Macrophyte-macroinvertebrate interactions in a lentic ecosystem and the effect of fluridone treatment to control Myriophyllum spicatum L.

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MACROPHYTE-MACROINVERTEBRATE INTERACTIONS IN A LENTIC ECOSYSTEM AND THE EFFECT OF FLURIDONE TREATMENT TO CONTROL *MYRIOPHYLLUM SPICATUM* L.

An Abstract of a Thesis

Submitted

in Partial Fulfillment

of the Requirements of the Degree of

Master of Science

Gregory J. Moeller

University of Northern Iowa

December 1997
Myriophyllum spicatum L. is an exotic macrophyte that can become pestiferous in lentic ecosystems. Two field studies were conducted to investigate: 1) epiphytic macroinvertebrates associated with *M. spicatum* and native macrophytes; and 2) epiphytic macroinvertebrate community response to fluridone treatment for *M. spicatum* control.

In the first study evaluating epiphytic macroinvertebrates associated with *M. spicatum* and native macrophytes, triplicate samples were collected at three sites in both Auburn and Zumbra Lakes, Minnesota, USA. One site in each lake contained primarily *M. spicatum*, the second site contained *M. spicatum* and native vegetation, and the third site was dominated by native vegetation. Mean macroinvertebrate taxa richness, total density and biomass were significantly higher in Auburn Lake than at corresponding sites in Zumbra Lake on most dates. Several significant differences in mean epiphytic macroinvertebrate taxa richness, total density and biomass were observed among the sites within both Auburn and Zumbra Lakes. However, these differences followed no apparent trend suggesting that epiphytic macroinvertebrates do not selectively colonize any of the macrophyte assemblages studied in Auburn or Zumbra Lakes.

The second study evaluated the secondary effects of fluridone treatment for *M. spicatum* control on epiphytic macroinvertebrate communities. Sites in Zumbra Lake, Minnesota were compared before and after fluridone application. One site contained predominantly *M. spicatum*, the second contained a mixture of *M. spicatum* and native vegetation, and the third possessed predominantly native vegetation. Triplicate macroinvertebrate samples were taken at 1 and 2 m depths at each sample site. Samples
were taken before treatment in July, August and September, 1993, and after the May 23, 1994 fluridone treatment (24 µg/L) in July, August and September, 1994 and 1995. Following herbicide application a decrease in macrophyte species richness and biomass at each site was associated with significant decreases in epiphytic macroinvertebrate mean taxa richness, densities and biomass.

Keywords: *Myriophyllum spicatum*, Fluridone, Macroinvertebrates, Macrophytes, Toxicity
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Entitled: MACROPHYTE-MACROINVERTEBRATE INTERACTIONS IN A LENTIC ECOSYSTEM AND THE EFFECT OF FLURIDONE TREATMENT TO CONTROL *MYRIOPHYLLUM SPICATUM* L.

has been approved as meeting the thesis requirement for the Degree of Master of Science.

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PROLOGUE

General Macrophyte Ecology

Macrophytes affect the aquatic environment and are affected by it. Macrophytes can alter light attenuation, temperature, water flow, sediment composition and water chemistry. They increase light attenuation by absorbing and reflecting light (Titus and Adams 1979). Because of this, macrophyte stands can increase vertical temperature gradients compared to open areas, but these gradients may be disrupted by water circulation (Dale and Gillespie 1977). Macrophytes can retard water flow in rivers and lakes causing increased sediment deposition (Weiler 1978). In addition, decomposing macrophytes add to sediment organic matter. Macrophytes can also affect dissolved oxygen, dissolved organic carbon, carbon speciation and pH. Submersed macrophytes can increase diel oxygen fluctuations (Ondok et al. 1984) because photosynthesis during daylight hours causes elevated dissolved oxygen levels, while macrophyte respiration and microbial decomposition decrease dissolved oxygen levels at night in the absence of photosynthesis. Because of this, diurnal dissolved oxygen supersaturation can occur along with nocturnal anoxia. Although most carbon species are retained by living macrophytes, as much as 10% of carbon species produced in photosynthesis are discharged from macrophytes to become dissolved organic compounds (Sondergaard 1981). Inorganic carbon can be precipitated on or absorbed by macrophytes (Wetzel 1960). Precipitation occurs when $\text{HCO}_3^-$ and $\text{Ca}^{++}$ combine to make $\text{Ca(HCO}_3)_2$, which then loses $\text{H}_2\text{O}$ and $\text{CO}_2$ and produces $\text{CaCO}_3$ (marl precipitate). Assimilation of $\text{CO}_2$ for photosynthesis follows a diel pattern. Aquatic plants take up more $\text{CO}_2$ during the day
for photosynthesis than they release through respiration. Removal of CO$_2$ increases pH because it causes increased OH$^-$ concentrations. Hydroxyl ion concentrations decrease at night because CO$_2$ is released by organisms without being taken up for photosynthesis.

Macrophytes can also affect biotic interactions. Macrophytes can be a detrital or direct food source to a few specialized macroinvertebrates, but they are not directly consumed by most macroinvertebrates (Newman 1991). However, macrophytes support assemblages of attached algae, bacteria, fungi, small metazoa and protozoa (Horne and Goldman 1994). These epiphytic “aufwuchs” provide nutrition for many grazing macroinvertebrates (Ogilvie 1988, Elser and Goldman 1991, Hann 1991, Shannon et al. 1994). The epiphytic algae in this attached association make a major contribution to primary production in lentic ecosystems (Lalonde and Downing 1991). The loss of macrophytes could adversely affect macroinvertebrate communities through loss of the epiphytic algae associated with them as well as loss of habitat.

Macrophytes serve as refugia for invertebrates (Newman 1991). Losee and Wetzel (1988) estimated that substrate surface area provided by macrophyte beds in Lawrence Lake, Michigan, USA was nearly 10 times greater than in open areas. Beckett et al. (1991) observed a significant difference between macroinvertebrate communities in the hydrosoil below vegetated areas and open areas. Benthic macroinvertebrate densities were 15 times greater below Ceratophyllum sp. beds and 7 times greater below Potamogeton sp. beds compared to open areas. An average of 45 species was found below vegetated beds, while open areas averaged 18 species. Schramm Jr. and Jirka (1989) also found that most macrophyte beds supported higher macroinvertebrate
densities than benthic sediments without macrophytes. However, Rasmussen (1988) found that greater macrophyte biomass resulted in decreased benthic macroinvertebrate biomass, but greater epiphytic macroinvertebrate biomass. The importance of macrophyte beds as macroinvertebrate habitat has been corroborated by Beckett et al. (1992). They found between 7,040 and 27,308 individuals/m² of macrophyte coverage, and it was estimated that a 20 x 60 m plant bed contained 30 million insects.

Epiphytic macroinvertebrate density and species richness supported by aquatic macrophytes may differ between plant species. Rosine (1955) found that plants with highly dissected leaves supported more epiphytic macroinvertebrates. In Muskee Lake, Colorado, USA, he noted that 100 cm² of *Chara delicatula* Ag., a macrophytic algae with a highly dissected morphology, tended to support more total epiphytic macroinvertebrates than the same area of *Potamogeton gramineus* L. and *Polygonum natans*, two flat-leaved vascular macrophytes. Other researchers have found that macrophytes with dissected leaves like *Ceratophyllum demersum* and *Myriophyllum spicatum* support greater macroinvertebrate density than ribbon-leaved plants like *Vallisneria americana* (Krecker 1939, Mrachek 1966).

Macrophytes also provide food and shelter for fish (Horne and Goldman 1994). Some fish consume aquatic plants and/or the macroinvertebrates on them. In addition, larval fish and smaller adult fish use these areas to escape predation by larger fish because plant beds provide cover and may be too dense for larger fish to enter.
The Haloragaceae is a large family of dicotyledonous plants, with the genus *Myriophyllum* having 39 species and representatives on every continent, excluding Antarctica (Cook 1985). Although *Myriophyllum* spp. have a widespread distribution, not all species are native to the regions they occupy.

*Myriophyllum spicatum* L. is an aquatic macrophyte native to Europe, Asia and northern Africa (Smith and Barko 1990). In North America, *M. spicatum* is considered an exotic species. Confusion discerning between *Myriophyllum spicatum* L. and *Myriophyllum sibiricum* Kom. (= *Myriophyllum exalbescens* Fern.) in early identifications has caused lack of consensus on the time and place of the first identified *M. spicatum* specimen (Smith and Barko 1990). Although several possible identifications were made in eastern locations in the late 1800s and early 1900s, the first correct determination is not known (Reed 1977, Couch and Nelson 1985). It may have been introduced to Chesapeake Bay from aquariums (Reed 1977), or shipping ballast (Aiken et al. 1979). Since introduction in the eastern United States, *M. spicatum* has spread through the Ohio River Valley into the Midwest and through the Atlantic and Gulf coast states into the Northeast and South, respectively. By 1996, *M. spicatum* had spread to 41 states (Grodowitz et al. 1997). Invasions by exotic species like *M. spicatum* have increased in frequency as worldwide transportation systems have been developed, and other non-native vegetative species have caused similar problems throughout the world (Schoonbee 1991).
Aiken et al. (1979, pp. 201-204) provide the following description of *M. spicatum* morphology:

Submersed aquatic herb with branching leafy shoot, 0.5-7 m long, most commonly in water 1-3 meters deep. Stem glabrous, becoming leafless toward the base by release or decay of leaves, branched near the water surface; growing apices tassel-like and often red, especially early in the growing season. Leaves whorled, 1.5-4.0 cm long, usually 4 in a whorl, most often with 14-24 pairs of filiform divisions; leaf outline feather-like, with basal division often about half the length of the leaf in Canadian material, more variable in European samples. Inflorescence a terminal spike, 5-20 cm long, often pink. The stem 5-20 nodes below the spike is almost double the rest of the stem in width, very rigid, characteristically curved so that this portion lies parallel to the water surface. Spike erect at anthesis, parallel to water surface at fruit set. Flowers verticillate in 4's, the whorls 2-ranked, adjacent whorls rotated 45°, lower flowers pistillate, upper flowers staminate; occasionally hermaphrodite flowers occur in the transition zone. Lower 2-4 whorls of floral bracts usually pectinate and often longer than the flowers; upper bracts entire, broader than long and shorter than the flowers. Female flowers lack perianth; gynoecium 4-lobed with pink, tufted, recurved, sessile stigmas. Male flowers with 4, pink, cauducous petals; stamens 8. Fruit subglobose, 2-3 mm long, 4-sulcate with two somewhat wrinkled ridges adjacent to the lines of dehiscence. The chromosome number 2n = 42 is here reported for plants from Guntersville Reservoir, Alabama.

Although *M. spicatum* can be found in all levels of water clarity, its morphology and distribution are affected by turbidity. In highly turbid water, *M. spicatum* grows in shallow areas where it forms a horizontal surface canopy (Titus and Adams 1979). In less turbid water, *M. spicatum* can be found at greater depths and may not reach the surface (Madsen et al. 1989). The low light intensities and high water temperatures found in eutrophic environments stimulate shoot elongation and canopy formation giving *M. spicatum* more biomass closer to the surface and increasing potential light absorption (Barko and Smart 1981). *Myriophyllum spicatum* adjusts to decreased light conditions by sloughing its lower leaves (Adams et al. 1974). Madsen et al. (1991) found *M. spicatum* performs better physiologically in high light, whereas many native species are low light
adapted. However, light penetration can be reduced so much by a *M. spicatum* canopy that macrophytes such as *Elodea canadensis, Potamogeton amplifolius, P. gramineaus, P. prelongus, P. robbinsii* and *Vallisneria americana* can be shaded out (Madsen et al. 1991).

*Myriophyllum spicatum* grows over a wide temperature range, but optimal growth occurs from 30 to 35°C (Titus and Adams 1979). At these temperatures, multiple biomass peaks and fragmentation periods occur each year (Grace and Tilly 1976). On the other end of the temperature spectrum, it can photosynthesize down to 10°C (Stanley and Naylor 1972). The ability to conduct photosynthesis at low temperatures allows for rapid spring growth (Barko et al. 1982). Although *M. spicatum* can be damaged by freezing hydrosoil temperatures (Stanley 1976), some shoots survive through winter without forming specialized overwintering structures such as turions (Perkins and Sytsma 1987). Other shoots are initiated in fall, but do not begin growth until spring. Because *M. spicatum* can thrive over a wide range of light and temperature conditions, it has the ability to become a dominant macrophyte in aquatic ecosystems (Madsen et al. 1991).

*Myriophyllum spicatum* prefers systems with an intermediate trophic status because it lacks the ability to compete with slower growing, nutritionally conservative species such as *Isoetes* spp. in oligotrophic ecosystems, and may be excluded by shading from phytoplankton and attached algae in hypereutrophic systems (Jones et al. 1983, Moss 1983). *Myriophyllum spicatum* is most successful in fine-textured inorganic sediments with a density near 0.9 g/mL (Barko and Smart 1986).
Aluminum sulfate added to water binds with available dissolved phosphate to form aluminum phosphate. The aluminum phosphate then precipitates to the sediments, effectively removing phosphorus from the water column (Horne and Goldman 1994). Messner and Narf (1987) found no reduction in *M. spicatum* growth when aluminum sulfate was added to the water to remove phosphorus, suggesting that its primary mode of phosphorus uptake is through the root system. *Myriophyllum spicatum* absorbs nitrogen as ammonium from sediment or as ammonium and/or nitrate from the water (Nichols and Keeney 1976). Uptake of cations and micronutrients occurs from the sediment where concentrations are greater than in the water column (Barko and Smart 1986). Carbohydrates are stored throughout the root and shoot system in *M. spicatum* (Perkins and Sytsma 1987).

Fragmentation is the primary mode of *M. spicatum* dispersal (Madsen et al. 1988), and fragments are often transported from one lake to another on boats and waterfowl. Submersed plants can be displaced following *M. spicatum* introduction (Bowes et al. 1977). For example, in Devils Lake, Wisconsin, USA, *M. spicatum* was found to be the second most abundant macrophyte (Lillie 1986). Its greatest abundance was in three large communities measuring 25 - 50 m by 300 m. Apparently, *M. spicatum* had reduced coverage and biomass of the third most abundant species, *Elodea canadensis*, in one area of the lake. However, the dominant species, *Potamogeton robbinsii*, was not displaced by *M. spicatum*. Lillie (1986) was unable to determine whether *M. spicatum* displaced the exotic *E. canadensis* or merely colonized areas vacated by *E. canadensis*. In the St. Clair and Detroit Rivers, *M. spicatum* caused minor problems, but did not displace native
vegetation in most areas (Schloesser and Manny 1984). This could be because it is not as well adapted to rivers. There are apparently no documented cases of *M. spicatum* completely displacing native macrophytes.

A typical *M. spicatum* "invasion" includes a period of explosive growth for 5-10 years, followed by slow decline. This resembles the population growth patterns of many organisms introduced to areas devoid of natural predators (Carpenter 1980). However, both native and exotic organisms have been observed feeding on *M. spicatum* in laboratory studies. Two native species, *Cricotopus myriophylli* (Chironomidae: Diptera) and *Euhrychiopsis lecontei* (Curculionidae: Coleoptera), feed on *M. spicatum* (McRae et al. 1990, Newman and Maher 1995). The non-native *Acentria* sp. (Pyralidae: Lepidoptera) and *Ctenopharyngodon idella* Val. (Chinese grass carp) have also been observed feeding directly on *M. spicatum* (Leslie et al. 1983). Carpenter (1980) hypothesized that *M. spicatum* declines in ecosystems not possessing these herbivores may result from a range of other factors such as toxin accumulation, herbicide application, harvesting, climate, nutrient availability, epiphytes, parasites, pathogens and inter/intraspecific competition.

In a long term study in Lake Opinicon, Ontario, Canada, Keast (1984) found that sediment organic matter content increased in areas colonized by *M. spicatum*. This change from preferred inorganic sediments (Barko and Smart 1986) may be another possible explanation for eventual *M. spicatum* decline. Keast (1984) also found that in the seven years between sample collections *M. spicatum* had primarily colonized 2.5-3.5 m depths which had minimal macrophyte coverage in the earlier samples. Minimal
penetration occurred in areas already dominated by *Potamogeton robbinsii*, *P. zosteriformis*, *P. richarsonii*, *P. pusillus* and *Vallisneria americana*. Elevated dissolved oxygen levels were measured above the sediment-water interface in *M. spicatum* sites, but no temperature variations were noted. *Myriophyllum spicatum* introduction had little effect on fish distribution and movements in Lake Opinicon. Benthic Amphipoda, Isopoda, Chironomidae (Diptera), Ephemeroptera and Lamellibranchia (Bivalvia: Mollusca) densities were greater in *M. spicatum* beds than in samples collected from the same sites that had possessed minimal vegetation seven years earlier. However, significantly fewer benthic macroinvertebrates/m² of sediment and epiphytic macroinvertebrates/m² of vegetation were found in *M. spicatum* beds than in mixed beds of *Potamogeton* spp. and *V. americana* (Keast 1984).

Similar to previous studies, Pardue and Webb (1985) found greater macroinvertebrate density and taxa richness in *M. spicatum* beds relative to open littoral areas, but the differences tended not to be statistically significant. Probably due to lack of habitat or food in the open sites, many macroinvertebrates had densities in *M. spicatum* areas double those in open littoral areas. Conversely, the burrowing mayfly *Hexagenia bilineata* (Ephemeridae: Ephemeroptera) was more abundant in open littoral areas, possibly due to difficulty burrowing in root systems. This may explain why Rasmussen (1988) found greater benthic macroinvertebrate biomass beneath open areas, while other researchers have observed greater benthic macroinvertebrate densities below macrophyte beds.
In summary, Keast et al. (1984) and Pardue and Webb (1985) found that the hydrosoil below *M. spicatum* beds provided better habitat than open areas. Krecker (1939) found *M. spicatum* supported greater macroinvertebrate density than other aquatic plants, but Keast (1984) found that *M. spicatum* supported lower macroinvertebrate densities than other macrophyte species. Because of the uncertainty about how *M. spicatum* affects macroinvertebrate populations, the objective of the work reported in Chapter One of this thesis was to evaluate whether epiphytic macroinvertebrate communities differ between *M. spicatum* and native vegetation in Auburn and Zumbra Lakes, Minnesota, USA.

**Control of Nuisance Macrophytes**

Nuisance macrophytes can cause problems such as reducing macrophyte species richness and dissolved oxygen, clogging water inlets and outlets, curtailing recreational activities, and adversely affecting other aquatic organisms. The three types of control strategies used to treat these pestiferous species are biological, physical and chemical control.

**Biological Control**

Biological control uses one organism to control another. The Chinese grass carp (*Ctenopharyngodon idella* Val.) was brought to the United States in 1963 to control nuisance macrophytes. Prior to establishment of Chinese grass carp in Deer Point Lake, Florida, USA, 1/3 of the lake possessed a surface apparent mix of *Potamogeton illinoensis* Morong and *M. spicatum* (Leslie et al. 1983). This sparsely developed reservoir with a mean depth of 2.3 m was stocked with 61 Chinese grass carp/ha.
Submerged macrophyte coverage declined to 66% and 97% of the original coverage in the third and fourth years following stocking, respectively, and *P. illinoensis* was eliminated by the fourth year. In addition, mean vegetative species richness from 16 sites was reduced from 15 to 7 in 4 years. Due to the large reduction in nontarget vegetation, it was concluded that the Chinese grass carp would not selectively control *M. spicatum*.

The use of native organisms for *M. spicatum* control has also been investigated.

Native insects such as *Euhrychiopsis lecontei* (Curculionidae: Coleoptera) and *Cricotopus myriophylli* (Chironomidae: Diptera) may provide more selective *M. spicatum* control. The weevil, *E. lecontei*, significantly reduced *M. spicatum* growth through larval and adult feeding on *M. spicatum* meristems, leaves and stems in a laboratory study (Creed and Sheldon 1993). In addition, *E. lecontei* feeding on *M. spicatum* created lesions that may have caused increased susceptibility to bacterial and fungal infections, and loss of buoyancy. In another laboratory study, McRae et al. (1990) found that larval *C. myriophylli* herbivory on *M. spicatum* meristems negatively affected plant growth. When colonized by one or more of these midge larvae, *M. spicatum* did not increase in length or biomass. Both *E. lecontei* and *C. myriophylli* prefer feeding on *M. spicatum* over the native congener *Myriophyllum sibiricum* when both plants are present (Creed and Sheldon 1993, McRae et al. 1990). In addition, Newman et al. (1997) found that developmental performance of *E. lecontei* reared on *M. spicatum* was as good or better than those reared on its native host *M. sibiricum*. Animal species are not the only potential control organisms. Fungi may also be used as a biocontrol agent.
Mycelia of the pathogenic fungus *Pythium carolinianum* isolated from *Myriophyllum brasiliense* (Camb.) were introduced to other *M. brasiliense* populations by Bernhardt and Duniway (1984). Up to 30% reductions in *M. brasiliense* biomass were achieved 13 weeks after centralized application of *P. carolinianum* isolates in the field. Although *P. carolinianum* was also found in *M. spicatum*, *Potamogeton pectinatus* L., *P. crispus* L. and *P. nodosus* L. shoots and overwintering propagules, only isolates from *M. brasiliense* were effective for *M. brasiliense* control. A similar fungus for control of *M. spicatum* has apparently not been isolated.

In most cases, positive results from biocontrol are relatively slow to develop, and concerned property owners and natural resource managers often turn to relatively faster methods of control.

**Physical Control**

Physical control methods, such as lake drawdowns and weed harvesting, are generally faster alternatives to biological control. Lake drawdown in freezing temperatures can be an effective short-term solution (Bates et al. 1985). However, this non-selective method adversely affects all flora and fauna. Mechanical cutting of *M. spicatum* is not a viable option because it creates plant fragments which lead to increased dispersal (Eichler et al. 1993). With this knowledge, Eichler et al. (1993) tested the effectiveness of suction harvesting, using a diver operated, hydraulic vacuum system, on *M. spicatum* in Lake George, New York, USA. Suction harvesting reduced this nuisance species from first to fifth most abundant macrophyte species at the treatment sites. *Myriophyllum spicatum* composed greater than 30% of vegetative cover prior to
harvesting and was reduced to less than 5% following harvesting. Recovery increased *M. spicatum* coverage to approximately 7% in the following year. This method is moderately selective, but it did remove *Ceratophyllum demersum* L. closely associated with the target species. All but one of the 7 treated sites increased in macrophyte species richness in the year following harvesting, leading Eichler et al. (1993) to believe *M. spicatum* may displace native plant species. Costs from this study were calculated to be $1.58/m² or $15,800/ha for labor alone. The costly, labor intensive nature of this method decreases its feasibility.

Chemical Control

Chemical control of nuisance macrophytes employs the use of herbicides which have the potential to produce rapid control. Both laboratory and field studies into the effects these chemicals have on aquatic systems have been conducted. Laboratory studies tend to concentrate on herbicide effects on individual organisms.

Jones and Winchell (1984) exposed individual *Potamogeton perfoliatus* L., *Ruppia maritima* L., *Zannichellia palustris* L. and *M. spicatum* plant shoots in 300 ml bottles to 0, 10, 25, 50, 100 and 250 µg/L atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) for two hours. Linear regression calculations were used to calculate the concentrations of this Hill reaction inhibitor (Shimabukuro and Swanson 1969) that caused 1 and 50% photosynthetic inhibition in each of these macrophytes. Similar concentrations (17 - 20 µg/L) caused a 1% photosynthetic inhibition in all four species (Jones and Winchell 1984). However, concentrations that caused a 50% photosynthetic inhibition in *M. spicatum* (104 µg/L) and *Z. palustris* (102 µg/L) were
significantly greater than those that caused the same inhibition in *P. perfoliatus* (77 µg/L) and *R. maritima* (91 µg/L). These researchers also observed that oxygen production in all four macrophyte species was significantly reduced by atrazine concentrations greater than 50 µg/L during the two hour period. Jones and Winchell (1984) also compared the effect atrazine and its degradation products (deethylated, deisopropyl and hydroxyatrazine) had on oxygen production using a similar experimental design. They found that atrazine decreased oxygen production significantly more than any of its degradation products. Since atrazine did not display greater toxicity to *M. spicatum* than to the other macrophytes, atrazine probably would not provide selective control of *M. spicatum*. Although most atrazine enters water from agricultural lands through runoff, fluridone is a herbicide intentionally applied to aquatic systems.

Fluridone (1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4(1H)-pyridinone) is a herbicide that causes plant chlorosis and death through carotenoid inhibition (Bartels and Watson 1978). Carotenoids are protective pigments that occur in all autotrophs, and assist in harvesting light energy by sequestering and transferring it to chlorophyll for use in photosynthesis (Young 1991). Carotenogenesis proceeds from phytoene, which possesses 3 conjugated double bonds (cdb), to phytofluene, with 5 cdb, to ζ-carotene, with 7 cdb, to neurosporine, with 9 cdb, to normal carotenes and xanthophylls which possess 11 cdb (Bartels and Watson 1978). Fluridone interrupts this process by interfering with the dehydrogenation enzymes that change phytoene to ζ-carotene. Without these protective pigments, chlorosis occurs as a result of chlorophyll degradation.
(Mordi 1993). If fluridone degradation occurs before uptake, carotenogenesis inhibition may be reduced.

Radiolabeled fluridone is used to track fluridone breakdown in degradation studies. Radiolabeled fluridone can be produced by heating a \(^{14}\)C methyl iodide, sodium hydroxide and N-desmethylfluridone mixture in a sealed tube for one hour. Water is then added to the cooled mixture to remove sodium hydroxide. The product is extracted with hexane and subsequently purified using column and thin-layer chromatography (Muir and Grift 1982). By tracking and identifying radiolabeled fluridone degradation products, researchers have learned a great deal about its breakdown pathways.

Fluridone does not hydrolyze in water but is subject to photodegradation (McCowen et al. 1979). In a laboratory study, Muir and Grift (1982) found that fluridone degradation pathways differ between water and hydrosoil. Incomplete photodegradation of 5.0 mg/L fluridone in pond water was observed in 900 mL Pyrex flasks placed in sunlight but not in dark controls after 3, 6, 9, 16 and 26 months. In the same study, microbial degradation was noted in sediments below pond water containing 5.0 mg/L fluridone in 125 mL culture flasks but not in autoclaved trials. Muir and Grift (1982) recovered fluridone-acid (1,4-dihydro-1-methyl-4-oxo-5-[3-(trifluoromethyl)phenyl]-3-pyridinecarboxylic acid), and a small amount of 4-hydroxyfluridone (1-methyl-3-(4-hydroxyphenyl)-5-[3-(trifluoromethyl)phenyl]-4(1H)-pyridinone) and the 2-hydroxy derivative from the culture flask sediments. The water contained desphenylfluridone (1-methyl-3-[3-(trifluoromethyl)phenyl]-4(1H) pyridinone) along with the sediment degradates. Saunders and Mosier (1983) examined degradation of 1 \(\mu g\)/L fluridone from
lake and pond water exposed to sunlight in unstoppered 100 mL glass bottles. Sample analysis after 7, 14, 21 and 27 days identified 3-trifluoromethyl benzoic acid, 3-trifluoromethyl benzaldehyde, benzaldehyde, benzoic acid and N-methylformamide in the treated water. Although the degradates differed between these two studies, both found that fluridone is a degradable compound. Radiolabeled fluridone and residue analyses can also be used to track fluridone degradation in the field.

