. Perth, Western Australia. 144pp.

RASMUSSEN, J. B., 1984: The life history, distribution and production of *Chironomus riparius* and *Glyptotendipes paripes* in a prairie pond. – *Hydrobiologia* **119**: 65–72.

ROSE, T. W., 1979: *Periphyton and Metaphyton in Lake Joondalup.* Honours Dissertation. – University of Western Australia, Perth.

WELCH, H. E., JORGENSON, J. K. & CURTIS, M. F., 1988: Emergence of Chironomidae (Diptera) in fertilized and natural lakes at Saqvacjuac, N.W.T. – *Can. J. Fish. Aquat. Sci.* **45**: 731–737.

WINTERBOURN, M. J., 1990: Interactions among nutrients, algae and invertebrates in a New Zealand mountain stream. – *Freshwater Biol.* **5**: 163–170.

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