Influence of Selected Sediment Physical Parameters on Spatial Distribution of Larval Glyptotendipes paripes (Diptera: Chironomidae) in Three Central Florida Lakes

Authors: Lobinske, Richard J., Ali, Arshad, Leckel, Robert J., and Frouz, Jan

Source: Florida Entomologist, 90(4) : 593-604

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/0015-4040(2007)90[593:IOSSPP]2.0.CO;2

INFLUENCE OF SELECTED SEDIMENT PHYSICAL PARAMETERS ON SPATIAL DISTRIBUTION OF LARVAL *GLYPTOTENDIPES PARIPES* (DIPTERA: CHIRONOMIDAE) IN THREE CENTRAL FLORIDA LAKES

RICHARD J. LOBINSKE[1,2], ARSHAD ALI[1], ROBERT J. LECKEL, JR.[1] AND JAN FROUZ[3]
[1]Mid-Florida Research and Education Center and Department of Entomology and Nematology, Institute of Food and Agricultural Sciences, University of Florida, 2725 Binion Road, Apopka, FL 32703, USA

[2]Leon County Mosquito Control and Stormwater Maintenance, 501 Appleyard Drive, Suite A, Tallahassee, FL 32304, USA

[3]Institute of Soil Biology ASCR, Na sádkách 7, CZ-37005, České Budějovice, Czech Republic

ABSTRACT

Spatial distribution of larvae of the pestiferous midge, *Glyptotendipes paripes* Edwards in relation to selected sediment physical conditions was monitored for 1 year in 3 eutrophic central Florida lakes. Two of these lakes (Monroe and Wauburg) supported a distribution pattern of high densities on the firm peripheral sediments of the lakes, while the third lake (Eustis) displayed the opposite pattern of higher densities in the soft sediments at the lake center. Linear and multivariate analyses revealed that the presence of larval fecal pellets and larger sized particles in the Lake Eustis sediments were strongly associated with the latter distribution pattern. In all 3 lakes, sediment dry weight, and particle size composition were not significantly associated with larval density. In these lakes, *G. paripes* distributions appear to be strongly influenced by the physical structure of the soft, organic sediments at the lake center; sediments with large particles and considerable accumulation of fecal pellets would support higher densities of the larvae which also exist in relatively firm sediments close to the lake margin. This provides valuable information to lake managers attempting population management of this nuisance species.

Key Words: Chironomidae, sediments, larval distribution, ecology

RESUMEN

Se realizó un monitoreo de la distribución espacial de la larva de mosca pestífera, *Glyptotendipes paripes* Edwards con relación a las condiciones físicas seleccionadas de sedimento por 1 año en 3 lagos eutróficos de la región central de la Florida. Dos de estos lagos (Monroe y Wauburg) presentaron un patrón de distribución de altas densidades sobre los sedimentos firmes del periférico de los lagos, mientras que el tercer lago (Eustis) mostró un patrón opuesto de altas densidades en los sedimentos blandos en el centro del lago. Los análisis de variables lineares y múltiples revelaron que la presencia de las pelotitas de heces de las larvas y partículas mas grandes en los sedimentos del Lago Eustis estaban fuertemente asociados con el patrón posterior de distribución. En los 3 lagos, el peso seco de sedimento y la composición del tamaño de las partículas no fueron significativamente asociados con la densidad de las larvas. En estos lagos, la distribución de *G. paripes* aparentemente esta influenciada fuertemente por la estructura física de los sedimentos orgánicos blandos en el centro del lago; los sedimentos con partículas grandes y la acumulación considerable de las pelotitas de heces soportarian las densidades mas altas de larvas las cuales tambien existen en los sedimentos relativamente firmes cerca de la orilla del lago. Este trabajo provee una información valiosa para las personas encargadas del manejo los lagos que tratan a manejar la población de esta fastidiosa especie.

Non-biting midges (Diptera: Chironomidae) that emerge in large numbers from natural or man-made (usually eutrophic) lakes are a source of public nuisance primarily to waterfront residents and businesses in central Florida (Ali 1996). Problems include restriction of outdoor activity, soiling of buildings and outdoor equipment, aesthetic nuisance, and possible incidences of human allergy (Gad El Rab et al. 1980; Giacomin & Tassi 1988). Economic losses associated with nuisance midges have been estimated at millions of dollars annually for many Florida cities (Anonymous 1977). In recent years, research has focused on larval control of nuisance midges (Ali 1996; Lobinske & Ali 2006). From both environmental and economic viewpoints, accurate implementation of control efforts is required to avoid unnecessary nontarget impacts and excessive costs. Toward this end, understanding the environmental factors that influence larval distribution in relatively large lakes is essential to enable efficient population sampling and management. The work of Lobinske et al. (2002) synthesized some of this information that helped to produce a computer model for estimating larval *Glyptotendipes paripes* Edwards field population distributions (Lobinske et al. 2004).

As early as 1959, Provost & Branch (1959) reported that *G. paripes* larvae most commonly occur in the peripheral areas of lakes on firm sand or mud/sand sediments, a pattern categorized as lake type 1 by Frouz et al. (2004). Similar distribution patterns of *G. paripes* were reported by Callahan & Morris (1987) and Cowell & Vodopich (1981). However, a later investigation of central Florida lakes (Lobinske et al. 2002) revealed an opposite distribution pattern of larval *G. paripes* predominating on soft, organic sediments in the deeper, central portions of Lake Yale (Lake County) that contained substantial amounts of larval chironomid fecal pellets. This distribution was categorized lake type 2 by Frouz et al. (2004), who also reported that fecal pellet accumulations in the soft, organic sediments of the lake center influenced the *G. paripes* larval distribution. Previously, Bradley & Beard (1969) discussed the possible importance of chironomid excrements influencing the particle size of lake bottom sediments. Since the computer model of Lobinske et al. (2004) was based on the lake type 1 chironomid larval distribution pattern, it would not be effective for a type 2 lake.

This study was conducted to investigate if the type 2 distribution pattern of *G. paripes* noted above would be duplicated in an additional type 2 lake, Lake Eustis, in Lake County. Two known type 1 lakes, Lake Monroe (Seminole and Volusia Counties), described by Frouz et al. (2004), and Lake Wauburg (Alachua County), described by Lobinske et al. (2002) were selected for comparison in this study. Chironomid larval monitoring programs often require routine collection of large numbers of samples (Lobinske & Ali 2006) to determine where control measures in a habitat should be implemented. This is because many habitats extend over hundreds or thousands of ha, too large for an economic treatment of the entire habitat. To streamline this process, several quick and simple sediment parameters were used in this study to determine if they could produce reliable information for distinguishing between lake types and estimating nuisance midge larval distributions.

Materials and Methods

Lakes Eustis and Monroe are each ~4,000 ha in surface area, and Lake Wauburg ~100 ha. All 3 lakes are shallow and eutrophic. Lake Monroe is located in the St. Johns River basin, whereas Lake Eustis is part of the Ocklawaha River basin, while Lake Wauburg drains into Payne's Prairie. These lakes are located over a broad section of central Florida.