In three Canadian ponds with little vegetation, half-lives of radiolabeled fluridone in hydrosoils below 70 to 700µg/L fluridone treated water were greater than one year, while the same initial concentrations were halved in 7 to 4 days, respectively, in the water column (Muir et al. 1980). Similarly, West et al. (1979) found an average fluridone half-life in water of 5 days in ponds in Michigan, New York and Florida, USA. The shorter half-life of fluridone in water compared to other herbicides such as simazine (Mauck et al. 1976) can be attributed to rapid fluridone dispersion, photodegradation, assimilation and adsorption. Significant fluridone dispersion has been observed by Sanders et al. (1979) and Farone and McNabb (1993). Although Muir and Grift (1982) identified fluridone degradates in the laboratory, they were unable to identify any degradates in 2 small ponds during 20 weeks following one fluridone treatment at 100 µg/L, possibly due to increased photodegradation. In a New York pond, West et al. (1979) found fluridone was not only degraded, but also assimilated by macrophytes and adsorbed onto the hydrosoil. In the one vegetated pond studied by Muir et al. (1980), adsorption to soil particles lagged behind disappearance from the water because fluridone apparently was first assimilated by vegetation and released into the hydrosoil upon macrophyte death.
The soil half-life is believed to have decreased after a second treatment because fewer plants were present to assimilate the fluridone. Although fluridone can be stored in aquatic macrophytes, it is probably not concentrated to a great degree.

West et al. (1979) calculated bioconcentration factors in vegetation samples containing predominantly one plant species obtained from ponds treated with 0.1 and 0.3 mg/L fluridone. Fluridone bioconcentration factors for samples containing predominately *Elodea canadensis*, *Hydrilla verticillata* and *Potamogeton amplifolius* were 1.2-50.0, 0-31.7 and 0-15.5, respectively. These results are questionable because the macrophytes were not continuously exposed to fluridone. *Potamogeton pectinatus* and *P. richardsonii* continuously exposed to 1.0 mg/L fluridone under controlled laboratory conditions assimilated and/or adsorbed approximately 1% of applied fluridone (Marquis et al. 1982). Apparently, no fluridone bioconcentration studies have been conducted with *M. spicatum*, but a number of laboratory studies have looked into the effect of fluridone on target and nontarget species.

Anderson (1981) initiated growth of *Potamogeton nodosus* and *P. pectinatus* winterbuds (dormant buds) using a cold treatment. Winterbuds in culture medium were then treated with 0.0 or 1.0 mg/L fluridone under a 12 hr photoperiod. The winterbuds were exposed to light for 0, 3, 6, 9 or 15 days, and maintained without light for the remaining days of the 15 day experiment. Measurements were taken after a 31 day, 12 hr photoperiod recovery stage in the absence of fluridone. Fluridone treated *Potamogeton nodosus* winterbud lengths were statistically similar to untreated dark and light control winterbuds until the sixth photoperiod. Although treated *P. pectinatus* winterbuds not
exposed to light were significantly shorter than untreated dark and light controls, treated winterbud growth in both species decreased significantly with increasing photoperiod. Chlorophyll a concentrations measured in *Potamogeton pectinatus* were not significantly lower than in controls until exposure to 15 photoperiods. Results from this study suggest that longer photoperiods may increase fluridone toxicity to aquatic plants.

Netherland et al. (1993) found that a single treatment of 12 µg/L fluridone in controlled environment growth chambers resulted in a nonsignificant decrease in *M. spicatum* growth, biomass and total chlorophyll content, compared to controls. However, he also observed substantial *M. spicatum* regrowth within 30 days after fluridone removal, apparently because the plants had not been damaged enough to prohibit regrowth. Other laboratory research has examined the biochemical response of *M. spicatum* exposed to fluridone. For example, Sprecher et al. (1993) exposed *M. spicatum* to 0 and 12 µg/L fluridone for 30 days in a laboratory. A two-fold increase in *M. spicatum* peroxidase enzyme activity was observed in the treated *M. spicatum*. After a 30 day recovery period enzyme levels were similar to controls. Laboratory studies have also found that photosynthetic organisms other than macrophytes can be directly affected by carotenoid inhibitors.

Phytoplankton and algal aufwuchs are important primary producers in lentic ecosystems. Vaisberg and Schiff (1976) found that exposure to 20 mg/L of the carotenoid inhibitor SAN 9789 (4-chloro-5-(methylamino)-2-(α,α,α-trifluoro-m-tolyl-3(2H)pyridazinone) for 72 hr caused phytoene concentration in *Euglena* to increase because carotenogenesis was inhibited. Carotenoid inhibition lead to an increase in
chlorophyll degradation and a reduction in thylakoid structures in the proplastids. 

Trevors and Vedelago (1985) found that the green alga *Scenedesmus quadricauda* exhibited population growth inhibition when exposed to fluridone concentrations from 0.5 - 10.0 mg/L for 15 days after culture initiation. However, when fluridone was added six days after growth initiation, 0.5 - 10.0 mg/L fluridone did not negatively affect *S. quadricauda* population growth, suggesting that established populations may be less susceptible. Similarly, Millie et al. (1990) found that chlorophyll a and biomass of *Oscillatoria agardhii* exhibited inverse relationships with respect to fluridone concentration when this cyanobacterium was treated with 0 - 100 µg/L fluridone.

Fluridone can also affect non-photosynthetic organisms.

Hamelink et al. (1986) evaluated acute and chronic fluridone toxicity to several macroinvertebrate and fish species in a laboratory study. Macroinvertebrates used in the acute tests were *Daphnia magna* (Daphniidae: Cladocera), *Gammarus psuedolimnaeus* (Gammaridae: Amphipoda), *Chironomus plumosus* (Chironomidae: Diptera), *Orconcetes immunis* (Cambaridae: Decapoda), *Crassostrea virginica* (Mollusca) and *Penaeus duorarum* (Crustacea). Fish species used were sheepshead minnow (*Cyprinodon variegatus*), channel catfish (*Ictalurus punctatus*), bluegill sunfish (*Lepomis macrochirus*), fathead minnow (*Pimephales promelas*) and rainbow trout (*Salmo gairdneri*). Hamelink et al. (1986) found fluridone was slightly more toxic to macroinvertebrates (mean LC$_{50} = 4.3$ mg/L) than to fish (mean LC$_{50} = 10.4$ mg/L). In chronic tests *Daphnia magna* exhibited significantly lower survival and reproduction after exposure to 0.2 mg/L fluridone for 21 days. However, these toxic concentrations are
an order of magnitude greater than the application rate (10-20 µg/L) normally used for *M. spicatum* control (SePRO Corp. 1994).

Overall, the laboratory studies discussed above found that fluridone causes photosynthetic inhibition, reduced growth and chlorosis in macrophytes, and that concentrations which affect organisms other than macrophytes are greater than those that affect macrophytes. Field studies have also evaluated the effect of herbicides on biotic and abiotic components of ecosystems.

Gordon et al. (1982) investigated the effects of endothall (7-oxabicyclo[2.2.1]-heptane-2,3-dicarboxylic acid) and simazine (2-chloro-4,6-bis(ethylamino)-s-triazine) on biotic and abiotic components of treatment and control ponds in Illinois, USA. Endothall application at 0.3 mg/L to the epilimnion (68% of pond volume) nearly eliminated all macrophytes in less than three months, while simazine applications of 1.0 mg/L applied to the entire pond volume (no stratification) nearly eliminated all macrophytes in 30 days. With both herbicides, macrophyte decomposition lead to decreased dissolved oxygen and increased alkalinity, carbon dioxide, particulate carbon, specific conductivity, total carbon and total dissolved solids. Bacterial populations in water, sediments and attached to macrophytes remained constant in both herbicide treatments. However, the low dissolved oxygen concentrations from macrophyte decay apparently caused a decrease in zooplankton, bluegill sunfish (*Lepomis macrochirus*) and bass (*Amphloplites* sp.) densities in the endothall treated pond. Phytoplankton densities increased in this pond possibly because of increased nutrients or reduced zooplankton grazing. However, phytoplankton densities decreased in the simazine treated pond because simazine is an algal toxicant.
Densities of bass and zooplankton were also significantly reduced by simazine treatment, potentially due to the dissolved oxygen decrease or reduced phytoplankton availability. Ostracoda (Crustacea), an omnivore capable of feeding on detrital plant material (Thorp and Covich 1991), were the only macroinvertebrates positively affected by both herbicides. The higher application concentration and longer half life of simazine (Mauck et al. 1976) compared to endothall (Hiltibran 1962), and simazine's toxicity to algae were major factors in the difference in phytoplankton response.

DeNoyelles et al. (1982) examined the secondary effects of 20 µg/L atrazine on plankton in experimental ponds. Phytoplankton growth decreased and community composition was altered by atrazine treatment. Zooplankton density and biomass decreased, apparently because of the decreased phytoplankton food source. Dewey (1986) treated experimental ponds with 20 to 120 µg/L atrazine. Although increased concentrations decreased macrophyte biomass, the algal macrophyte Chara sp. was not affected at concentrations below 100 µg/L. Non-predatory insect densities (collector-gatherers, scrapers, grazers, macrophyte leaf miners and filterers) were significantly reduced in the 120 µg/L atrazine treatments possibly because of decreased food resources. There was no change in predatory insect densities, so a macroinvertebrate community composition change resulted.

A number of mesocosm and field studies have investigated the use of fluridone to control Hydrilla verticillata, an exotic macrophyte from Sri Lanka that infests waters in the southern U.S. (Van and Steward 1985, Schmitz et al. 1987, MacDonald et al. 1993, Miller et al. 1993). Doong et al. (1993) examined the effect of 0, 0.05, 0.5 and 50 µg/L
fluridone on mature and immature (5-day old) *H. verticillata* carotenoid and chlorophyll concentrations in 900 L outdoor vaults after 12 weeks. Carotenoid and chlorophyll levels decreased with increasing fluridone concentrations and exposure time in both mature and immature plants (Doong et al. 1993). Unfortunately some studies have only reported application rates.

Sanders et al. (1979) applied fluridone as 4 A.S. (aqueous suspension containing 4 lb active ingredient/gallon) at 0, 0.84, and 1.70 kg of active ingredient (AI)/ha at 18 test plots in Gatun Lake, Panama. Several plots treated with 0.84 kg AI/ha possessed chlorotic vegetation within one week followed by nonsignificant biomass decreases 4 to 8 weeks after treatment, while other *H. verticillata* beds treated at this concentration exhibited sublethal exposure characteristics such as isolated chlorosis. *Hydrilla verticillata* biomass decreased significantly in some plots treated at 1.70 kg AI/ha, and this application rate was determined to be the lowest of the tested concentrations to cause significant biomass reduction. Fluridone had little effect on dissolved oxygen, nitrate-nitrogen, ammonia-nitrogen, total phosphates, total alkalinity, specific conductance, apparent color, hardness or pH of water treated with 1.7 kg AI/ha relative to the reference areas. The half-life of fluridone in water samples ranged from 2 to 5 days, which may have been distorted due to fluridone dispersion to non-treated areas. Fluridone residues were not present in the hydrosoil of any plots. No significant differences between treatment and reference plots were observed in phytoplankton, zooplankton or benthic macroinvertebrate densities at any concentration.
Arnold (1979) also concluded that fluridone poses no significant threat to phytoplankton, zooplankton or benthic macroinvertebrates. He studied a pond treated with 0.3 mg/L fluridone for *H. verticillata* control. *Hydrilla verticillata*, *Cabomba caroliniana* Gray., *Elodea canadensis* Michx., *Najas guadalupensis* (Spreng.) Magnus., *Nuphar advena* Ait., *Panicum hemitomon* Schult., *Panicum purpurascens* Raddi, *P. repens* L., *Pontederia cordata* L., *Sagittaria* spp. and *Typha* spp. exposed to fluridone decreased in biomass in less than 81 days. No significant change in dissolved oxygen, pH, biological oxygen demand, color, dissolved solids, hardness, nitrate-N, specific conductance, total phosphates or turbidity was observed over the sampling period. Unlike the study by Sanders et al. (1979), hydrosoil residues suggested that, along with uptake by plants and photodegradation, fluridone was transferred from water to hydrosoil. Phytoplankton densities decreased, possibly as a result of fluridone toxicity at this relatively high concentration, while zooplankton densities may have decreased due to reduction in the phytoplankton food source. However, phytoplankton and zooplankton densities rebounded in 28 and 22 days, respectively, and benthic macroinvertebrate densities did not significantly differ between pretreatment and posttreatment samples. In contrast to the field work done on *H. vertillata* control, relatively few studies have investigated the ecological effects of herbicides used for *M. spicatum* control, and apparently no published studies have thoroughly investigated fluridone control of *M. spicatum* in the field.

Getsinger et al. (1994) examined the effect of 0, 25, 50 and 100 µg/L bensulfuron methyl (methyl-2-[[[[[(4,6-dimethoxy-2-pyrimidinyl)amino]-
carbonyl]amino]sulfonyl]methyl]benzoate) on *M. spicatum, V. americana* and *P. nodosus* in containers within outdoor fiberglass tanks. It was believed that bensulfuron methyl might be relatively safe because the site of action of this sulfonyleurea herbicide is the enzyme acetolactate synthase which is not present in animals (Colvin 1996). Acetolactate synthase catalyzes a step in the synthesis of the amino acids isoleucine and valine which are necessary for plant growth. After 12 weeks of herbicide treatment, *M. spicatum* biomass was significantly lower in each treatment than in the controls, and while the control shoot length increased by 35%, treated shoot lengths decreased by approximately 97% in each treatment concentration. *Vallisneria americana* and *P. nodosus* standing biomass was also significantly lower than the controls after 12 weeks. These results suggest that efficacy of this herbicide was more dependant on exposure period than on concentration. Bensulfuron methyl only inhibited growth when in contact with plants because healthy regrowth was observed in root crowns of all species from all treatments placed in clean water for 4 weeks following exposure, with least regrowth in plants exposed to the highest concentration. Although bensulfuron methyl may not be toxic to animals, it was just as toxic to the two native macrophytes as it was to *M. spicatum*. Therefore, it cannot be used for species-specific *M. spicatum* control.

Farone and McNabb (1993) used aerial imaging to evaluate vegetation changes caused by point application of 9.3 L/ha fluridone for *M. spicatum* control in selected areas of a 142 ha lake-pond ecosystem in Washington, USA. Fluridone reduced floating leaved plant coverage by an average of 28% within one year at several sites in direct contact with fluridone. Due to significant fluridone dispersion from the treated lake, total eradication
of floating leaved plants occurred within one year in the two connected ponds even though only one application was made on the groundwater connected pond, and no herbicide was applied to the surface water connected pond.

Many chemicals have been added to aquatic systems to control exotic vegetation. Herbicides such as endothall and simazine affect fauna and water chemistry. Similarly, atrazine negatively affects phytoplankton, zooplankton and insects. In addition, no herbicide has exhibited selective control of pestiferous macrophytes at suggested application rates. Predominately more studies have evaluated the effects of fluridone treatment on *H. verticillata* than on *M. spicatum* because *H. verticillata* causes major problems in areas that support year-round growth. Although fluridone has not offered selective control of exotic plant species at the tested concentrations, it does not decrease dissolved oxygen levels or affect other organisms at concentrations suggested for macrophyte control. Therefore, fluridone has become the herbicide of choice for controlling nuisance macrophytes.

The ultimate *M. spicatum* control strategy may be integrated pest management in which a combination of physical, biological and chemical control strategies is employed. For instance, *Neochetina eichhorniae* (Curculionidae: Coleoptera) and paclobutrazol (1-(4-chlorophenyl-4,4-dimethyl-2-1,2,4-triazol-1-yl)pentan-3-ol) were used in combination to effectively control *Eichhornia crassipes* (Mart.) Solms in outdoor tanks (Van and Center 1994). More research should be conducted in this area to integrate the benefits from various control methods.
Removal of too many aquatic plants is an unnecessary disruption for aquatic communities. Therefore, care must be taken not to induce extra strain on an ecosystem regardless the method(s) used. Beckett (1991, p. 88) stated:

Aquatic macrophytes are often regarded as nuisances and are removed by herbicides, drawdown, or mechanical means. Removal of these plants creates, in effect, larger expanses of our “open zones” with the same physical features. Much of the structure of the habitat is lost, and finer sediments are eroded since the habitat now lacks the plants which formerly reduced water movement.

The objective of the work reported in Chapter Two of this thesis was to investigate if fluridone treatment significantly influenced epiphytic macroinvertebrate assemblages associated with *M. spicatum* and native vegetation in Zumbra Lake, Minnesota, USA. A field approach was used because single-species laboratory tests do not provide an adequate estimate of toxicity at the ecosystem level (Pontasch and Cairns 1991). Fluridone was used because it has not been found to cause decreased dissolved oxygen as a result of rapid macrophyte decomposition, or harm organisms other than aquatic plants. In addition, there is a lack of published field research on *M. spicatum* control with this herbicide.

In summary, this thesis is composed of two chapters. The first chapter is concerned with *M. spicatum* ecology, and the macroinvertebrates associated with *M. spicatum* and native vegetation. The second chapter investigates the indirect effects of fluridone applied for *M. spicatum* control on epiphytic macroinvertebrates.
Literature Cited


CHAPTER ONE

EPHYTIC MACROINVERTEBRATE COMMUNITIES ASSOCIATED
WITH DISSIMILAR AQUATIC MACROPHYTE ASSEMBLAGES

Abstract

To evaluate the effects of the exotic macrophyte *Myriophyllum spicatum* (Eurasian watermilfoil) on epiphytic macroinvertebrate communities, samples were collected at three sites in both Auburn and Zumbra Lakes, Minnesota, USA. One site in each lake contained primarily *M. spicatum*, the second site contained *M. spicatum* and native vegetation, and the third site was dominated by native vegetation. Mean macroinvertebrate taxa richness, total density and biomass were significantly higher in Auburn Lake than at corresponding sites in Zumbra Lake on most dates. Several significant differences in mean epiphytic macroinvertebrate taxa richness, total density and biomass were observed among the sites within both Auburn and Zumbra Lakes. However, these differences followed no apparent trend suggesting that epiphytic macroinvertebrates do not selectively colonize any of the macrophyte assemblages studied in Auburn or Zumbra Lakes.

Keywords: *Myriophyllum spicatum*, Macroinvertebrates, Macrophytes
Introduction

Macrophytes can alter water chemistry, sediment composition, light attenuation, temperature and water flow in aquatic systems (Wetzel 1960, Titus and Adams 1979, Dale and Gillespie 1977, Morris and Barker 1977, Weiler 1978, Sondergaard 1981, Pokorny and Rejmankova 1983, Ondok et al. 1984). However, this research focused on how macrophytes affect biotic interactions. Macrophytes support assemblages of attached algae, bacteria, fungi, small metazoa and protozoa (Horne and Goldman 1994). The algae in these epiphytic “aufwuch” communities make a major contribution to primary production in lentic ecosystems (Lalonde and Downing 1991). These communities provide nutrition for many grazing macroinvertebrates which, in turn, become a source of food for invertebrate and vertebrate predators (Ogilvie 1988, Elser and Goldman 1991, Hann 1991, Shannon et al. 1994). Macrophyte loss could adversely affect macroinvertebrate communities through loss of the epiphytic food source associated with these plants, and the refugia they offer from vertebrate predators such as fish (Losee and Wetzel 1988, Schramm Jr. and Jirka 1989, Newman 1991). However, macrophytes also provide food and shelter for fish (Horne and Goldman 1994). Some fish consume aquatic plants and/or the organisms on them. Larval fish and smaller adult fish use these areas to escape predation by larger fish because plant beds offer cover and are often too dense for larger fish to enter.

Previous studies have examined the effect of macrophyte presence on macroinvertebrates. Beckett et al. (1991) observed a significant difference between benthic macroinvertebrate densities in the hydrosoil below vegetated areas and open
areas. Total benthic macroinvertebrate densities were significantly greater below *Ceratophyllum demersum* and *Potamogeton nodosus* beds than below open areas. An average of 45 species was found below vegetated beds, while open areas only averaged 18 species. However, Rasmussen (1988) found that although greater macrophyte biomass resulted in increased epiphytic macroinvertebrate biomass, benthic macroinvertebrate biomass decreased below the denser macrophyte beds. Other researchers have found that epiphytic macroinvertebrate assemblages supported by aquatic macrophytes may also differ among plant species.

Rosine (1955) found that plants with highly dissected leaves supported more epiphytic macroinvertebrates. In Muskee Lake, Colorado, USA, he noted that 100 cm² of *Chara delicatula* Ag., a macrophytic algae with a highly dissected morphology, tended to support more total epiphytic macroinvertebrates than the same area of *Potamogeton gramineus* L. and *Polygonum natans*, two flat-leaved vascular macrophytes. Other researchers have had similar results (Krecker 1939, Mrachek 1966). These findings suggest that 2º production would be higher in beds of macrophytes with a highly dissected morphology such as *Myriophyllum spicatum* L.

*Myriophyllum spicatum* L. (Eurasian watermilfoil) is native to Europe, Asia and northern Africa (Smith and Barko 1990). In North America, *M. spicatum* is considered a pestiferous exotic species. Following introduction to the eastern United States near the turn of the century, *M. spicatum* had spread to 41 states by 1996 (Grodowitz et al. 1997). *Myriophyllum spicatum* is a submersed macrophyte, with a branched leafy shoot 0.5-7 m long, that is usually found in water 1-3 m deep (Aiken et al. 1979). Although *M.*
*spicatum* is found in all levels of water clarity, it forms a horizontal surface canopy in shallow, turbid water (Titus and Adams 1979). In less turbid water, it can be found at greater depths, and it may not reach the surface (Madsen et al. 1989). Light penetration can be reduced so much by *M. spicatum*’s dense canopy that macrophyte species such as *Elodea canadensis, Potamogeton amplifolius, P. gramineus, P. praelongus, P. robbinsii* and *Vallisneria americana* can be shaded out (Madsen et al. 1991). Although *M. spicatum* grows over a wide temperature range, optimal growth occurs from 30 to 35°C (Titus and Adams 1979). At these temperatures, multiple biomass peaks and fragmentation periods occur each year (Grace and Tilly 1976). On the other end of the temperature spectrum, it can photosynthesize down to 10°C (Stanley and Naylor 1972) which allows for rapid spring growth (Barko et al. 1982). Because *M. spicatum* can thrive over a wide range of light and temperature conditions, it has the potential to become a dominant macrophyte in aquatic ecosystems (Madsen et al. 1991). Fragmentation is the primary mode of dispersal of this species (Madsen et al. 1988).

After introduction to Devils Lake, Wisconsin, USA, in less than 10 years *M. spicatum* became the second most abundant macrophyte in terms of coverage and biomass by displacing the third most abundant species, *Elodea canadensis* (Lillie 1986). The most dominant species in Devils Lake, *Potamogeton robbinsii*, was not displaced by *M. spicatum*. In Lake Wingra, Wisconsin *M. spicatum* was believed to have displaced *Vallisneria americana, Potamogeton amplifolius, P. illinoensis, P. freisii* and *P. praelongus* (Nichols and Mori 1971). In contrast, *M. spicatum* colonization in Lake Opinicon, Ontario, Canada, occurred primarily in areas with little native macrophyte
coverage, and it only penetrated minimally into established beds of *Potamogeton robbinsii*, *P. zosteriformis*, *P. richardsonii*, *P. pusillus* and *Vallisneria americana* (Keast 1984). Although *M. spicatum* may displace native species, few studies have investigated the effects of *M. spicatum* “invasions” on macroinvertebrate communities.

Epiphytic macroinvertebrate taxa richness, density and biomass have been quantified per unit of plant surface area, plant length, plant biomass and sediment area. Because these observations cannot be numerically compared, it is difficult to make comparisons among studies that quantified epiphytic macroinvertebrates differently. Keast (1984) found that mixed beds of *Potamogeton* spp. and *Vallisneria americana* in Lake Opinicon supported significantly more benthic macroinvertebrates/m² of sediment and epiphytic macroinvertebrates/m² of vegetation surface than *M. spicatum*. In contrast, Krecker (1939) found that *M. spicatum* and *Potamogeton crispus* tended to support higher epiphytic macroinvertebrate densities/3.33 m of plant length than *Potamogeton compressus*, *P. pectinatus*, *Elodea canadensis*, *Najas flexilis* and *Vallisneria spiralis*. He also observed approximately the same number of macroinvertebrate genera/3.33 m of plant length on *M. spicatum* as on *Potamogeton crispus*, *Najas flexilis* and *Elodea canadensis*.

*Myriophyllum spicatum* has the ability to become abundant in aquatic systems, but the few previous studies that examined the effect of *M. spicatum* on epiphytic macroinvertebrate communities were not conclusive. Therefore, the objective of this study was to determine if mean epiphytic macroinvertebrate taxa richness, total density
and biomass varied among macrophyte beds with different amounts of *M. spicatum* in Auburn and Zumbra Lakes, Minnesota, USA.

**Materials and Methods**

**Study Area**

*Myriophyllum spicatum* was first observed in Auburn and Zumbra Lakes in 1989. These two Minnesota lakes were sampled in July, August and September, 1993 to evaluate epiphytic macroinvertebrate community structure present in "*M. spicatum,*" "mixed" (*M. spicatum* and native vegetation) and "native" vegetation beds.

Auburn Lake has two basins separated by a cattail (*Typha* sp.) marsh (Fig. 1.1). The nearly circular western basin used in this study has a surface area of 57.1 ha, a maximum depth of 25.6 m and a littoral zone that occupies approximately 48% of the basin. Water enters this basin from two adjoining wetlands and flows out via an outlet at the north end. Areas not bordered by wetlands have deciduous trees in the shoreline riparian zone. This moderately fertile, hard-water basin (Table 1.1) had rooted vegetation down to 3 m depth in 1993. Crowell et al. (1996) found thirteen submersed, free-floating and floating-leaved plant taxa in 1993. Treatment with 2,4-dichlorophenoxyacetic acid (2,4-D) and Garlon A (active ingredient - triclopyr) in the littoral zone each year from 1989 to 1993 did not slow *M. spicatum* spread in Auburn Lake.
Fig. 1.1. Map of Auburn Lake, Minnesota showing the location of the "M. spicatum," "mixed" and "native" sites. Six samples were collected at each site in July, August and September, 1993.
Table 1.1. Mean (± 1 std error) chlorophyll a, secchi depth, total phosphorus and turbidity in Auburn and Zumbra Lakes from July through September, 1993. Adapted from Crowell et al. (1996).

<table>
<thead>
<tr>
<th>Lake</th>
<th>Chlorophyll a (µg / L)¹</th>
<th>Secchi Depth (m)¹</th>
<th>Total Phosphorus (mg / L)¹</th>
<th>Turbidity (ntus)²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auburn</td>
<td>31.2 ± 7.95</td>
<td>1.4 ± 0.13</td>
<td>0.041 ± 0.003</td>
<td>4.4 ± 0.28</td>
</tr>
<tr>
<td>Zumbra</td>
<td>16.8 ± 1.73</td>
<td>2.1 ± 0.19</td>
<td>0.026 ± 0.003</td>
<td>2.6 ± 1.5</td>
</tr>
</tbody>
</table>

¹n = 5; ²n = 12

Zumbra Lake's irregular shoreline surrounds a 65.6 ha basin with a maximum depth of 17.7 m (Fig. 1.2). The littoral zone occupies 55% of the basin and rooted vegetation was found down to 4 m depth in 1993. Although there is no permanent flow, water is transported to/from other lakes during high water periods. Zumbra Lake is also a moderately fertile, hard-water lake. However, it was not as eutrophic as Auburn Lake in 1993 (Table 1.1). Its shoreline is moderately developed and in some areas lawns reach the water. In undeveloped areas, woodlands and marshes are dominant. In each of the four years following identification of *M. spicatum* in Zumbra Lake (1989-1992) 2,4-D was applied (Garlon A was not used), but it was unable to slow *M. spicatum* spread. In 1993, twenty submersed, free-floating and floating-leaved vascular plant taxa were found in Zumbra Lake (Crowell et al. 1996).

