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REPARING EFFICIENT SAMPLING PLANS BASED ON A SPATIO-TEMPORAL CHIRONOMIDAE (DIPTERA) LARVAL DISTRIBUTION MODEL

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Abstract

A spatio-temporal larval distribution model of the nuisance midge *Glyptotendipes paripes* Edwards (Diptera: Chironomidae) was used to design resource efficient sampling plans for the assessment of location(s) supporting nuisance population levels of this species in Lake Monroe (central Florida, USA). The model used bathymetric and sediment maps with lake water levels and temperatures of the prior month to estimate lake areas supporting relatively low larval populations (<100/m^2) that require minimal monitoring effort, and areas that potentially support nuisance levels of *G. paripes* larvae, requiring greater sampling resources. The advantage of this system is that the geographic stratification can be altered for each sampling effort to meet prevailing conditions in the lake and without relying on a generic stratification that may not match the existing lake situation.

Key Words: Sampling plans, Chironomidae, nuisance, computer model, larvae

Resumen

El modelo de distribución espacio-temporal de larvas de la mosca fastidiosa *Glyptotendipes paripes* Edwards (Diptera: Chironomidae) fue usado para el diseño de un plan de muestreo para el uso eficiente de los recursos para la evaluación de las localidades que soportan niveles de poblaciones fastidiosas de esta especie en el Lago Monroe (en la region central de la Florida, USA). Este modelo utiliza mapas batimetricos (medida de la profundidad del agua) y de sedimento junto con los niveles de aqua y temperaturas del lago del mes anterior para estimar el área del lago que puede soportar poblaciones relativamente bajas de larvas (<100/m^2) y que requieren un esfuerzo mínimo para realizar el monitoreo, y las áreas que potencialmente pueden soportar niveles fastidiosos de larvas de *G. paripes*, y que puede requerir mas recursos para realizar el muestreo. La ventaja de este sistema es que la estratificación geográfica puede ser alterada para cada esfuerzo hecho para el muestreo, tomando en cuenta las condiciones prevalacientes en el lago y sin depender de una estratificacion genérica que posiblemente no va de acuerdo con la situación existente del lago.

Glyptotendipes paripes Edwards (Diptera: Chironomidae) is one of the major nuisance midge species in some parts of central Florida, USA (Ali 1995). Because immature *G. paripes* are benthic and distributed in aggregates in lakes that extend over hundreds or thousands of hectares, population sampling for research or management purposes is tedious, time-consuming, and costly. For highly aggregated populations, an optimized, stratified sampling plan to examine populations is often the most efficient method (Cochran 1963). In this effort, after collecting preliminary samples, adjustment is made to collect proportionally more samples from strata with higher variances than those with low variances. Each sampling stratum should be internally homogeneous in relation to the study organism. Based upon this method, *G. paripes* larval populations have been successfully examined in 3 central Florida lakes (Lobinske et al. 2002). However, water levels in these lakes may undergo wide fluctuations over the course of a year or between years. The distributions of the immature *G. paripes* are associated with water depth in relation to sediment conditions, so the actual strata within a lake will vary with the water level. As part of ongoing research on nuisance chironomids in central Florida, ecological data in relation to immature *G. paripes* were used to develop a spatio-temporal model of their distributions (Lobinske 2001; Lobinske et al. 2004). For the present study, the model was used with selected environmental conditions prevailing in Lake Monroe (Volusia and Seminole Counties, Florida) to determine time-specific stratification of the lake for the enhancement of sampling efficiency. Preliminary sampling plans for Lake Monroe were tested on 4 occasions between Apr and Jul 2003.

