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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

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ABSTRACT

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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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 HCO_3^- and Ca^{++} combine to make $Ca(HCO_3)_2$, which then loses H_2O and CO_2 and produces $CaCO_3$ (marl precipitate). Assimilation of CO_2 for photosynthesis follows a diel pattern. Aquatic plants take up more 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/m^2 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 cm^2 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.

Myriophyllum spicatum L.

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^{o}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^{o}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/m^2 of sediment and epiphytic macroinvertebrates/m^2 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. lencontei* 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 $\$1.58/m^2$ 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. Radiolabled 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 μg/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-trifluro-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 (*Amploplites* 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 sulfonylurea 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.

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CHAPTER ONE

EPIPHYTIC 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 cm^2 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 2° 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. gramineaus*, *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/m^2 of sediment and epiphytic macroinvertebrates/m^2 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 compresus*, *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.

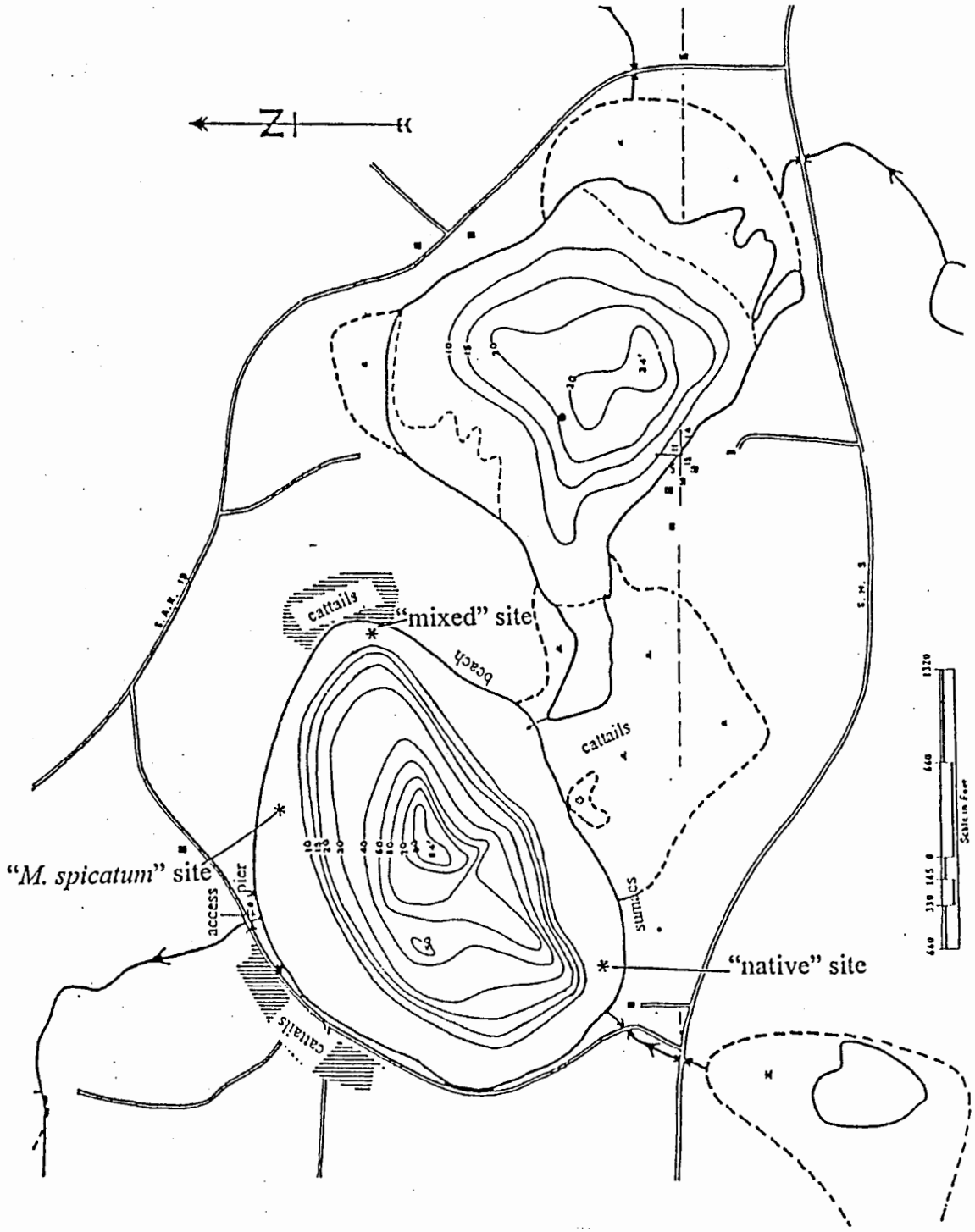

Fig. 1.1. Map of Auburn Lake, Minnesota showing the location of the "*M. spicatum*," "mixed" and "native" sites. Six samples were collected at each site in July, August and September, 1993.

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).

Lake	Chlorophyll a (μg / L)[1]	Secchi Depth (m)[1]	Total Phosphorus (mg / L)[1]	Turbidity (ntus)[2]
Auburn	31.2 ± 7.95	1.4 ± 0.13	0.041 ± 0.003	4.4 ± 0.28
Zumbra	16.8 ± 1.73	2.1 ± 0.19	0.026 ± 0.003	2.6 ± 1.5

[1]n = 5; [2]n = 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.

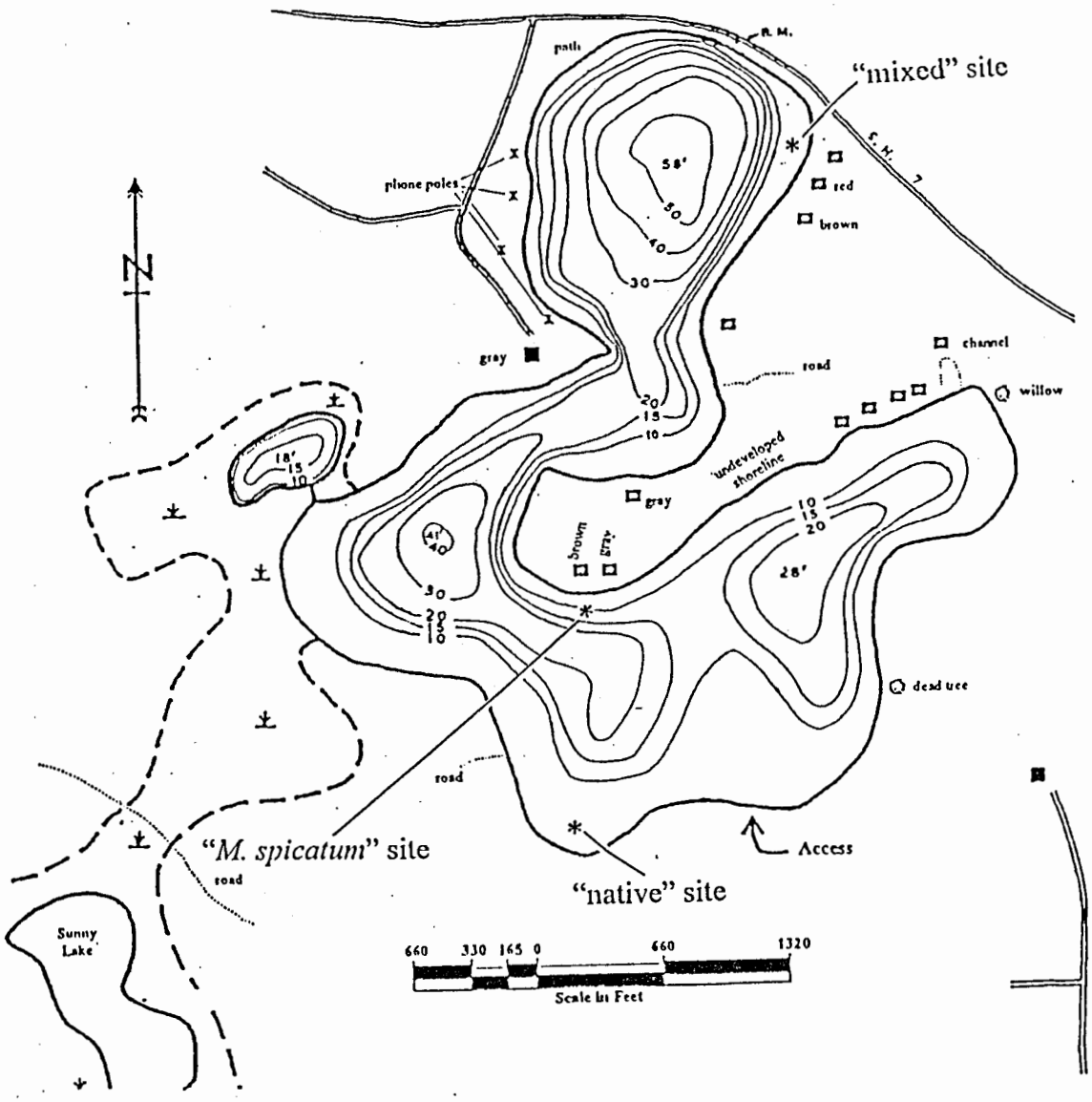

Fig. 1.2. Map of Zumbra Lake, Minnesota showing the location of the "*M. spicatum*," "mixed" and "native" sites. Six samples were collected at each site in July, August and September, 1993.

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 inG79 mbra 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 Zumbra Lakes in July, August and September, 1993. P values are from a Kruskal-Wallis test; n = 6.

Site	Month	Lake	Mean Taxa Richness/ 0.093 m^2	Mean Taxa Richness/ 0.093 m^2 Standard Error	Taxa Richness/ 0.093 m^2 P Value	Density Mean/m^2	Density/ m^2 Standard Error	Density/ m^2 P Value	Biomass (g/m^2) Mean	Biomass (g/m^2) Standard Error	Biomass (g/m^2) P Value
"*M. spicatum*"	July	Auburn	21.0000	1.93	0.0101	10877.8300	3608.50	0.0063	0.3770	0.1040	0.0161
		Zumbra	7.8333	2.73		1399.7800	690.82		0.0998	0.0536	
	August	Auburn	19.5000	3.08	0.0538	15547.9400	6869.60	0.0547	0.4826	0.1766	0.3367
		Zumbra	11.1667	1.66		4263.7800	739.33		0.1561	0.0480	
	September	Auburn	13.0000	1.29	0.9358	2962.4500	836.90	0.5218	0.3885	0.1058	0.2623
		Zumbra	12.5000	1.34		3631.9100	525.96		0.1512	0.0179	
"Mixed"	July	Auburn	18.5000	3.91	0.0446	5393.2700	1369.27	0.0450	0.4305	0.1071	0.0450
		Zumbra	7.8333	1.70		1072.2100	291.66		0.0968	0.0307	
	August	Auburn	21.3333	1.58	0.0038	9331.2700	1731.37	0.0039	0.5071	0.0897	0.0039
		Zumbra	9.6667	1.20		1480.3300	486.67		0.0746	0.0231	
	September	Auburn	21.8333	3.20	0.0301	19187.0100	8443.37	0.0039	0.9255	0.4926	0.0039
		Zumbra	14.3333	1.33		2450.5100	305.94		0.1405	0.0288	
"Native"	July	Auburn	19.1667	1.08	0.0154	7487.5700	2212.49	0.2002	0.4958	0.1572	0.0374
		Zumbra	13.6667	1.23		3699.9300	1206.03		0.1294	0.0523	
	August	Auburn	20.6667	3.04	0.0367	6447.5800	2290.70	0.1495	0.3008	0.0675	0.0547
		Zumbra	11.5000	1.23		3436.8000	396.06		0.1129	0.0133	
	September	Auburn	18.0000	1.10	0.0038	14867.7400	6673.49	0.0374	1.6757	0.7722	0.0039
		Zumbra	8.8333	1.42		2498.8400	1217.30		0.0865	0.0374	

