SEASONAL CHANGES OF LARVAL FOOD AND FEEDING OF *CHIRONOMUS CRASSICAUDATUS* (DIPTERA: CHIRONOMIDAE) IN A SUBTROPICAL LAKE

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ABSTRACT. The food of *Chironomus crassicaudatus* midge larvae in Lake Monroe, central Florida, was investigated from May 1981 to April 1982. Gut contents of larvae collected monthly from 16 stations in the lake were analyzed. Quantitative samples of water collected monthly at the mud-water interface at each station were analyzed for the larval food composition in the water. The larvae fed primarily on Cyanobacteria (blue-green algae). Blue-green algae were predominant in the water as well as in the larval guts, forming 63–87% and 52–84% of the total organisms observed in the water and in the larval guts, respectively. Populations of these organisms in the water were lowest in the summer. A highly significant relationship existed between the monthly mean percent of blue-green algae in the larvae and in the water. In general, the larvae were nonselective feeders in that the organisms enumerated in the water were also found in the gut.

INTRODUCTION

Since the confirmation by Walshe (1947) regarding the filter-feeding mechanism of *Chironomus* midge larvae, several studies on the feeding habits of nonpredatory chironomids have been reported. These studies have focused on the importance of phytoplankton (Jonasson and Kristiansen 1967, Kajak and Warda 1968, Alfred 1974, Johannsson 1980), detritus (Izvekova 1971, Moore 1979, 1980) and/or bacteria (Baker and Bradnam 1976) in the diet of *Chironomus* larvae. Midge larval gut contents in relation to the algae present in layers of sediments in the larval habitats were investigated (Kajak and Warda 1968, Kajak and Rybak 1970). Chironomid larval feeding habits by examining their fecal materials were studied (Jonasson and Kristiansen 1967, Davies 1975). The relationship of midge food composition in the larvae and in the associated water in natural habitats was also studied on a short-term basis (Provost and Branch 1959, Alfred 1974).

In Florida, Provost and Branch (1959) investigated the larval food of *Glyntotendipes paripes* Edwards, a predominant midge species in Polk County lakes. In recent years, *G. paripes* and *Chironomus crassicaudatus* Malloch have prevailed in large numbers in central Florida lakes (Ali and Baggs 1982, Ali and Fowler 1983) and periodic massive emergences of their adults have posed severe nuisance and economic problems for people residing or working near these midge sources (Ali 1980).

The present study on the feeding habits of *C. crassicaudatus* larvae under natural conditions was made in a subtropical environment. The larval gut contents in relation to available food in the associated water in a lake were investigated for 1 year. Such basic information on chironomid ecology is useful in understanding and developing control criteria against pestiferous species of midges.

MATERIALS AND METHODS

The study was conducted in Lake Monroe, located at approximately 28° 50′ N latitude and 81° 15′ W longitude, in Seminole and Volusia counties, central Florida. Lake Monroe is 4,000 ha at the surface and 2–3 m deep. The St. Johns River flows through the lake in an east to west direction. The city of Sanford borders the south end of the lake. Water in Lake Monroe is turbid, and sediments consist primarily of mud ooze and fine silt with some areas predominated by sand.

Sixteen permanent sampling stations in different areas of the lake were selected for the monthly collections of midge larvae and the lake water during May 1981 to April 1982. Three samples of water at the mud-water interface (feeding zone of the larvae) were collected at each station by employing a core sampler designed to lift an undisturbed column of water from the lake bottom (Ali 1984). Each water sample (ca. 50 ml) was collected with a syringe and transferred from the core tube (Ali 1984) into a polyethylene bottle to which 0.5 to 1.0 ml of acid Lugol's solution was added to kill and preserve the collected organisms.

Samples of midge larvae at each station were collected with a 15 x 15 cm Ekman dredge. The larval samples at each station were collected immediately after collecting the water samples. The collected sediments were sifted through a 0.5 mm pore screen and the living 3rd and 4th instar *C. crassicaudatus* were placed in 4-dram bottles containing distilled water and 3–4 drops of acid Lugol's solution.