Materials and Methods

The model uses the spatial matrix techniques of Allen et al. (1996, 2001), Brewster & Allen

(1997) and Brewster et al. (1997) with the computer software Matlab® (The Mathworks, Inc., Natik, MA) as developed by Lobinske (2001) and Lobinske et al. (2004) to examine *G. paripes* populations. The model uses spatial maps (in matrix form) of lake bathymetry modified by lake level deviation from mean, and sediment conditions to determine the habitat suitability of each spatial cell. For this study, the spatial maps were configured as 50 × 50 matrices, with each cell representing approximately 3.5 ha of surface area. In addition, inputs for water temperature (as an influence on development rate), and Secchi disk transparency as an estimator of phytoplankton (midge larval food) abundance were included in the model. Within the model, the population is represented by a three-dimensional matrix consisting of the "X" and "Y" coordinates that provide spatial location on the above maps, and the "Z" coordinate that represents number of individuals at each life stage. A Lefkovitch population growth matrix (Lefkovitch 1965), detailed by Lobinske et al. (2004) was applied to the model population at each spatial grid cell for each time step in the calculation to simulate developmental success and survival. A dispersal function was applied at the simulated egg laying stage. Output of projected log(n+1) transformed population levels in each spatial cell was in graphic (Fig. 1) and numeric forms. Lake Monroe was one of the validation data sets used by Lobinske et al. (2004) to test the model and Fig. 1 is an example from that validation dataset. As can be seen clearly, under low water levels in the lake, high populations of immatures occurred farther away from the shore, whereas under high water levels, high populations occurred close to shore. This scenario was one of the principal reasons for the present study because a fixed stratified sampling plan would not be sensitive to these population shifts and thus, would not accurately represent the actual strata. For population management purposes, intensive sampling is needed in areas anticipated to support nuisance (>500 immatures/m^2) or near-nuisance (100 to 500 immatures/m^2) population densities. Meanwhile non-nuisance areas anticipated to support densities below 100/m^2 require less monitoring. When tested for fit to these 2 strata (<100 and >100 immatures/m^2), the model had a 0.88 correct prediction rate for Lake Monroe (Lobinske et al. 2004). With this success rate, it was decided to use the model to fit sampling strata in Lake Monroe based on current lake conditions. Surveys were conducted monthly from Apr through Jul 2003.

To determine the sampling strata for the lake for a given month, mean water level at the United States Geologic Survey data station 02234500 (outlet of Lake Monroe to the St. Johns River) for the month prior to sampling was used (representing the approximate development time of immatures that would be collected during the sample effort), with water temperature and Secchi disk transparency data collected during the same prior month. The model was run for 30 simulated days and grid cells above and below densities of 100/m^2 were assessed. The high density strata were marked and proportion of the lake area in each stratum determined. These stratum borders could then be plotted on lake maps (Fig. 2), and percentages of areas in the high density stratum are summarized in Table 1. Based on the previous month's larval *G. paripes* data, an optimized sampling plan based on these 2 strata was calcu-