Lakes Eustis and Wauburg were sampled for chironomid larvae and sediments on a monthly basis from Apr to Sep 2002, and from Jan to Mar 2003. Lake Monroe was sampled during Jun, Jul, and Sep 2002, and then again in Feb and Mar 2003. For Lake Eustis, 40 sample locations were randomly determined and distributed over the entire habitat during each sampling session, while 20 random locations each were sampled in Lakes Monroe and Wauburg per session.

A double-hulled pontoon boat was used to sample Lakes Eustis and Monroe, and a flat-bottom jon boat used to sample Lake Wauburg. At each sample location in Lakes Eustis and Monroe, water depth was determined with a boat-mounted depth finder (Model Humminbird Wide 100, Techsonic Industries, Eufaula, IL) while a weighted sounding line was used to measure depth in Lake Wauburg. For all lakes, sample locations were recorded with a Global Positioning System receiver (Model GPS 12, Garmin International, Olathe, KS). Two 15 × 15-cm Ekman dredge samples were collected from each location. Collected sediments were subjectively classified as sand, muck, or mixed, based on distinct visual appearance. Sand samples were composed almost entirely of sand grains, off-white to pale gray in color or sometimes tinted green by algae. Muck samples were dark brown to black, had a very loose composition, and the constituent particles were very soft. Mixed samples were composed of sand grains interspersed with various amounts of muck sediments. One dredge sample was washed through a 350-µm mesh screen and the retained material transferred to a 1-L wide-mouth plastic bottle for transport to the laboratory. These benthic samples were examined in a gridded white pan for midge larvae within 24 h of collection by standard methods (Ali et al. 1977). Chironomid larvae were identified with the keys of Epler (2001) and counted. Nuisance midges (*G. paripes* and *Chironomus crassicaudatus* Malloch) were identified to species and others to convenient higher taxonomic level. From the second dredge sample, 300-400 cm^3 of the top 5 cm of sediment was collected and transferred to a labeled Whirlpak bag, transported to the laboratory, and stored at -10°C until processed and analyzed for sediment physical parameters. At the time of processing, the samples were thawed overnight and each sample mixed thoroughly. With the method described in Lobinske et al. (2002), approximately 1 g of sediment from each sample was weighed into a tared, labeled beaker and dried at 90°C for 24 h to determine percent sediment dry weight (DW). This gives a fast determination of relative amount of dry matter to water present in the sediments. To determine percent particle size composition, about 1 cm^3 of sediment was washed through a series of 1000, 500, 250, and 125-µm mesh sieves. The material retained by each sieve and that passed through all sieves was respectively transferred to tared, labeled beakers and dried as above. About 1 cm^3 volume of sediment from each sample was transferred to a Petri dish, flooded with deionized water, and examined with a stereo dissecting microscope under 4-10× to estimate relative content of visibly distinguishable components. With an eyepiece mounted grid to estimate volume, the relative composition of fine particulate organic matter (FPOM), sand, detritus, and fecal pellets were evaluated according to the following percent volume scale: 0 = 0%, 1 = <10%, 2 = 10-20%, 3 = 20-50%, 4 = 50-<100%, and 5 = 100%.

Statistical analysis of sediment parameters between lakes was conducted with Instat V. 3.05 (Graphpad Software, San Diego, CA). Comparisons of sediment parameters between lakes for each basic sediment type (sand, muck, or mixed) were made with one-way analysis of variance (ANOVA) with Tukey-Kramer post tests. Ali et al. (2003) reported that similar sediment parameters had little or no significant effect on seasonal abundance of benthic invertebrates in Lake Jesup (Seminole County), so simple ANOVA was chosen instead of a time-series analysis. Canonical Correspondence Analysis (CCA) (ter Braak & Smilauer 1998) was used to elucidate comparative influences of sediment physical parameters on the chironomid community in each lake with the software Canoco for Windows V. 4 (Center for Biometry, CPRO-DLO, Wageningen, Netherlands, and Microcomputer Power, Ithaca, NY). This multivariate analysis provides an efficient means to show how community parameters and organisms interact with each other. For the current analysis, only significant ($P < 0.05$, permutation test) sediment physical parameters chosen by forward selection and separately for each lake were used in CCA. Graphical interpretations of larval and sediment distributions were prepared with SlideWrite V. 6.1 (Advanced Graphics Software, Encinitas, CA).

Results and Discussion

The mean values of selected parameters of muck, sand, and mixed sediments from Lakes Eustis, Monroe, and Wauburg are compared in Table 1. The most consistent series of significant differences between the lakes can be seen in the muck sediment parameters. All physical parameters of muck sediment examined from type 2 Lake Eustis were significantly different from one or both other lakes. Most noticeable among these differences were the chironomid fecal pellet values, lower relative amount of FPOM, and greater proportion of particles >250 µm in size. As hypothesized for a type 2 lake, the density of larval *G. paripes* was significantly greater in Lake Eustis muck sediments than the other lakes. This is similar to the muck sediments and *G. paripes* larval distribution in type 2 Lake Yale (Frouz et al. 2004; Lobinske et al. 2002). Possibly related, McLachlan (1976) reported that *G. paripes* larvae showed a preference for larger particles in the muck sediments of a bog lake. Important significant differences also were noted for muck sediments of type 1 Lake Monroe. Percent particle sizes from 125 to 1,000 µm were significantly lower, while proportion of particles <125 µm was considerably higher, indicating overall finer grained organic sediments in that lake. Sediment dry weight was significantly higher for Lake Monroe muck sediments and density of *G. paripes* larvae was lowest. For mixed sediments, Lake Eustis was the only lake with chironomid fecal pellets present in the sediment. For sand substrates, sediments from Lake Eustis had a significantly higher dry weight than the other lakes, and fewer *G. paripes* larvae. Due to the high sample variances, this difference was only significant between Lake Eustis and Lake Wauburg. Other chironomid midge larvae collected include *C. crassicaudatus*, *Cryptochironomus* sp., *Pseudochironomus* sp., *Polypedilum* sp., Tanytarsini, and Tanypodinae; data for these midges are not shown because of their relatively small numbers but were included in the community analysis.

Significant correlations were detected for some muck sediment parameters and *G. paripes* log(n+1) larval density (Table 2). Larval density was negatively correlated with proportion of muck particles <125 µm, and positively correlated with proportion of particles retained in 250- and 500-µm pore sieves, and with proportion of fecal pellet content. This is consistent with the findings of Frouz et al. (2004), who reported that type 2 sediments which overall contained high concentrations of fecal pellets had a higher proportion of large particles. This allowed for higher levels of dissolved oxygen concentration within the sediments conducive for immature *G. paripes* to build longer larval tubes than in other sediment types.