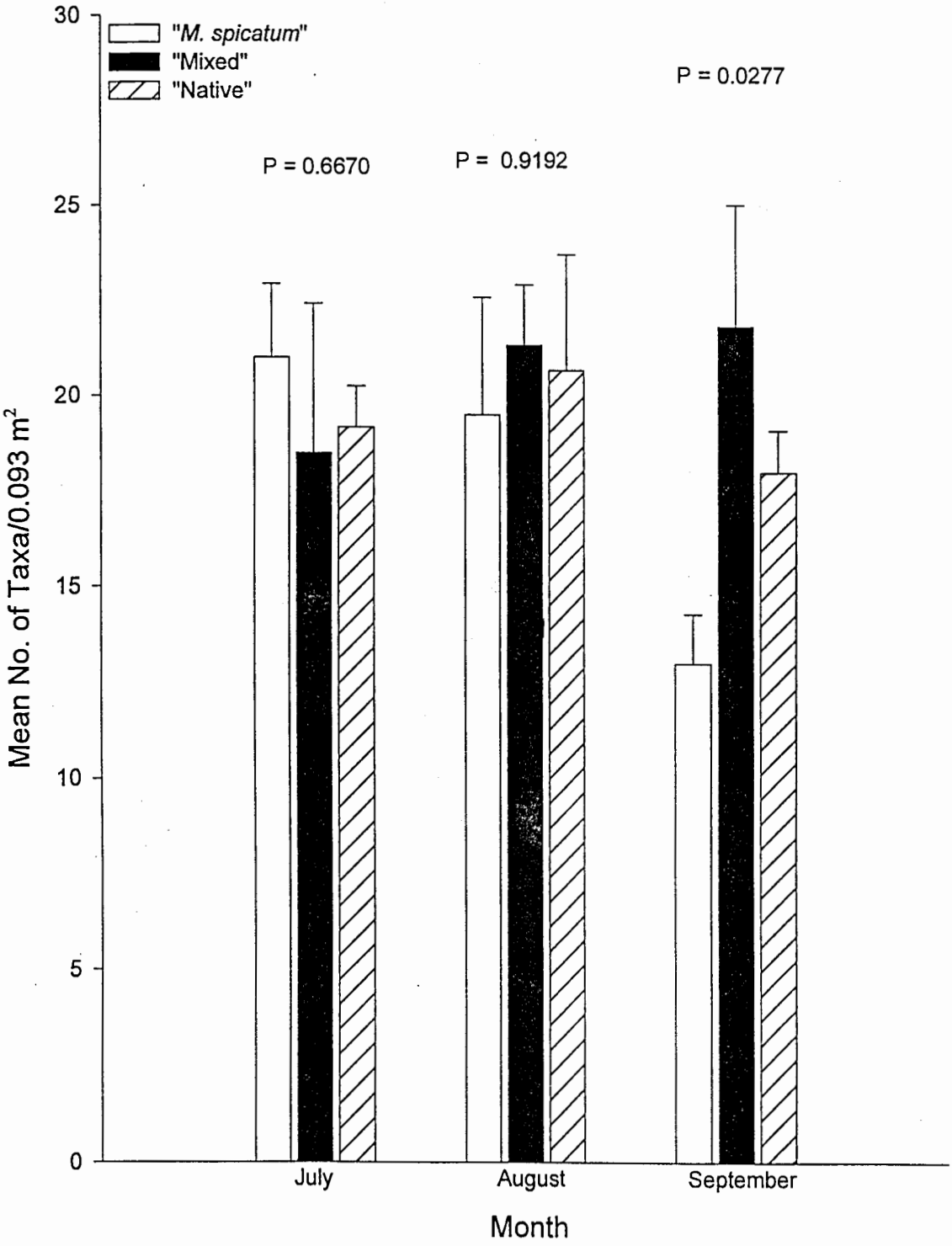

Fig. 1.3. Mean macroinvertebrate taxa richness/0.093 m^2 at the "*M. spicatum*," "mixed" and "native" sites in Auburn Lake in July, August and September, 1993. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences among sites on each sampling date.

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.

Taxa	Month	Site	Mean	Standard Error	P Value
Phylum Annelida	July	*M. spicatum*	0.8333	0.31	
		Mixed	1.8333	0.48	0.1831
		Native	2.1667	0.65	
	August	*M. spicatum*	1.1667	0.48	
		Mixed	2.0000	0.45	0.4238
		Native	1.8333	0.48	
	September	*M. spicatum*	1.6667	0.42	
		Mixed	1.3333	0.21	0.3541
		Native	2.5000	0.67	
Phylum Mollusca					
Class Gastropoda	July	*M. spicatum*	2.0000	0.26	
		Mixed	1.6667	0.33	0.5842
		Native	1.6667	0.21	
	August	*M. spicatum*	2.1667	0.31	
		Mixed	1.5000	0.22	0.2155
		Native	1.6667	0.21	
	September	*M. spicatum*	1.6667	0.21	
		Mixed	1.3333	0.33	0.0508
		Native	2.3333	0.21	
Phylum Arthropoda					
Class Crustacea	July	*M. spicatum*	1.1667	0.17	
		Mixed	1.3333	0.33	0.7681
		Native	1.3333	0.21	
	August	*M. spicatum*	1.6667	0.33	
		Mixed	1.5000	0.34	0.7993
		Native	1.8333	0.40	
	September	*M. spicatum*	1.3333	0.21	
		Mixed	1.6667	0.33	0.4227
		Native	1.1667	0.17	
Class Insecta					
Order Coleoptera	July	*M. spicatum*	0.8333	0.48	
		Mixed	0.0000	0.00	0.0342
		Native	0.0000	0.00	
	August	*M. spicatum*	0.3333	0.21	
		Mixed	0.1667	0.17	0.6662
		Native	0.6667	0.42	
	September	*M. spicatum*	0.0000	0.00	
		Mixed	0.3333	0.33	0.5861
		Native	0.5000	0.50	
Order Diptera	July	*M. spicatum*	2.1667	0.31	
		Mixed	1.6667	0.42	0.3536
		Native	1.5000	0.34	
	August	*M. spicatum*	1.6667	0.61	
		Mixed	1.8333	0.60	0.9432
		Native	1.8333	0.40	
	September	*M. spicatum*	0.5000	0.22	
		Mixed	1.0000	0.37	0.4653
		Native	0.5000	0.22	

Table 1.3 cont.

Taxa	Month	Site	Mean	Standard Error	P Value
Order Ephemeroptera	July	*M. spicatum*	1.0000	0.00	
		Mixed	0.8333	0.17	0.5879
		Native	0.8333	0.17	
	August	*M. spicatum*	1.1667	0.31	
		Mixed	1.0000	0.00	0.4925
		Native	0.8333	0.17	
	September	*M. spicatum*	0.6667	0.21	
		Mixed	0.6667	0.21	0.8019
		Native	0.5000	0.22	
Order Lepidoptera	July	*M. spicatum*	0.8333	0.31	
		Mixed	0.5000	0.22	0.1900
		Native	0.1667	0.17	
	August	*M. spicatum*	0.0000	0.00	
		Mixed	0.1667	0.17	0.5879
		Native	0.1667	0.17	
	September	*M. spicatum*	0.0000	0.00	
		Mixed	0.1667	0.17	0.3679
		Native	0.0000	0.00	
Order Odonata	July	*M. spicatum*	0.8333	0.17	
		Mixed	0.6667	0.21	0.4925
		Native	0.5000	0.22	
	August	*M. spicatum*	0.8333	0.31	
		Mixed	1.0000	0.00	0.4990
		Native	0.6667	0.21	
	September	*M. spicatum*	1.1667	0.17	
		Mixed	1.1667	0.31	0.8447
		Native	1.3333	0.21	
Order Trichoptera	July	*M. spicatum*	6.3333	0.80	
		Mixed	5.8333	1.38	0.3017
		Native	6.6667	0.33	
	August	*M. spicatum*	5.8333	0.91	
		Mixed	7.1667	0.60	0.8086
		Native	6.3333	1.36	
	September	*M. spicatum*	2.5000	0.43	
		Mixed	9.5000	1.88	0.6043
		Native	5.1667	0.70	
"Other"	July	*M. spicatum*	2.0000	0.26	
		Mixed	1.6667	0.33	0.3396
		Native	1.5000	0.22	
	August	*M. spicatum*	2.0000	0.45	
		Mixed	2.0000	0.45	0.9576
		Native	1.8333	0.48	
	September	*M. spicatum*	1.3333	0.33	
		Mixed	2.1666	0.31	0.1133
		Native	1.3333	0.21	

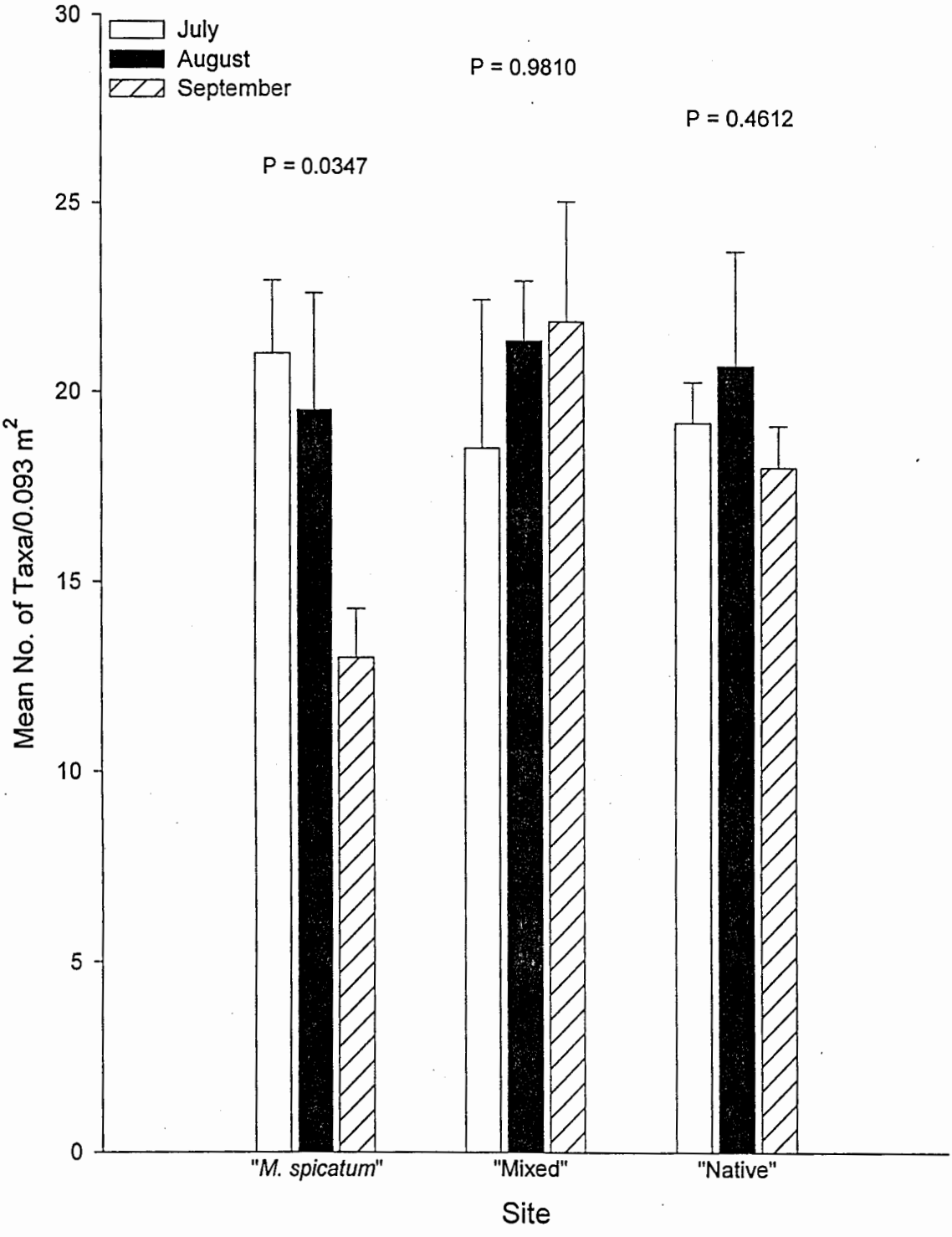

Fig. 1.4. Mean macroinvertebrate taxa richness/0.093 m^2 in July, August and September, 1993 at the "*M. spicatum*," "mixed" and "native" sites in Auburn Lake. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences within sites over the sampling period.

Table 1.4. Comparison of mean macroinvertebrate taxa richness/0.093 m^2 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.

Taxa	Site	Month	Mean	Standard Error	P Value
Phylum Annelida	*M. spicatum*	July	0.8333	0.31	
		August	1.1667	0.48	0.3460
		September	1.6667	0.42	
	Mixed	July	1.8333	0.48	
		August	2.0000	0.45	0.4314
		September	1.3333	0.21	
	Native	July	2.1667	0.65	
		August	1.8333	0.47	0.8570
		September	2.5000	0.67	
Phylum Mollusca					
Class Gastropoda	*M. spicatum*	July	2.0000	0.26	
		August	2.1667	0.31	0.3957
		September	1.6667	0.21	
	Mixed	July	1.6667	0.33	
		August	1.5000	0.22	0.5765
		September	1.3333	0.33	
	Native	July	1.6667	0.21	
		August	1.6667	0.21	0.0797
		September	2.3333	0.21	
Phylum Arthopoda					
Class Crustacea	*M. spicatum*	July	1.1667	0.17	
		August	1.6667	0.33	0.4227
		September	1.3333	0.21	
	Mixed	July	1.3333	0.33	
		August	1.5000	0.34	0.8504
		September	1.6667	0.33	
	Native	July	1.3333	0.21	
		August	1.8333	0.40	0.3515
		September	1.1667	0.17	
Class Insecta					
Order Coleoptera	*M. spicatum*	July	0.8333	0.48	
		August	0.3333	0.21	0.1503
		September	0.0000	0.00	
	Mixed	July	0.0000	0.00	
		August	0.1667	0.17	0.5861
		September	0.3333	0.33	
	Native	July	0.0000	0.00	
		August	0.6667	0.42	0.3628
		September	0.5000	0.50	
Order Diptera	*M. spicatum*	July	2.1667	0.31	
		August	1.6667	0.61	0.0306
		September	0.5000	0.22	
	Mixed	July	1.6667	0.42	
		August	1.8333	0.60	0.4514
		September	1.0000	0.37	
	Native	July	1.5000	0.34	
		August	1.8333	0.40	0.0339
		September	0.5000	0.22	

Table 1.4 cont.