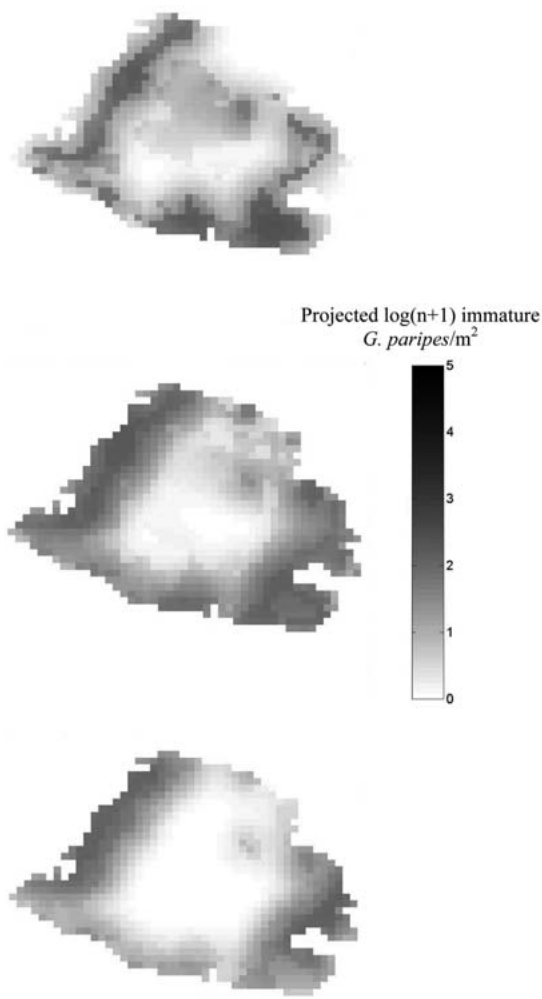

Fig. 1. Example graphic output of a computer model showing alterations in *Glyptotendipes paripes* larval distributions with changing water level; top = historic mean – 1 meter, middle = historic mean, bottom = historic mean + 1 meter, when other input parameters are kept the same (Secchi disk transparency = 50 cm and water temperature = 25.0°C).

lated by the method of Cochran (1963), according to the formula:

$$n_h = \left(\frac{N_h SE_h}{\sum(N_h SE_h)}\right)n$$

where "n_h" is the calculated number of samples to be collected the stratum, "N_h" is the spatial area of the stratum, "SE_h" is the standard error of the mean for the stratum, and "n" is total number of samples scheduled to be collected. For the 40 samples collected in Apr, 14 were collected from the low density stratum and 26 from the high density stratum. Either 20 or 40 locations were sampled per month. A simple random generation computer program was used to generate random sample locations in each stratum.

A Global Positioning System receiver was used to navigate a boat to each sample location. One Ekman dredge sample was collected at each location and the contents processed according to standard methods (Ali et al. 1977) to enumerate *G. paripes* larvae and pupae. Larvae were identified with the keys of Epler (2001). Immature distributions in the lake were graphically plotted and compared to the stratification plan for fit. Stratified mean and standard deviation of immature densities were calculated for each occasion.

Results and Discussion

During Apr and May 2003, *G. paripes* populations remained below the nuisance threshold of 500 immatures/m^2 at all sample locations, even in the >100/m^2 stratum (Fig. 2). During Jun 2003, five locations were above nuisance threshold level with mean immature density of 1086/m^2 (Table 1). Seven locations during Jul 2003 exceeded the nuisance threshold, with 2 supporting >10,000 immatures/m^2; mean immature density was 1,939/m^2. All identified locations with nuisance densities fell within the predicted high density strata (Fig. 2).

These preliminary data indicate that the computer model was an efficient tool for determining the geographic boundaries of the sampling strata. This can be very important in a system like Lake Monroe, where water levels within the lake can fluctuate by as much as 1.5 m annually. Because *G. paripes* immature distributions are heavily influenced by water depth, this variation can dramatically alter the locations of high larval densities within the lake and the geographic boundaries of