In the laboratory, each water sample was examined by taking 3 separate 1 ml aliquots in

Sedgwick-Rafter counting cells. The aliquots were taken while the sample was being gently agitated with a magnetic stirrer. An Olympus BH phase-contrast microscope equipped with a Whipple ocular grid was used. Five fields of view in an X pattern, one near each corner and one in the middle of the Sedgewick-Rafter cell containing the subsample were examined under 200× magnification (Kurtak 1979). Organisms totally or partially (50% or more) covered by the image of the grid were counted. The counts were converted to numbers per ml of each sample (APHA 1980). For taxonomic purposes, the relatively recent classification of living organisms presented in Barnes (1984) was followed. Organisms, such as euglenoids, dinoflagellates and cryptomonads were placed under Protozoa following Lee et al. (1985). However, specific identifications of most genera were made by using keys in Prescott (1982) and Edmondson (1963).

For gut content analysis, each larva was measured (length) and carefully dissected under 10 or 20× magnification of a binocular dissecting microscope. An incision was made along the length of the larval body to expose the alimentary tract; and diameter and length of the larval gut, while intact, were measured and recorded. The alimentary tract was then removed from the larva by using watchmaker's forceps and placed in 0.1 ml Palmer-Maloney counting cell containing two drops of distilled water. The entire foregut and the anterior 50% of the mesenteron were retained in the cell while the rest of the mesenteron was carefully separated and discarded. The larval buccal cavity was held closed with the forceps while separating the unwanted portion of mesenteron to prevent any loss of gut contents. The walls of the fore- and the midgut were opened longitudinally with the forceps, and the contents were teased out in the distilled water. The open and now empty portion of the gut was removed from the cell and discarded. The extruded gut material was gently mixed into the distilled water by using the forceps to attain an even dispersion of the material in the counting cell. Where needed, more distilled water was added with a micropipette to completely fill the well of the counting cell and a cover slip was then placed and the cell examined under 200× magnification of the phase-contrast microscope. Five fields in the X pattern were viewed, and the total or partial (50% or

Table 1. Genera of Cyanobacteria, Chlorophyta, Chrysophyta and protozoan orders Euglenida, Dinoflagellida and Cryptomonadida occurring in Lake Monroe, Seminole and Volusia counties, Florida, May 1981–April 1982

Cyanobacteria (Blue-green algae)	Chlorophyta (Green algae)	Chrysophyta (Diatoms, yellow-green and yellow-brown algae)	Euglenida (Euglenoids)	Dinoflagellida (Dinoflagellates)	Cryptomonadida (Cryptomonads)
*Anabaena**	*Actinastrum*	*Amphiprora**	*Euglena**	*Glenodinium*	*Cryptomonas*
*Anacystis**	*Ankistrodesmus**	*Amphora**	*Lepocinclis**	*Gymnodinium**	
Arthrospira	*Arthrodesmus**	*Bacillaria*	*Phacus**		
Chroococcus	*Botryococcus**	*Chaetoceros**			
Dactylococcopsis	*Chlamydomonas*	*Cocconeis*			
*Gloeocapsa**	*Chodatella**	*Coscinodiscus**			
Gloeothece	*Closterium*	*Cyclotella**			
*Lyngbya**	*Coelastrum**	*Diatoma*			
*Merismopedia**	*Cosmarium**	*Diploneis**			
Microcystis	*Crucigenia**	*Fragilaria*			
Nostoc	*Dictyosphaerium**	*Gyrosigma**			
Oscillatoria	*Franceia**	*Mallomonas*			
Spirulina	*Golenkinia**	*Melosira**			
	Micrasterias	*Navicula**			
	*Oocystis**	*Nitzschia**			
	*Pediastrum**	*Pinnularia**			
	*Polyedriopsis**	*Stauroneis**			
	*Scenedesmus**	*Surirella**			
	*Schroederia**	*Synedra**			
	*Selenastrum**	*Tabellaria*			
	Spirogyra	*Tetracyclus*			
	Staurastrum	*Tetragoniella**			
	*Tetraedron**				
	*Treubaria**				
	Volvox				