Taxa	Site	Month	Mean	Standard Error	P Value
Order Ephemeroptera	*M. spicatum*	July	1.0000	0.00	
		August	1.1667	0.31	0.2691
		September	0.6667	0.21	
	Mixed	July	0.8333	0.17	
		August	1.0000	0.00	0.3220
		September	0.6667	0.21	
	Native	July	0.8333	0.17	
		August	0.8333	0.17	0.3513
		September	0.5000	0.22	
Order Lepidoptera	*M. spicatum*	July	0.8333	0.31	
		August	0.0000	0.00	0.0082
		September	0.0000	0.00	
	Mixed	July	0.5000	0.22	
		August	0.1667	0.17	0.3513
		September	0.1667	0.17	
	Native	July	0.1667	0.17	
		August	0.1667	0.17	0.5879
		September	0.0000	0.00	
Order Odonata	*M. spicatum*	July	0.8333	0.17	
		August	0.8333	0.31	0.4577
		September	1.1667	0.17	
	Mixed	July	0.6667	0.21	
		August	1.0000	0.00	0.2691
		September	1.6667	0.31	
	Native	July	0.5000	0.22	
		August	0.6667	0.21	0.0523
		September	1.3333	0.21	
Order Trichoptera	*M. spicatum*	July	6.3333	0.80	
		August	5.8333	0.91	0.0115
		September	2.5000	0.43	
	Mixed	July	5.8333	1.38	
		August	7.1667	0.60	0.4326
		September	9.5000	1.88	
	Native	July	6.6667	0.33	
		August	6.3333	1.36	0.3919
		September	5.1667	0.70	
"Other"	*M. spicatum*	July	2.0000	0.26	
		August	2.0000	0.45	0.2473
		September	1.3333	0.33	
	Mixed	July	1.6667	0.33	
		August	2.0000	0.45	0.6641
		September	2.1667	0.31	
	Native	July	1.5000	0.22	
		August	1.8333	0.48	0.5157
		September	1.3333	0.21	

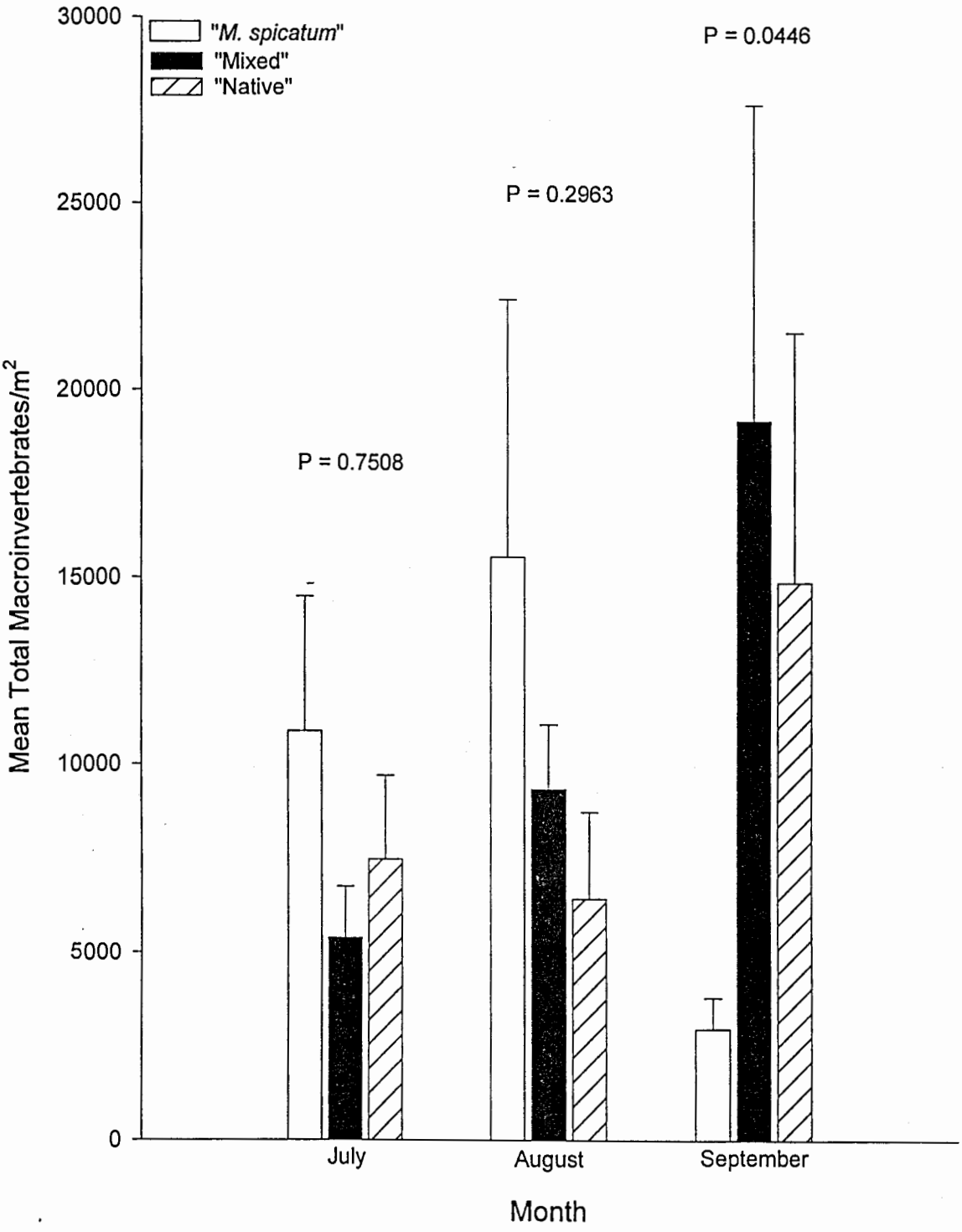

Fig. 1.5. Mean total macroinvertebrate densities/m^2 at the "*M. spicatum*," "mixed" and "native" sites in Auburn Lake in July, August and September, 1993. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences among sites on each sampling date.

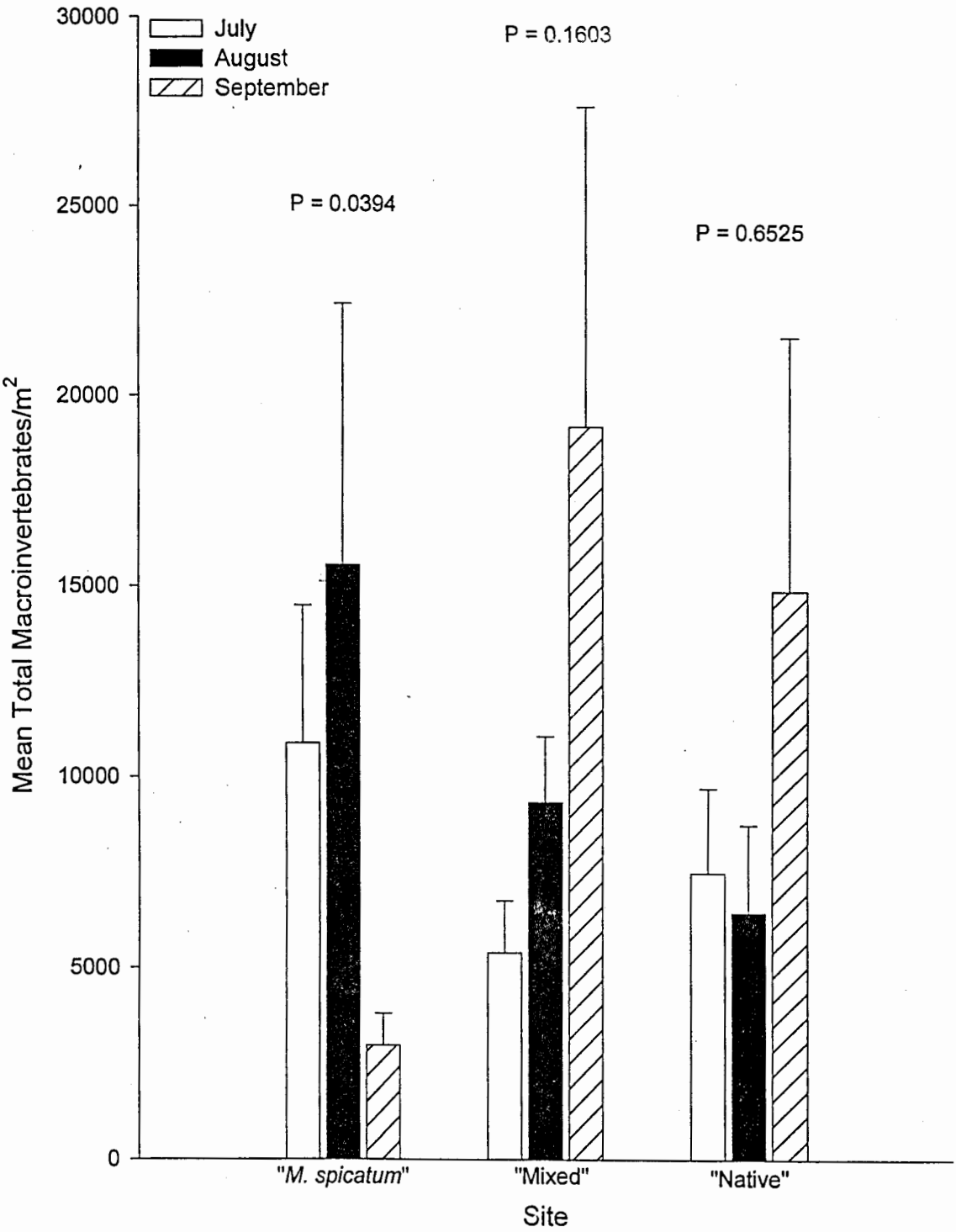

Fig. 1.6. Mean total macroinvertebrate densities/m^2 in July, August and September, 1993 at the "*M. spicatum*," "mixed" and "native" sites in Auburn Lake. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences within sites over the sampling period.

Table 1.5. Comparison of mean macroinvertebrate densities/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.

Taxa	Month	Site	Mean	Standard Error	P Value
Phylum Annelida	July	*M. spicatum*	16.1100	8.20	
		Mixed	128.8800	68.10	0.0435
		Native	157.5200	51.26	
	August	*M. spicatum*	429.6000	384.83	
		Mixed	844.8800	445.32	0.0767
		Native	116.3500	64.35	
	September	*M. spicatum*	48.3300	15.87	
		Mixed	2377.1200	2267.85	0.0251
		Native	295.3500	86.27	
Phylum Mollusca					
Class Gastropoda	July	*M. spicatum*	719.5800	279.42	
		Mixed	282.8200	101.19	0.2637
		Native	168.2600	53.39	
	August	*M. spicatum*	386.6400	105.49	
		Mixed	84.1300	11.24	0.1097
		Native	356.2100	147.45	
	September	*M. spicatum*	254.1800	75.27	
		Mixed	102.0300	35.05	0.0610
		Native	291.7700	54.30	
Phylum Arthropoda					
Class Crustacea	July	*M. spicatum*	2119.3600	1329.92	
		Mixed	1059.6800	353.99	0.9599
		Native	998.8200	287.80	
	August	*M. spicatum*	889.6300	273.47	
		Mixed	2174.8500	794.77	0.0623
		Native	447.5000	205.33	
	September	*M. spicatum*	834.1400	287.58	
		Mixed	3810.9100	2046.67	0.1345
		Native	3581.7900	1292.52	
Class Insecta					
Order Coleoptera	July	*M. spicatum*	25.0600	18.94	
		Mixed	0.0000	0.00	0.0345
		Native	0.0000	0.00	
	August	*M. spicatum*	5.3700	3.67	
		Mixed	1.7900	1.79	0.6419
		Native	32.2200	22.01	
	September	*M. spicatum*	0.0000	0.00	
		Mixed	3.5800	3.58	0.5861
		Native	14.3200	14.32	
Order Diptera	July	*M. spicatum*	6682.0700	2109.90	
		Mixed	3715.4600	807.53	0.3235
		Native	5446.9700	1898.07	
	August	*M. spicatum*	11805.0500	5142.82	
		Mixed	4117.0000	804.00	0.2195
		Native	4476.7900	2395.72	
	September	*M. spicatum*	1240.4700	379.96	
		Mixed	8164.1900	5328.69	0.2621
		Native	8590.2100	4879.90	

Table 1.5 cont.