Spatial distributions of FPOM, sand, and fecal pellets are presented in Figs. 1-3. All 3 lakes show the common distribution of muck (high FPOM content) sediments at the basin center and more sand content around the lake perimeter. The high concentration of fecal pellets in Lake Eustis middle portion can be clearly seen in Fig. 1. Spatial distributions of sediment particle size are shown in Figs. 4-6. Differences between the 3 lakes are clearly noticeable, including the trend showing a relatively larger percent composition of particles >250 µm in Lake Eustis, a more even distribution of particles <500 µm in Lake Wauburg, and a

TABLE 1. MONTHLY MEAN ± SD VALUES OF SELECTED SEDIMENT PHYSICAL PARAMETERS AND *GLYPTOTENDIPES PARIPES* LARVAL DENSITIES IN 3 EUTROPHIC CENTRAL FLORIDA LAKES, 2002 TO 2003. ENTRIES IN A ROW WITH THE SAME LETTER FOLLOWING ARE NOT SIGNIFICANTLY DIFFERENT ($P > 0.05$) BY ANOVA WITH TUKEY-KRAMER POST-TESTS.

Parameter	Type 2—Lake Eustis	Type 1—Lake Monroe	Type 1—Lake Wauburg
		Muck Sediments	
	$n = 211$	$n = 67$	$n = 118$
Depth (ft)	10.7 ± 2.7 b	9.0 ± 1.5 a	9.4 ± 1.7 a
% Dry Weight	7.0 ± 6.0 a	12.9 ± 4.8 b	7.9 ± 5.3 a
FPOM[a]	3.5 ± 0.7 a	4.0 ± 0.4 b	4.0 ± 0.5 b
Detritus[a]	0.03 ± 0.27 a	0.07 ± 0.14 ab	0.2 ± 0.6 b
Fecal Pellets[a]	2.8 ± 1.0 b	0.0 ± 0.0 a	0.01 ± 0.1 a
Sand[a]	1.1 ± 0.5 a	1.5 ± 0.8 b	1.5 ± 0.7 b
% 1000 µm	1.5 ± 3.9 b	0.4 ± 0.8 a	1.0 ± 2.1 ab
% 500 µm	19.7 ± 12.6 c	5.2 ± 6.8 a	10.2 ± 7.5 b
% 250 µm	44.7 ± 12.7 c	12.5 ± 12.4 a	34.4 ± 14.6 b
% 125 µm	20.5 ± 8.7 b	17.6 ± 8.7 a	25.0 ± 6.1 c
% <125 µm	14.0 ± 11.6 a	64.3 ± 23.7 c	29.5 ± 21.3 b
G. paripes larvae/dredge	23.3 ± 45.4 b	1.2 ± 8.8 a	8.2 ± 56.9 a
		Mixed Sediments	
	$n = 12$	$n = 8$	$N = 19$
Depth (ft)	8.0 ± 2.2 a	6.6 ± 1.8 a	6.4 ± 2.4 a
% Dry Weight	48.6 ± 24.4 a	38.0 ± 10.7 a	30.8 ± 18.4 a
FPOM[a]	2.2 ± 0.9 a	2.9 ± 0.6 a	2.7 ± 1.2 a
Detritus[a]	0.6 ± 1.0 a	1.0 ± 1.4 a	1.6 ± 1.1 a
Fecal Pellets[a]	1.3 ± 1.1 b	0.0 ± 0.0 a	0.0 ± 0.0 a
Sand[a]	3.3 ± 1.2 a	3.5 ± 0.8 a	3.1 ± 0.8 a
% 1000 µm	2.9 ± 3.5 a	2.6 ± 4.0 a	3.7 ± 5.4 a
% 500 µm	17.2 ± 9.3 b	1.9 ± 1.8 a	14.4 ± 2.6 b
% 250 µm	56.3 ± 12.2 b	7.7 ± 7.1 a	51.1 ± 9.0 b
% 125 µm	21.6 ± 11.8 a	40.7 ± 18.0 b	21.1 ± 5.2 a
% <125 µm	2.0 ± 2.3 a	47.1 ± 27.6 b	9.7 ± 10.0 a
G. paripes larvae/dredge	15.3 ± 33.5 a	26.1 ± 42.0 a	52.4 ± 138.2 a
		Sand Sediments	
	$n = 57$	$n = 20$	$N = 27$
Depth (ft)	8.1 ± 3.6 b	5.3 ± 1.8 a	5.4 ± 2.6 a
% Dry Weight	74.5 ± 3.5 b	68.5 ± 4.5 a	71.3 ± 5.6 a
FPOM[a]	0.8 ± 0.6 a	0.9 ± 0.8 a	1.0 ± 0.6 a
Detritus[a]	0.2 ± 0.5 a	0.2 ± 0.4 a	1.1 ± 0.9 b
Fecal Pellets[a]	0.2 ± 0.5 a	0.0 ± 0.0 a	0.0 ± 0.0 a
Sand[a]	4.3 ± 0.4 b	4.4 ± 0.5 b	4.0 ± 0.2 a
% 1000 µm	5.2 ± 6.4 b	0.6 ± 1.9 a	4.1 ± 2.8 ab
% 500 µm	17.5 ± 7.7 b	1.1 ± 1.2 a	18.0 ± 6.5 b
% 250 µm	59.5 ± 10.0 b	28.7 ± 22.2 a	58.0 ± 6.3 b
% 125 µm	17.3 ± 6.4 a	57.0 ± 15.6 b	18.1 ± 3.2 a
% <125 µm	0.5 ± 0.6 a	12.7 ± 13.5 b	1.8 ± 1.3 a
G. paripes larvae/dredge	1.3 ± 6.6 a	44.5 ± 128.0 ab	119.7 ± 205.4 b

[a]Relative volume composition values: 0 = 0%, 1 = <10%, 2 = 10-20%, 3 = 20-50%, 4 = 50-<100%, and 5 =100%.

TABLE 2. SIGNIFICANT CORRELATION COEFFICIENTS OF MUCK SEDIMENT PARAMETERS WITH LOG(N+1) *GLYPTOTENDIPES PARIPES* IMMATURE DENSITY IN 3 EUTROPHIC CENTRAL FLORIDA LAKES, COLLECTED 2002 TO 2003.

