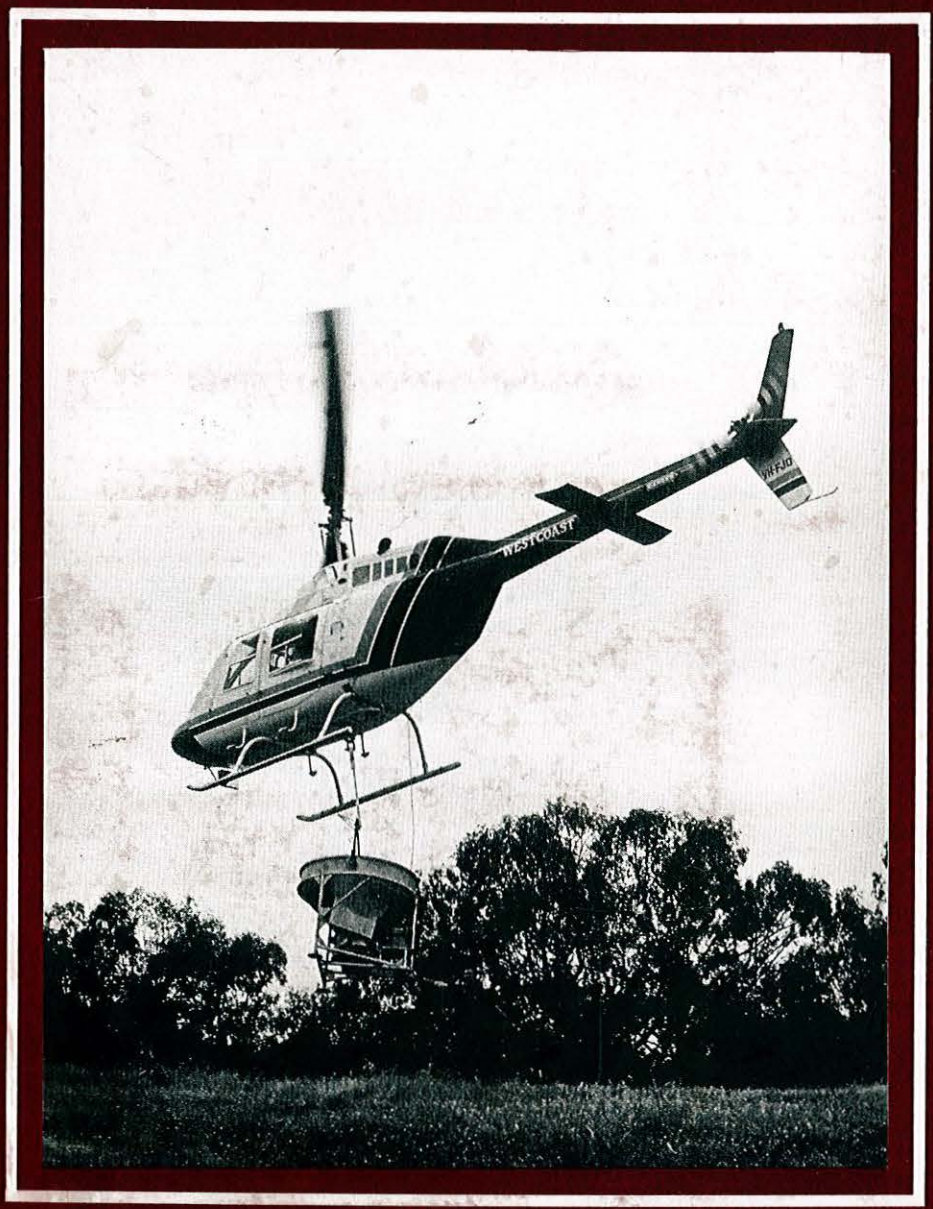
TOWARDS MORE EFFECTIVE CONTROL OF NUISANCE CHIRONOMIDS (MIDGES) IN METROPOLITAN WETLANDS, PERTH, WESTERN AUSTRALIA



J.A. DAVIS, A.M. PINDER, K.M. TRAYLER & S.A. HARRINGTON

MURDOCH UNIVERSITY

1990

Towards More Effective Control of Nuisance Chironomids (Midges) in Metropolitan Wetlands, Perth, Western Australia.

A Report on the Third Year of Research (June 1989 to May 1990)

Prepared for

The Midge Research
Steering Committee

By

J.A. Davis
A.M. Pinder
K.M. Trayler
S.A. Harrington

School of Biological and
Environmental Sciences
Murdoch University
Murdoch W.A. 6150

May 1990

CONTENTS

Page

ACKNOWLEDGEMENTS

A Midge Research Steering Committee was established in Perth in August 1987 to oversee research into more effective and environmentally acceptable methods of reducing the nuisance caused by non-biting midges to residents living near wetlands in the Perth metropolitan region. During the 1989/90 research the steering committee comprised representatives from the Department of Conservation and Land Management, the Environmental Protection Authority, the Department of Planning and Urban Design, and the Cities of Armadale, Cockburn, Melville, Perth, South Perth, Stirling, Swan, and Wanneroo and the University of Western Australia.

This study was funded by the three state and eight local government authorities listed above and their interest and support is gratefully acknowledged.

Composition of the 1989/90 Midge Research Steering Committee

Mr. J. Lane	CALM (Chairperson)
Dr. R. Humphries	EPA (Co-chairperson)
Mr. J. Sutton	"
Ms. M. Ward	DPUD
Mr. J. Stubbs/ Mr. N. Hume	City of Armadale
Mr. D. Ashby/ Mr. C. Lister	City of Cockburn
Mr. G. Dunne	City of Melville
Mr. A. Van Leeuwen	City of Perth
Mr. B. Burnett	City of South Perth
Mr. D. Rajah	City of Stirling
Mr. P. Kampen/ Mr. M. Pasalich	City of Swan
Mr. J. Erceg	" "
Ms. L. Schwarzbach/ Mr. G. Potter	City of Wanneroo
Dr. D. Edward	University of Western Australia

The Chairperson, Mr Jim Lane together with Dr. Bob Humphries and Mr. John Sutton of the EPA are particularly thanked for their guidance and advice throughout the year.

Representatives of Local Government Authorities provided assistance in various ways and their contributions were greatly appreciated. The collection of adult midge samples from residents living near Forrestdale Lake and North Lake was carried out by the Armadale and Cockburn City Councils respectively. Perth and Wanneroo City Councils provided samples of larvae from their monitoring programmes for identification. The assistance of Cockburn and Melville City Councils during the field trials at North Lake was invaluable, as was the cooperation of Drew Haswell from CALM during the Forrestdale Lake field experiment. Adrian Van Leeuwen and the City of Perth are thanked for providing data collected from the Lake Monger light traps.

We are especially indebted to Wellcome Australia Ltd. for provision of the Sumilarv insecticide, and in particular Mr. Steve Broadbent for helpful advice and discussions. We also gratefully acknowledge the EPA and the Health

Department of WA for allowing the whole lake Sumilarv experiments to be carried out at North Lake.

Many residents living adjacent to Forrestdale and North Lakes either regularly collected samples of adult midges or allowed us to hang light traps or thermometers on their properties.

Nutrient analyses were carried out by Mr. M. Lund and staff of the Centre for Water Research at Murdoch University. Weather data for Perth was obtained from the Bureau of Meteorology.

Sue Harrington left the project in September to take up a position at the Department of Agriculture. We are indebted to Sue for the high standards she brought to the study and the hard work she put in over two and a half years with the project.

We would like to thank Ms. Karen McRoberts and Mr. Jonathon Mercer for their invaluable and enthusiastic involvement in the project during the summer months. Mr. Mark Garkaklis competently carried out the job of 'midge troubleshooter' during the summer and wrote up a summary of his advice to local government as a chapter of this report. Ms. S. Balla and Mr. M. Garkaklis assisted in the field work and Mr M. Lund coordinated continued sampling of Jackadder Lake as a followup to the Alum experiment carried out during the 1988/89 research.

SUMMARY

1. This report describes the results of the third year (1989/90) of a research programme undertaken to determine more effective and environmentally acceptable methods for control of nuisance midges near urban wetlands.

2. The effectiveness of Abate under field conditions at North Lake and Forrestdale Lake was investigated by the use of enclosures to compare the density of midge larvae in treated and untreated (control) areas before and after the aerial application of Abate to each lake. Six enclosures set up at North Lake in September were destroyed by a sudden storm and no results were obtained. However, although not definitive, the results of the larval monitoring programme suggested that the September application of Abate at the lake was ineffective because larval numbers increased after the treatment.

Six enclosures were constructed at Forrestdale Lake to enable the effectiveness of an Abate treatment in December to be assessed. Abate was applied at a rate of 2.2kg/ha. Tray catches revealed that the actual mean application rate was 3.02 ± 1.03 kg/ha, indicating that the application was fairly even and the rate accurate. Densities of *Polypedilum nubifer* were significantly lower ($P < 0.01$) after the treatment than before. However there was no significant difference between treated and control areas. It was unlikely that the dramatic population decrease observed throughout the lake and in the treated and control areas would have occurred naturally within the controls, rather the controls were contaminated by pesticide shortly after the experiment began. Continued use of Abate at Forrestdale appears justified on the basis that it still appears effective against *P. nubifer* when applied correctly at the maximum rate for a given depth of water.

Despite the recent difficulties encountered with the use of enclosures for monitoring the effectiveness of Abate, their successful use in field trials of Sumilarv and previously with Abate in 1988 suggest that their use should be continued.

3. Laboratory trials were undertaken to determine the susceptibility of larvae of the major pest species, *P. nubifer*, to Sumilarv 0.5G, an insect growth regulator. Probit analysis of the results indicated that 50, 75 and 90 % inhibition of emergence should be achieved by using application rates of 1.7, 4.4 and 10.0 kg/ha respectively. An application rate of 10 kg/ha (assuming a depth of 50 cm) is probably the most suitable rate for use in the urban wetlands against *P. nubifer*. Further laboratory testing is required to determine the susceptibility of other pest species, in particular, that of *Chiromomus occidentalis*.

4. Two field trials of Sumilarv 0.5G were performed at North Lake during the summer of 1989/90. Enclosures were constructed in the littoral region

of the eastern side of the lake to enable the effectiveness of Sumilarv 0.5G to be assessed by comparing the rate of adult emergence in treated and untreated (control) areas before and after application of the IGR. A helicopter was used to apply Sumilarv to the littoral region at an application rate of 10kg/ha (50 gAI/ha) on both occasions.

Statistical analysis of the results of the first field trial (two way ANOVA) revealed a significant difference between the rate of emergence of adult midges in the treated enclosures compared with the controls ($P<0.01$). There was a significant decrease ($P<0.01$) in the rate of midges emerging from the treated enclosures three days after application of Sumilarv and a 99% reduction occurred after nine days. There were no significant changes in the rate of midges emerging from the control enclosures during the trial. Emergence of *P. nubifer* and *C. alternans* were both affected in this way.

The results of the second trial were not as clear as that of the first possibly because the number of midges emerging prior to the second application of Sumilarv was very low. The rate of emergence from the control enclosures was significantly higher ($P<0.01$) than that from the treated enclosures however the rate of emergence from both decreased after treatment.

5. The results of both the field and laboratory trials of Sumilarv indicate that it has considerable potential as an alternative to Abate for the control of midges. Information provided by Wellcome indicates that Sumilarv may be sold at a comparable cost to Abate on a per hectare basis and should be registered for use in Australia by 1992. Sumilarv is desirable from an ecological and environmental viewpoint because it is likely to affect a much narrower range of organisms than Abate which is a fairly broad spectrum organophosphate pesticide. However insufficient information is currently available on the effects of Sumilarv on the non-target fauna of Perth wetlands for its exact ecological impacts to be known.

6. The "evenness" of the application of granular Sumilarv to North Lake by helicopter was investigated during both trials with floating aluminium trays to catch the Sumilarv as it was applied. Insignificant amounts of Sumilarv were obtained in the trays indicating that the 'treated' enclosures and the water immediately adjacent to them had not received any Sumilarv. As a consequence Sumilarv was added to the treated enclosures by hand. This result clearly indicated the importance of checking that a homogeneous application of a pesticide has occurred, otherwise poor results may be attributed to an ineffective compound or an ill-timed application when in fact large areas of the lake may have remained untreated. In this case a high rate of release of Sumilarv from the hopper may have resulted in all of the compound being released before the helicopter had covered the entire littoral area.

In the second trial almost half of the trays were sunk by the downdraft generated by the helicopter. The mean rate of application calculated from the remaining trays was 3.3 ± 0.9 kg Sumilarv/ha with a range of 0 - 7.1 kg/ha. The mean application rate was considerably lower than the intended

10kg/ha however this may be an underestimate of the application rate for the entire littoral region because of the low number of trays from which catches were scored.

7. The use of a helicopter for application of granular pesticides is considered to be an improvement over fixed wing aircraft. The helicopter can target specific regions, for example, the littoral zone of a lake, much more easily than a fixed-wing aircraft which usually has to make a number of short straight passes. However problems concerning the rate of release of granules from the hopper still need to be addressed to ensure that a homogenous distribution of pesticide occurs over the target area.

8. The regular (fortnightly) larval monitoring programme first undertaken by the Murdoch research team in 1987 was continued for a third year at North Lake and Forrestdale Lake in 1989/90. Physico-chemical and nutrient data were also recorded for each sampling occasion at each lake. The qualitative adult sampling programme and assessment of midge nuisance levels by householders was continued by the Cockburn and Armadale City Councils respectively.

Regular larval sampling programmes were continued at Lake Goollelal and Lake Monger by the Wanneroo and Perth City Councils respectively, and samples of larvae from these lakes were identified to species level by the Murdoch research team.

Quantitative data on adult midge nuisance and species composition were collected using light traps placed near four residences at North Lake. Data on adult emergence were collected at Forrestdale and North Lakes during the summer months using submerged emergence traps.

9. As observed in 1988/89 the pattern of change, peaks in larval density and species composition of the larval populations were quite different between North Lake and Forrestdale Lake. Adult species composition and nuisance levels also varied between the two lakes. Much of these differences probably occured because Forrestdale Lake almost dried out in late summer whilst North Lake contained permanent water over the summer months and so physico-chemical conditions within the two lakes were quite different. Such differences mean that different strategies have to be employed for midge control at the two lakes.

10. Larval abundances at both Forrestdale Lake and North Lake were the highest recorded since the start of research at both lakes. Abate was applied twice at Forrestdale Lake and each treatment was considered to be effective because it resulted in a 99% or more reduction in larval density and a substantial reduction in nuisance problems.

Despite high larval densities at North Lake the nuisance problems experienced by residents were comparatively low. Both Abate and Sumilarv were applied to the lake twice. Adult emergence declined by more than

95% within two weeks of each of the Sumilarv treatments and emergence remained low for the next two to three weeks, in both cases. No reduction in emergence or larval densities was recorded after the first Abate treatment but a moderate reduction was recorded after the second application.

Larval densities at Lake Goollelal were lower than during 1988/89 and no treatment was considered necessary. Abate was applied twice to Lake Monger, no data was available on the effectiveness of the first treatment but the second appeared to be successful.

11. Four light traps were used to collect adult midges at selected residences at North Lake from November 1988 to March 1989. The influence of wind speed and direction on catches was examined but no general relationships were detected. These results suggested that midge distribution is not highly influenced by wind however the wind data used was for Perth city rather than North Lake. Micrometeorological conditions are probably important and a more thorough analysis would involve continuous local weather monitoring while light traps were operating.

12. Analysis of the three years of environmental data collected at Forrestdale Lake revealed that the timing of a dramatic increase in the population of *P. nubifer* and hence the onset of nuisance swarms appeared to be dependant upon water temperature, depth and chlorophyll-*a* concentrations (a measure of algal abundance). Severe midge problems have been experienced at the lake four to five weeks after the depth has fallen below 90 cm, four to seven weeks after water temperature is first recorded above 25 ^{o}C and seven weeks after the first peak in chlorophyll-*a* was recorded. These results indicate that environmental data can be used in a predictive capacity to identify the onset of midge problems at the lake.

13. Rainfall appears to be the most important climatic variable influencing midge populations because it directly influences lake depth and indirectly influences water temperature (which is partly a function of depth) and algal growth (partly a function of water temperature and nutrients washed into the lake with winter runoff). This finding has implications for the role that climate change may play with regard to future wetland water levels, water temperatures and the time of onset of midge problems in shallow wetlands.

14. A 'midge troubleshooter' was employed over summer to assist councils with setting up their own monitoring programmes. As a result of feedback from that initiative, further information is provided in this report to assist local government personnel with the use of the standard method for monitoring larval densities.

15. Several alternatives to the chemical control of midges were investigated during 1989/90. Positive results obtained from eleven light

traps placed on the north-western side of Lake Monger by Perth City Council indicated that light traps are potentially important as part of an integrated midge control programme. Although the dataset that has been obtained so far is limited, the lights were estimated to trap between 7 and 11% of the midges emerging from the lake per night. If further lights are installed at the lake total catches are expected to rise to an amount which may result in a substantial impact upon the problem.

16. The use of alum to reduce algal blooms (an important food source for larval midges) at Jackadder Lake had previously been noted to result in a short term improvement in water quality and a reduction in the abundance of larval midges. Data now obtained on phosphorus levels indicate that alum has the potential to reduce phosphorus concentrations in Perth wetlands. However large scale use of alum may not be desirable as overseas studies have drawn attention to possible links between the use of alum in water supply storages and Alzheimers disease.

17. Economic, effective and environmentally safe use of pesticides for midge control requires that they are used only at strategic times. Determining the most appropriate time for treatment has been a major objective of this study. The use of larval density thresholds was suggested in the previous report as a guide to the timing of treatments. This approach appears useful at North Lake where a good monitoring programme is in place and larval densities increased gradually over spring. An additional approach using critical values of environmental parameters is suggested for Forrestdale Lake where larval densities increased dramatically within two weeks. The use of these critical parameters in conjunction with a larval density threshold should result in accurate prediction of impending midge problems and the most appropriate time to treat the lake.

18. The results of research so far indicate that short term control of midge problems will be improved by the monitoring of larval densities, water depth and temperature so that larval thresholds and critical values can be used to predict appropriate times to treat. Sumilarv holds considerable promise as an alternative to Abate at lakes where the former appears ineffective. Homogenous distribution of pesticide is also important for effective control and the use of helicopters rather than fixed wing aircraft should facilitate more specific treatment of problem areas, in particular, the littoral zone of deep wetlands. However, for these techniques to be of any value management procedures also need to be established to allow swift response (i.e rapid treatment) to predictions of impending midge problems. Further attention to this aspect of midge control is needed on the part of local and state government authorities.

19. The proposed major objectives of midge research in 1990/91 are :

a) Field and laboratory testing of Sumilarv and determination of effects on the non-target fauna. Field testing will focus on whole lake trials at Lake

Monger. The light traps already installed, used in conjunction with emergence traps, will provide valuable information on adult abundances in response to treament. The presence of the light traps and installation of a local weather station at the lake would provide the ability to examine the effects of micrometeorological conditions on midge swarms.

b) Testing of the predictive capacity of the observed relationship between environmental parameters and nuisance outbreaks of *P. nubifer*. This will involve the continuation of larval and environmental monitoring programmes at Forrestdale Lake. Less intensive monitoring will be undertaken at North Lake because of the time constraints imposed by field trials at Lake Monger. However sufficient data will be collected to enable the possible impact of reduced nutrient inputs, due to the diversion of the Veterinary Farm drain, on midge densities to be determined.

c) Consideration of water quality management issues will be undertaken as part of a more holistic approach to midge control. There is evidence in both the scientific literature, and in data collected from Perth lakes, to suggest that eutrophication has a positive effect upon chironomid densities. While further work is required to establish more definite links the evidence is sufficient to suggest that poor water quality in general, and nutrient enrichment in particular of the urban wetlands must be addressed as a longer term approach to the solution of midge problems.

INTRODUCTION

This report describes the results obtained from the third year of a research programme undertaken to investigate more effective and environmentally acceptable methods of controlling midges near some of Perth's major wetlands. The results of the first two years of study were reported previously (Davis, Harrington and Pinder, 1988, 1989) and readers are asked to consult those reports to obtain a background to the work reported here.

The objectives for the third year of study were as follows:

1. To undertake laboratory and field testing of insect growth regulators (IGRs), synthetic pyrethroids and granulated Bti.

- Results obtained in the previous two years of study indicated that an alternative to Abate was needed for effective short term control of midge problems at many of the urban wetlands. The high rates of Abate needed to achieve 95% mortality of *P. nubifer* under controlled conditions in the laboratory suggested that some resistance to Abate was present in the gene pool of this species. In addition Abate is considered to be less effective in eutrophic waters. Many of the urban wetlands where Abate is used are highly eutrophic, for example, Bibra Lake, Lake Monger and North Lake. An alternative to Abate which was not influenced by eutrophication would be desirable for treatment of midge problems at these lakes.

Abate is the only compound registered for use against midges in Western Australia and alternative compounds are not freely available. The choice of compounds to be tested largely depended upon whether or not they could be obtained in sufficient quantity and appropriate formulation for both our trials and subsequent use by local authorities on a scale similar to the use of Abate. In the course of this year's study it became evident that only Sumilarv, an IGR, and Perigen, a synthetic pyrethroid, fulfilled these criteria. The use of synthetic pyrethroids is not ecologically desirable in wetlands because of their high toxicity to fish, and no supplier of sufficient quantities of Bti in a granular form could be found. Sumilarv, a new compound which should be registered and available for use within the next two years, was made available to the Midge Study Team for testing by Wellcome Australia

2. To monitor the effectiveness of selected midge control treatments applied by local authorities.

- Pesticides which appear to be effective under laboratory conditions may not necessarily achieve the control expected when applied to a wetland. Laboratory results act as a guide to expected effectiveness in the field but local conditions may mediate effects in a variety of ways. For this reason field testing of pesticide treatments was considered to be an important component of this years study and monitoring of treatments at both North Lake and Forrestdale Lake was proposed.

To properly determine the effectiveness of an application of a pesticide to a wetland it is important that a control area remain untreated. Plastic

enclosures were successfully used at North Lake in 1988 to determine the effectiveness of an aerial application of Abate to the lake. Treatment and control areas were used so that the effects of the pesticide on larval densities could be separated from any natural fluctuations that may have occurred. Similar enclosures were to be used at North Lake and Forrestdale Lake to monitor treatments during this study.

Because poor control of midge problems following a treatment may also be the result of patchy application rather than an ineffective pesticide it is important that the "evenness" of distribution of an aerial application of a pesticide is monitored. This was to be undertaken at both lakes using a series of floating trays.

3. To continue larval and adult monitoring programmes at North Lake and Forrestdale Lake and to collect the environmental data necessary to construct a predictive model of midge production.

- Last year we noted that our objectives in monitoring the abundance of larval and adult midges at North Lake and Forrestdale Lake were twofold. Firstly, at the conclusion of the first year of study we had suggested a density of 2 000 larvae of *P. nubifer* per square metre as the threshold which signalled the onset of nuisance swarms of adults. During the second year of study this estimate was refined such that a threshold of 500 larvae/m^2 appeared more appropriate for a large lake such as Forrestdale while a density higher than 2 000 larvae/m^2 was probably a more suitable threshold for North Lake. Further data relating larval densities and adult nuisance levels were required from the 1989/90 study to enable better estimations of the threshold levels to be made. In addition, as in previous years, the monitoring data collected in 1989/90 would be sent fortnightly to the relevant local authorities so that treatment with Abate (or Sumilarv at North Lake) could be undertaken at the most appropriate times.

We also needed to obtain reliable estimates of population densities to provide a basis for determing the factors which influence the distribution and abundance of the pest species. We needed to determine the environmental conditions which resulted in an increase in the pest species to unacceptable levels. Such data would enable midge problems to be predicted in advance from fairly simple monitoring of environmental parameters.

Continuation of this approach for the third year of study was considered to be extremely important because it would provide a data set of sufficient temporal duration to indicate interannual variability in midge abundances and problem outbreaks at the urban wetlands.

4. To undertake further development of a standard method of monitoring larval midge densities for use by local authorities.

- The importance of monitoring larval densities so that larvicides can be applied at the most appropriate time is well recognised, however the success of this approach depends upon the implementation of a suitable sampling programme. A simple but accurate standard method for monitoring larval densities that could be used by the staff of local authorities was developed

during the second year of the study. A 'midge troubleshooter', Mr Mark Garkaklis, was appointed for three months during the summer of 1989/90 to assist members of the Steering Committee who were running their own monitoring programmes. Mark was also asked to identify further information that could be provided to improve implementation of the standard monitoring programme.

5. To investigate alternatives (both short and long term) to the chemical control of midges.

- The number of midges caught at a large light trap placed on the western side of Bibra Lake by Cockburn City Council in October 1988 indicated that light traps may have some potential as part of an integrated midge control programme. Eleven light traps were installed on the north-western shore of Lake Monger in February 1990 and information on their design and numbers of adult midges caught during February and March has been provided for inclusion in this report by Adrian Van Leeuwen of the City of Perth.

Last year an experiment was undertaken at Jackadder Lake to determine the potential of alum to reduce nutrient concentrations in lakes, and thus reduce algal blooms (an important food source for midges). Some of the initial results were presented in last years report. Since that time, nutrient analyses have been completed and further sampling has been carried out. This additional data are discussed in this report.

FIELD TESTING OF THE EFFECTIVENESS OF ABATE

INTRODUCTION

When pesticides are applied to lakes or other water bodies to control midge populations, a subsequent reduction in that population is expected. The effects of the pesticide on the midge population needs to be assessed so that ineffective and uneconomic treatments are not continued. However, monitoring of midge larval densities before and after the pesticide treatment is not sufficient to enable the effects of the pesticide to be separated from any natural decrease in the population that may also have occurred. To properly determine the effect of the pesticide, some areas of the water body must remain untreated. This theory was put into practice by using enclosures to test the effectiveness of Abate in the field during the 1988/89 research programme.

One of the priorities for the 1989/90 research was to test the effectiveness of Abate under field conditions at both North Lake and Forrestdale Lake. The application of Abate to North Lake in September appeared to be ineffective as midge larval numbers increased (Fig. 15). Enclosures had been set up to monitor the effectiveness of the treatment but these were destroyed by a sudden storm event. As a consequence of this unexpected natural disruption, no results were obtained from this experiment.

The application of Abate to Forrestdale Lake in December was followed by a rapid decline in the midge population (Fig. 15). Enclosures were set up to determine whether the decline was due to Abate or to a natural population flux and the results of this experiment are discussed in greater detail below.

Results obtained during the previous year's (1988/89) research indicated that the distribution of pesticide applied by fixed wing aircraft was patchy. Application by helicopter was suggested as an alternative and all pesticides used during the 1989/90 study were to be applied by this method, depending upon the availability of the helicopter. The helicopter carries a hopper which is filled with the required amount of pesticide and calibrated to release the pesticide at a given rate (Fig. 1A). The 'evenness' or 'patchiness' of distribution of the granular pesticides and/or the rate at which they were applied, were measured using interception trays to catch the pesticide as it fell.

FORRESTDALE LAKE FIELD EXPERIMENT

METHODS

Enclosure Design

Six enclosures were constructed using the same material and methods as used for the Abate experiment at North Lake during the 1988/89 study (Davis, Harrington and Pinder 1989). The construction of the enclosures and the application of Abate to the lake took place on the 19th December 1989.

The enclosures were placed in water, approximately 40cm deep, on the north eastern side of the lake, over a substrate of sandy clay. The top of the

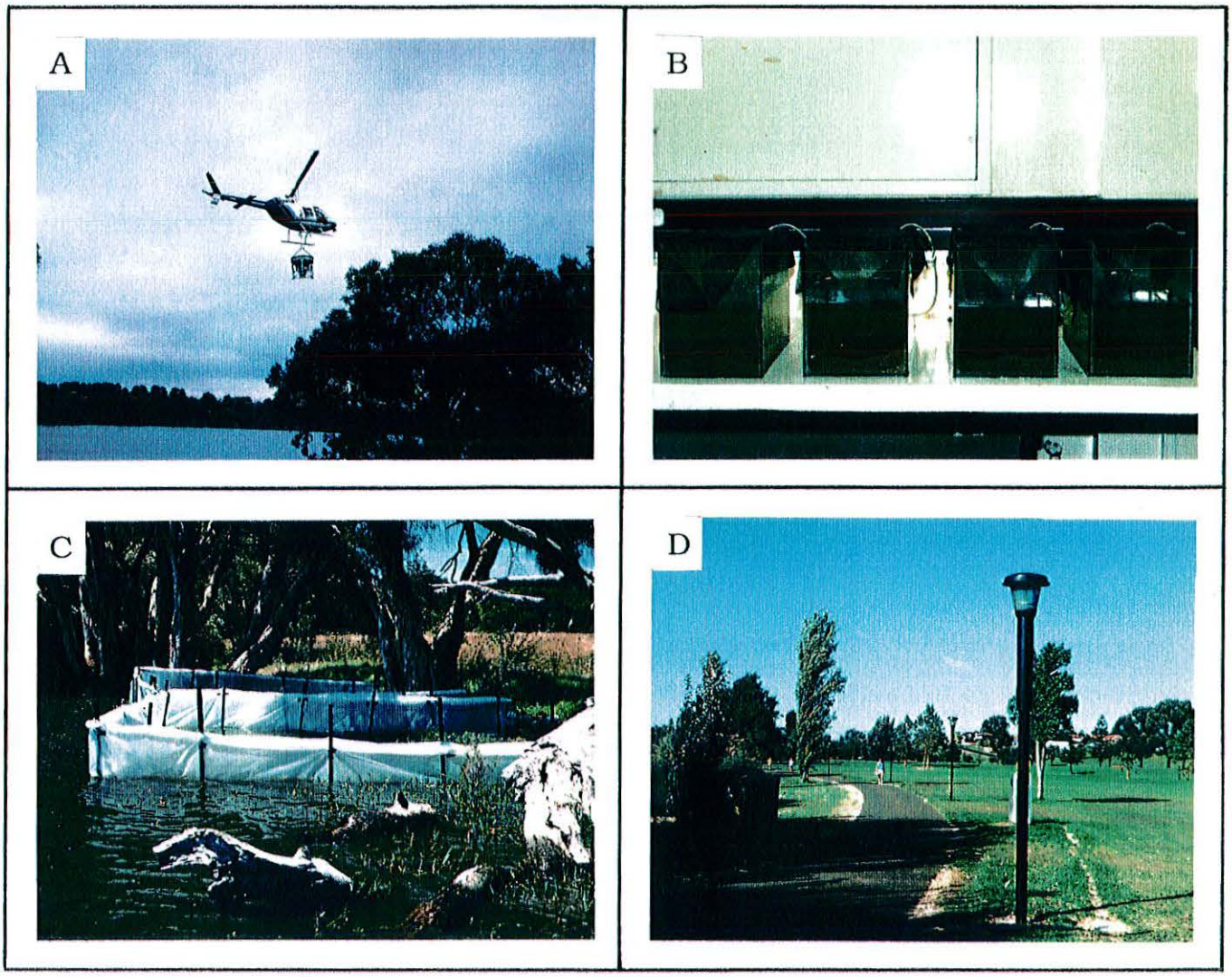


Figure 1. Photographs showing A: Helicopter used to apply pesticides to Forrestdale and North Lakes, B: Aquaria used to test Sumilarv 0.5G in the laboratory, C: Enclosures used at North Lake for field trials of Sumilarv 0.5G, D: Light traps installed at Lake Monger.

enclosures were tied above the water surface to metal star pickets and the bottom edges were weighed down with bricks tied around the PVC pipes. Black plastic sheeting was used to cover all the enclosures when the pesticide was being applied. Due to time constraints, no larval samples (sediment cores) and only one water sample was taken before the application of Abate to the lake. The application by helicopter at a rate of 2.2 kg/ha (110 gAI/ha) took place in the early afternoon. Immediately after application, the covers were removed from all the enclosures and larval samples were collected. The density of midge larvae in those samples was assumed to be identical to that which would have been present before the application. Abate was then applied, by hand, at a rate of 2.2 kg/ha to three of the enclosures. The remaining enclosures received no pesticide and thus, acted as controls. Larval and water samples were taken on three further occasions: three, eight and sixteen days after treatment.

On each sampling occasion, three sediment cores were collected from each enclosure using a corer of 9.8cm diameter. The locations of these were determined randomly, and in such a way that an area was cored only once. In addition nine cores were taken from the sediment outside the enclosures on each occasion. The sediment samples were preserved and sorted at a later date using the calcium chloride differential flotation method.

The water sample taken before the application of Abate, was assumed to be representative of the water in all of the enclosures. Subsequent water samples were taken from each enclosure and from three locations in the adjacent water, on each occasion. The water samples were taken back to the laboratory for measurement of pH and conductivity. The concentration of chlorophyll-a in these water samples was determined by M. Lund at Murdoch University.

Measurement of the Evenness of the Abate Application

Abate was added to the treated enclosures by hand to ensure that the enclosures received only the required amount of pesticide. Thus the effectiveness of Abate at a rate of 2.2 kg/ha in the field could be determined. However, this would not provide any indication of the evenness or effectiveness of the actual helicopter application. Information regarding this aspect of the study was obtained by the use of interception trays.

Aluminium baking trays (0.1m deep x 0.25m^2) were used to catch the granular Abate as it was applied. One tray was placed on top of each covered enclosure and three were placed on the water at random around the enclosures. No trays were placed around the rest of the lake due to constraints on time. The granules from each tray were counted and weighed and the equivalent mean application rate per hectare was calculated.

RESULTS

Distribution of Abate

Three trays were overturned by wind and wave action generated by the helicopter. The mean application rate calculated from the six remaining trays was 3.02 ± 1.03 kg/ha. The desired rate of 2.2 kg/ha falls within this range.

Changes in Larval Density
Polypedilum nubifer and *Chironomus occidentalis* constituted 84% and 14%, respectively, of the total larval density before the application of Abate and so the following analysis is restricted to these two species. The changes in the density of these species in the control and treated enclosures and in the area immediately surrounding them ('external') are shown in Figure 2.

Prior to the application of Abate there were no significant differences in *P.nubifer* density in the three sampling areas. The actual densities recorded were 12 372 ± 2 498, 10 419 ± 1 635 and 5 846 ± 1117 larvae/m^2 in the treated and control enclosures and the external area, respectively. Densities recorded in all three areas, three days after the application of Abate, were significantly lower ($P < 0.01$) than those recorded prior to treatment. The density of *P. nubifer* in the treated and control enclosures and in the external area had fallen to 28 ± 19, 113 ± 50 and 14 ± 14 larvae/m^2, respectively. After the initial decline, there was no significant changes in the density of larvae in all of the three areas sampled for the remainder of the experiment.

The pattern of change in the density of *C. occidentalis* during the course of the experiment was almost identical to that of *P.nubifer*. On all sampling occasions, the density of *P. nubifer* and *C. occidentalis* larvae in the control enclosures was not significantly different from that of the treated enclosures and the external area. It is unlikely that such a large population decrease would have occurred naturally within the control enclosures. Thus, it is probable that the control enclosures were contaminated by pesticide shortly after the experiment began.

Environmental Parameters
All of the physical parameters (pH, conductivity, chlorophyll-a, oxygen and temperature) measured, were within the normal ranges recorded for Forrestdale Lake. These parameters did not differ significantly between the three sampling areas during the course of the experiment. For this reason, this small data set has not been included here.

DISCUSSION

Application of Abate
The application of Abate appeared to be successful in terms of evenness, in that the desired rate of 2.2 kg Abate/ha was within the range of rates recorded in the area around the enclosures. Without more trays placed around the lake it is impossible to extrapolate this to suggest that the entire lake received the correct rate, however, it was pleasing to find that the desired rate was achieved in the one area that was monitored.

Changes in Larval Density
It is likely that the rapid decline in the densities of *P. nubifer* and *C.occidentalis* larvae was due to the Abate application but without any data from an effective control area, it is not possible to distinguish the effect of the pesticide from what might have been a natural population crash.

The enclosures used for this experiment were identical in design to those used for the Abate experiment at North Lake during the 1988/89 study. At

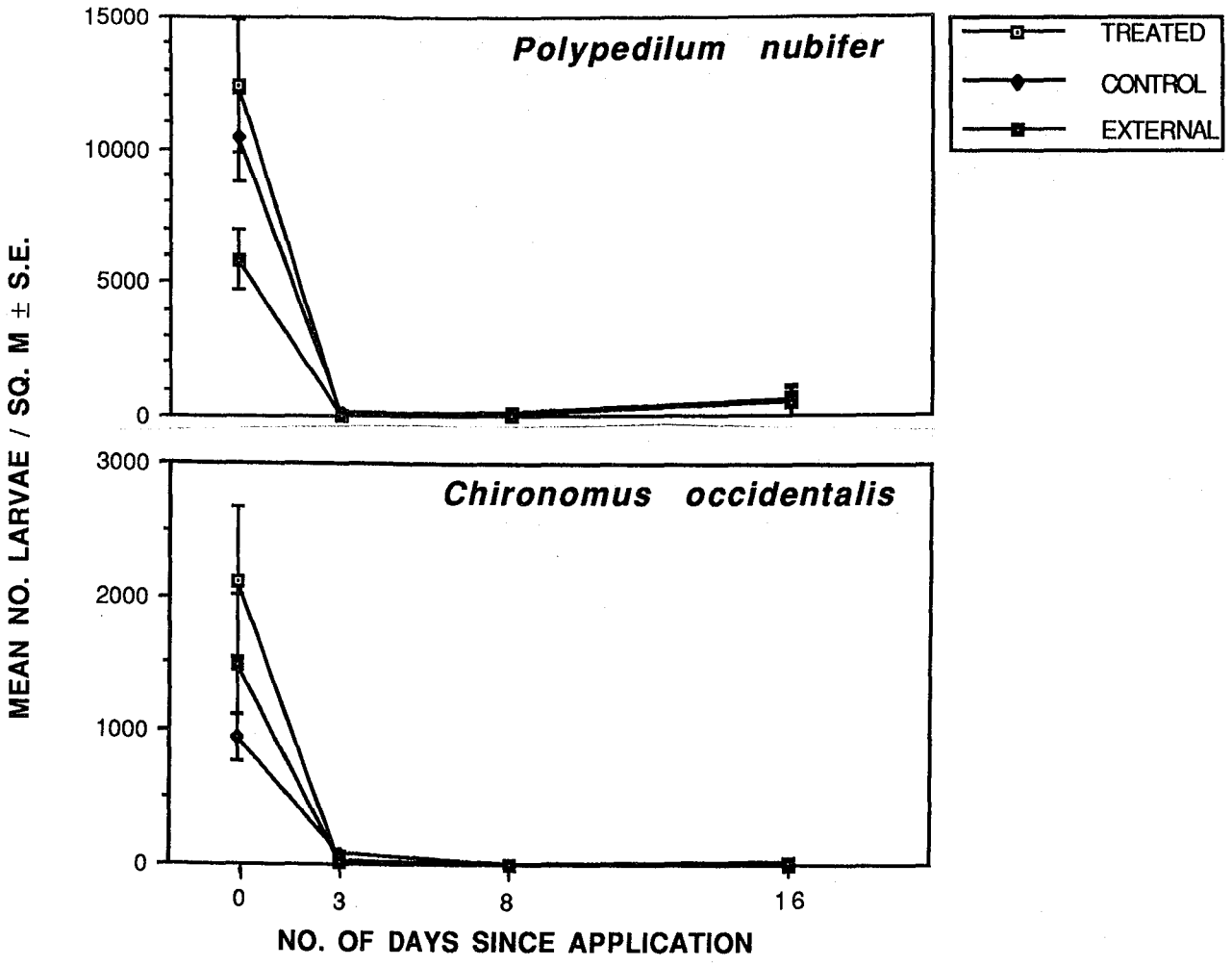


Figure 2. Changes in the density of *Polypedilum nubifer* and *Chironomus occidentalis* larvae within the treated and control enclosures and the external area during the field testing of Abate at Forrestdale Lake, December 1989.