Taxa	Month	Site	Mean	Standard Error	P Value
Order Ephemeroptera	July	*M. spicatum*	417.0700	186.69	
		Mixed	232.7000	148.60	0.5541
		Native	109.1900	32.15	
	August	*M. spicatum*	180.7900	42.64	
		Mixed	218.3800	53.46	0.3847
		Native	125.3000	42.12	
	September	*M. spicatum*	21.4800	13.30	
		Mixed	637.2400	398.06	0.2581
		Native	25.0600	13.20	
Order Lepidoptera	July	*M. spicatum*	17.9000	8.62	
		Mixed	7.1600	3.58	0.1644
		Native	1.7900	1.79	
	August	*M. spicatum*	0.0000	0.00	
		Mixed	1.7900	1.79	0.5861
		Native	3.5800	3.58	
	September	*M. spicatum*	0.0000	0.00	
		Mixed	5.3700	5.37	0.3679
		Native	0.0000	0.00	
Order Odonata	July	*M. spicatum*	93.0800	30.34	
		Mixed	34.0100	19.88	0.1536
		Native	12.5300	7.02	
	August	*M. spicatum*	166.4700	64.72	
		Mixed	132.4600	11.66	0.5542
		Native	91.2900	33.47	
	September	*M. spicatum*	82.3400	33.47	
		Mixed	289.9800	128.52	0.0272
		Native	511.9400	149.67	
Order Trichoptera	July	*M. spicatum*	554.9000	135.30	
		Mixed	347.2600	137.78	0.4336
		Native	413.4900	104.23	
	August	*M. spicatum*	533.4200	148.11	
		Mixed	579.9600	135.51	0.5726
		Native	408.1200	77.40	
	September	*M. spicatum*	91.2900	42.40	
		Mixed	2514.9500	1162.60	0.0039
		Native	771.4900	267.69	
"Other"	July	*M. spicatum*	232.7000	73.51	
		Mixed	125.3000	34.82	0.4751
		Native	179.0000	55.44	
	August	*M. spicatum*	1150.9700	964.61	
		Mixed	1176.0300	435.21	0.2667
		Native	390.2200	256.21	
	September	*M. spicatum*	390.2200	232.39	
		Mixed	1281.6400	469.90	0.1493
		Native	785.8100	485.28	

"*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/m^2 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.

Taxa	Site	Month	Mean	Standard Error	P Value
Phylum Annelida	*M. spicatum*	July	16.1100	8.20	
		August	429.6000	384.83	0.3101
		September	48.3300	15.87	
	Mixed	July	128.8800	68.10	
		August	844.8800	445.32	0.1814
		September	2377.1200	2267.85	
	Native	July	157.5200	51.26	
		August	116.3500	64.35	0.1068
		September	295.3500	86.27	
Phylum Mollusca					
Class Gastropoda	*M. spicatum*	July	719.5800	279.42	
		August	386.6400	105.49	0.4223
		September	254.1800	75.27	
	Mixed	July	282.8200	101.19	
		August	84.1300	11.24	0.4433
		September	102.0300	35.05	
	Native	July	168.2600	53.39	
		August	356.2100	147.45	0.3299
		September	291.7700	54.30	
Phylum Arthropoda					
Class Crustacea	*M. spicatum*	July	2119.3600	1329.92	
		August	889.6300	273.47	0.9599
		September	834.1400	287.58	
	Mixed	July	1059.6800	353.99	
		August	2174.58500	794.77	0.5805
		September	3810.9100	2046.67	
	Native	July	998.8200	287.80	
		August	447.5000	205.33	0.0120
		September	3581.7900	1292.52	
Class Insecta					
Order Coleoptera	*M. spicatum*	July	25.0600	18.94	
		August	5.3700	3.67	0.1541
		September	0.0000	0.00	
	Mixed	July	0.0000	0.00	
		August	1.7900	1.79	0.5861
		September	3.5800	3.58	
	Native	July	0.0000	0.00	
		August	32.2200	22.01	0.3255
		September	14.3200	14.32	
Order Diptera	*M. spicatum*	July	6682.0700	2019.90	
		August	11805.0500	5142.82	0.0314
		September	1240.4700	379.96	
	Mixed	July	3175.4600	807.53	
		August	4117.0000	804.00	0.8488
		September	8164.1900	5328.69	
	Native	July	5446.9700	1898.07	
		August	4476.7900	2395.72	0.8054
		September	8590.2100	4879.90	

Table 1.6 cont.

Taxa	Site	Month	Mean	Standard Error	P Value
Order Ephemeroptera	*M. spicatum*	July	417.0700	186.69	
		August	180.7900	42.64	0.0420
		September	21.4800	13.30	
	Mixed	July	232.7000	148.60	
		August	218.3800	53.46	0.6400
		September	637.2400	398.06	
	Native	July	109.1900	32.15	
		August	125.3000	42.12	0.0836
		September	25.0600	13.20	
Order Lepidoptera	*M. spicatum*	July	17.9000	8.62	
		August	0.0000	0.00	0.0085
		September	0.0000	0.00	
	Mixed	July	7.1600	3.58	
		August	1.7900	1.79	0.4161
		September	5.3700	5.37	
	Native	July	1.7900	1.79	
		August	3.5800	3.58	0.5861
		September	0.0000	0.00	
Order Odonata	*M. spicatum*	July	93.0800	30.34	
		August	166.4700	64.72	0.7440
		September	82.3400	33.47	
	Mixed	July	34.0100	19.88	
		August	132.4600	11.66	0.0430
		September	289.9800	128.52	
	Native	July	12.5300	7.02	
		August	91.2900	33.48	0.0031
		September	511.9400	149.66	
Order Trichoptera	*M. spicatum*	July	554.9000	135.30	
		August	533.4200	148.11	0.0110
		September	91.2900	42.40	
	Mixed	July	347.2600	137.78	
		August	579.9600	135.51	0.0268
		September	2514.9500	1162.60	
	Native	July	413.4900	104.23	
		August	408.1200	77.40	0.7508
		September	771.4900	267.69	
"Other"	*M. spicatum*	July	232.7000	73.51	
		August	1150.9700	964.61	0.9472
		September	390.2200	232.39	
	Mixed	July	125.3000	34.82	
		August	1176.0300	435.21	0.0380
		September	1281.6400	469.90	
	Native	July	179.0000	55.44	
		August	390.2200	256.21	0.9445
		September	785.8100	485.28	

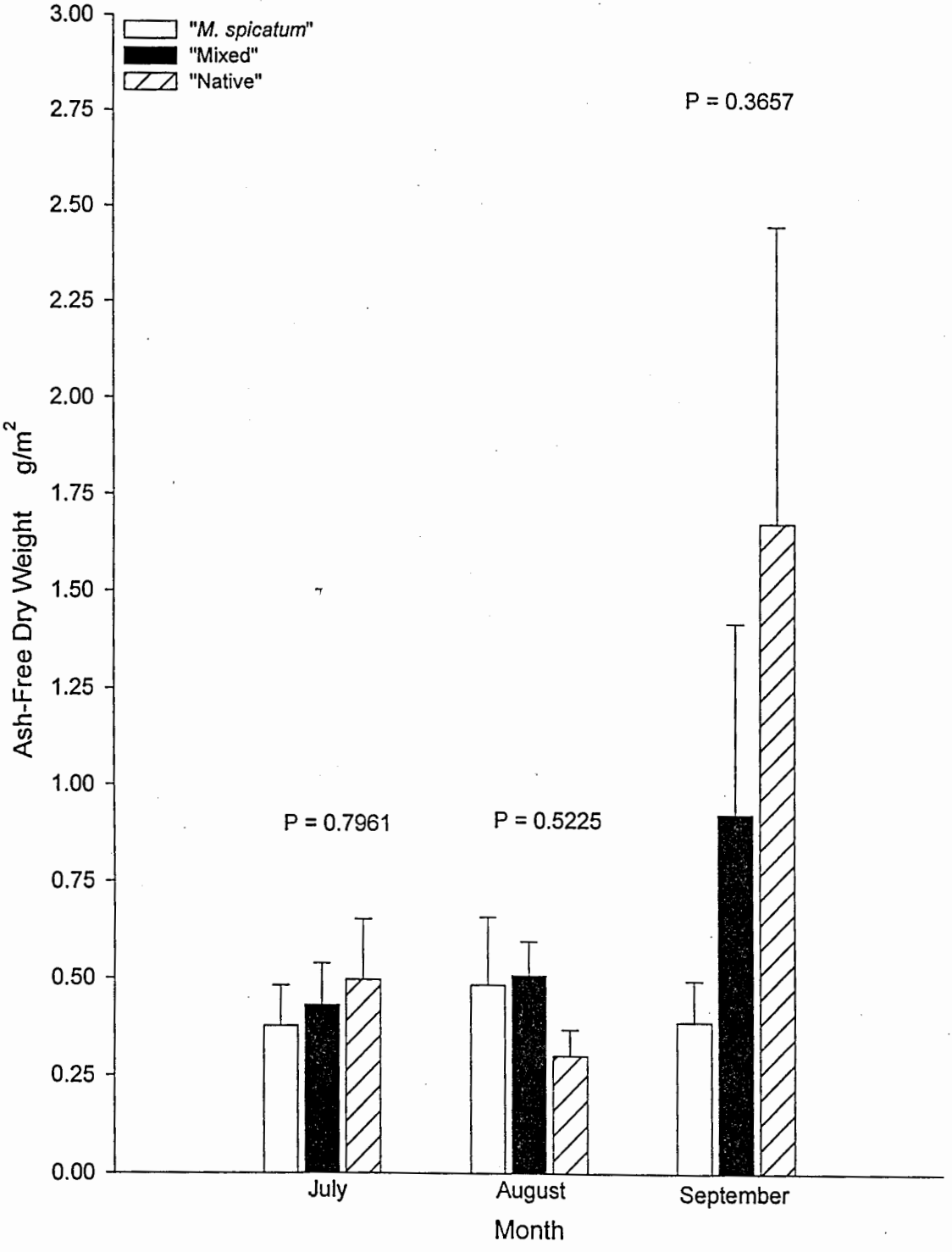

Fig. 1.7. Mean macroinvertebrate AFDW (g/m^2) at the "*M. spicatum*," "mixed" and "native" site in Auburn Lake in July, August and September, 1993. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences among sites on each sampling date.

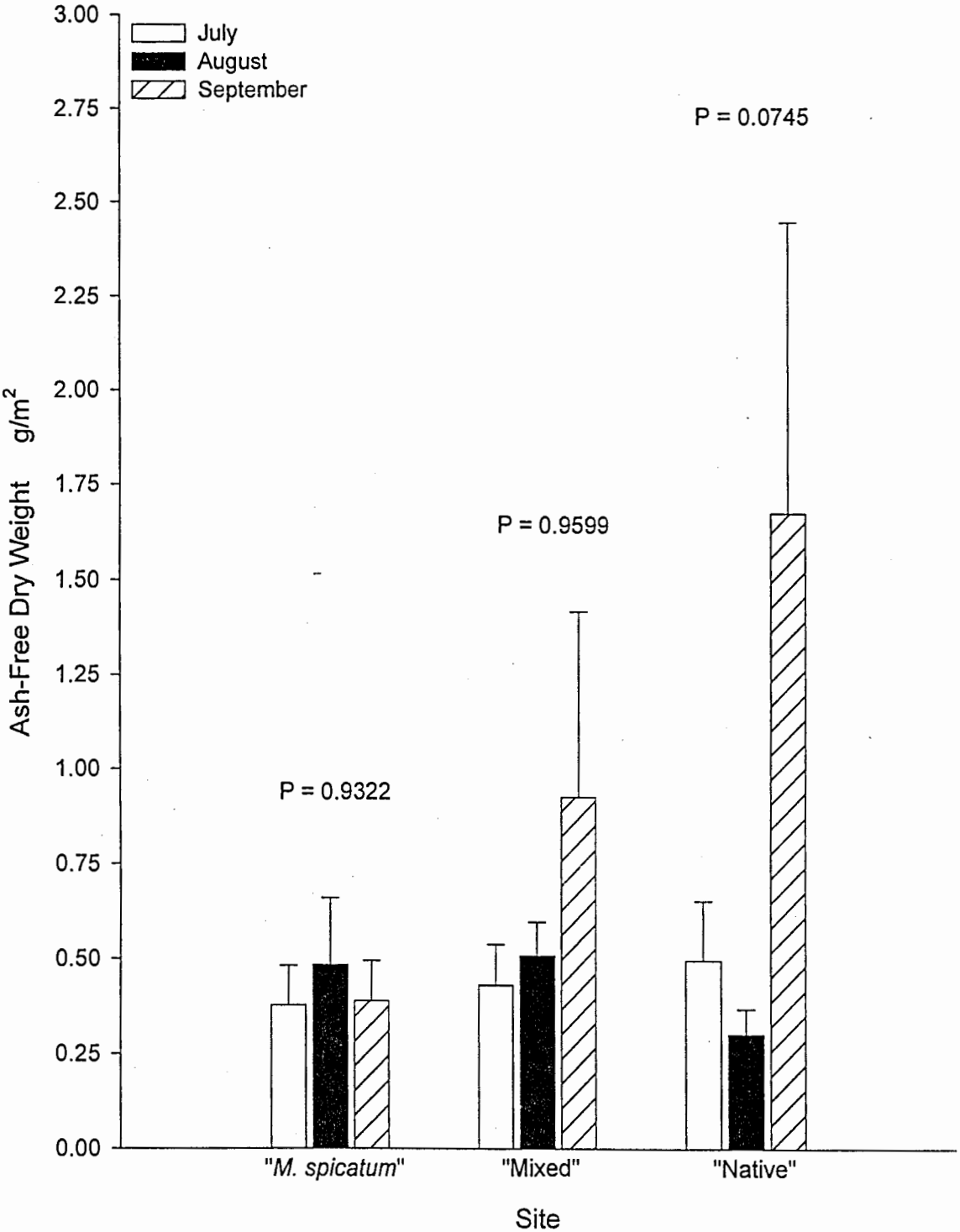

Fig. 1.8. Mean macroinvertebrate AFDW (g/m^2) in July, August and September, 1993 at the "*M. spicatum*," "mixed" and "native" sites in Auburn Lake. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences within sites over the sampling period.