Three sampling sites were established in each lake based on *M. spicatum* abundance. The "*M. spicatum*" site was dominated by *M. spicatum*, the "mixed" site contained roughly equal amounts of *M. spicatum* and native vegetation and the "native" site contained primarily native vegetation.
Fig. 1.2. Map of Zumbra Lake, Minnesota showing the location of the "M. spicatum," "mixed" and "native" sites. Six samples were collected at each site in July, August and September, 1993.
Sample Collection and Analysis

Three macrophyte samples were taken from both 1 and 2 m depths at each site in July, August and September, 1993. The sampler consisted of a clear polyethylene bag (0.093 m\(^2\) x 1.7 m) with an attached 0.5 mm mesh sieve on the top and a removable 0.5 mm mesh sieve on the bottom. Divers drew the sampler over macrophytes to the sediment-water interface. Macrophyte stems were detached from their roots, and the sieve at the base of the sampler was attached. Each sample collected all macrophytes from 0.093 m\(^2\) of sediment. After excess water had drained through the bottom sieve it was removed, and the macrophytes were placed in jars containing rose bengal and 70% EtOH. The samples were then transferred to the laboratory for macroinvertebrate sorting and identification. Some samples were subsampled because of excessive macroinvertebrate densities. Subsamples were taken by randomly selecting vegetation from one quadrant of a four quadrant sample splitter. Samples and subsamples were sorted by hand to separate macroinvertebrates from macrophytes using a 2X magnification lens. Macroinvertebrates were identified to the lowest practical taxonomic level using keys by Merritt and Cummins (1984), and Thorp and Covich (1991). Coleoptera, Ephemeroptera, Lepidoptera, Odonata (Insecta) and Gastropoda (Mollusca) were identified to genus. Trichoptera (Insecta) were identified to either genus or species, while Diptera (Insecta) were identified to various taxonomic levels. For example, dipterans such as *Probezzia glabra* (Ceratopogonidae) were identified to species, while the thousands of Chironomidae were only identified to subfamily because further identification requires mounting individual head capsules. Although *Hyalella azteca*
(Crustacea: Amphipoda) was identified to species, other members of class Crustacea (Cladocera, Copepoda, Isopoda and Ostracoda) were only identified to order. Annelida in class Hirudinea were identified to species, but organisms in class Oligochaeta (Annelida) were not identified further. The “Other” category was composed of Subclass Acari (Arthropoda: Arachnida), Phylum Nematoda, Dugesia sp. (Turbellaria: Macroturbellaria), Corixidae (Insecta: Hemiptera) and Hydra sp. (Cnidaria: Hydroidea). These taxa were found in low and/or highly variable densities over time.

Mean biomass measurements in this study are only relative values because macroinvertebrates tend to lose mass when stored in EtOH (Heise et al. 1988). Samples were dried at 60°C in uniform foil envelopes to a constant weight. Once cool, dry weights were measured and recorded. The envelopes were then ashed in a muffle furnace at 500°C for 2 hours, cooled to room temperature in a desiccator, and the ash weights were recorded. The dry weight minus the ash weight is reported as the ash-free dry weight (AFDW).

Data Analysis

Raw macroinvertebrate data in this study were not normally distributed and transformations of raw mean taxa richness, total density and biomass data did not sufficiently normalize the distributions. Therefore, the nonparametric one-way Kruskal-Wallis test was used to compare macroinvertebrate community structure data in corresponding sites between lakes, among sites within each lake during separate months, and within each site over the sampling period.
Results

Mean macroinvertebrate taxa richness, total density and biomass were significantly higher on most dates in Auburn Lake than at corresponding sites in Zumbra Lake (Table 1.2). In addition, Coleoptera and Lepidoptera were found in Auburn Lake but not in Zumbra Lake. Therefore, data from the two lakes have been analyzed separately.

Auburn Lake

Mean taxa richness in Auburn Lake was similar among sites during July and August (Fig. 1.3). However, lower taxa richness at the “M. spicatum” site in September caused a significant difference among the sites. Although Ephemeroptera was the only taxonomic group that did not have lower mean taxa richness at the “M. spicatum” site than at one of the other sites in September (Table 1.3), the significant September decrease in taxa richness at the “M. spicatum” site (Fig. 1.4) was caused primarily by reduced numbers of Trichoptera taxa (Table 1.4).

Mean macroinvertebrate total density at the “M. spicatum” site in Auburn Lake was greater than at the other two sites in July and August, but these differences were not statistically significant (Fig. 1.5). However, density was significantly higher at the “mixed” and “native” sites in September because of a significant drop in total density at the “M. spicatum” site in combination with nonsignificant increases at the “mixed” and “native” sites (Fig. 1.6). Lower September density at the “M. spicatum” site relative to the “mixed” and “native” sites was caused by lower Annelida, Crustacea, Diptera, Odonata, Trichoptera and “Other” densities (Table 1.5), while the decrease within the
Table 1.2. Comparison of mean macroinvertebrate taxa richness, total density and biomass between sites in Auburn and Zumba Lakes in July, August and September, 1993. P values are from a Kruskal-Wallis test; n = 6.

<table>
<thead>
<tr>
<th>Site</th>
<th>Month</th>
<th>Lake</th>
<th>Mean Taxa Richness/0.093 m²</th>
<th>Mean Taxa Richness/0.093 m² Standard Error</th>
<th>Density Mean/m²</th>
<th>Density/m² Standard Error</th>
<th>Density/m² P Value</th>
<th>Biomass (g/m²) Mean</th>
<th>Biomass (g/m²) Standard Error</th>
<th>Biomass (g/m²) P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;M. spicatum&quot;</td>
<td>July</td>
<td>Auburn</td>
<td>21.0000</td>
<td>1.97</td>
<td>10877.8300</td>
<td>3608.50</td>
<td>0.0063</td>
<td>0.3770</td>
<td>0.1040</td>
<td>0.0161</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Zumba</td>
<td>7.8333</td>
<td>2.73</td>
<td>1399.7800</td>
<td>690.82</td>
<td>0.0998</td>
<td>0.0536</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>August</td>
<td>Auburn</td>
<td>19.5000</td>
<td>3.08</td>
<td>15547.9400</td>
<td>6869.60</td>
<td>0.0547</td>
<td>0.4826</td>
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<td>Zumba</td>
<td>11.1667</td>
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<td>September</td>
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<td>21.8333</td>
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<td>0.9255</td>
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<td>1.33</td>
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<td>7487.5700</td>
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<td>Auburn</td>
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Fig. 1.3. Mean macroinvertebrate taxa richness/0.093 m² at the "M. spicatum," "mixed" and "native" sites in Auburn Lake in July, August and September, 1993. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences among sites on each sampling date.
Table 1.3. Comparison of mean macroinvertebrate taxa richness/0.093 m\(^2\) at the "M. spicatum," "mixed" and "native" sites in Auburn Lake during July, August and September, 1993. P values are from a Kruskal-Wallis test for differences among sites on each sampling date.

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Month</th>
<th>Site</th>
<th>Mean</th>
<th>Standard Error</th>
<th>P Value</th>
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<tbody>
<tr>
<td>Phylum Annelida</td>
<td>July</td>
<td>M. spicatum</td>
<td>0.8333</td>
<td>0.31</td>
<td>0.1831</td>
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<td></td>
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<td>1.8333</td>
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<td>0.65</td>
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<td>M. spicatum</td>
<td>1.1667</td>
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Fig. 1.4. Mean macroinvertebrate taxa richness/0.093 m² in July, August and September, 1993 at the "M. spicatum," "mixed" and "native" sites in Auburn Lake. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences within sites over the sampling period.
Table 1.4. Comparison of mean macroinvertebrate taxa richness/0.093 m² in July, August and September, 1993 at the “M. spicatum,” “mixed” and “native” sites in Auburn Lake. P values are from a Kruskal-Wallis test for differences within sites over the sampling period.

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Fig. 1.5. Mean total macroinvertebrate densities/m$^2$ at the "M. spicatum," "mixed" and "native" sites in Auburn Lake in July, August and September, 1993. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences among sites on each sampling date.
Fig. 1.6. Mean total macroinvertebrate densities/m² in July, August and September, 1993 at the "M. spicatum," "mixed" and "native" sites in Auburn Lake. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences within sites over the sampling period.
Table 1.5. Comparison of mean macroinvertebrate densities/m² at the “M. spicatum,” “mixed” and “native” sites in Auburn Lake during July, August and September, 1993. P values are from a Kruskal-Wallis test for differences among sites on each sampling date.

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“M. spicatum” site over time was predominantly due to decreased Crustacea and Diptera densities (Table 1.6). Overall, none of the groups exhibited preferences among vegetation types during the study period. For example, mean Diptera and Odonata densities were highest at the “M. spicatum” site in July and August, but lowest at that site in September (Table 1.6).

In Auburn Lake, mean biomass did not significantly differ among sites on any sampling date (Fig. 1.7) or within a site over time (Fig. 1.8). Although mean total biomass was highest at the “native” site and lowest in the “M. spicatum” site in September, a trend that reflects the density differences noted above, high within-site variability, which may have resulted from the presence or absence of larger organisms such as trichopterans, ephemeropterans and odonates, resulted in no significant difference among sites (Fig. 1.7). In addition, the biomass similarities among sites in July and August suggest that macroinvertebrate biomass, an important indicator of “fish food” availability, was not decreased in “M. spicatum” areas.

Zumbra Lake

No significant differences in mean taxa richness among sites were present in Zumbra Lake during the sampling period (Fig. 1.9). Although the number of taxa at the “native” site was close to being significantly higher in July (P = 0.0531), the “native” site supported an almost significantly lower (P = 0.0638) mean number of taxa during September. Greater “native” taxa richness in July resulted from more Crustacea, Diptera, Ephemeroptera, Odonata, Trichoptera and “Other” taxa (Table 1.7). Conversely, the higher mean taxa richness in the “M. spicatum” and “mixed” sites relative to the “native”
Table 1.6. Comparison of mean macroinvertebrate densities/m² in July, August and September, 1993 at the "M. spicatum," "mixed" and "native" sites of Auburn Lake. P values are from a Kruskal-Wallis test for differences within sites over the sampling period.

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Fig. 1.7. Mean macroinvertebrate AFDW (g/m²) at the "M. spicatum," "mixed" and "native" site in Auburn Lake in July, August and September, 1993. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences among sites on each sampling date.
Fig. 1.8. Mean macroinvertebrate AFDW (g/m²) in July, August and September, 1993 at the "M. spicatum," "mixed" and "native" sites in Auburn Lake. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences within sites over the sampling period.
Fig. 1.9. Mean macroinvertebrate taxa richness/0.093 m$^2$ at the "M. spicatum," "mixed" and "native" sites in Zumbra Lake in July, August and September, 1993. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences among sites on each sampling date.
Table 1.7. Comparison of mean macroinvertebrate taxa richness/0.093 m$^2$ at the “M. spicatum,” “mixed” and “native” sites in Zumba Lake during July, August and September, 1993. P values are from a Kruskal-Wallis test for differences among sites on each sampling date.

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site in September was a result of greater mean Annelida, Ephemeroptera, Gastropoda, Odonata, Trichoptera and "Other" taxa. Within sites over time, mean total taxa richness increased at the "M. spicatum" site, increased significantly at the "mixed" site, and decreased at the "native" site (Fig. 1.10). July and August were significantly different from September at the "mixed" site because mean taxa richness within major taxonomic groups increased in September (Table 1.8). Overall, it appears that in Zumbra Lake M. spicatum has the ability to support as many macroinvertebrate taxa as "native" vegetation.

In July, the "native" site tended to support higher densities of macroinvertebrates than the other two sites (Fig. 1.11). However, the "M. spicatum" site supported the most macroinvertebrates in both August and September, with significantly greater mean total densities at the "M. spicatum" and "native" sites than at the "mixed" site during August. Higher mean total density at the "native" site in July was caused by higher Diptera, Ephemeroptera, Odonata, Trichoptera, and "Other" densities relative to the other two sites (Table 1.9). In August, lower mean Annelida and Diptera densities at the "mixed" site were the major reason for the significantly lower mean total density at that site. Dipterans were the one taxa responsible for the higher mean total density at the "M. spicatum" site in September. Mean total macroinvertebrate densities at the three sites exhibited different trends over time (Fig. 1.12). They decreased slightly in the "native" site after July, increased in the "mixed" site, and increased significantly in the "M. spicatum" site. Greater Annelida, Diptera, Ephemeroptera and Odonata mean densities caused the higher densities at the "M. spicatum" site in August and September (Table 1.10). The increase in mean total densities over the sampling period at the "mixed" site
Fig. 1.10. Mean macroinvertebrate taxa richness/0.093 m² in July, August and September, 1993 at the "M. spicatum," "mixed" and "native" sites in Zumbra Lake. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences within sites over the sampling period.
Table 1.8. Comparison of mean macroinvertebrate taxa richness/0.093 m² within major taxa in July, August and September, 1993 at the "M. spicatum," "mixed" and "native" sites in Zumbra Lake. P values are from a Kruskal-Wallis test for differences within sites over the sampling period.

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Fig. 1.11. Mean total macroinvertebrate densities/m² at the "M. spicatum," "mixed" and "native" sites in Zumbra Lake in July, August and September, 1993. Error bars are one standard error. P values were determined using Kruskal-Wallis test for differences among sites on each sampling date.
Table 1.9. Comparison of mean macroinvertebrate densities/m² at the “M. spicatum,” “mixed” and “native” sites in Zumbra Lake during July, August and September, 1993. P values are from a Kruskal-Wallis test for differences among sites on each sampling date. *spicatum* site.

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Fig. 1.12. Mean total macroinvertebrate densities/m² in July, August and September, 1993 at the "M. spicatum," "mixed" and "native" sites in Zumbra Lake. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences within sites over the sampling period.
Table 1.10. Comparison of mean macroinvertebrate densities/m² in July, August and September, 1993 at the *M. spicatum*, mixed and native sites in Zumbra Lake. P values are from a Kruskal-Wallis test for differences within sites over the sampling period.

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Fig. 1.13. Mean macroinvertebrate AFDW (g/m²) at the "M. spicatum," "mixed" and "native" sites in Zumbra Lake in July, August and September, 1993. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences among sites on each sampling date.
Fig. 1.14. Mean macroinvertebrate AFDW (g/m$^2$) in July, August and September, 1993 at the "M. spicatum," "mixed" and "native" sites in Zumba Lake. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences within sites over the sampling period.
was a result of an increase in mean densities of all taxa, while the decrease at the 
“native” site was caused by decreased crustacean, dipteran, gastropod and trichopteran 
densities (Table 1.10).

Similar to Auburn Lake, there were no significant differences or consistent trends 
in mean total biomass among sites on any sampling date (Fig. 1.13) or over time within a 
site (Fig. 1.14) in Zumbra Lake. Mean macroinvertebrate biomass at the sites on a given 
date in Zumbra Lake followed a trend similar to mean total densities (Figs. 1.11; 1.13). 
The “native” site supported the greatest biomass in July, but the lowest biomass in 
September. This probably resulted from the same taxa that caused the observed changes 
in densities. In addition, a similar relationship was realized between mean total density 
and mean total biomass at each site over time (Figs. 1.12; 1.14).

Discussion

Greater macroinvertebrate mean taxa richness, total density and biomass in 
Auburn Lake than in Zumbra Lake could have resulted from many factors. However, 
total phosphorus, chlorophyll a, turbidity and light attenuation were greater in Auburn 
Lake than in Zumbra Lake, indicating that Auburn Lake is more eutrophic (contains more 
phytoplankton), and therefore, more productive than Zumbra Lake. It is generally 
accepted that greater primary production from macrophytes and epiphytic algae causes 
greater macroinvertebrate density and biomass (Smith 1992).

Large within-site variability was present in samples from each habitat type. This 
variability may have been reduced by increased sample size, but macroinvertebrate 
communities can vary substantially within small areas because of the heterogeneity of
natural habitats. For example, Pardue and Webb (1985) obtained three replicate samples from three sample sites in two habitat types. They observed significant differences in macroinvertebrate communities between vegetated and open sites, but believed that within-site variability reduced the number of significant differences they found. Data variability in this study may have reduced the number of significant differences, but it appears that increasing the number of samples would not have affected the overall results.

It is interesting to note that mean total density and biomass in the "M. spicatum" site of both lakes peaked in August. However, no trends were observed at the "mixed" and "native" sites in either lake. It is possible that M. spicatum may begin senescence earlier than other macrophytes resulting in reduced habitat in September. Although there were significant differences in some comparisons between sites in each lake and within sites over time, the most important finding from this study was that there were no apparent trends in epiphytic macroinvertebrate community parameters among vegetation types. In addition, the same kinds of macroinvertebrates were found on all three types of macrophyte beds within each lake. These findings are contrary to the results of Keast (1984) who found lower epiphytic macroinvertebrate densities associated with M. spicatum than with mixed Potamogeton spp. and Vallisneria americana macrophyte beds. Krecker (1939) found M. spicatum supported approximately the same kinds of macroinvertebrates but in higher densities/3.33 m of plant length than five other macrophyte species. The results from this study suggest that macroinvertebrates in Auburn and Zumba Lakes were not negatively or positively affected by M. spicatum.
Conclusion

Although many scientists believe *M. spicatum* is detrimental to aquatic systems, the major finding of this study is that "*M. spicatum*" does not appear to affect mean epiphytic macroinvertebrate taxa richness, total density or biomass compared to "native" vegetation in Auburn or Zumbra Lakes.
Literature Cited


CHAPTER TWO
MACROINVERTEBRATE COMMUNITY RESPONSE TO FLURIDONE TREATMENT FOR *MYRIOPHYLLUM SPICATUM* L.
CONTROL IN A LENTIC ECOSYSTEM

ABSTRACT

*Myriophyllum spicatum* L. (Eurasian watermilfoil) is an exotic macrophyte that can become pestiferous in lentic ecosystems. One option for *M. spicatum* control is application of fluridone (1-methyl-3-phenyl-5-[3 (trifluoromethyl)-phenyl]-4(1H)-pyridinone), a herbicide that causes chlorosis through carotenoid inhibition. To evaluate the secondary effects of fluridone on epiphytic macroinvertebrate communities, sites in Zumbra Lake, Minnesota, USA were compared before and after fluridone application. One site contained predominantly *M. spicatum*, the second contained a mixture of *M. spicatum* and native vegetation, and the third possessed predominantly native vegetation. Triplicate macroinvertebrate samples were taken at 1 and 2 m depths at each sample site. Samples were taken before treatment in July, August and September, 1993, and after the May 23, 1994 treatment (24 µg/L) in July, August and September, 1994 and 1995. Epiphytic macroinvertebrate communities at all sites were significantly affected by fluridone treatment through loss of habitat and the epiphytic algal food base.

Keywords: *Myriophyllum spicatum*, Fluridone, Macroinvertebrates, Macrophytes
Introduction

Nuisance aquatic macrophytes can curtail recreational activities and clog water inlets and outlets. In addition, exotic macrophytes may reduce native macrophyte species richness and affect other aquatic organisms. Biological, physical and chemical methods are used to control pestiferous species such as *Myriophyllum spicatum* L., an exotic macrophyte introduced to the United States around the turn of this century, which is now present in at least 41 states (Grodowitz et al. 1997). Biological control of *M. spicatum* includes use of the non-selective Chinese grass carp (*Ctenopharyngodon idella* Val.) which feeds on most aquatic macrophytes (Leslie et al. 1993). Two native insects *Cricotopus myriophylli* (Chironomidae: Diptera) and *Euhrychiopsis lecontei* (Curculionidae: Coleoptera) have been found to feed more selectively on *M. spicatum* (McRae et al. 1990, Creed and Sheldon 1993, Newman and Maher 1995). Newman et al. (1997) also found that developmental performance of *E. lecontei* reared on *M. spicatum* was as good or better than those reared on *E. lecontei*’s native host plant, *M. sibiricum*. Physical control methods, which traditionally include such practices as lake drawdowns and weed harvesting, may be a more rapid alternative to biological control. Lake drawdown in freezing temperatures can be an effective short term solution (Bates et al. 1985), but this non-selective method adversely affects all aquatic flora and fauna. Mechanical cutting of *M. spicatum* is not a viable option because it creates plant fragments which lead to increased dispersal (Eichler et al. 1993). Chemical control of nuisance macrophytes can also result in rapid control, but in most cases is non-selective. Herbicides such as endothall and simazine not only affect macrophytes, but also the fauna.
and water chemistry (Gordon et al. 1982). Similarly, atrazine negatively affects phytoplankton, zooplankton and insects (DeNoyelles et al. 1982). Much like other herbicides, fluridone (1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4(1H)-pyridinone) has generally not offered selective control of any exotic plant species at the tested application rates. However, fluridone (Fig. 2.1) has not been found to significantly alter water quality or affect other aquatic organisms at the concentrations (10-20 µg/L) used for macrophyte control (Arnold 1979, Sanders et al. 1979). Therefore, fluridone, the active ingredient in Sonar®, is one of the most widely used aquatic herbicides. However, more studies have evaluated the effects of fluridone treatment on the exotic macrophyte *Hydrilla verticillata* (Van and Steward 1985, Schmitz et al. 1987, MacDonald et al. 1993, Miller et al. 1993) than on *M. spicatum* because *H. verticillata* causes major problems in areas that support year-round plant growth. Fluridone inhibits carotenogenesis through interference with the dehydrogenation enzymes that change phytoene to ζ-carotene (Bartels and Watson 1978). Without these protective pigments, chlorosis occurs as a result of chlorophyll degradation (Mordi 1993). Carotenogenesis inhibition may be reduced as fluridone is degraded.

![Fig. 2.1. Molecular structure of fluridone (1-methyl-3-phenyl-5-[3-(trifluoromethyl)-phenyl]-4(1H)-pyridinone).](image)
Fluridone does not hydrolyze in water but is subject to photodegradation (McCowen et al. 1979). In a laboratory degradation study, Muir and Grift (1982) found that fluridone degradation pathways differ between water and hydrosoil. Photodegradation of 5 mg/L fluridone in pond water was observed in stoppered 900 mL Pyrex flasks placed in sunlight but not in dark controls. In the same study microbial degradation was noted in sediment below pond water containing 5 mg/L fluridone in 125 mL culture flasks but not in autoclaved trials. Muir and Grift (1982) recovered fluridone-acid (1,4-dihydro-1-methyl-4-oxo-5-[3-(trifluoromethyl)phenyl]-3-pyridinecarboxylic acid), and a small amount of both 4-hydroxyfluridone (1-methyl-3-(4-hydroxyphenyl)-5-[3-(trifluoromethyl)phenyl]-4(1H)-pyridinone) and the 2-hydroxy derivative from the culture flask sediments. The water contained desphenylfluridone (1-methyl-3-[3-(trifluoromethyl)phenyl]-4(1H) pyridinone) along with the sediment degradates. However, no degradates were identified in two small ponds following 100 µg/L fluridone treatments, potentially because of increased photodegradation (Muir and Grift 1982).

Half-lives of radiolabeled fluridone in hydrosoils below pond water treated with 70 to 700 µg/L water were greater than 1 year, while the same initial concentrations were halved in 7 to 4 days, respectively, in the water column (Muir et al. 1980). Similarly, West et al. (1979) found an average half-life for fluridone in pond water of 5 days in Michigan, New York and Florida, USA. In the New York pond, West et al. (1979) found fluridone was not only degraded, but also assimilated by macrophytes and adsorbed onto the hydrosoil. In addition, significant fluridone dispersion has been observed (Sanders et al. 1979, Farone and McNabb 1993), potentially because of its relatively high 12 mg/L
water solubility. The short half life of fluridone in water, its tendency to rapidly disperse from the area of application, its assimilation by macrophytes and its adsorption to hydrosols make it difficult to determine and maintain the proper exposure concentration for pestiferous macrophyte control.

Netherland et al. (1993) found that 12 µg/L fluridone in controlled environment growth chambers resulted in a nonsignificant decrease in *M. spicatum* growth, biomass and total chlorophyll content, compared to controls. However, he also observed substantial *M. spicatum* regrowth within 30 days after fluridone removal, apparently because the plants had not been damaged enough to prohibit regrowth.

Farone and McNabb (1993) used areal imaging to evaluate vegetation changes caused by point application of 9.3 L/ha fluridone for *M. spicatum* control in selected areas of a 142 ha lake-pond ecosystem in Washington, USA. Fluridone reduced floating leaved plant coverage by an average of 28% within one year at several sites in direct contact with fluridone. Due to significant fluridone dispersion from the treated lake, total eradication of floating leaved plants occurred within one year in the two connected ponds even though only one application was made on the groundwater connected pond, and no herbicide was applied to the surface water connected pond.

Fluridone can also be toxic to nontarget algae, invertebrates and fish. Trevors and Vedelago (1985) found that the green algae *Scenedesmus quadricauda* exhibited growth inhibition when exposed to 0.5 - 10.0 mg/L fluridone for 15 days immediately upon culture initiation. However, when fluridone was added 6 days after growth initiation and continued for 15 days, identical fluridone concentrations did not negatively affect *S.*
quadricauda growth, suggesting that established populations may be less susceptible. In another laboratory study, Hamelink et al. (1986) found fluridone was more acutely toxic to six macroinvertebrates (mean LC$_{50}$ = 4.3 mg/L) than to five fish (mean LC$_{50}$ = 10.4 mg/L). During a chronic test Daphnia magna (Crustacea: Cladocera) exhibited significantly lower survival and reproduction after exposure to 0.2 mg/L for 21 days. Although these toxic concentrations are an order of magnitude greater than the suggested 10 - 20µg/L application rate for macrophyte control (SePRO Corp. 1994), apparently no published field studies have investigated fluridone’s effects on epiphytic macroinvertebrates.

The objective of work reported here was to determine if fluridone treatment significantly influenced epiphytic macroinvertebrate assemblages associated with native vegetation and M. spicatum in Zumbra Lake, Minnesota, USA.

Materials and Methods

Study Area

The first observation of M. spicatum in Zumbra Lake was made in 1989. Zumbra Lake's irregular shoreline surrounds a 65.6 ha basin with a maximum depth of 17.7 m (Fig. 2.2). The littoral zone occupied 55% of the basin and rooted vegetation was found down to 4 m depth in 1993. Although there is no permanent flow, water is exchanged with other lakes during high water periods. Zumbra Lake is a moderately fertile (Table 2.1), hard-water lake (Crowell et al. 1996). Its shoreline is somewhat developed, and in some areas lawns reach the water. In undeveloped areas, woodland and wetland habitats
Fig. 2.2. Map of Zumbra Lake, Minnesota showing the location of the "M. spicatum," "mixed" and "native" sites. Six samples were collected at each site in July, August and September, 1993, 1994 and 1995.
are dominant. In the four years following *M. spicatum*’s identification in Zumbra Lake (1989-1992), the herbicide 2,4-D (2,4-dichlorophenoxyacetic acid) was applied in an unsuccessful attempt to slow *M. spicatum* spread. In 1993, twenty submersed, free-floating and floating-leaved vascular plant taxa were found in Zumbra Lake (Crowell et al. 1996).

Table 2.1. Mean chlorophyll a and secchi depth in Zumbra Lake from July through September, 1993, 1994 and 1995. Adapted from Welling et al. (1996).

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Observations</th>
<th>Chlorophyll a (µg / L)</th>
<th>Secchi Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>5</td>
<td>17</td>
<td>2.1</td>
</tr>
<tr>
<td>1994</td>
<td>6</td>
<td>25</td>
<td>1.6</td>
</tr>
<tr>
<td>1995</td>
<td>5</td>
<td>43</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Three sampling sites were established in Zumbra Lake based on the abundance of *M. spicatum* relative to other macrophyte species. The “*M. spicatum*” site was dominated by *M. spicatum*, the “mixed” site contained roughly equal amounts of *M. spicatum* and native vegetation, and the “native” site was dominated by native vegetation. Epiphytic macroinvertebrates were sampled at these three sites in July, August and September, 1993, 1994 and 1995 to evaluate the effects of a May 23, 1994 fluridone application on epiphytic macroinvertebrate community structure.