North Lake this enclosure design was extremely successful in terms of preventing the water in the control and treated enclosures from being contaminated by the lake water. An explanation for why the enclosures were not effective at Forrestdale Lake may be that the sandy-clay substrate of the lake is more porous than the sandy substrate at North Lake and thus the water from outside the enclosures was able to leach into the enclosures. An alternative explanation is that the enclosures were the targets of vandalism. Although there was no visible damage to the structure of the enclosures, it is possible that they were tampered with, so that their position on the lake bed was altered.

Any further enclosure experiments that occur at Forrestdale Lake will need to be modified so that the problems that occurred here do not occur again. An enclosure design which can be pushed further into the sediment may be more appropriate for this lake. The enclosures should also be placed well away from the residential area to lessen likely problems with vandalism.

Conclusions

Enclosure experiments are the preferred method for testing pesticides in the field as they provide a number of useful research advantages (Lundgren, 1985; Solomon *et al.*, 1980). In particular, they provide information about the fate and toxicity of pesticides which are not otherwise obtainable from laboratory experiments.

This experiment, together with the Abate experiment at North Lake in September 1989, highlighted some of the difficulties involved with field trials using enclosures. Some of these problems may be overcome by modifying the design of enclosures to suit the particular environment in which they are placed. However, neither naturally occurring disruptions, such as sudden and severe storms, nor unnatural disruptions, such as vandalism, can be foreseen and have to be accepted as some of the drawbacks of attempting to undertake field studies.

TESTING OF THE EFFECTIVENESS OF SUMILARV 0.5G IN THE LABORATORY AND THE FIELD

INTRODUCTION

Much of the 1989/90 research program focussed on the investigation of the insect growth regulator, Sumilarv, as an alternative to Abate. Sumilarv 0.5G was developed by the Sumitomo Chemical Company of Japan and is a 0.5% granular formulation of pyriproxyfen (JHA S-31183), a juvenile hormone analogue which mimics the action of a naturally occuring juvenile hormone.

A brief description and a diagrammatic representation of the way in which Sumilarv works on houseflies is given in Appendix 1. During the development of an insect, a naturally occuring juvenile hormone is present and is essential for larval moulting. The juvenile hormone acts upon larval cells and prevents them maturing. Development into the pupal and adult forms is brought about by a rapid decrease in the amount of juvenile hormone present. An exogenous application of a juvenile hormone analogue (JHA), such as Sumilarv, to the larvae will artificially keep juvenile hormone levels high and thus prevent successful development into pupal and adult forms. This principal can be applied to midges.

The active ingredient of Sumilarv (pyriproxyfen; JHA-S31183) has been tested in the U.S.A. (Estrada and Mulla, 1986; Mulla *et al.*, 1986; Schaefer and Muira, 1987; Schaefer *et al.*, 1988) for its effectiveness on mosquitoes. These laboratory and field trials have shown this product to be effective against mosquitoes. In Tanzania, Sumilarv applied at a rate of 10 kg/ha in the field was found to cause 100% inhibition of emergence of mosquitoes for up to 21 days after application (Hemingway *et al.*, 1985). The Sumitomo Chemical Company has found Sumilarv to be effective against both mosquitoes and houseflies (Appendix 1). In Japan, Sumilarv 0.5G is registered for use against mosquitoes, houseflies, mothflies and midges. Sumilarv 0.5G is also registered for use against flies and mosquitoes in Argentina and Korea.

Midges belong to an insect group which have the ability to postpone their development into the pupal stage until the level of juvenile hormone is low. If the delay is abnormally long, normal pupation and further development rarely occur (Staal, 1972). Death due to the presence of a JHA is not normally direct and is often delayed. For this reason, larval mortality is not a good indicator of JHA effectiveness. Monitoring of adult emergence is a more accurate method of assessing the effectiveness of a JHA.

A laboratory test of the effectiveness of Sumilarv against *Polypedilum nubifer* larvae was carried out during the 1988/89 research (Davis, Harrington and Pinder, 1989). The results of this trial suggested that Sumilarv applied at a rate of between 5 and 50 gAI/ha (1 to 10 kg product/ha) would effectively inhibit adult emergence, however it was concluded that further testing was required. The results of further laboratory trials against *P. nubifer* are presented here.

Laboratory trials are useful for providing essential information on

susceptibility of a particular species to Sumilarv, however they provide no information on the effectiveness of Sumilarv under field conditions where physico-chemical or biological factors might alter the effect of the pesticide. For this reason, Sumilarv was assessed under field conditions at North Lake on two occasions over the summer of 1989/90.

Ten kg/ha of Sumilarv (50 gAI/ha) was the rate chosen to be tested in the field trials. There were two reasons for this decision. Firstly, the Tanzanian study (Hemingway *et al.*, 1985) had found 10 kg/ha to be effective in the field against mosquitoes. And secondly, this rate was found to be effective against midges in the laboratory trial during the 1988/89 study. Sumilarv was applied by helicopter and the treatment was monitored in the area of the enclosures using interception trays to catch the Sumilarv as it fell. The effectiveness of Sumilarv was determined by observing adult emergence and monitoring larval density. Only data collected for the enclosure experiment are presented here. The effect of Sumilarv and other pesticides on both adult emergence and larval density in the whole of North Lake is discussed in Chapter 4 of this report.

Sumilarv is an insect growth regulator and, as such, it should affect a much narrower range of organisms than Abate, a broad spectrum organophosphate pesticide. During the field experiments, it was possible to monitor the emergence of a non-dipteran insect group, mayflies (Ephemeroptera), to determine whether these insects were affected by Sumilarv. These results are presented, together with a summary table of all available information regarding the non-target effects of Sumilarv.

METHODS

Laboratory Trials

Three trials of Sumilarv 0.5G were carried out against *P. nubifer* between January and March, 1990. A summary of each of the laboratory trials is presented in Table 1. On each occasion, eighteen aquarium tanks were used and two centimeters of washed sand was placed in the bottom of each tank. The tanks were then filled with 10 litres of lake water and left to settle for two days. To avoid anoxic conditions developing within the tanks, algae which had settled to the bottom, was siphoned off with 2 litres of water, leaving 8 litres in each tank. Three tanks were kept as controls and Sumilarv 0.5G was added to the rest of the tanks to give five different concentrations between 5 and 100 gAI/ha (assuming 50cm depth) with three replicates of each. Midges were then collected with a sweep net at the same lake from which the water was taken. Fifty 3rd or 4th instar *P. nubifer* larvae were added to each tank and wire mesh (1.5mm) was placed over the top of the tanks to stop any emergent midges escaping (Fig 1B). The tanks were aerated during the day but not during the night, to avoid disturbing pupation and emergence. The tanks were monitored daily and dead pupae and live or dead adults were removed. The experiments were terminated when pupal mortality in the control aquaria reached 20%. The activity of Sumilarv was assessed as the percentage inhibition of emergence. This was calculated by comparing the total emergence from each concentration tested with that of the control aquaria.

EXPERIMENT	DATE BEGUN	DATE COMPLETED	TIME TO COMPLETION (DAYS)	WATER & LARVAE COLLECTED FROM	TEMPERATURE RANGE (°C)	CONCENTRATIONS TESTED (g AI/ha)					
						5	10	25	50	75	100
1	12-Jan	20-Jan	9	NORTH LAKE	21-32	+	+	+	+	-	+
2	26-Jan	15-Feb	19	NORTH LAKE	17-36	-	+	+	+	+	+
3	15-Mar	17-Mar	3	BIBRA LAKE	19-29	-	+	+	+	+	+

Table 1. Details of the three laboratory experiments to test the effectiveness of Sumilarv against *Polypedilum nubifer*.

Field Trials

General

Two field trials were performed over the summer period of 1989/90, the first in November/December and the second in January/February. The methods employed varied in some aspects and therefore each experiment will be discussed separately. Both trials took place at North Lake and utilized enclosures constructed in the littoral region on the eastern side of the lake. In addition, a helicopter was used to apply Sumilarv 0.5G to the littoral region of the lake at a rate of 10 kg/ha (50 gAI/ha) for both trials.

Enclosure Design

Six $25m^2$ x 1m high enclosures were constructed in the littoral region of the lake (Fig. 1C). As the enclosures were bounded by the shore line, it was only necessary that they had three sides. Metal star pickets were used to form the framework for the enclosures. The enclosures were made from clear (200µm thick) polyethylene plastic and heat sealing was used to form 15cm hems at the top and bottom of the enclosures. PVC pipes (40mm diameter), which were filled with water and capped, were placed in the bottom hems to weigh the bottom of the enclosures down. Bricks were tied to the pipes to add additional weight to the bottom hems. PVC pipes (20mm diameter) were placed in the top hems to form a rigid support by which the enclosures were tied to the pickets.

First Sumilarv Field Trial

The enclosures were placed in water up to 40cm deep, one day prior to application of pesticide. Sumilarv was applied to the littoral region of the lake at a rate of 10 kg/ha in the early morning of 2nd November 1989. At the time there was a slight north-easterly breeze.

Shortly before the Sumilarv application was to occur, the three enclosures chosen to be controls were covered by black plastic to prevent them receiving pesticide. The remaining enclosures were left uncovered so that they would receive pesticide as it was applied by the helicopter. Aluminium baking trays (0.1m deep x $0.25m^2$) were used to catch the granular Sumilarv as it was applied. One tray was placed in each enclosure and three were placed outside the enclosures. Immediately after application, the trays were collected and the covers were removed from the control enclosures. The granules recovered from each tray were collected and taken back to the laboratory where they were weighed and the mean application rate per hectare was calculated, four days later. What was originally thought to have been Sumilarv granules in the trays was identified as sand. Only two of the tray samples contained Sumilarv and these were only insignificant amounts. Thus, it was assumed that the treated enclosures and the area immediately surrounding the enclosures did not receive any Sumilarv. Six days after treatment (7th of November), Sumilarv was added by hand to the treated enclosures at the rate of 10 kg/ha. Henceforth, all sampling dates referred to are relative to this date of application to the enclosures.

Adult emergence was monitored every night for six nights prior to the application of the pesticide to the enclosures. After application, emergence traps were set every second night until completion of the experiment. On

each occasion, three submerged emergence traps (described in the 1988/89 report) were placed in each enclosure and a total of nine traps were placed in the area immediately outside the enclosures ('external'). The emergent midges were collected in the morning, preserved and quantified at a later date. Care was taken to ensure that each time the emergence traps were set, they were placed a short distance from where they had been previously.

Larval samples were taken six days and then one day prior to treatment, and seven days and twenty days after treatment. All larval samples were collected using a corer of 9.8cm diameter. On each sampling occasion, three sediment cores were taken from each enclosure. The core samples were collected from an area in the enclosures separate from where the emergence traps were set. Within the designated area, the location of the cores was determined randomly, and in such a way that an area was cored only once. In addition, nine core samples were collected from the sediment in the area external to the enclosures on each occasion. The sediment samples were preserved and sorted at a later date using the calcium chloride differential flotation method.

A water sample and oxygen and temperature profiles were taken from each enclosure, and from three locations in the adjacent open water, on each sampling occasion. The water samples were taken back to the laboratory for measurement of pH and conductivity. The chlorophyll-a concentration of these water samples were determined, either by the Nutrient Analysis Laboratory of the Centre for Water Research, or by M. Lund, both at Murdoch University.

This field experiment lasted for 24 days, at which point the water level in the enclosures became too shallow to set emergence traps.

Second Sumilarv Field Trial

As with the first field trial, six enclosures were constructed in the littoral region on the eastern side of the lake. Although the enclosures were in the same general location, they were not constructed on exactly the same site as the first group of enclosures. This was because evaporation had caused the lake depth to decrease and thus the lake edge to recede. Sumilarv was applied by helicopter at a rate of 10 kg/ha in the early morning of 30th January 1990. At the time the wind was gusty and coming from a north easterly direction.

Prior to the treatment, covers were placed on all of the enclosures. This was done to avoid the problems with application which were experienced in the previous experiment. After the application of the pesticide to the lake, the covers were removed from all of the enclosures and 10 kg/ha Sumilarv was added, by hand, to three of the enclosures. The remaining three enclosures acted as controls.

The application of pesticide to the lake was monitored more thoroughly in this experiment. The evenness of the helicopter application to the littoral region and the influence of tree cover on the rate of application were measured by placing interception trays around the lake. Fifteen, aluminium baking trays (0.1m deep x $0.25m^2$) were used to catch the granular Sumilarv as it was

applied. Twelve trays were placed in pairs and one of each pair was placed in the open, whilst the other was placed under nearby tree cover. Three trays were placed in the area immediately outside the enclosures. All trays were floated on the water surface and submerged bricks were used to anchor their position. The granules collected from each tray were counted and weighed and the equivalent mean application rate per hectare was calculated.

Adult emergence was monitored for three nights prior to the application of Sumilarv and then every three days after the application until the completion of the experiment. Water samples were taken one day prior to, and then six and sixteen days after treatment. Larval samples and oxygen and temperature profiles were taken prior to the treatment and again sixteen days later. The methods employed in monitoring adult emergence, sampling and sorting of larvae, measuring oxygen and temperature data and in collecting and analysing water samples were identical to those described for the first field experiment.

This experiment was terminated after only 13 days by an unexpected storm event which lifted the bottom of the enclosures up from the lake bed and thus allowed the lake water to enter both the treated and control enclosures. For this reason, none of the physical data taken on day sixteen is presented. However, larval data collected on day sixteen will be presented as this is likely to have been representative of larval numbers before the storm event.

Non-Target Insect Emergence

Non-target insect fauna that emerged as adults in the emergence traps were collected and their numbers recorded. The mayfly, *Tasmanocoenis tillyardi*, emerged in sufficient numbers for the effect of Sumilarv on this species to be assessed. Other insects such as caddisflies, dragonflies and beetles also emerged but not in high enough numbers for changes in emergence rates to be analysed.

Analyses of Emergence Data

Adult midge emergence data collected from both of the field trials were analysed in the same way. For convenience, the days before and after treatment were divided into groups and only species contributing more than 10% to the total midge emergence were analysed. All data were log transformed for the analyses.

Data collected from the two treatment types were compared by two-way analyses of variance (ANOVA) over time. Data from within each treatment type were analysed by one-way ANOVA and Tukey's Multiple Comparison test. Inhibition of emergence (IE) in the treated enclosures was calculated using a formula which takes into account fluctuations in the rate of emergence in the control enclosures, and also, any initial differences in the rate of emergence in the treated and control enclosures (Mulla *et al.*, 1971):

$$\%IE = 100 - \{ [(C1/T1) \times (T2/C2)] \times 100 \}$$

Where C1 = number of adults emerging from the control enclosures prior to treatment; C2 = number of adults emerging from the control enclosures after treatment; T1 = number of adults emerging from the treated enclosures before treatment; T2 = number of adults emerging from the treated

enclosures after treatment.

The non-target emergence data collected from both experiments were analysed in the same way as the midge emergence data.

RESULTS

Laboratory Trials

All of the laboratory trials were terminated when pupal mortality reached 20% in the control aquaria. Thus, each experiment lasted for a different length of time. Whereas the second experiment lasted for 19 days, the first and third experiments lasted for only 9 and 3 days, respectively. Inhibition of emergence in the test aquaria was calculated by comparing the total emergence for each replicated concentration with that of the control aquaria.

Figure 3 shows the effect of different concentrations of Sumilarv on the emergence of *P. nubifer* during the three trials. A concentration of 20 kg/ha Sumilarv resulted in a mean percentage inhibition of emergence (%IE) of 98% ± 2% for the three trials. At 5 and 10 kg/ha, emergence was inhibited by 75 ± 9% and 85% ± 6%, respectively.

Probit analysis was used to analyse the data from these experiments. An explanation of this procedure is given in the 1988 midge research report. The output generated by the probit analysis is summarized in Table 2. The probit procedure indicated that 50, 75 and 90%IE should be achieved by using application rates of 1.7, 4.4 and 10.0 kg/ha of Sumilarv, respectively.

First Sumilarv Field Experiment

Changes in Larval Density

Larval densities (number of larvae/m^2) recorded in the treated and control enclosures and in the area immediately outside the enclosures (external) are shown in Figure 4. *P. nubifer* was the most abundant species present. There were no significant changes in the density of larvae in the treated and control enclosures and the external area during the experiment (P=0.99, 0.30, and 0.67, respectively). Larval densities in the three areas sampled were not significantly different throughout the experiment.

Changes in the Emergence of Adult Midges

Adult midges were collected in emergence traps in the period between dusk and dawn. The number of midges emerging/m^2/night is expressed as the rate of emergence. The rate of emergence of adult midges during this experiment, is shown in Figure 5. There was a marked decline in the rate of midges emerging in the treated enclosures after the application of Sumilarv. The rate of emergence from the treated enclosures on the night prior to the treatment was 249 ± 63 adults/m^2. Five days after treatment, the number of midges emerging from the same enclosures had dropped to 0 adults/m^2 and remained low until twenty two days after treatment, at which time emergence began to increase. However, posttreatment emergence did not increase to pretreatment levels for the remainder of this experiment. Emergence in the

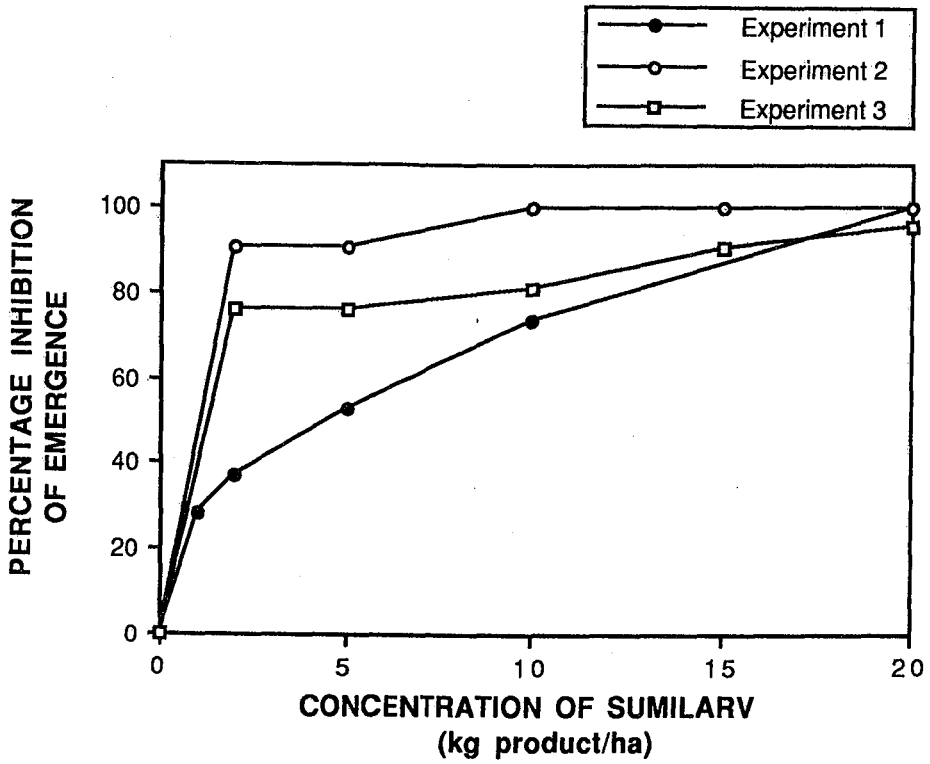


Figure 3. Results of three laboratory tests to assess the effectiveness of different concentrations of Sumilarv 0.5G, as determined by the percentage inhibition of emergence of *Polypedilum nubifer*.

	DEGREE OF INHIBITION OF EMERGENCE		
	50%	75%	90%
CONCENTRATION REQUIRED (kg product/ha)	1.72	4.36	10.03

Table 2. Results of the probit analysis of the three laboratory trials.

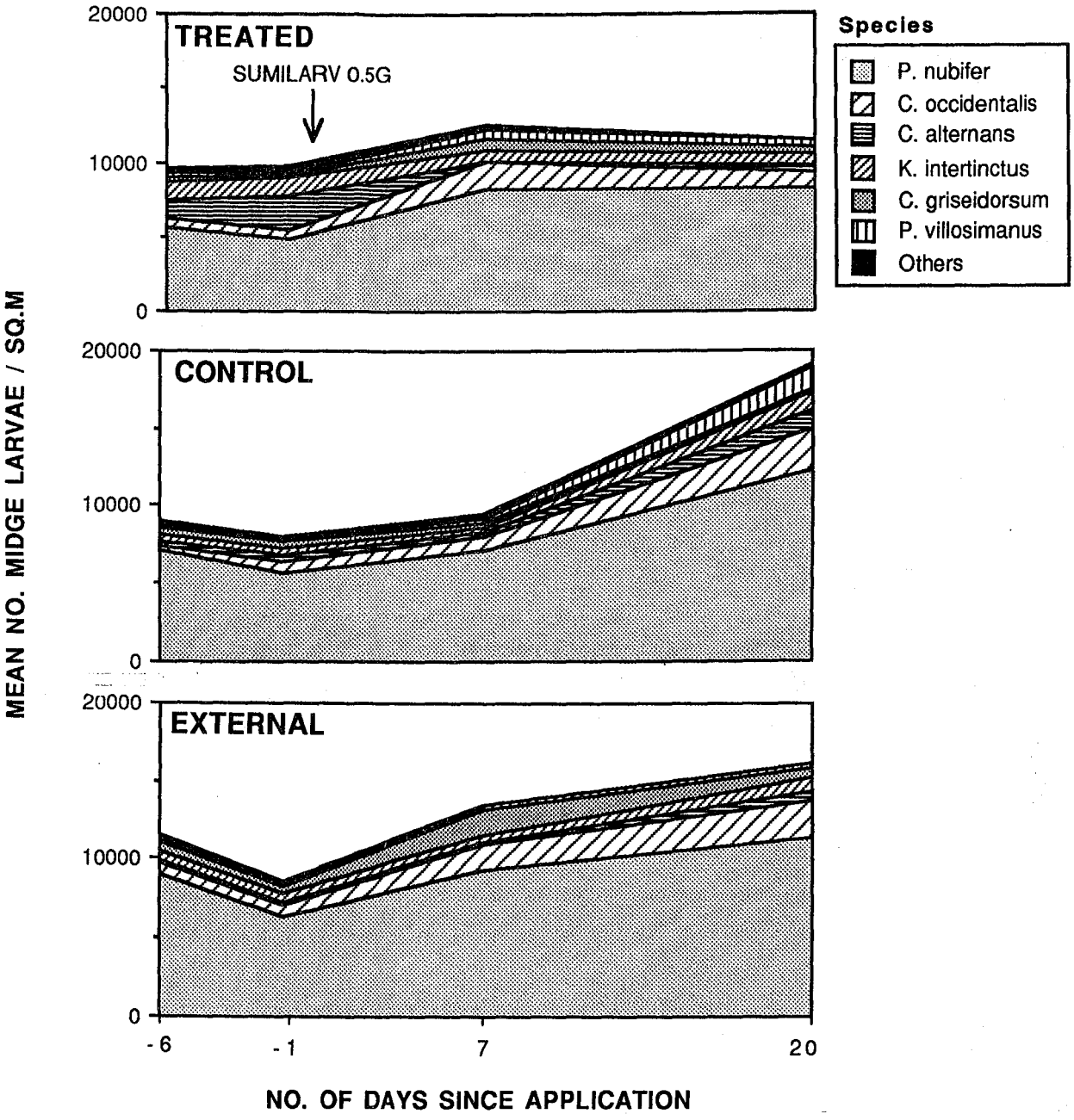


Figure 4. Changes in the cumulative density of chironomid larvae within the treated and control enclosures and the external area during the first field trial of Sumilarv 0.5G at North Lake, November 1989.

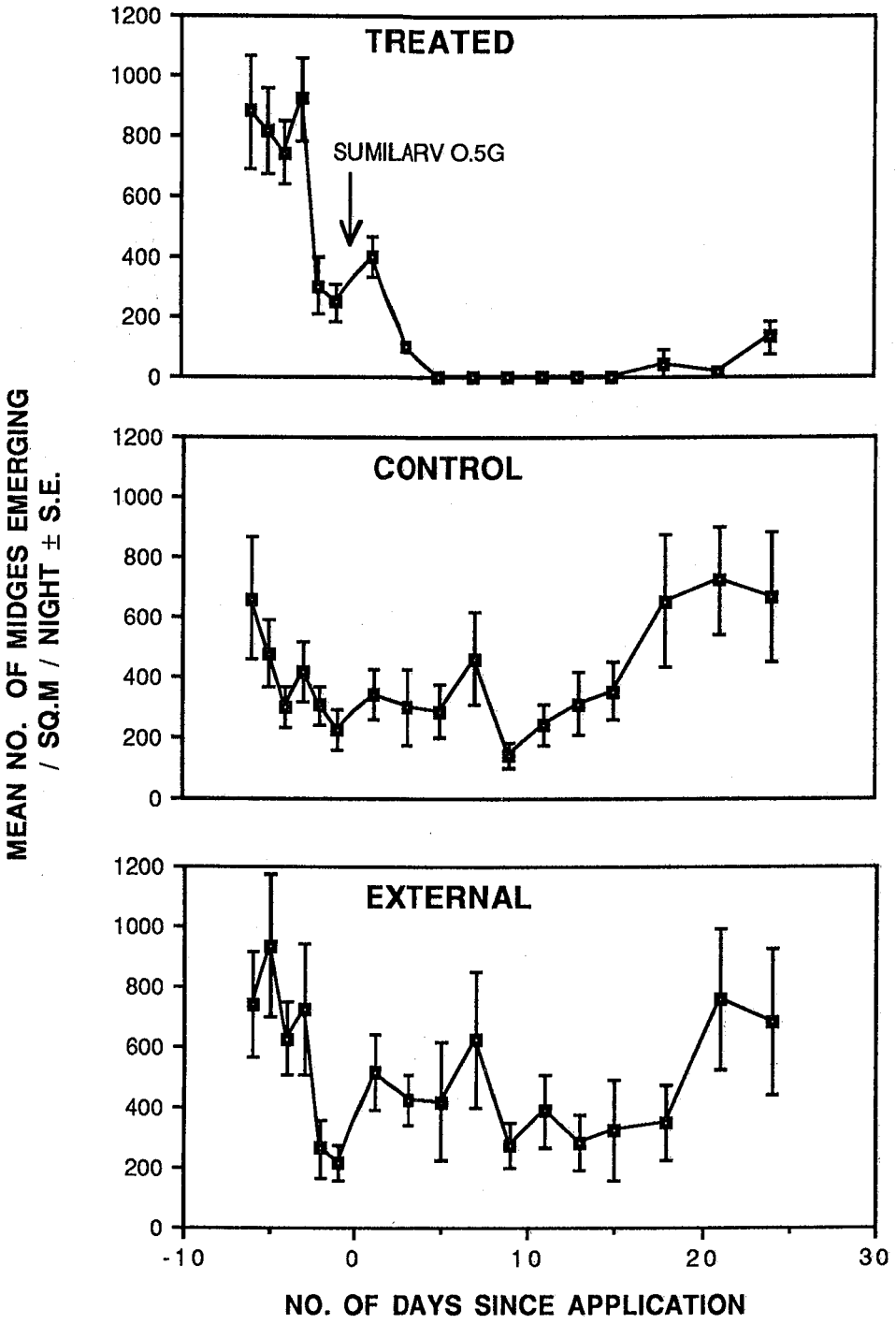


Figure 5. Changes in the rate of emergence of adult chironomids within the treated and control enclosures and the external area during the first field trial of Sumilarv 0.5G at North Lake, November 1989.

control enclosures and external area tended to vary during the experiment but never fell below 140 ± 40 adults/m^2 and 215 ± 56 adults/m^2, respectively. The pattern of emergence in these two areas was remarkably similar throughout this experiment.

The changes in the species composition of the emerging midges from each enclosure type and the external area are shown in Figure 6. Only species which contributed more than 10% to the total are shown as separate species. These were *P. nubifer*, *Kiefferulus intertinctus* and *Chironomus alternans*. A rapid decline in emergence of all species was observed in the treated enclosures after treatment and emergence remained well below pretreatment levels for the rest of the experiment.

The patterns of adult emergence were similar in both the control and external areas (Fig. 6). However, changes over time were observed in the species composition of emerging midges in both areas. Interestingly, *P. nubifer* constituted as much as 80% of the total abundance of larvae at any one time (Fig. 4), but rarely constituted more than 50% of the total adult midge emergence in either the control enclosures or the external area. The maximum ratio of adults emerging to density of larvae was 5% for *P. nubifer*. The maximum ratios recorded for *K. intertinctus* and *C.alternans* were 52% and 42% respectively.

Table 3 shows the results of statistical analyses of the data collected during this experiment. The results of the two-way ANOVA comparing the rate of emergence of all species combined (and individually *P. nubifer*, *C. alternans* and *K. intertinctus*) in the treated enclosures with that of the control enclosures, showed that the two areas differed significantly ($P<0.01$) throughout the experiment. There were no significant changes in the rate of total adult midges emerging from the control enclosures during the experiment. However, there was a significant decrease ($P<0.01$) in the total rate of midges emerging from the treated enclosures within 3 days of the application of Sumilarv, with a 99% reduction in emergence occurring after 9 days. *P. nubifer* and *C. alternans* were similarly effected. The emergence of *K. intertinctus* from the control enclosures increased significantly ($P<0.01$) during this experiment. By contrast, emergence of this species from the treated enclosures declined significantly ($P<0.01$), and a 100% reduction in emergence was recorded after 9 days.

Environmental Parameters

The oxygen concentration in the water taken from outside and from within the enclosures varied from 7-12 mg/L during this experiment (Fig.7). The samples were taken at different times of the day on each occasion, and since oxygen concentrations tend to vary temporally, a direct comparison of these measurements would not be meaningful. Oxygen levels measured in the control and treated enclosures tended to be similar on each day. Levels in the external area were not consistently higher or lower than in the enclosures. Little change was recorded in oxygen profile in any of the three areas. The concentration of oxygen on the lake bed did not differ from the surface level with the exception of a decrease on the lake bed which was observed one week after treatment in the enclosures.

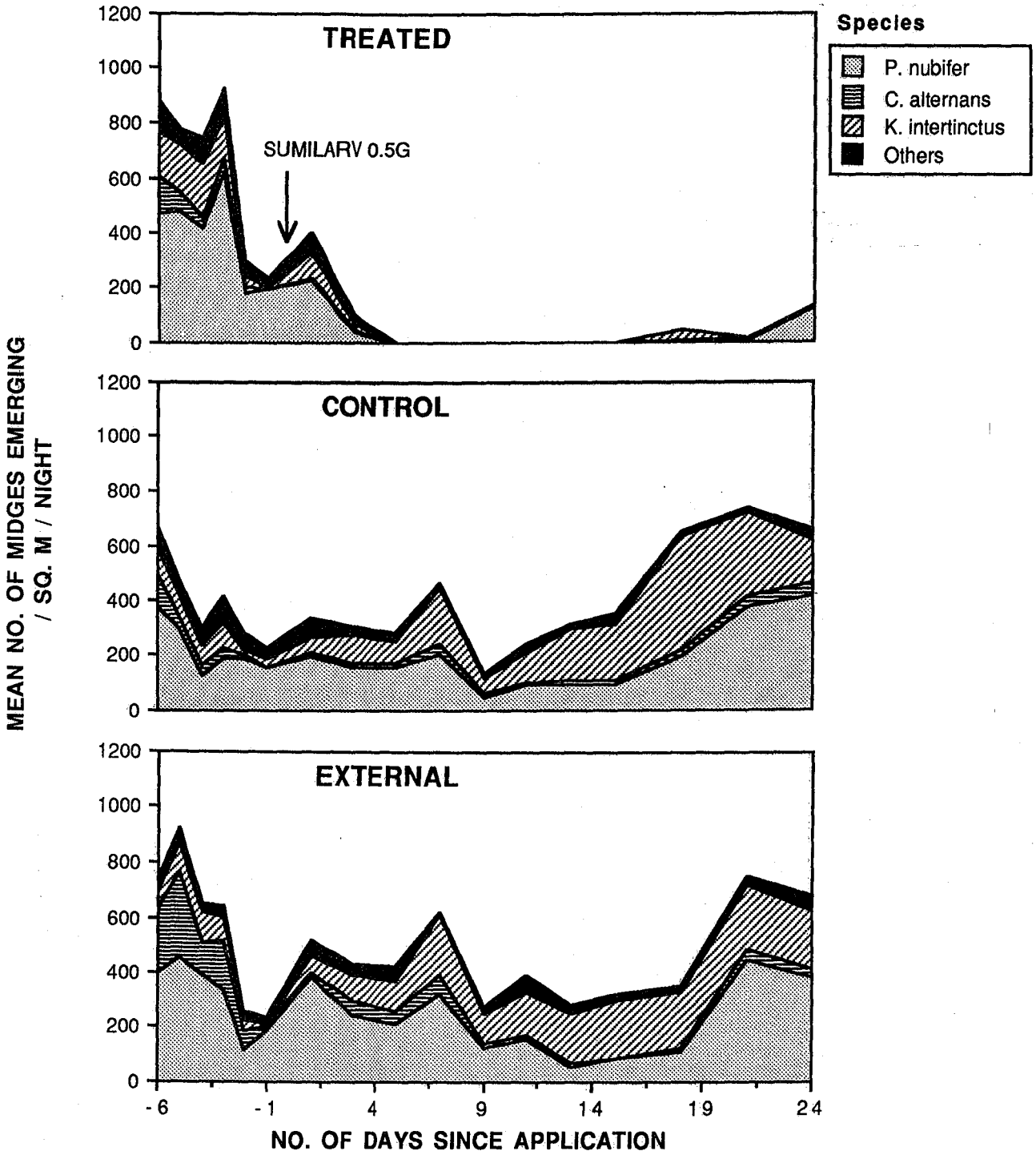


Figure 6. Changes in the cumulative rate of emergence of adult chironomids within the treated and control enclosures and the external area during the first field trial of Sumilarv 0.5G at North Lake, November 1989.

Table 3. Results of statistical analyses on chironomid emergence data obtained from the treated and control enclosures during the first field trial of Sumilarv 0.5G at North Lake, November 1989.

MEAN NO. OF ADULTS EMERGING / SQ. M / NIGHT PRE- AND POST-TREATMENT (DAYS)														
SPECIES	PRETREAT	1-3	4-9	10-21	22+	SIGNIFICANCE	PRETREAT	1-3	4-9	10-21	22+	SIGNIFICANCE	TREAT vs. CONT
	SUMILARV 10kg/ha						CONTROL						
Total	668a	251c	2b	13b	130d	* *	399a	326a	295a	430a	670a	NS	* *
	[0]	[54]	[99]	[98]	[88]								
Polypedilum nubifer	394a	131c	1b	3b	122c	* *	244a	177a	136a	158a	417a	NS	* *
	[0]	[26]	[99]	[99]	[83]								
Chironomus alternans	56a	12ab	0c	1c	2bc	* *	44a	15a	24a	20a	61a	NS	* *
	[0]	[37]	[100]	[97]	[97]								
Kiefferulus intertinctus	123a	60a	0b	8b	0b	* *	68a	78ab	114ab	227b	154ab	* *	* *
	[0]	[60]	[100]	[98]	[100]								

Means in a row followed by the same letter are not significantly different from each other.

Numbers in parentheses represent % inhibition of adult emergence after treatment. See p. 15 of text for greater detail.

TREAT vs. CONT: comparison of emergence from treated and control enclosures over time by two- way ANOVA.

Significance: NS = not significant; * and ** = significant at 5 and 1% levels, respectively.

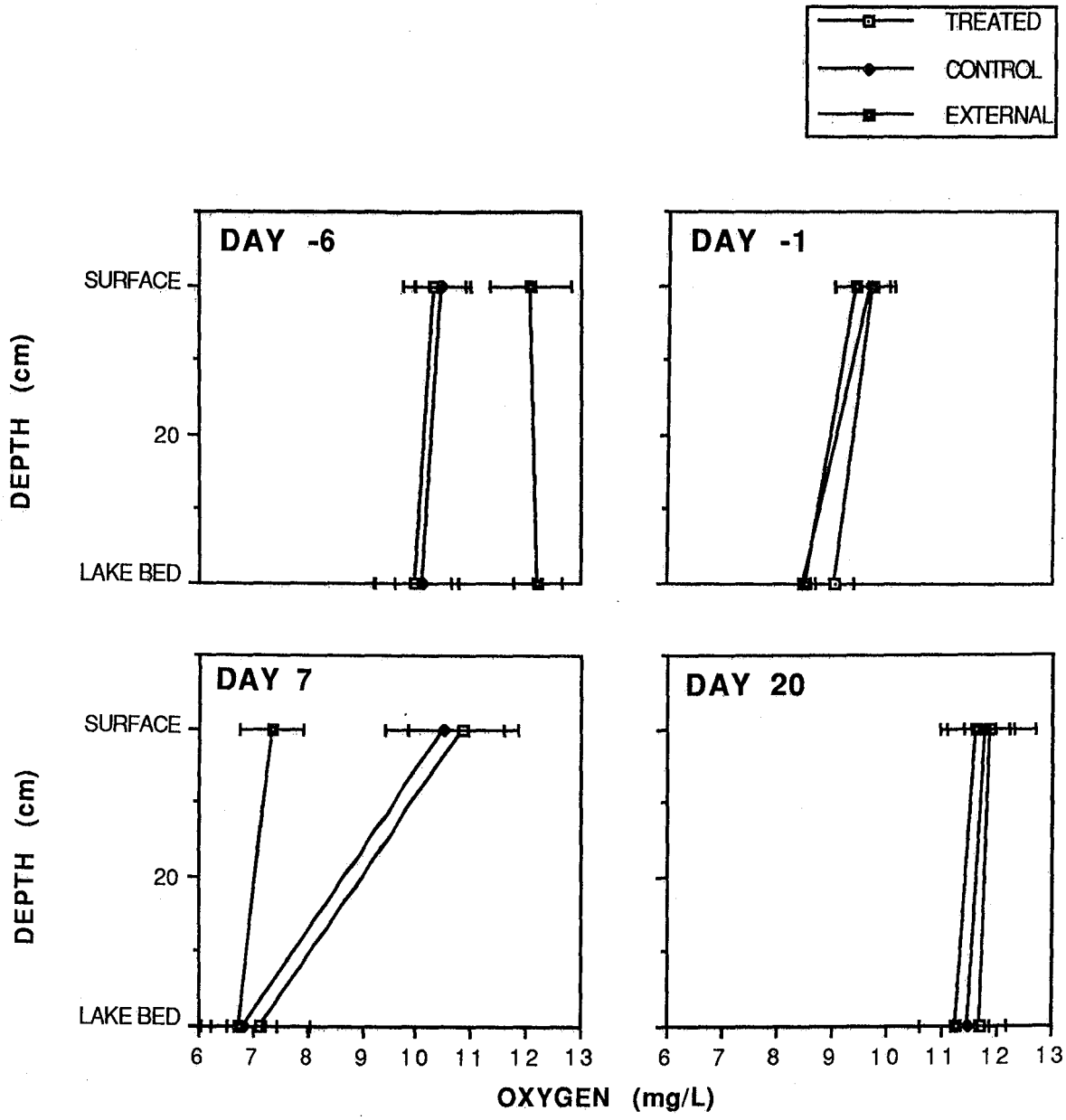


Figure 7. Depth profiles of dissolved oxygen concentration within the treated and control enclosures and the external area, six and one day prior to the application of Sumilarv and seven and twenty days afterwards, during the first field trial of Sumilarv 0.5G at North Lake, November 1989.