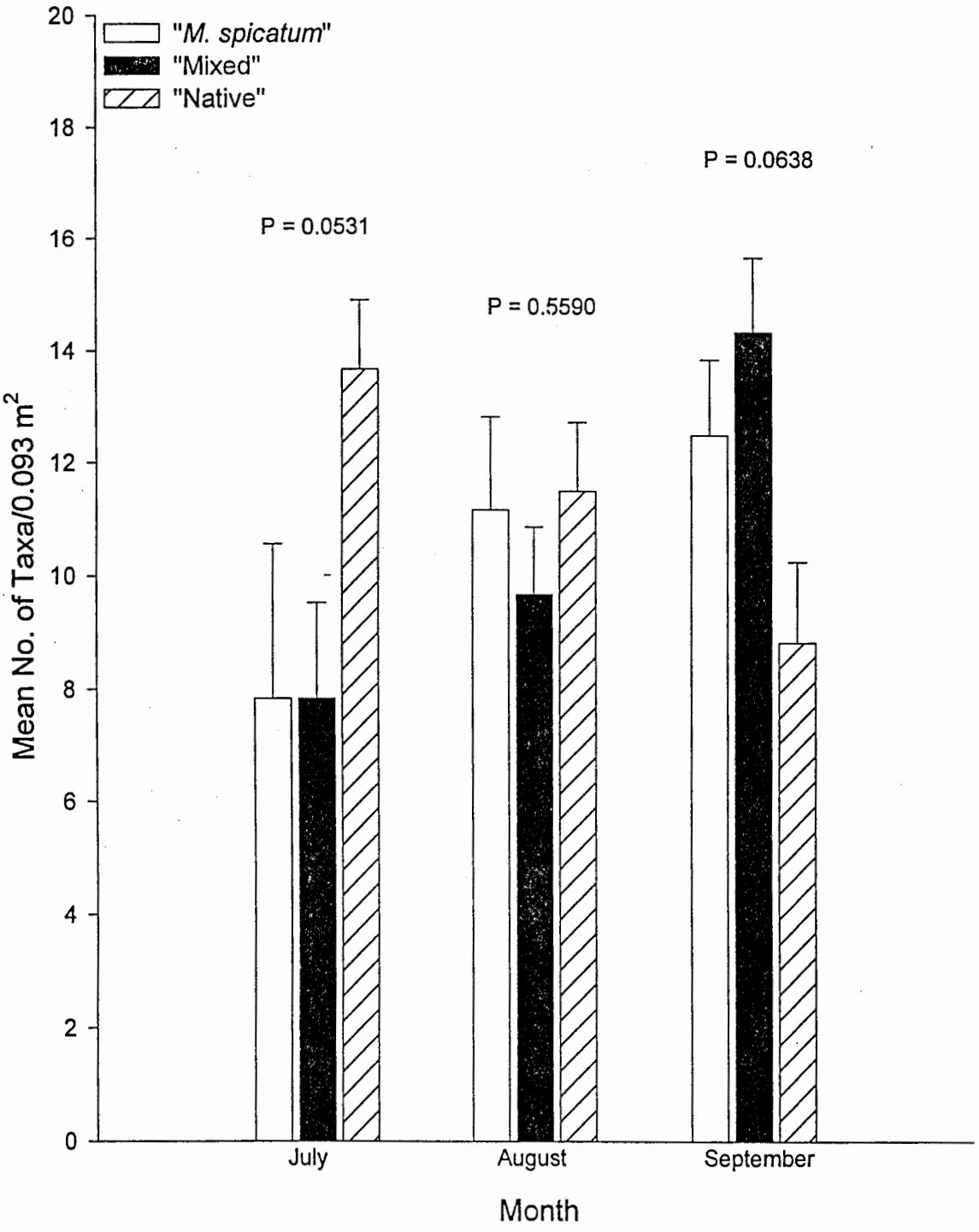

Fig. 1.9. Mean macroinvertebrate taxa richness/0.093 m^2 at the "*M. spicatum*," "mixed" and "native" sites in Zumbra Lake in July, August and September, 1993. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences among sites on each sampling date.

Table 1.7. Comparison of mean macroinvertebrate taxa richness/0.093 m^2 at the "*M. spicatum*," "mixed" and "native" sites in Zumbra Lake during July, August and September, 1993. P values are from a Kruskal-Wallis test for differences among sites on each sampling date.

Taxa	Month	Site	Mean	Standard Error	P Value
Phylum Annelida	July	*M. spicatum*	1.0000	0.37	
		Mixed	0.3333	0.21	0.3006
		Native	0.8333	0.31	
	August	*M. spicatum*	0.8333	0.17	
		Mixed	0.8333	0.17	0.9999
		Native	0.8333	0.17	
	September	*M. spicatum*	1.6667	0.61	
		Mixed	0.8333	0.31	0.2542
		Native	0.5000	0.22	
Phylum Mollusca					
Class Gastropoda	July	*M. spicatum*	1.3333	0.42	
		Mixed	0.6667	0.21	0.3852
		Native	1.3333	0.49	
	August	*M. spicatum*	0.8333	0.31	
		Mixed	0.5000	0.22	0.6538
		Native	1.0000	0.45	
	September	*M. spicatum*	0.8333	0.17	
		Mixed	1.1667	0.40	0.1086
		Native	0.3333	0.21	
Phylum Arthropoda					
Class Crustacea	July	*M. spicatum*	0.6667	0.21	
		Mixed	0.5000	0.22	0.4925
		Native	0.8333	0.17	
	August	*M. spicatum*	1.0000	0.37	
		Mixed	1.3333	0.21	0.5215
		Native	1.5000	0.22	
	September	*M. spicatum*	1.0000	0.26	
		Mixed	2.0000	0.00	0.0084
		Native	1.0000	0.26	
Class Insecta					
Order Diptera	July	*M. spicatum*	0.5000	0.34	
		Mixed	0.3333	0.21	0.1552
		Native	1.5000	0.50	
	August	*M. spicatum*	1.5000	0.34	
		Mixed	0.8333	0.31	0.3424
		Native	1.5000	0.43	
	September	*M. spicatum*	0.3333	0.21	
		Mixed	1.1667	0.31	0.1112
		Native	0.6667	0.21	
Order Ephemeroptera	July	*M. spicatum*	0.8333	0.31	
		Mixed	0.8333	0.17	0.7388
		Native	1.0000	0.00	
	August	*M. spicatum*	1.1667	0.40	
		Mixed	0.5000	0.22	0.3169
		Native	0.8333	0.17	
	September	*M. spicatum*	0.8333	0.17	
		Mixed	1.3333	0.21	0.0866
		Native	0.6667	0.21	

Table 1.7 cont.

Taxa	Month	Site	Mean	Standard Error	P Value
Order Odonata	July	*M. spicatum*	0.1667	0.17	
		Mixed	0.1667	0.17	0.7382
		Native	0.3333	0.21	
	August	*M. spicatum*	1.0000	0.00	
		Mixed	0.8333	0.17	0.1194
		Native	0.5000	0.22	
	September	*M. spicatum*	1.6667	0.33	
		Mixed	1.3333	0.21	0.0185
		Native	0.5000	0.22	
Order Trichoptera	July	*M. spicatum*	1.0000	0.45	
		Mixed	2.1667	0.48	0.0045
		Native	3.8333	0.31	
	August	*M. spicatum*	1.5000	0.50	
		Mixed	1.8333	0.40	0.8086
		Native	1.5000	0.43	
	September	*M. spicatum*	2.6667	0.95	
		Mixed	2.6667	0.71	0.6043
		Native	1.6667	0.67	
"Other"	July	*M. spicatum*	0.3333	0.21	
		Mixed	0.8333	0.31	0.0457
		Native	1.3333	0.21	
	August	*M. spicatum*	0.3333	0.21	
		Mixed	0.8333	0.40	0.4624
		Native	0.8333	0.31	
	September	*M. spicatum*	0.6667	0.33	
		Mixed	1.0000	0.37	0.5468
		Native	0.5000	0.34	

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

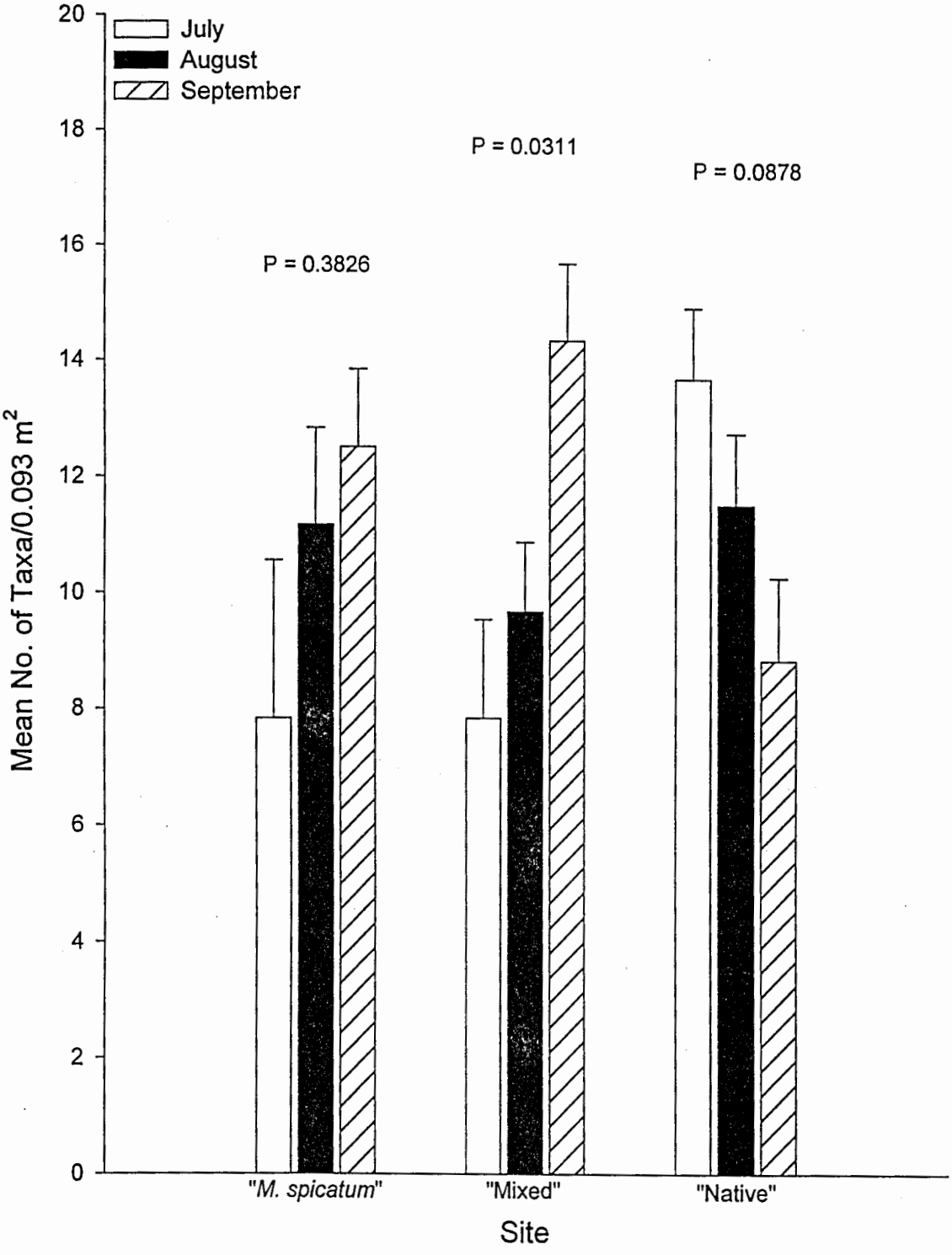

Fig. 1.10. Mean macroinvertebrate taxa richness/0.093 m^2 in July, August and September, 1993 at the "*M. spicatum*," "mixed" and "native" sites in Zumbra Lake. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences within sites over the sampling period.

Table 1.8. Comparison of mean macroinvertebrate taxa richness/0.093 m^2 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.