**Fluridone Application**

Fluridone is the active ingredient (41.7% by volume) in Sonar® A.S. (SePRO Corp. 1994). A single application of this aqueous suspension was made (May 23, 1994)
using an airboat with a trailing arm to dispense the herbicide 30 cm below the water surface. A total of 71.06 L of Sonar A.S. was distributed in an attempt to provide a whole lake concentration of ~ 10 µg/L fluridone (Welling et al. 1996).

Sample Collection and Analysis

In July, August and September, 1993, samples were taken from Zumbra Lake to determine pretreatment macroinvertebrate community composition. Sampling was repeated in July, August and September, 1994 and 1995 to evaluate macroinvertebrate community structure following fluridone treatment. On each sampling date three macrophyte samples were taken from both 1 and 2 m depths at each site. The sampling equipment consisted of a clear polyethylene bag (0.093 m² x 1.7 m) with a 0.5 mm mesh sieve on each end. Divers drew the sampler down through the water column to the sediment-water interface. Macrophyte stems were detached from their roots, and the sieve at the base of the sampler was attached. Each sample collected all macrophytes from 0.093 m² of sediment. After water had drained through the bottom sieve it was removed, and the macrophytes were placed in jars containing rose bengal and 70% EtOH. The samples were then transported to the laboratory for macroinvertebrate sorting and identification. Some samples were subsampled because of excessive macroinvertebrate densities. Subsamples were taken by randomly selecting vegetation from one quadrant of a four quadrant sample splitter. Samples and subsamples were hand sorted to separate macrophytes from macroinvertebrates using a 2X magnification lens. Macroinvertebrates were identified to the lowest practical taxonomic level using keys by Merritt and Cummins (1984), and Thorp and Covich (1991). Ephemeroptera, Odonata (Insecta) and
Gastropoda (Mollusca) were identified to genus. Trichoptera (Insecta) were identified to either genus or species, while Diptera (Insecta) were identified to various taxonomic levels. For example, dipterans such as *Probezzia glabra* (Ceratopogonidae) were identified to species, while the thousands of Chironomidae were only taken to subfamily because further identification requires mounting individual head capsules. Although *Hyallela azteca* (Crustacea: Amphipoda) was identified to species, other members of class Crustacea (Cladocera, Copepoda, Isopoda and Ostracoda) were only identified to order. Annelida in class Hirudinea were identified to species, but organisms in class Oligochaeta were not identified further. The “Other” category was composed of various minor taxa including subclass Acari (Arthropoda: Arachnida), phylum Nematoda, *Dugesia* sp. (Turbellaria: Macroturbellaria), Corixidae (Insecta: Hemiptera) and *Hydra* sp. (Cnidaria: Hydroidea). These taxa were grouped together due to low and/or highly variable densities.

Macroinvertebrate biomass measurements in this study are only relative values because macroinvertebrates tend to lose weight when stored in EtOH (Heise et al. 1988). Samples were dried at 60°C in uniform foil envelopes to a constant weight (dry weight). The envelopes were then ashed in a muffle furnace at 500°C for 2 hours, cooled to room temperature in a desiccator, and the ash weights were recorded. The dry weight minus the ash weight is reported as the ash-free dry weight (AFDW). Although mean macroinvertebrate taxa richness data are reported as taxa richness/0.093 m², mean density and biomass measurements were divided by sample area (0.093 m²) to estimate the number of macroinvertebrates or biomass/m².
Plant communities were semi-quantitively sampled at 51 sites during July through September, 1993, 1994 and 1995 to determine how target and nontarget vegetation were affected (Welling et al. 1996). These researchers also determined fluridone concentrations at 6 sites on 8 dates during 1994.

Data Analysis

Raw macroinvertebrate taxa richness, density and biomass data in this study were not normally distributed and transformations did not sufficiently normalize the distributions. Therefore, the non-parametric Kruskal-Wallis test was used to detect statistically significant changes in macroinvertebrate community structure at individual sites over the sampling period.

Results

Variability in fluridone concentrations was low on most sampling dates (Table 2.2). Mean fluridone concentrations in Zumbra Lake were greater than the targeted 10 \( \mu \text{g/L} \) initial concentration for at least 14 days, but the actual mean initial concentration (24\( \mu \text{g/L} \)) was reduced by half within seven days. Thereafter, concentrations slowly decreased, and fluridone analysis was discontinued after November 1, 1994. Submergent vegetation was chlorotic at all sites by July, 1994, the first sampling date after treatment. Phytoplankton chlorophyll a increased (Table 2.1), while secchi depth decreased throughout the sampling period (Welling et al. 1996). It appears that the lack of nutrient uptake by macrophytes in combination with nutrient release during macrophyte decay resulted in increased phytoplankton biomass.
Table 2.2. Mean fluridone concentrations following Sonar® A.S. herbicide application to Zumbra Lake on May 23, 1994. All samples were collected during 1994. Modified from Crowell et al. (1996).

<table>
<thead>
<tr>
<th>Date</th>
<th>Sample Size</th>
<th>Mean Fluridone Concentration (µg/L)</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 24</td>
<td>6</td>
<td>24.0</td>
<td>3.20</td>
</tr>
<tr>
<td>May 31</td>
<td>6</td>
<td>12.0</td>
<td>0.54</td>
</tr>
<tr>
<td>June 6</td>
<td>7</td>
<td>12.0</td>
<td>0.55</td>
</tr>
<tr>
<td>June 21</td>
<td>6</td>
<td>9.8</td>
<td>0.53</td>
</tr>
<tr>
<td>July 22</td>
<td>6</td>
<td>6.8</td>
<td>0.50</td>
</tr>
<tr>
<td>August 18</td>
<td>6</td>
<td>5.7</td>
<td>0.28</td>
</tr>
<tr>
<td>September 29</td>
<td>6</td>
<td>3.9</td>
<td>0.19</td>
</tr>
<tr>
<td>November 1</td>
<td>6</td>
<td>1.4</td>
<td>0.65</td>
</tr>
</tbody>
</table>

In 1993, 96% of Welling et al.’s (1996) 51 sampling stations possessed macrophytes, and a mean number of 4 plant taxa/station was observed. The percent of vegetated stations following fluridone treatment decreased to 63% and 43% by August 1994 and 1995, respectively. The mean number of plant taxa/station was reduced to 1 in both posttreatment years. The percentage of stations on Zumbra Lake containing individual macrophyte species was also reduced by herbicide treatment (Table 2.3). For example, the percentage of stations containing *Ceratophyllum demersum, Myriophyllum spicatum* and *Potamogeton zosteriformis* decreased after treatment. *Myriophyllum spicatum* exhibited a more pronounced decrease than the other species, and it was the only major species not found in the second posttreatment year. The percentage of stations where *Nymphaea* sp. and *P. pectinatus* were found decreased in the first year after
treatment, but rebounded in the second year after treatment. These data suggest that fluridone exhibited some selectivity in regard to *M. spicatum* control. Although macrophytes were present in low levels at most stations during August, 1995, no macrophytes were present at the three sampling sites used in this study during September, 1995.

Table 2.3. Percentage of 51 stations containing the indicated species on Zumbra Lake during August, 1993, 1994 and 1995. Species which did not exceed 24% occurrence on at least one sampling date are not included. Fluridone application was made on May 23, 1994. Modified from Welling et al. (1996).

<table>
<thead>
<tr>
<th>Taxa</th>
<th>1993</th>
<th>1994</th>
<th>1995</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Ceratophyllum demersum</em></td>
<td>84</td>
<td>57</td>
<td>4</td>
</tr>
<tr>
<td><em>Myriophyllum spicatum</em></td>
<td>94</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td><em>Potamogeton zosteriformis</em></td>
<td>39</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td><em>Nymphaea</em> sp.</td>
<td>57</td>
<td>24</td>
<td>43</td>
</tr>
<tr>
<td><em>Potamogeton pectinatus</em></td>
<td>22</td>
<td>0</td>
<td>29</td>
</tr>
</tbody>
</table>

Macroinvertebrate taxa richness (Fig. 2.3A-C), total densities (Fig. 2.4A-C) and biomass (Fig. 2.5A-C) at each site in July, 1994, 7 weeks after treatment, were similar to pretreatment values, but these parameters decreased significantly thereafter. The similarity between macroinvertebrate community parameters at each site before treatment and in the first sampling date after treatment was probably due to fluridone’s slow mode of action. The chlorotic vegetation present still provided macroinvertebrate habitat. After July, each of the macroinvertebrate community parameters tended to decrease
Fig. 2.3. Mean macroinvertebrate taxa richness/0.093 m$^2$ at three sites in Zumbra Lake: A, "M. spicatum" site; B, "mixed" site; and C, "native" site. Six samples were taken from each site on each sampling date. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences within sites over time.
Fig. 2.4. Mean total macroinvertebrate densities/m² at three sites in Zumbra Lake: A, "M. spicatum" site; B, "mixed" site; and C, "native" site. Six samples were taken from each site on each sampling date. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences within sites over time.
Fig. 2.5. Mean macroinvertebrate AFDW (g/m²) at three sites in Zumba Lake: A, "M. spicatum" site; B, "mixed" site; and C, "native" site. Six samples were taken from each site on each sampling date. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences within sites over time.
more rapidly at the “M. spicatum” site (Fig. 2.3-5A) than at the “mixed” (Fig. 2.3-5B) and “native” (Fig. 2.3-5C) sites. This suggests that the habitat and/or attached food source associated with vegetation at the “M. spicatum” site was affected more than those associated with vegetation at the other sites, apparently because M. spicatum itself was affected more than other vegetation. Mean taxa richness, density and biomass of each taxonomic group also decreased significantly at each site over the sampling period, except for nonsignificant decreases in “Other” taxa richness and densities at the “mixed” site, and Odonata densities at “native” site. These nonsignificant decreases were attributed to high sample variation.

**Discussion**

Initial fluridone concentrations in Zumbra Lake were greater than desired apparently because application volume was not corrected for stratification at the time of application and the fluridone did not penetrate the thermocline (Crowell et al. 1996). However, the rate of fluridone dissipation from Zumbra Lake water was similar to results from other field studies. The half-life of the initial mean fluridone concentration in Zumbra Lake water (7 days) was comparable to those determined by West et al. (1979) and Muir et al. (1980). Fluridone applied at a concentration greater than 21 ppb (µg/L) to Parkers Lake, Minnesota, USA followed the same dissipation trend from water as in Zumbra Lake (Crowell et al. 1996).

Application of fluridone to Zumbra Lake affected the target M. spicatum and nontarget vegetation. Similar results have been found in other studies. For instance, Arnold (1979) found that one 0.3 mg/L fluridone application reduced nontarget Elodea
canadensis, Cabomba caroliniana, Najas guadalupensis, Typha spp., Panicum hemitomon, P. purpurascens, P. repens, Sagittaria spp., Pontederia cordata and Nuphar advena biomass. Unfortunately, some field studies have only reported the rate of application rather than the application concentration. Sanders et al. (1979) applied fluridone at 0.84 kg/ha to 18 test plots in Gatun Lake, Panama. Several plots treated with 0.84 kg/ha possessed chlorotic vegetation within 1 week followed by biomass changes 4 to 8 weeks after treatment, while other groups treated at this concentration exhibited sublethal exposure characteristics such as isolated chlorosis.

Although Arnold (1979) and Sanders (1979) both found that benthic macroinvertebrates were not significantly affected by fluridone, apparently the loss of habitat and the attached food source provided by aquatic vegetation for macroinvertebrates in this study caused a significant reduction of mean macroinvertebrate taxa richness, total density and biomass.

**Conclusion**

Fluridone applied to Zumbra Lake affected many factors. Epiphytic macroinvertebrate communities were indirectly affected by fluridone treatment through loss of habitat and the epiphytic algal food base. The increase in phytoplankton chlorophyll a and decrease in secchi depth are attributed to increased nutrient availability from macrophyte decay and decreased macrophyte uptake.


EPILOGUE

Several modifications may have improved these studies. Water chemistry measurements such as dissolved oxygen and pH should have been collected at each of the sites during macrophyte sample collection. These measurements might have provided a more thorough explanation of the trends, or lack of, in certain comparisons. Macrophyte biomass, which could have been determined easily because macrophytes were collected with macroinvertebrates, might also have provided more insight regarding observed macroinvertebrate community parameters. It also would have been advantageous to sample benthic macroinvertebrate communities in addition to epiphytic macroinvertebrate communities during the fluridone study to determine if any of the epiphytic macroinvertebrates moved into the benthos after macrophyte reduction.

Although the methods could have been modified slightly, the results obtained from this study are still valid. Mean epiphytic macroinvertebrate taxa richness, total density and biomass associated with *M. spicatum* were similar to those at the “native” sites in Auburn or Zumbra Lakes suggesting that *M. spicatum* “invasions” are not as ecologically destructive as is widely believed. Fluridone applied to Zumbra Lake for *M. spicatum* control had many effects. The percentage of stations containing macrophytes decreased following fluridone treatment. A subsequent increase in phytoplankton chlorophyll a and decrease in secchi depth were attributed to increased nutrient availability caused by decaying macrophytes. Epiphytic macroinvertebrate communities were indirectly affected by fluridone treatment through loss of habitat and the epiphytic algal food base.
Many property owners and natural resource managers use various methods to control *M. spicatum* because they believe it is detrimental to aquatic systems. This study provides evidence against whole-lake fluridone application for *M. spicatum* control. Epiphytic macroinvertebrate communities did not differ between “*M. spicatum*” and “native” sites in Aubum or Zumbra Lakes. Fluridone applied to Zumbra Lake impacted epiphytic macroinvertebrate communities more than the *M. spicatum* itself by reducing the habitat and attached food resources associated with each macrophyte assemblage causing epiphytic macroinvertebrate communities to decline.
APPENDIX A: Statistical analysis system (SAS) program used in Chapter One to analyze for differences in aquatic macroinvertebrate taxa richness/0.093 m² between the “M. spicatum,” “mixed” and “native” sites in Auburn and Zumbra Lakes on each sampling date.

TITLE “TAXA RICHNESS/0.093 M² AT COMPARABLE SITES BETWEEN LAKES ON EACH DATE”;
DATA RICHNESS;
INFILE “EPINVERT”;
INPUT LAK $ SEQUENCE SITE DEPTH REP DATE SET TYPE CAENISSP BAETISSP STENOINT TRICORYT ENALAGSP ISCHNURA ARGIA GOMPHIDA NEHLENIA SOMATOSP TETRAGON EPIPRINC PACHLONG MACROTOHE HSIMULAN HYDRORRI CHEUMATO IMOBILUS LEPTAMER OCINERAS TRITARDA TRINJUST TRIADA TRIANODE NECTALBI CERGLGMS LEPTOESP LEPTUPA NECTOPSY OECETISP OXYETHSP ORTHOTSP HYDROPSY HYDROPSP HYDRUPUA HYTILAS SPOLYCENT POLYCI NE POLYREMO POLYINTR CYRFNAT NEURECSP POLYCNISP AGRYPNIA TIPULARV CHIRONOM CHIRONAE TANYPNAE ORTHONAE PROBGLAB CULCOIDE MUSCUPA CERATPUP MIPIDIDA CHIRPPUA HEMERO DR HYALAZTE ACARIxxx COEPODA HYDRASPx CLADOCER NEMATODA OLIGOCHA MENETUSS PHYSELLA FERRISIADUGESIAS HSTAGNAL HELOBDEL HELONGAT PMULTILI PORNATA OTRANSLU PPARASIT AHETEROC MLUCIDIA MFERIDIA EPUNCTAT EROBDEL BPALUDOS BPICTA PMARAMOR STENOPEL HYPERODE CURCLARV CORILARV CORIXIDA PELTODYT LIXUSSP OSTRACOD ATOCHA ACENTRIA PARAPYNX SPHINGID LEPIDPUP ISOPOD; *CAENISSP = CAENIS SP.
*BAETISSP = BAETIS SP.
*STENOINT = STENONEMA INTEGRUM
*TRICORYT = TRICORYTHODES SP.
*ENALAGSP = ENALAGMA SP.
*ISCHNURA = ISCHNURA SP.
(ARGIA = ARGIA SP.
*GOMPHIDA = GOMPHIDAE SP.
*NEHLENIA = NEHLENNA SP.
*SOMATOSP = SOMATOCHLORA SP.
*TETRAGON = TETRAGONEURIA SP.
*EPIPRINC = EPITHECA PRINCEPS
*PACHLONG = PACHYDIPLAX LONGIPENNIS
*MACROTHERE = MACROTHERMIS SP.
*HSIMULAN = HYDROPSYCHE SIMULANS
*HYDRORRI = HYDROPSYCHE ORRIS
*CHEUMATO = CHEUMATOPSYCHE SP.
*IMOBILUS = OECETIS IMMOBILIS
*LEPTAMER = LEPTOCRUS AMERICANUS
*OCINERAS = OECETIS CINERAS
*TRITARDA = TRIANODES TARDER
*TRINJUST = TRIANTODES INJUST
*TRIADA = TRIANODES ABA
*TRIANODE = TRIANODES SP.
*NECTALBI = NECTOPSYCHE ALBIDA
*CERGLGMS = CERACLEA GLAGMUS
*LEPTOESP = LEPTOCRUS SP.
*ERPOBDEL = ERPOBDELLA SP.
*BPALUDOS = BATRACOBDELLA PALUDOSA
*BPICTA = BATRACOBDELLA PICTA
*PMARAMOR = PLACOBDELLA MARAMORATA
*STENOPEL = STENOPELMUS SP.
*HYPERODE = HYPERODES SP.
*CURCLAV = CURCLIONIDAE LARVAE
*CORILAV = CORIXIDAE LARVAE
*CORIXIDA = CORIXIDAE
*PELTODYT = PELTODYTES SP.
*LIXUSSP = LIXUS SP.
*OSTRACOD = OSTRACODA
*ATOCHA = ANTOCHA SP.
*ACENTRIA = ACENTRIA SP.
*PARAPYNX = PARAPOYNX SP.
*SPHINGID = SPHINGIDAE
*LEPIDPUP = LEPIDOPTERA PUPAE
*ISOPODA = ISOPODA

IF CAENISSP = 0 THEN A = 0; ELSE A = 1;
IF BAETISSP = 0 THEN B = 0; ELSE B = 1;
IF STENOINT = 0 THEN C = 0; ELSE C = 1;
IF TRICORYT = 0 THEN D = 0; ELSE D = 1;
IF ENALAGSP = 0 THEN E = 0; ELSE E = 1;
IF ISCHNURA = 0 THEN F = 0; ELSE F = 1;
IF ARGIA = 0 THEN G = 0; ELSE G = 1;
IF GOMPHIDA = 0 THEN H = 0; ELSE H = 1;
IF NEHLENIA = 0 THEN I = 0; ELSE I = 1;
IF SOMATOSP = 0 THEN J = 0; ELSE J = 1;
IF TETRAGON = 0 THEN K = 0; ELSE K = 1;
IF EPIPRINC = 0 THEN L = 0; ELSE L = 1;
IF PACHLONG = 0 THEN M = 0; ELSE M = 1;
IF MACROTHE = 0 THEN N = 0; ELSE N = 1;
IF HSIMULAN = 0 THEN O = 0; ELSE O = 1;
IF HYDRORRI = 0 THEN P = 0; ELSE P = 1;
IF CHEUMATO = 0 THEN Q = 0; ELSE Q = 1;
IF IMOBILUS = 0 THEN R = 0; ELSE R = 1;
IF LEPTAMER = 0 THEN S = 0; ELSE S = 1;
IF OCINERAS = 0 THEN T = 0; ELSE T = 1;
IF TRITARDA = 0 THEN U = 0; ELSE U = 1;
IF TRINJUST = 0 THEN V = 0; ELSE V = 1;
IF TRIADA = 0 THEN X = 0; ELSE X = 1;
IF TRIANODE = 0 THEN Y = 0; ELSE Y = 1;
IF NECTALBI = 0 THEN Z = 0; ELSE Z = 1;
IF CERGLGMS = 0 THEN AA = 0; ELSE AA = 1;
IF LEPTOCSP = 0 THEN BB = 0; ELSE BB = 1;
IF LEPTPUPA = 0 THEN CC = 0; ELSE CC = 1;
IF NECTOPSY = 0 THEN DD = 0; ELSE DD = 1;
IF OECETISP = 0 THEN EE = 0; ELSE EE = 1;
IF OXYETHSP = 0 THEN FF = 0; ELSE FF = 1;
IF ORTHOTSP = 0 THEN GG = 0; ELSE GG = 1;
IF HYDROPSY = 0 THEN HH = 0; ELSE HH = 1;
IF HYDROPSP = 0 THEN II = 0; ELSE II = 1;
IF HYDRPUPA = 0 THEN JJ = 0; ELSE JJ = 1;
IF HYTILASP = 0 THEN KK = 0; ELSE KK = 1;
IF POLYCENT = 0 THEN LL = 0; ELSE LL = 1;
IF POLYCINE = 0 THEN MM = 0; ELSE MM = 1;
IF POLYREMO = 0 THEN NN = 0; ELSE NN = 1;
IF POLYINTR = 0 THEN OO = 0; ELSE OO = 1;
IF CYRNFRAT = 0 THEN PP = 0; ELSE PP = 1;
IF NEURECSP = 0 THEN QQ = 0; ELSE QQ = 1;
IF POLYCNSP = 0 THEN RR = 0; ELSE RR = 1;
IF AGRYPNIA = 0 THEN SS = 0; ELSE SS = 1;
IF TIPULARV = 0 THEN TT = 0; ELSE TT = 1;
IF PROBGLAB = 0 THEN VV = 0; ELSE VV = 1;
IF CULCOIDE = 0 THEN XX = 0; ELSE XX = 1;
IF MUSCPUPA = 0 THEN YY = 0; ELSE YY = 1;
IF CERATPUP = 0 THEN ZZ = 0; ELSE ZZ = 1;
IF EMPIPIDIDA = 0 THEN AAA = 0; ELSE AAA = 1;
IF CHIRPUPA = 0 THEN BBB = 0; ELSE BBB = 1;
IF HEMERODR = 0 THEN CCC = 0; ELSE CCC = 1;
IF HYALAZTE = 0 THEN DDD = 0; ELSE DDD = 1;
IF ACARinx = 0 THEN EEE = 0; ELSE EEE = 1;
IF COPEPODA = 0 THEN FFF = 0; ELSE FFF = 1;
IF HYDRASPx = 0 THEN GGG = 0; ELSE GGG = 1;
IF CLADOCE = 0 THEN HHH = 0; ELSE HHH = 1;
IF NEMATODA = 0 THEN III = 0; ELSE III = 1;
IF OLIGOCHA = 0 THEN JJJ = 0; ELSE JJJ = 1;
IF MENETUSS = 0 THEN KKK = 0; ELSE KKK = 1;
IF PHYSELLA = 0 THEN LLL = 0; ELSE LLL = 1;
IF FERRISIA = 0 THEN MMM = 0; ELSE MMM = 1;
IF DUGESIAS = 0 THEN NNN = 0; ELSE NNN = 1;
IF HSTAGNAL = 0 THEN OOO = 0; ELSE OOO = 1;
IF HELOBDEL = 0 THEN PPP = 0; ELSE PPP = 1;
IF HELONGAT = 0 THEN QQQ = 0; ELSE QQQ = 1;
IF PMULTIL = 0 THEN RRR = 0; ELSE RRR = 1;
IF PORNATA = 0 THEN SSS = 0; ELSE SSS = 1;
IF OTRANSLU = 0 THEN TTT = 0; ELSE TTT = 1;
IF PPARASIT = 0 THEN UUU = 0; ELSE UUU = 1;
IF AETEROC = 0 THEN VVV = 0; ELSE VVV = 1;
IF MLUCIDIA = 0 THEN XXX = 0; ELSE XXX = 1;
IF MFERIDIA = 0 THEN YYY = 0; ELSE YYY = 1;
IF EPUNCTAT = 0 THEN ZZZ = 0; ELSE ZZZ = 1;
IF ERPOBDEL = 0 THEN AAAA = 0; ELSE AAAA = 1;
IF BPALUDOS = 0 THEN BBBB = 0; ELSE BBBB = 1;
IF BPICTA = 0 THEN CCCC = 0; ELSE CCCC = 1;
IF PMARAMOR = 0 THEN DDDD = 0; ELSE DDDD = 1;
IF STENOPEL = 0 THEN EEEE = 0; ELSE EEEE = 1;
IF HYPERODE = 0 THEN FFFF = 0; ELSE FFFF = 1;
IF CURCLARV = 0 THEN GGGG = 0; ELSE GGGG = 1;
IF CORILARV = 0 THEN HHHH = 0; ELSE HHHH = 1;
IF CORIXIDA = 0 THEN IIII = 0; ELSE IIII = 1;
IF PELTODYT = 0 THEN JJJj = 0; ELSE JJJj = 1;
IF LIXUSSP = 0 THEN KKKK = 0; ELSE KKKK = 1;
IF OSTRACOD = 0 THEN LLLL = 0; ELSE LLLL = 1;
IF ATOCHA = 0 THEN MMMM = 0; ELSE MMMM = 1;
IF ACENTRIA = 0 THEN NNNN = 0; ELSE NNNN = 1;
IF PARAPYNX = 0 THEN OOOO = 0; ELSE OOOO = 1;
IF SPHINGID = 0 THEN PPPP = 0; ELSE PPPP = 1;
IF LEPIDPUP = 0 THEN QQQQ = 0; ELSE QQQQ = 1;
IF ISOPODA = 0 THEN RRRR = 0; ELSE RRRR = 1;
IF CHIRONAE = 0 THEN SSSS = 0; ELSE SSSS = 1;
IF TANYPNAE = 0 THEN TTTT = 0; ELSE TTTT = 1;
IF ORTHONAE = 0 THEN UUUU = 0; ELSE UUUU = 1;
NUMTAXA = A+B+C+D+E+F+G+H+I+J+K+L+M+N+O+P+Q+R+S+T+U+V+X+Y+Z+
         AA+BB+CC+DD+EE+FF+GG+HH+II+JJ+KK+LL+MM+NN+OO+PP+QQ+RR+SS+TT+
         VV+XX+YY+ZZ+AAA+BBB+CCC+DDD+EEE+FFF+GGG+HHH+III+JJJ+KKK+LLL+
         MMM+NNN+OOO+PPP+QQQ+RRR+SSS+TTT+UUU+VVV+XXX+YYY+ZZZ+
         AAAA+BBBB+CCCC+DDDD+EEEE+FEEE+FFFF+GGGG+HHHH+IIII+JJJJ+KKKK+
         LLLL+MMMM+NNNN+OOOO+PPPP+QQQQ+RRRR+SSSS+TTTT+UUUU;
PROC PRINT;
PROC SORT;
BY SET SITE LAK;
PROC MEANS N MIN MAX RANGE MEAN VAR STD STDERR CV SKEWNESS KURTOSIS;
BY SET SITE LAK
VAR NUMTAXA;
PROC CHART;
BY SET SITE
VBAR LAK/DISCRETE SUMVAR = NUMTAXA TYPE = MEAN;
PROC NPAR1WAY ANOVA WILCOXON;
BY SET SITE;
CLASS LAK;
VAR NUMTAXA;
APPENDIX B: Statistical analysis system (SAS) program used in Chapter One to analyze for differences in aquatic macroinvertebrate densities/m² between the “M. spicatum,” “mixed” and “native” sites in Auburn and Zumbra Lakes on each sampling date.