Water temperatures in the control and treated enclosures were similar during the experiment (Fig.8). The temperature of water outside the enclosures was generally cooler than inside the enclosures. Whereas the temperature of the water inside the enclosures only varied by about 1°C throughout the experiment, the temperature of the water outside the enclosures varied by as much as 3°C. Little variation occurred in the temperature profile in any of the three areas.

The concentration of chlorophyll-a in the enclosures varied considerably during the experiment. Concentrations recorded in the two enclosure types were similar (Fig. 9) and were as high as 217 µg/L five days prior to treatment. The lowest concentration, 134µg/L, was recorded four days later. Chlorophyll-a concentrations recorded in the water from outside the enclosures decreased from 199 µg/L to 143 µg/L prior to treatment but gradually increased again to 201 µg/L twenty days after treatment.

Conductivity, increased in all the areas sampled during the experiment (Fig. 9). The range of conductivities recorded was 528 to 848 µS/cm. The pH recorded in each of the three areas was similar (Fig. 9). A decrease in pH was observed for all three areas nine days after treatment with pH levels in the external area as low as 7.2. The highest pH recorded during this experiment was 9.2 which was recorded in the control enclosures five days prior to treatment.

Second Sumilarv Field Trial

Distribution of Sumilarv 0.5G

Six of the fifteen interception trays placed in the littoral region around the lake were sunk by wind and wave action generated by the helicopter. As many of these were one of a pair, placed either in the shade or in the open water, a meaningful interpretation of the influence of tree cover was not possible. The mean rate of application calculated from the remaining nine trays was 3.3 ± 0.9 kg Sumilarv/ha. The range of application rates determined from the trays was 0 - 7.1 kg/ha.

Changes in Larval Density

P. nubifer accounted for 90% of larval abundance in each of the three sampling areas prior to the application of Sumilarv, with densities in excess of 20 000 larvae/m^2 being recorded (Fig. 10). Sixteen days after the application of Sumilarv significant decreases in the density of larvae had occurred in both the treated and control enclosures and in the external area ($P<0.05$, $P<0.05$ and $P<0.01$, respectively).

Changes in the Emergence of Adult Midges

The rate of midge emergence from the treated and control enclosures and the external area during the second field experiment is presented in Figure 11. A decline in the rate of emergence was observed in all areas before treatment occurred. Prior to the application of Sumilarv, the rate of emergence was very low, considering the high density of larvae that were present in the benthos (Fig. 10). Despite the already low rate of emergence, there was still a decline in emergence in the treated enclosures after the application of Sumilarv (Fig. 11). The emergence rate from these enclosures on the night prior to application was 64 ± 16 adults/m^2. Six days after application, this had fallen to

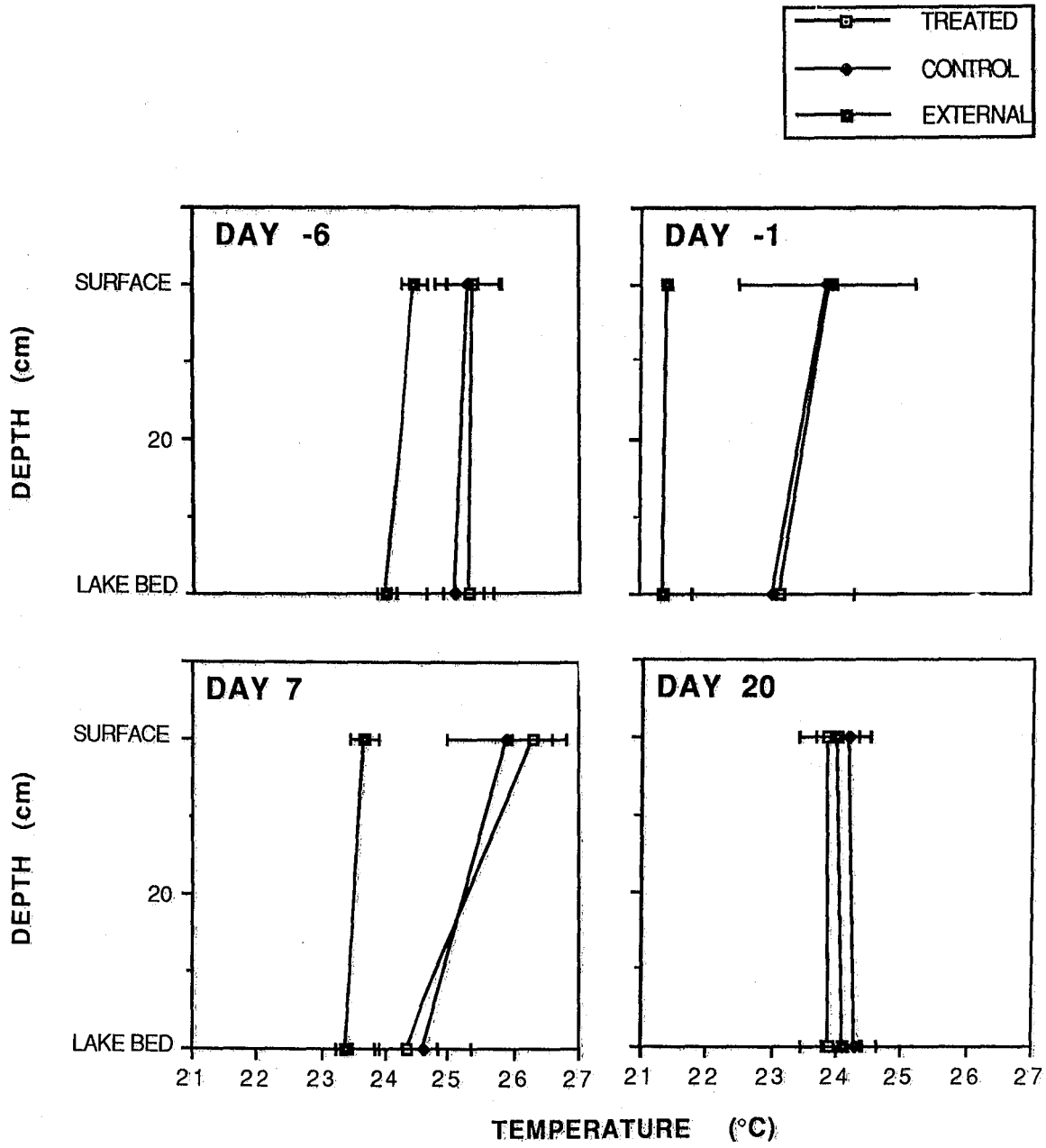


Figure 8. Depth profiles temperature within the treated and control enclosures and the external area, six and one day prior to the application of Sumilarv and seven and twenty days afterwards, during the first field trial of Sumilarv 0.5G at North Lake, November 1989.

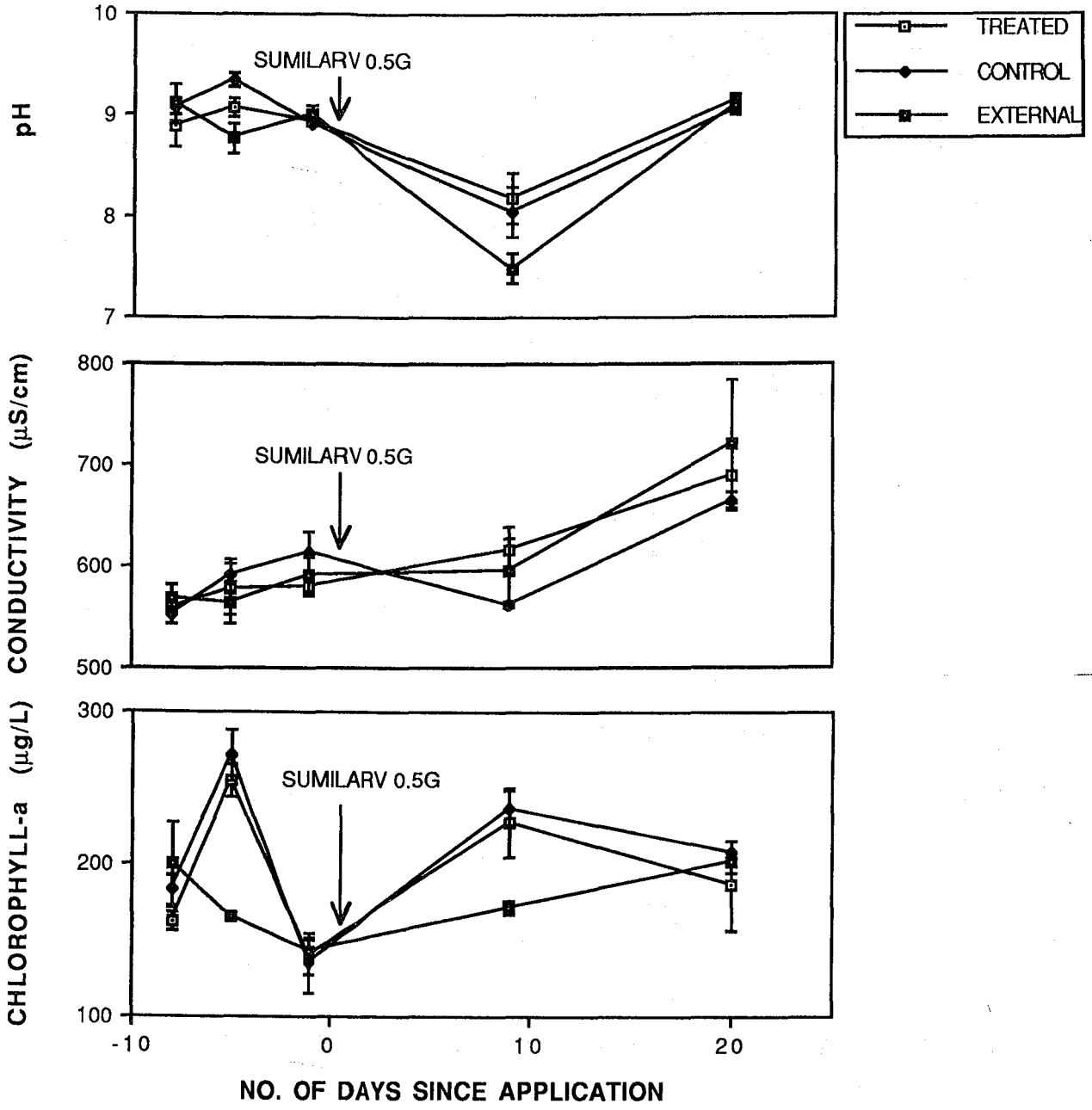


Figure 9. Changes in pH, conductivity and concentration of chlorophyll-a within the treated and control enclosures and the external area during the first field trial of Sumilarv 0.5G at North Lake, November 1989.

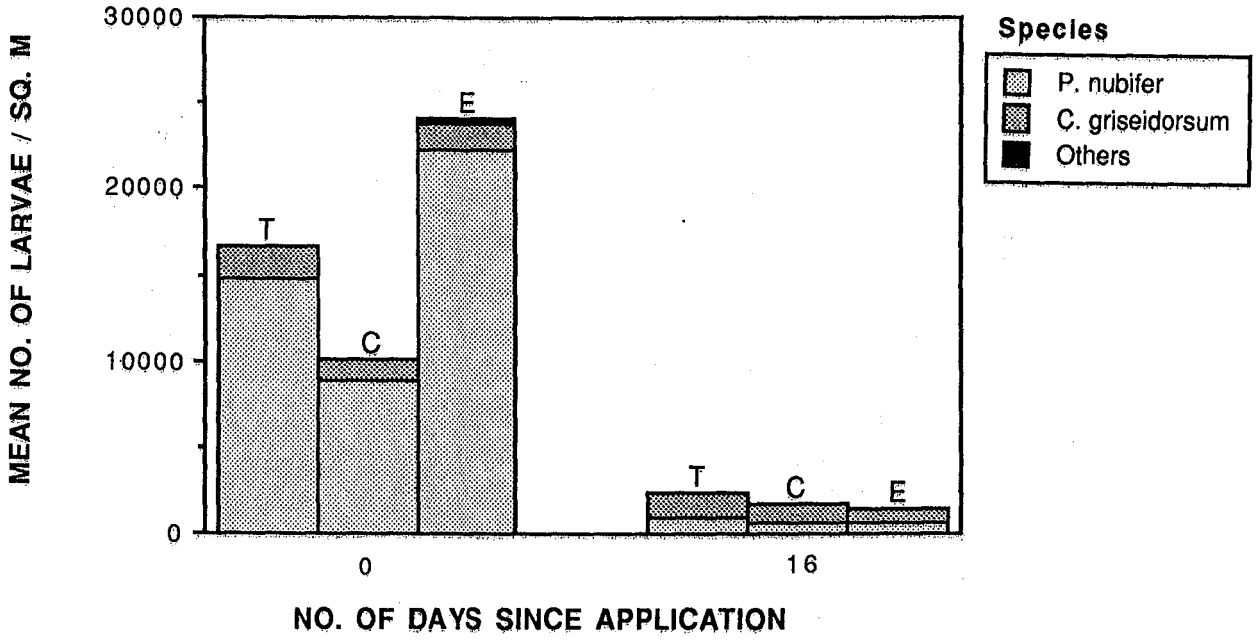


Figure 10. Cumulative density of chironomid larvae within the treated (T) and control (C) enclosures and the external (E) area prior to the application of Sumilarv and sixteen days afterwards, during the second field trial of Sumilarv 0.5G at North Lake, February 1990.

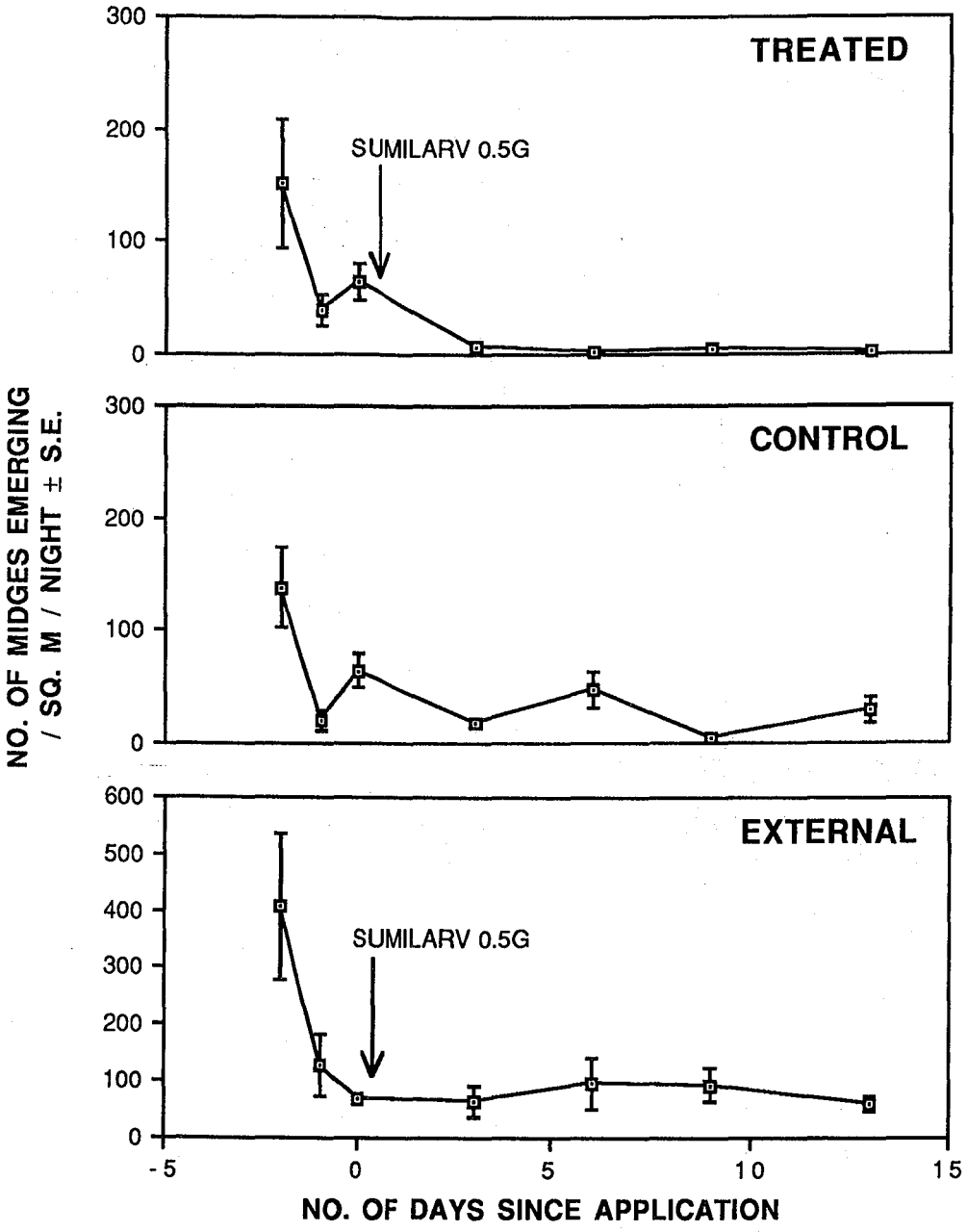


Figure 11. Changes in the rate of emergence of adult chironomids within the treated and control enclosures and the external area during the second field trial of Sumilarv 0.5G at North Lake, February 1990.

2 ± 2 adults/m^2. In the control enclosures, the rate of emergence varied during the experiment. The rate of emergence of adult midges from the external area did not seem to change markedly after treatment.

The changes in the species composition of the emergent midges from the treated and control enclosures and the external area for this second experiment are shown in Figure 12. *Cryptochironomus griseidorsum* and *P. nubifer* were the only species that contributed more than 10% to the total number of midges emerging. Three days after the application of Sumilarv to the treated enclosures *P. nubifer* emergence was reduced to 0 adults/m^2 . The rate of emergence of *C. griseidorsum* was reduced to low levels in the treated enclosures, but emergence was not completely suppressed. In the control enclosures, the emergence of *P. nubifer* dropped to 0 adults/m^2 on day nine.

The results of statistical analyses performed upon the data from this experiment are presented in Table 4. The rate of emergence of total midges and *P. nubifer* from the control enclosures was significantly higher ($P<0.01$) than the rate of emergence from the treated enclosures. However, there was no significant difference between the rate of *C. griseidorsum* emerging from the treated enclosures and the rate emerging from the control enclosures throughout the experiment.

A significant reduction in the rate of emergence of midges occurred in both the treated and control enclosures over time ($P<0.01$ and $P<0.05$, respectively), although it was less dramatic and sudden in the control enclosures. The rate of emergence of *P. nubifer* was also significantly reduced in both enclosure types ($P<0.01$). However, a 100%IE was recorded for this species 3 days after the application of Sumilarv to the treated enclosures

Environmental Parameters

Both the water temperature and the concentration of dissolved oxygen recorded in the external area were higher than that of the treated and control enclosures prior to the application of Sumilarv (Fig. 13). Neither of these parameters varied with depth.

Conductivity and pH increased in all of the sampled areas within six days of the application (Fig. 14). The highest recorded conductivity and pH were 1640 µS/cm and 9.47, respectively.

The concentration of chlorophyll-a did not differ greatly between the three areas during the experiment. A decline in chorophyll-a concentration was observed in all areas within six days of the application of Sumilarv (Fig.14).

Non - Target Fauna

The data collected on the mayfly, *T. tillyardi*, during both of the field trials was analysed in the same way as the adult midge data. Table 5 shows the results of these analyses. There was no significant difference between the number of *T. tillyardi* emerging in the treated and control enclosures during the first experiment. During the second experiment, the emergence of this species was significantly higher in the control enclosures than in the treated enclosures ($P<0.05$). The rate of *T. tillyardi* emerging from the control

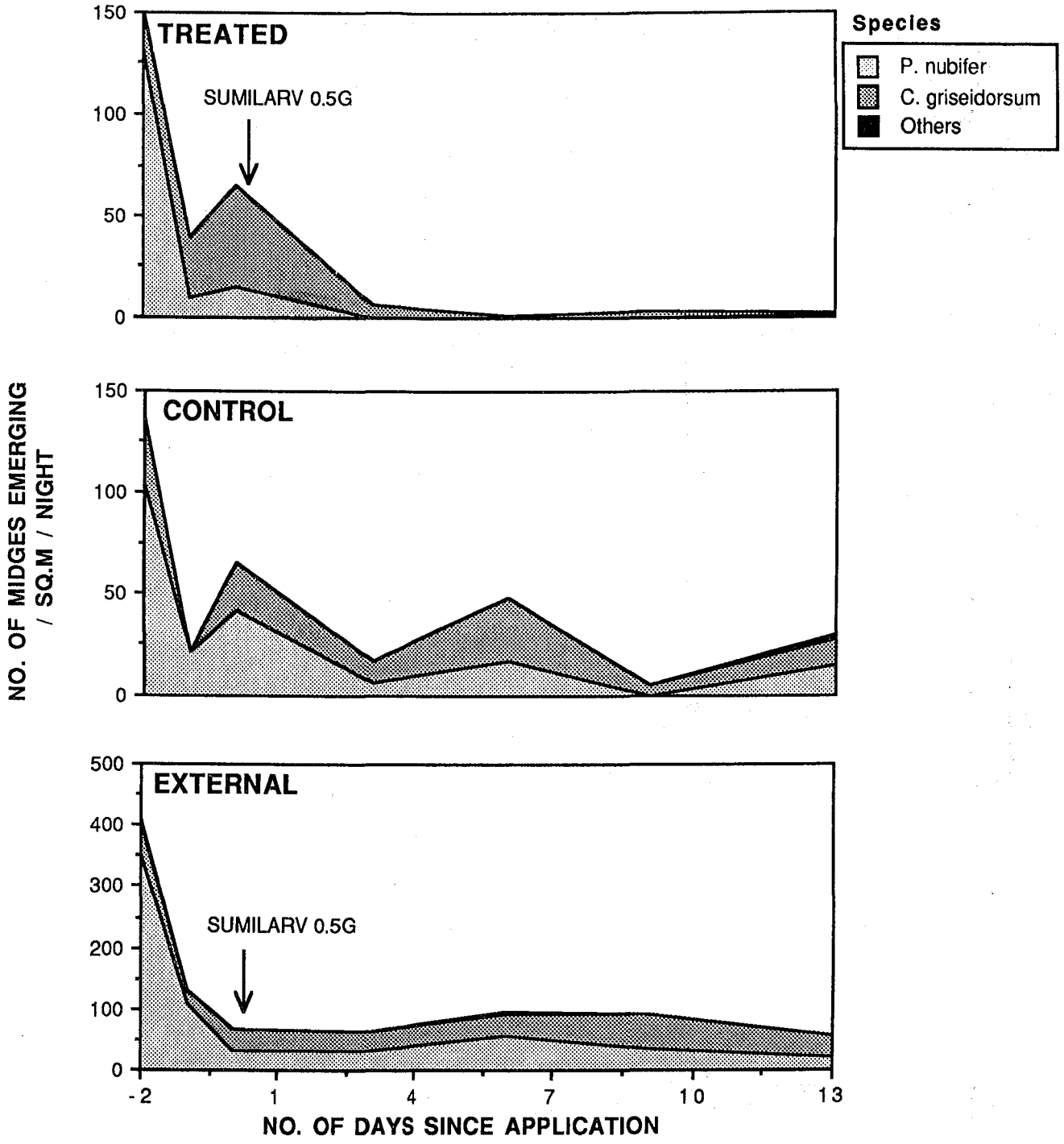


Figure 12. Changes in the cumulative rate of emergence of adult chironomids within the treated and control enclosures and the external area during the second field trial of Sumilarv 0.5G at North Lake, February 1990.

Table 4. Results of statistical analyses on chironomid emergence data obtained from the treated and control enclosures during the second field trial of Sumilarv 0.5G at North Lake, February 1990.

	MEAN NO. OF ADULTS EMERGING / SQ. M / NIGHT PRE- AND POST-TREATMENT (DAYS)												
SPECIES	PRETREAT	1-3	4-9	10-21	22+	SIGNIFICANCE	PRETREAT	1-3	4-9	10-21	22+	SIGNIFICANCE	TREAT vs. CONT
	SUMILARV 10 kg/ha						CONTROL						
Total	85a [0]	6b [69]	3b [91]	2b [93]	-	* *	74a	17ab	28b	29ab	-	*	* *
Polypedilum nubifer	52a [0]	0b [100]	0b [100]	1b [93]	-	* *	55a	6b	9b	15b	-	* *	* *
Cryptochironomus griseidorsum	33a [0]	6b [69]	3b [91]	1b [96]	-	* *	19a	11a	20a	13a	-	NS	NS

Means in a row followed by the same letter are not significantly different from each other.

Numbers in parentheses represent % inhibition of adult emergence after treatment. See p. 15 of text for greater detail.

TREAT vs. CONT: comparison of emergence from treated and control enclosures over time by two- way ANOVA.

Significance: NS = not significant; * and ** = significant at 5 and 1% lev respectively.

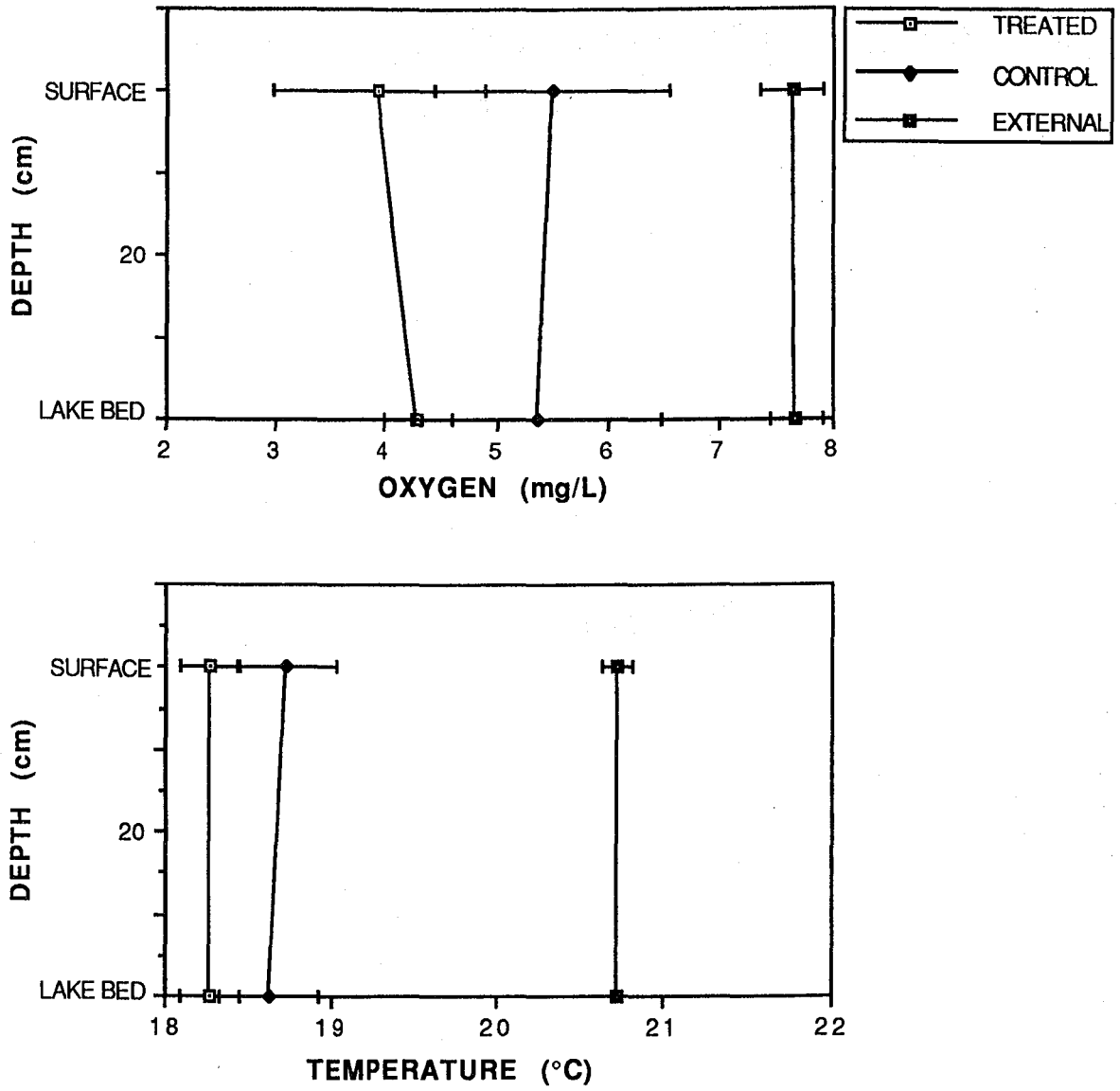


Figure 13. Depth profiles of dissolved oxygen concentration and temperature within the treated and control enclosures and the external area, prior to the application of Sumilarv during the second field trial of Sumilarv 0.5G at North Lake, February 1990.

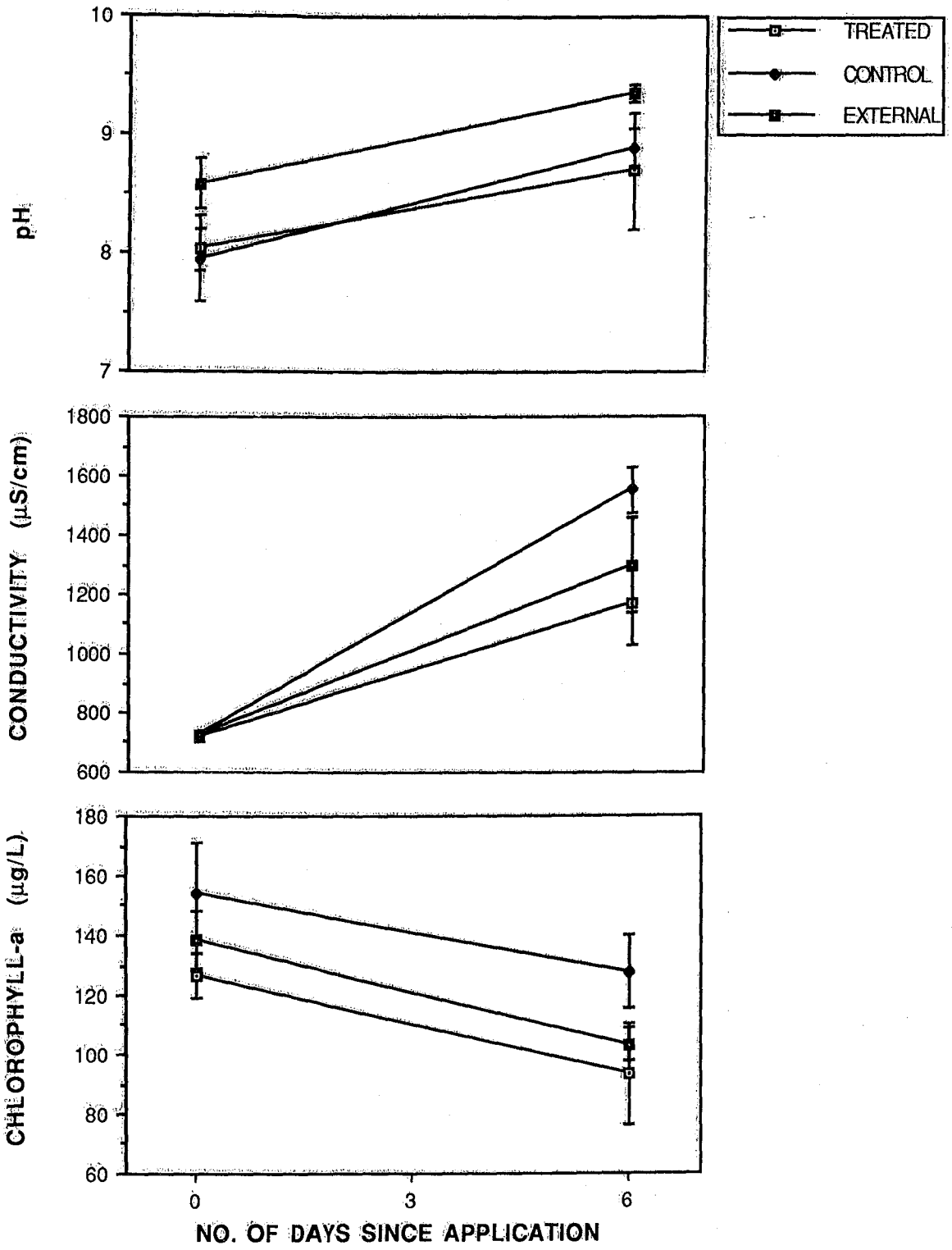


Figure 14. Changes in pH, conductivity and concentration of chlorophyll-a within the treated and control enclosures and the external area during the second field trial of Sumilarv 0.5G at North Lake, February 1990.

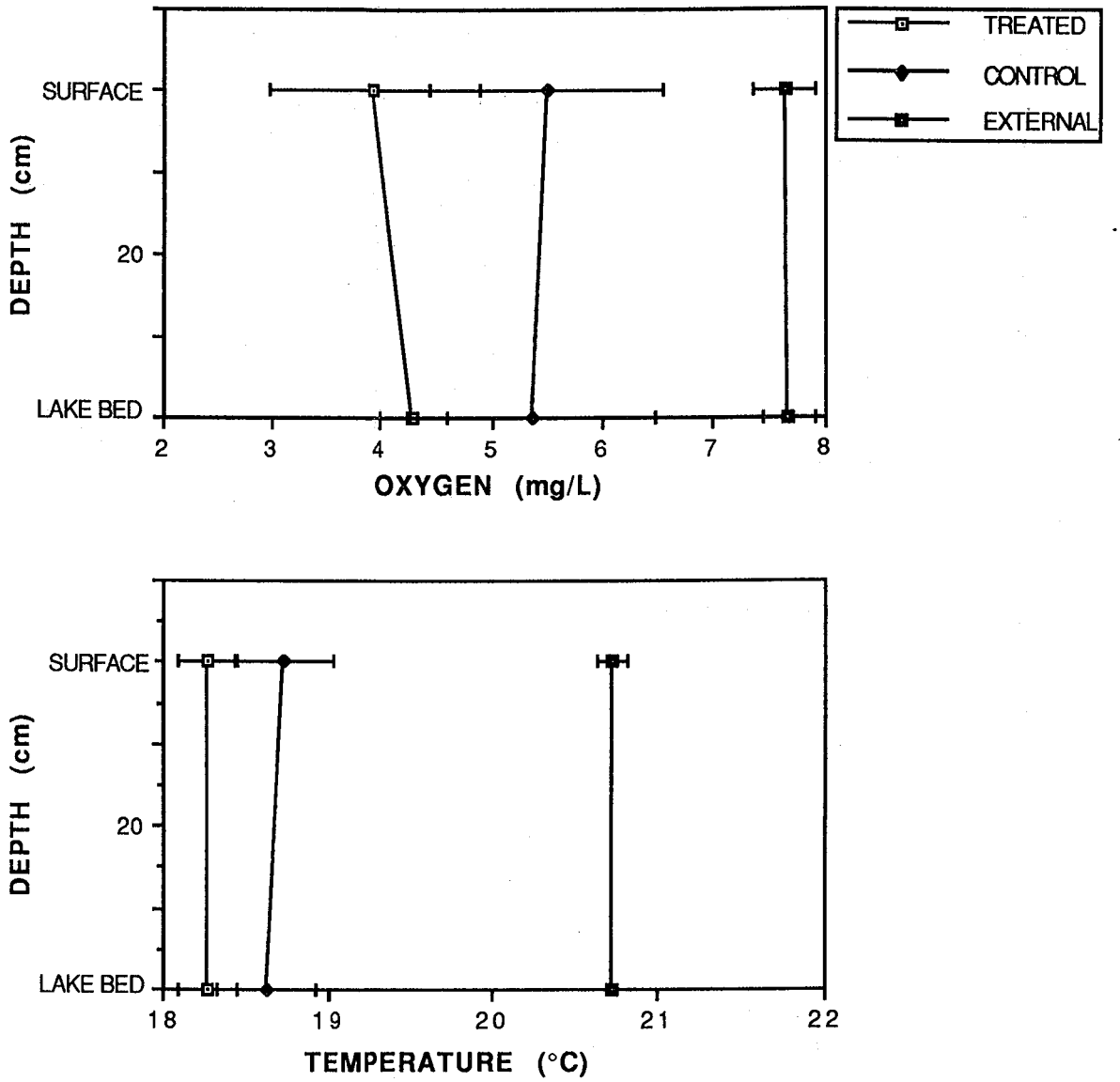


Figure 13. Depth profiles of dissolved oxygen concentration and temperature within the treated and control enclosures and the external area, prior to the application of Sumilarv during the second field trial of Sumilarv 0.5G at North Lake, February 1990.