Taxa	Site	Month	Mean	Standard Error	P Value
Phylum Annelida	*M. spicatum*	July	1.0000	0.37	
		August	0.8333	0.17	0.6195
		September	1.6667	0.61	
	Mixed	July	0.3333	0.21	
		August	0.8333	0.17	0.2296
		September	0.8333	0.31	
	Native	July	0.8333	0.31	
		August	0.8333	0.17	0.5124
		September	0.5000	0.22	
Phylum Mollusca					
Class Gastropoda	*M. spicatum*	July	1.3333	0.42	
		August	0.8333	0.31	0.4274
		September	0.8333	0.17	
	Mixed	July	0.6667	0.21	
		August	0.5000	0.22	0.3418
		September	1.6667	0.40	
	Native	July	1.3333	0.50	
		August	1.0000	0.45	0.2730
		September	0.3333	0.21	
Phylum Arthropoda					
Class Crustacea	*M. spicatum*	July	0.6667	0.21	
		August	1.0000	0.37	0.6420
		September	1.0000	0.26	
	Mixed	July	0.5000	0.22	
		August	1.3333	0.21	0.0021
		September	2.0000	0.00	
	Native	July	0.8333	0.17	
		August	1.5000	0.22	0.1126
		September	1.0000	0.26	
Class Insecta					
Order Diptera	*M. spicatum*	July	0.5000	0.34	
		August	1.5000	0.34	0.0243
		September	0.3333	0.21	
	Mixed	July	0.3333	0.21	
		August	0.8333	0.31	0.2689
		September	1.1667	0.31	
	Native	July	1.5000	0.50	
		August	1.5000	0.43	0.5676
		September	0.6667	0.21	
Order Ephemeroptera	*M. spicatum*	July	0.8333	0.31	
		August	1.1667	0.40	0.6870
		September	0.8333	0.17	
	Mixed	July	0.8333	0.17	
		August	0.5000	0.22	0.0464
		September	1.3333	0.21	
	Native	July	1.0000	0.00	
		August	0.8333	0.17	0.3220
		September	0.6667	0.21	

Table 1.8 cont.

Taxa	Site	Month	Mean	Standard Error	P Value
Order Odonata	*M. spicatum*	July	0.1667	0.17	
		August	1.0000	0.00	0.0023
		September	1.6667	0.33	
	Mixed	July	0.1667	0.17	
		August	0.8333	0.17	0.0062
		September	1.3333	0.21	
	Native	July	0.3333	0.21	
		August	0.5000	0.22	0.8086
		September	0.5000	0.22	
Order Trichoptera	*M. spicatum*	July	1.0000	0.45	
		August	1.5000	0.50	0.4163
		September	2.6667	0.95	
	Mixed	July	2.1667	0.48	
		August	1.8333	0.40	0.5671
		September	2.6667	0.71	
	Native	July	3.8333	0.31	
		August	1.5000	0.43	0.0143
		September	1.6667	0.67	
"Other"	*M. spicatum*	July	0.3333	0.21	
		August	0.3333	0.21	0.6832
		September	0.6667	0.33	
	Mixed	July	0.8633	0.31	
		August	0.8333	0.40	0.9223
		September	1.0000	0.37	
	Native	July	1.3333	0.21	
		August	0.8333	0.31	0.1395
		September	0.5000	0.34	

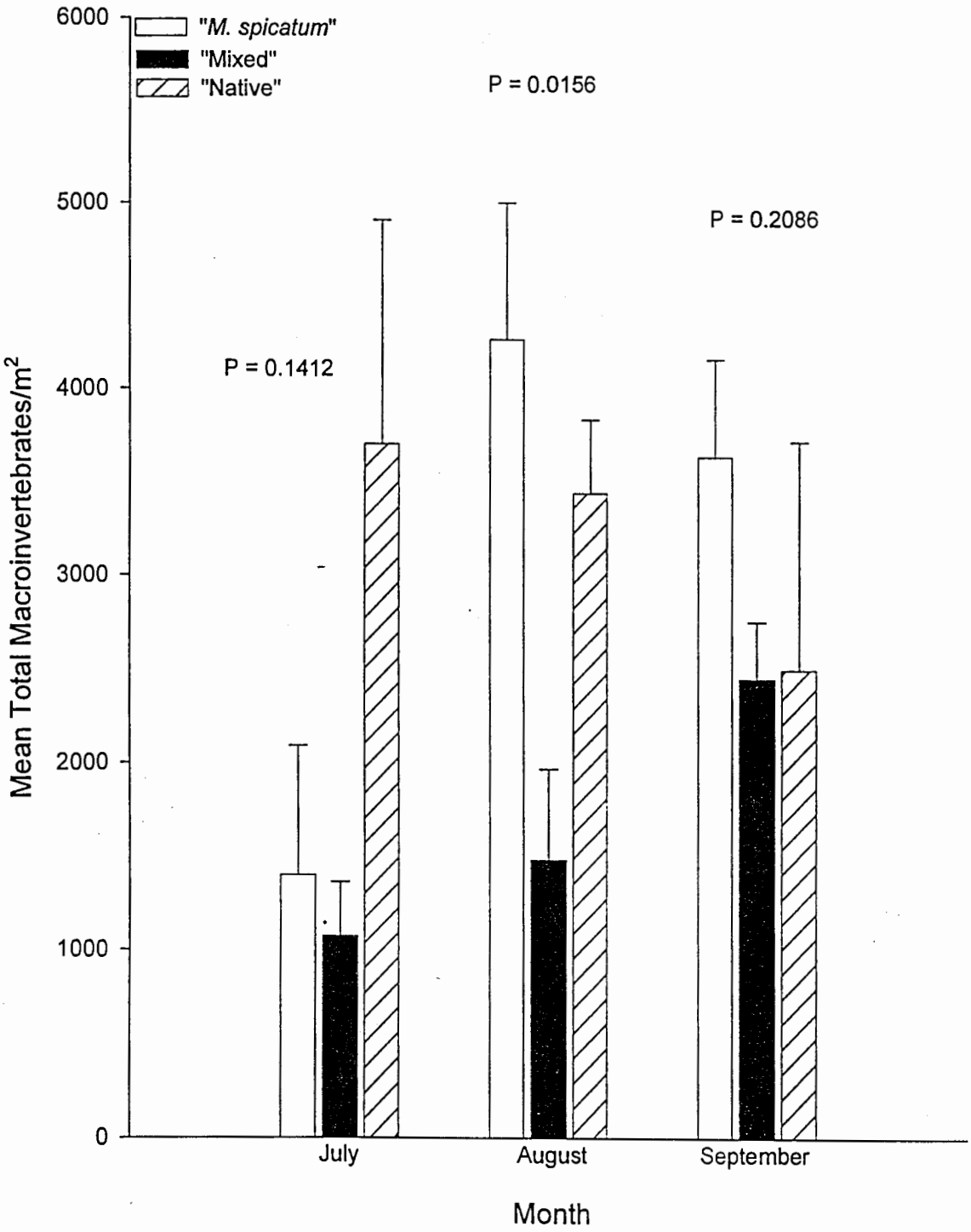

Fig. 1.11. Mean total macroinvertebrate densities/m^2 at the "*M. spicatum*," "mixed" and "native" sites in Zumbra Lake in July, August and September, 1993. Error bars are one standard error. P values were determined using Kruskal-Wallis test for differences among sites on each sampling date.

Table 1.9. Comparison of mean macroinvertebrate densities/m^2 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.

Taxa	Month	Site	Mean	Standard Error	P Value
Phylum Annelida	July	*M. spicatum*	19.6900	11.57	
		Mixed	12.5300	10.53	0.5478
		Native	12.5300	5.13	
	August	*M. spicatum*	161.1000	81.56	
		Mixed	42.9600	14.93	0.6187
		Native	196.9000	112.46	
	September	*M. spicatum*	44.7500	15.54	
		Mixed	85.9200	45.40	0.6909
		Native	37.5900	22.31	
Phylum Mollusca					
Class Gastropoda	July	*M. spicatum*	245.2300	107.09	
		Mixed	17.9000	8.16	0.2496
		Native	64.4400	24.96	
	August	*M. spicatum*	26.8500	14.61	
		Mixed	10.7400	5.55	0.7012
		Native	42.9600	25.87	
	September	*M. spicatum*	46.5400	17.02	
		Mixed	44.7500	18.69	0.0885
		Native	8.9500	5.83	
Phylum Arthropoda					
Class Crustacea	July	*M. spicatum*	372.3200	206.84	
		Mixed	94.8700	51.46	0.5346
		Native	229.1200	197.19	
	August	*M. spicatum*	96.6600	41.32	
		Mixed	105.6100	46.10	0.9304
		Native	94.8700	35.45	
	September	*M. spicatum*	227.4500	111.39	
		Mixed	259.5500	95.76	0.1861
		Native	87.7100	51.61	
Class Insecta					
Order Diptera	July	*M. spicatum*	630.0800	311.17	
		Mixed	784.0200	234.38	0.0579
		Native	3001.8300	974.79	
	August	*M. spicatum*	3798.3800	737.54	
		Mixed	1197.5100	441.90	0.0394
		Native	3012.5700	490.96	
	September	*M. spicatum*	2980.3500	550.25	
		Mixed	1544.7700	210.45	0.1136
		Native	2008.3800	893.65	
Order Ephemeroptera	July	*M. spicatum*	23.2700	11.57	
		Mixed	50.1200	18.11	0.2620
		Native	71.6000	31.21	
	August	*M. spicatum*	39.3800	22.98	
		Mixed	28.6400	20.69	0.6862
		Native	23.2700	5.83	
	September	*M. spicatum*	98.4500	35.34	
		Mixed	132.4600	24.12	0.1548
		Native	96.6600	83.93	

Table 1.9 cont.

Taxa	Month	Site	Mean	Standard Error	P Value
Order Odonata	July	*M. spicatum*	1.7900	1.79	
		Mixed	1.7900	1.79	0.7382
		Native	3.5800	2.26	
	August	*M. spicatum*	66.2300	28.20	
		Mixed	19.6900	9.37	0.0286
		Native	7.1600	3.58	
	September	*M. spicatum*	130.6700	48.30	
		Mixed	186.1600	35.26	0.0660
		Native	66.2300	32.74	
Order Trichoptera	July	*M. spicatum*	62.6500	34.57	
		Mixed	76.9700	34.35	0.0326
		Native	263.1300	84.33	
	August	*M. spicatum*	71.6000	33.93	
		Mixed	53.7000	15.19	0.7093
		Native	41.1700	17.63	
	September	*M. spicatum*	46.5400	18.11	
		Mixed	91.2900	40.73	0.6674
		Native	39.3800	18.74	
"Other"	July	*M. spicatum*	44.7500	38.67	
		Mixed	34.0100	11.57	0.4077
		Native	53.7000	24.49	
	August	*M. spicatum*	3.5800	2.26	
		Mixed	21.4800	12.09	0.3159
		Native	17.9000	8.16	
	September	*M. spicatum*	7.1600	3.58	
		Mixed	105.6100	62.03	0.4745
		Native	153.9400	151.80	

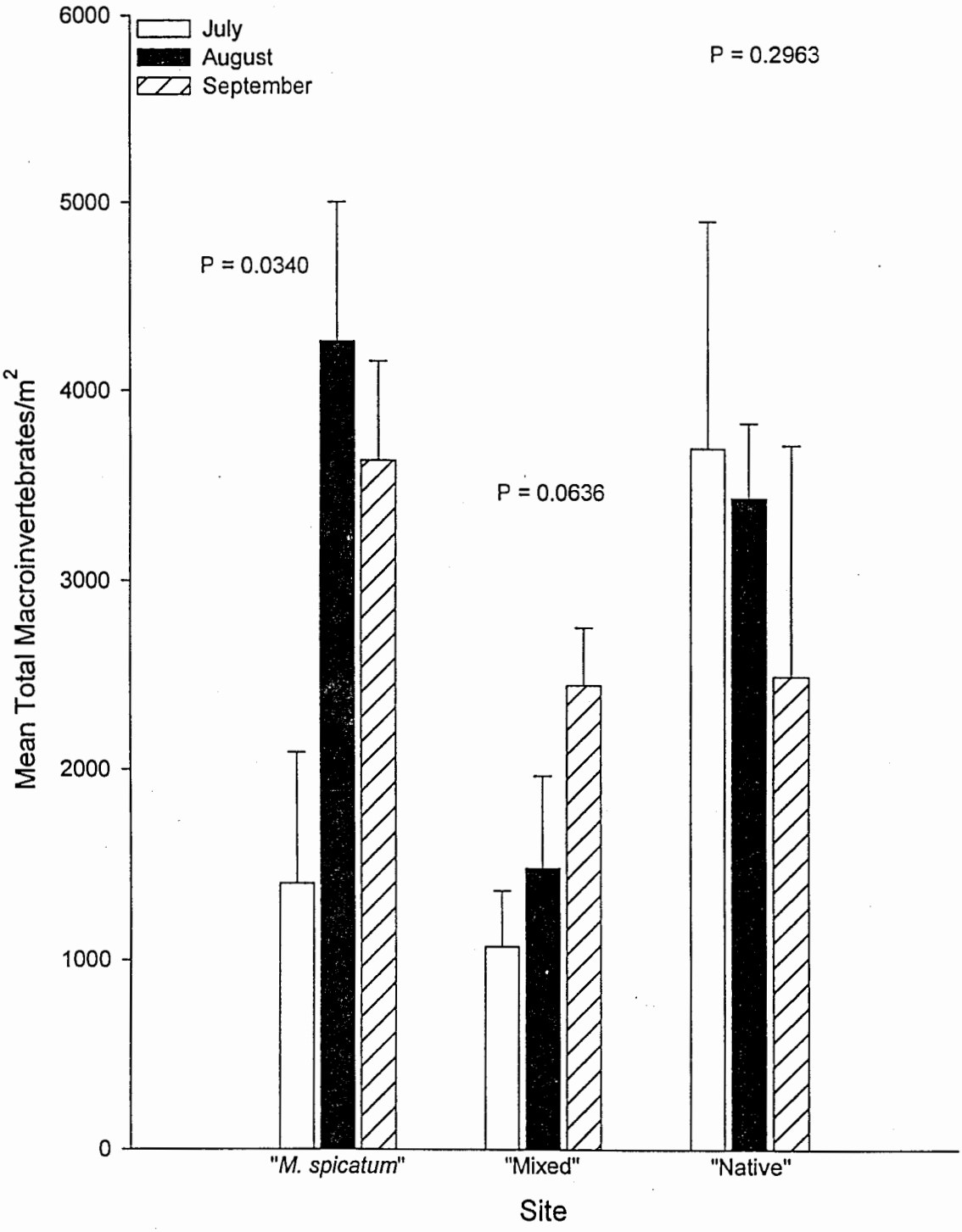

Fig. 1.12. Mean total macroinvertebrate densities/m^2 in July, August and September, 1993 at the "*M. spicatum*," "mixed" and "native" sites in Zumbra Lake. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences within sites over the sampling period.