TITLE "DENSITIES/M2 AT COMPARABLE SITES BETWEEN LAKES FOR EACH DATE";
DATA DENSITY;
INFILE "EPINVERT";
  INPUT LAK $ SEQUENCE SITE DEPTH REP DATE SET TYPE CAENISSP BAETISSP
    STENOINT TRICORYT ENALAGSP ISCHNURA ARGIA GOMPHIDA NEHLENIASOMATOSP
    TETRAGON EPIPRINC PACHLONG MACROTHE HSIMULAN HYDRORRI CHEUMATO
    IMOBILUS LEPTAMER OCINERAS TRITARDA TRINJUST TRIADA TRIANODE NECTALBI
    CERGLGMS LEPTOCSP LEPTPUPA NECTOPSY OECETISP OXYETHSP ORTHOTSP HYDROPSY
    HYDROPSP HYDRPUPA HYTILASP POLYCENT POLYCREPOLYREMPOLYINTR
    CYRNFRAT NEURECSP POLYCSPN AGRYPinia TIPULARV CHIRONOM CHIRONAE
    TANYNPAE ORTHONAE PROBGLAB CULCOIDE MUSCPUPA CERATTPUPA EMPIRIDA
    CHIRPUPA HEMERODR HYALAZTE ACAR1xxx COPEPODA HYDRASPX CLADOCER
    NEMATODA OLIGOCHE MENETUSS PHY'SELLA FUGESIAS HSTAGNALL
    HELOBDEL HELONGAT PMULTILI PORNATA OTRANSLU PPARASIT AHETEROC MLUCIDIA
    MFERIDIA EPUNCTAT ERPOBDEL BPALUDOS BPICTA PMARAMOR STENOPEL HYPERODE
    CURCLARV CORILARV CORIXIDA PILTODYT LIXUSSP OSTRACOD ATOCHA ACENTRIA
    PARAPYNX SPHINGID LEPIDPUPP UNOPODA;
  *CAENISSP = CAENIS SP.
  *BAETISSP = BAETIS SP.
  *STENOINT = STENONEMA INTEGRUM
  *TRICORYT = TRICORYTHODES SP.
  *ENALAGSP = ENALAGMA SP.
  *ISCHNURA = ISCHNURA SP.
  *ARGIA = ARGIA SP.
  *GOMPHIDA = GOMPHIDAE SP.
  *NEHLENIASOMATOSP = SOMATOCHLORA SP.
  *TETRAGON = TETRAGONEURIA SP.
  *EPIPRINC = EPITHECA PRINCEPS
  *PACHLONG = PACHYDIPLAX LONGIPENNIS
  *MACROTHE = MACROTHERMIS SP.
  *HSIMULAN = HYDROPSYCHE SIMULANS
  *HYDRORRI = HYDROPSYCHE ORRIS
  *CHEUMATO = CHEUMATOPSYCHE SP.
  *IMOBILUS = OECETIS IMOBILOUS
  *LEPTAMER = LEPTOCERUS AMERICANUS
  *OCINERAS = OECETIS CINERASCENS
  *TRITARDA = TRIANODES TARDA
  *TRINJUST = TRIANODES INJUSTA
  *TRIADA = TRIANODES ABA
  *TRIANODE = TRIANODES SP.
  *NECTALBI = NECTOPSYCHE ALBIDA
  *CERGLGMS = CERACLEA GLAGMUS
  *LEPTOCP = LEPTOCERUS SP.
  *LEPTPUPA = LEPTOCERUS SP. PUPAE
*BPALUDOS = BATRACOBDELLA PALUDOSA
*BPICTA = BATRACOBDELLA PICTA
*PMARAMOR = PLACOBDELLA MARAMORATA
*STENOPEL = STENOPELMUS SP.
*HYPERODE = HYPERODES SP.
*CURLARV = CURCLIONIDAE LARVAE
*CORILARV = CORIXIDAE LARVAE
*CORIXIDA = CORIXIDAE
*PELTODYT = PELTODYTES SP.
*LIXUSSP = LIXUS SP.
*OSTRACOD = OSTRACODA
*ATOCHA = ANTOCHA SP.
*ACENTRIA = ACENTRIA SP.
*PARAPYNX = PARAPOYNX SP.
*SPHINGID = SPHINGIDAE
*LEPIDPUP = LEPIDOPTERA PUPAE
*ISOPODA = ISOPODA

CAENISSm = 10.74*CAENISSP;
BAETISSm = 10.74*BAETISSP;
STENOINm = 10.74*STENOINT;
TRICORYm = 10.74*TRICORYT;
ENALAGSm = 10.74*ENALAGSP;
ISCHNURm = 10.74*ISCHNURA;
ARGAm = 10.74*ARGIA;
GOMPHIDm = 10.74*GOMPHIDA;
NEHLENm = 10.74*NEHLENA;
SOMATOSm = 10.74*SOMATOSP;
TETRAGOm = 10.74*TETRAGON;
EPIPRINm = 10.74*EPIPRINC;
PACHLONm = 10.74*PACHLONG;
MACROTHm = 10.74*MACROTHE;
HSIMULAm = 10.74*HSIMULAN;
HYDRORRm = 10.74*HYDRORRI;
CHEUMATm = 10.74*CHEUMATO;
IMOBILUm = 10.74*IMOBILUS;
LEPTAMEm = 10.74*LEPTAMER;
OCINERAm = 10.74*OCINERAS;
TRITARDm = 10.74*TRITARDA;
TRINJUSm = 10.74*TRINJUST;
TRIADAm = 10.74*TRIADA;
TRIANODm = 10.74*TRIANODE;
NECTALBm = 10.74*NECTALBI;
CERGLGMm = 10.74*CERGLGMS;
LEPTOCSm = 10.74*LEPTOCSP;
LEPTPUPm = 10.74*LEPTPUPA;
NECTOPSm = 10.74*NECTOPSY;
OECETISm = 10.74*OECETISP;
OXYETHSm = 10.74*OXYETHSP;
ORTHOTSm = 10.74*ORTHOTSP;
HYDROPSm = 10.74*HYDROPSY;
HYDROPm = 10.74*HYDROPSP;
HYDRPUm = 10.74*HYDRPUPA;
HYTILASm = 10.74*HYTILASP;
POLYCENm = 10.74*POLYCEN;
POLYCIINm = 10.74*POLYCIINE;
POLYREMm = 10.74*POLYREMO;
POLYINTm = 10.74*POLYINTR;
CYRNFRAm = 10.74*CYRNFRA;
NEURECSm = 10.74*NEURECSP;
POLYCNSm = 10.74*POLYCNSP;
AGRYPNIm = 10.74*AGRYPNIA;
TIPULARm = 10.74*TIPULARV;
CHIRONDm = 10.74*CHIRONOM;
PROBGLAm = 10.74*PROBGLAB;
CULCOIDm = 10.74*CULCOIDE;
MUSCPUPm = 10.74*MUSCPUPA;
CERATPUMm = 10.74*CERATPUP;
EMPIDIDm = 10.74*EMPIDIDA;
CHIRNPUm = 10.74*CHIRPU;
HEMERODm = 10.74*HEMERORD;
HYALAZTm = 10.74*HYALAZTE;
ACARixxm = 10.74*ACARixxx;
COPEPODm = 10.74*COPEPODA;
HYDRASPm = 10.74*HYDRASPx;
CLADOCEm = 10.74*CLADOCER;
NEMATODm = 10.74*NEMATOD;
OLIGOCHm = 10.74*OLIGOCHA;
MENETUSm = 10.74*MENETUS;
PHYSELLm = 10.74*PHYSELLA;
FERRISIm = 10.74*FERRISIA;
DUGESIAm = 10.74*DUGESIAS;
HSTAGNAm = 10.74*HSTAGNA;
HELOBDEm = 10.74*HELOBDEL;
HELONGAm = 10.74*HELONGAT;
PMULTIlm = 10.74*PMULTILI;
PORNATAm = 10.74*PORNATA;
OTRANSLm = 10.74*OTRANSLU;
PPARASIm = 10.74*PPARASIT;
AHETEROm = 10.74*AHETERO;
MLUCIDIm = 10.74*MLUCIDIA;
MFERIDIm = 10.74*MFERIDIA;
EPUNCTAm = 10.74*EPUNCTAT;
EPOBDEm = 10.74*EPOBDEL;
BPALUDOm = 10.74*BPALUDOS;
BPICTAm = 10.74*BPICTA;
PMARAMOm = 10.74*PMARAMOR;
STENOPEm = 10.74*STENOPEL;
HYPERODm = 10.74*HYPERODE;
CURCLARm = 10.74*CURCLARV;
CORILArm = 10.74*CORILARV;
CORIXIDm = 10.74*CORIXIDA;
PHELODYm = 10.74*PELTODYT;
LIXUSSPm = 10.74*LIXUSSP;
OSTRACOm = 10.74*OSTRACOD;
ATOCHAm = 10.74*ATOCHA;
ACENTRIm = 10.74*ACENTRIA;
PARAPYNm = 10.74*PARAPYNX;
SPHINGIm = 10.74*SPHINGID;
LEPIDPUm = 10.74*LEPIDPUP;
ISOPODAm = 10.74*ISOPODA;

Ephem = CAENISSm+BAETISSm+STENOINm+TRICORYm;
Odonata = ENALAGSm+SOMATOSm+TETRAGOm+EPIPRINm+PACHLONm+MACROTHm+
ISCHNUVm+ARGIAm+GOMPHIDm+NEHLENlm;
Trichop = HSIMULAm+HYDRORRm+CHEUMATm+IMOBILUm+LEPTAMEm+OCINERAm+
TRITAROm+TRINJUStm+NECTALBm+LEPTOCSm+LEPTPUPm+NECTOPSm+OECETISm+
OXYETHSm+ORTHOTSm+HYDROPSm+HYDROPm+HYDRPUPm+HYTILASm+POLYCINm+
+POLYCENm+NEURECSm+CYRNFRAm+POLYCNSm+TRIADAm+TRIANODm+
CERGLGm+POLYREMm+POLYINTm+AGRYPNm;
Diptera = CHIRONDm+PROBGLAm+CULCOIDm+CEPATPIm+CHIRPUPm+TIPULARm+
MUSCPUPm+EMPIDIDm+HEMERODm+ATOCHA;
Crustac = HYALAZTm+COPEPODm+CLADOCEm+OSTRACOm+ISOPODAm;
ANNELID = HSTAGNAm+PMULTILm+OTRANSUm+PPARASIm+AHETEROm+MLUCIDIm+
EPUNCTAm+ERPOBEDm+BPAUDOm+PMARAMUm+OLIGOChm+HELOBDEm+
HELONGAm+PORNATAm+MFERIDIm+BPICtm;
OTHER = ACARixxm+HYDRASPm+NEMATODm+DUGESIAm+CORILArm+CORIXIdm;
COLEOP = STENOPEm+HYPERODm+CURLARAm+LIXUSSPm+PELTODYm;
LEPIDOP = ACENTRIm+PARAPYNm+SPHINGIm+LEPIDPUpm;
Gastro = MENETUSm+PHYSEllm+FERRISm;
TOTAL = Ephem+Odonata+Trichop+Diptera+Crustac+ANNELID+OTHER+Gastro+
LEPIDOP+COLEOP;

PROC PRINT;
PROC SORT;
BY SET SITE LAK;
PROC MEANS N MIN MAX RANGE MEAN VAR STD STDERR CV SKEWNESS KURTOSIS;
BY SET SITE LAK;
VAR TOTAL;
PROC CHART;
BY SET SITE;
VBAR LAK/DISCRETE SUMVAR = TOTAL TYPE = MEAN;
PROC NPAR1WAY ANOVA WILCOXON;
BY SET SITE;
CLASS LAK;
VAR TOTAL;
APPENDIX C: Statistical analysis system (SAS) program used in Chapter One to analyze for differences in aquatic macroinvertebrate AFDW (g/m²) between the "M. spicatum," "mixed" and "native" sites in Auburn and Zumbra Lakes on each sampling date.

```
TITLE "AFDW/M² AT COMPARABLE SITES BETWEEN LAKES FOR EACH DATE";
DATA AFDW;
INFILE "BIOMASS";
INPUT LAK $ SEQUENCE SITE DEPTH REP DATE SET TYPE WEIGHT;
WGHT = WEIGHT * 10.74;
PROC PRINT;
PROC SORT;
BY SET SITE LAK;
PROC MEANS N MIN MAX RANGE MEAN VAR STD STDERR CV SKEWNESS KURTOSIS;
BY SET SITE LAK;
VAR WGHT;
PROC CHART;
BY SET SITE;
VBAR LAK/DISCRETE SUMVAR = WGHT TYPE = MEAN;
PROC NPAR1WAY ANOVA WILCOXON;
BY SET SITE;
CLASS LAK;
VAR WGHT;
```
APPENDIX D: Statistical analysis system (SAS) program used in Chapter One to analyze for differences in aquatic macroinvertebrate taxa richness/0.093 m² among the “M. spicatum,” “mixed” and “native” sites within Auburn and Zumbra Lakes on each sampling date.

TITLE "RICHNESS/0.093 m² AT SITES WITHIN A LAKE BY DATE";
DATA RICHNESS;
  INFILE "EPINVERT";
  FORMAT LAK $ SEQUENCE SITE DEPTH REP DATE SET TYPE CAENISSP BAETISSP
  STENOINT TRICORYT ENALAGSP ISCHNURA ARGIA GOMPHIDA NEHLENIA SOMATOSP
  TETRAGON EPIPRINC PACHLONG MACROTHE HSIMULAN HYDRORRI CHEUMATO
  IMOBILUS LEPTAMER OCINERAS TRITARDA TRINJUST TRIADA TRIANODE NECTALBI
  CERGLGMS LEPTCSP LEPTPUPA NECTOPSY OECETISP OXYETHSP ORTHOTSP HYDROPSY
  HYDROPSP HYDRPUPA HYTILASP POLYCENT POLYCINE POLYREMO POLYINTR
  CYRNFRA NEURECSP POLYCNSP
  AGRYPNIA TIPULARV CHIRONOM CHIRONAE TANYNIAE ORTHONIAE PROBGLAB
  CULCOIDE MUSCPUPA CERATPUP EMPIDIDA CHIRLPUPA HEMERODR HYALAZTE ACARIxxx
  COPEPODA HYDRASPX CLADOCER NEMATODA OLGOCOA MENTUSS PHYSELLA
  FERRISIA DUGESIAS HSTAGNA HELOBDEL HELONGAT MULTILI PORNATA OTANSLU
  PPARASIT AHETERO MLCIDIA MFERIDIA EPUNCTAT ERPOBDEL BPALUDOS BPICITA
  PMARAMOR STENOPEL HYPERODE CURXLRV CORILAV CORIXIDA PELTODYT LIXUSSP
  OSTRACOD ATOCHA ACENTRIA PARAPYNX SPHINGID LEPIDPUP ISOPODA;
*CAENISSP = CAENIS SP.
*BAETISSP = BAETIS SP.
*STENOINT = STENONEMA INTEGRUM
*TRICORYT = TRICORYTHODES SP.
*ENALAGSP = ENALAGMA SP.
*ISCHNURA = ISCHNURA SP.
*ARGIA = ARGIA SP.
*GOMPHIDA = GOMPHIDAE SP.
*NEHLENIA = NEHLENNIA SP.
*SOMATOSP = SOMATOCHLORA SP.
*TETRAGON = TETRAGONEURIA SP.
*EPULPRINC = EPITHECA PRINCEPS
*PACHLONG = PACHYDIPLAX LONGIPENNIS
*MACROTHE = MACROTHEMIS SP.
*HSIMULAN = HYDROPSYCHE SIMULANS
*HYDRORRI = HYDROPSYCHE ORRIS
*CHEUMATO = CHEUMATOPSYCHE SP.
*IMOBILUS = OECETIS IMMOBILIS
*LEPTAMER = LEPTOCERUS AMERICANUS
*OCINERAS = OECETIS CINERASCENS
*TRITARDA = TRIANODES TARDA
*TRINJUST = TRIANODES INJUSTA
*TRIADA = TRIANODES ABA
*TRIANODE = TRIANODES SP.
*NECTALBI = NECTOPSYCHE ALBIDA
*CERGLGMS = CERACLEA GLAGMUS
*LEPTCSP = LEPTOCERUS SP.
*LEPTPUPA = LEPTOCERUS SP. PUPAE
*NECTOPSY = NECTOPSYCHE SP.
*OECEISP = OECEIS SP.
*OXYETHSP = OXYETHIRA SP.
*ORTHOTSP = ORHTOTRICHIA SP.
*HYDROPSY = HYDROPSYCHIDAE
*HYDROSP = HYDROPSYCIDAE SP.
*HYDRPUPA = HYDROPSYCIDAE SP. PUPAE
*HYTILASP = HYDROPTILA SP.
*POLYCENT = POLYCENTROPUS CENTRALIS
*POLYCINE = POLYCENTROPUS CINERUS
*POLYREMO = POLYCENTROPUS REMOTUS
*POLYINTR = POLYCENTROPUS INTERRUPTUS
*CYRNFрат = CYRNELLUS FRATURNUS
*NEURECSP = NEURECLIPSIS SP.
*POLYCNSP = POLYCENTROPUS SP.
*A GRYPNIA = AGRYPNIA SP.
*TIPULARV = TIPULIDAE SP. PUPAE
*CHIRONOM = CHIRONOMIDAE
*CHIRONAE = CHIRONOMINAE
*TANYPNAE = TANYPODINAE
*ORTHONAE = ORTHOCLADINAE/DIAMESINAE
*PROBGLAB = PROBEZZIA GLABRA
*CULCOIDE = CULCOIDES SP.
*MUSCPUPA = MUSCIDAE PUPAE
*CERATPUP = CERATOPOGONIDAE PUPAE
*EMPIDIDA = EMPIDIDAE
*CHIRPUPA = CHIRONOMIDAE PUPAE
*HEMERODR = HEMERODROMIA SP.
*HYALAZTE = HYALLELA AZTECA
*ACARIxxx = ACARI
*COPEPODA = COPEPODA
*HYDRASPx = HYDRA SP.
*CLADOCER = CLADOCERA
*NEMATODA = NEMATODA
*OLIGOCHA = OLIGOCHAETA
*MENETUSS = MENETUS SP.
*PHYSELLA = PHYSELLA SP.
*FERRISIA = FERRISIA SP.
*DUGESIAS = DUGESIA SP.
*HSTAGNAL = HELOBDELLA STAGNALS
*HELOBDEL = HELOBDELLA SP.
*HELONGAT = HELOBDELLA ELONGATA
*PMULTILI = PLACOBDELLA MULTILNATE
*PORNATA = PLACOBDELLA ORNATA
*OTRANSLU = OLIGOBDELLA TRANSCLUDENS
*PPARASIT = PLACOBDELLA PARASITICA
*AHETEROC = ALBOGLOSSIPHONIA HETEROCLITA
*MLUCIDAD = MARVINMEYERIA LUCIDIA
*MFERIDIA = MOOREOBDELLA FERVIDA
*EPUNCTAT = ERPOBDELLA PUNCTATA
*ERPOBDEL = ERPOBDELLA SP.
*BPALUDOS = BATRACOBDELLA PALUDOSA
*BPICTA = BATRACOBDELLA PICTA
*PMARAMOR = PLACOBDELLA MARAMORA
*STENOPEL = STENOPELMUS SP.
*HYPERODE = HYPERODES SP.
*CURCLARV = CURCLIONIDAE LARVAE
*CORILARV = CORIXIDAE LARVAE
*CORIXIDA = CORIXIDAE
*PELTODYT = PELTODYTES SP.
*LIXUSSP = LIXUS SP.
*OSTRACOD = OSTRACODA
*ATOCHA = ANTOCHA SP.
*ACENTRIA = ACENTRIA SP.
*PARAPYNX = PARAPOYNX SP.
*SHPINGID = SHPINGIDAE
*LEPIDPUP = LEPIDOPTERA PUPAE
*ISOPODA = ISOPODA

IF CAENISSP = 0 THEN A = 0; ELSE A = 1;
IF BAETISSP = 0 THEN B = 0; ELSE B = 1;
IF STENOINT = 0 THEN C = 0; ELSE C = 1;
IF TRICORYT = 0 THEN D = 0; ELSE D = 1;
IF ENALAGSP = 0 THEN E = 0; ELSE E = 1;
IF ISCHNURA = 0 THEN F = 0; ELSE F = 1;
IF ARGIA = 0 THEN G = 0; ELSE G = 1;
IF GOMPHIDA = 0 THEN H = 0; ELSE H = 1;
IF NEHLENA = 0 THEN I = 0; ELSE I = 1;
IF SOMATOSP = 0 THEN J = 0; ELSE J = 1;
IF TETRAGON = 0 THEN K = 0; ELSE K = 1;
IF EPICPRINC = 0 THEN L = 0; ELSE L = 1;
IF PACHLONG = 0 THEN M = 0; ELSE M = 1;
IF MACROTHE = 0 THEN N = 0; ELSE N = 1;
IF HSIMULAN = 0 THEN O = 0; ELSE O = 1;
IF HYDRORRI = 0 THEN P = 0; ELSE P = 1;
IF CHEUMATO = 0 THEN Q = 0; ELSE Q = 1;
IF IMOBILUS = 0 THEN R = 0; ELSE R = 1;
IF LEPTAMER = 0 THEN S = 0; ELSE S = 1;
IF OCINERAS = 0 THEN T = 0; ELSE T = 1;
IF TRITARDA = 0 THEN U = 0; ELSE U = 1;
IF TRINJUST = 0 THEN V = 0; ELSE V = 1;
IF TRIADA = 0 THEN X = 0; ELSE X = 1;
IF TRIANO DE = 0 THEN Y = 0; ELSE Y = 1;
IF NECTALBI = 0 THEN Z = 0; ELSE Z = 1;
IF CERGLGMS = 0 THEN AA = 0; ELSE AA = 1;
IF LEPTOCSP = 0 THEN BB = 0; ELSE BB = 1;
IF LEPTPUPA = 0 THEN CC = 0; ELSE CC = 1;
IF NECTOPSY = 0 THEN DD = 0; ELSE DD = 1;
IF OECETISP = 0 THEN EE = 0; ELSE EE = 1;
IF OXYETHSP = 0 THEN FF = 0; ELSE FF = 1;
IF ORTHOTSP = 0 THEN GG = 0; ELSE GG = 1;
IF HYDROPSY = 0 THEN HH = 0; ELSE HH = 1;
IF HYDROPSP = 0 THEN II = 0; ELSE II = 1;
IF HYDRPUPA = 0 THEN JJ = 0; ELSE JJ = 1;
IF HYTILASP = 0 THEN KK = 0; ELSE KK = 1;
IF POLYCENT = 0 THEN LL = 0; ELSE LL = 1;
IF POLYCINE = 0 THEN MM = 0; ELSE MM = 1;
IF POLYREMO = 0 THEN NN = 0; ELSE NN = 1;
IF POLYINTR = 0 THEN OO = 0; ELSE OO = 1;
IF CYRNFRAT = 0 THEN PP = 0; ELSE PP = 1;
IF NEURECSP = 0 THEN QQ = 0; ELSE QQ = 1;
IF POLYCNISPE = 0 THEN RR = 0; ELSE RR = 1;
IF AGYPNIA = 0 THEN SS = 0; ELSE SS = 1;
IF TIPULARV = 0 THEN TT = 0; ELSE TT = 1;
IF PROBGLAB = 0 THEN VV = 0; ELSE VV = 1;
IF CULCOIDE = 0 THEN XX = 0; ELSE XX = 1;
IF MUSCPUPA = 0 THEN YY = 0; ELSE YY = 1;
IF CERATPUP = 0 THEN ZZ = 0; ELSE ZZ = 1;
IF EMPIPIDA = 0 THEN AAA = 0; ELSE AAA = 1;
IF CHIRPUPA = 0 THEN BBB = 0; ELSE BBB = 1;
IF HEMERODR = 0 THEN CCC = 0; ELSE CCC = 1;
IF HYALAZTE = 0 THEN DDD = 0; ELSE DDD = 1;
IF ACARxxx = 0 THEN EEE = 0; ELSE EEE = 1;
IF COPEPODA = 0 THEN FFF = 0; ELSE FFF = 1;
IF HYDRASPx = 0 THEN GGG = 0; ELSE GGG = 1;
IF CLADOCER = 0 THEN HHH = 0; ELSE HHH = 1;
IF NEMATODA = 0 THEN III = 0; ELSE III = 1;
IF OLIGOCHA = 0 THEN JJJ = 0; ELSE JJJ = 1;
IF MENETUSS = 0 THEN KKK = 0; ELSE KKK = 1;
IF PHYSELLA = 0 THEN LLL = 0; ELSE LLL = 1;
IF FERRISIA = 0 THEN MMM = 0; ELSE MMM = 1;
IF DUGESIAS = 0 THEN NNN = 0; ELSE NNN = 1;
IF HSTIGNAL = 0 THEN OOO = 0; ELSE OOO = 1;
IF HELOBDEL = 0 THEN PPP = 0; ELSE PPP = 1;
IF HELONGAT = 0 THEN QQQ = 0; ELSE QQQ = 1;
IF PMULTILI = 0 THEN RRR = 0; ELSE RRR = 1;
IF PORNATA = 0 THEN SSS = 0; ELSE SSS = 1;
IF OTRANSLU = 0 THEN TTT = 0; ELSE TTT = 1;
IF PPARASIT = 0 THEN UUU = 0; ELSE UUU = 1;
IF AHETEROC = 0 THEN VVV = 0; ELSE VVV = 1;
IF MLUCIDIA = 0 THEN XXX = 0; ELSE XXX = 1;
IF MFERIDIA = 0 THEN YYY = 0; ELSE YYY = 1;
IF EPUNCTAT = 0 THEN ZZZ = 0; ELSE ZZZ = 1;
IF ERPOBDEL = 0 THEN AAAA = 0; ELSE AAAA = 1;
IF BPALUDOS = 0 THEN BBBB = 0; ELSE BBBB = 1;
IF BPICTA = 0 THEN CCCC = 0; ELSE CCCC = 1;
IF PMARAMOR = 0 THEN DDDD = 0; ELSE DDDD = 1;
IF STENOPEL = 0 THEN EEEE = 0; ELSE EEEE = 1;
IF HYPERODE = 0 THEN FFFF = 0; ELSE FFFF = 1;
IF CURCLARV = 0 THEN GGGG = 0; ELSE GGGG = 1;
IF CORILARV = 0 THEN HHHH = 0; ELSE HHHH = 1;
IF CORIXIDA = 0 THEN IIII = 0; ELSE IIII = 1;
IF PELTODYT = 0 THEN JJJJ = 0; ELSE JJJJ = 1;
IF LIXUSSP = 0 THEN KKKK = 0; ELSE KKKK = 1;
IF OSTRACOD = 0 THEN LLLL = O; ELSE LLLL = I;
IF ATOCHA = 0 THEN MMMM = O; ELSE MMMM = I;
IF ACENTRIA = 0 THEN NNNN = O; ELSE NNNN = I;
IF PARAPYNX = 0 THEN OOOO = O; ELSE OOOO = I;
IF SPHINGID = 0 THEN PPPP = O; ELSE PPPP = I;
IF LEPIDPUP = 0 THEN QQQQ = O; ELSE QQQQ = I;
IF ISOPODA = 0 THEN RRRR = O; ELSE RRRR = I;
IF CHIRONAE = 0 THEN SSSS = O; ELSE SSSS = I;
IF TANYPNAE = 0 THEN TTTT = O; ELSE TTTT = I;
IF ORTHONAE = 0 THEN UUUU = O; ELSE UUUU = I;
NUMTAXA = A+B+C+D+E+F+G+H+I+J+K+L+M+N+O+P+Q+R+S+T+U+V+X+Y+Z+
    AA+BB+CC+DD+EE+FF+GG+HH+II+JJ+KK+LL+MM+NN+OO+PP+QQ+RR+SS+TT+
    VV+XX+YY+ZZ+AAA+BBB+CCC+DDD+EEE+FFF+GGG+HHH+III+JJJ+KKK+LLL+
    MMM+NNN+OOO+PPP+QQQ+RRR+SSS+TTT+UUU+VVV+XX+YY+ZZZ+
    AAAA+BBBB+CCCC+DDDD+EEEE+FFFF+GGGG+HHHH+IIII+JJJJ+KKKK+LLLL+
    MMMM+NNNN+OOOO+PPPP+QQQQ+RRRR+SSSS+TTTT+UUUU;
PROC PRINT;
PROC SORT;
BY LAK SET SITE;
PROC MEANS N MIN MAX RANGE MEAN VAR STD STDERR CV SKEWNESS KURTOSIS;
BY LAK SET SITE;
VAR NUMTAXA;
PROC CHART;
BY LAK SET;
VBAR SITE/DISCRETE SUMVAR = NUMTAXA TYPE = MEAN;
PROC NPAR1WAY ANOVA WILCOXON;
BY LAK SET;
CLASS SITE;
VAR NUMTAXA;
APPENDIX E: Statistical analysis system (SAS) program used in Chapter One to analyze for differences in aquatic macroinvertebrate densities/m² among the "M. spicatun," "mixed" and "native" sites within Auburn and Zumbra Lakes on each sampling date.