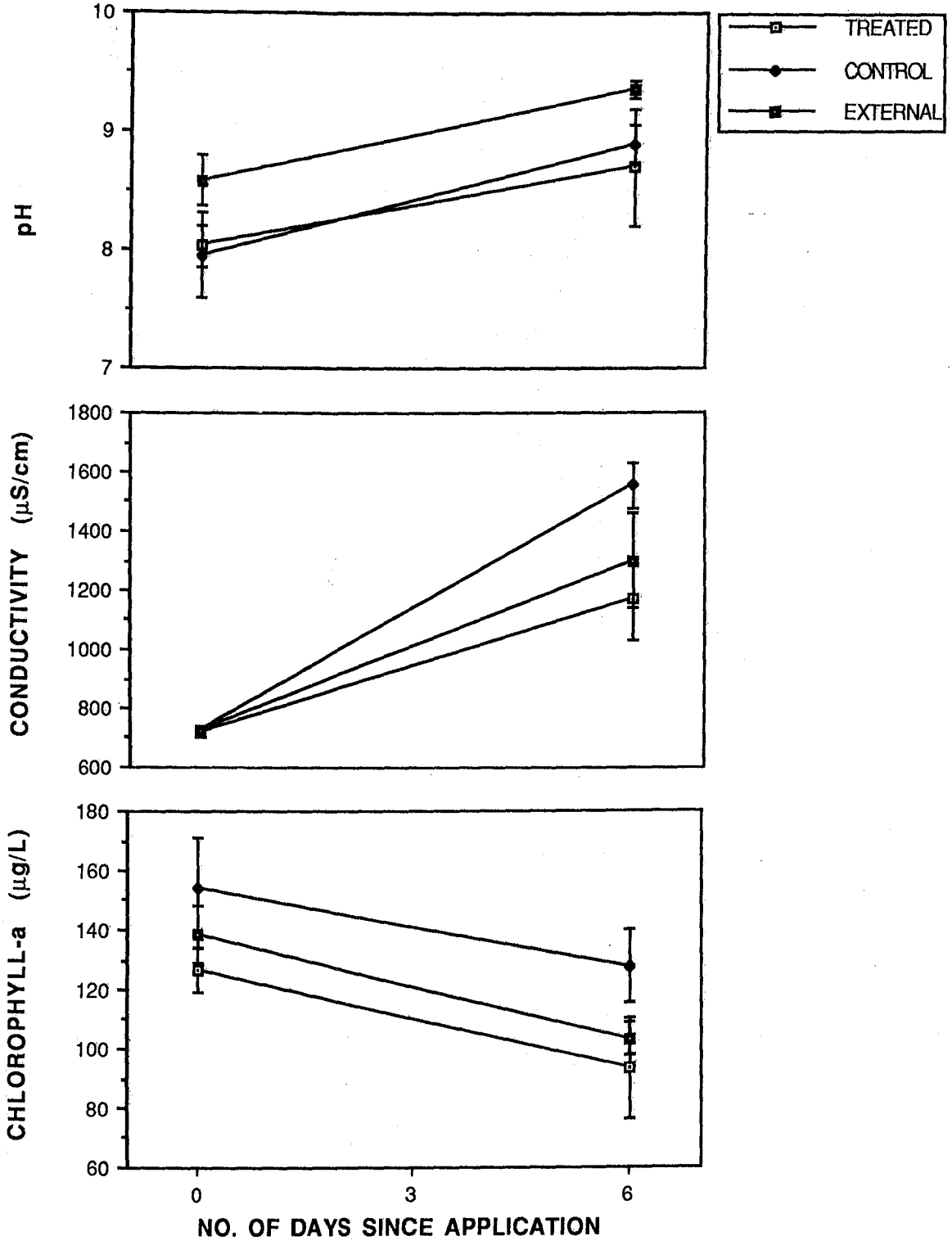


Figure 14. Changes in pH, conductivity and concentration of chlorophyll-a within the treated and control enclosures and the external area during the second field trial of Sumilarv 0.5G at North Lake, February 1990.

Table 5. Results of statistical analyses on mayfly, *Tasmanocoenis tillyardi* emergence data obtained from treated and control enclosures during the first and second field trial of Sumilarv 0.5G at North Lake, November 1989 and February 1990, respectively.

	MEAN NO. OF MAYFLY EMERGING / SQ.M / NIGHT PRE- AND POST-TREATMENT (DAYS)												
EXPERIMENT	PRETREAT	1-3	4-9	10-21	22+	SIGNIFICANCE	PRETREAT	1-3	4-9	10-21	22+	SIGNIFICANCE	TREAT vs. CONT
	SUMILARV 10 kg/ha						CONTROL						
ONE	97a [0]	139ac [#]	25b [55]	4b [83]	31abc [58]	* *	95a	55ab	53ab	23b	73ab	* *	NS
TWO	36a [0]	34a [#]	20a [71]	4a [96]	-	NS	30a	28a	57a	78a	-	NS	*

Means in a row followed by the same letter are not significantly different from each other.

Numbers in parentheses represent % inhibition of adult emergence after treatment. See p. 15 of text for greater detail.

Increase in emergence

TREAT vs. CONT: comparison of emergence from treated and control enclosures over time by two- way ANOVA.

Significance: NS = not significant; * and ** = significant at 5 and 1% levels respectively.

enclosures did not change significantly during this experiment. A 96%IE was recorded in the treated enclosures thirteen days after the application of Sumilarv. However, changes in the rate of emergence in the treated enclosures were not significant

Table 6 is a summary table of the information available on the non-target effects of Sumilarv. The source of information, the types of tests, the types of organisms tested and the rates used are presented. The conclusions of the authors regarding the effects of Sumilarv are also given.

DISCUSSION

Laboratory Trials

The results of the laboratory trials suggest than 10 kg/ha of Sumilarv is required to achieve a 90% inhibition of emergence of *P.nubifer* under controlled laboratory conditions. Further laboratory trials of Sumilarv are required to determine the most effective rate against other chironomid pest species such as *Chiromomus occidentalis*. However, before these trials are undertaken, the experimental design may need modification in order to reduce pupal mortality in the control aquaria and thus extend the duration of the trials.

First Field Trial

The Effects of Sumilarv on Larval Density

Juvenile hormone analogues such as Sumilarv are known to have an indirect and delayed effect on larval mortality (Staal, 1972). This may explain why Sumilarv appeared to have no effect on larval density during this experiment. Alternatively, any effect that Sumilarv had on the density of larvae may have been masked by the colonization of midges from areas of North Lake that had been missed by the uneven helicopter application of Sumilarv to the lake. Clearly, larval density is not a useful indicator of Sumilarv effectiveness, in this instance.

Effects of Sumilarv on Adult Emergence

The similarities observed between the pattern of emergence of adult midges in the control and external areas indicated that the area immediately outside the enclosures received no pesticide. This further justifies the decision to add Sumilarv by hand to the treated enclosures, after it was found that there was no Sumilarv on the interception trays.

Sumilarv applied at a rate of 10 kg/ha was highly effective against all of the major midge species in the trial (*P. nubifer, C. alternans* and *K. intertinctus*). The emergence of these midge species was suppressed for at least 21 days.

Environmental Parameters

All of the environmental parameters recorded in the control and treated enclosures were similar throughout this experiment. This suggests that any differences in the rate of emergence in these two areas was due to Sumilarv and not to differing environmental conditions.

The temperature recorded outside the enclosures was often lower than that recorded inside the enclosures and this may be due to greater mixing of the

Table 6. Summary of the available information on the non-target effects of Sumilarv 0.5G.

AUTHOR	METHODS	CONCENTRATION (AI)	TAXA	EFFECTS
SUMITOMO UNPUBLISHED DATA	LABORATORY TESTS	0.85 mg/L	RAINBOW TROUT - JUVENILE	LC50 96hr
		0.45 mg/L	CARP - JUVENILE	LC50 96hr
		>1.00 mg/L	ALGAE	EC50 96hr
		2.70 mg/L	KILLIFISH - ADULT	LC50 96hr
		>10 mg/L	- EMBRYO	EFFECTIVE LEVEL GIVEN
		~ 0.3 mg/L	- YOLK SAC FRY	EFFECTIVE LEVEL GIVEN
		1 mg/L	- POST LARVAE	EFFECTIVE LEVEL GIVEN
		3 mg/L	- JUVENILE	EFFECTIVE LEVEL GIVEN
		1 mg/L	MOLLUSC (HORNSHELL)	EFFECTIVE LEVEL GIVEN
		~ 0.2 mg/L	FRESHWATER SHRIMP	EFFECTIVE LEVEL GIVEN
		0.1 - 1.0 mg/L	COPEPODA	EFFECTIVE LEVEL GIVEN
		>10 mg/L	BRINE SHRIMP	EFFECTIVE LEVEL GIVEN
		>0.1 mg/L	DRAGONFLY	EFFECTIVE LEVEL GIVEN
SUMITOMO TECHNICAL REPORT	LABORATORY TESTS	>5000 mg/kg	RAT	LD50 ACUTE ORAL
		>2000 mg/kg	RAT	LD50 ACUTE DERMAL
SUMITOMO SUMILARV PRODUCT BROCHURE	LABORATORY TESTS	-	GUINEA PIGS	NO SKIN SENSITIZATION
		4.16mg/L	CARP	LC50 96hr
		10mg/L	DAPHNIA	LC50 3hr
MULLA et al., 1987	FIELD OBSERVATIONS	NOT GIVEN	CLAM SHRIMP	REDUCED IN NUMBER
		NOT GIVEN	CLADOCERA	REDUCED IN NUMBER
		NOT GIVEN	DRAGONFLY NYMPH	MILDLY REDUCED IN NUMBER
SCHAEFER et al., 1988	LABORATORY TESTS	0.01 mg/L	CLADOCERA	NO SIGNIFICANT EFFECTS AFTER 14 DAYS
		0.01 mg/L	COPEPODA	NO SIGNIFICANT EFFECTS AFTER 14 DAYS
SCHAEFER et al., 1988	EXPERIMENTAL RICE PLOTS	0.0056kg/ha	CLADOCERA	NO EFFECT
		0.0056kg/ha	COPEPODA	NO EFFECT
		0.0056kg/ha	OSTRACODA	NO EFFECT
		0.0056kg/ha	DAMSELFLIES	NO EFFECT
		0.0056kg/ha	DRAGONFLIES	NO EFFECT
		0.0056kg/ha	BEETLES	NO EFFECT
		0.0056kg/ha	CHIRONOMIDS	NO EFFECT
		0.0056kg/ha	CULICOIDES	NO EFFECT
		0.0056kg/ha	HYDRA	NO EFFECT
MULLA et al., 1986	EXPERIMENTAL PONDS	0.01 & 0.025 kg/ha	MAYFLY NAIADS	NO MARKED EFFECTS
		0.01 & 0.025 kg/ha	DRAGONFLY NAIADS	NO MARKED EFFECTS
		0.01 & 0.025 kg/ha	DIVING BEETLES	NO MARKED EFFECTS
		0.01 & 0.025 kg/ha	OSTRACODS	NO MARKED EFFECTS

water by wind and wave action outside the enclosures. This may also account for the difference in dissolved oxygen levels and chlorophyll-a levels between the enclosed and external areas. Thus, the differences in these environmental parameters recorded between the enclosed areas and the external area are likely to have been an effect of the enclosures.

Dissolved oxygen and temperature measurements did not differ greatly with depth in any of the areas. This is probably due to the shallow depth of these areas (the maximum depth was only 40cm). Changes in conductivity during the experiment may be related to evaporative processes and the declining water level of the lake.

Second Field Trial

Distribution of Sumilarv 0.5G

Despite gusty wind conditions, the application of Sumilarv in this second experiment was more satisfactory than in the first field experiment. However, it was far from ideal. The mean rate of application calculated from the interception trays was 3.3 kg/ha. Although this was much lower than the desired rate of 10 kg/ha, it may not be a true reflection of the application rate, as many of the interception trays had sunk and the number remaining was not sufficient to accurately determine the application rate for the whole of the lake. The wide range of application rates calculated (0-7.1 kg/ha) indicates that the application was patchy. Uneven applications of pesticide must be avoided for effective midge control. Correct calibration of the helicopter speed and hopper release mechanism is required to ensure even distribution of pesticide at pre-determined rates.

Effects of Sumilarv on Larval Density

Larval density declined in all areas sampled during this second field experiment. If Sumilarv was having a direct effect on the abundance of larvae, then the decline in larval density in the treated enclosures should have been greater than the decline in the control enclosures, however this was not the case.

An indirect effect of Sumilarv is likely to have caused the decline in larval abundance in all areas. The rate of adult emergence in the lake was suppressed by the application of Sumilarv. Thus there was probably a reduction in the number of midges laying eggs. If the number of new larvae colonizing the areas sampled was lower than larval mortality, then the density of larvae in these areas would decline. It is unfortunate, that larval densities were not recorded between the time of application and then sixteen days later, as this might have given a better indication of the delayed effect of Sumilarv on larval mortality.

Effects of Sumilarv on Adult Emergence

The application of Sumilarv reduced the emergence of midges over the whole of the lake (Fig. 18) and thereby reduced larval density which, in turn, further reduced emergence. This, indirect effect, may explain the decline in the emergence of total midges and *P. nubifer* which occurred in both the treated and control enclosures. Emergence in the treated enclosures was reduced to a greater extent than in the control enclosures and this was due to the direct effect of Sumilarv, suppressing emergence.

This experiment was terminated unexpectedly by a storm and thus we have no indication of how the longevity of Sumilarv control would have compared with the first field experiment.

Environmental Parameters
As with the first field experiment, all of the measurements of physical parameters were similar in the treated and control enclosures throughout this experiment. Thus, the differences in emergence rates observed in the two areas are likely to be due to the effects of Sumilarv and not to differing environmental conditions. None of the measurements of these parameters were outside the range which has been recorded for North Lake in the past.

Non - Target Fauna
Effects of Sumilarv on Mayflies
Sumilarv had no effect on the emergence of *T. tillyardi* in the first field experiment. However, this species did appear to be affected after thirteen days exposure to the pesticide in the second field experiment. This anomaly will require further investigation.

Effects of Sumilarv on Non-Target Fauna
Much of the information gathered from various literature sources on the non-target effects of Sumilarv suggests that this product does not adversely effect non-target fauna. However, the methodology in the literature was often inadequately documented, the results were usually not statistically analysed and the effects observed were often ill-defined. Despite these limitations, it would appear that Sumilarv is non-toxic to a wide range of organisms at field rates.

Before Sumilarv can be registered in Perth, a number of E.P.A. criteria must be satisfied (J. Sutton, pers. comm.). An investigation of the effects of Sumilarv on the non-target fauna (particularly aquatic insects) which inhabit Perth wetlands is required.

Conclusions
These field and laboratory experiments show that Sumilarv has considerable potential for the control of nuisance midges and may be an effective alternative to Abate, especially in lakes where the latter does not appear to be effective. However, more information is required on the effectiveness and persistence of Sumilarv under field conditions. In addition, there is a need to determine the most effective rate of Sumilarv on midges other than *P. nubifer*, under laboratory conditions and, to determine more precisely the effect of Sumilarv on larval mortality.

In terms of cost, information obtained from S. Broadbent of Wellcome (the Australian agents for Sumilarv 0.5G) suggests that Sumilarv will be comparable with Abate on a per hectare basis. It is likely that the price of Sumilarv will be between $3 and $6/kg. Thus, if Sumilarv is applied at 10 kg/ha (assuming 50cm depth) then a cost of application of between $30 and $60/ha can be expected. At present the cost of Abate is $13.50/kg. The cost of applying Abate at 2.5 kg/ha (assuming 50cm depth), the maximum rate which is at currently being used to control midge nuisance levels at some Perth lakes, is

$33.75/ha. If Wellcome can maintain the cost of Sumilarv at the lower end of the range then this product will be economically comparable with Abate.

From an environmental viewpoint, because Sumilarv is an insect growth regulator, it is likely to affect a much narrower range of organisms than Abate, which is a broad spectrum organophosphate pesticide. However, the information which is currently available on the non-target effects of Sumilarv is not sufficient and requires further investigation.

It would seem logical to suggest that midges might never develop resistance to a juvenile hormone analogue, such as Sumilarv, which mimics a naturally occurring and indispensible hormone for normal development. However, Schneiderman (1972) suggested that insects already have the mechanisms to inactivate, sequester and excrete natural juvenile hormone and thereby, many juvenile hormone analogues at specific times in their development. Since the application of pesticides acts as a powerful sieve for concentrating resistant mutants, Schneiderman (1972) concluded that the existence of those mechanisms guarantees that natural selection could produce populations resistant to exogenous juvenile hormone analogues. Indeed, resistance to the JHA, methoprene, has already been recorded in mosquitoes (Mian and Mulla, 1982). In addition, some organophosphate resistant strains of mosquitoes have shown cross-resistance to methoprene through selection (Brown and Brown, 1974). This has also been documented for houseflies (Georghiou et al., 1978).

LARVAL AND ADULT MONITORING PROGRAMMES

INTRODUCTION

Regular sampling of the larval midge populations at Forrestdale Lake and North Lake continued throughout 1989 and until March 1990. In addition, samples of larvae from Lake Goollelal and Lake Monger, collected as part of the monitoring programmes of Wanneroo and Perth City Councils respectively, were identified by the Murdoch research team.

At both Forrestdale Lake and North Lake emergence traps were used to monitor emergence of adults from late spring to the end of summer. A number of residents living close to these lakes continued to collect adult specimens from around their houses and to score the level of midge nuisance that they had experienced for the previous two to four weeks. Quantitative measurements of adult midge abundance and species composition in residential areas adjacent to North Lake were made using light traps over a four month period between late spring and early autumn. This was the second year that emergence traps and light traps were used to provide information about the adult stage.

One of the reasons for sampling these two lakes so comprehensively was to increase knowledge on the relationships between midge larval populations, adult nuisance levels and environmental variables. This may lead to improved control of midges in both the short and longer terms. If a link can be established between the initial increase in midge larval density, the onset of nuisance problems and one or more physico-chemical factors then it may be possible to develop a much simpler monitoring programme. Better control will be achieved if the onset of midge problems can be predicted simply, quickly and with a high degree of confidence. Analysis of the three years of data that have been collected at Forrestdale Lake shows considerable promise in this regard. Improvements in pesticide application techniques (in particular, timing) should also follow from this approach, where the effects of treatments on larval and adult abundance are being recorded.

Longer term control will involve improving lake water quality, thus any links that can be established between water quality and midge abundance will provide impetus for the initiation of longer term solutions.

DESCRIPTIONS OF STUDY SITES

Descriptions of Forrestdale Lake, North Lake, Lake Goollelal and Lake Monger, including lake area, lake depth and lake vegetation are presented in the first report (Davis, Harrington and Pinder, 1988) and will not be repeated here.

METHODS

General

As for the 1988/89 study Forrestdale Lake and North Lake were the focus of this years midge monitoring programme. A corer and plankton tow net were used to sample midge larvae in the sediment and water column respectively. On each sampling occasion environmental parameters (water depth, and water and air temperatures) were recorded, and samples of water were collected for analysis of pH, conductivity and the concentrations of total phosphorus, total nitrogen and chlorophyll-a. Sampling was carried out at weekly to fortnightly intervals during summer and monthly during winter, from March 1989 to March 1990, continuing on from the previous years sampling.

Estimates of adult midge emergence were made at Forrestdale Lake and North Lake using submerged emergence traps. This information was collected with the aim of determining the relationship between larval abundance and emergence of adult midges.

Light traps were placed at selected houses adjacent to North Lake for the purpose of quantitatively determining the abundance of adult midges at these residences. The light trap catches were collected three nights a week over a period of seventeen weeks. In addition, a small number of residents at North Lake and Forrestdale Lake were asked to comment on the extent of the nuisance caused by adult midges each fortnight or month and to collect adult midges from their houses with an aspirator for later identification by the Murdoch research team.

Meteorological data for Perth (including air temperature, rainfall and wind strength and direction) were obtained from the Bureau of Meteorology.

The methods used in the field monitoring programmes at particular lakes are outlined below.

Larval Sampling

This section briefly describes the methods used in the larval monitoring programme that was undertaken from March 1989 until March 1990. The methods that were used were the same as those described in the first years report (Davis, Harrington and Pinder, 1988) and that report should be consulted for detailed information.

Forrestdale Lake

Sampling of Forrestdale Lake took place every month during autumn and winter (April to August 1989), fortnightly during spring (September to November 1989), and weekly (occasionally fortnightly) during summer (December 1989 to March 1990). Only the northern half of the lake was sampled because of its large size. On each sampling occasion twenty cores (diameter 9.8cm) were taken from the open water region at locations determined using pairs of random numbers. An additional six cores were taken from within the *Typha* beds around the lake perimeter. The density of larvae in the water column was determined using a plankton tow net (34cm diameter and 76μm mesh size). Two four metre tows were taken on each

occasion, until the water became too shallow to sample.

North Lake
Larval sampling was carried out at monthly intervals during autumn and winter (March to August 1989), at weekly to fortnightly intervals during the spring (September to November 1989) and then at fortnightly intervals during the summer (December 1989 to March 1990). Each time the lake was sampled twenty cores (diameter 9.8cm) were taken from the shallow littoral region, each located using a pair of random numbers. Ten additional cores were taken from the central region using a long handled corer. The water column was sampled for planktonic larvae using a plankton tow net (34cm diameter and 76μm mesh size). Two tows were taken over a distance of four metres each.

Sorting and identification
The techniques used to preserve, sort and identify the core samples from North Lake and Forrestdale Lake were the same as those described in the previous two reports (Davis, Harrington and Pinder 1988 and 1989).

Lake Goollelal
The City of Wanneroo sampled Lake Goollelal on twelve occasions between late April 1989 and late February 1990. Samples were collected from ten sites using an 800ml scoop attached to a long handle. Larvae were sorted from the substrate in the field using a sieve of 1.25mm mesh size. Samples of larvae from each site were given to the Murdoch research team for identification. The City of Wanneroo is constructing a corer and its use in future will enable larval densities recorded at Lake Goollelal to be compared with those obtained at other lakes.

Lake Monger
In early 1989 the City of Perth began using a corer to collect samples of larval midges from the lake sediments. Up until December 1989 only the deeper central regions of the lake were sampled, and as a result *Polypedilum nubifer* was rarely recorded. On the advice of Mr Garkaklis (the midge troubleshooter - see chapter five) the sampling programme was modified to include the shallow littoral (edge) region. Subsequently, between January and March 1990 the edge region was sampled to the exclusion of the central region. Larvae from these samples were identified by the Murdoch research team. A further improvement in the sampling programme would be the sampling of both the central and littoral regions and a programme to do this has been designed by Mr Garkaklis.

Adult Emergence
Submerged emergence traps were used at both Forrestdale Lake and North Lake during the spring and summer of 1989/90. The design of these is illustrated and described in the 1989 report. At Forrestdale Lake three traps were placed at each of two locations (on the north-west and north-east sides). At North Lake two traps were placed at each of three locations (on the north, south and east sides). Emergence rates were calculated from the number of midges caught in each trap over one 24 hour period. The traps were used at Forrestdale Lake between mid September 1989 and mid January 1990 and at North Lake between mid September 1989 and mid March 1990. The traps

were set whenever larval sampling was performed and more frequently at North Lake during field experiments.

Adult Nuisance Assessment

At North Lake two methods were employed to assess the level of nuisance caused by adult midges. The first method involved three residents collecting adult midges with the aid of an aspirator and scoring the level of nuisance for the past month or fortnight as either low, moderate, high or extreme. The aspirator collections were purely qualitative and allowed us to determine which species were causing problems. The nuisance levels scored by each resident were given a numerical value of one, two, three or four depending upon the severity of the problem. These values were added together for any one date and an average value calculated. These values must be considered as general guide only, because they represent the opinion of only a small number of residents and one value represents the nuisance level experienced over one to four weeks. This method was also employed at Forrestdale Lake where up to six residents collected midges between late November 1989 and mid February 1990.

The second method employed at North Lake was the use of four light traps to collect adult midges at selected residences. The design of these traps is described in the 1989 report. Traps one and two were placed at adjacent houses on the northern side of the lake (across Farrington Road), and traps three and four were placed at adjacent houses on the western side. All four traps were hung from external pergolas in positions that were considered to be of equal visibility from the lake. The traps were set on the same three consecutive nights each week for eighteen weeks between November 1989 and March 1990. An automatic timing switch turned the traps on at 7.30pm and off at 4.30am. Collection of the midges occurred as early as possible on the following day. These were preserved for later counting and identification in the laboratory.

Environmental Parameters

Information on water depth, water and air temperature and water quality was collected on each sampling occasion at Forrestdale Lake and North Lake.

Lake depths were read from staff gauges and water and air temperatures were recorded from maximum-minimum thermometers located at each lake. For the analyses of water quality, five small water samples were collected at evenly distributed points around each lake. These were mixed together in the laboratory and pH and conductivity were measured on the pooled sample. Part of the pooled sample was filtered for chlorophyll-a analysis and two (100 ml) samples were frozen for later analyses of total nitrogen and total phosphorus. Nutrient analyses were carried out by the Centre for Water Research Nutrient Analysis Laboratory and Mark Lund at Murdoch University. Data for air temperature, rainfall and wind strength and direction for Perth City were obtained from the Bureau of Meteorology.

RESULTS AND DISCUSSION

For ease of discussion, this section is divided into several subsections. A general description of the observed changes in larval density and adult abundance is followed by a more detailed discussion the changes in midge populations that occurred after each application of pesticide. The physico-chemical changes that occurred in the lakes are then described and possible relationships between these and chironomid populations are discussed. Finally the light trap results for North Lake are examined in relation to meteorological data for Perth. Some of the scientific names of species of midges that occur in Perth have been updated, a list of the updated names and those used previously are given in Appendix two.

Changes in Larval and Adult Midge Populations

This section describes the changes in larval and adult populations that occurred at Forrestdale Lake, North Lake, Goollelal Lake and Lake Monger during the 1989/90 monitoring. Figures 15 to 20 show the changes in larval and adult populations that occurred at these lakes.

Forrestdale Lake

The highest density recorded in the *Typha* beds was 510 ± 257 larvae/m^2 in early December (Fig. 16). *Chironomus alternans* dominated the larval midge community within this region from the time of reflooding in June 1989, until just before it dried out in December. Towards the end of December 1989 a brief peak in *Chironomus occidentalis* and *P. nubifer* was observed as *C. alternans* became relatively less abundant.

Three discrete phases of larval abundance and species composition occurred in the open water region of Forrestdale Lake (Fig. 16). Between April and July 1989 the density of larvae in the open water region did not exceed 500 larvae/m^2, during this time various species were dominant. However it was rare for these dominant species to exceed 50% of the total.

From August until late November 1989 *C. occidentalis* accounted for between 66 to 92% of the total density of larvae. The maximum recorded total density during these months was 1 624 ± 372 larvae/m^2 on 5 October, at this time *C. occidentalis* occurred at a density of 1 076 ± 433 larvae/m^2. The density of *P. nubifer* during this period ranged from 17 ± 11 to 166 ± 73 larvae/m^2. The latter density was recorded on the 8 November.

On the 4 December 1989 the density of larvae increased to 6 039 ± 1 730 larvae/m^2, *C. occidentalis* and *P. nubifer* accounted for 51% and 40% of this total respectively. By 13 December the total density of larvae had increased to 8 739 ± 1 195 larvae/m^2, and *C. occidentalis* and *P. nubifer* accounted for 40% and 58% respectively. One week later the lake was treated with Abate and the density of larvae fell by 99%. Only three weeks after this, the density of *P. nubifer* had increased to 5 669 ± 2 211 larvae/m^2 and residents were experiencing 'high' nuisance problems. This short recovery period suggests a development time of less than three weeks for *P. nubifer*. On all but two of the subsequent sampling occasions *P. nubifer* accounted for over 90% of total larval density.

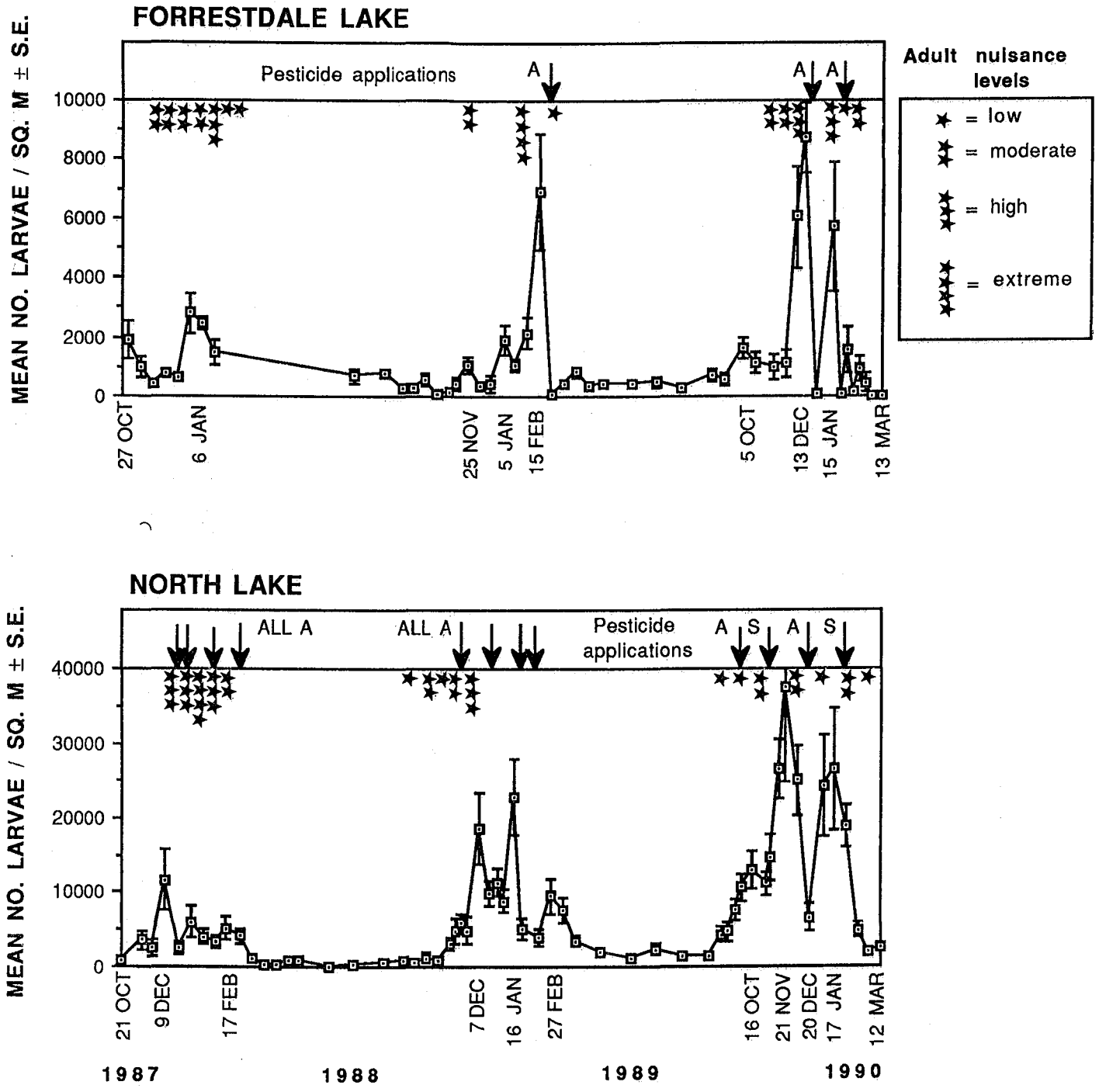


Figure 15. Changes in the mean density of chironomid larvae at Forrestdale Lake and North Lakes, October 1987 to March 1990. Data for Forrestdale Lake are for the entire open water region whereas the North Lake data represent the littoral region only. Means and standard errors are shown. Adult nuisance levels and the dates on which Abate and Sumilarv were applied are indicated. A = Abate, S = Sumilarv 0.5G.

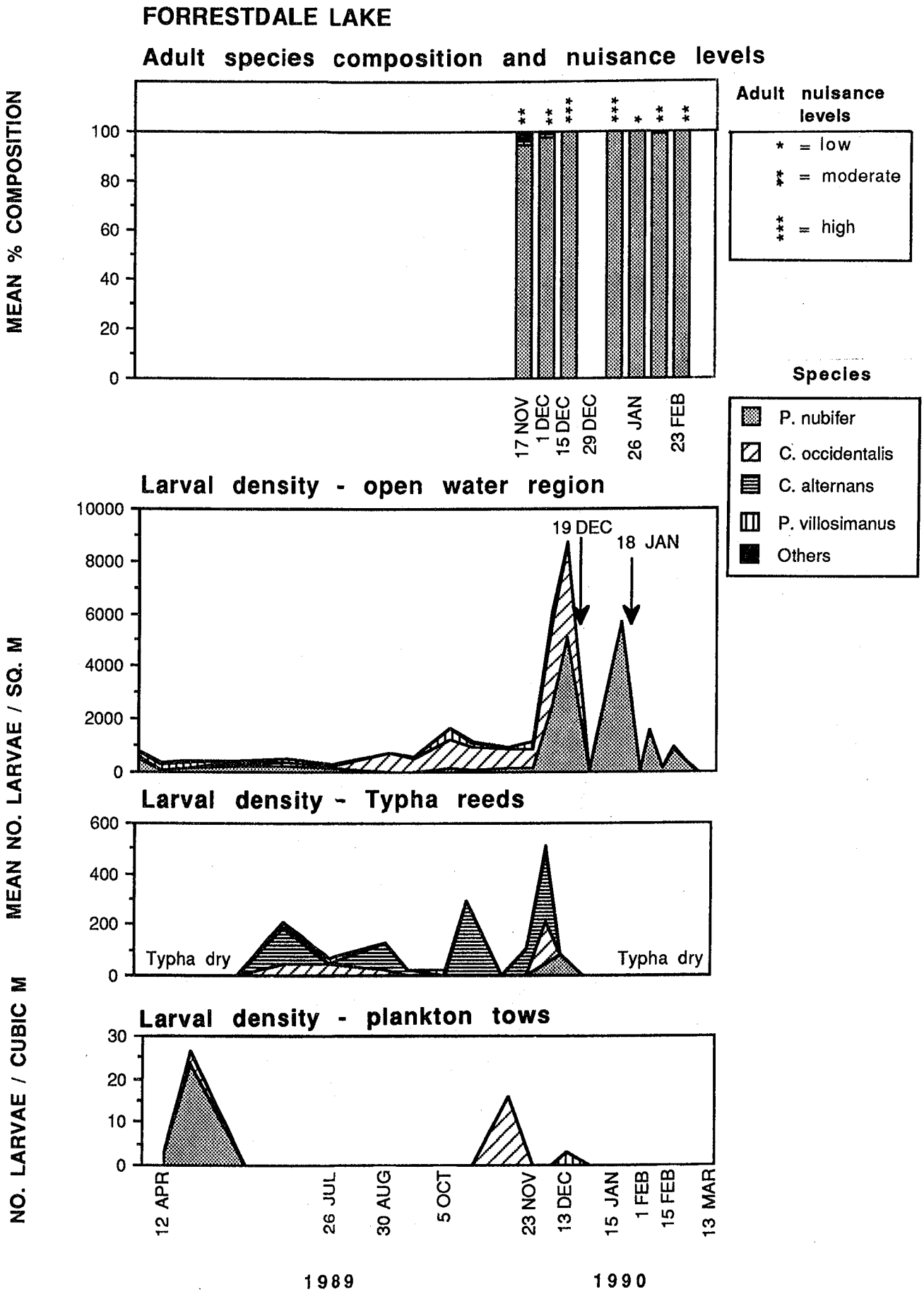


Figure 16. Changes in the species composition (aspirator collections) and nuisance levels for adult chironomids, cumulative density of larvae in the open water region and *Typha* region, and in plankton tows at Forrestdale Lake, March 1989 to March 1990. The dates on which Abate were applied to the lake are indicated.

Chironomid larvae were rarely found in plankton tows, and on the few occasions that they did occur, both abundance and species composition did not appear to correlate with benthic larval densities (Fig. 16).

The pattern of change in larval species composition and density was similar in certain respects to that recorded during the previous two years. Either *C. occidentalis* or *C. alternans* have been the most abundant species during spring and early summer followed by a rapid increase in the abundance of *P. nubifer*. The initial peak in larval density that resulted in nuisance problems occurred earlier this year than in the previous two years. The first peak in *P. nubifer* occurred in early January and mid February of the summers of 1987/88 and 1988/89 respectively. This year the first peak in larval density and the onset of nuisance problems occurred in mid December. Larval abundance was also the highest recorded at Forrestdale Lake since the start of midge research at the lake. An increase in the maximum density of larvae has been recorded in each successive year that monitoring has been carried out at Forrestdale Lake : 2 100 ± 180 larvae/m^2 (in 1985/86), 2 783 ± 666 larvae/m^2 (in 1987/88), 6 905 ±1 962 larvae/m^2 (in 1988/89) and 8 739 ± 1 195 larvae/m^2 (in 1989/90).

Of the nine occasions when emergence traps were set at Forrestdale Lake, adult chironomids were caught on only three. The maximum emergence was 70 adults/m^2 on 13 December (the date on which maximum density of larvae was recorded). The failure of these traps to catch emerging adults on other sampling occasions remains unexplained. It is possible that at low larval densities the probability of catching adults in small emergence traps set for one night is very low. Cores were not taken specifically from the areas where the traps were set and so the larval density in these areas was unknown. After 13 December there were only two sampling dates on which the density of larvae exceeded 1 000/m^2 and, given that only three to four percent of larvae emerge per night, these results appear reasonable

Nuisance problems at Forrestdale Lake began in early December this year. As would have been expected given the early peak in larval density this was earlier than in previous years. *P. nubifer* accounted for more than 90% of adults collected by residents on all occasions.

North Lake

In September 1989 the density of larvae in the littoral region of North Lake began to rise above the low autumn/winter levels (Fig. 17), reaching over 12000 larvae/m^2 by mid-October. By mid-November over 37 000 larvae/m^2 were recorded in this region. This was despite applications of Abate in late September and Sumilarv in early November. Larval density then declined to 25 009 ± 4 632 larvae/m^2 two weeks before an Abate treatment on 14 December. After this treatment the total density of larvae declined further to 6 612 ± 1 836 larvae/m^2. Within three weeks this had again increased to over 23 000 larvae/m^2. A second peak of over 26 000 larvae/m^2 was reached before numbers declined to nearly 2 000 larvae/m^2 four weeks after the second Sumilarv treatment.