Parameter	r	P	N
Particles <125 µm	-0.423	<0.0001	391
Particles 250 µm	0.448	<0.0001	391
Particles 500 µm	0.273	<0.0001	391
Fecal content	0.379	<0.0001	391

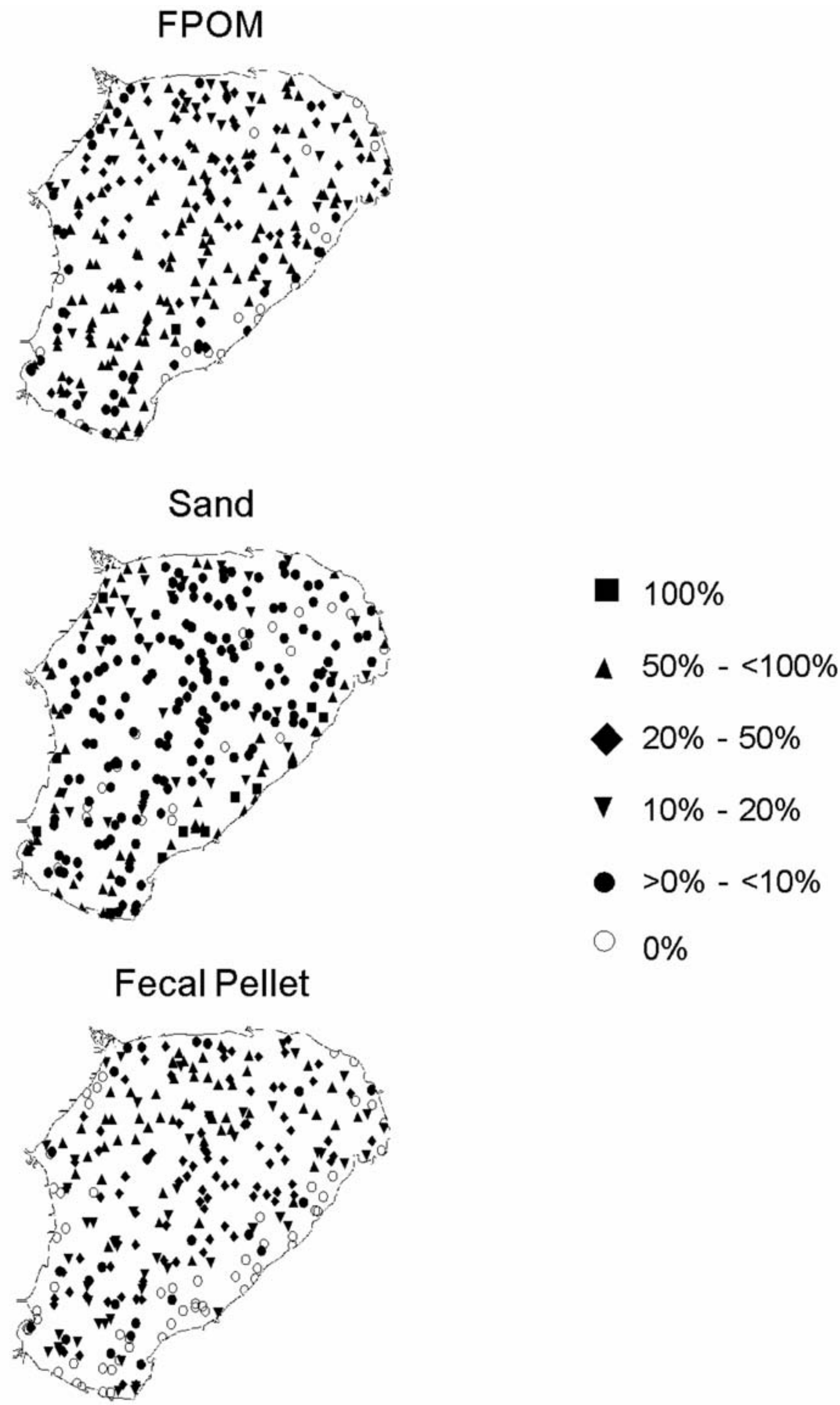

Fig. 1. Spatial distribution and percent relative contents [Fine Particulate Organic Matter (FPOM), Sand and Larval Fecal Pellets] of all individual sediment samples collected (n = 280) monthly from Lake Eustis (Lake County, central Florida), Apr to Sep, 2002 and Jan to Mar, 2003.

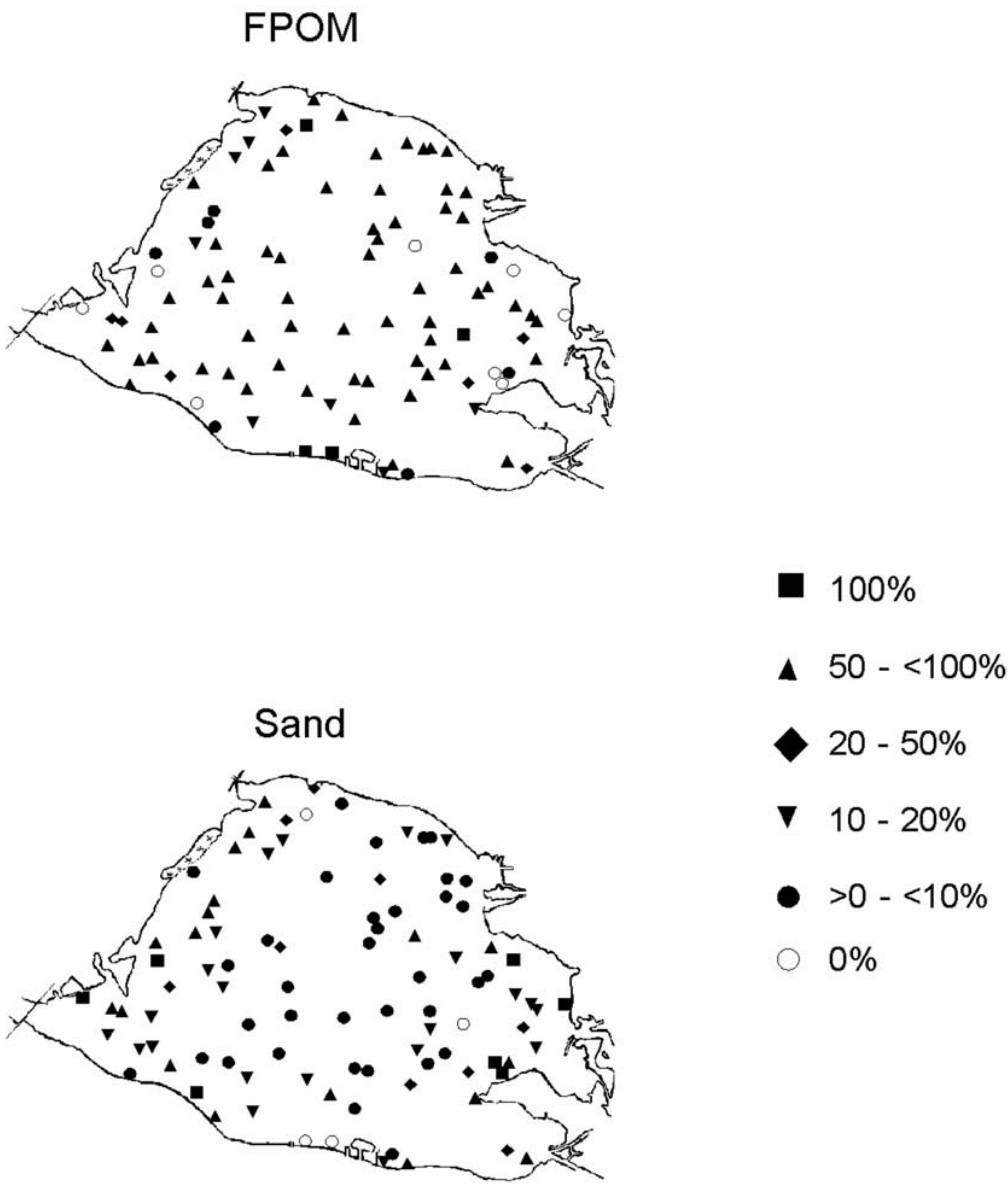

Fig. 2. Spatial distribution and percent relative contents [Fine Particulate Organic Matter (FPOM) and Sand] of all individual sediment samples collected (n = 95) monthly from Lake Monroe (Seminole and Volusia Counties, central Florida), Jun, Jul and Sep in 2002 and Feb and Mar in 2003.