TITLE "DENSITY/ m² AT SITES WITHIN A LAKE BY DATE";
DATA DENSITY;
INFILE "EPINVERT";
INPUT LAK $ SEQUENCE SITE DEPTH REP DATE SET TYPE CAENISSP BAETISSP STENOINT TRICORYT ENALAGSP ISCHNURA ARGIA GOMPHIDA NEHLENNIA SOMATOSP TETRAGON EPIPRINC PACHLONG MACROTBE HSIMULAN HYDROPSYCHE ORRIS CHEUMATOIMOBILUS LEPTAMER OCINERAS TRITARDA TRINJUST TRIANODE NECTALBI CERGLGMS LEPTOCSP LEPTPUPA NECTOPSY OECETISP OXYETHSP ORTHOTSP HYDROPSYCHE HYDRPUPA HYTILASP POLYCENT POLYCINE POLYREMO POLYINTR CYRPNAT NEURECSP POLCNSP AGRYPNIA TIPULARV CHIRONOM CHIRONAE TANYPNAE ORTHONAE PROBGLAB CULCOIDE MUSCPUPA CERACAT PUP PPARASIT AHETEROC MUCIDIA MFERDIA EPUNCTAT EPOBDEL BPALUDOS BPICTA PMARAMOR STENOPEL HYPERODE CURCLARV CORILARV CORIXIDA PELTODYT LIXUSSP OSTRACOD ATOCHA ACENTRIA PARAPYNX SPHINGID LEPIDPUP ISOPODA;
*CAENISSP = CAENIS SP.
*BAETISSP = BAETIS SP.
*STENOINT = STENONEMA INTEGRUM
*TRICORYT = TRICORYTHODES SP.
*ENALAGSP = ENALAGMA SP.
*ISCHNURA = ISCHNURA SP.
*ARGIA = ARGIA SP.
*GOMPHIDA = GOMPHIDAE SP.
*NEHLENNIA = NEHLENNIA SP.
*SOMATOSP = SOMATOCHLORA SP.
*TETRAGON = TETRAGONEURIA SP.
*EPIPRINC = EPITHECA PRINCEPS
*PACHLONG = PACHYDIPLAX LONGIPENNIS
*MACROTHE = MACROTHEMIS SP.
*HSIMULAN = HYDROPSYCHE SIMULANS
*HYDROPSYCHE ORRIS
*CHEUMATO = CHEUMATOPSYCHE SP.
*IMOBILUS = OECETIS IMOBILUS
*LEPTAMER = LEPTOCERUS AMERICANUS
*OCINERAS = OECETIS CINERASCENS
*TRITARDA = TRIANODES TARDA
*TRINJUST = TRIANODES INJUSTA
*TRIANTA = TRIANODES ABA
*TRIANGULUS = TRIANODES SP.
*NECTALBI = NECTOPSYCHE ALBIDA
*CERGLGMS = CERACLEA GLAGMUS
*LEPTOCSP = LEPTOCERUS SP.
*LEPTPUPA = LEPTOCERUS SP. PUPAE
*NECTOPSY = NECTOPSYCHE SP.  
*OECEISP = OECEITIS SP.  
*OXYETHSP = OXYETHIRA SP.  
*ORTHOTSP = ORTHOTRICHIA SP.  
*HYDROSP = HYDROPSYCHIDAE  
*HYDROPSP = HYDROPSYCIDA SP.  
*HYDRPUPA = HYDROPSYCIDA SP. PUPAE  
*HYTILASP = HYDROPTILA SP.  
*POLYCENT = POLYCENTROPUS CENTRALIS  
*POLYCINE = POLYCENTROPUS CINEREUS  
*POLYREMO = POLYCENTROPUS REMOTUS  
*POLYINTR = POLYCENTROPUS INTERUPTUS  
*CYRNFRAT = CYRNELLUS FRATURNUS  
*NEURECSP = NEURECLIPSIS SP.  
*POLYCNSP = POLYCENTROPUS SP.  
*AGRYPNIA = AGRYPNIA SP.  
*TIPULARV = TIPULIDAE SP. PUPAE  
*CHIRONOM = CHIRONOMIDAE  
*CHIRONAE = CHIRONOMINAE  
*TANYPNAE = TANYPODINAE  
*ORTHONAE = ORTHOCLADIINAE/DIAMESINAE  
*PROBGLAB = PROBEZZIA GLABRA  
*CULCOIDE = CULCOIDES SP.  
*MUSCPUPA = MUSCIDAE PUPAE  
*CERATPUP = CERATOPOGONIDAE PUPAE  
*EMPIDIDA = EMPIDIDAE  
*CHIRPUPA = CHIRONOMIDAE PUPAE  
*HEMERODR = HEMERODROMIA SP.  
*HYALAZTE = HYALLELA AZTECA  
*ACARxxx = ACARI  
*COPEPODA = COPEPODA  
*HYDRA x = HYDRA SP.  
*CLADOCER = CLADOCERA  
*NEMATODA = NEMATODA  
*OLIGOCHA = OLIGOCHAETA  
*MENETUSS = MENETUS SP.  
*PHYSELLA = PHYSELLA SP.  
*FERRISIA = FERRISIA SP.  
*DUGESIAS = DUGESIA SP.  
*HSTAGNAL = HELOBDELLA STAGNALIS  
*HELOBDEL = HELOBDELLA SP.  
*HELONGAT = HELOBDELLA ELONGATA  
*PMULTILI = PLACOBDELLA MULTILNEATA  
*PORNATA = PLACOBDELLA ORNATA  
*GTRANSLU = OLIGOBDELLA TRANSUSCENS  
*PPARASIT = PLACOBDELLA PARASITICA  
*AHERETOC = ALBOGLOSSIPHONIA HETEROCITICA  
*MUCIDIA = MARVINMEYERIA LUCIDIA  
*MFIRIIDA = MOOREOBDELLA FERVIDA  
*EPUNCTAT = ERPOBDELLA PUNCTATA  
*ERPOBDEL = ERPOBDELLA SP.
*BPALUDOS = BATRACOBDELLA PALUDOSA
*BPICTA = BATRACOBDELLA PICTA
*PMARAMOR = PLACOBDELLA MARAMORATA
*STENOPEL = STENOPELMUS SP.
*HYPERODE = HYPERODES SP.
*CURCLARV = CURCILONIDAE LARVAE
*CORLARV = CORIXIDAE LARVAE
*CORIXIDA = CORIXIDAE
*PELTOYDT = PELTOYDTES SP.
*LIXUSSP = LIKUS SP.
*OSTRACOD = OSTRACODA
*AUTOCHA = ANTOCHA SP.
*ACENTRIA = ACENTRIA SP.
*PARAPYNX = PARAPYNX SP.
*SPHINGID = SPHINGIDAE
*LEPIDPUP = LEPIDOPTERA PUPAE
*ISOPODA = ISOPODA
CAENISSm = 10.74*CAENISSP;
BAETISSm = 10.74*BAETISSP;
STENOINm = 10.74*STENOINT;
TRICORYm = 10.74*TRICORYT;
ENALAGSm = 10.74*ENALAGSP;
ISCHNURm = 10.74*ISCHNURA;
ARGIAM = 10.74*ARGIA;
GOMPHIDm = 10.74*GOMPHIDA;
NEHLENIm = 10.74*NEHLENIA;
SOMATOSm = 10.74*SOMATOSP;
TETRAGOm = 10.74*TETRAGON;
EPIPRINm = 10.74*EPIPRINC;
PACHLOIm = 10.74*PACHLONG;
MACROTHIm = 10.74*MACROTHE;
HSIMULAm = 10.74*HSIMULAN;
HYDRORRm = 10.74*HYDRORRI;
CHEUMATm = 10.74*CHEUMATO;
IMOBILUm = 10.74*IMOBILUS;
LEPTAMEEm = 10.74*LEPTAMER;
OCINERAm = 10.74*OCINERAS;
TRITARDm = 10.74*TRITARDA;
TRINUSm = 10.74*TRINJUST;
TRIADAm = 10.74*TRIADA;
TRIANODm = 10.74*TRIANODE;
NECTALBm = 10.74*NECTALBI;
CERGLGMm = 10.74*CERGLGMS;
LEPTOCSm = 10.74*LEPTOCSP;
LEPTPUPm = 10.74*LEPTPUPA;
NECTOPSm = 10.74*NECTOPS;
OECETISm = 10.74*OECETISP;
OXYETHSm = 10.74*OXYETHSP;
ORTHOTSm = 10.74*ORTHOTSP;
HYDROPSm = 10.74*HYDROPS;
HYDROPm = 10.74*HYDROPSP;
HYDRPUPm = 10.74*HYDRPUPA;
HYTILASm = 10.74*HYTILASP;
POLYCENm = 10.74*POLYCENT;
POLYCINm = 10.74*POLYCINE;
POLYREMm = 10.74*POLYREMO;
POLYINTm = 10.74*POLYINTR;
CYRNFRAm = 10.74*CYRNFRAT;
NEURECSm = 10.74*NEURECSP;
POLYCNSm = 10.74*POLYCNSP;
AGRYPNIm = 10.74*AGRYPNIA;
TIPULARm = 10.74*TIPULARV;
CHIRONDm = 10.74*CHIRONOM;
PROBGLAm = 10.74*PROBGLAB;
CULCOIDm = 10.74*CULCOIDE;
MUSCPUPm = 10.74*MUSCPUPA;
CERATPUp = 10.74*CERATPUP;
EMPIDIIm = 10.74*EMPIDIIDA;
CHIRPUPm = 10.74*CHIRPUPA;
HEMERODm = 10.74*HEMERODR;
HYALAZTm = 10.74*HYALAZTE;
ACARlxxm = 10.74*ACARIxxx;
COPEPODm = 10.74*COPEPODA;
HYDRASpm = 10.74*HYDRASPx;
CLADOCEm = 10.74*CLADOCE;
NEMATODm = 10.74*NEMATODA;
OLIGOCHm = 10.74*OLIGOCHA;
MENETUSm = 10.74*MENETUSS;
PHYSELLm = 10.74*PHYSELLA;
FERRISIm = 10.74*FERRISIA;
DUGESIAm = 10.74*DUGESIAS;
HSTAGNAm = 10.74*HSTAGNAL;
HELOBDEm = 10.74*HELOBDEL;
HELONGAm = 10.74*HELONGAT;
PMULTIlm = 10.74*PMULTILI;
PORNATAm = 10.74*PORNATA;
OTRANSLm = 10.74*OTRANSLU;
PAPPARASIm = 10.74*PAPPARASIT;
AHETEROm = 10.74*AHETEROC;
MLUCIDIm = 10.74*MLUCIDIA;
MFERIDIm = 10.74*MFERIDIA;
EPUNCTAm = 10.74*EPUNCTAT;
ERPOBDEm = 10.74*ERPOBDEL;
BPALUDOm = 10.74*BPALUDOS;
BPICITA = 10.74*BPICITA;
PMARAMOm = 10.74*PMARAMOR;
STENOPEm = 10.74*STENOPEL;
HYPERODm = 10.74*HYPERODE;
CURCLARm = 10.74*CURCLARV;
CORILARm = 10.74*CORILARV;
CORIXIDm = 10.74*CORIXIDIA;
PELTODYm = 10.74*PELTODYT;
LIXUSSPm = 10.74*LIXUSSP;
OSTRACOm = 10.74*OSTRACOD;
ATOCHAm = 10.74*ATOCHA;
ACENTRIm = 10.74*ACENTRIA;
PARAPYNNm = 10.74*PARAPYNX;
SPHINGIm = 10.74*SPHINGID;
LEPIDPUPm = 10.74*LEPIDPUP;
ISOPODAm = 10.74*ISOPODA;

EPHEM = CAENISSm+BAETISSm+STENOINm+TRICORYm;
ODONATA = ENALAGSm+SOMATOSm+TETRAGOm+EPIPRINm+PACHLONm+MACROTHm+ISCHNURm+ARGIAm+GOMPIdm+NEHLENm;
TRICHOP = HSIMULAm+HYDRORRm+CHEUMATm+IMOBILUm+LEPTAMEm+OCINERAm+
TRITARDm+TRINJUSm+NECTALbm+LEPTOCSm+LEPTPUPm+NECTOPSm+OECETISm+
OXYETHSm+ORTHOTSn+HYDROPSm+HYDROPlm+HYDRPUPm+HYTILAsm+POLYCENm+
POLYCINm+NEURECSm+CYRNFRAm+POLYCNSm+TRIADAm+TRIANODm+CERGLGMm+
POLYREMm+POLYINTm+AGRPm;
DIPTERA = CHIRONDm+PROBGLAm+CULCOIDm+CERATUPm+CHIRPUm+TIPUIARm+
MUSCPUPm+EMPIDIDm+HEMERODm+ATOCHA;
CRUSTAC = HYALAZtm+COPEPODm+CLADOCEm+OSTRACOm+ISOPODA;
ANNELID = HSTAGNAm+PMULTIm+OTRANSLm+PPARASIm+AHETEROm+MLUCIDm+
EPUNCTAm+ERPOBDEm+BPALUDOm+PMARAMOm+OLIGOCHm+HELOBDEM+HELONGAm+
PORNATAm+MFERIDIm+BPICTAm;
OTHER = ACARixxm+HYDRASPm+NEMATODm+DUGESIAm+CORILARM+CORIXIDm;
COLEOP = STENOPEm+HYPERODm+CURCLARM+LIXUSSPm+PELTOYm;
LEPIDOP = ACENTRIm+PARAPYNm+SPHINGIm+LEPIDPUp;
GASTRO = MENETUSm+PHYSELLm+FERRISim;
TOTAL = EPHEm+ODONATA+TRICHOP+DIPTERA+CRUSTAC+ANNELID+OTHER+GASTRO+
LEPIDOP+COLEOP;

PROC PRINT;
PROC SORT;
BY LAK SET SITE;
PROC MEANS N MIN MAX RANGE MEAN VAR STD STDERR CV SKEWNESS KURTOSIS;
BY LAK SET SITE;
VAR TOTAL;
PROC CHART;
BY LAK SET;
VBAR SITE/DISCRETE SUMVAR = TOTAL TYPE = MEAN;
PROC NPAR1WAY ANOVA WILCOXON;
BY LAK SET;
CLASS SITE;
VAR TOTAL;
APPENDIX F: Statistical analysis system (SAS) program used in Chapter One to analyze for differences in aquatic macroinvertebrate AFDW (g/m²) among the "M. spicatum," "mixed" and "native" sites within Auburn and Zumbra Lakes on each sampling date.

TITLE "AFDW/0.093 M2 AT SITES WITHIN A LAKE BY DATE";
DATA AFDW;
INFILE "BIOMASS";
INPUT LAK $ SEQUENCE SITE DEPTH REP DATE SET TYPE WEIGHT;
WGHT = WEIGHT * 10.74;
PROC PRINT;
PROC SORT;
BY LAK SET SITE;
PROC MEANS N MIN MAX RANGE MEAN VAR STD STDERR CV SKEWNESS KURTOSIS;
BY LAK SET SITE;
VAR WGHT;
PROC CHART;
BY LAKE SET;
VBAR SITE/DISCRETE SUMVAR = WGHT TYPE = MEAN;
PROC NPAR1WAY ANOVA WILCOXON;
BY LAK SET;
CLASS SITE;
VAR WGHT;
APPENDIX G: Statistical analysis system (SAS) program used in Chapter One to analyze for differences in aquatic macroinvertebrate taxa richness/0.093 m² within the “M. spicatum,” “mixed” and “native” sites over time.

TITLE "TAXA RICHNESS/0.093 M² EACH SITE OVER TIME";
DATA RICHNESS;
INFILE "EPINVERT";
INPUT LAK $ SEQUENCE SITE DEPTH REP DATE SET TYPE CAENISSP BAETISSP STENOINT TRICORYT ENALAGSP ISCHNURA ARGIA GOMPHERDA NEHLENIA SOMATOSP TETRAGON EPIPRINC PACHLONG MACROTHE HSIMULAN HYDROPSY CHEUMATO IMOBILUS LEPTAMER OCINERAS TRITARDA TRINJUST TRIADA TRIANODE NECTALBI CERGLGMS LEPTOCSP LEPTUPA NECTOPSIS OECETISP OXYETHSP ORTHOTSP HYDROPSY HYDROPSY HYDROPSY HYDROPSY HYDROPSY HYDROPSY POLYCENT POLYCYNE POLYREMO POLYINTR CYRNFRAT NEURECL POLYCNSP AGRYPNIA TIPULARY CHIRONOM CHIRONAE TANYPNAE ORTHONAE PROBGLAB CULCOIDE MUSCPUPA CERATPUP EMPIDIDA CHIRPUPA HEMERODR HYALAZTE ACARIII COPEPODA HYDRASx CLADOCER NEMATODA OLIGOCHA MENETUSS PHYSELLA FERRISIA DUGIESIAR HISTAGNAL HELOBDEL HELONGAT PMULTI PORNATA OTRANSU PPARASIT AHETEROC MLUCIDIA MFERIDIA EPUNCTAT ERPOBDEL BPALUDOS BPICLIT APMARAMOR STENOPEL HYPERODE CURCULARY CORILARY CORIXIDA PELTODYT LIXUSSP OSTRACOD ATOCHA ACENTRIA PARAPYNX SPHINGID LEPIDPUP ISOPODA;
*CAENISSP = CAENIS SP.
*BAETISSP = BAETIS SP.
*STENOINT = STENONEMA INTEGRUM
*TRICORYT = TRICORYTHODES SP.
*ENALAGSP = ENALAGMA SP.
*ISCHNURA = ISCHNURA SP.
*ARGIA = ARGIA SP.
*GOMPHERDA = GOMPHERDAE SP.
*NEHLENIA = NEHLENIA SP.
*SOMATOSP = SOMATOCHLORA SP.
*TETRAGON = TETRAGONEURIA SP.
*EPIPRINC = EPITHECA PRINCEPS
*PACHLONG = PACHYDIPLAX LONGIPENNIS
*MOCOTHE = MACROTHEMIS SP.
*HSIMULAN = HYDROPSYCHE SIMULANS
*HYDRORRI = HYDROPSYCHE ORRIS
*CHEUMATO = CHEUMATOPSYPHE SP.
*IMOBILUS = OECETIS IMOBILUS
*LEPTAMER = LEPTOCERUS AMERICANUS
*OCINERAS = OECETIS CINERASCENS
*TRITARDA = TRIANODES TARDA
*TRINJUST = TRIANODES INJUSTA
*TRIADA = TRIANODES ABA
*TRIANODE = TRIANODES SP.
*NECTALBI = NECTOPSYPHE ALBIDA
*CERGLGMS = CERACLEA GLAGMUS
*LEPTOCSP = LEPTOCERUS SP.
*ERPOBDEL = ERPOBDELLA SP.
*BPALUDOS = BATRACOBDELLA PALUDOSA
*BPICTA = BATRACOBDELLA PICTA
*PMARAMOR = PLACOBDELLA MARAMORATA
*STENOPEL = STENOPELMUS SP.
*HYPERODE = HYPERODES SP.
*CURLARV = CURCLIONIDAE LARVAE
*CROILARV = CORIXIDAE LARVAE
*CROIXIDA = CORIXIDAE
*PELTODYT = PELTODYTES SP.
*LIXUSSP = LIXUS SP.
*OSTRACOD = OSTRACODA
*ATOCHA = ANTOCHA SP.
*ACENTRIA = ACENTRIA SP.
*PARAPYNX = PARAPOYNX SP.
*SPhINGID = SPhINGIDAE
*LEPIDPUP = LEPIDOPTERA PUPAE
*ISOPODA = ISOPODA

IF CAENISSP = 0 THEN A = 0; ELSE A = 1;
IF BAETISSP = 0 THEN B = 0; ELSE B = 1;
IF STENOINT = 0 THEN C = 0; ELSE C = 1;
IF TRICORYT = 0 THEN D = 0; ELSE D = 1;
IF ENALAGSP = 0 THEN E = 0; ELSE E = 1;
IF ISCHNURA = 0 THEN F = 0; ELSE F = 1;
IF ARGIA = 0 THEN G = 0; ELSE G = 1;
IF GOMPHIDA = 0 THEN H = 0; ELSE H = 1;
IF NEHLENIA = 0 THEN I = 0; ELSE I = 1;
IF SOMATOSP = 0 THEN J = 0; ELSE J = 1;
IF TETRAGON = 0 THEN K = 0; ELSE K = 1;
IF EPIPRINC = 0 THEN L = 0; ELSE L = 1;
IF PACHLONG = 0 THEN M = 0; ELSE M = 1;
IF MACROTHE = 0 THEN N = 0; ELSE N = 1;
IF HSIMULAN = 0 THEN O = 0; ELSE O = 1;
IF HYDRORRI = 0 THEN P = 0; ELSE P = 1;
IF CHEUMATO = 0 THEN Q = 0; ELSE Q = 1;
IF IMOBILUS = 0 THEN R = 0; ELSE R = 1;
IF LEPTAMER = 0 THEN S = 0; ELSE S = 1;
IF OCINERAS = 0 THEN T = 0; ELSE T = 1;
IF TRITARDA = 0 THEN U = 0; ELSE U = 1;
IF TRINJUST = 0 THEN V = 0; ELSE V = 1;
IF TRIADA = 0 THEN X = 0; ELSE X = 1;
IF TRIANODE = 0 THEN Y = 0; ELSE Y = 1;
IF NECTALBI = 0 THEN Z = 0; ELSE Z = 1;
IF CERGLOGMS = 0 THEN AA = 0; ELSE AA = 1;
IF LEPTOCSP = 0 THEN BB = 0; ELSE BB = 1;
IF LEPTPUPA = 0 THEN CC = 0; ELSE CC = 1;
IF NECTOPSY = 0 THEN DD = 0; ELSE DD = 1;
IF OECETISP = 0 THEN EE = 0; ELSE EE = 1;
IF OXYETHSP = 0 THEN FF = 0; ELSE FF = 1;
IF ORTHOTSP = 0 THEN GG = 0; ELSE GG = 1;
IF HYDROPSY = 0 THEN HH = 0; ELSE HH = 1;
IF HYDROPSP = 0 THEN II = 0; ELSE II = 1;
IF HYDRPUPA = 0 THEN JJ = 0; ELSE JJ = 1;
IF HYTILASP = 0 THEN KK = 0; ELSE KK = 1;
IF POLYCEN = 0 THEN LL = 0; ELSE LL = 1;
IF POLYREMO = 0 THEN NN = 0; ELSE NN = 1;
IF POLYINTR = 0 THEN QQ = 0; ELSE QQ = 1;
IF CYRNFRAT = 0 THEN PP = 0; ELSE PP = 1;
IF NEURECSP = 0 THEN QQ = 0; ELSE QQ = 1;
IF POLYCNSP = 0 THEN RR = 0; ELSE RR = 1;
IF EMPIPIDA = 0 THEN AAA = 0; ELSE AAA = 1;
IF CHIRPUPA = 0 THEN BBB = 0; ELSE BBB = 1;
IF HEMERODR = 0 THEN CCC = 0; ELSE CCC = 1;
IF HYALAZTE = 0 THEN DDD = 0; ELSE DDD = 1;
IF ACARIXXX = 0 THEN EEE = 0; ELSE EEE = 1;
IF COPEPODA = 0 THEN FFF = 0; ELSE FFF = 1;
IF HYDRASPx = 0 THEN GGG = 0; ELSE GGG = 1;
IF CLADOCER = 0 THEN HHH = 0; ELSE HHH = 1;
IF NEMATODA = 0 THEN IIII = 0; ELSE IIII = 1;
IF OLIGOCHA = 0 THEN JJJJ = 0; ELSE JJJJ = 1;
IF MENTUSS = 0 THEN KKK = 0; ELSE KKK = 1;
IF PHYSELLA = 0 THEN LLLL = 0; ELSE LLLL = 1;
IF FERRISIA = 0 THEN MMM = 0; ELSE MMM = 1;
IF DUGESIAS = 0 THEN NNN = 0; ELSE NNN = 1;
IF HSTAGNAL = 0 THEN OOO = 0; ELSE OOO = 1;
IF HELOBDEL = 0 THEN PPP = 0; ELSE PPP = 1;
IF HELONGAT = 0 THEN QQQ = 0; ELSE QQQ = 1;
IF PMULTILI = 0 THEN RRR = 0; ELSE RRR = 1;
IF PORNATA = 0 THEN SSS = 0; ELSE SSS = 1;
IF OTRANSLU = 0 THEN TTT = 0; ELSE TTT = 1;
IF PPARASIT = 0 THEN UUUU = 0; ELSE UUUU = 1;
IF BATEROC = 0 THEN VVVV = 0; ELSE VVVV = 1;
IF MLUCIDIA = 0 THEN XXX = 0; ELSE XXX = 1;
IF MFERIDIA = 0 THEN YYYY = 0; ELSE YYYY = 1;
IF EPUNCTAT = 0 THEN ZZZZ = 0; ELSE ZZZZ = 1;
IF ERPOBDEL = 0 THEN AAAAA = 0; ELSE AAAAA = 1;
IF BPALUDOS = 0 THEN BBBB = 0; ELSE BBBB = 1;
IF BPICTA = 0 THEN CCCC = 0; ELSE CCCC = 1;
IF PMARAMOR = 0 THEN DDDD = 0; ELSE DDDD = 1;
IF STENOP = 0 THEN EEEE = 0; ELSE EEEE = 1;
IF HYPERODE = 0 THEN FFFF = 0; ELSE FFFF = 1;
IF CURCLARV = 0 THEN GGGG = 0; ELSE GGGG = 1;
IF CORILARV = 0 THEN HHHH = 0; ELSE HHHH = 1;
IF CORIXIDA = 0 THEN IIII = 0; ELSE IIII = 1;
IF FELTODYT = 0 THEN JJJJ = 0; ELSE JJJJ = 1;
IF LIXUSSP = 0 THEN KKKK = 0; ELSE KKKK = 1;
IF OSTRACOD = 0 THEN LLLL = 0; ELSE LLLL = 1;
IF ATOCHA = 0 THEN MMMM = 0; ELSE MMMM = 1;
IF ACENTRIA = 0 THEN NNNN = 0; ELSE NNNN = 1;
IF PARAPYNX = 0 THEN OOOO = 0; ELSE OOOO = 1;
IF SPHINGID = 0 THEN PPPP = 0; ELSE PPPP = 1;
IF LEPIDPUP = 0 THEN QQQQ = 0; ELSE QQQQ = 1;
IF ISOPODA = 0 THEN RRRR = 0; ELSE RRRR = 1;
IF CHIRONAE = 0 THEN SSSS = 0; ELSE SSSS = 1;
IF TANYPNAE = 0 THEN TTTT = 0; ELSE TTTT = 1;
IF ORTHONAE = 0 THEN UUUU = 0; ELSE UUUU = 1;
NUMTAXA = A+B+C+D+E+F+G+H+I+J+K+L+M+N+O+P+Q+R+S+T+U+V+X+Y+Z+
    AA+BB+CC+DD+EE+FF+GG+HH+II+JJ+KK+LL+MM+NN+OO+PP+QQ+RR+SS+TT+
    VV+XX+YY+ZZ+AAA+BBB+CCC+DDD+EEE+FFF+GGG+HHH+III+JJJ+KKK+LLL+
    MMM+NNN+OOO+PPP+QQQ+RRR+SSS+TTT+UUU+VVV+XXX+YYY+ZZZ+
    AAAA+BBBB+CCCC+DDDD+EEEE+FFFF+GGGG+HHHH+IIII+JJJJ+KKKK+LLLL+
    MMMM+NNNN+OOOO+PPPP+QQQQ+RRRR+SSSS+TTTT+UUUU;
*EPHEM = A+B+C+D;
*ODONATA = E+F+G+H+I+J+K+L+M+N;
*TRICHOP = O+P+Q+R+S+T+U+V+X+Y+Z+AA+BB+CC+DD+EE+FF+GG+HH+II+JJ+KK+
    LL+MM+NN+OO+PP+QQ+RR+SS;
*DIPTERA = TT+VV+XX+YY+ZZ+AAA+BBB+CCC+MMMM;
*CROSTAC = DDD+FFF+HHH+LLL+RRRR;
*ANNELID = JJJ+OOO+PPP+QQQ+RRR+SSS+TTT+UUU+VVV+XXX+YYY+ZZZ+
    AAAA+BBBB+CCCC+DDDD;
*OTHER = EEE+GGG+III+NNN+HHHH+III;
*COLEOP = EEEE+FFFF+GGGG+KKKK;
*LEPIDOP = NNNN+OOOO+PPPP+QQQQ;
*GASTRO = KKK+LLL+MMM;
*TOTAL = EPHEM+ODONATA+TRICHOP+DIPTERA+CRUSTAC+ANNELID+OTHER+GASTRO+
    LEPIDOP+COLEOP;
IF SET = 1 THEN MONTH = 1;
IF SET = 5 THEN MONTH = 1;
IF SET = 9 THEN MONTH = 1;
IF SET = 2 THEN MONTH = 2;
IF SET = 6 THEN MONTH = 2;
IF SET = 10 THEN MONTH = 2;
IF SET = 3 THEN MONTH = 3;
IF SET = 7 THEN MONTH = 3;
IF SET = 11 THEN MONTH = 3;
IF SET = 1 THEN YEAR = 1993;
IF SET = 5 THEN YEAR = 1994;
IF SET = 9 THEN YEAR = 1995;
IF SET = 2 THEN YEAR = 1993;
IF SET = 6 THEN YEAR = 1994;
IF SET = 10 THEN YEAR = 1995;
IF SET = 3 THEN YEAR = 1993;
IF SET = 7 THEN YEAR = 1994;
IF SET = 11 THEN YEAR = 1995;
PROC PRINT;
PROC SORT;
BY LAK SITE YEAR SET;
PROC MEANS N MIN MAX RANGE MEAN VAR STD STDERR CV SKEWNESS KURTOSIS;
BY LAK SITE YEAR SET;
VAR NUMTAXA;
PROC CHART;
BY LAK SITE YEAR;
VBAR SET/DISCRETE SUMVAR = NUMTAXA TYPE = MEAN;
PROC NPARIWAY ANOVA WILCOXON;
BY LAK SITE YEAR;
CLASS SET;
VAR NUMTAXA;
APPENDIX H: Statistical analysis system (SAS) program used in Chapter One to analyze for differences in aquatic macroinvertebrate densities/m² within the "M. spicatum," "mixed" and "native" sites over time.