As in previous years *P. nubifer* was the dominant species in the littoral region of North Lake throughout the year (Fig. 17). The maximum contribution by

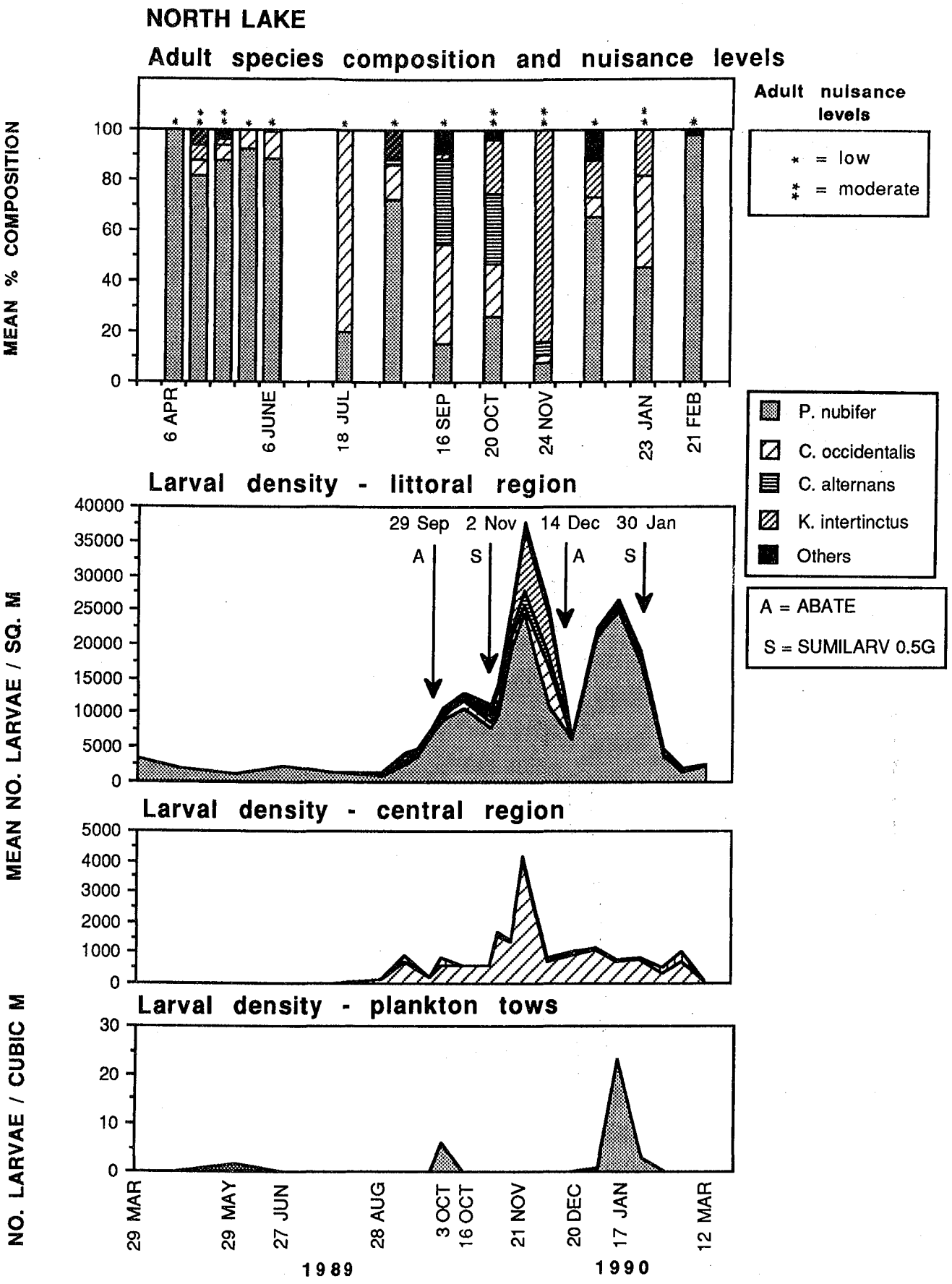


Figure 17. Changes in the species composition (aspirator collections) and nuisance levels for adult chironomids, cumulative density of larvae in the littoral and central regions, and in plankton tows at North Lake, March 1989 to March 1990. The dates on which Abate (A) or Sumilarv 0.5G (S) were applied to the lake are indicated.

any other species was 23.5% by *Kiefferulus intertinctus* following the first Sumilarv application (1 November). However, after the following Abate application *P. nubifer* again accounted for greater than 90% of total larval density. The dominance of *P. nubifer* was reduced and the contribution of *K. intertinctus* and *Cryptochironomus griseidorsum* increased after the second Sumilarv treatment.

In the deeper central regions of the lake *C. occidentalis* was the most abundant species, accounting for more than 80% of the larvae on most sampling occasions (Fig. 17). *Procladius villosimanus* was also common, as is often observed when *C. occidentalis* is the dominant species. The highest density of larvae recorded in this region (4 268 ± 1 831 larvae/m^2) coincided with the peak in the littoral region. This year the central region supported high larval densities, with greater than 500 larvae/m^2 occurring on 14 sampling occasions. By contrast this figure had been exceeded only four times between October 1987 and March 1989.

Larvae were caught in the plankton tows on only four sampling occasions (Fig. 17). The purpose of collecting larvae in this manner was to attempt to predict increases in benthic larval abundance by monitoring the abundance of planktonic first instar larvae. Knowledge of the behaviour of these early instar larvae is limited and their distribution and duration in the water column is unknown for many Perth species. Edward (1964) found that newly hatched larvae of *P. nubifer* remained in the water column for only a few hours after hatching. An analysis of chironomid population dynamics (Davis, Harrington and Pinder, 1988, 1989) suggested that *P. nubifer* has asynchronous development and thus hatching and larval dispersion should be continuous. In view of this, the two tows taken every fortnight were probably insufficient to adequately sample the planktonic larval populations. Before planktonic larvae can become a useful predictor of impending midge problems a great deal more needs to be known about their biology, this would involve much more intensive plankton sampling than is currently being performed.

The rate of adult emergence at North Lake is shown in Figure 18. *P. nubifer* was the most abundant species collected in these traps as would have been predicted from the larval data. The effects of the two Sumilarv treatments are clearly visible. It is interesting to note that while larval density continued to rise after the first Sumilarv treatment, the emergence declined by 99%. The percentage contribution of *P. nubifer* to total emergence was higher this year than last year while no difference was observed in larval density. This may be a consequence of using more emergence traps over a wider area, giving a more accurate result. If the the dates following the first Sumilarv application are ignored, then the average percentage of larvae emerging per night is approximately 4% (measured on nine dates). After each Sumilarv treatment, this percentage was usually less than 1% and as low as 0.075%.

The species composition of the adult samples collected by residents (Fig. 17) was not consistent with the composition of collections obtained from the light traps (Fig. 18), as was noted for the 1988/89 summer. A comparison of the species composition of larvae collected from the lake, with the aspirator collections, suggests that *K. intertinctus*, *C. occidentalis* and *C. alternans*

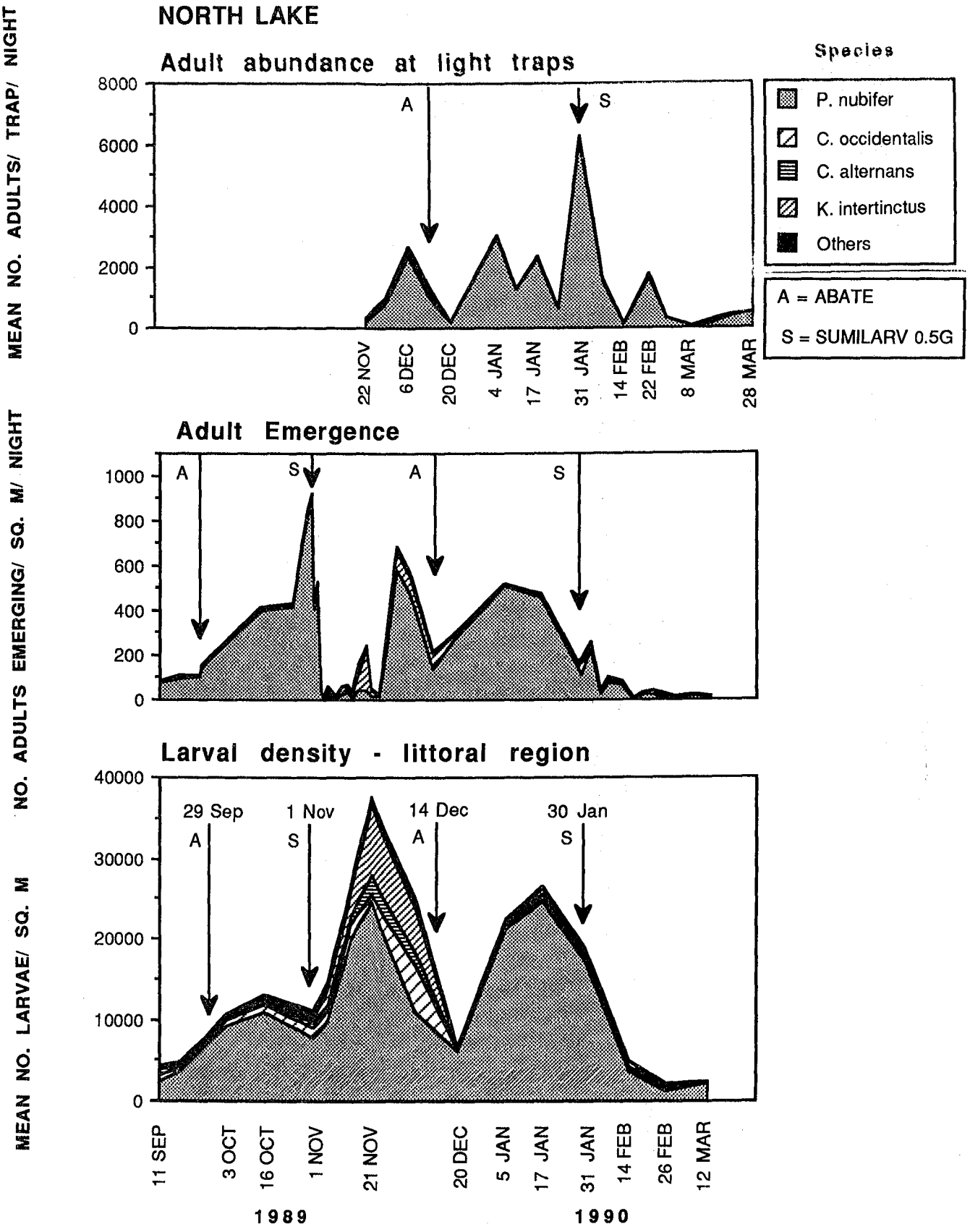


Figure18. Changes in the cumulative numbers of adult chironomids at light traps per night, adults emerging per square metre over 24 hours and density of larvae for the littoral region of North Lake, September 1989 to March 1990. Light trap collections began in November 1989. Note the different Y-axis scales. The dates on which Abate (A) or Sumilarv 0.5G (S) were applied to the lake are indicated.

were disproportionately represented in the residents collections. Interestingly, these are the larger, more colourful species. The light traps did not collect so many of these species, with *P. nubifer* accounting for greater than 90% of most catches. These results indicate that a human bias towards these species may be occurring. To avoid this light traps are considered to be the preferred method of assessing numbers of adult midges away from the lake.

Changes in the mean light trap catches per week for all four traps combined are shown in Figure 18, and for each trap individually in Figure 19. Catches generally reflect the patterns of larval abundance and numbers of adults emerging from the lake. In particular, the increase in *K. intertinctus* larvae in November is reflected in both the emergence and light trap data. An apparent exception is the peak in abundance of adults at the western light traps immediately after the second Sumilarv application (30 January), which does not correspond to a peak in larval abundance or emergence. At this time both larval abundance and emergence were declining. Light trap catches may not always reflect the level of emergence if adult midges are coming from another source. At North Lake some of the midges caught in the traps may have emerged from nearby Bibra Lake, perhaps explaining some of the unexpected peaks in adult abundance. This highlights the importance of simultaneously treating all adjacent lakes that are known to be the source of nuisance problems. This should prevent recolonization from other areas after a Sumilarv treatment in addition to more effectively reducing nuisance levels. By preventing recolonization the effect of a pesticide should be extended. The light trap data are discussed in more detail (especially in relation to wind data) later in this chapter.

Lake Goollelal

At Lake Goollelal larval species composition was dominated by *C. occidentalis*, *P. nubifer* and *Cladopelma curtivalva*, with a small peak in *Procladius villosimanus* (Fig. 20). Of these, *P. nubifer* was the most abundant species on most sampling occasions. Larval density was generally lower than during the 1988/89 spring and summer and this resulted in no treatments being neccesary.

Lake Monger

Two sampling programmes were used during the period April 1989 to February 1990. A good deal of the nuisance problems at Lake Monger are caused by *P. nubifer*. However, the sampling staff of the City of Perth had trouble locating high densities of larvae of this species as the monitoring programme only included the central region. After sampling the shallow sandy littoral regions high densities of *P. nubifer* were found and a new monitoring programme was established. *C. occidentalis* was the most abundant species in the central region of the lake, ranging from 638 ±141 to 1 656 ± 493 larvae/m^2 (Fig. 20). In the littoral region *P. nubifer* was the most abundant species with densities of 286 ± 64 to 17 974 ± 8 676 larvae/m^2 (Fig. 20). Two Abate 50SG treatments were required at this lake, the first on the 21 December (2kg/ha) and the second on the 10 January (4 kg/ha). These were targeted towards *P. nubifer* in the littoral region of the lake. Data was not available on the effectiveness of the first treatment. However, the second treatment appears to have been fairly effective (Fig. 20).

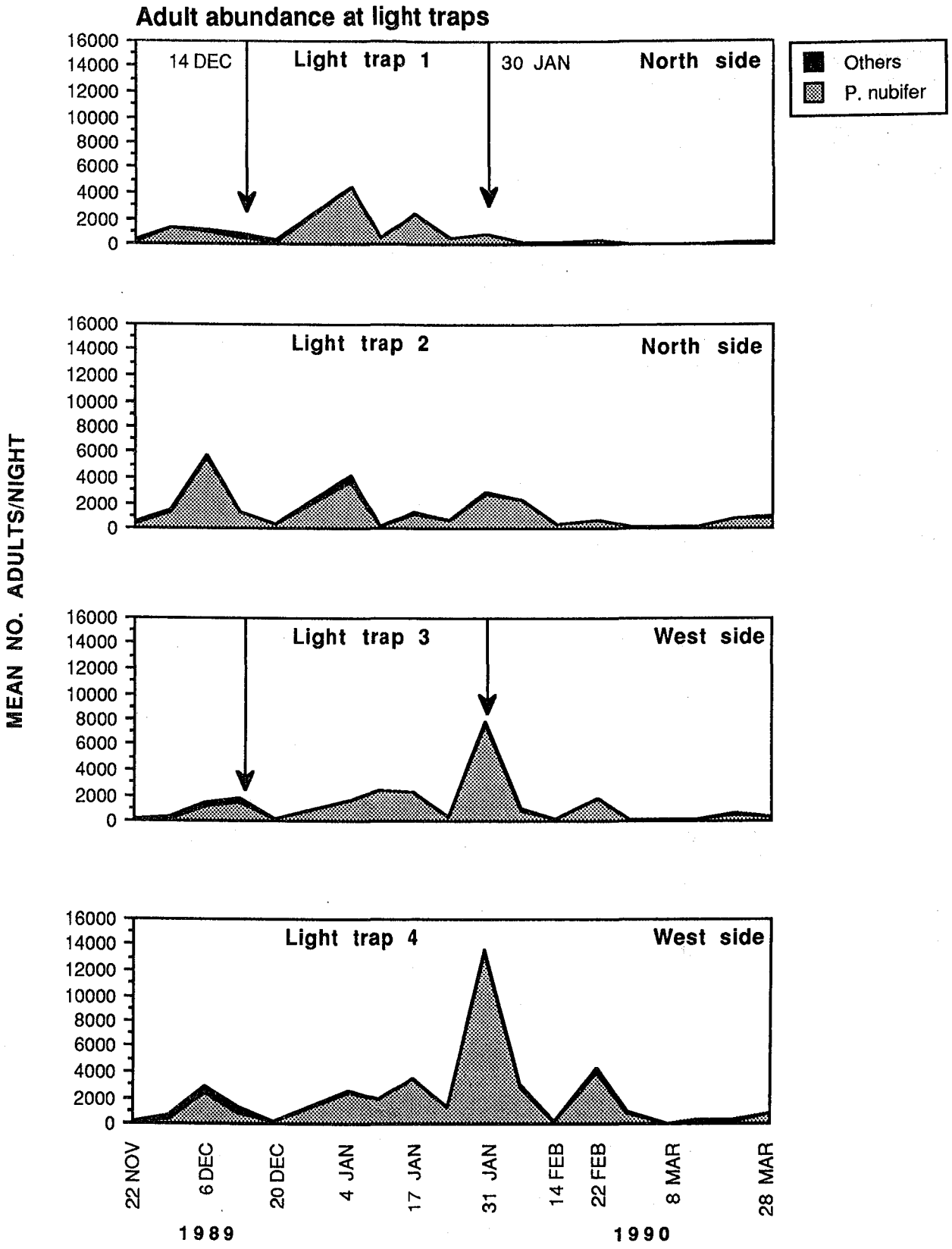


Figure 19. Changes in the cumulative number of adult chironomids at light traps per night at four residences near North Lake, November 1989 to March 1990. The dates on which Abate (A) or Sumilarv 0.5G (S) were applied to the lake are indicated.

P. nubifer larval density decreased from over 17 000 larvae/m^2 to less than 300 larvae/m^2 in a two week period.

Nuisance Problems and Pesticide Applications

The following is a description of the changes in larval density and adult emergence that took place after insecticide applications were made at Forrestdale Lake and North Lake. These cannot be wholly ascribed to the effects of the pesticide as other natural changes also influence larval density. However when large decreases in the density of larvae occur after a treatment, without a correspondingly large increase in adult emergence, then the effect is likely to be due to the pesticide. For the two Sumilarv treatments at North Lake controlled experiments using enclosures indicated that decreases in emergence were due to the pesticide. Changes in the density of larvae over the two and a half year period between October 1987 and March 1990 at Forrestdale and North Lake are shown in Figure 15. Also indicated on these graphs are the dates on which pesticide applications occurred and the level of nuisance experienced by residents in nearby suburbs. Figures 16 to 18 show this years larval and emergence data in more detail.

Forrestdale Lake

During the summer of 1989/90 two applications of Abate were carried out at Forrestdale Lake. Following each of the applications a reduction in total larval density of over 99% occurred. On both occasions this resulted in a substantial reduction of nuisance problems (Fig. 16). This was despite the edge 30m of the lake (which supported the highest *P. nubifer* densities) not being treated so as not to risk harming the waterbirds. Nuisance problems at Forrestdale Lake were initially recorded in early December 1989 and after some delay the lake was treated with Abate on 19 December (Figs. 15 and 16). The onset of midge problems was experienced earlier this year than during the 1988/89 summer, and favourable environmental conditions allowed midge populations to increase in density (to 5 707 ± 2 211 total larvae/m^2 and 5 669 ± 2 215 *P. nubifer*/m^2) one month after this first treatment. A consequence of this was the need for a second Abate treatment on the 18 January. During the 1988/89 summer the first problems were not experienced until February and, following the single Abate treatment, midge populations did not recover to nuisance densities. Year to year variation in the date of onset of nuisance problems and the degree of post-treatment recovery of midge populations at Forrestdale Lake are most easily explained by varying environmental conditions, as will be discussed later in this chapter.

North Lake

Overall, the nuisance problems (using the residents' nuisance scores as an indicator) experienced this year at North Lake were comparatively low (Figs. 15 and 17). No high or extreme nuisance scores were recorded. This is surprising considering the high larval densities (Fig. 15).

The first application of Abate at North Lake took place on 29 September 1989. This treatment was planned as a Sumilarv application, however difficulties were experienced with helicopter availability. As the enclosures had already been placed in the lake, a decision was made to apply Abate

10SG by boat. An increase, rather than the expected decrease in larval density was observed in the lake following the Abate treatment.

On 2 November 1989 Sumilarv 0.5G was applied to the littoral area of North Lake by helicopter at the rate of 10kg/ha. A rapid increase in larval density was recorded after this treatment (Fig. 17). The reason for this continued increase in larval density may be that parts of the lake received little or no Sumilarv (as apparent from the tray catches). Thus adults may still have been emerging from these areas and laying eggs in the lake. In addition, adults from nearby Bibra Lake may have been laying eggs in North Lake. Because of the nature of Sumilarv toxicity, larval density is not a suitable measure of Sumilarv effectiveness. Instead, adult emergence rates are monitored (information on the mode of action of Sumilarv is given in Chapter three). Changes in the rate of adult emergence for the 1989/90 summer are shown in Figure 18. In the following discussion 'adults/m^2' refers to the mean number of adults caught per night. The emergence of adults decreased by 93.2% (from 914 to 62 adults/m^2) within six days of the Sumilarv treatment (Fig. 18). Over the same period the emergence of *P. nubifer* decreased by 100% (874 to 0 adults/m^2). Three weeks after treatment emergence was still only 25 adults/m^2. However one week later total emergence was recorded at 689 adults/$m^2$and *P. nubifer* emergence was recorded at 579 adults/m^2. No reduction in emergence was observed after the first Abate treatment(Fig. 18).

On 14 December a second application of Abate was made by helicopter to the littoral region. Over a three week period larval density decreased from 25009 ± 4 632 larvae/m^2 (6 December) to 6 612 ± 1 836 larvae/m^2 (Fig. 17). A lesser reduction in the density of *P. nubifer* was observed (10 962 ± 2 648 larvae/m^2 to 6 115 ± 1 853 larvae/m^2). Emergence was 217 adults/m^2 one day prior to treatment and increased to 521 adults/m^2 three weeks after treatment.

Towards the end of January 1990 a decision was made to carry out a second Sumilarv experiment at North Lake. Ten kg/ha was applied to the littoral region by helicopter on 30 January. Emergence of adults decreased from 182 adults/m^2 to 7 adults/m^2 over the next two weeks (Fig. 18). Larval density also decreased from 18 872 ± 2 848 larvae/m^2 to 4 891 ± 907 larvae/m^2 over this period. No recovery of either larval or adult numbers was observed. Light trap catches at North Lake also decreased over the two week period from 6 304 ±1 745 to 158 ± 66 adults/night.

In summary, emergence declined by more than 95% within two weeks of each of the two Sumilarv treatments at North Lake. Very low levels of emergence were then recorded for the next two to three weeks. After the first Abate treatment no reduction in either emergence or density of larvae was observed. A moderate reduction in the density of larvae was recorded after the Abate was applied for the second time and this appeared to bring about a short term reduction in nuisance problems (as measured by light trap catches) (Fig. 18).

Influence of Wind on Light Trap Catches at North Lake

Figures 18 and 19 show the adult abundance and species composition at the

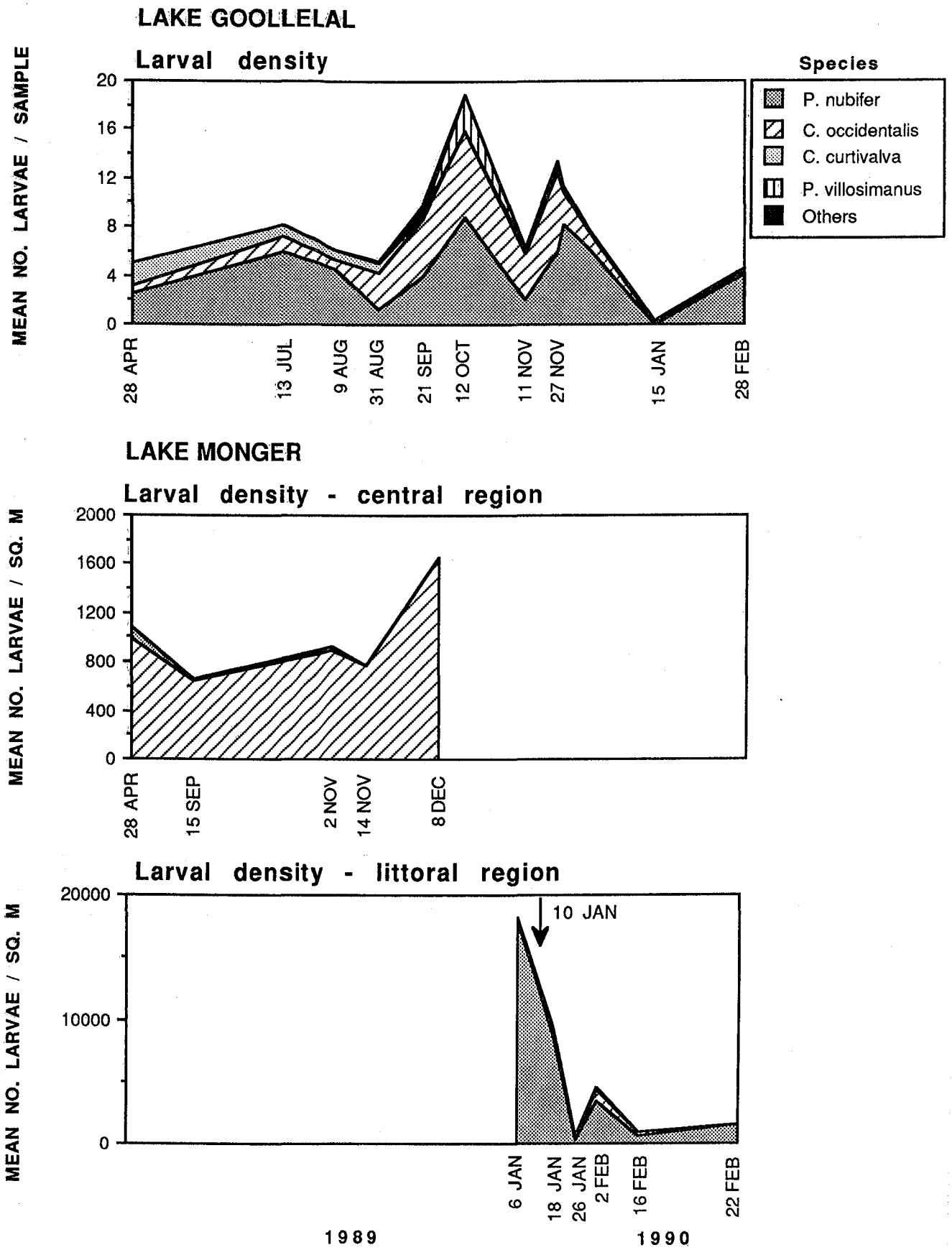


Figure 20. Changes in the cumulative density of larvae for Goollelal Lake, April 1989 to February 1990, changes in the cumulative density of larvae in the central and littoral regions of Lake Monger, April 1989 to February 1990.

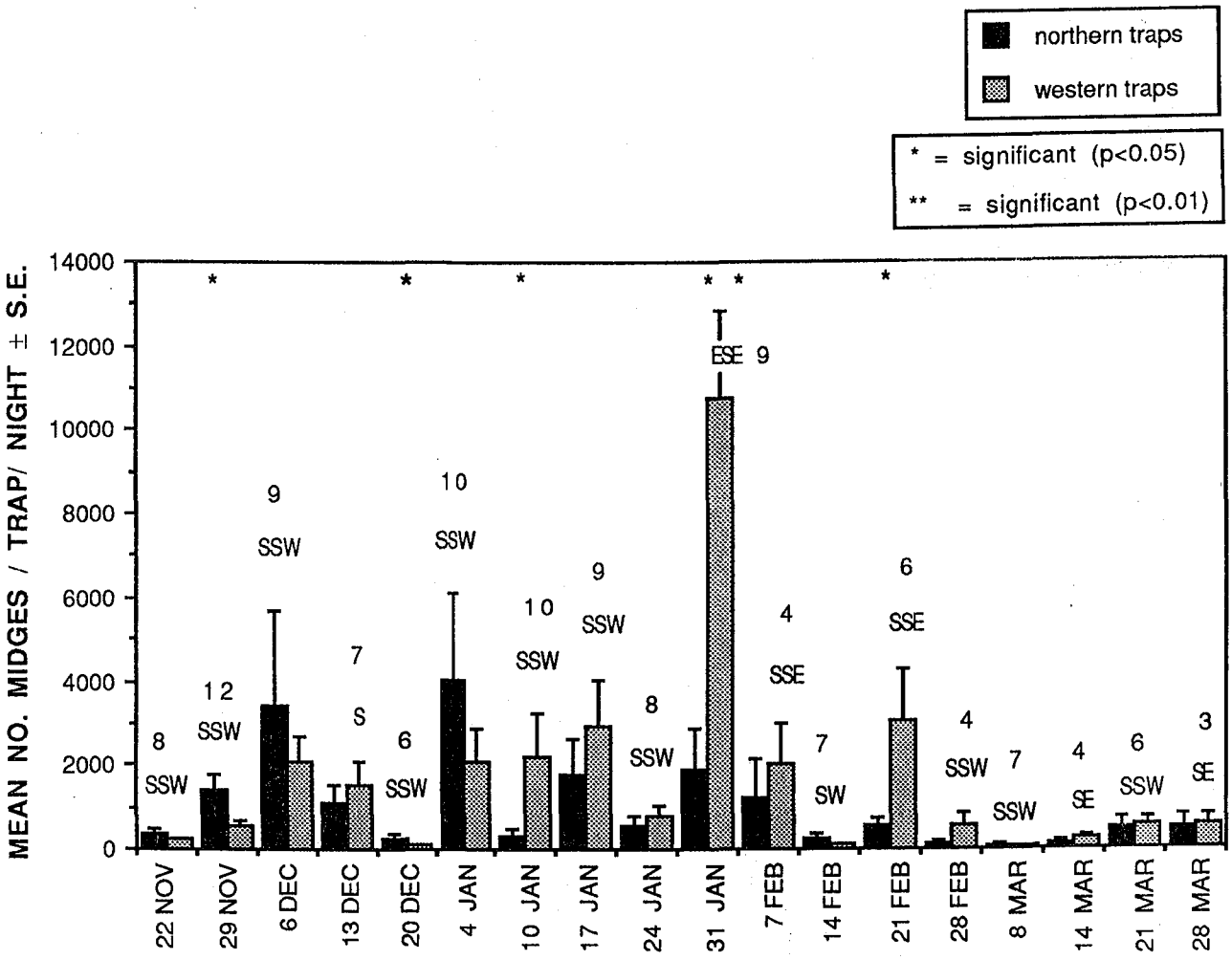


Figure 21. Changes in the number of adult chironomids at two light traps on the western side and two on the northern side of North Lake, November 1989 to March 1990. Each pair of columns represent the mean number of adults caught at the traps for three consecutive days each week for eighteen weeks.

light traps on the northern and western sides of North Lake. These were actually NNW and WSW respectively from the centre of the lake. The data is also plotted as a column graph with the northern and western traps as column pairs (Fig. 21). Each pair of columns represents the mean number of midges caught per night (over three consecutive nights per week for eighteen weeks), by two light traps on the north side and two on the west side. Above each pair of columns is the mean wind speed and direction recorded for Perth between 7.00pm and 12.00pm for the same three nights, by the Bureau of Meteorology. T-tests were used to compare the northern and western catches for each week.

In general no relationship between adult midge abundance and distribution at light traps and wind speed and direction is apparent. Between late November 1989 and late January 1990 the mean wind direction was SSW to SW and six to twelve knots. With this wind direction it would be expected that the northern traps would have greater midge catches than the western traps if the adults are highly influenced by wind speed and direction. During this time a significant difference ($P<0.05$) between adult abundance at the northern and western traps was found for only three of the nine weeks. (Fig. 21). On these three weeks the wind speed was twelve, ten and six knots in a SSW direction. In late January the wind direction turned ESE at a mean wind speed of nine knots for a few days. On these three days significantly more adults ($P<0.05$) were caught by the western traps than by the northern traps. However by the following week wind direction had turned SSE and remained SE to SW until the end of March. For these last two months little difference between the catches of the northern and western traps were observed. On only one of these last eight weeks was the abundance of adults significantly different ($P<0.05$) between the northern and western traps (Fig. 21). On this occasion the wind speed was 6 knots.

Any relationship may have been obscured by the fact that the data was averaged for each three day period. However, when light trap catches for each day were compared to wind data on that day there still appeared to be no clear relationship.

The results of this study, using wind data for the general Perth area, suggest that the distribution of midges is not highly influenced by wind. This wind data may not accurately reflect local wind conditions at North Lake. Local features such as tree cover, land relief and buildings may all influence micrometeorological conditions. A more thorough analysis would involve continuous local weather monitoring while the light traps were set. Stronger winds may influence midge distribution to a greater degree, however such winds are not common during the summer. It is also possible that some or all of the midges caught by light traps originated in Bibra Lake. Southerly winds would almost certainly blow Bibra Lake midges towards both the northern and western light traps.

Environmental Parameters - Results

Monthly rainfall and monthly mean maximum and minimum air temperature data for Perth City over the period January 1987 to March 1990 are presented in Figure 22. Wind data for Perth City, covering the period from

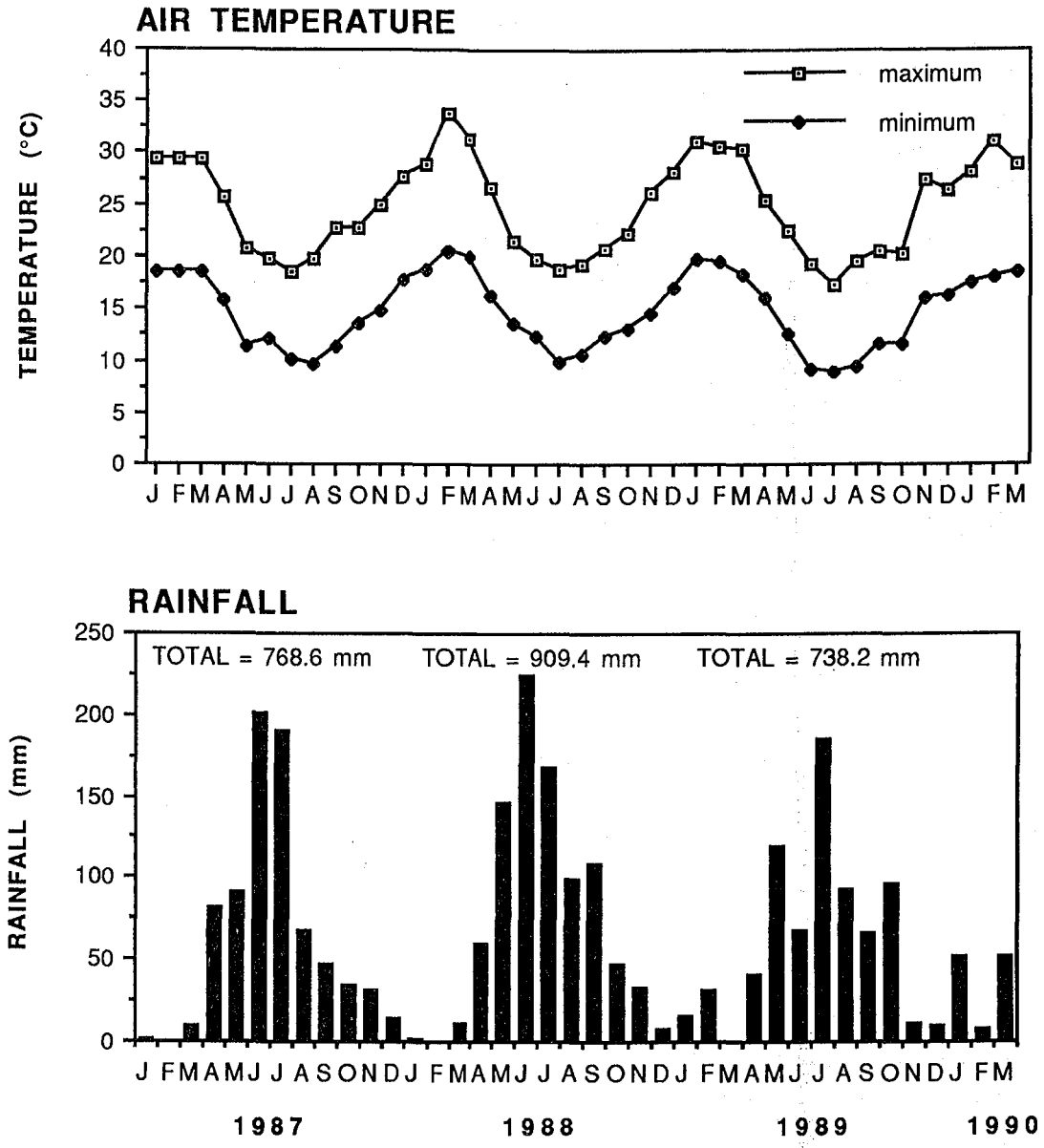


Figure 22. Weather data for Perth City for January 1987 to March 1990. Monthly maximum and minimum temperatures and monthly rainfall are shown.

late November 1989 to March 1990, is given in Figure 21. This comprises mean wind speed and direction between 7.00 p.m. and 12.00 p.m. on nights that the light traps were set. Changes in lake depths, water temperature, conductivity and pH at Forrestdale and North Lakes are given in Figures 23 and 24, and changes in chlorophyll-a, total phosphorus and total nitrogen are given in Figures 25 and 26. The wind data have already been discussed in relation to adult abundance in residential areas.

Rainfall appears to be the most important climatic variable with respect to lake depth (as can be seen in Figures 22 to 24) and ultimately for the timing of midge population increases (though perhaps not maximum midge abundance). At North Lake during 1989 the maximum water depth was 2.88m on 1 November (Fig. 24). This was lower than the maximum of 3.18m recorded on 5 October 1988, but approximately the same as that recorded during 1987. Similarly, at Forrestdale Lake maximum water depth was lower during 1989 (0.92m) than during 1988 (1.45m) (Fig. 23). A maximum depth was not recorded for 1987. The suggestion that the high 1988 rainfall was related to the higher larval abundance at Forrestdale Lake and North Lake (Davis, Harrington and Pinder, 1989), was not borne out by this years results. An even higher abundance of larvae was observed at these lakes during the 1989/90 research, despite the lower rainfall during 1989.

At North Lake there appears to be very little inter-annual variation in water temperature (Fig. 24). The water temperature at Forrestdale Lake is strongly related to water depth. This is reflected in high maximum and low minimum water temperatures during the periods of shallow water depth (Fig. 23). The increase in water temperature during spring and summer is influenced by the maximum water depth during the previous winter, which in turn is dependant upon rainfall. If winter water depth is higher, then it will take longer for the lake to become shallower and longer for temperatures to increase. As temperature is a major determinant of the rate of insect development this has implications for chironomid production.

Conductivity at North Lake fluctuated seasonally between 600 and 1100 µS/cm over the three years of this study (Fig 24). By contrast at Forrestdale Lake conductivity has varied between 1 700 and 20 100 µS/cm (Fig. 23). On occasions when Forrestdale Lake has dried out or become extremely shallow conductivity has risen above 20 000 µS/cm due to evapoconcentration. This increase in conductivity is tolerated by the larvae of some midge species (e.g.*Tanytarsus fuscithorax*) but not others (e.g. *P. nubifer*).