Table 1.10. Comparison of mean macroinvertebrate densities/m^2 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.

Taxa	Site	Month	Mean	Standard Error	P Value
Phylum Annelida	*M. spicatum*	July	19.6900	11.57	
		August	161.1000	81.56	0.2166
		September	44.7500	15.54	
	Mixed	July	12.5300	10.53	
		August	42.9600	14.93	0.2192
		September	85.9200	45.40	
	Native	July	12.5300	5.13	
		August	196.9000	112.46	0.1322
		September	37.5900	22.31	
Phylum Mollusca					
Class Gastropoda	*M. spicatum*	July	245.2300	107.09	
		August	26.8500	14.61	0.2807
		September	46.5400	17.09	
	Mixed	July	17.9000	8.16	
		August	10.7400	5.55	0.1979
		September	44.7500	18.69	
	Native	July	64.4400	24.96	
		August	42.9600	25.87	0.2629
		September	8.9500	5.83	
Phylum Arthropoda					
Class Crustacea	*M. spicatum*	July	372.3200	206.84	
		August	96.6600	41.32	0.3891
		September	277.4500	111.39	
	Mixed	July	94.8700	51.46	
		August	105.6100	46.10	0.1444
		September	259.5500	95.76	
	Native	July	229.1200	197.19	
		August	94.8700	35.45	0.6970
		September	87.7100	51.61	
Class Insecta					
Order Diptera	*M. spicatum*	July	630.0800	311.17	
		August	3798.3800	737.54	0.0054
		September	2980.3500	550.25	
	Mixed	July	784.0200	234.38	
		August	1197.5100	441.90	0.0930
		September	1544.7700	210.45	
	Native	July	3001.8300	974.79	
		August	3012.5700	490.96	0.4436
		September	2008.3800	893.65	
Order Ephemeroptera	*M. spicatum*	July	23.2700	11.57	
		August	39.3800	22.98	0.2583
		September	98.4500	35.34	
	Mixed	July	50.1200	18.11	
		August	28.6400	20.69	0.0219
		September	132.4600	24.12	
	Native	July	71.6000	31.21	
		August	23.2700	5.83	0.0993
		September	96.6600	83.93	

Table 1.10 cont.

Taxa	Site	Month	Mean	Standard Error	P Value
Order Odonata	*M. spicatum*	July	1.7900	1.79	
		August	66.2300	28.20	0.0031
		September	130.6700	48.30	
	Mixed	July	1.7900	1.79	
		August	19.6900	9.37	0.0013
		September	186.1600	35.26	
	Native	July	3.5800	2.26	
		August	7.1600	3.58	0.4718
		September	66.2300	32.74	
Order Trichoptera	*M. spicatum*	July	62.6500	34.57	
		August	71.6000	33.93	0.9293
		September	46.5400	18.11	
	Mixed	July	76.9700	34.35	
		August	53.7000	15.19	0.9591
		September	91.2900	40.73	
	Native	July	263.1300	84.33	
		August	41.1700	17.63	0.0062
		September	39.3800	18.74	
"Other"	*M. spicatum*	July	44.7500	38.67	
		August	3.5800	2.26	0.8068
		September	7.1600	3.58	
	Mixed	July	34.0100	11.57	
		August	21.4800	12.09	0.7405
		September	105.6100	62.03	
	Native	July	53.7000	24.49	
		August	17.9000	8.16	01564
		September	153.9400	151.80	

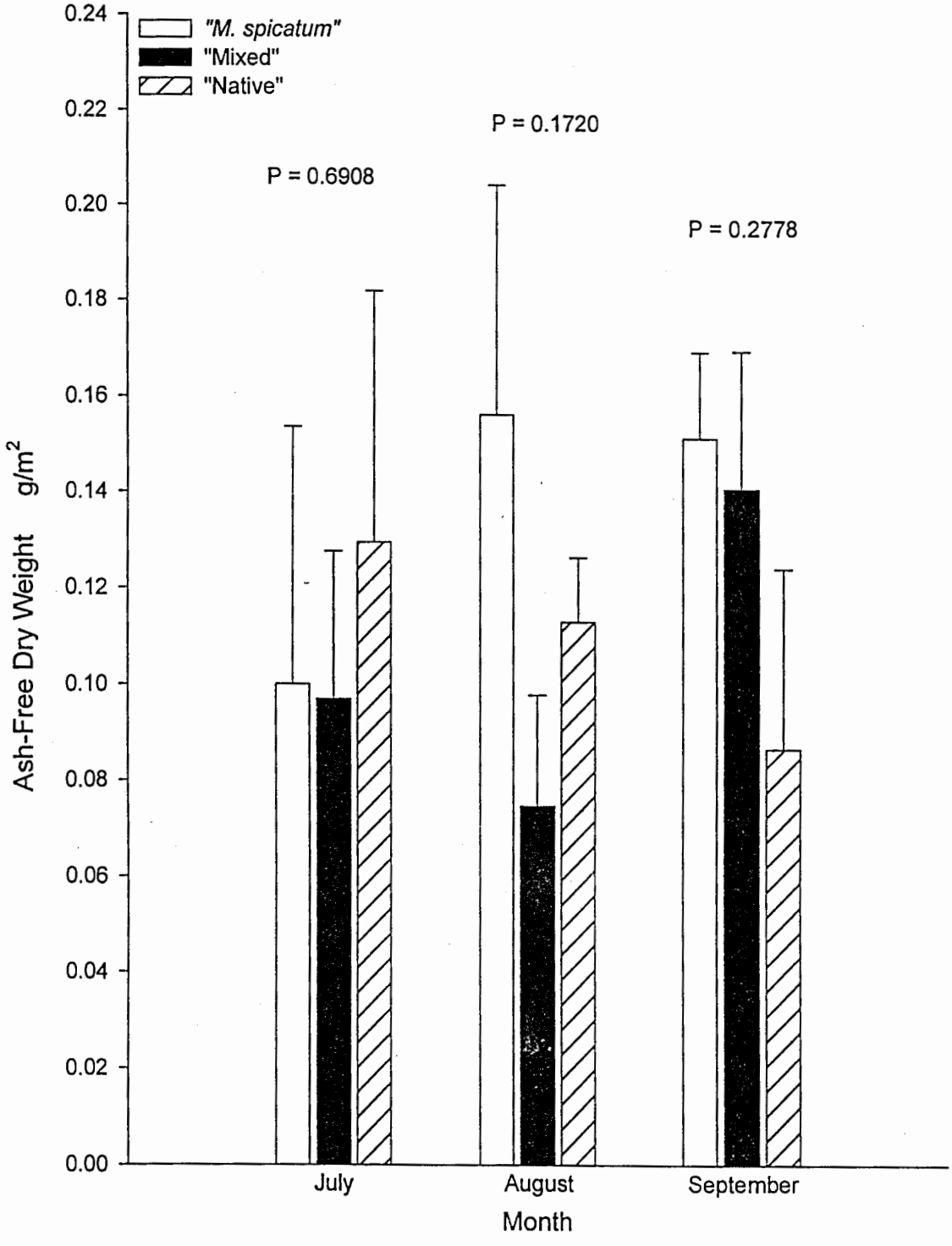

Fig. 1.13. Mean macroinvertebrate AFDW (g/m^2) at the "*M. spicatum*," "mixed" and "native" sites in Zumbra Lake in July, August and September, 1993. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences among sites on each sampling date.

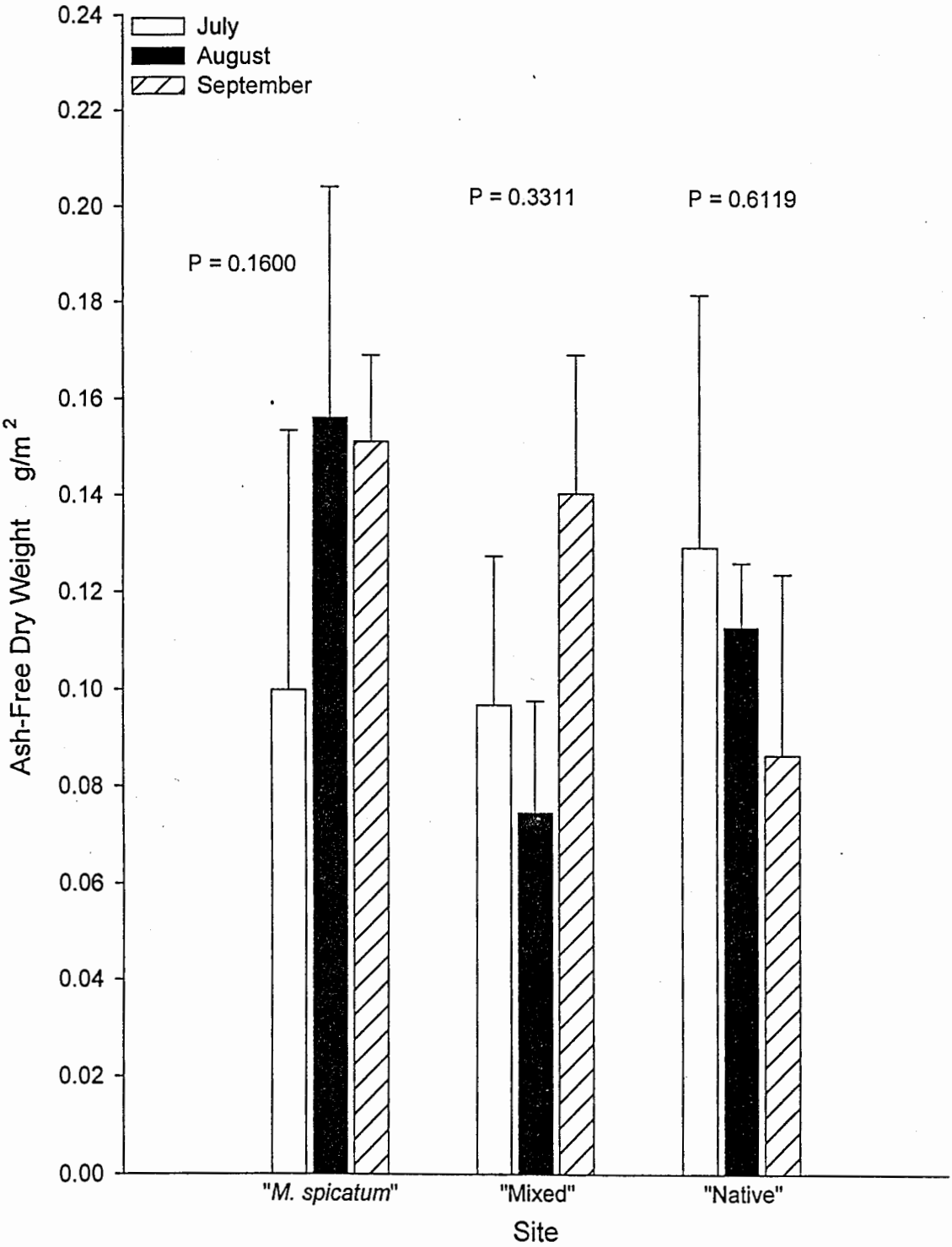

Fig. 1.14. Mean macroinvertebrate AFDW (g/m^2) in July, August and September, 1993 at the "*M. spicatum*," "mixed" and "native" sites in Zumbra Lake. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences within sites over the sampling period.

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 Zumbra 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.

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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.