TITLE "DENSITIES/M² IN EACH SITE OVER TIME";
DATA DENSITY;
INFILE "EPINVERT";
  INPUT LAK $ SEQUENCE SITE DEPTH REP DATE SET TYPE CAENISSP BAETISSP STENOINT TRICORYT ENALAGSP ISCHNURA ARGIA GOMPHIDA NEHLENIASOMATOSP TETRAGON EPIPRINC PACHLONG MACROTHE HSIMULAN HYDRORRI CHEUMATO IMOBILUS LEPTAMER OCNERAS TRITARDA TRINJUST TRIADA TRIANODE NECTALBI CERGLGMS LEPTOCSP LEPTPUPA NECTOSPY OECETISP OXYETHSP ORTHOTSP HYDROPSY HYDROPSP HYDRPUPA HYTILASP POLYCENT POLYCINE POLYCREMO POLYINTR CYRMFRAT NEURECSP POLYCNSP ARGYPNIA TIPULARV CHIRONOM CHIRONAE TANYPOAE ORTHONAE PROBGLAB CULCOIDE MUSCPUPA CERATTPUP EPMIDIDA CHIRPUPA HEMERODR HYALAZTE ACARIxxx COPEPODA HYDRASPx CLADOCER NEMATODA OLIGOCHA MENETUSS PHYSELLA FERRISIA DUGESIAS IASTAGNATHELOBDEL HELONGAT FMULTILI PORNATA ORTRANSU PPARASIT AHETEROC MLUCIDIA MFERIDIA EUNPCTAT ERPOBDEL BPALUDOS BPICTA PMARAMOR STENOPEL HYPERODE CURCLARV CORILARV CORIXIDA PELTODYT LIXUSSP OSTRACOD ATOCHA ACENTRIA PARAPYNX SPHINGID LEPIDPUP ISOPODA;
*CAENISSP = CAENIS SP.
*BAETISSP = BAETIS SP.
*STENOINT = STENONEMA INTEGRUM
*TRICORYT = TRICORYTHODES SP.
*ENALAGSP = ENALAGMA SP.
*ISCHNURA = ISCHNURA SP.
*ARGIA = ARGIA SP.
*GOMPHIDA = GOMPHIDAE SP.
*NEHLENIASOMATOCHLORA SP.
*TETRAGON = TETRAGONEURIA SP.
*EPIPRINC = EPITHECA PRINCEPS
*PACHLONG = PACHYDIPLOX LONGIPENNIS
*MACROTHE = MACROTHEMIS SP.
*HSIMULAN = HYDROPSYCHE SIMULANS
*HYDRORRI = HYDROPSYCHE ORRIS
*CHEUMATO = CHEUMATOPSYCHE SP.
*IMOBILUS = OECETIS IMMOBILIS
*LEPTAMER = LEPTOCERUS AMERICANUS
*OCINERAS = OECETIS CINERASCONS
*TRITARDA = TRIANODES TARDA
*TRINJUST = TRIANODES INJUSTA
*TRIADA = TRIANODES ABA
*TRIANODE = TRIANODES SP.
*NECTALBI = NECTOSPYCHE ALBIDA
*CERGLGMS = CERACLEA GLAGMUS
*LEPTOCSP = LEPTOCERUS SP.
*LEPTPUPA = LEPTOCERUS SP. PUPAE
*NECTOPSY = NECTOPSYCHE SP.
*OECETISP = OECETIS SP.
*OXYETHSP = OXYETHIRA SP.
*ORTHOTSP = ORTHOTRICHIA SP.
*HYDROPSY = HYDROPSYCHIDAE
*HYDROSP = HYDROPSYCIDAE SP.
*HYDRPUPA = HYDROPSYCIDAE SP. PUPAE
*HYTILASP = HYDROPTILA SP.
*POLYCENT = POLYCENTROPUS CENTRALIS
*POLYCINE = POLYCENTROPUS CINEREUS
*POLYREMO = POLYCENTROPUS REMOTUS
*POLYINTR = POLYCENTROPUS INTERUPTUS
*CYRNFRAT = CYRNELLUS FRATURNUS
*NEURECSP = NEURECLIPSIS SP.
*POLYCNSP = POLYCENTROPUS SP.
*GRYPNIA = AGYRPNIA SP.
*TIPULARV = TIPULIDAE SP. PUPAE
*CHIRONOM = CHIRONOMIDAE
*CHIRONAE = CHIRONOMINAE
*TANYPNAE = TANYPODINAE
*ORTHONAE = ORTHOCLADIINAEGINAES/DIAMESINAE
*PROBGLAB = PROBEZZIA GLABRA
*CULCOIDE = CULCOIDES SP.
*MUSCPUPA = MUSCIDAE PUPAE
*CERATPUP = CERATOPONIDAE PUPAE
*EMPIDIDA = EMPIDIDAE
*CHIFUPA = CHIRONOMIDAE PUPAE
*HEMERODR = HEMERODROMIA SP.
*HYALAZTE = HYALLELA AZTECA
*ACARxxx = ACARI
*COPEPODA = COPEPODA
*HYDRAx = HYDRA SP.
*CLADOCER = CLADOCERA
*NEMATODA = NEMATODA
*OLIGOCHA = OLIGOCHAETA
*MENETUSS = MENETUS SP.
*PHYSELLA = PHYSELLA SP.
*FERRISIA = FERRISIA SP.
*DUGESIAS = DUGESIA SP.
*HSTAGNAL = HELOBDELLA STAGNALIS
*HELOBDEL = HELOBDELLA SP.
*HELONGAT = HELOBDELLA ELONGATA
*PMULTILI = PLACOBDELLA MULTILNEATA
*PORNATA = PLACOBDELLA ORNATA
*OTRANSLU = OLIGOBDELLA TRANSLUSCENS
*PPARASIT = PLACOBDELLA PARASITICA
*AHETEROC = ALBOGLOSSIPHONIA HETEROCLITA
*MLUCIDIA = MARVINMEYERIA LUCIDIA
*MFERIDIA = MOOREOBDELLA FERVIDA
*EPUNCTAT = ERPOBDELLA PUNCTATA
*ERPOBDEL = ERPOBDELLA SP.
*BPALUDOS = BATRACOBDELLA PALUDOSA
*BPICTA = BATRACOBDELLA PICTA
*PMARAMOR = PLACOBDELLA MARAMORATA
*STENOPEL = STENOPELMUS SP.
*HYPERODE = HYPERODES SP.
*CURCLARV = CURCLIONIDAE LARVAE
*CORILARV = CORIXIDAE LARVAE
*CORIXIDA = CORIXIDAE
*PELTODYT = PELTODYTES SP.
*LIXUSSP = LIXUS SP.
*OSTRACOD = OSTRACODA
*ATOCHA = ANTOCHA SP.
*ACENTRIA = ACENTRIA SP.
*PARAPYNX = PARAPOYNX SP.
*SPhingid = SPhingidae
*LEPIDPUP = LEPIDOPTERA PUPAE
*ISOPODA = ISOPODA
CAENISSm = 10.74*CAENISSP;
BAETISSmi = 10.74*BAETISSP;
STENOINTm = 10.74*STENOINT;
TRICORYm = 10.74*TRICORYT;
ENALAGSm = 10.74*ENALAGSP;
ISCHNURm = 10.74*ISCHNURA;
ARGIAm = 10.74*ARGIA;
GOMPHIDm = 10.74*GOMPHIDA;
NEHLENIm = 10.74*NEHLENIA;
SOMATOSm = 10.74*SOMATOSP;
TETRAGOm = 10.74*TETRAGON;
EPiPRInm = 10.74*EPiPRINC;
PACHLONGm = 10.74*PACHLONG;
MACROTHEm = 10.74*MACROTHE;
HSIMULAm = 10.74*HSIMULAN;
HYDRORRm = 10.74*HYDRORRI;
CHEUMATm = 10.74*CHEUMATO;
IMOBILUm = 10.74*IMOBILUS;
LEPTAMEm = 10.74*LEPTAMER;
OCINERAm = 10.74*OCINERAS;
TRITARDm = 10.74*TRITARDA;
TRINJUSm = 10.74*TRINJUST;
TRIADA m = 10.74*TRIADA;
TRIANODm = 10.74*TRIANODE;
NECTALBm = 10.74*NECTALBI;
CERGLGMm = 10.74*CERGLGMS;
LEPTOCSp = 10.74*LEPTOCSp;
LEPTPUPm = 10.74*LEPTPUPA;
NECTOPSm = 10.74*NECTOPSY;
OECETISm = 10.74*OECETISP;
OXYETHSm = 10.74*OXYETHSP;
ORTHOTSm = 10.74*ORTHOTSP;
HYDROPm = 10.74*HYDROPSP;
HYDRPUPm = 10.74*HYDRPUPA;
HYTILASm = 10.74*HYTILASP;
POLYCENm = 10.74*POLYCENT;
POLYCINm = 10.74*POLYCINE;
POLYREMm = 10.74*POLYREMO;
POLYINTm = 10.74*POLYINTR;
CYRNFRAm = 10.74*CYRNFRAT;
NEURECSm = 10.74*NEURECSP;
POLYCNSm = 10.74*POLYCNSP;
AGRYPNlm = 10.74*AGRYPNIA;
TIPULARm = 10.74*TIPULARV;
CHIRONDm = 10.74*CHIRONOM;
PROBGLAm = 10.74*PROBGLAB;
CULCOIDm = 10.74*CULCOIDE;
MUSCPUPm = 10.74*MUSCPUPA;
CERATPUm = 10.74*CERATPUP;
EMPIDIDm = 10.74*EMPIDIDA;
CHIRPUPm = 10.74*CHIRPUPA;
HEMERODm = 10.74*HEMERODR;
HYALAZTm = 10.74*HYALAZTE;
ACARIxxxm = 10.74*ACARIxxx;
COPEPODm = 10.74*COPEPODA;
HYDRASPM = 10.74*HYDRASPx;
CLADOCEm = 10.74*CLADOCE;
NEMATODm = 10.74*NEMATODA;
OLIGOCHm = 10.74*OLIGOCHA;
MENETUSm = 10.74*MENETUSS;
PHYSELLm = 10.74*PHYSELLA;
FERRISlm = 10.74*FERRISIA;
DUGESIAm = 10.74*DUGESIAS;
HSTAGNAm = 10.74*HSTAGNAL;
HELOBDEM = 10.74*HELOBDEL;
HELONGAm = 10.74*HELONGAT;
PMULTILm = 10.74*PMULTILI;
PORNATAm = 10.74*PORNATA;
OTRANSLm = 10.74*OTRANSLU;
PPARASIm = 10.74*PPARASIT;
AHETEROm = 10.74*AHETEROC;
MLUCIDIm = 10.74*MLUCIDIA;
MFERIDIm = 10.74*MFERIDIA;
EPUNCTAm = 10.74*EPUNCTAT;
ERPOBDEM = 10.74*ERPOBDEL;
BPALUDOom = 10.74*BPALUDOS;
BPICTAm = 10.74*BPICTA;
PMARAMOm = 10.74*PMARAMOR;
STENOPEEm = 10.74*STENOPEL;
HYPERODm = 10.74*HYPERODE;
CURCLARm = 10.74*CURCLARV;
CORILARm = 10.74*CORILARV;
CORIXIDm = 10.74*CORIXIDA;
PELTODYm = 10.74*PELTODYT;
LIXUSSpm = 10.74*LIXUSSp;
OSTRACOm = 10.74*OSTRACOD;
ATOCHAm = 10.74*ATOCHA;
ACENTRIm = 10.74*ACENTRIA;
PARAPYNm = 10.74*PARAPYNX;
SPHINGIm = 10.74*SPHINGID;
LEPIDPUm = 10.74*LEPIDPUP;
ISOPODAm = 10.74*ISOPODA;
EPHEM = CAENISSm+BAETISSm+STENOINNm+TRICORYm;
ODONATA = ENALAGSm+SOMATOSm+TETRAGOm+EPIPRINm+PACHLONm+MACROTHm+
ISCHNURm+ARGIAM+GOMPHIDm+NEHLENIm;
TRICHOP = HSIMULAm+HYDRORRm+CHEUMATm+IMOBILUm+LEPTAMEm+OCINERAm+
TRITARDm+TRINJUSm+NECTALBm+LEPTOCSm+LEPTPUPm+NECTOPSm+OECETISm
+OXYETHSm+ORTHOTSm+HYDROPSm+HYDROPm+HYDRPUPm+HYTILAsm+POLYCE
m+POLYCIIm+NEURECSm+CURNFRAm+POLYCNSm+TRIADAm+TRIANODm+CEERGL
Mm+POLYREMm+POLYINTm+AGRYPNm;
DIPTERA = PROBGLAm+CULCOIDm+PERATPUm+CHIRFUPm+TIPULARm+MUSCPUPm+
EMPIDIDm+HEMERODm+ATOCHAm+CHIRONDm;
CRUSTAC = HYALAZtm+COPEPODm+CLADOCEm+OSTRACOm+ISOPODAm;
ANNELID = HSTAGNAm+PMULTIm+OTRANSLm+PPARASIm+AHETEROm+MLUCIDIm+
EMPUNCTAm+ERPOBDEM+BPALUDEm+PMARAMOm+OLIGOCHm+HELOBDEm+HELO
GAm+PORNATAm+MFERIDm+BPICtm;
OTHER = ACARixxm+HYDRASPm+NEMATODm+DUGESIAm+CORILARm+CORIXIDm;
COLEOP = STENOPEm+HYPERODm+CURCLARm+LIXUSSpm+PELTODYm;
LEPIDOP = ACENTRIM+PARAPYNm+SPHINGIm+LEPIDPUm;
GASTRO = MENETUSm+PHYSELLm+FERRISm;
TOTAL = EPHFEM+ODONATA+TRICHOP+DIPTERA+CRUSTAC+ANNELID+OTHER+GASTRO+
LEPIDOP+COLEOP;
IF SET = 1 THEN MONTH = 1;
IF SET = 5 THEN MONTH = 1;
IF SET = 9 THEN MONTH = 1;
IF SET = 2 THEN MONTH = 2;
IF SET = 6 THEN MONTH = 2;
IF SET = 10 THEN MONTH = 2;
IF SET = 3 THEN MONTH = 3;
IF SET = 7 THEN MONTH = 3;
IF SET = 11 THEN MONTH = 3;
IF SET = 1 THEN YEAR = 1993;
IF SET = 5 THEN YEAR = 1994;
IF SET = 9 THEN YEAR = 1995;
IF SET = 2 THEN YEAR = 1993;
IF SET = 6 THEN YEAR = 1994;
IF SET = 10 THEN YEAR = 1995;
IF SET = 3 THEN YEAR = 1993;
IF SET = 7 THEN YEAR = 1994;
IF SET = 11 THEN YEAR = 1995;
PROC PRINT;
PROC SORT;
BY LAK SITE YEAR MONTH;
PROC MEANS N MIN MAX RANGE MEAN VAR STD STDERR CV SKEWNESS KURTOSIS;
BY LAK SITE YEAR MONTH;
VAR TOTAL;
PROC CHART;
BY LAK SITE YEAR;
VBAR MONTH/DISCRETE SUMVAR = TOTAL TYPE = MEAN;
PROC NPAR1WAY ANOVA WILCOXON;
BY LAK SITE YEAR;
CLASS MONTH;
VAR TOTAL;
APPENDIX I: Statistical analysis system (SAS) program used in Chapter One to analyze for differences within aquatic macroinvertebrate AFDW (g/m²) in the "M. spicatum," "mixed" and "native" sites over time.

TITLE "AFDW/M² AT SITES WITHIN A LAKE BY DATE";
DATA AFDW;
INFILE "BIOMASS";
INPUT LAK $ SEQUENCE SITE DEPTH REP DATE SET TYPE WEIGHT;
WGHT = WEIGHT * 10.74;
IF SET = 1 THEN MONTH = 1;
IF SET = 5 THEN MONTH = 1;
IF SET = 9 THEN MONTH = 1;
IF SET = 2 THEN MONTH = 2;
IF SET = 6 THEN MONTH = 2;
IF SET = 10 THEN MONTH = 2;
IF SET = 3 THEN MONTH = 3;
IF SET = 7 THEN MONTH = 3;
IF SET = 11 THEN MONTH = 3;
IF SET = 1 THEN YEAR = 1993;
IF SET = 5 THEN YEAR = 1994;
IF SET = 9 THEN YEAR = 1995;
IF SET = 2 THEN YEAR = 1993;
IF SET = 6 THEN YEAR = 1994;
IF SET = 10 THEN YEAR = 1995;
IF SET = 3 THEN YEAR = 1995;
IF SET = 7 THEN YEAR = 1994;
IF SET = 11 THEN YEAR = 1995;
PROC PRINT;
PROC SORT;
BY LAK YEAR SITE MONTH;
PROC MEANS N MIN MAX RANGE MEAN VAR STD STDERR CV SKEWNESS KURTOSIS;
BY LAK YEAR SITE MONTH;
VAR WGHT;
PROC CHART;
BY LAK YEAR SITE;
VBAR MONTH/DISCRETE SUMVAR = WGHT TYPE = MEAN;
PROC NPAR1WAY ANOVA WILCOXON;
BY LAK YEAR SITE;
CLASS MONTH;
VAR WGHT;
APPENDIX J: Statistical analysis system (SAS) program used in Chapter Two to analyze for differences in aquatic macroinvertebrate taxa richness/0.093 m² within the “M. spicatum,” “mixed” and “native” sites in Zumbra Lake over the sampling period.