greater relative percent composition of smaller particles (<250 µm) in Lake Monroe. The study lakes show a similar pattern in sediment DW distribution (Figs. 4-6), low sediment DW at the lake center, and increasing DW around the periphery. In Lake Monroe, however, sediments in the lake center had a higher DW (mostly 20-40% compared to 0-20%) than the other two lakes and the high DW sediments of the perimeter extended further into the lake (Fig. 5). The higher DW is probably a product of the smaller particle sizes, which allowed the sediment to compact more

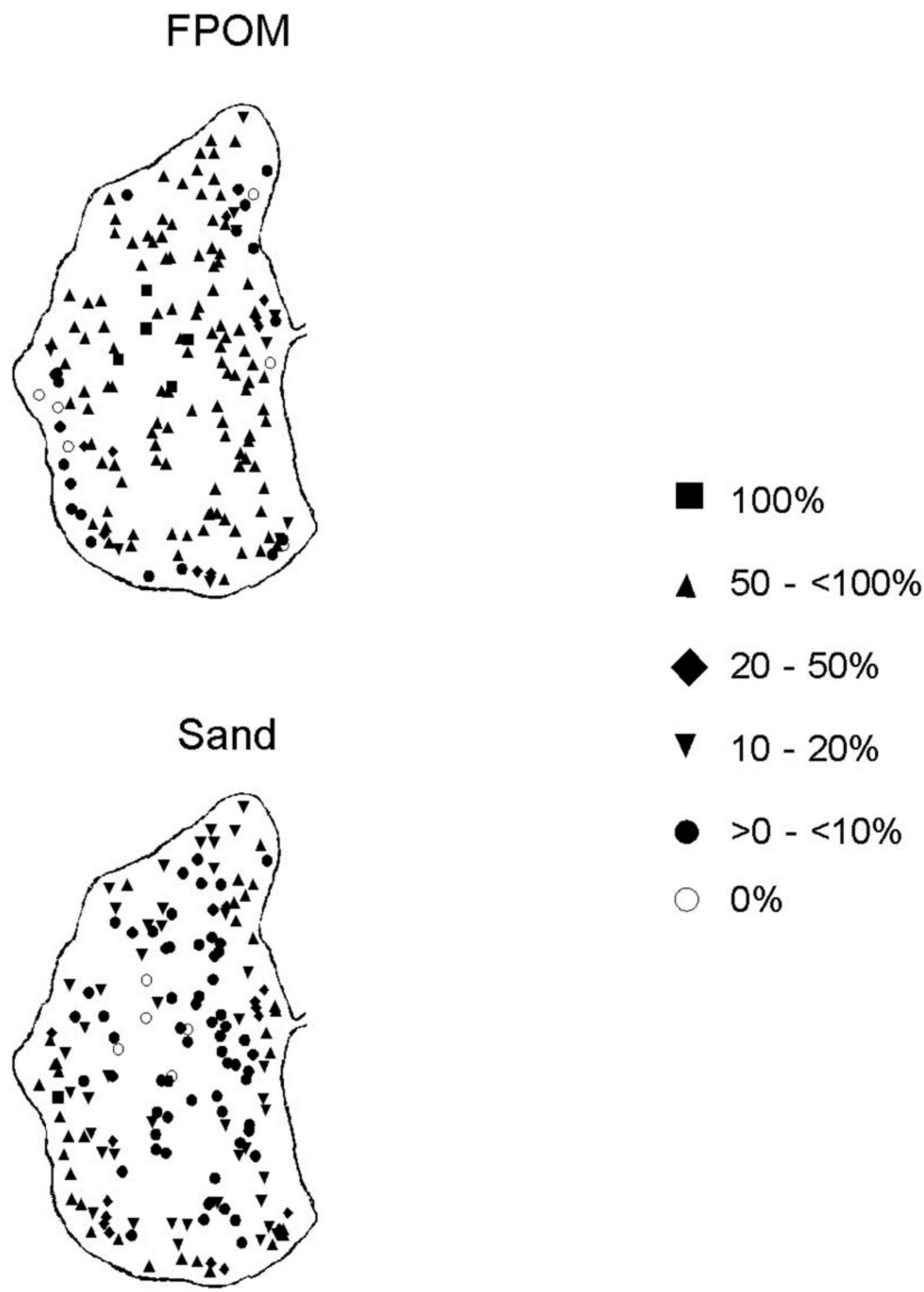

Fig. 3. Spatial distribution and percent relative contents [Fine Particulate Organic Matter (FPOM) and Sand] of all individual sediment samples collected (n = 165) monthly from Lake Wauburg (Alachua County, central Florida), Apr to Sep, 2002 and Jan to Mar, 2003.