* Recognized in the gut contents of *Chironomus crassicaudatus* larvae collected from Lake Monroe during May 1981 to April 1982. *Tetragoniella* and *Mallomonas*, under Chrysophyta, were the only yellow-green and yellow-brown algae, respectively.

more) organisms under the Whipple grid were identified and counted. The gut dimensions of each larva were used to calculate number of organisms per gut volume (Moore 1979). A total of 370 *C. crassicaudatus* larvae ranging from 11 to 24 mm in body length were used.

RESULTS AND DISCUSSION

Thirteen genera of Cyanobacteria (blue-green algae), 25 genera of Chlorophyta (green algae), 22 genera of Chrysophyta (20 genera of diatoms and one genus each of yellow-green and yellow-brown algae), and 6 genera of protozoan orders Euglenida (euglenoids) (3 genera), Dinoflagellida (dinoflagellates) (2 genera) and Cryptomonadida (cryptomonads) (1 genus) were recognized in the water and/or in the larval guts of *C. crassicaudatus* during the study period (Table 1). Eight genera of blue-green algae taken in water samples were not found in the larval guts. Similarly, 7 genera of green algae, 6 genera of diatoms, and 1 genus each of yellow-brown algae (*Mallomonas*), dinoflagellates (*Glenodinium*), and cryptomonads (*Cryptomonas*) were present in the water samples, but did not occur in the larval guts (Table 1). However, the organisms present in the water but absent from the larval guts were relatively scarce and collectively formed < 5% of the total organisms observed in the monthly water samples.

Seasonal population trends of collected organisms at the mud-water interface in Lake Monroe are shown in Fig. 1. Blue-green algae were predominant and formed 63–87% of the total organisms observed in the monthly samples; their numbers ranged from 166,955/ml in July 1981 to a maximum of 374,562/ml in February 1982. *Anacystis*, *Gloeocapsa*, *Lyngbya* and *Anabaena*, in that order, were the predominant blue-green algae in the water. The green algae formed 7–19% of the total organisms observed in the monthly samples with numbers ranging from 20,062/ml in April 1982 to 59,446/ml in September 1981. The major green algae belonged to the genera, *Ankistrodesmus*, *Pediastrum*, *Scenedesmus*, *Schroederia*, and *Selenastrum*. Monthly populations of diatoms ranged from 2 to 13% of the total organisms, with a numerical range of 6,751/ml in May 1981 to 40,294/ml in January 1982. *Navicula*, *Nitzschia*, and *Synedra* were the predominant genera of diatoms. The euglenoids, yellow-green and yellow-brown algae, dinoflagellates and some unidentified algae (mostly filamentous) constituted < 1 to 10% of the total organisms observed in the monthly water samples. Generally, populations of total organisms in the water were lower in the summer season than in the other seasons (Fig. 1), and this trend