During 1989/90 the pH of North Lake water fluctuated between 7.0 and 9.8, as it has in the previous two years (Fig. 24). Similarly the pH of Forrestdale Lake water (Fig. 23) varied between 7.1 and 9.1, this is also similar to pH levels recorded in previous years.

The concentration of chlorophyll-a at North Lake reached an initial peak in spring and then fluctuated throughout the summer months (Fig. 26). During the 1989 a spring maximum of 233 µg/l was recorded. This compares with maximum concentrations of 242 and 606 µg/l during the springs of 1988 and 1987 respectively. Similarly, concentrations of chlorophyll-a at

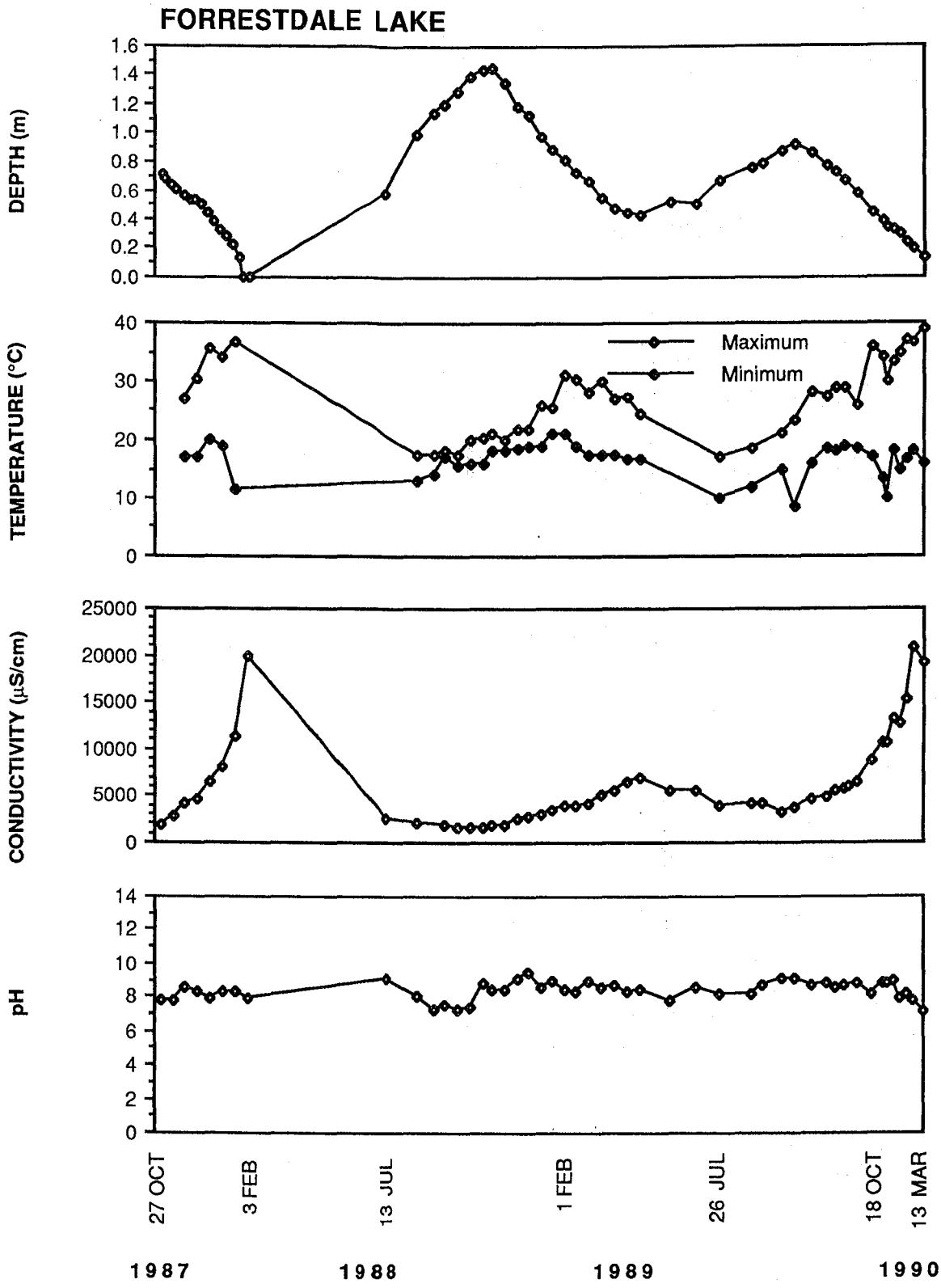


Figure 23. Changes in lake depth, temperature, conductivity and pH at Forrestdale Lake, October 1987 to March 1990.

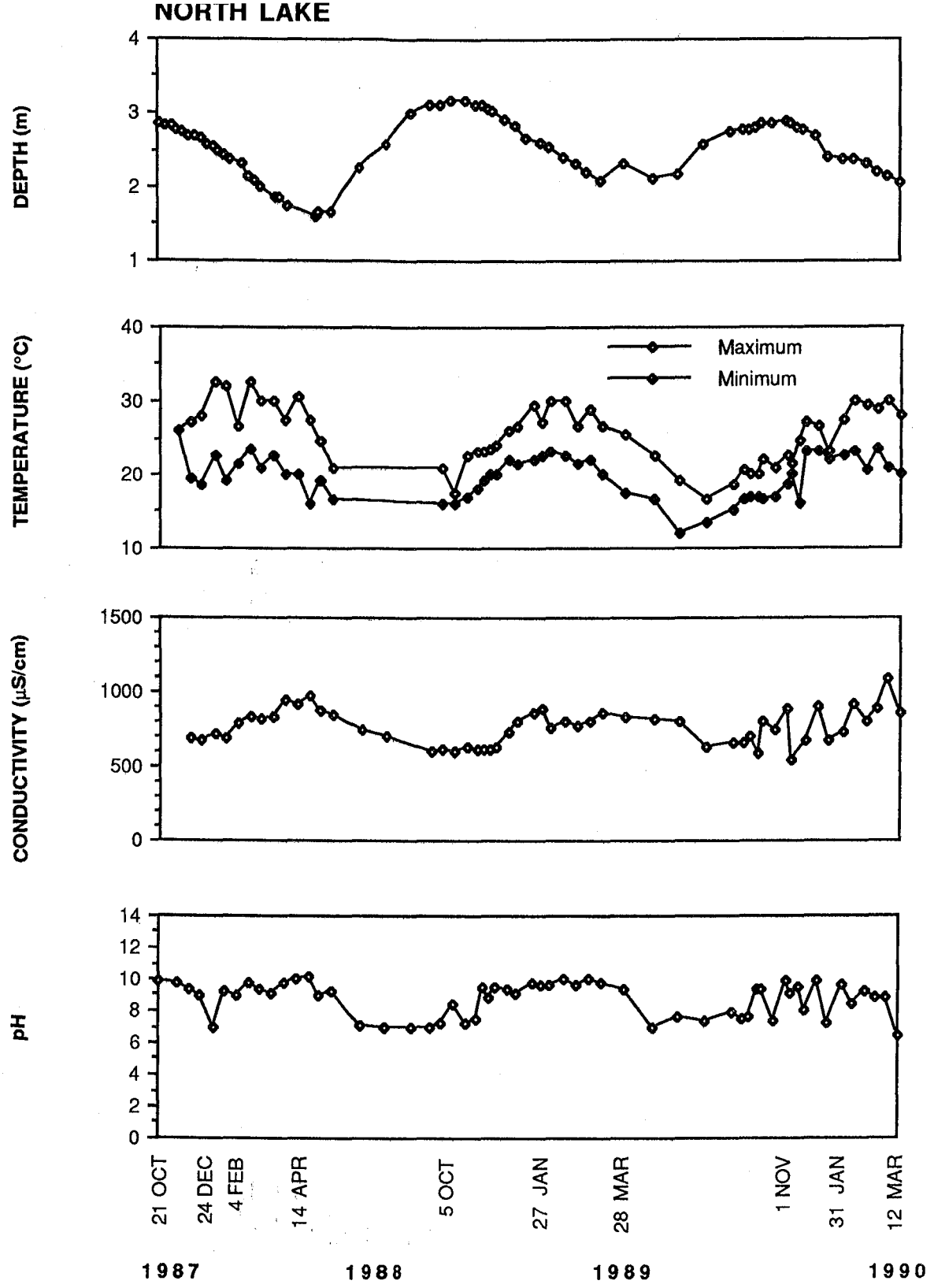


Figure 24. Changes in lake depth, temperature, conductivity and pH at North Lake, October 1987 to March 1990.

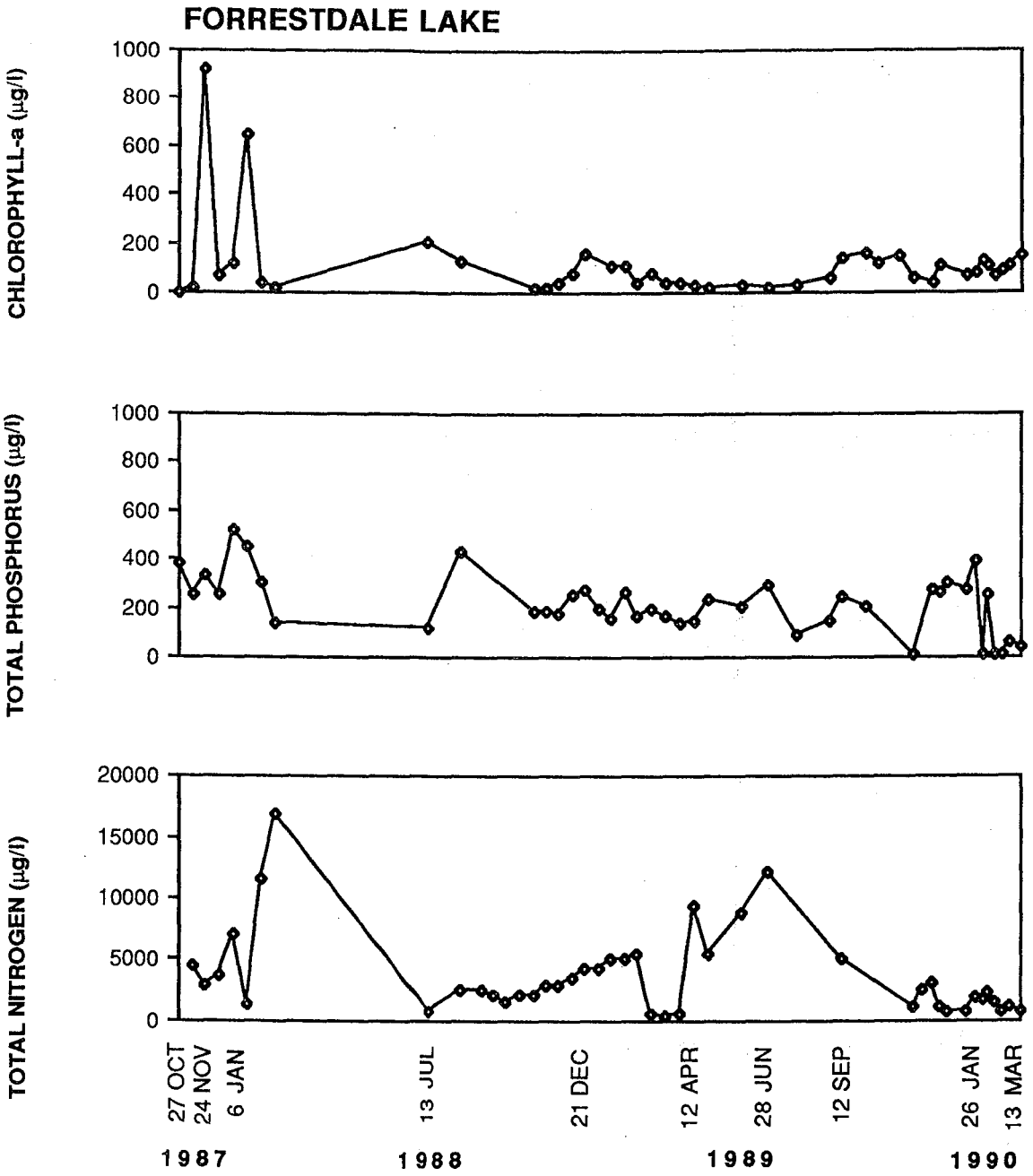


Figure 25. Changes in the concentration of chlorophyll-a, total phosphorus and total nitrogen at Forrestdale Lake, October 1987 to March 1990.

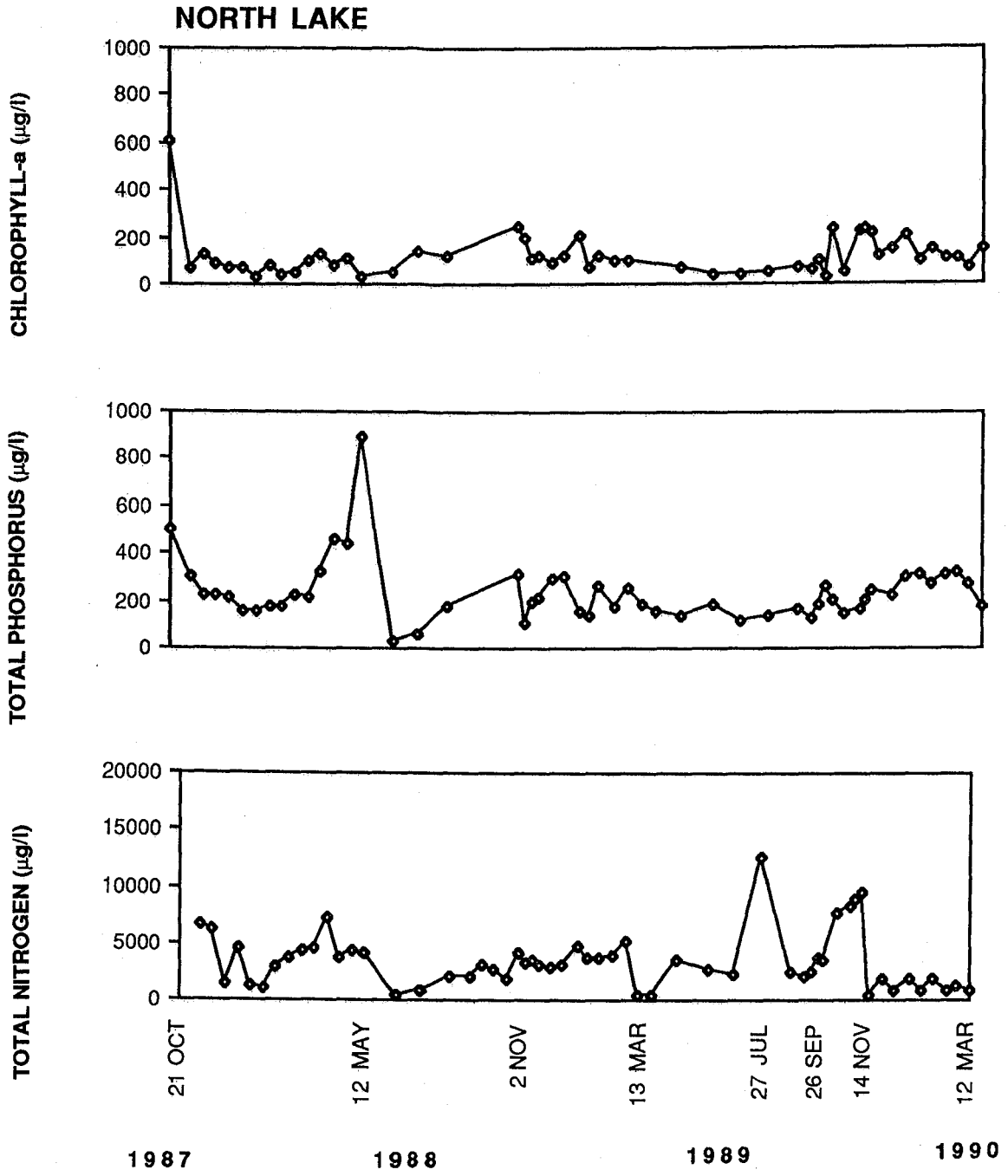


Figure 26. Changes in the concentration of chlorophyll-a, total phosphorus and total nitrogen at North Lake, October 1987 to March 1990.

Forrestdale Lake (Fig. 25) were highest during spring and summer, when high temperatures promote increased algal growth.

No clear seasonal pattern is evident in the concentrations of nitrogen and phosphorus at either Forrestdale Lake or North Lake (Figs 25 and 26). Major fluctuations in both of these parameters have been recorded in various seasons at both lakes. The levels of total nitrogen at North Lake were unusually low after the 1 November 1989. This coincides with a change in the personnel that were contracted to carry out the analyses. Whether the former concentrations were too high or the latter ones too low is not known. The veterinary farm drain that originates on the campus of Murdoch University has been shown to be a major source of phosphorus to North Lake (Bayley *et al.* 1989). The flow in this drain has now been stopped, and future monitoring may reveal reductions in nutrients in North Lake.

Environmental Parameters and Midge Populations - Discussion

Water temperature, chlorophyll-a concentration and lake depth are plotted with larval density at Forrestdale Lake and North Lake in Figures 27 and 28. The use of environmental variables to predict changes in insect populations has been the aim of many pest control projects throughout the history of modern entomology. Uvarov (1931) wrote one of the first reviews of such techniques. Two of the major determinants of aquatic insect development and population growth are temperature and food availability (Pinder, 1986). Temperature affects metabolic processes such as food assimilation and thus growth rates of larval midges (Johannsson, 1980 and Mackey, 1977). Egg hatching of chironomids has also shown to respond positively to temperature (Hilsenhoff, 1966). Chlorophyll-a is a measure of algal abundance and so can be used as a measure of the potential food resource available to larval midges. Several studies (including Rasmussen, 1984 and Davies, 1980) have found that increased algal abundance has a positive effect upon chironomid production.

To elucidate the relationships between these physical parameters and chironomid populations it is necessary to accumulate data over several years. Midge populations have now been studied at Forrestdale Lake and North Lake for three summers, and the relationships between these variables are becoming clearer.

There are several ways of using environmental variables to predict population changes. One way is to find variables that are strongly correlated with larval density. Any change in a strongly correlated variable will be associated with a corresponding change in larval density. Knowledge of the environmental variable at one time would allow prediction of larval density on a later date. Analysis of environmental and midge data for Forrestdale Lake and North Lake failed to find strong correlations. Significant correlations have been found between chironomid abundance and chlorophyll-a for several lakes in the Perth area (Rolls, 1989). However, this type of correlation provides evidence for eutrophication being a contributing factor to high midge abundance, rather than being useful as a predictive tool.

A second method of employing physico-chemical data for predictive purposes is the use of critical values. When a critical value of an environmental

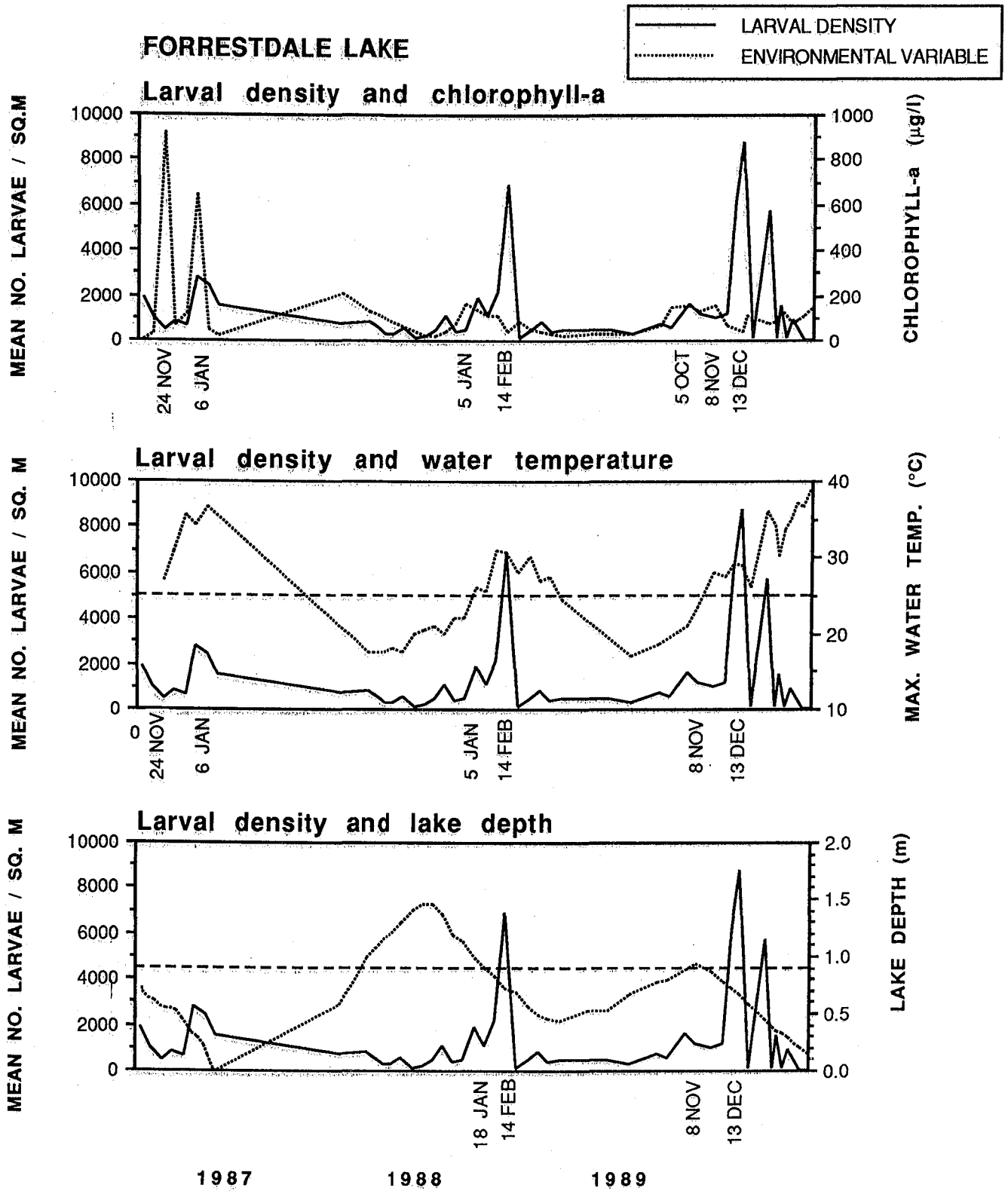


Figure 27. Changes in the density of larvae with changes in the concentration of chlorophyll-a, maximum water temperature and lake depth at Forrestdale Lake, October 1987 to March 1990.

parameter is exceeded a change in midge larval populations can be expected to occur after a predictable time. Unlike using a highly correlated variable this type of analysis will allow prediction of the date of larval density increase but not the magnitude.

Each lake in Perth appears to have a different chironomid population as well as characteristic physical and chemical features. A consequence of this is that a model describing the relationship between chironomid populations and their environment at one lake will not represent events at another lake. For this reason it is unlikely that a single model will be applicable at all lakes. However, it may be possible that some similar lakes can be represented by similar predictive models.

Forrestdale Lake

At Forrestdale Lake the timing of the first peak in larval density and hence the onset of nuisance problems appears to be dependent upon water depth, chlorophyll-a concentration and water temperature (Fig. 27). Maximum water temperature is used in the following discussion, in preference to minimum or mean temperature, as it appears to have a more useful critical level.
The first major incease in larval density (6905/m^2) in 1988/89 occurred in mid-February, five weeks after the maximimum water temperature was first recorded above 25°C (Fig. 27). In 1989/90 this first major increase in larval density (6039/m^2) was recorded in mid-December, four weeks after this critical temperature was exceeded. One week later larval density had increased further to 8739/m^2. The first maximum temperature recorded during 1987 was 27°C, however it is not known whether this was the first time that 25°C was exceeded. Given the time of year and the shape of the curve in Figure 27, this is likely to be the first maximum temperature over 25°C. A peak in larval density of 2783/m^2 occurred on 6 January seven weeks later.

From this data set it would appear that larval densities at Forrestdale Lake will be high enough to cause 'high' to 'extreme' nuisance problems four to seven weeks after the water temperature is first recorded above 25°C. Lesser peaks in larval density (with populations composed mainly of *Chironomus* spp.) appear to occur when maximum temperature is between 20 and 25°C (Fig. 27). During this time 'low' to 'moderate' nuisance problems are often experienced.

At Forrestdale Lake there appears to be a longer period (of between six and ten weeks) between the first spring increase in chlorophyll-a concentration and peaks of larval abundance (Fig. 27). A small increase in the density of *Chironomus* spp. (to over 1000 larvae/m^2) appears to occur within two weeks of this increase in chlorophyll-a.

For the past two years a severe midge problem has been recorded four to five weeks after lake depth has fallen below 90cm. The rate of depth decrease partially determines changes in temperature and consequently chlorophyll-a concentration. Water depth is itself determined by annual rainfall and evaporation rates. Thus it is possible that the timing of midge problems may be predicted from the amount of rainfall and maximum water depth.

At Forrestdale Lake the maximum water depth was higher in 1988 than during both 1987 and 1989. As a consequence of this, the lake did not become shallow until later in the summer of 1988/89. Therefore water temperature did not rise as fast, and midge density did not increase to nuisance proportions until later in the summer. By contrast, during 1989 rainfall and maximum water depth were lower, hence water temperature and chlorophyll-a concentration increased earlier. As a result of this, midge problems were experienced early in the summer. Two Abate treatments were necessary over the 1989/90 summer. By monitoring winter rainfall it may be possible to predict in advance whether midge problems will occur early or late in the summer.

Further collection of data at Forrestdale Lake may allow this formula to be further developed to allow midge management personnel to use both environmental parameters and larval density to predict midge problems.

For these techniques to be of any value, management procedures need to be established that will allow swift response to predictions of impending midge problems. In previous years delays in both prediction of problems and implementation of control measures have resulted in severe nuisance problems at Forrestdale Lake. The former was due to lack of knowledge of the density of larvae which causes nuisance problems and how environmental variables might be used in a predictive capacity. The latter results from the disagreements which have occurred between state and local government authorities as to where responsibility rests for midge control at this lake. This matter requires resolution before effective midge control can be implemented.

North Lake

The onset of nuisance problems at North Lake does not appear to occur at a specific sharp increase in larval density as occurs at Forrestdale Lake (Figs. 15 to 17). For this lake larval density may still be the best available predictor of impending midge problems as larval density increases gradually. Moderate problems can occur at fairly low densities (< 2 000 larvae/m^2) or not until high densities (>10 000 larvae/m^2) have been reached. More severe problems do not occur until densities have risen above 5 000 larvae/m^2, if they occur at all (during the 1989/90 spring and summer no 'high' or 'extreme' nuisance scores were recorded).

In the past two years larval density at North Lake had risen above 2 000 larvae/m^2 shortly after maximum temperature has exceeded 20°C (Fig. 28). Very high larval densities (>10 000 larvae/m^2) are then observed four to seven weeks later. Twenty degrees might be used at North Lake as the critical water temperature as problems have usually begun by the time 25°C is exceeded. In the past two years moderate nuisance problems were being experienced at North Lake by the time discernable peaks in chlorophyll-a concentrations were observed.

In summary there are several environmental factors that are potentially useful in predicting the sharp increases in the density of larvae that causes severe nuisance problems at Forrestdale Lake. With further data collection and analysis this may lead to a simple monitoring programme and more effective

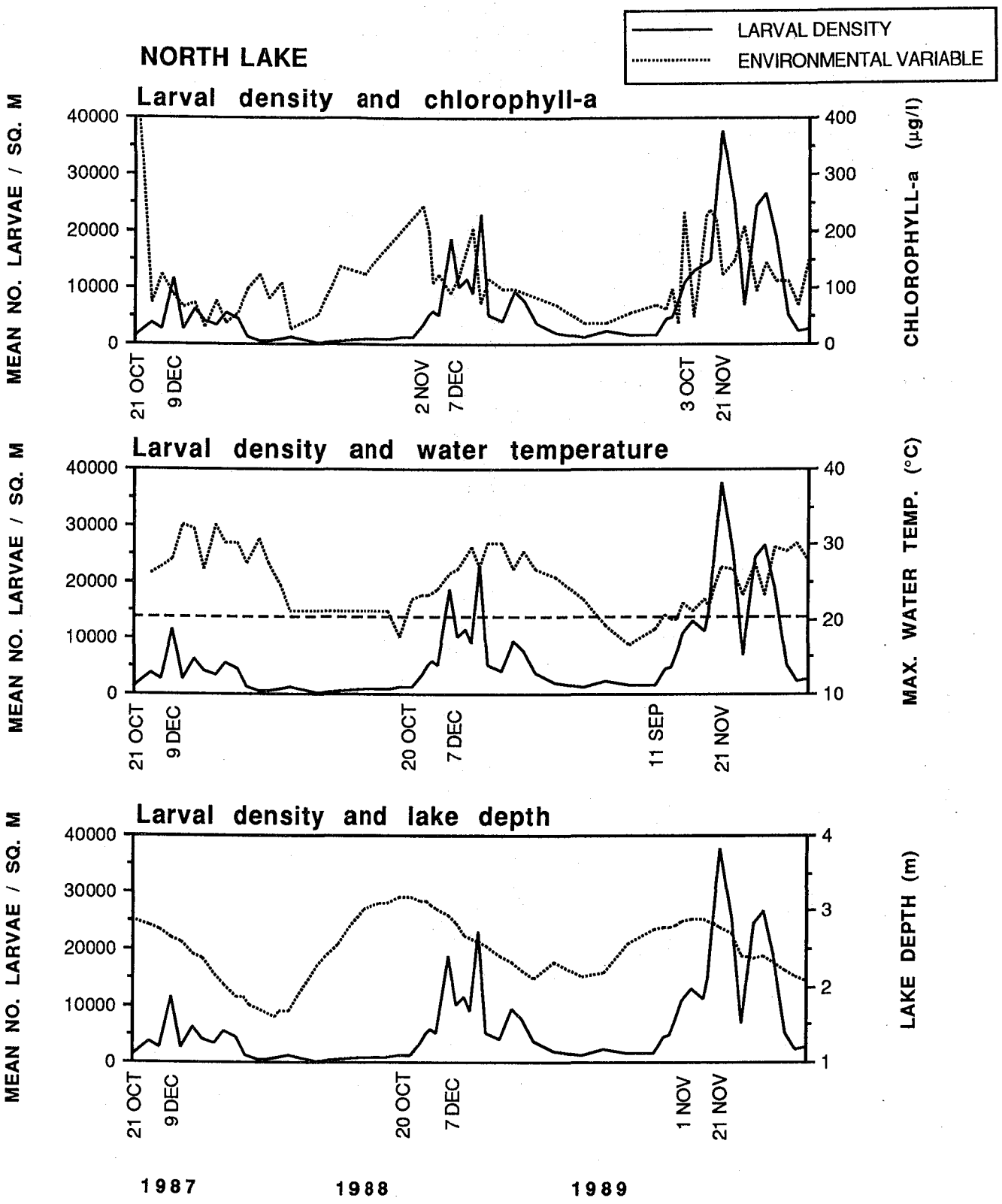


Figure 28. Changes in the density of larvae with changes in the concentration of chlorophyll-a, maximum water temperature and lake depth at North Lake, October 1987 to March 1990.

control of midges at this lake. At North Lake the relationship between larval density and nuisance problems is less clear and environmental variables may have less predictive capacity.

SUMMARY AND IMPLICATIONS FOR MIDGE CONTROL

Several implications for midge control arise from the preceding discussion of the monitoring programmes. Firstly it is evident that a completely universal formula for midge control in Perth lakes is unlikely to be found. Different lakes require different approaches because of their unique physical, chemical and biological composition. This problem is common for terrestrial as well as aquatic pest control programs (Horn, 1988). However, some lakes, such as North Lake and Lake Monger, may have similar problems and so midge control programs will have some common aspects. Although this discussion focuses on Forrestdale Lake and North Lake many of the topics discussed are relevant to other lakes.

Abate still appears to be effective at Forrestdale Lake. However, at other lakes, such as North Lake and Lake Monger, Abate is probably no longer a reliable midge control agent. Sumilarv holds considerable promise as an alternative to Abate at these lakes. Previously we suggested that high concentrations of algae in the water column may inhibit the toxicity of Abate. This summer two applications of Abate were made to North Lake. The first (when chlorophyll-a concentration was 34µg/l) resulted in no net decrease in *P. nubifer* abundance. The second treatment (which occurred when the concentration of chlorophyll-a was between 150 and 200µg/l) was followed by a 44% decrease in *P. nubifer* abundance. At Forrestdale Lake, Abate treatments were effective at chlorophyll-a concentrations of 44 and 72µg/l. These results neither support nor negate the algal inhibition hypothesis but do reveal the need for controlled experimental investigation of this problem.

One explanation for the greater effect of the second Abate treatment at North Lake may be that the earlier Sumilarv treatment reduced the proportion of the population that was resistant to Abate. The population may also have been affected by the Sumilarv application by virtue of the fact that larvae which are prevented from emerging survive for some time before dying (Staal, 1972) and so a reduction in larval density may have been about to occur as a consequence.

Sumilarv and Abate should not be used at the same lake at the same time, however they may effectively be used alternatively at the same lake. Metcalf (1980) stated that dual application of insecticides (application at the same time) is to be discouraged, because this tends to lead to resistance of the pest to both pesticides. Alternating the use of the two pesticides, which may be possible at some lakes where Abate is still effective, may extend the useful life of both Abate and Sumilarv if the latter is found to be suitable.

Economic, effective and environmentally sound use of pesticides for midge control requires that they are used only at strategic times. Determining the most strategic time to apply a pesticide has been one of the major aims of this research. Larval density thresholds were proposed in the previous report as a

guide for the timing of treatments. This approach should be useful where good monitoring programmes are in place and larval densities do not increase dramatically over a time period of days rather than weeks. Larval monitoring can effectively be used to time treatments at North Lake for instance, where larval density increased gradually during spring.

However, in addition to a good monitoring programme successful control also requires a well defined procedure for the initiation of a pesticide application. This procedure or preparation needs to take place so that treatments can be undertaken as soon as monitoring data indicates that the threshold for treatment has been reached. At North Lake, during 1989, a treatment was first recommended in mid-September, when larval density had exceeded 2 000 larvae/m^2. This early increase in density was unexpected and so, due to helicopter unavailabilty and time required for enclosure construction, treatment was delayed until late-September, by which time the larval density had risen to over 7 000 larvae/m^2. The longevity of control by the ensuing treatment was likely to be less than it may have been because of the large numbers of eggs that may have already been laid. The results of this study indicate that the first treatment of North Lake may have to take place as early as September.

Based on the nuisance scores received from residents near North Lake for the past three years moderate to high problems can be experienced when larval densities exceed 2 000 larvae/m^2 (1988) or not until 10 000 larvae/m^2 is exceeded (1989). The reason for this discrepancy is not known. A conservative approach to the problem would involve using the 2 000 larvae/m^2 threshold and treating when this level is first exceeded, in an attempt to keep larval density low. For this approach to be successful an effective pesticide needs to be used, and all nearby midge habitats need to be treated simultaneously. Simultaneous treatment of nearby lakes should slow down the rate of recolonization after a treatment, and reduce the need for successive treatments. For the same reason, the treatment of a lake needs to be carried out thoroughly to prevent large patches of the desired treatment area receiving no pesticide, as occurred at North Lake during the first Sumilarv experiment.

The high application rate of Sumilarv (10kg/ha) necessitates a high rate of release from the helicopter hopper. When a small area is being treated (for example the 5 ha littoral area of North Lake) only 50 kg needs to be applied, this leaves no room for error. Applications might be improved if the release is lowered, even if two or more passes are required over the desired area.

The use of the helicopter this year was considered to be an improvement over a fixed wing aircraft. The helicopter can target narrow bands more easily because it follows the bands rather than flying many short straight passes. A thorough study of the evenness of the helicopter application over a whole lake was not successful as the downdraft of the helicopter tended to overturn floating trays. An improved design of catch tray is required for future studies.

At Forrestdale Lake it was planned to sample the lake fortnightly until larval density began to rise. Based on previous data this rise was not expected until January or February. The rise in larval density in early October 1989 was

mainly due to an increase in *C. occidentalis* and no reports of complaints were recorded. The density of *P. nubifer* was less than 200 larvae/m^2 during this time and so no treatment was thought to be required. In late November the density of *P. nubifer* increased from 152 to 2 440 larvae/m^2 within two weeks and nuisance problems began to occur. The rapid increase in larval density of the problem species at this lake makes prediction of problems based on larval density impracticable. However, monitoring of environmental parameters shows considerable promise as an alternative prediction system at Forrestdale Lake.

Initially the timing of the problem (early or late summer) may possibly be predicted by the maximum winter/spring depth and amount of rainfall. Monitoring of the maximum weekly or fortnightly water temperature and water depth, and possibly chlorophyll-a, may then allow the prediction of a severe problem within weeks of critical values being attained. After this time larval monitoring can then be undertaken weekly. As the increase in *P. nubifer* occurs so rapidly an initial treatment may be required as *P. nubifer* approaches or excceeds 500 larvae/m^2. The use of this formula during 1989 would have resulted in a treatment taking place after the density of *P. nubifer* was recorded at 152 ± 68 larvae/m^2. Weekly sampling may have revealed a density closer to 500 larvae/m^2 one week before the major increase, this would have been nine weeks after both the first peak in chlorophyll-a and four weeks after maximum water temperature exceeded 25°C, and lake depth fell below 90cm. Further treatments may still be required after the first application, as *P. nubifer* again begins to increase towards 500 larvae/m^2.

Two problems remain at Forrestdale Lake, even if prediction of the initial outbreak is improved. Firstly, even though Abate appeared to be effective the extremely rapid development of *P. nubifer* at high temperatures meant that problems reccured within a month. This may mean that in some years at least two and possibly three treatments may be required.

The second problem has already been discussed above and refers to the fact that for control methods to be of any value management procedures need to be established that will allow swift response to predictions of impending problems. At present such a mechanism does not exist for Forrestdale Lake.

Further evaluation of the role of environmental parameters in the prediction of the onset of midge problems is still required and this will be a priority of research undertaken in 1990/91. If these techniques are found to be useful at Forrestdale Lake, then similar environmental monitoring may profitably be performed along with normal larval monitoring at other lakes by management personnel.

Despite the promise offered by Sumilarv and by improved prediction and monitoring techniques the midge problem in Perth is likely continue because of the underlying problem of the increasing eutrophication of the urban wetlands. There is evidence in both the scientific literature, and in data collected from Perth lakes, to suggest that eutrophication has a positive effect upon chironomid densities. There is also some evidence that high midge larval densities cause increased nutrient transfer from the sediment to the water column (Gallep, 1979 and Tatrai, 1988). While further work is

required to establish more definite links the evidence is sufficient to suggest that poor water quality in general and nutrient enrichment in particular of the urban wetlands must be addressed as a longer term approach to the solution of midge problems.