TITLE “TAXA RICHNESS/M2 AT EACH SITE OVER TIME”;
DATA RICHNESS;
INFILE "EPINVERT’;
INPUT LAK $ SEQUENCE SITE DEPTH REP DATE SET TYPE CAENISSP BAETISSP STENOINT TRICORYT ENALAGSP ISCHNURA ARGIA GOMPHIDA NEHLENIA SOMATOSP TETRAGON EPIPRINC PACHLONG MACROTHER HSIMULAN HYDRORRI CHEUMATO IMOBILUS LEPTAMER OCINERAS TRITARDA TRINJUST TRIADA TRIANODE NECTALBI CERGLGMS LEPTOCSP LEPTPUPA NECTOPSY OECETISP OXYETHSP ORTHOTSP HYDROPSY HYDROPSP HYDRPUPA HYTILASP POLYCENT POLYCINE POLYREMO POLYINTR CYRNRFRAT NEURECSP POLYCNISP AGRYPNA TIPULARV CHIRONOM CHIRONAE TANYPNAE ORTHONAE PROBLAB CULCOIDE MUSCPUPA CATRAPUP EMPIPIDA CHIRPUPA HEMERODR HYALAZTE ACARIxxx COPEPODA HYDRASPx CLADOCER NEMATODA OLIOCHA MENETUSS PHYSELLA FERRISIA DUGESIAS HSTAGNAL HELOBDEL HELONGAT PMULTILI PORNATA OTRANSLU PPARASIT AHETEROC MLUCIDIA MFERIDIA EPUNCTAT ERPOBDEL BPALUDOS BPICTA PMARAMOR STENOPEL HYPERODE CURCLARV CORILARV CORIXIDA FELTODYT LIXUSSP OSTRACOD ATOCHA ACENTRIA PARAPYNX SPHINGID LEPIIDUP ISOPODA;
*CAENISSP = CAENIS SP.
*BAETISSP = BAETIS SP.
*STENOINT = STENONEMA INTEGRUM
*TRICORYT = TRICORYTHODES SP.
*ENALAGSP = ENALAGMA SP.
*ISCHNURA = ISCHNURA SP.
*ARGIA = ARGIA SP.
*GOMPHIDA = GOMPHIDAE SP.
*NEHLENIA = NEHLENNIA SP.
*SOMATOSP = SOMATOCHLORA SP.
*TETRAGON = TETRAGONEURIA SP.
*EPIPRINC = EPITHECA PRINCEPS
*PACHLONG = PACHYDIPLAX LONPIENNIS
*MACROTHER = MACROTHERIUS SP.
*HSIMULAN = HYDROPSYCHE SIMULANS
*HYDRORRI = HYDROPSYCHE ORRIS
*CHEUMATO = CHEUMATOPSYCHE SP.
*IMOBILUS = OECETIS IMOBILIS
*LEPTAMER = LEPTOCRUS AMERICANUS
*OCINERAS = OECETIS CINERAS
*TRITARDA = TRIANODES TARD
*TRINJUST = TRINANODES INJU
*TRIADA = TRIANODES ABA
*TRIANGE = TRIANODA SP.
*NECTALBI = NECTOPSYCHE ALBIDA
*CERGLGMS = CERACLEA GLAGMUS
*LEPTOCSP = LEPTOCRUS SP.
*LEPTPUPA = LEPTOCRUS SP. PUPAE
*NECTOPY = NECTOPSYCHE SP.
*OECETISP = OECETIS SP.
*OXYETHSP = OXYETHIRA SP.
*ORTHOTSP = ORTHOTRICHIA SP.
*HYDROPSY = HYDROPSYCHIDAE
*HYDROPSP = HYDROPSYCIDAE SP.
*HYDRPUPA = HYDROPSYCIDAE SP. PUPAE
*HYTILASP = HYDROPTILA SP.
*POLYCEN = POLYCENTROPUS CENTRALIS
*POLYCINE = POLYCENTROPUS CINEREUS
*POLYREMO = POLYCENTROPUS REMOTUS
*POLYINTR = POLYCENTROPUS INTERUPTUS
*CYRNFRAT = CYRNELLUS FRATURNUS
*NEURECSP = NEURECLIPSIS SP.
*POLYCNSP = POLYCENTROPUS SP.
*AGRYPNIA = AGRYPNIA SP.
*TIPULARV = TIPULIDAE SP. PUPAE
*CHIRONOM = CHIRONOMIDAE
*CHIRONAE = CHIRONOMINAE
*TANYPNAE = TANYPODINAE
*ORTHONAE = ORTHOCLADIINAE/DIAMESINAE
*PROBGLAB = PROBEZZIA GLABRA
*CULCOIDE = CULCOIDES SP.
*MUSCPUPA = MUSCIDAE PUPAE
*CERATPUP = CERATOPOGONIDAE PUPAE
*EMPIDIDA = EMPIDIDAE
*CHIRPUPA = CHIRONOMIDAE PUPAE
*HEMERODR = HEMERODROMIA SP.
*HYALAZTE = HYALLELA AZTECA
*ACARIxxx = ACARI
*COPEPODA = COPEPODA
*HYDRASPx = HYDRA SP.
*CLADOCER = CLADOCERA
*NEMATODA = NEMATODA
*OLIGOCHA = OLIGOCHAETA
*MENETUSS = MENETUS SP.
*PHYSSELLA = PHYSSELLA SP.
*FERRISIA = FERRISIA SP.
*DUGESIAS = DUGESIA SP.
*HSTAGNAL = HELOBDELLA STAGNALIS
*HELOBDEL = HELOBDELLA SP.
*HELONGAT = HELOBDELLA ELONGATA
*PMULTILI = PLACOBDELLA MULTILNEATA
*PORNATA = PLACOBDELLA ORNATA
*OTRANSLU = OLIGOBDELLA TRANSLUSCENS
*PPARASIT = PLACOBDELLA PARASITICA
*AHETEROC = ALBOGLOSSIPHONIA HETEROCLITA
*MLUCIDIA = MARVINMTEYERIA LUCIDIA
*MFERIDIA = MOOREOBDELLA FERVIDA
*EPUNCTAT = ERPOBDELLA PUNCTATA
*ERPOBDEL = ERPOBDELLA SP.
*BPALUDOS = BATRACOBDELLA PALUDOSA
*BPICTA = BACTARACOBDELLA PICTA
*PMARAMOR = PLACOBDELLA MARAMORATA
*STENOPEL = STENOPELMUS SP.
*HYPERODE = HYPERODES SP.
*CURLARV = CURCLIONIDAE LARVAE
*CORILARV = CORIXIDAE LARVAE
*CORIXIDA = CORIXIDAE
*PELTOHYD = PELTODYTES SP.
*LIXUSSP = LIXUS SP.
*OSTRACOD = OSTRACODA
*AOTOCHA = ANTOCHA SP.
*ACENTRIA = ACENTRIA SP.
*PARAPYNX = PARAPYX SP.
*SINGID = SPHINGIDAE
*LEPIDPUP = LEPIDOPTERA PUPAE
*ISOPODA = ISOPODA
IF CAENISSP = 0 THEN A = 0; ELSE A = 1;
IF BAETISSP = 0 THEN B = 0; ELSE B = 1;
IF STENOINT = 0 THEN C = 0; ELSE C = 1;
IF TRICORYT = 0 THEN D = 0; ELSE D = 1;
IF ENALAGSP = 0 THEN E = 0; ELSE E = 1;
IF ISCHNURA = 0 THEN F = 0; ELSE F = 1;
IF ARGIA = 0 THEN G = 0; ELSE G = 1;
IF GOMPHIDA = 0 THEN H = 0; ELSE H = 1;
IF NEHLENIA = 0 THEN I = 0; ELSE I = 1;
IF SOMATOSP = 0 THEN J = 0; ELSE J = 1;
IF TETRAGON = 0 THEN K = 0; ELSE K = 1;
IF EPIPRINC = 0 THEN L = 0; ELSE L = 1;
IF PACHLONG = 0 THEN M = 0; ELSE M = 1;
IF MACROTHE = 0 THEN N = 0; ELSE N = 1;
IF HSIMULAN = 0 THEN O = 0; ELSE O = 1;
IF HYDROORG = 0 THEN P = 0; ELSE P = 1;
IF CHEUMATO = 0 THEN Q = 0; ELSE Q = 1;
IF MOBILUS = 0 THEN R = 0; ELSE R = 1;
IF LEPTAMER = 0 THEN S = 0; ELSE S = 1;
IF OCINERAS = 0 THEN T = 0; ELSE T = 1;
IF TRITARDA = 0 THEN U = 0; ELSE U = 1;
IF TRIJUST = 0 THEN V = 0; ELSE V = 1;
IF TRIADA = 0 THEN X = 0; ELSE X = 1;
IF TRIANODE = 0 THEN Y = 0; ELSE Y = 1;
IF NECTALBI = 0 THEN Z = 0; ELSE Z = 1;
IF CERGLGMS = 0 THEN AA = 0; ELSE AA = 1;
IF LEPTOCSP = 0 THEN BB = 0; ELSE BB = 1;
IF LEPTPUPA = 0 THEN CC = 0; ELSE CC = 1;
IF NECTOPSY = 0 THEN DD = 0; ELSE DD = 1;
IF OECETISP = 0 THEN EE = 0; ELSE EE = 1;
IF OXYETHSP = 0 THEN FF = 0; ELSE FF = 1;
IF ORTHOTSP = 0 THEN GG = 0; ELSE GG = 1;
IF HYDROPSY = 0 THEN HH = 0; ELSE HH = 1;
IF HYDRPUP = 0 THEN II = 0; ELSE II = 1;
IF HYDRPUPA = 0 THEN JJ = 0; ELSE JJ = 1;
IF HYTILASP = 0 THEN KK = 0; ELSE KK = 1;
IF POLYCENT = 0 THEN LL = 0; ELSE LL = 1;
IF POLYCINE = 0 THEN MM = 0; ELSE MM = 1;
IF POLYREMO = 0 THEN NN = 0; ELSE NN = 1;
IF POLYINTR = 0 THEN OO = 0; ELSE OO = 1;
IF CYRNFRAT = 0 THEN PP = 0; ELSE PP = 1;
IF NEURECSP = 0 THEN QQ = 0; ELSE QQ = 1;
IF POLYNESP = 0 THEN RR = 0; ELSE RR = 1;
IF AGRYNPNAV = 0 THEN SS = 0; ELSE SS = 1;
IF TIPULARV = 0 THEN TT = 0; ELSE TT = 1;
IF PROBGLAB = 0 THEN VV = 0; ELSE VV = 1;
IF CULCOIDE = 0 THEN XX = 0; ELSE XX = 1;
IF MUSCPUPA = 0 THEN YY = 0; ELSE YY = 1;
IF CERATPUP = 0 THEN ZZ = 0; ELSE ZZ = 1;
IF EMPIPIDDA = 0 THEN AAA = 0; ELSE AAA = 1;
IF CHIRPUPA = 0 THEN BBBB = 0; ELSE BBBB = 1;
IF HEMERODR = 0 THEN CCC = 0; ELSE CCC = 1;
IF HYALAZTE = 0 THEN DDD = 0; ELSE DDD = 1;
IF ACHRIPxxx = 0 THEN EEE = 0; ELSE EEE = 1;
IF COPEPODA = 0 THEN FFF = 0; ELSE FFF = 1;
IF HYDRASPx = 0 THEN GGG = 0; ELSE GGG = 1;
IF CLADOCE = 0 THEN HHH = 0; ELSE HHH = 1;
IF NEMATODA = 0 THEN III = 0; ELSE III = 1;
IF OLIGOCHE = 0 THEN JJJ = 0; ELSE JJJ = 1;
IF MENETUSS = 0 THEN KKK = 0; ELSE KKK = 1;
IF PHYSELLA = 0 THEN LLL = 0; ELSE LLL = 1;
IF FERRISIA = 0 THEN MMM = 0; ELSE MMM = 1;
IF DUGESIAS = 0 THEN NNN = 0; ELSE NNN = 1;
IF HSTAGNAI = 0 THEN OOO = 0; ELSE OOO = 1;
IF HELODEL = 0 THEN PPP = 0; ELSE PPP = 1;
IF HElongAT = 0 THEN QQQ = 0; ELSE QQQ = 1;
IF PMULTIL = 0 THEN RRR = 0; ELSE RRR = 1;
IF PORNATA = 0 THEN SSS = 0; ELSE SSS = 1;
IF OTRANSLU = 0 THEN TTT = 0; ELSE TTT = 1;
IF PPARASIT = 0 THEN UUU = 0; ELSE UUU = 1;
IF AHETEROC = 0 THEN VVV = 0; ELSE VVV = 1;
IF MLUCIDIA = 0 THEN XXX = 0; ELSE XXX = 1;
IF MFERIDIA = 0 THEN YYY = 0; ELSE YYY = 1;
IF EPUNCTAT = 0 THEN ZZZ = 0; ELSE ZZZ = 1;
IF EROBDEL = 0 THEN AAA = 0; ELSE AAA = 1;
IF BPALUDOS = 0 THEN BBBB = 0; ELSE BBBB = 1;
IF BPICTA = 0 THEN CCC = 0; ELSE CCC = 1;
IF PMARAMOR = 0 THEN DDDD = 0; ELSE DDDD = 1;
IF STENOPEL = 0 THEN EEEE = 0; ELSE EEEE = 1;
IF HYPERODE = 0 THEN FFF = 0; ELSE FFF = 1;
IF CURCLARV = 0 THEN GGGG = 0; ELSE GGGG = 1;
IF CORILARV = 0 THEN HHHH = 0; ELSE HHHH = 1;
IF CORIXIDA = 0 THEN III = 0; ELSE III = 1;
IF PELTODYT = 0 THEN JJJJ = 0; ELSE JJJJ = 1;
IF LIXUSSP = 0 THEN KKKK = 0; ELSE KKKK = 1;
IF OSTRACOD = 0 THEN LLLL = 0; ELSE LLLL = 1;
IF ATOCHA = 0 THEN MMMM = 0; ELSE MMMM = 1;
IF ACENTRIA = 0 THEN NNNN = 0; ELSE NNNN = 1;
IF PARAPYNX = 0 THEN QOOO = 0; ELSE QOOO = 1;
IF SPHINGID = 0 THEN PPPP = 0; ELSE PPPP = 1;
IF LEPIDPUP = 0 THEN QQQQ = 0; ELSE QQQQ = 1;
IF ISOPODA = 0 THEN RRRR = 0; ELSE RRRR = 1;
IF CHIRONAE = 0 THEN SSSS = 0; ELSE SSSS = 1;
IF TANYNPNAE = 0 THEN TTNT = 0; ELSE TTNT = 1;
IF ORTHONAE = 0 THEN UUUU = 0; ELSE UUUU = 1;
NUMTAXA = A+B+C+D+E+F+G+H+I+J+K+L+M+N+O+P+Q+R+S+T+U+V+X+Y+Z+
    AA+BB+CC+DD+EE+FF+GG+HH+II+JJ+KK+LL+MM+NN+OO+PP+QQ+RR+SS+TT+
    VV+XX+YY+ZZ+AAA+BBB+CCC+DDD+EEE+FFF+GGG+HHH+III+JJJ+KKK+LLL+
    MMM+NNN+OOO+PPP+QQQ+RRR+SSS+TTT+UUU+VVV+XXX+YYY+ZZZ+
    AAAAA+BBBBB+CCCCC+DDDDD+EEEE+FFFF+GGGG+HHHH+III+JJJ+KKKK+LLLL+
    MMMMM+NNNNN+OOOOO+PPPPP+QQQQQ+RRRRR+SSSSS+TTTTT+UUUUU;
*EPHEM = A+B+C+D;
*ODONATA = E+F+G+H+I+J+K+L+M+N;
*TRICHOP = O+P+Q+R+S+T+U+V+X+Y+Z+AA+BB+CC+DD+EE+FF+GG+HH+II+JJ+KK+
    LL+MM+NN+OO+PP+QQ+RR+SS;
*DIPTERA = TT+VV+XX+YY+ZZ+AAA+BBB+CCC+MMMM;
*CRUSTAC = DDDD+FFFF+HHHH+LLLL+RRRR;
*ANNELID = JJJ+OOOO+PPPP+QQQQ+RRRR+SSSS+TTTT+UUU+VVV+XXX+YYY+ZZZ+
    AAAAA+BBBBB+CCCCC+DDDDD;
*OTHER = EEEE+GGGG+HHHH+III;
*COLEOP = EEEE+FFFF+GGGG+KKKK;
*LEPIDOP = NNNNN+OOOOO+PPPPP+QQQQQ;
*GASTRO = KKK+LLL+MMM;
*TOTAL = EPHNM+ODONATA+TRICHOP+DIPTERA+CRUSTAC+ANNELID+OTHER+GASTRO+
    LEPIDOP+COLEOP;
IF SET = 1 THEN MONTH = 19931;
IF SET = 5 THEN MONTH = 19941;
IF SET = 9 THEN MONTH = 19951;
IF SET = 2 THEN MONTH = 19932;
IF SET = 6 THEN MONTH = 19942;
IF SET = 10 THEN MONTH = 19952;
IF SET = 3 THEN MONTH = 19933;
IF SET = 7 THEN MONTH = 19943;
IF SET = 11 THEN MONTH = 19953;
PROC PRINT;
PROC SORT;
BY LAK SITE MONTH;
PROC MEANS N MIN MAX RANGE MEAN VAR STD STDERR CV SKEWNESS KURTOSIS;
BY LAK SITE;
VAR NUMTAXA;
PROC CHART;
BY LAK SITE;
VBAR MONTH/DISCRETE SUMVAR = NUMTAXA TYPE=MEAN;
PROC NPARIWAY ANOVA WILCOXON;
BY LAK SITE;
CLASS MONTH;
VAR NUMTAXA;
APPENDIX K: Statistical analysis system (SAS) program used in Chapter Two to analyze for differences in aquatic macroinvertebrate densities/m² within the “M. spicatum,” “mixed” and “native” sites in Zumbra Lake over the sampling period.

TITLE "DENSITIES/M² AT EACH SITE OVER TIME'';
DATA DENSITY;
INFILE "EPINVERT";
INPUT LAK $ SEQUENCE SITE DEPTH REP DATE SET TYPE CAENISSP BAETISSP STENOINT TRICORYT ENALAGSP ISCHNURA ARGIA GOMPHIDA NEHLENIA SOMATOSP TETRAGON EPIPRINC PACHLONG MACROTHE HSIMULAN HYDRORRI CHEUMATO IMOBILUS LEPTAMER OCINERAS TRITARDA TRINJUST TRIADA TRIANODE NECTALBI CERGLGMS LEPTOCSP LEPTPUPA NECTOPSY OECETISP OXYETHSP ORTHOTSP HYDROPSIS HYDRPUPA HYTILASP POLYCENT POLYCINE POLYREMO POLYINTR CYRINFRAT NEURECSP POLYCNSP AGRYPNIA TIPULARV CHIRONOM CHIRONAE TANYNPNAE ORTHONAE PROBGLAB CULCOIDE MUSCPUPA CERATPUP EMPIDIDA CHIRPUPA HEMERODR HYALAZTE ACARIxxx COPEPODA HYDRASPx CLADOCER NEMATODA OLIGOCHA MENETUSS PHYSELLA FERRISIA DUGESIAS HSTAGNAL HELOBDEI. HELONGAT PMULTILI PORNATA OTRANSU PPARASIT AHETEROC MLUCIDIA MFERIDIA EPUNCTAT EPPOBDL BPALUDOS BPICTA PMARAMOR STENOPEL HYPERODE CURCLAV CORILAV CORIXIDA PELTODYT LIXUSSP OSTRACOD ATOCHA ACENTRIA PARAPYNX SPHINGID LEPIDPUP ISOPODA;
*CAENISSP = CAENIS SP.
*BAETISSP = BAETIS SP.
*STENOINT = STENONEMA INTEGRUM
*TRICORYT = TRICORYTHODES SP.
*ENALAGSP = ENALAGMA SP.
*ISCHNURA = ISCHNURA SP.
*ARGIA = ARGIA SP.
*GOMPHIDA = GOMPHIDAE SP.
*NEHLENIA = NEHLENNIA SP.
*SOMATOSP = SOMATOCHLORA SP.
*TETRAGON = TETRAGONEURIA SP.
*EPIPRINC = EPITHECA PRINCEPS
*PACHLONG = PACHYDIPLAX LONGIPENNIS
*MACROTHE = MACROTHEMIS SP.
*HSIMULAN = HYDROPSYCHE SIMULANS
*HYDRORRI = HYDROPSYCHE ORRIS
*CHEUMATO = CHEUMATOPSYCHE SP.
*IMOBILUS = OECETIS IMOBILIS
*LEPTAMER = LEPTOCERUS AMERICANUS
*OCINERAS = OECETIS CINERASCENS
*TIRATA = TRIANODES TARDA
*TRINJUST = TRIANODES INJUSCE
*TRIADA = TRIANODES ABA
*TRIANODE = TRIANODES SP.
*NECTALBI = NECTOPSYCHE ALBIDA
*CERGLGMS = CERACLEA GLAGMUS
*LEPTOCSP = LEPTOCERUS SP.
*LEPTPUPA = LEPTOCERUS SP. PUPAE
*NECTOPSY = NECTOPSYCHE SP.
*OECETISP = OECETIS SP.
*OXYETHSP = OXYETHIRA SP.
*ORTHOTSP = ORTHOTRICHIA SP.
*HYDROPSY = HYDROPSYCHIDAE
*HYDROPS = HYDROPSYCIDAE SP.
*HYDRPUPA = HYDROPSYCIDAE SP. PUPAE
*HYTILASP = HYDROPTILA SP.
*POLYCENT = POLYCENTROPUS CENTRALIS
*POLYCINE = POLYCENTROPUS CINEREUS
*POLYREMO = POLYCENTROPUS REMOTUS
*POLYINTR = POLYCENTROPUS INTERUPTUS
*CYRNFRAT = CYRNELLUS FRATURNUS
*NEURECSP = NEURECLIPSIS SP.
*POLYCNISP = POLYCENTROPUS SP.
*AGRYPNIA = AGRYPNIA SP.
*TIPULARV = TIPULIDAE SP. PUPAE
*CHIRONOM = CHIRONOMIDAE
*CHIRONAE = CHIRONOMIDAE
*TANYPN = TANYPODINAE
*ORTHONAE = ORTHOCLADIINAE/DIAMESINAE
*PROBGLAB = PROBEZZIA GLABRA
*CULCOIDE = CULCOIDES SP.
*MUSCPUPA = MUSCIDEAE PUPAE
*CERATPUP = CERATOPOGONIDAE PUPAE
*EMPIDIDA = EMPIDIDAE
*CHIRPUPA = CHIRONOMIDAE PUPAE
*HEMERODR = HEMERODROMIA SP.
*HYALAZTE = HYALLELA AZTECA
*ACARixxx = ACARI
*COPEPODA = COPEPODA
*HYDRASPx = HYDRA SP.
*CLADOCER = CLADOCERA
*NEMATODA = NEMATODA
*OLIGOCHA = OLIGOCHAETA
*MENETUSS = MENETUS SP.
*PHYSELLA = PHYSELLA SP.
*FERRISIA = FERRISIA SP.
*DUGESIAS = DUGESIA SP.
*HSTAGNAL = HELOBDELLA STAGNALIS
*HELOBDEL = HELOBDELLA SP.
*HELONGAT = HELOBDELLA ELONGATA
*PMULTILI = PLACOBDELLA MULTILNEATA
*PORNATA = PLACOBDELLA ORNATA
*OTRANSLU = OLIGOBDELLA TRANSCLUSCENS
*PPARASIT = PLACOBDELLA PARASITICA
*AHETEROC = ALBOGLOSSIPHONIA HETEROCLITA
*MLUCIDIA = MARVINMEYERIA LUCIDIA
*MFERIDIA = MOOREOBDELLA FERVIDA
*EPUNCTAT = ERPOBDELLA PUNCTATA
*ERPOBDEL = ERPOBDELLA SP.
*BPALUDOS = BATRACOBDELLA PALUDOSA
*BPICTA = BATRACOBDELLA PICTA
*PMARAMOR = PLACOBDELLA MARAMORATA
*STENOPEL = STENOPELMUS SP.
*HYPERODE = HYPERODES SP.
*CURLARV = CURCLIONIDAE LARVAE
*CORILARV = CORIXIDAE LARVAE
*CORIXIDA = CORIXIDAE
*PELTODYT = PELTODYTES SP.
*LIXUSSP = LIXUS SP.
*OSTRACOD = OSTRACODA
*ATOCHA = ANTOCHA SP.
*ACENTRIA = ACENTRIA SP.
*PARAPYNX = PARAPYNX SP.
*SPHINGID = SPHINGIDAE
*LEPIDPUP = LEPIDOPTERA PUPAE
*ISOPODA = ISOPODA
CAENISSm = 10.74*CAENISSP;
BAETISSm = 10.74*BAETISSP;
STENOINm = 10.74*STENOINT;
TRICORYm = 10.74*TRICORYT;
ENALAGSm = 10.74*ENALAGSP;
ISCHNURm = 10.74*ISCHNURA;
ARGIAM = 10.74*ARGIA;
GOMPHIDm = 10.74*GOMPHIDA;
NEHLENIm = 10.74*NEHLENIAN;
SOMATOSm = 10.74*SOMATOSP;
TETRAGOMm = 10.74*TETRAGON;
EPIPRINm = 10.74*EPIPRINC;
PACHLONm = 10.74*PACHLONG;
MACROTIm = 10.74*MACROTHE;
HSIMULAm = 10.74*HSIMULAN;
HYDRORRm = 10.74*HYDRORRI;
CHEUMATm = 10.74*CHEUMATO;
IMOBILUm = 10.74*IMOBILUS;
LEPTAMEm = 10.74*LEPTAMER;
OCINERAm = 10.74*OCINERAS;
TRITARDm = 10.74*TRITARDA;
TRINJUSm = 10.74*TRINJUST;
TRIADAm = 10.74*TRIADA;
TRIANODm = 10.74*TRIANODE;
NECTALBm = 10.74*NECTALBI;
CERGLGMm = 10.74*CERGLGMS;
LEPTOCSm = 10.74*LEPTOCS;
LEPTPUPm = 10.74*LEPTPUPA;
NECTOPSm = 10.74*NECTOFSY;
OECETISm = 10.74*OECETISP;
OXYETHSm = 10.74*OXYETHISP;
ORTHOTSm = 10.74*ORTHOTSP;
HYDROPSm = 10.74*HYDROPSY;
HYDROPm = 10.74*HYDROPSP;
HYDRPUPm = 10.74*HYDRPUPA;
HYTILASm = 10.74*HYTILASP;
POLYCEnm = 10.74*POLYCENT;
POLYCINnm = 10.74*POLYCINE;
POLYREEm = 10.74*POLYREMO;
POLYINTm = 10.74*POLYINTR;
CYRFRAm = 10.74*CYRFRA;
NEURECESm = 10.74*NEURECES;
POLYCNSm = 10.74*POLYCNS;
AGRPNIIm = 10.74*AGRPNI;
TIPULARm = 10.74*TIPULAR;
CHIRONDm = 10.74*CHIRON;
PROBGlAm = 10.74*PROBUG;
CULCOIDm = 10.74*CULCOIDE;
MUSCPUPm = 10.74*MUSCPUP;
CERATPUm = 10.74*CERATPUP;
EMPIDIDm = 10.74*EMPIDID;
CHRRPUPm = 10.74*CHRRPUP;
HEMEROODm = 10.74*HEMEROOD;
HYALAZTm = 10.74*HYALAZTE;
ACARlxxm = 10.74*ACARlxxx;
COPEPODm = 10.74*COPEPOD;
HYDRASPm = 10.74*HYDRASP;
CLADOCEm = 10.74*CLADOCER;
NEMATODm = 10.74*NEMMATOD;
OLIGOCHAm = 10.74*OLIGOCHA;
MENETUSm = 10.74*MENETUS;
PHYSELLm = 10.74*PHYSELL;
FERRISIm = 10.74*FERRIS;
DUGESIAm = 10.74*DUGESIAS;
HSTAGNALm = 10.74*HSTAGNAL;
HELOBDEm = 10.74*HELOBDEL;
HELONGAm = 10.74*HELONGAT;
MULTILm = 10.74*MULTILI;
PORNAm = 10.74*PORNA;
TRANSLm = 10.74*TRANSL;
PPARASIm = 10.74*PPARAS;
AHETEROm = 10.74*AHETERO;
MLUCIDIm = 10.74*MLUCIDA;
MFERIDIm = 10.74*MFERIDIA;
EPUNCTAm = 10.74*EPUNCTAT;
ERPOBDEm = 10.74*ERPOBDEL;
BPALUDOm = 10.74*BPALUDOS;
BPICTAm = 10.74*BPICTA;
PMARAMOm = 10.74*PMARAMOR;
STENOPEm = 10.74*STENOPE;
HYPERODm = 10.74*HYPERODE;
CURCLARm = 10.74*CURCLAR;
CORILARm = 10.74*CORILAR;
CORIXIDm = 10.74*CORIXIDA;
PCLTODYm = 10.74*PCLTODY;
LIXUSSpm = 10.74*LIXUSS;
OSTRACOm = 10.74*OSTRACOD;
ATOCHAm = 10.74*ATOCHA;
ACENTRIm = 10.74*ACENTRIA;
PARAPYNm = 10.74*PARAPYNX;
SPHINGIm = 10.74*SPHINGID;
LEPIDPUm = 10.74*LEPIDPUP;
ISOPODAm = 10.74*ISOPODA;
EPHEM = CAENISSm+BAETISSm+STENOINm+TRICORYm;
ODONATA = ENALAGSm+SOMATOM+TETRAGOm+EPIPRINm+PACHLONm+MACROTHm+
       ISCHNUm+ARGIAM+GOMPHIDm+NEHLENIm;
TRICHOP = HSIMULAm+HYDRORRm+CHEUMATm+IMOBILUm+LEPTAMEm+OCINERAm+
       TRITARDm+TRINJUSm+NECTALBm+LEPTOCSm+LEPTPUm+NECTOPSm+OECETISm+
       OXYETHSm+ORTHOTSm+HYDROPSm+HYDROPm+HYDRPUpm+HYTILASm+POLYCENm+
       POLYCINm+NEURECESm+CYRNRFAm+POLYCNsm+TRIADAm+TRIANODm+CERGLGMm+
       POLYREMm+POLYINTm+AGRYPNm;
DIPTERA = PROBGLAm+CULCOIDm+CERATPUm+CHIRUPUm+TIPULArm+MUSCPUPm+
       EMPIDIDm+HEMERODm+ATOCHAm+CHIRONDm;
CRUSTAC = HYALAZTm+COPEPODm+CLADOCEm+OSTRACOm+ISOPODAm;
ANNELID = HSTAGNAm+PMULTIm+OTRANSLm+PPARASIm+AHETEROm+MLUCIDIm+
       EPUNCTAm+ERPOBDEm+BPALUDOm+PMARAMOm+OLIGOChm+HELOBDEm+HElON
       GAm+PORNATAm+MFERIDIm+BPICAm;
OTHER = ACARixxm+HYDRASPm+NEMATODm+DUGESIAm+CORILArm+CORIXIDm;
COLEOP = STENOPEm+HYPERODm+CURCLArm+LIXUSSm+PELTODYm;
LEPIDOP = ACENTRIm+PARAPYNm+SPHINGIm+LEPIDPUp;
GASTRO = MENETUSm+PHYSELLm+FERRISim;
TOTAL = EPHEm+ODONATA+TRICHOP+DIPTERA+CRUSTAC+ANNELID+OTHER+GASTRO+
       LEPIDOp+COLEOp;
IF SET = 1 THEN MONTH = 19931;
IF SET = 5 THEN MONTH = 19941;
IF SET = 9 THEN MONTH = 19951;
IF SET = 2 THEN MONTH = 19932;
IF SET = 6 THEN MONTH = 19942;
IF SET = 10 THEN MONTH = 19952;
IF SET = 3 THEN MONTH = 19933;
IF SET = 7 THEN MONTH = 19943;
IF SET = 11 THEN MONTH = 19953;
PROC PRINT;
PROC SORT;
BY LAK SITE MONTH;
PROC MEANS N MIN MAX RANGE MEAN VAR STD STDERR CV SKEWNESS KURTOSIS;
BY LAK SITE MONTH;
VAR TOTAL;
PROC CHART;
BY LAK SITE;
VBAR MONTH/DISCRETE SUMVAR = TOTAL TYPE = MEAN;
PROC NPAR1WAY ANOVA WILCOXON;
BY LAK SITE;
CLASS MONTH;
VAR NUMTAXA;
APPENDIX L: Statistical analysis system (SAS) program used in Chapter Two to analyze for differences in aquatic macroinvertebrate AFDW (g/m²) within the "M. spicatum," "mixed" and "native" sites in Zumbra Lake over the sampling period.

TITLE "AFDW/M² AT EACH SITE OVER TIME";
DATA AFDW;
INFILE "BIOMASS";
INPUT LAK $ SEQUENCE SITE DEPTH REP DATE SET TYPE WEIGHT;
WGHT = WEIGHT * 10.74;
IF SET = 1 THEN MONTH = 19931;
IF SET = 5 THEN MONTH = 19941;
IF SET = 9 THEN MONTH = 19951;
IF SET = 2 THEN MONTH = 19932;
IF SET = 6 THEN MONTH = 19942;
IF SET = 10 THEN MONTH = 19952;
IF SET = 3 THEN MONTH = 19933;
IF SET = 7 THEN MONTH = 19943;
IF SET = 11 THEN MONTH = 19953;
PROC PRINT;
PROC SORT;
BY LAK SITE MONTH;
PROC MEANS N MIN MAX RANGE MEAN VAR STD STDERR CV SKEWNESS KURTOSIS;
BY LAK SITE MONTH;
VAR WGHT;
PROC CHART;
BY LAK SITE;
VBAR MONTH/DISCRETE SUMVA = WGHT TYPE = MEAN;
PROC NPAR1WAY ANOVA WILCOXON;
BY LAK SITE;
CLASS MONTH;
VAR WGHT;
APPENDIX M: "Epinvert" data set used to estimate and analyze mean epiphytic macroinvertebrate taxa richness/0.093 m² and total densities/m² at the “M. spicatum,” “mixed” and “native” sites in Auburn and Zumbra Lakes in July, August and September, 1993, and in Zumbra Lake in July, August and September, 1993, 1994 and 1995.

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APPENDIX N: “Biomass” data set used to estimate and analyze epiphytic macroinvertebrate AFDW (g/m²) at the “M. spicatum,” “mixed” and “native” sites in Auburn and Zumbra Lakes in July, August and September, 1993, and in Zumbra Lake in July, August and September, 1993, 1994 and 1995.

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