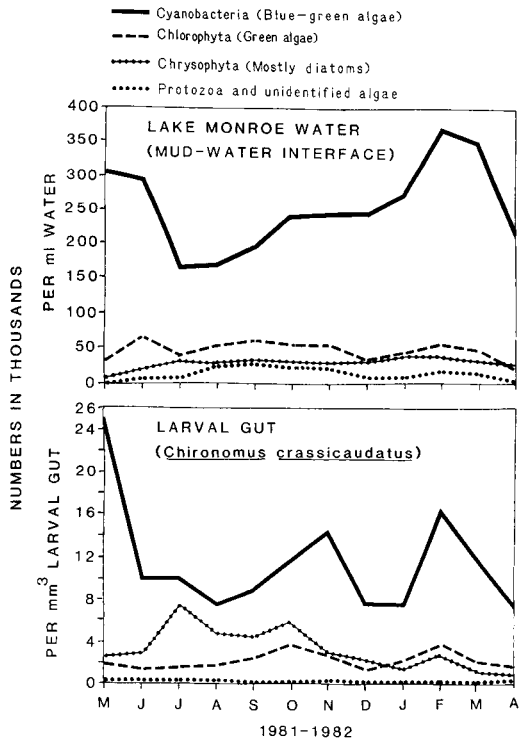

Fig. 1. Monthly quantitative composition of Cyanobacteria (blue-green algae), Chlorophyta (green algae), Chrysophyta (mostly diatoms), Protozoa (Euglenida, Dinoflagellida and Cryptomonadida) and some unidentified algae in the larval guts of *Chironomus crassicaudatus*, and seasonal population trends of these organisms in the associated water at the mud-water interface in Lake Monroe, Seminole-Volusia counties, central Florida, May 1981–April 1982.

was dictated by the blue-green algae which were the most predominant organisms throughout the study period.

In the 370 *C. crassicaudatus* larvae examined during this study, the foregut and 50% mesenteron gut volumes had a mean value of 4.23 mm^3. The mean number of organisms per larva amounted to 14,357/mm^3. The larvae fed primarily on blue-green algae (Fig. 1). In the monthly observations, blue-green algae (mostly *Anacystis*, *Gloeocapsa*, *Lyngbya* and *Merismopedia*) ranged from 52 to 84% of the total organisms in the larval guts. The numbers of blue-green algae ranged from 7,256/mm^3 larval gut in April 1982 to 24,846/mm^3 larval gut in May 1981. Green algae (mostly *Pediastrum*, *Scenedesmus* and *Schroederia*) formed 6–20% (1,262 to 3,830/mm^3 larval gut) of the total organisms observed monthly in the larval gut. Diatoms (mostly *Cyclotella*, *Nitzschia*, *Surirella* and *Synedra*) comprised 8 to 39% (769 to 7,435/mm^3 larval gut) of the monthly totals of organisms in

the larval gut. The euglenoids, yellow-green and yellow-brown algae, dinoflagellates and some other unidentified algae formed between 0.1 and 2.4% of the total organisms in the guts of the monthly collected larvae. Particles of detritus, sand, pollen, and spicules of Porifera were also sporadically detected in the gut contents.

The percentage composition of blue-green algae, green algae, diatoms and other Chrysophyta, and other organisms observed in the larvae and in the associated lake water at the feeding zone of the larva are shown in Fig. 2. Blue-green algae formed 68% of the total organisms in the larvae and 73% of the total organisms in the water. A highly significant relationship existed between the monthly mean percent of blue-green algae in the larvae and in the water ($r = 0.894$, $P < 0.01$, $n = 12$) (Fig. 3). Green