FURTHER GUIDELINES ON THE USE OF A STANDARD METHOD FOR MONITORING LARVAL MIDGE DENSITIES - A REPORT FROM THE 'MIDGE TROUBLESHOOTER', MARK GARKAKLIS

INTRODUCTION

Recognising the need of local government authorities for advice concerning midge problems in lakes other than those being studied by the Murdoch research team a 'midge troubleshooter' (Mr Mark Garkaklis) was appointed for three months during the 1989/90 season. Mark was initially trained in the various monitoring techniques used by the Murdoch research team and briefed on the current options for midge control. Mark was then available to visit the offices of members of the Midge Research Steering Committee to provide hands on assistance with midge control problems. This involved assistance with the setting up of monitoring programmes and advising on midge sorting and identification techniques. This position was considered to be perhaps the most effective means of transferring research results to management.

The remainder of this chapter provides a summary of the information identified by Mark as being most useful to the members of local authorities who were establishing their own midge monitoring programmes. This information has been reproduced here to provide a permanent record that may be of use to both established and newly created monitoring programmes in the future.

FIELD SAMPLING

Theoretical Aspects of Larval Monitoring

The short term objective of any larval monitoring programme is to establish the immediate status of midge populations within a wetland. However, a consistent sampling programme will yield additional information. For example, it will indicate the effectiveness of larvicide treatments and, in combination with environmental data, will provide information on the environmental quality of a wetland.

To achieve these objectives the results obtained from a sampling programme must have a certain degree of accuracy. For example, the midge research team originally designed a sampling programme to provide larval density results with an uncertainty of no greater than 30%. To maintain this degree of accuracy, a sampling programme must be based on the distribution of midge larvae over the entire area of the wetland, and must account for the relevant aspects of the biology and ecology of the dominant species present.

Three important biological aspects to remember when designing a sampling programme are:

1) Midge populations are patchy. A single female midge can lay an enormous number of eggs. This may result in population distribution patterns comprising of extremely high larval densities close to areas with low larval

densities.

2) Each species has definite habitat preferences. For example, *Polypedilum nubifer* predominantly occurs in the shallow edge areas of a lake, whilst *Chironomus occidentalis* often occurs in deeper, less oxygenated water. A change in the dominant species present may indicate a change in environmental conditions. For example, *Tanytarsus fuscithorax* may become more dominant as salinity increases.

The implications of patchy population distributions are as follows. If the samples are taken from areas with predominantly high densities of larvae, then the mean density of larvae will be exaggerated. If the sampling programme is biased toward regions of low larval numbers, then the mean density of larvae will be underestimated. The sampling programme must include enough samples to ensure that both high and low density areas are sampled. Similarly, if sampling is biased toward one habitat type then the resulting mean density of larvae will not accurately reflect the actual density of larvae in the whole lake.

Identification can allow management personnel to judge effectiveness of Abate treatments against particular species. The ability to adjust treatments according to the dominant species will lead to a more cost effective treatment programme.

3) Given favourable conditions, midge abundance can increase from low densities to nuisance levels in a matter of weeks. The sampling programme must be repeated at least fortnightly to be certain that a rapid increase in midge numbers is not missed.

This leads to a major concern expressed by local authorities regarding the sampling procedure. Given the nature of midge population dynamics, how can the final result generated by the sampling programme be truly representative of the midge numbers over the entire lake? The answer to this is that the final result should not be expressed solely as a single average value but should be represented by a narrow range of possible values, within which the true value lies.

The **sample mean** determined as the average number of larvae in the cores must reflect the actual mean density of larvae in the lake (known as the **population mean**). To establish a degree of certainty for the sample mean a range of values higher and lower than this value is calculated. This range varies with the number of samples taken. If a large number of samples are taken, the range within which the average value lies is narrower than it would be if a small number of samples is taken. If the number of samples taken is very low, then the range of possible values may be so wide that the result is meaningless.

The range of values is called the **standard error** of the sample mean. It is calculated from the degree with which each sample value varies from the mean value, and is ultimately a function of the number of samples taken. The following example will be used to explain this concept.

Example 1 : Three core samples.

sample number	**1**	**2**	**3**
number of larvae	0	42	6

The average number of larvae per core (= **sample mean**) for all core samples is:

$$\textbf{sample mean} = \frac{0+42+6}{3} = 16 \text{ larvae per core}$$

The **standard error** is calculated using the following stepwise method.

1) subtract the mean value from each core value

e.g. 0 - 16 = -16
42 - 16 = 26
6 - 16 = -10

2) square each value from above e.g. $(-16)^2 = 256$
$(26)^2 = 676$
$(-10)^2 = 100$

3) add all values from 2) e.g. 256 + 676 + 100 = 1032

4) divide the result from 3) by the number of samples taken

e.g. 1032 / 3 = 344

5) take the square root of 4) e.g. square root of 344 = 18.5

This value is known as the **standard deviation**. It is used to calculate the **standard error** by the following steps:

6) subtract 1 away from the number of samples taken

e.g. 3-1 = 2

7) take the square root of the number calculated in 6)

e.g. square root of 2 = 1.414

8) divide the number calculated in step 7) into the standard deviation calculated in step 5)

e.g. 18.5 / 1.414 = 13.1

This is the standard error. The final result is;

the sample mean ± the standard error

16 larvae per core ± 13 larvae per core

That is, the larval density for the entire lake falls within the range of 3 larvae per core (16-13) to 29 larvae per core (16+13). Therefore, the result is meaningless since the value could be as low as 382 larvae/m^2 or it could be as high as 3692 larvae/m^2 (assuming a 10cm diameter corer was used).

Example 2 : 18 core samples

sample number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
number of larvae	0	42	6	0	42	6	0	42	6

sample number	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
number of larvae	0	42	6	0	42	6	0	42	6

Average number of larvae = 16 larvae per core, therefore, the standard deviation = **18.55** (following steps 1 to 5 above).

The standard error = standard deviation divided by the square root of the number of samples minus one (following steps 6 to 8 above).

standard error = 18.55/square root (18-1)
standard error = 4.5

The final result is **16 ± 4.5 larvae per core.**

Therefore, the overall value varies from 1464 larvae/m^2 to 2610 larvae/m^2. Note the much narrower range of values when the number of samples is increased from three to eighteen. This result indicates that the actual density of larvae is at least 1464/m^2 but probably higher.

This procedure appears to be complicated. In actual fact it is more tedious than complicated and will become easy with a little practise. Most calculators have statistical functions which take the tedium out of these calculations and yield a result very quickly.

In summary the following points should be noted:

1) The design of a sampling programme must account for patchy population distributions. Therefore, the sampling programme must not be biased

towards either densly or sparsely populated areas.

2) Species collected should be identified.

3) The sampling programme must be repeated at least fortnightly during the time when problems are experienced.

4) Ideally, the number of samples taken should result in a standard error of 30% or less of the sample mean.

Practical Field Sampling.
The procedure for larval monitoring was described in the 1989 report to the Midge Steering Committee. In response to general enquiries regarding this procedure an expanded description is given here.

To generate quantitative data each sample must be taken using the same techniques and the assessment procedure must be consistent. For example, the area of substrate collected in each sample must be identical. Maintaining consistency implies that modifications or 'short-cuts' to the procedure must not compromise the integrity of the sample.

Equipment

1) 10 cm diameter substrate corer. Stainless steel is the preferred material however, aluminium will suffice. A drawing of this device can be found in the 1989 report. An additional 0.75m extension is also useful for use at deep lakes.

2) Waterproof paper. Small squares of this paper are used to identify each core sample. Pencil written lables are indelible in water and alcohol.

3) Waders.

4) Plastic bags, elastic bands etc.

5) Dip stick for measuring lake water depths at each sampling point. For very deep samples use guage marks on the corer to determine water depth.

6) Two 'maximum-minimum' type thermometers for each wetland to record water temperatures.

Procedure.

1) Identify each sampling point on a schematic map of the wetland prior to going into the field. This will allow senior staff to delegate sampling to less experienced employees. More importantly it ensures the wetland is sampled consistently. A record of sampling points coupled with overall results provides useful diagnostic data in the long-term. Sample sites can either be determined on a completely random basis on each occasion, or can be taken at random around fixed sampling points.

2) Take an appropriate number of samples for each wetland. For example, on small ornamental lakes between seven and ten samples should be appropriate (depending on the size of the resultant standard error). Larger wetlands will require between ten and twenty samples. A greater number of samples may be required from wetlands with variable water depths and substrates. It is often best to separate cores from deeper regions from cores of shallower areas, and to analyse them separately.

3) Samples should be taken using a standard size corer and the corer should be vertical when the samples are taken. When emptying the sample into a plastic bag, ensure that no surface strata is lost from the sample. Label each core sample by placing a waterproof paper label into the bag. Information on the label should include;

-wetland
-date
-core number
-core location

Record the type of substrate at each location. For example, the following classifications may be an appropriate starting point;

-sandy
-sandy/clay
-clay
-organic matter (om)
-om/sand
-om/clay

4) Record the water depth at each sampling point using the dip stick.

5) Record the lake water depth from a reference depth guage.

Local authorities are encouraged to record simple environmental data on each sampling occasion. With a consistent sampling programme over several seasons, patterns of emergence corresponding to particular environmental events may become apparent. For example, larval densities at Forrestdale Lake appear to increase rapidly at a particular water temperature. Once a pattern is observed then it may be possible to predict problems with adult midges based on environmental data. This will result in an enormous saving of time in the longer term (refer to Chapter 4 for a discussion of this subject). By recording sediment type the sampler will become familiar with the sediment preferences of different species.

6) Anchor one max-min thermometer in a shallow area of the wetland and the other in a deeper section. Record the maximum and minimum water temperatures on each sampling occasion. The thermometers should be reset when they are first put into place and again after each reading.

Separation of Midge Larvae from Sediments.
The calcium chloride flotation method is the best procedure for separation of midge larvae. Samples should be sorted immediately although this is not always possible. Short term storage requires refrigeration of the samples. Long term storage requires refrigeration plus preservation in alcohol. Approximately 200ml of technical grade alcohol is used to preserve each sample.

Equipment.

1) Two plastic buckets.

2) Technical grade calcium chloride. This is available in 25kg bags.

3) Stainless steel sieves. The aperture size should be no greater than 0.25mm. Use of a larger aperture sieve will result in a loss of midge larvae. A 0.5mm aperture sieve and a 1.0mm sieve are sometimes useful for removing and washing organic material within the sample.

4) White, flat bottom sorting tray.

5) One pair of fine tweezers.

6) Rubber gloves.

Procedure

1) Make-up a solution of calcium chloride prior to sorting. To do this add about 2.5kg of calcium chloride flakes to 4 litres of water. Stir this solution until all of the salt is dissolved. As with any salt solution, this solution will be irritable to the skin. It is therefore recommended that rubber gloves are worn during sorting.

2) A scum usually develops once the calcium chloride solution has been left to stand. This can be removed by repeated scooping with the 0.25mm sieve or by using a folded cloth.

3) Drain any excess water or preservative alcohol from the sample using the 0.25mm sieve. This will avoid dilution of the calcium chloride.

4) Transfer all of the sample to the calcium chloride solution. Ensure all of the sample is removed from the bag.

5) Break up the sediment sample so that no lumps remain (this is important).

6) Allow the suspended solids to settle. The midge larvae will float to the surface. They can be 'scooped-off' using the 0.25mm sieve. Wash water through the sieve to remove fine particulate material before transfering the scooped material to the white sorting tray. Alternatively the midges can be picked straight from the bucket. Collect the midge larvae using the tweezers and preserve them in small vials of alcohol. The waterproof paper label can also be transferred to the vial.

7) Repeat steps 5 and 6 twice to recover all of the larvae and then pick off any larvae still in the buckets.

8) The calcium chloride solution can be recovered by straining the slurry material through the 0.25mm sieve into another bucket. This solution can be re-used several times as long as some fresh calcium chloride flakes are added to maintain the solution strength after every five to ten samples.

Calculation of the Number of Larvae per Square Metre (Using the data from the **standard error** example 2)

Average = 16 larvae per core ± 4 larvae per core

These values must be multiplied by the number of times a single core fits into a square metre. Use the following formula:

$$\textbf{Multiplying Factor} = \frac{1}{3.14*radius*radius}$$

For a corer with a diameter of 10cm or 0.1 metres, the radius is equal to 0.05 metres. Therefore,

$$\textbf{Multiplying Factor} = \frac{1}{3.14 \times 0.05 \times 0.05}$$

$$= 127.3$$

That is, the final result must be multiplied by 127.4. Thus 16 ± 4.5 larvae per core becomes ;

(16 x 127.3) ± (4.5 x127.3)

= 2037 larvae per square metre ± 579 larvae per square metre

Thus the true density of larvae within the wetland lies between 1458 and 2616 larvae per square metre.

Frequency of Sampling

As previously mentioned, monitoring of wetlands during the summer must be repeated fortnightly. This regime is altered slightly when a pesticide is applied to the wetland. It is important to assess the effectiveness of these treatments. Therefore, sampling and assessment should take place one day before treatment and one week after treatment. The normal fortnightly regime can then be resumed.

Midge Larvae Identification

With a small amount of practice identification of midge larvae becomes very quick. There are usually only one or two features which must be recognised to identify a particular species. However, a stereomicroscope is essential for

this procedure. A simple key for the identification of common species is available from Murdoch University (A Guide to the Identification of Common Midge Larvae in the Perth Metropolitan Area.).

LAKE MONGER LIGHT TRAPS

During 1990 the City of Perth initiated the use of light traps at Lake Monger for the purpose of midge control. In addition the lights also provide illumination of the foot/cycle path which encircles the lake. This is the first time that the large scale use of light traps has been employed at a wetland in Perth. The following information regarding this innovative approach was provided by Mr Adrian Van Leeuwen of the City Of Perth.

Eleven light traps have been installed on the north-western shore of the lake and have been in use since February 1990 (Fig. 1D). Each light trap comprises a 70 watt high pressure sodium light source atop a 3.5 m pole. Located beneath each light is an extraction fan which sucks insects away from the light source into a fine stainless steel mesh receptacle. The traps are emptied regularly and the catches are counted by sub-sampling.

The mean number of midges caught has varied from 261 ± 155 to 128 000 ± 22 042 per trap per night, and the total number caught ranged from 3000 to 1 400 000 midges per night (Fig. 29). The number of midges caught was generally higher in March than during February. The observed variation in midge abundance is probably a function of both population densities within the lake and prevailing climatic conditions, however, further work is needed to verify these suggestions.

The Lake Monger light traps usually caught more than the mean number of midges caught by the Bibra Lake light trap (13 306 ± 10 945; maximum 51 072) in 1988/89. Assuming that 3% of larval midges emerge on any one night and that *Polypedilum nubifer* (the main species caught in the light traps), is abundant in only the littoral region, which is assumed to be 2.6 ha in area, then the number of *P. nubifer* emerging from Lake Monger per night can be calculated. Larval density was determined on two occasions while the light traps were set, the emergence of *P. nubifer* based on these densities are 500 000 (16th February) and 1 200 000 (22nd February) per night. The total light trap catches (from all eleven traps) on the closest nights were 56850 (17th February) and 88 600 (22nd February) per trap, these were 11.4% and 7.4% of the assumed *P. nubifer* emergence respectively. These are based on estimates of emergence only and reliable emergence data are required for a more precise comparison of emergence and light trap catches.

While the exact impact of the lights has not been determined experimentally, the fact that large numbers of midges have been caught by the traps indicates that they are playing a positive role in midge control at the lake. A catch of 7 - 11% of total emergence per night should be large enough to cause some decrease in nuisance swarms in residential areas. Further lights are proposed to be provided at the lake in the coming twelve months and these will be placed along the southern shore. These additional lights may increase the total catch to 20% or more.

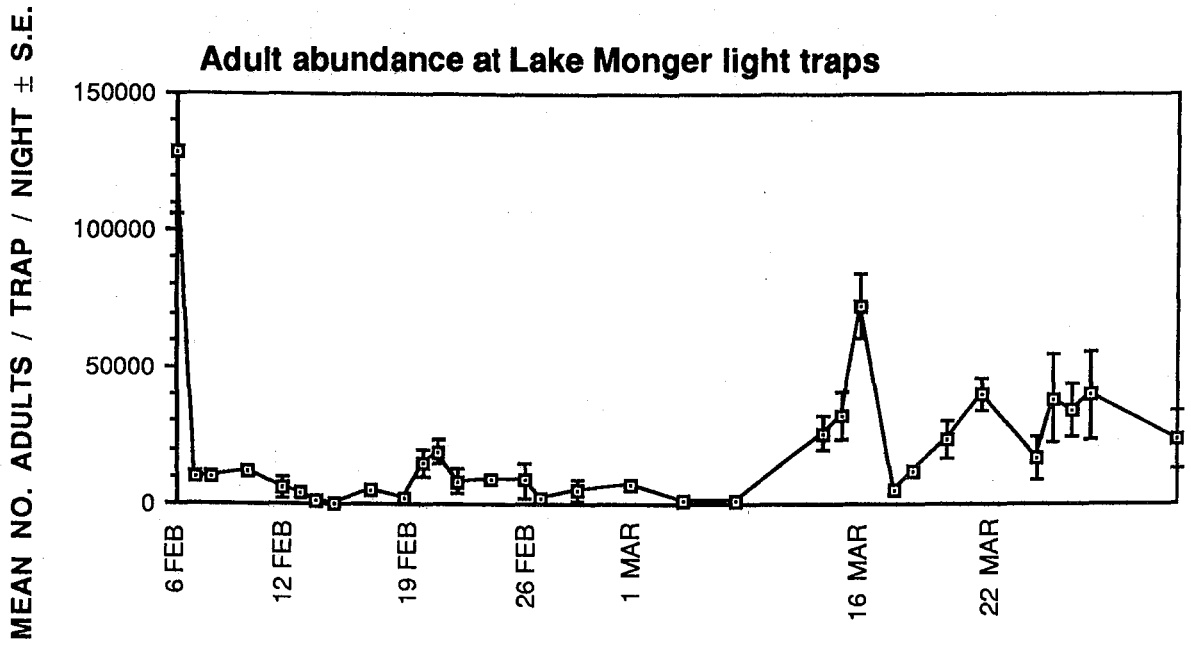


Figure 29. Changes in the number of adults at the Lake Monger light traps, February to April 1990. Means and standard errors are shown.

UPDATE ON THE JACKADDER LAKE ALUM EXPERIMENT

INTRODUCTION

The 1989 midge research report presented some results of an experiment that was designed to investigate the effects of the addition alum to the water quality of Jackadder Lake. This chapter presents some additional results obtained during the latter half of 1989.

Alum (aluminium sulphate) binds with the phosphorus in the water column and sediment (Cooke *et al.*, 1986). The resulting insoluble forms of phosphorus are then no longer available for plant growth. This should then limit growth of phytoplankton and so reduce the food resource available to chironomid larvae. For this reason the addition of alum to a lake was considered to be a potential alternative to pesticides for midge control.

Alum was added to Jackadder Lake during January 1989. The experiment was conducted by Mark Lund (Murdoch University) and the City of Stirling. An enclosure, which acted as a control area, was constructed and financed by City of Stirling. Changes in chironomid densities during the experiment were monitored by the Murdoch research team.

The 1989 report concluded that some short-term improvements in water quality and larval abundance had occurred. However data on nutrient concentrations were not available at the time the 1989 report was produced, and so are presented in this chapter.

METHODS

The methods used to apply the alum and sample the lake were given in the 1989 report. A description of Jackadder Lake and an illustration of the control enclosure was also given. The following methods refer only to the unique features of the later sampling.

In the previous report larval data was presented from December 1988 to March 1989. The lake has been sampled for larvae and water quality on four occasions since that time, between May and December 1989.

On the first two of these occasions nine and fifteen cores were taken in the littoral region of the control and treated areas respectively. On 26 October fifteen cores were taken from the littoral area of the lake, three of which fell within the region used as the control area. These three were still plotted separately to the remaining 12 cores. However, by this time it was apparent that the enclosure was no longer a barrier to water movement between the two areas. For this reason it was decided not to specifically sample the control area in December, and so fifteen cores were taken at evenly distributed sites in the littoral area of the lake.

A sweep net and a corer were used to take samples of the zooplankton and macroinvertebrate fauna of the treated and control areas.

Monitoring of various water quality parameters continued until December 1989. The pH, and concentrations of chlorophyll-a, total phosphorus and total nitrogen of water in the control and treated areas were determined by M. Lund.

RESULTS

Larval Density

Figure 30 shows the changes in total larval density, and in the densities of *Polypedilum nubifer*, *Cryptochironomus griseidorsum* and *Procladius villosimanus* in the treated and control regions of Jackadder Lake, between December 1988 and December 1989.

The control area initially supported much higher densities of larvae than the treated area. After the addition of alum to the lake a rapid decrease in larval density was observed in both of these areas. No difference in total larval density between the two areas was then observed until June. In June the density of larvae was found to be higher in the control area than in the treated area. However in October no difference was recorded.

Changes in the density of *P. nubifer* followed similar patterns to changes in total larval density (Fig. 30). Before treatment larval density in the control area (7685 ± 1564 larvae/m^2) was greater than in the treated area (2761 ± 706 larvae/m2). An initial decline in density in both areas was followed by a three month period during which little difference in abundance was evident between the two areas. In May, larval density was higher in the treated than in the control area, whereas in June and October the opposite was recorded.

Prior to the alum addition the density of *C. griseidorsum* in the treated areas (433 ± 87 larvae/m^2) was similiar to that of the control area (454 ± 161 larvae/m^2) (Fig. 30). After treatment the density of larvae in the treated area declined to 85 ± 31 larvae/m^2 within a week. By contrast larval density in the control area declined gradually over 10 weeks to 34 ± 17 larvae/m^2. Little difference in the density of larvae was then observed between the two areas on subsequent occasions.

Within the control area the abundance of *P. villosimanus* larvae declined from 169 ± 127 larvae/m^2 before treatment to zero larvae/m^2 one month later (Fig. 30). No such decline was observed in the treated area during this time. From the end of March until June 1989 the density of this species was less than 35 larvae/m^2 in both areas. In October *P. villosimanus* was more abundant in the treated area than in the control.

The density of *P. nubifer* and *C. griseidorsum* declined after treatment with alum, and did not increase to pre-treatment levels for the duration of the monitoring. *P. villosimanus* exceeded pre-treatment densities in the treated area.

The larval density recorded in the whole lake was lower in December 1989 than that recorded in December 1988. However, this is a comparison of two

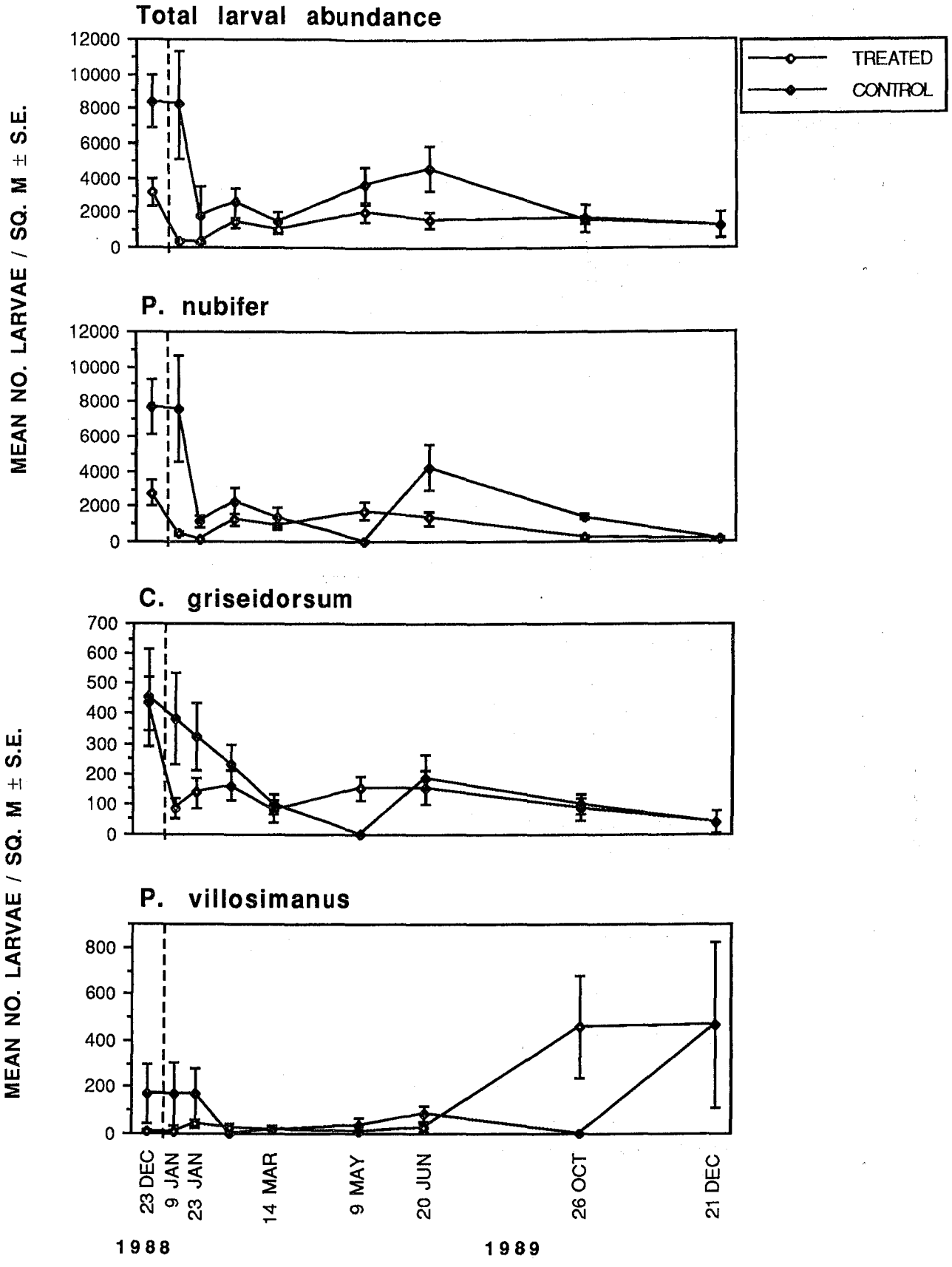


Figure 30. Changes in the total density of larvae, and in the density of *P. nubifer*, *C. griseidorsum*, *P. villosimanus*, within the treated and control areas of Jackadder Lake, December 1988 to December 1990.

dates only and cannot be used to make broad statements about year to year differences in midge abundance.

Effects on other invertebrates
Zooplankton species richness was not affected by the alum addition although the abundance of two species (a cyclopoid copepod and a rotifer) were significantly reduced in the treated area two weeks after treatment. These populations recovered several weeks later. Macroinvertebrate populations did not appear to be affected by the addition of alum, other than short term reductions in the abundance of some species (Lund, in press).

Environmental parameters
Figure 31 shows changes in the concentrations of total phosphorus, total nitrogen and chlorophyll-a in the treated and control areas during the monitoring period.

Before the application of alum, there appeared to be no difference in the concentration of total phosphorus between the control and treated areas (Fig. 31). In the treated area a range of 58 to 79 µg/l was observed while in the control area 47 to 80µg/l was recorded. Two weeks after the treatment with alum the phosphorus concentration declined to 17 µg/l in the treated area, before rising to a steady concentration of between 50 and 56 µg/l for the next four months. By October the concentration of phosphorus (82 µg/l) had risen to pretreatment levels in the treated area, before rising to 113 µg/l by December. In the control areas the concentration of total phosphorus after the addition of alum remained between 63 and 79 µg/l until June. In October total phosphorus in this region was recorded at 40 µg/l, half the concentration in the treated area. By December both the control and treated areas had higher phosphorus concentrations (115 and 113 µg/l respectively). Overall, total phosphorus levels in the treated area were lower than in the control area until June.

Prior to the addition of alum nitrogen concentrations were increasing from between 500 and 1 000 µg/l to between 1 500 and 2 000 mg/l (Fig. 31). A drop in both areas was observed after the addition of alum, followed by a gradual rise over the next few months to between 750 and 1250 µg/l. Similar concentrations were then maintained for the rest of the monitoring period.

Similar concentrations of chlorophyll-a were recorded in the treated and control areas throughout the study (Fig. 31). A decrease in chlorophyll-a concentration before treatment (from 122 - 29 µg/l to 9 - 17 µg/l) was followed by increasing concentrations for the rest of the summer and autumn. Winter then saw a drop in chlorophyll-a concentrations to between 29 and 38 µg/l.

DISCUSSION

After the addition of alum a decrease in the concentration of phosphorus in the treated area was recorded while no such decrease was observed in the control enclosure. This suggests that the addition of alum did acheive a

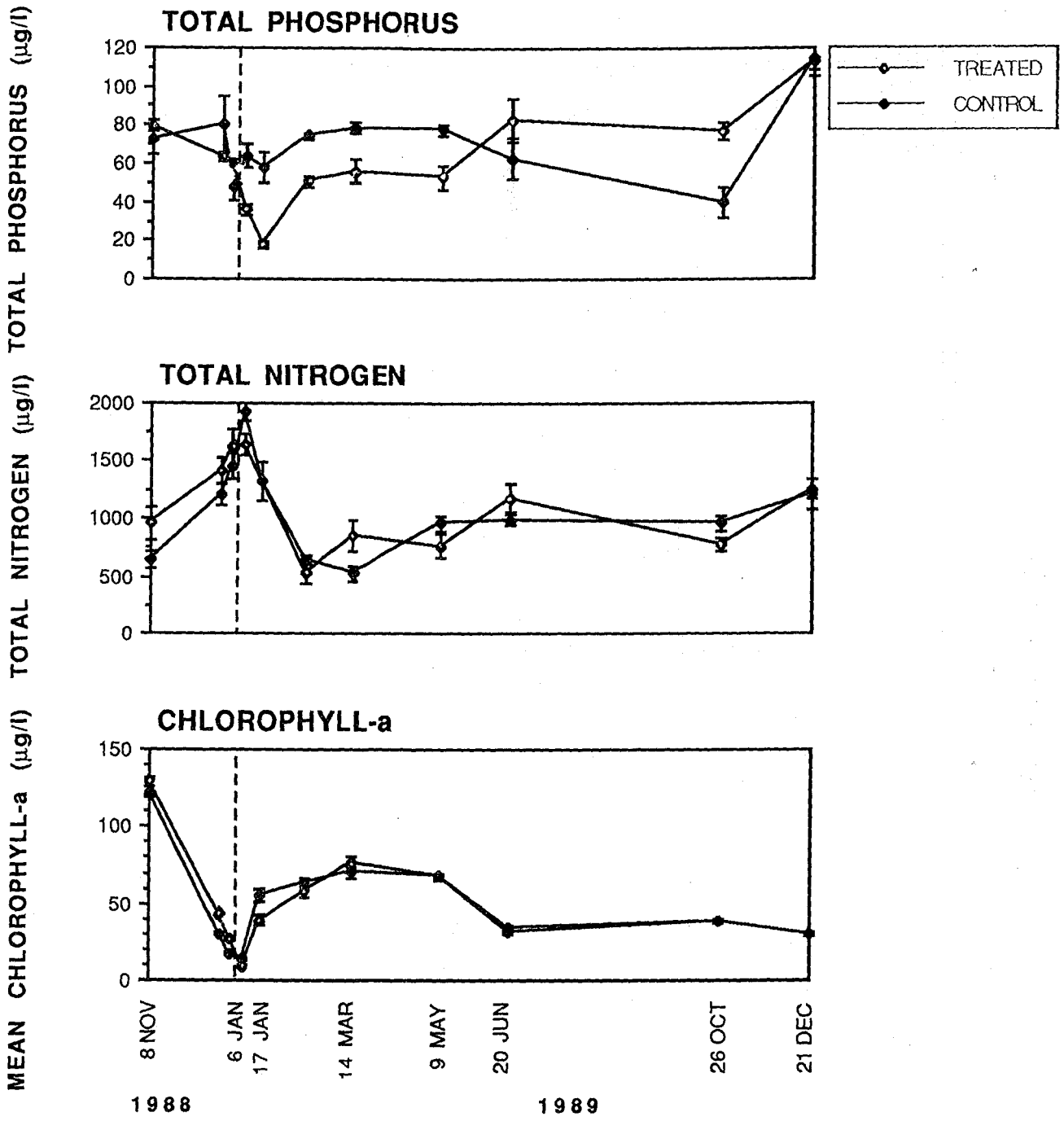


Figure 31. Changes in the concentrations of total phosphorus, total nitrogen and chlorophyll-a, within the treated and control areas of Jackadder Lake, November 1988 to December 1990.

reduction in phosphorus concentration. However concentrations returned to pre-treatment levels in June, presumably as a result of an influx of nutrients to the lake occurring as a result of winter rainfall. Changes in nitrogen concentration are not expected as a direct consequence of alum treatment (Gasperino *et al.* 1979) and none were observed at Jackadder Lake. This is beneficial because any increase in the N:P ratio will favour the growth of green algae over blue-green algae.

The reduction in phosphorus concentration was obviously not sufficient to reduce the level of phytoplankton abundance, as evidenced by the chlorophyll-a concentrations. However an increase in benthic filamentous green algae was noticed in the months following the alum addlition, which can indicate lower trophic status (M. Lund pers comm.).

A reduction in midge larval density was observed immediately after the alum addition, however this reduction occurred in both the treated and control areas. This may have been due to declining algal abundance, which was occurring in both the treated and control areas. The alum may have had some direct toxicological effect upon the larvae, or caused an early increase in emergence (as is often observed after application of a pesticide). Total larval density, and the density of *P. nubifer* and *C. griseidosrum* did not return to pre-treatment levels during the study. The abundance of larvae throughout the study was generally within the range that has been observed in previous years (Davis, Harrington and Pinder, 1988), with the exception of *P. villosimanus*, which was relatively high in abundance in October and December 1989. In addition, the decrease that was seen to occur after the alum treatment, was no greater in magnitude than has been observed naturally at this lake during 1988. The 1988 decrease in larval density followed a similar reduction in chlorophyll-a concentration.

In the 1989 report it was suggested that insufficient alum was added to the lake to cause the desired reduction in pH, which would have led to more efficient removal of phosphorus (Cooke *et al.*, 1986). A reduction of pH from 8.3 before treatment to 7.1 (in the control) and 6.8 (in the treated area) occurred within two days of the treatment. This suggests that some leakage of alum into the control enclosure occurred.

As the decrease in total phosphorus concentration that occurred in the treated area was not evident in the control enclosure, it would seem that this leakage was not sufficient to reduce the phosphorus levels in the control area. However, as lake depth rose in winter and spring it was obvious that the barriers were no longer effectively separating treated and control areas. This may explain the similar phosphorus concentration in the two areas in June and December 1989.

This experiment has shown that alum has the potential to reduce phosphorus concentrations in Perth lakes. Perhaps if enough alum had been added to reduce the pH to 6.0 then an even greater effect may have occurred, leading to reductions in algal growth and midge abundance. The treatment may have been more effective it was carried out in spring when inorganic phosphorus concentration is at a maximum, as aluminium does not bind as easily to organic phosphorus compounds. However, such effects

were not achieved and further studies are required if the usefulness of alum is to be determined.

CONCLUSIONS AND IMPLICATIONS FOR MANAGEMENT

Data obtained during the third year of research into Perth's midge problems will contribute to the better management of the problem in several ways.

Sumilarv, a juvenile hormone analogue (JHA) type insect growth regulator (IGR), has been identified as an alternative to the organophosphate pesticide, Abate, for short term control at lakes where the latter no longer always provides control, for example, North Lake and Lake Monger. Laboratory trials conducted so far indicate that an application rate of 10 kg/ha (in water 50 cm deep) of Sumilarv 0.5G should achieve control in Perth wetlands. Wellcome have indicated that Sumilarv will be comparable in cost to Abate on a per hectare basis and that it is expected to be registered for use in Australia by 1992. Information on the effects of Sumilarv on non-target wetland invertebrates is poor and this aspect of its use is a priority for research in 1990/91.

Abate still appears to be an effective compound for midge control at Forrestdale Lake but proper timing of treatments is essential for good control. The rapid increase in *P. nubifer* which occurred over a very short period this summer indicated the need for use of critical values of environmental parameters in addition to larval thresholds to predict the onset of midge problems at the lake. Analysis of the three years of environmental data collected at the lake in conjunction with the larval monitoring programme revealed that nuisance swarms occur approximately 5 weeks after the depth has dropped below 90 cm and 4-7 weeks after the water temperature exceeds 25°C. The larval threshold for *P. nubifer* of 500 larvae/m^2 suggested last year still appears to be appropriate for this lake.

A larval threshold for *P. nubifer* of up to 5000 larvae/m^2 may be more appropriate for North Lake than the 2000 larvae/m^2 suggested in the previous report. Thresholds of larval densities that signal the onset of midge problems must be detected for appropriate timing of pesticide applications. Monitoring programmes to do this need to be established at all lakes with a history of midge problems. It is unlikely that midge problems will be successfully controlled if the status of midge populations at a lake are not known. Simple monitoring of environmental parameters such as depth, water temperature, pH and conductivity should also be undertaken in conjunction with the larval monitoring programme. Further guidelines for the standard monitoring programme described in last years report are given in this report.

Appropriate timing of a pesticide treatment is also dependent upon management agencies being able to organise a treatment within days rather than weeks after larval thresholds and critical environmental values are reached. This is an issue which needs to be addressed for Forrestdale Lake before September 1990 if midge problems are to be sucessfully controlled at the lake over the coming summer.

In addition to accurate timing of a pesticide application the distribution of pesticide within the target area (for example, the littoral zone of North Lake or the entire area of Forrestdale lake) must be even, as a patchy application

may leave large areas untreated and sufficient midges present to recolonise treated areas. Use of a helicopter or boat for pesticide application appears preferable to the use of a fixed wing aircraft for delivery of pesticide to target areas.

Differences between lakes in terms of degree of enrichment, physico-chemical attributes and composition and abundance of midge populations means that no universal formula for the solution of midge problems will be found. In addition, no single action, for example, treatment with pesticide, will solve problems indefinitely. An integrated approach to midge control is required where several control techniques are applied simultaneously. For example, the use of light traps in addition to pesticide treatments (if larval threshhold levels are exceeded) plus a reduction in nutrient inputs and the replanting of fringing vegetation are all techniques that could be used in combination to good effect.

The links between poor water quality, and eutrophication in particular, with midge problems are strong enough to suggest that the issue of water quality management in the urban wetlands needs to be addressed as part of a more holistic approach to the control of midge problems.

FUTURE RESEARCH DIRECTIONS

A major objective of the final year of research will be the field testing of Sumilarv. This is the first compound tested by us to display real potential as an alternative to Abate. Because some field results have already been obtained for North Lake the focus of further field tests next spring and summer will be at Lake Monger. The light traps already installed, used in conjunction with emergence traps, will provide valuable information on adult abundances in response to treatment. The presence of the light traps and installation of a local weather station at the lake will enable determination of the effects of micrometeorological conditions on midge swarms. Laboratory testing of Sumilarv and its effects on non-target fauna will also be undertaken.