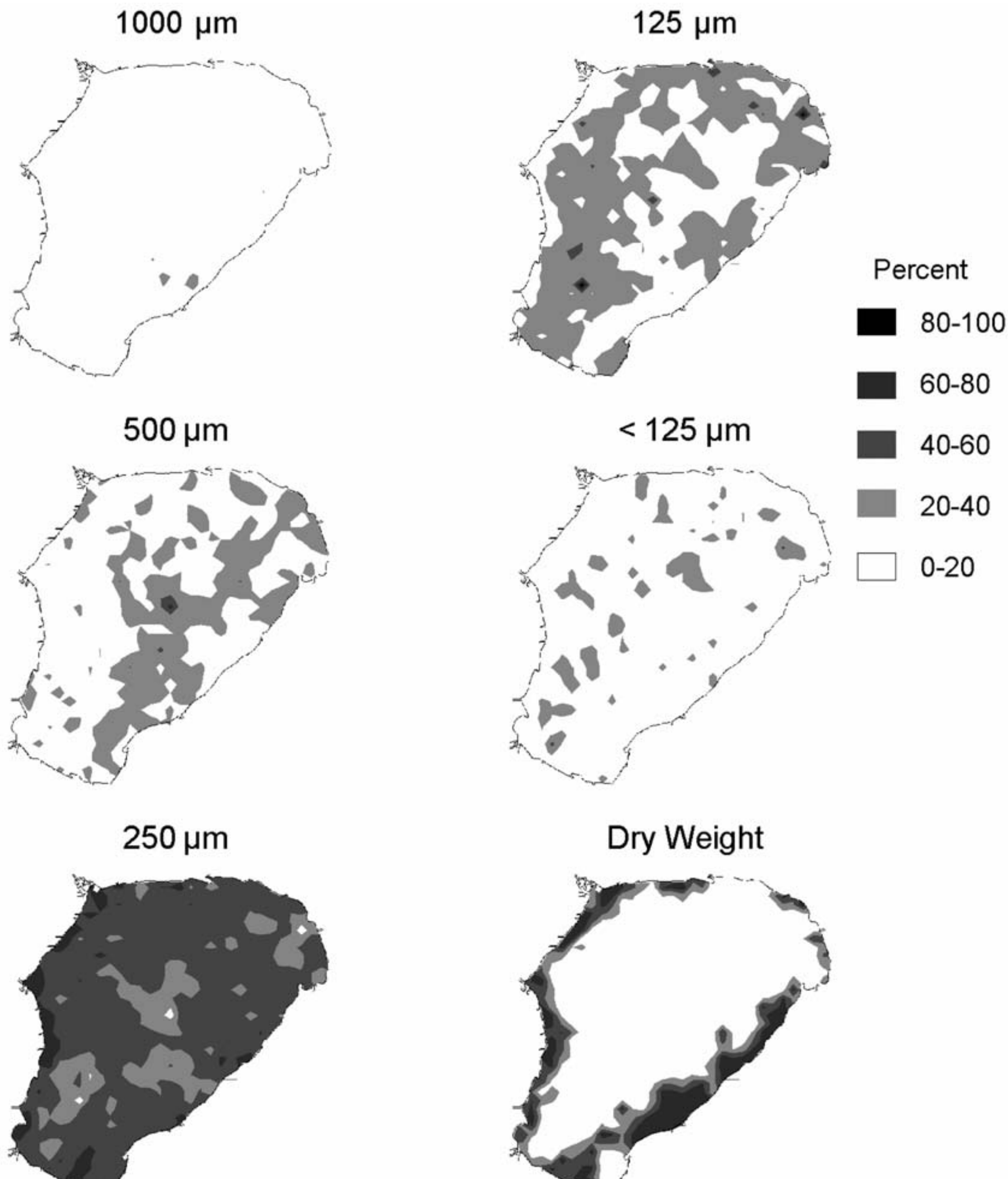

Fig. 4. Spatial percent composition of sediment particles of different sizes, as retained by specified mesh sizes, and sediment dry weight in Lake Eustis (Lake County, central Florida), 2002-2003.

densely than in the other 2 lakes. In relation to *G. paripes* larval survival, Frouz et al. (2004) reported that the water in small particle dense organic sediments had lower concentrations of dissolved oxygen than larger particle loose sediments found in type 2 lakes.

Figure 7 shows CCA results of chironomid larvae with selected sediment physical parameters in the 3 lakes. Larvae of *G. paripes*, *Cryptochironomus* sp., and *Pseudochironomus* sp. recovered from type 1 Lakes Monroe and Wauburg were positively correlated with sand content as

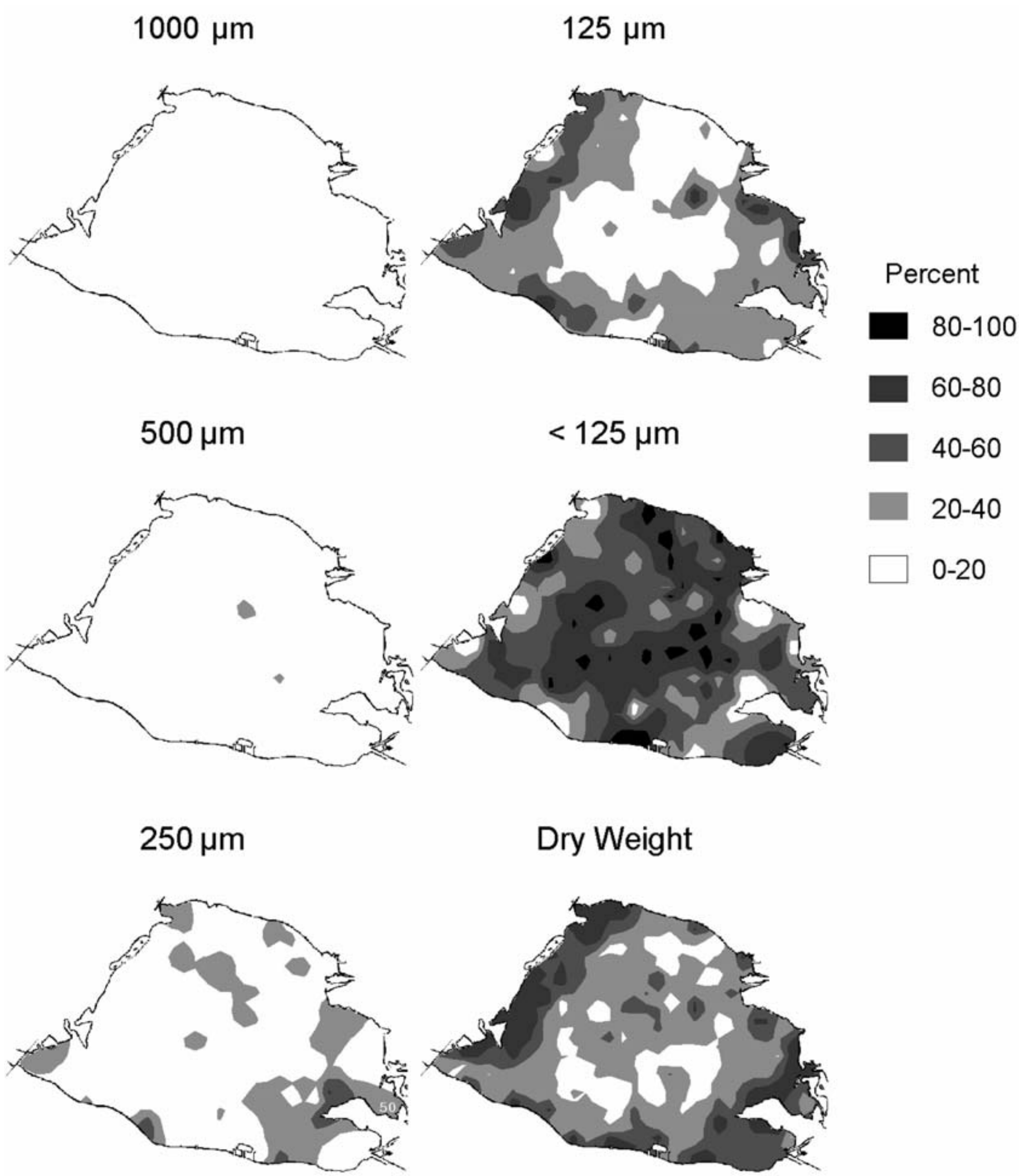

Fig. 5. Spatial percent composition of sediment particles of different sizes, as retained by specified mesh sizes, and sediment dry weight in Lake Monroe (Seminole and Volusia Counties, central Florida), 2002-2003.