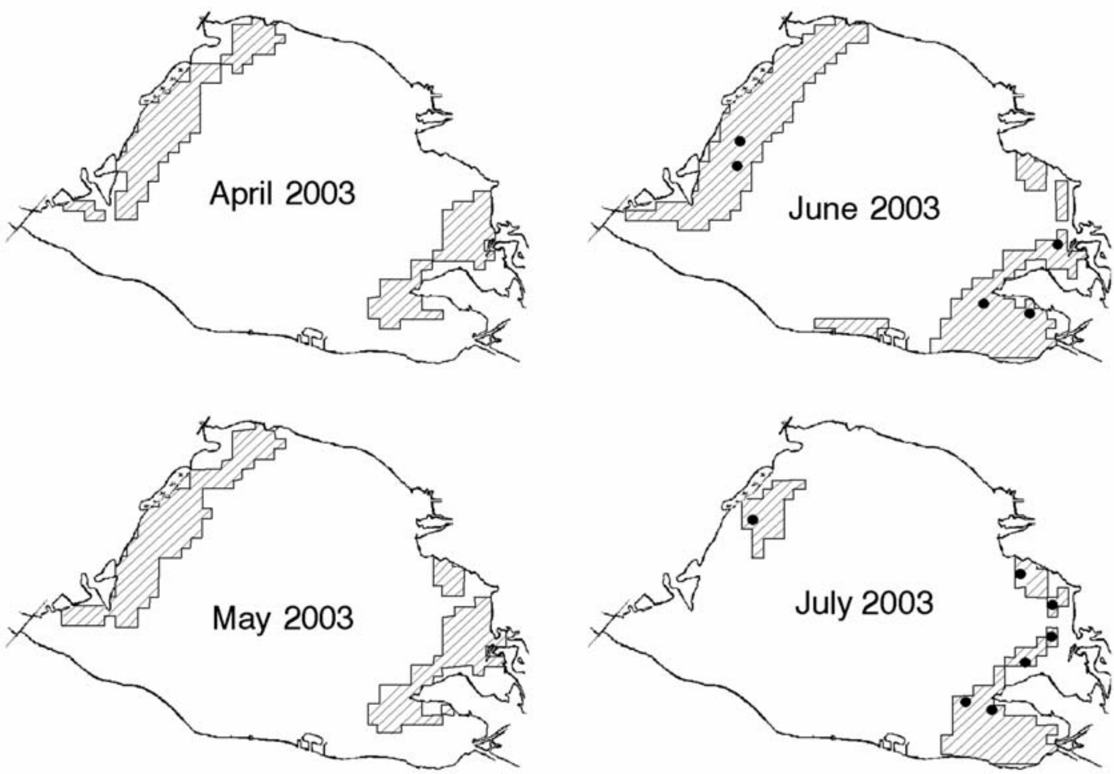

Fig. 2. Monthly (Apr to Jul 2003) stratification for immature *Glyptotendipes paripes* sampling in Lake Monroe, central Florida, based on projected (by computer model) densities >100/m^2 (within shaded area) and <100/m^2 (outside shaded area). Dots indicate the sample locations with field densities greater than the nuisance threshold of 500/m^2.

TABLE 1. PERCENT RELATIVE AREA OF HIGH DENSITY STRATUM, STRATIFIED MEAN DENSITY (NUMBER/M^2) AND STANDARD DEVIATION OF IMMATURE *GLYPTOTENDIPES PARIPES* COLLECTED MONTHLY FROM LAKE MONROE, CENTRAL FLORIDA, USA (APR-JUL 2003).

Sample month	High density stratum (% of lake surface area)	Mean	SD
Apr	14.3	61	25
May	16.0	390	179
Jun	23.4	1,086	470
Jul	10.4	1,939	1,239

the actual strata with water level changes. Combining this ability to adjust sampling stratification with the established method of optimized stratified sampling, the majority of the sample effort can be targeted to the strata likely to have the highest variability in density and most likely the nuisance levels. The remainder of the lake with low variability will likely support very low populations that require considerably less monitoring effort. The reduction in monitoring effort with this system can be highly advantageous. For example, Lake Monroe is approximately 4,000 ha in surface area; however, the projected high density stratum consisted of approximately 416 to 936 ha. Focusing most of the sample effort on this smaller geographic area would facilitate greater sample precision in obviously less time and labor compared to simple random sampling or systematic sampling requiring more samples.

Additional work is proposed to compare independently collected, systematic samples of immature *G. paripes* populations in Lake Monroe to further test the efficiency of the model to predict strata with high population levels within the lake. If confirmed, the model should be useful in the planning of operational control strategies for nuisance midges in Lake Monroe, and perhaps elsewhere. For other lakes, detailed bathymetric and sediment maps for each lake would be needed and rendered into matrix format. Based on the reports of Frouz et al. (2004), *G. paripes* populations in lakes with organic sediments containing significant levels of chironomid fecal pellets would have a dramatically different distribution pattern that this model would not accurately forecast. Therefore, the preliminary sediment mapping should include examination of these fecal pellets to determine the suitability of this model for use on that particular lake.

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