Larval and environmental monitoring programmes will be continued at Forrestdale Lake with special attention being given to testing of the predictive capacity of the observed relationship between environmental parameters and nuisance outbreaks of *P. nubifer*. Less intensive monitoring will be undertaken at North Lake because of the time constraints imposed by field trials at Lake Monger. However sufficient data will be collected from North Lake to enable the possible impact of reduced nutrient inputs, due to the diversion of the Murdoch University veterinary farm drain, on midge densities, to be determined.

Assessment of the effectiveness of Sumilarv requires monitoring of levels of adult emergence, which requires different methods to those employed to measure larval densities and monitor the efffectiveness of Abate. Because it is important that all pesticide treatments are monitored (so that ineffective and uneconomic treatments are not continued) a workshop will be held for members of the Midge Steering Committee and their staff to provide advice on the construction and use of emergence traps.

Consideration of water quality management issues will be undertaken as part of a more holistic approach to midge control. There is evidence in data collected from the urban wetlands to suggest that chironomid abundance is positively associated with nutrient enrichment. Further work is required to establish exact links but the issue of poor water quality, particularly nutrient enrichment of the urban wetlands, must be addressed as part of a longer term approach to midge problems.

REFERENCES

Anderson, N. H. and Cummins, K. W. (1979). Influence of diet on the life histories of aquatic insects. Journal of the Fisheries Research Board of Canada. 36: 335 - 342.

Bayley, P., Deeley, D. M., Humphries, R. and Bott, G. (1989). Nutrient Loading and Eutrophication of North Lake, Western Australia. EPA Technical Series. EPA, Perth, Western Australia.

Brown, T. M. and Brown, A. W. A. (1974). Experimental induction of resistance to a juvenile hormone mimic. Journal of Economic Entomology. 67: 799 - 801.

Davies, I. J. (1980). Relationships between dipteran emergence and phytoplankton production in the Experimental Lakes Area, Northwestern Ontario. Canadian Journal of Fisheries and Aquatic Sciences. 37: 523 - 533.

Davis, J. A., Christidis, F., Wienecke, B. C., Balla, S. A. and Rolls, S. W. (1986). Forrestdale Lake Chironomid Study. Murdoch University, W.A.

Davis, J. A., Harrington, S. A. and Pinder, A. M. (1988). Investigations Into More Effective Control of Nuisance Chironomids (Midges) in Metropolitan Wetlands, Perth, Western Australia (Unpublished report for the Midge Research Steering Committee).

Davis, J. A., Harrington, S. A. and Pinder, A. M. (1989). Further Investigations Into the Control of Nuisance Chironomids (Midges) in Metropolitan Wetlands, Perth, Western Australia. (Unpublished report for the Midge Research Steering Committee).

Edward, D. H. D. (1964). The Biology and Taxonomy of the Chironomidae of S.W. Australia. Unpub. Ph.D Thesis. University of Western Australia. Perth.

Estrada, J. G. and Mulla, M. S. (1986). Evaluation of two insect growth regulators against mosquitoes in the laboratory. Journal of the American Mosquito Control Association. 2: 57 - 60.

Gallep, G. W. (1979). Chironomid influence on phosphorus release in sediment-water microcosms. Ecology. 60: 547 - 556.

Georghio, G. P., Lee, S. and DeVries, D. H. (1978). Development of resistance to the juvenoid Methoprene in the housefly. Journal of Economic Entomology. 71: 544 - 547.

Hemingway, J., Magayuka, S. A. and Lines, J. (1985). Report on the efficacy of juvenile hormone mimic against *Cx. quinquefasciatus* and *An. gambiae* in field trials in Tanzania. Unpub. report. London School of Hygiene and Tropical Medicine, England.

Hilsenhoff, W. L. (1966). The biology of *Chironomus plumosus* in Lake Winnebago, Wisconsin. Annals of the Entomological Society of America. 59: 465 - 473.

Horn, D. J. (1988). Ecological Approach to Pest Management. Elsevier Applied Science Publishers, England.

Johannsson, O. E. (1980). Energy dynamics of the eutrophic chironomid *Chironomus plumosus* F. *semireductus* from the Bay of Quinte, Lake Ontario, Canada. Canadian Journal of Fisheries and Aquatic Sciences. 37: 1254 - 1265.

Learner, M. A., Wiles, P. R. and Pickering, J. G. (1989). The influence of aquatic macrophyte identity on the composition of chironomid fauna in a former gravel pit, Berkshire, England. Aquatic Insects. 11: 183 - 191.

Lundgren, A. (1985). Model ecosystems as a tool in freshwater and marine research. Archives of Hydrobiology Supplements. 70: 157 - 194.

Mackey, A. P. (1977). Growth and development of larval chironomidae. Oikos. 28: 270 - 275.

Menn, J. J. and Beroza, M. (1972). Insect Juvenile Hormones: Chemistry and Action. Academic Press, London.

Metcalf, R. L. (1980). Changing role of insecticides in crop production. Annual Review of Entomology. 25: 219 - 256.

Norgard, R. B. (1976). The economics of improving pesticide use. Annual Review of Entomology. 21: 45 - 60.

Pinder, L. C. V. (1986). Biology of the freshwater Chironomidae. Annual Review of Entomology. 31: 1-23.

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

Rolls, S. W. (1989). The Potential of Northern Hemisphere Biotic Indices as Indicators of Water Quality in Wetlands on the Swan Coastal Plain, Western Australia. Murdoch University. Western Australia.

Schaefer, C. H. and Miura, T. (1987). New mosquito larvicides: efficacy, nontarget effects, and environmental persistance. In, Mosquito Control Research Annual Report. University of California, California.

Schneiderman, H. A. (1972). Insect hormones and insect control. In, Insect Juvenile Hormones : Chemistry and Action. (Menn, J. J. and Beroza, M., eds.) Academic Press, London.

Solomon, K. R., Smith, K. E., Guest, G., Yoo, J. Y. and Kaushik, N. K. (1980). The use of limnocorrals in studying the effects of pesticides in the aquatic ecosystem. Canadian Technical Report on Fisheries and Aquatic Sciences. 975: 1 - 9.

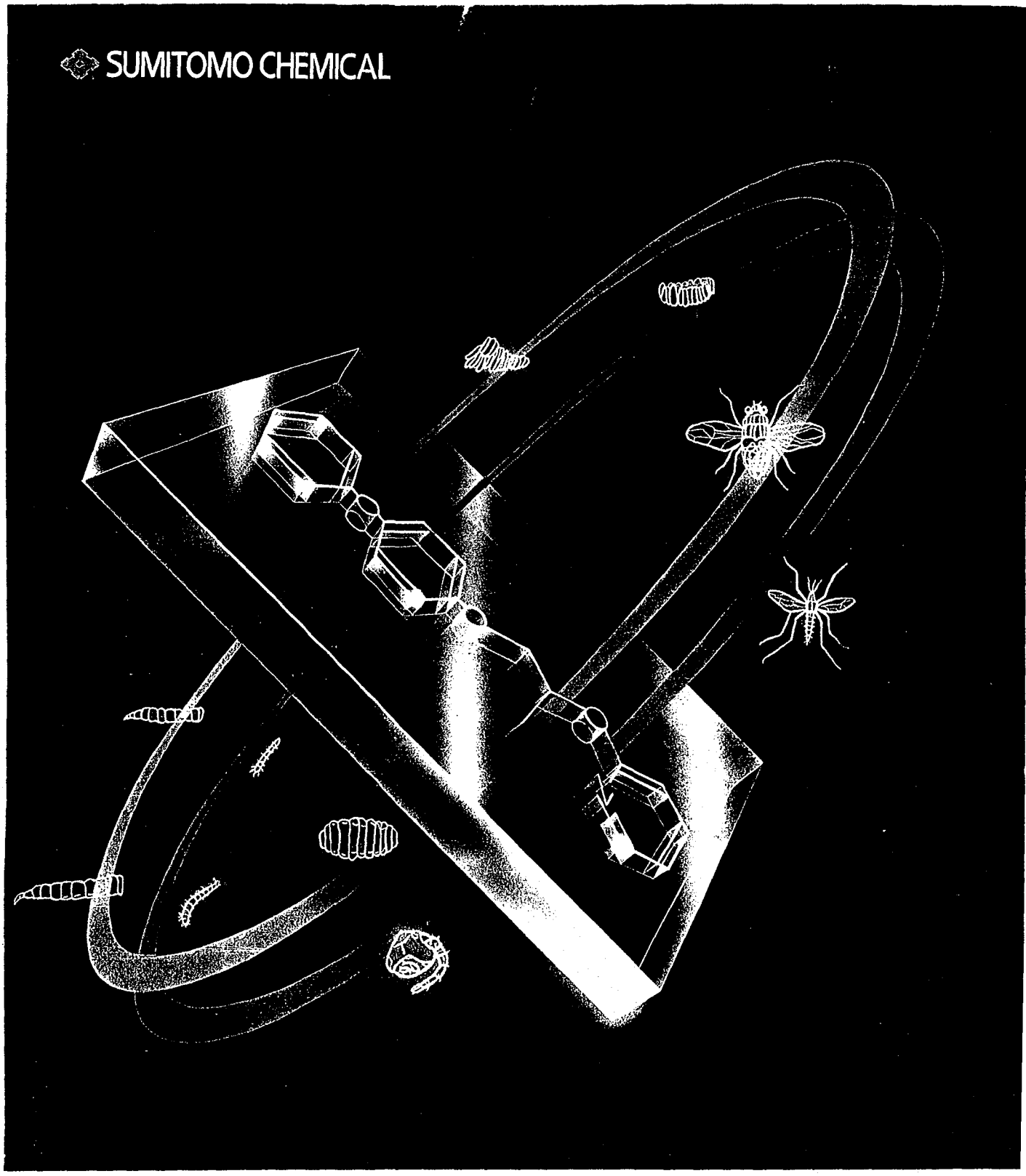
Staal, G. B. (1972). Biological activity and bioassay of juvenile hormone analogs. In, Insect Juvenile Hormones : Chemistry and Action. (Menn, J. J. and Beroza, M., eds.) Academic Press, London.

Sumitomo Chemical Co. Ltd. (no date). Insect Growth Regulator, Sumilarv 0.5G. (Product Brochure). Sumitomo Chemical Company, Osaka.

Sumitomo Chemical Co. Ltd. (no date). Proposed Test Plan of JHM (S-31183) for Mosquito. Technical Report. Sumitomo Chemical Company, Osaka.

Tatrai, I. (1988). Experiments on nitrogen and phosphorus release by *Chironomus* ex gr. *plumosus* from the sediments of Lake Balaton, Hungary. Int. Revue Ges. Hydrobiol. 73: 627-640.

Uvarov, B. P. (1931). Insects and climate. Transactions of the Entomological Society of London. 79: 174 - 186.



Insect Growth Regulator

Sumilarv® 0.5G

Try Sumilarv for Perfect Pest Control, Toward a World without Pest Problems.

As a new generation insecticide, juvenile hormone analogue (JHA), Sumilarv, provides you with a new approach to insect control.
Stop pest propagation with Sumilarv. For nonrecurring populations, no more problems with pests. Forever !
Now why Sumilarv? Because it breaks the life cycle of the insect, prevents a pre-adult from maturing into an adult. Thus, it can't reproduce, resulting in a decreased population. If a faster, stronger and longer lasting pest elimination system is desired, Sumilarv should be used in combination with adulticides. The choice of Sumilarv is a key to success in the control of fly, mosquito, flea and other insect populations.

Thanks to Sumilarv . . .

- Long-term pest population elimination, by subtly altering insects' life cycle.
- At low levels, it promises strongly effective control.
- Won't harm man and animals.

Thanks to Sumilarv . . .

Long-Term Pest Population Elimination, by Subtly Altering Insects' Life Cycle.

What is Sumilarv?

Sumilarv is a larvicide with a unique mode of action. It is a juvenile hormone analogue (JHA) and mimics a natural insect hormone.
JH plays an important role in an insect's development from an egg into an adult. For larval moulting, the presence of JH is essential. On the contrary, in the absence of JH, pupal or adult moulting is induced. Herein lies the significance of Sumilarv.
By the application of an exogenous juvenile hormone analogue (JHA), such as Sumilarv, to the insect larvae, their hormonal balance is upset. It prevents successful moulting of larvae into pupae, and later into adults.

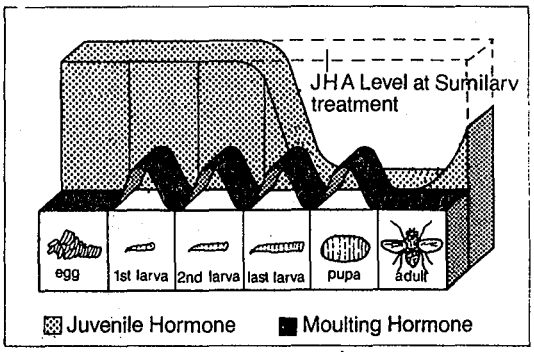


Fig.1 Schematic changes in the JH titres of a housefly and mode of action of JHA

What Happens with the Application of Sumilarv?

Against flies and mosquitoes, Sumilarv inhibits their life cycles at the pupal stages. Where applied, larvae develop normally to pupation, but they cannot become adults. That is, normal maturing into an adult capable of reproduction is inhibited. And thus, the target population gradually decreases.

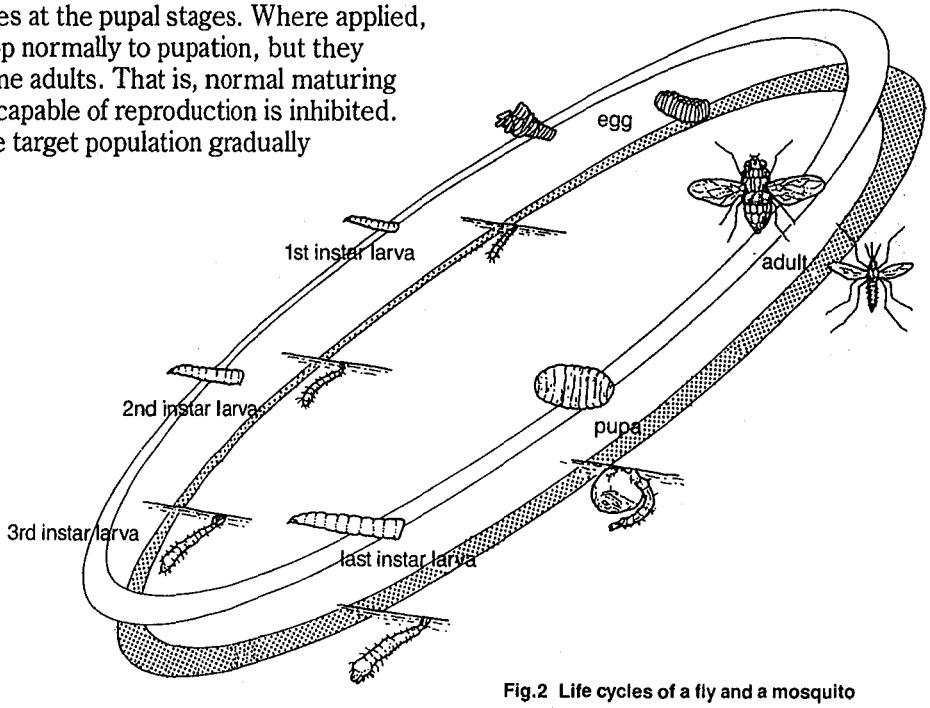


Fig.2 Life cycles of a fly and a mosquito

Sumilarv 0.5G

Formulation:	Granule	
Composition:	Sumilarv (Pyriproxyfen)	0.5
	Adjuvants	4.0
	Carrier	balance
		100.0 (% w/w)

Thanks to Sumilarv . . .

At Low Levels, It Promises Surprisingly Effective Control.

Sumilarv is much more effective than organophosphates, pyrethroids or other JH insecticides against larvae of flies and mosquitoes, being active at substantially lower rates. Moreover, it provides the long-lasting control you have been seeking.
If combined with adulticides, you can easily attain optimum perfect pest control.

Extremely High Biological Activity in Lab.

Sumilarv is several 100 × more effective against housefly larvae (*Musca domestica*, 4-day-old larvae) than other compounds.
Sumilarv shows similar superiority against mosquitoes (*Culex pipiens pallens*, 4th instar larvae).

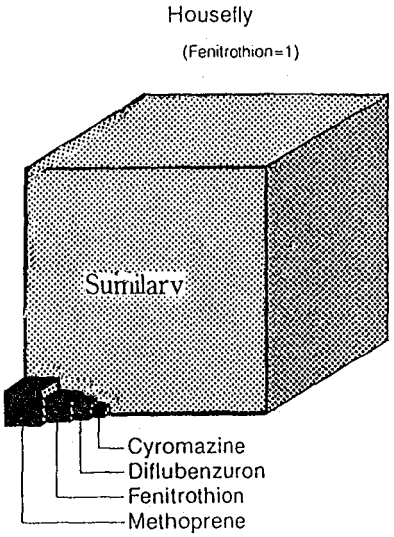


Fig.3 Relative emergence inhibition efficacy of Sumilarv and various insecticides

High Performance in the Field

Sumilarv has demonstrated its high potency in field tests. Sumilarv 0.5G is effective against flies in a waste treatment facility at a rate of 40g per square meter. Furthermore, a pig house trial showed that Sumilarv 0.5G combined with an adulticide space spray gave more rapid and complete control of flies. Similarly, with mosquito control, Sumilarv provided 100% inhibition of emergence for 12 weeks in a fire pond. This powerful larvicidal action allows long term control of flies and mosquitoes, thus promoting a more healthy and comfortable environment for all to enjoy.

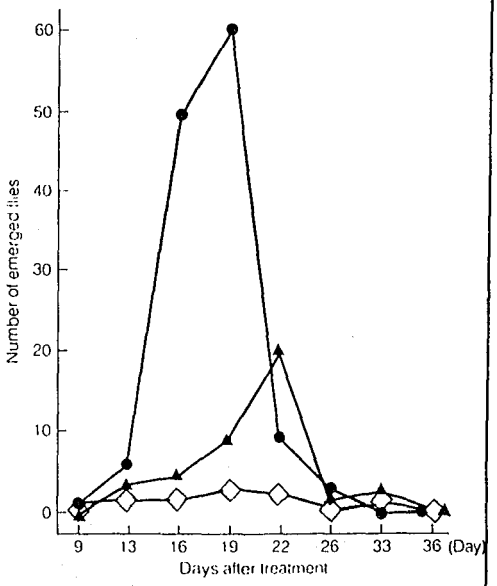
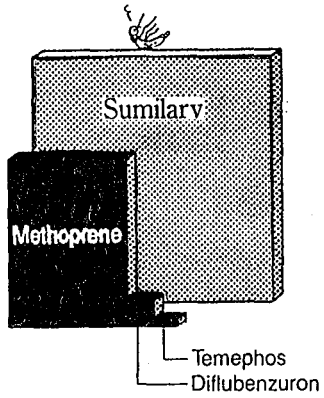


Fig.4 Field evaluation of Sumilarv for flies in a waste treatment facility

● Sumilarv 0.5G 40g/m² (0.2g A.I./m²)
▲ Dimilin 25WP 4g/2ℓ/m² (1g A.I./m²)
◇ Control

Mosquito
(Sumilarv=1)



Test method: Housefly — Artificial medium method
Mosquito — Immersion method

The efficacies are shown by IC_{50} (μg/g medium) for Sumilarv and Methoprene, and by LC_{50} (μg g medium) for other compounds.

Thanks to Sumilarv . . .

Won't Harm Man and Animals.

Sumilarv will not harm man and animals.
Unlike conventional insecticides, Sumilarv acts only against insects. It is insect-specific.
It only controls insects and has no effect upon non-target animals, such as livestock, pets, birds and fish.

Sumilarv is an ideal insecticide which can safely be used for the long-lasting control of houseflies and mosquitoes.

Toxicity of Sumilarv 0.5G

Acute toxicity:	Oral LD_{50} (rats)	> 5000 mg/kg
	Dermal LD_{50} (rats)	> 2000 mg/kg
Skin sensitization:	Negative (guinea pigs)	
Aquatic toxicity:	Acute LC_{50} (carp) at 96 hrs of observation time	832 mg/L
	Acute LC_{50} (*Daphnia* sp.) at 3 hrs of observation time	> 2000 mg/L

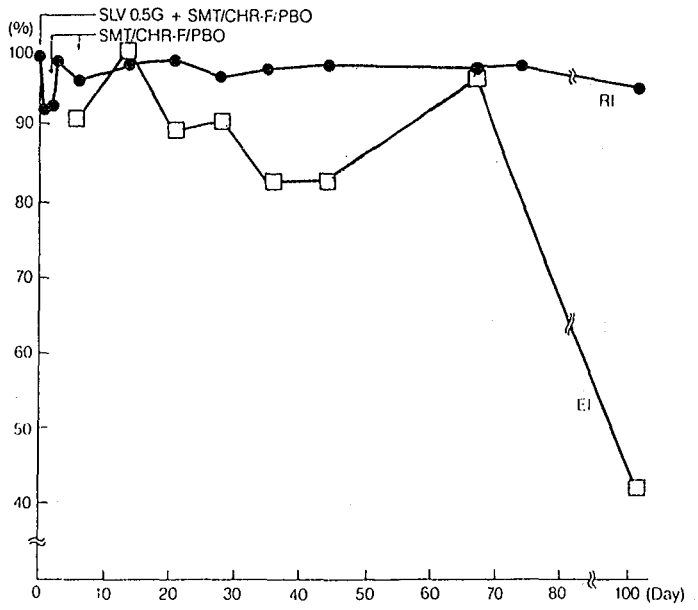


Fig.5 Field evaluation of Sumilarv for flies in a pig house

Test material: Larvicide — Sumilarv 0.5G, 20g/m², single treatment
Adulticide — Sumithion/Chrisron Forte/PBO (5/5/15%EC), 15ml/m², three treatments
Method: Number of adults in a certain area was counted and RI was calculated. Larvae and pupae were collected from the test site. Number of emerged adults was counted and EI was calculated

RI: Recovery Inhibition (%)

$$= \left(1 - \frac{\text{No. of adults counted after treatment}}{\text{No. of adults counted before treatment}}\right) \times 100$$

EI: Emergency Inhibition (%)

$$= \left(1 - \frac{\text{No. of emerged adults}}{\text{No. of collected larvae and pupae}}\right) \times 100$$

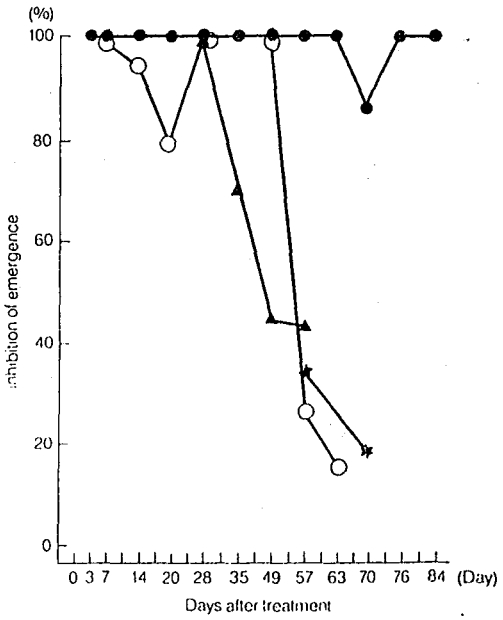


Fig.6 Field evaluation of Sumilarv for mosquitoes in a fire pond (24m³)

- ● Sumilarv 0.5G 20g/m³ (0.1 ppm A.I.)
- ○ Sumilarv 0.5G 10g/m³ (0.05 ppm A.I.)
- ✱ Altosid 10F 5g/m³ (0.5 ppm A.I.)
- ▲ Dimilin 25WP 2g/m³ (0.5 ppm A.I.)

How to Use Sumilarv 0.5G, for Successful Pest Control

For Fly Control

Learn Fly Habits, Prior to Using Sumilarv

The most harmful insect in an animal house or a waste treatment facility is the housefly. Knowing its life cycle and habits is vital to attaining more efficient fly control.
An adult housefly lays 50 ~ 150 eggs five or six times during its lifetime. The eggs hatch in a day, and the resulting larvae moult twice to become pupae and then adults.
Housefly larvae prefer the dark and will dig down into a dung/garbage pile to breed, particularly, the upper part of the pile near surface, which has the optimum temperature of 20 ~ 28°C for growth.
On the contrary, larvae can't survive at the lower central region of the pile, due to high temperatures 50 ~ 60°C.
4th instar larvae are willing to metamorphose to pupae in dry places. So, they crawl out of the interior and move about on the surface or dry soil around garbage piles when pupating.

Sumilarv 0.5G is a larvicide subtly utilizing the above-mentioned housefly larval habits. Once it contacts 4th instar larvae, development will be inhibited.

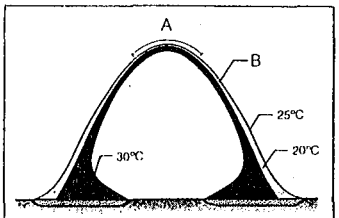


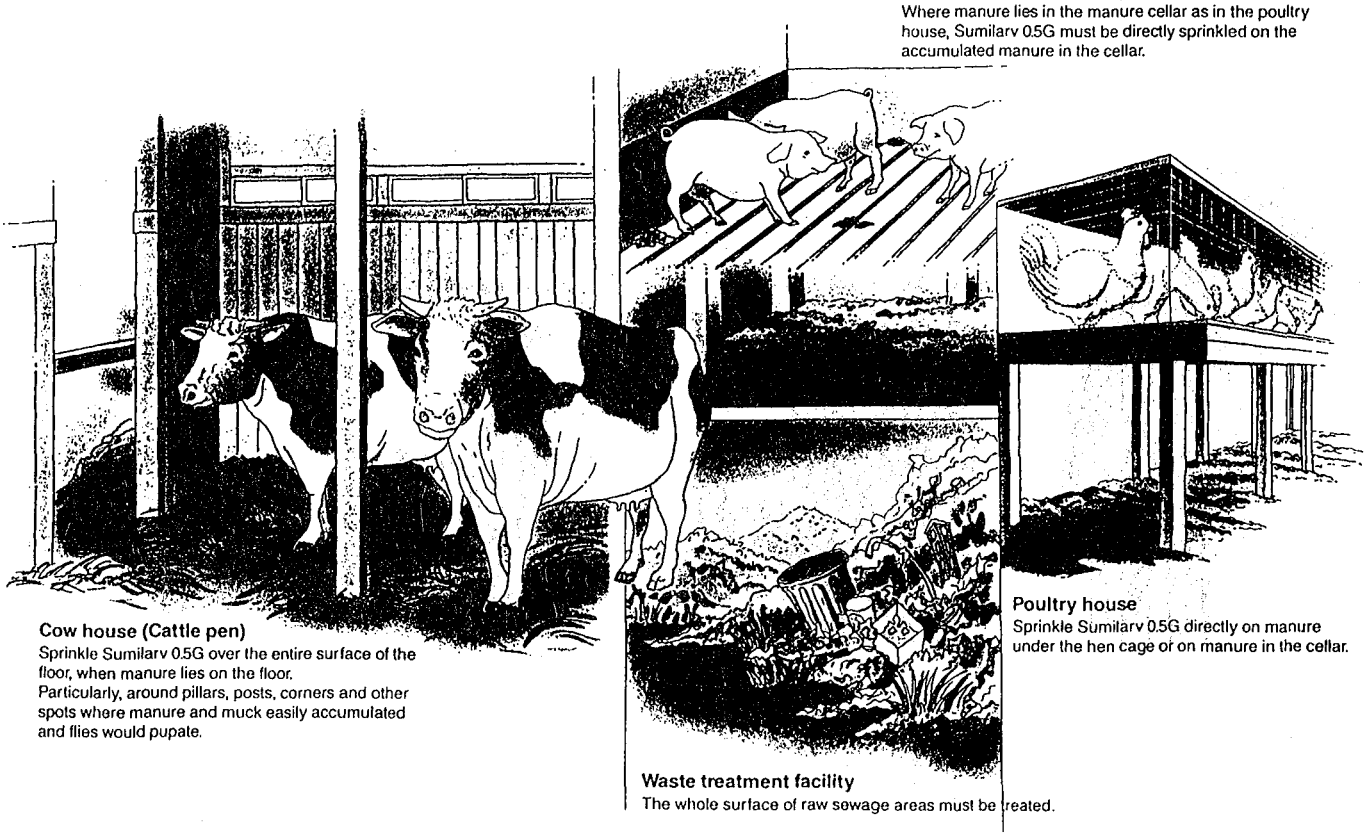
Fig.7 Cross-section of manure compost pile showing area inhabited by housefly larvae (Gotaas, 1956)

A : Area too hot to be inhabited
B : Area too dry to be inhabited
■ : Inhabited area
▫ : Area in loose soil into which larvae sometimes migrate

Where to use Sumilarv 0.5G?

Sprinkle Sumilarv 0.5G all over housefly breeding sites such as livestock and poultry houses or waste treatment facilities, as uniformly as possible.

Pig house
Sprinkle Sumilarv 0.5G over the whole surface of floor, where manure lies on the floor, as in the cow house. Where manure lies in the manure cellar as in the poultry house, Sumilarv 0.5G must be directly sprinkled on the accumulated manure in the cellar.



Cow house (Cattle pen)
Sprinkle Sumilarv 0.5G over the entire surface of the floor, when manure lies on the floor.
Particularly, around pillars, posts, corners and other spots where manure and muck easily accumulated and flies would pupate.

Waste treatment facility
The whole surface of raw sewage areas must be treated.

Poultry house
Sprinkle Sumilarv 0.5G directly on manure under the hen cage or on manure in the cellar.

When and how often to use Sumilarv 0.5G?

The time required for fly growth depends upon temperature. For a housefly, it takes about 10 days at 25°C, from egg-laying to the birth of a new fly. The higher the temperature, the faster it develops. Where it is below 10°C or beyond 35°C, they can't breed.
Sumilarv 0.5G must be applied at the beginning of fly propagation, to attain the most effective control. For example, it should be applied before the adult fly population reaches a nuisance level as follows:

4–5 flies/board (m^2) in a poultry house
4–5 flies/head in a pig house
12–25 flies/head in a cow house

If the manure depth is over 20 cm, another Sumilarv 0.5G treatment is required.

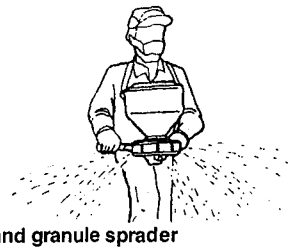
What amount is required to achieve results?

Sumilarv 0.5G should be applied at the rate of 20 g/m^2 single application or at 10 g/m^2 double applications with 2 weeks interval

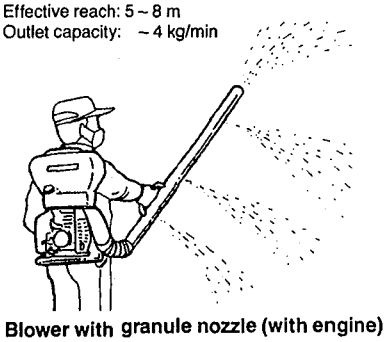
Poultry house (80 m × 10 m)	≧ 8 kg/house
Farrowing unit (2 m × 3 m)	≧ 60 g/unit
Breeding pen (4 m × 5 m)	≧ 200 g/pen
Others	≧ 10 g/m^2

How to use?

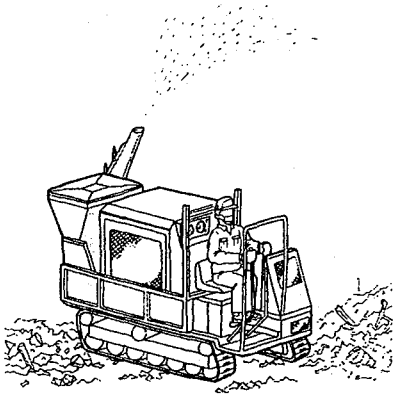
Sumilarv 0.5G can be easily applied manually or by machinery.



Hand granule sprader
Effective reach: 5 ~ 8 m
Outlet capacity: ~ 4 kg/min



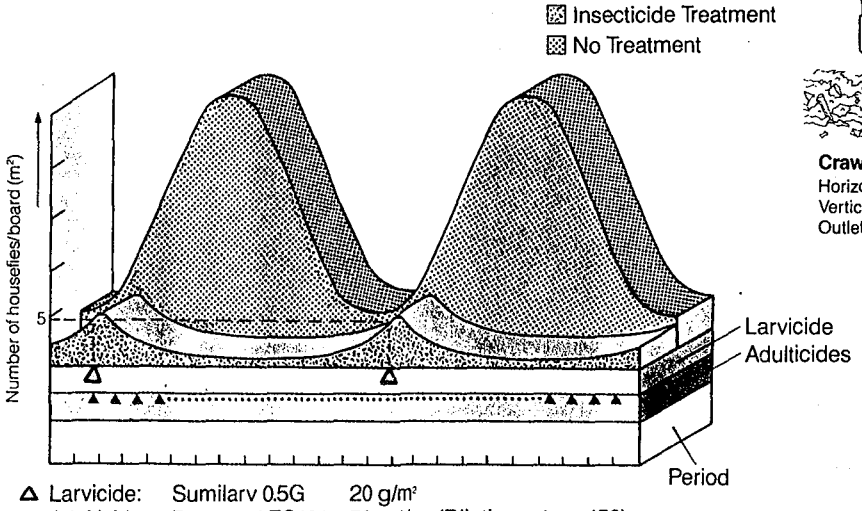
Blower with granule nozzle (with engine)
Effective reach: 15 m
Outlet capacity: ~ 12 kg/min



Crawler mount type power granuler
Horizontal throw (in still air): 30 m
Vertical throw (in still air): 20 m
Outlet capacity: ~ 25 kg/min

Recommended control system against houseflies, by the combination of Sumilarv 0.5G and adulticides

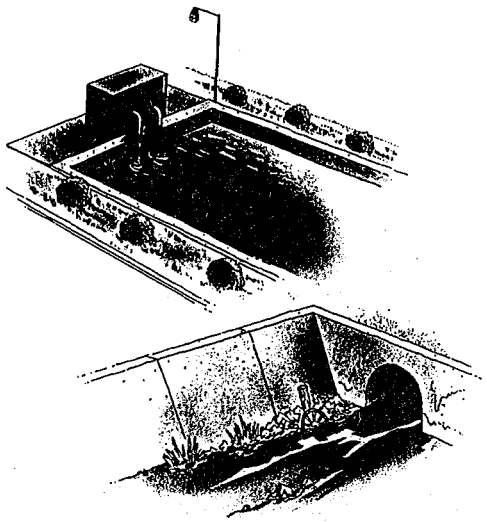
To reduce the overall fly population more quickly and surely, one needs an effective control system. A combination of Sumilarv 0.5G with adulticides offers such a system.
A recommended control system is shown below.



△ Larvicide: Sumilarv 0.5G 20 g/m²
▲ Adulticides: Pesguard FG161 50 mℓ/m² (Dilution rate × 150)
Sumithion-NP 20 ~ 25 mℓ/m² (Dilution rate × 100)
Spray adulticides, Pesguard FG161 and SMT-NP, alternately once every two weeks.

Fig.8 Recommended fly control system in a poultry house (80 m × 10 m)

For Mosquito Control



Where to use Sumilarv 0.5G?

Apply Sumilarv 0.5G at mosquito breeding sites:
standing water: reservoir, swamp, rain pool, pond, cistern, etc.
running water: drain, ditch, creek, stream, river, etc.

What amount is required to achieve results?

Standing water

Sumilarv 0.5G should be used as shown in the table below, based upon a target concentration of 0.01–0.05 ppm A.I. (2–10 g/m³ of Sumilarv 0.5G).

Depth (cm)	Sumilarv 0.5G (kg/ha)
10	2–10
20	4–20
30	6–30
50	10–50

*Water volume in the treated area (t) = length (m) × width (m) × average depth (m)

Running water

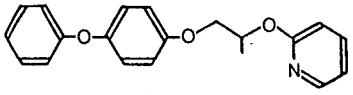
Sumilarv 0.5G should be used as shown in the table above, based upon a target concentration of 0.01–0.05 ppm A.I. (2–10 g/m³ of Sumilarv 0.5G) against flow volume per hour.

*Running water volume (t)/hour = width (m) × depth (m) × flow rate (m/hour)

How often to use Sumilarv?

Apply Sumilarv 0.5G once a month.

Physical and Chemical Properties

Trade Name	Sumilarv® 0.5G
Common Name of A.I.	Pyriproxyfen
Chemical Structure of A.I.	
Appearance	Pale yellowish granule
Content of A.I.	More than 0.5% (w/w)
Particle size distribution	More than 95% (w/w) (between 300 μm to 1000 μm)
Bulk density	Loosely packed 0.71 (g/ml) Tightly packed 0.93 (g/ml)
Moisture content	Less than 1%
Stability	Stable at least 6 months at 40°C and 50°C, and 3 years under normal room temperatures. Sumilarv 0.5G is quite stable under these conditions.

SUMITOMO CHEMICAL

Sumitomo Chemical Co., Ltd.
Household & Public Hygiene Chemicals Division
33-5, 4-chome, Kitahama, Chuo-ku, Osaka 541, Japan

NNZ-89I90II-500 Ⓜ E-0001 Printed in Japan

APPENDIX TWO

Species of Chironomidae Recorded in or near Perth Metropolitan Wetlands

SUBFAMILY	GENUS	SPECIES	PREVIOUS NAME
TANYPODINAE	*Alotanypus*	sp.	*Anatopynia sp.*
	Procladius	*villosimanus*	
		paludicola	
	Paramerina	*levidensis*	*Pentaneura levidensis*
	Ablebesmia	*notabilis*	
	Coelopynia	*pruinosa*	
ORTHOCLADIINAE	*Paralimnophyes*	*pullulus*	*Limnophyes pullulus*
	Cricotopus	*sp.1 (C. albitibia ?)*	
		sp.2	
	Corynoneura	sp.	
CHIRONOMINAE	*Tanytarsus*	*fuscithorax*	
		bispinosus	
	Chironomus	*occidentalis*	*Chironomus australis*
		tepperi	
		alternans	
	Chironomus (?)	sp.1	
	Cladopelma	*curtivalva*	
	Cryptochironomus	*griseidorsum*	
	Dicrotendipes	*conjunctus*	
	Kiefferulus	*intertinctus*	*Chironomus intertinctus*
		martini	*Chironomus martini*
	Polypedilum	*nubifer (?)*	
	Paratanytarsus	*grimmii*	*Lundstroemia parthenogenetica*

Several unidentified species not included