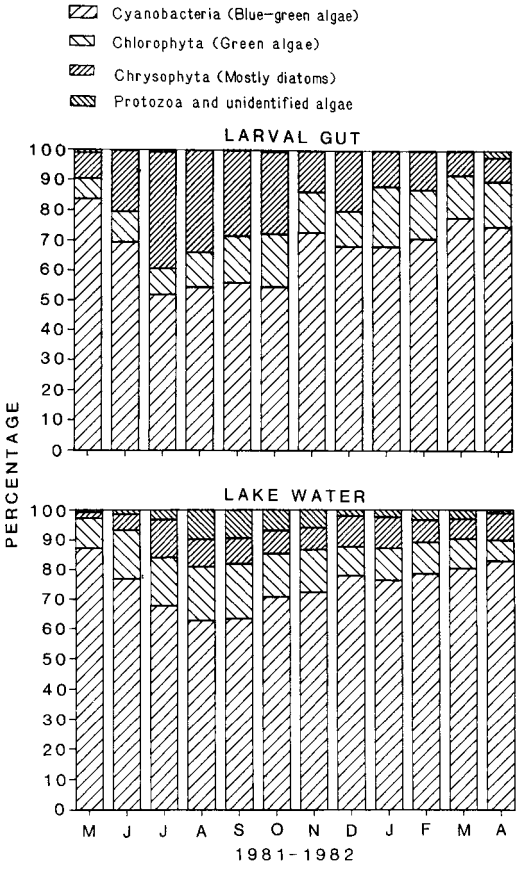

Fig. 2. Monthly percentage compositions of Cyanobacteria (blue-green algae), Chlorophyta (green algae), Chrysophyta (mostly diatoms), Protozoa (Euglenida, Dinoflagellida and Cryptomonadida) and some unidentified algae in larval guts of *Chironomus crassicaudatus* and in the associated overlying water in Lake Monroe, Seminole-Volusia counties, central Florida May 1981–April 1982.

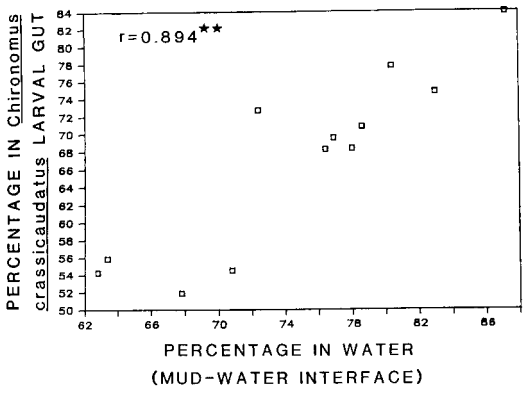

Fig. 3. Relationship between Cyanobacteria (blue-green algae) in water (at the mud-water interface) and in the guts of the water-associated larvae of *Chironomus crassicaudatus* in Lake Monroe, Seminole-Volusia counties, Florida. Plotted values are monthly mean percent blue-green algae of the total observed organisms.

algae occurred in the same proportions (13%) in the larvae and in the water. A similar comparison of diatoms, however, indicated a higher proportion (19%) in the larvae than found in the associated water (9%). This could be the result of more efficient feeding by the larvae on the diatoms, or some insoluble empty frustules of diatoms being retained in the midgut for longer periods of time than the other gut contents, thus inflating the proportion of diatoms in the larvae.

Based on the similarities of the food in the larvae (*C. crassicaudatus*) and in their environment, it can be suggested that the larva, in general, is a nonselective feeder and ingests food items in the proportions they occur in the surrounding water. These findings lend credence to the suggestion of Provost and Branch (1959), Alfred (1974) and Moore (1979) that the importance of different types of food in the larval diet of several Chironomidae might be chiefly influenced by their availability in the local environment. The relatively few particles of micro-detritus and other materials in *C. crassicaudatus* larvae indicate that the larva is generally a filter feeder, although it might also scrape materials from the substrates.

Although several studies on the food composition of larval Chironomidae have been reported in the literature (e.g., Izvekova 1971, Kajak and Warda 1968, Moore 1979, and others), most of these are related to Chironomidae of subarctic or temperate zones. The only study comparable to the present investigation is that of Provost and Branch (1959) which showed that *G. paripes* larvae fed overwhelmingly (98.7%) on phytoplankton, with blue-green algae forming

60.7% of the total phytoplankton. Their findings are compatible with the observations made on *C. crassicaudatus* in the present study.

It is evident from this study that the abundance of blue-green algae, green algae, diatoms, etc., generally resulting from nutrient loading to the lakes, would be conducive to increases in *C. crassicaudatus* populations by way of the food chain effect on its rate of development and hence abundance. As a result, it is suggested that the manipulation of nutrient loading to some habitats producing chironomids at nuisance levels may be a management tool for reducing midge larvae resulting in lower levels of adult midge emergence.

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