well as with sediment DW, and negatively correlated with FPOM particles <125 µm in size and water depth, in agreement with previous reports. Corresponding with the linear regression analysis, *G. paripes* larval density in Lake Eustis was correlated with fecal pellet and FPOM content by CCA (Fig. 7), while *Cryptochironomus* sp. and *Pseudochironomus* sp. larvae were still influenced by sediment parameters in the same way as in the type 1 lakes. Presence of fecal pellets appears to be the primary factor influencing *G. paripes* larval distribution in type 2 Lake Eustis, similar to the fecal pellet/larval distribution association reported by Frouz et al. (2004) for type 2 Lake Yale. Because fecal pellets and FPOM were closely associated in Lake Eustis sediments, and no corre-

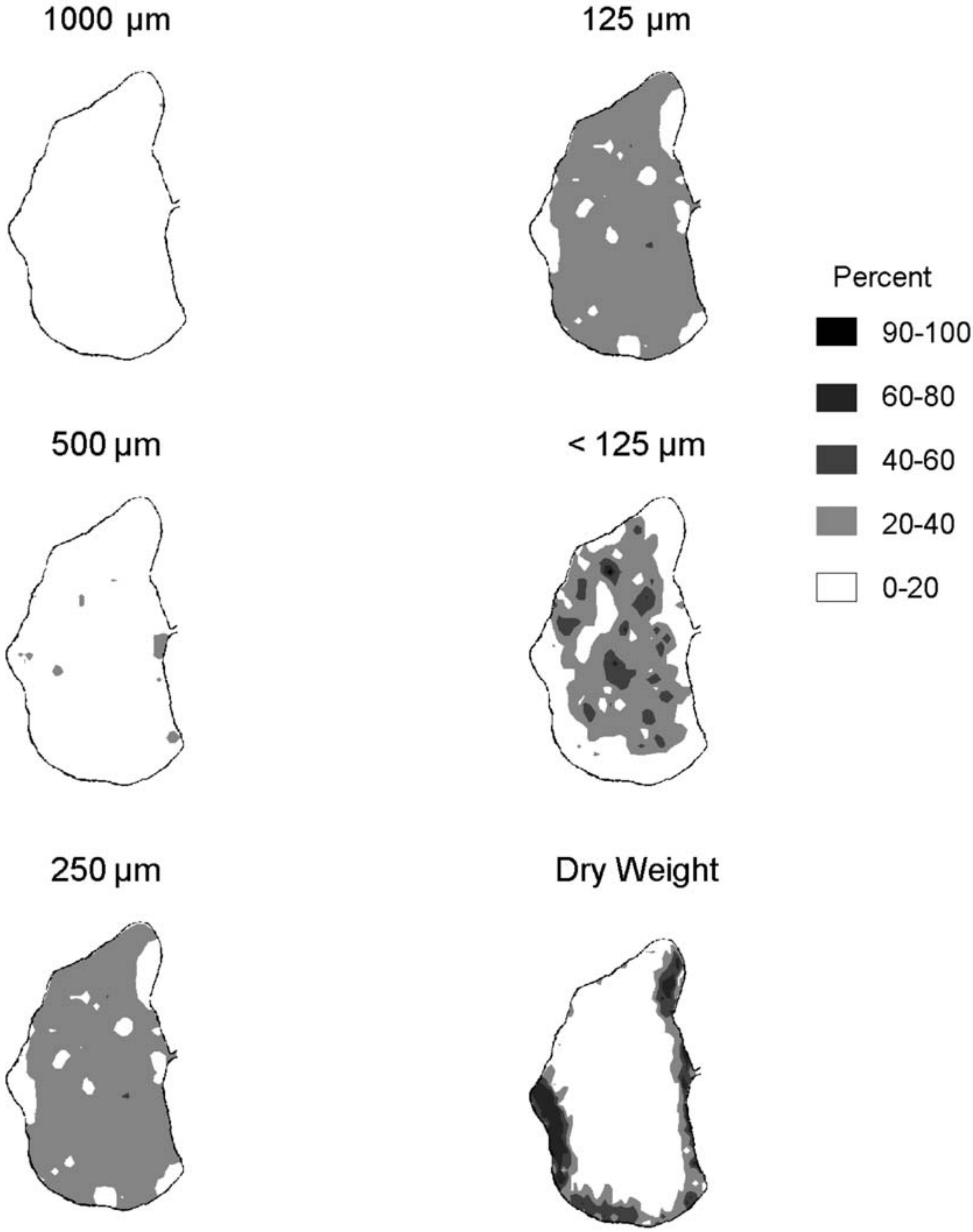

Fig. 6. Spatial percent composition of sediment particles of different sizes, as retained by specified mesh sizes, and sediment dry weight in Lake Wauburg (Alachua County, central Florida), 2002-2003.

lation of larvae with FPOM in the other lakes was noted, the correlation of *G. paripes* larvae with FPOM was likely a co-linearity artifact.

While the full reasons for the 2 opposite *G. paripes* larval distributions are not entirely clear, an important factor certainly is the differences in

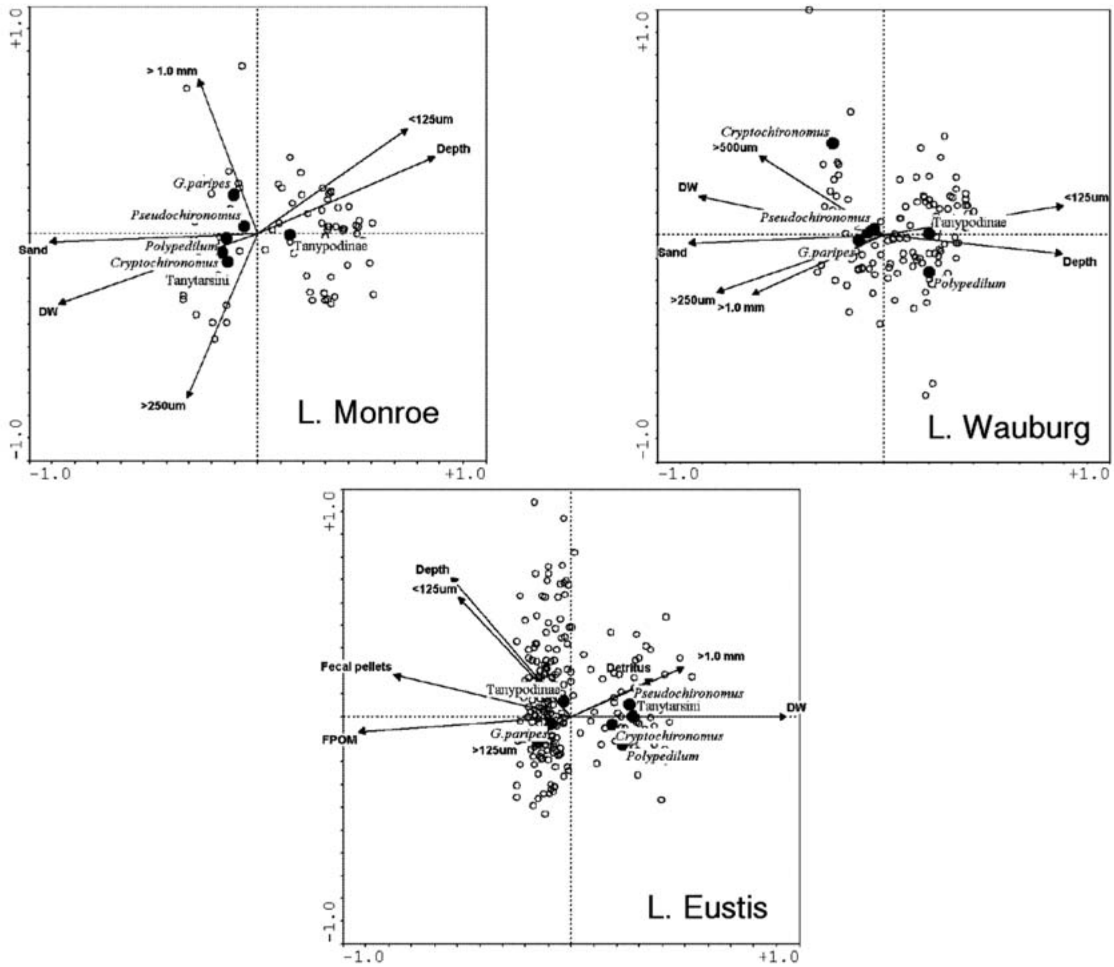

Fig. 7. Canonical Correspondence Analysis of Chironomidae community in Lakes Eustis, Monroe, and Wauburg (central Florida) with selected physical sediment parameters.

muck sediments found at the lake center. The presence of fecal pellets and generally larger particles apparently make the muck sediment more attractive or suitable for survival of *G. paripes* larvae than the fine particle muck sediments encountered in Lake Monroe or Lake Wauburg, or the sand sediments of Lake Eustis. Most likely, this is a result of more oxygen availability in the fecal pellet dominated sediments, as reported by Frouz et al. (2004), as well as the ability of larvae to build longer and deeper protective tubes. The ability to exploit the lake center habitat also may provide larvae with some protection from predation by organisms that typically hunt closer to shore.

For the majority of central Florida lakes, the lake type 1 distribution of *G. paripes* larvae is expected to occur and tools such as the computer model of Lobinske et al. (2004) can be used to assist managers in targeting control measures. For lake type 2, this model would be far less effective, but the use of the simple sediment physical parameters described in the current study would provide an effective means to survey and target larval populations in lake centers. When a lake manager makes an initial survey of a lake bottom, the presence/absence of fecal pellets in the lake center muck sediments will determine if a lake type 1 or lake type 2 distribution of *G. paripes* should be expected. This knowledge will allow managers to focus surveillance and control measures on those areas most likely to support nuisance larval densities.

Literature Cited

Ali, A. 1996. Pestiferous Chironomidae and their management, pp. 487-513 *In* D. Rosen, F. D. Bennett, and J. L. Capinera (eds.), Pest Management in the Subtropics: Integrated Pest Management—A Florida Perspective. Intercept, Andover, UK.

ALI, A., R. J. LOBINSKE, J. FROUZ, AND R. J. LECKEL, JR. 2003. Spatial and temporal influences of environmental conditions on benthic macroinvertebrates in northeast Lake Jesup, central Florida. Florida Sci. 66: 69-83.

ALI, A., M. S. MULLA, B. A. FEDERICI, AND F. W. PELSUE. 1977. Seasonal changes in chironomid fauna and rainfall reducing chironomids in urban flood control channels. Environ. Entomol. 6: 619-622.

ANONYMOUS. 1977. Economic Impact Statement. Blind Mosquito (Midge) Task Force, Sanford Chamber of Commerce. Seminole County, FL.

BRADLEY, W. H., AND M. E. BEARD. 1969. Mud Lake Florida, its algae and alkaline brown water. Limnol. Oceangr. 14: 889-897.

CALLAHAN, J. L., AND C. D. MORRIS. 1987. Survey of 13 Polk County, Florida lakes for mosquito (Diptera: Culicidae) and midge (Diptera: Chironomidae) production. Florida Entomol. 70: 471-478.

COWELL, B. C., AND D. S. VODOPICH. 1981. Distribution and seasonal abundance of benthic macroinvertebrates in a subtropical Florida lake. Hydrobiologia 78: 97-105.

EPLER, J. H. 2001. Identification Manual for the Larval Chironomidae (Diptera) of North and South Carolina. A Guide to the Taxonomy of the Midges of the Southeastern United States, Including Florida. Special Publication SJ2001-SP13. North Carolina Department of Environment and Natural Resources, Raleigh, NC, and St. Johns River Water Management District, Palatka, FL.

FROUZ, J., R. J. LOBINSKE, AND A. ALI. 2004. Influence of Chironomidae (Diptera) faecal pellet accumulation on lake sediment quality and larval abundance of pestiferous midge *Glyptotendipes paripes.* Hydrobiologia 518: 169-177.

GAD EL RAB, M. O., D. R. THATCHER, AND A. B. KAY. 1980. Widespread IgE-mediated hypersensitivity in the Sudan to the 'green nimitti' midge *Cladotanytarsus lewisi* (Diptera: Chironomidae). II. Identification of a major allergen. Clinical Exp. Immunol. 41: 389-396.

GIACOMIN, C., AND G. C. TASSI. 1988. Hypersensitivity to chironomid *Chironomus salinarius* (non-biting midge living in the Lagoon of Venice) in a child with serious skin and respiratory symptoms. Boll. Inst. Sieroter. Milan 67: 72-75.

LOBINSKE, R. J., AND A. ALI. 2006. Population monitoring, ecology and control possibilities for nuisance midges (Diptera: Chironomidae). Tech. Bull. Fla. Mosq. Control Assoc. 7: 63-66.

LOBINSKE, R. J., A. ALI, AND J. FROUZ. 2002. Ecological studies of spatial and temporal distributions of Larval Chironomidae (Diptera) with emphasis on *Glyptotendipes paripes* in three central Florida lakes. Environ. Entomol. 31: 637-647.

LOBINSKE, R. J., J. L. STIMAC, AND A. ALI. 2004. A spatially explicit computer model for immature distributions of *Glyptotendipes paripes* (Diptera: Chironomidae) in central Florida lakes. Hydrobiologia 519: 19-27.

MCLACHLAN, A. J. 1976. Factors restricting the range of *Glyptotendipes paripes* Edwards (Diptera: Chironomidae) in a bog lake. J. Animal Ecol. 45: 105-113.

PROVOST, M. W., AND N. BRANCH. 1959. Food of chironomid larvae in Polk County lakes. Florida Entomol. 42: 49-62.

TER BRAAK, C. J. F. AND P. SMILAUER. 1998. Canoco Reference Manual and Users Guide to Canoco for Windows: software for Canonical Community Ordination (Version 4). Microcomputer Power, Ithaca, NY.