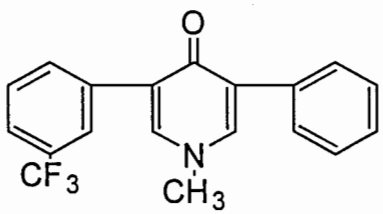

Fig. 2.1. Molecular structure of fluridone (1-methyl-3-phenyl-5-[3-(trifluoromethyl)-phenyl]-4(1H)-pyridinone).

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, Faronc 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 hydrosoils 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

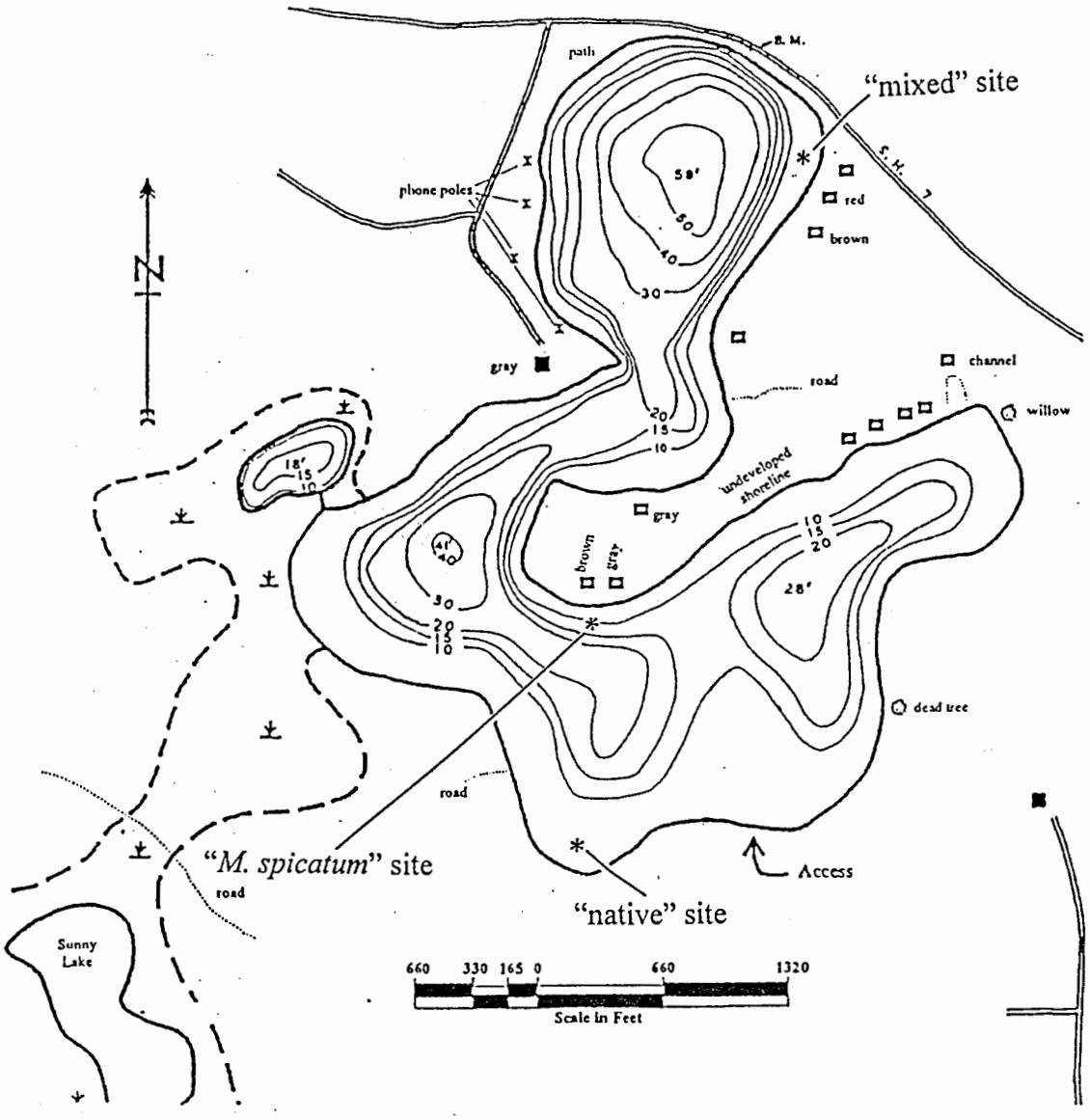

Fig. 2.2. Map of Zumbra Lake, Minnesota showing the location of the "*M. spicatum*," "mixed" and "native" sites. Six samples were collected at each site in July, August and September, 1993, 1994 and 1995.

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).

Year	Number of Observations	Chlorophyll a (μg / L)	Secchi Depth (m)
1993	5	17	2.1
1994	6	25	1.6
1995	5	43	0.9

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 m^2 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 m^2 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 m^2, mean density and biomass measurements were divided by sample area (0.093 m^2) to estimate the number of macroinvertebrates or biomass/m^2.

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 μg/L initial concentration for at least 14 days, but the actual mean initial concentration (24μg/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).

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

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).

Taxa	1993	1994	1995
Ceratophyllum demersum	84	57	4
Myriophyllum spicatum	94	8	0
Potamogeton zosteriformis	39	8	4
Nymphaea sp.	57	24	43
Potamogeton pectinatus	22	0	29

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

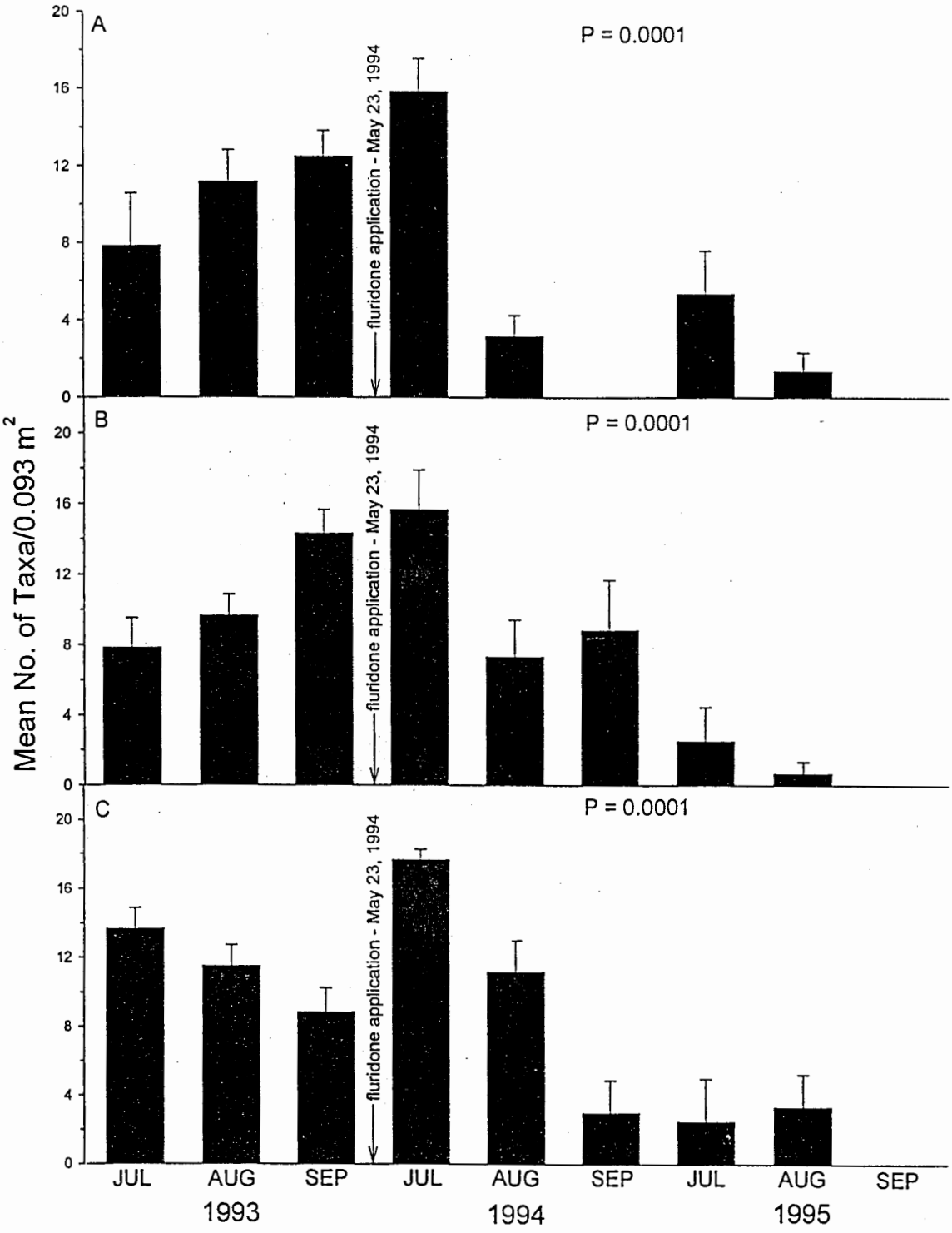

Fig. 2.3. Mean macroinvertebrate taxa richness/0.093 m^2 at three sites in Zumbra Lake: A, "*M. spicatum*" site; B, "mixed" site; and C, "native" site. Six samples were taken from each site on each sampling date. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences within sites over time.

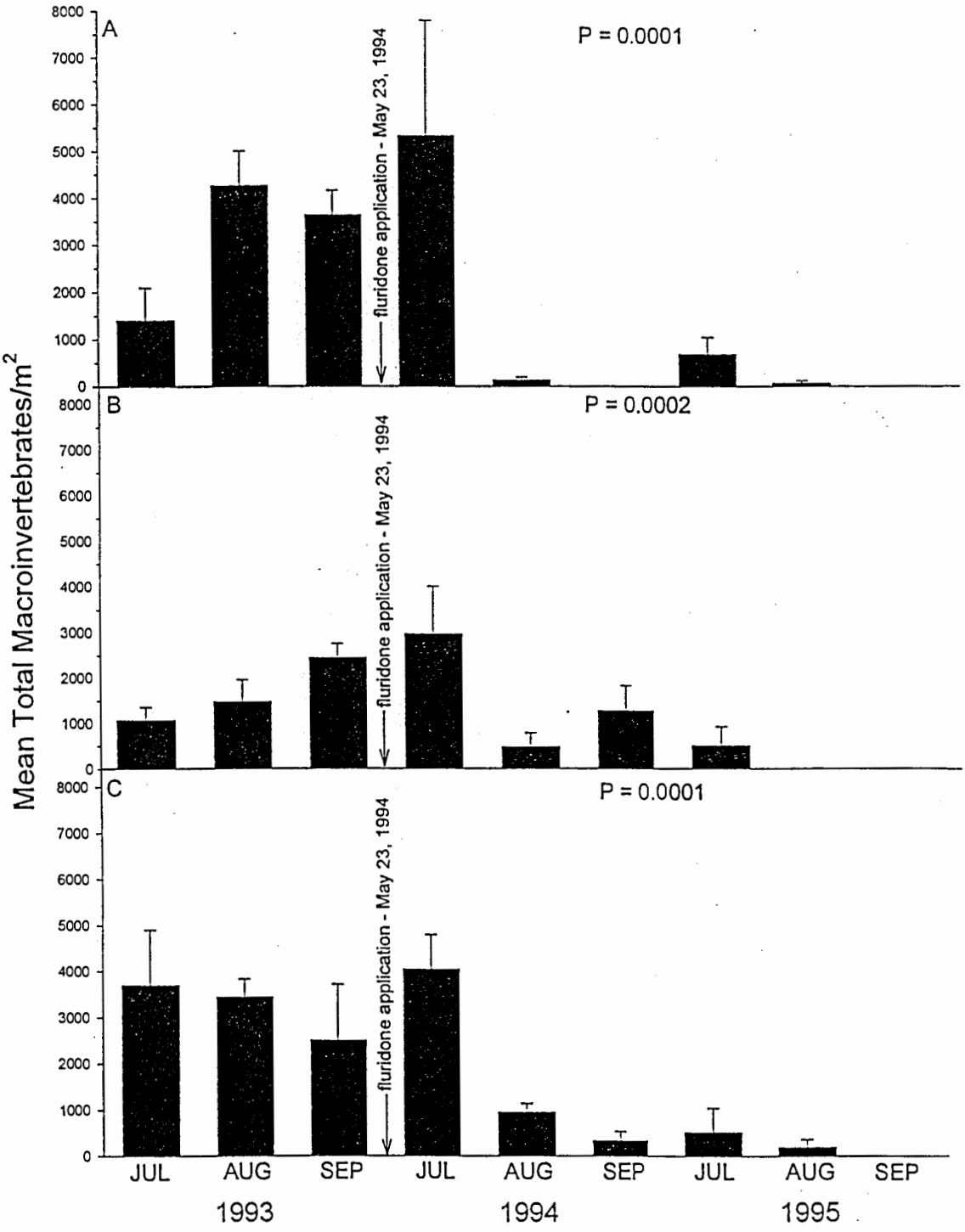

Fig. 2.4. Mean total macroinvertebrate densities/m^2 at three sites in Zumbra Lake: A, "*M. spicatum*" site; B, "mixed" site; and C, "native" site. Six samples were taken from each site on each sampling date. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences within sites over time.

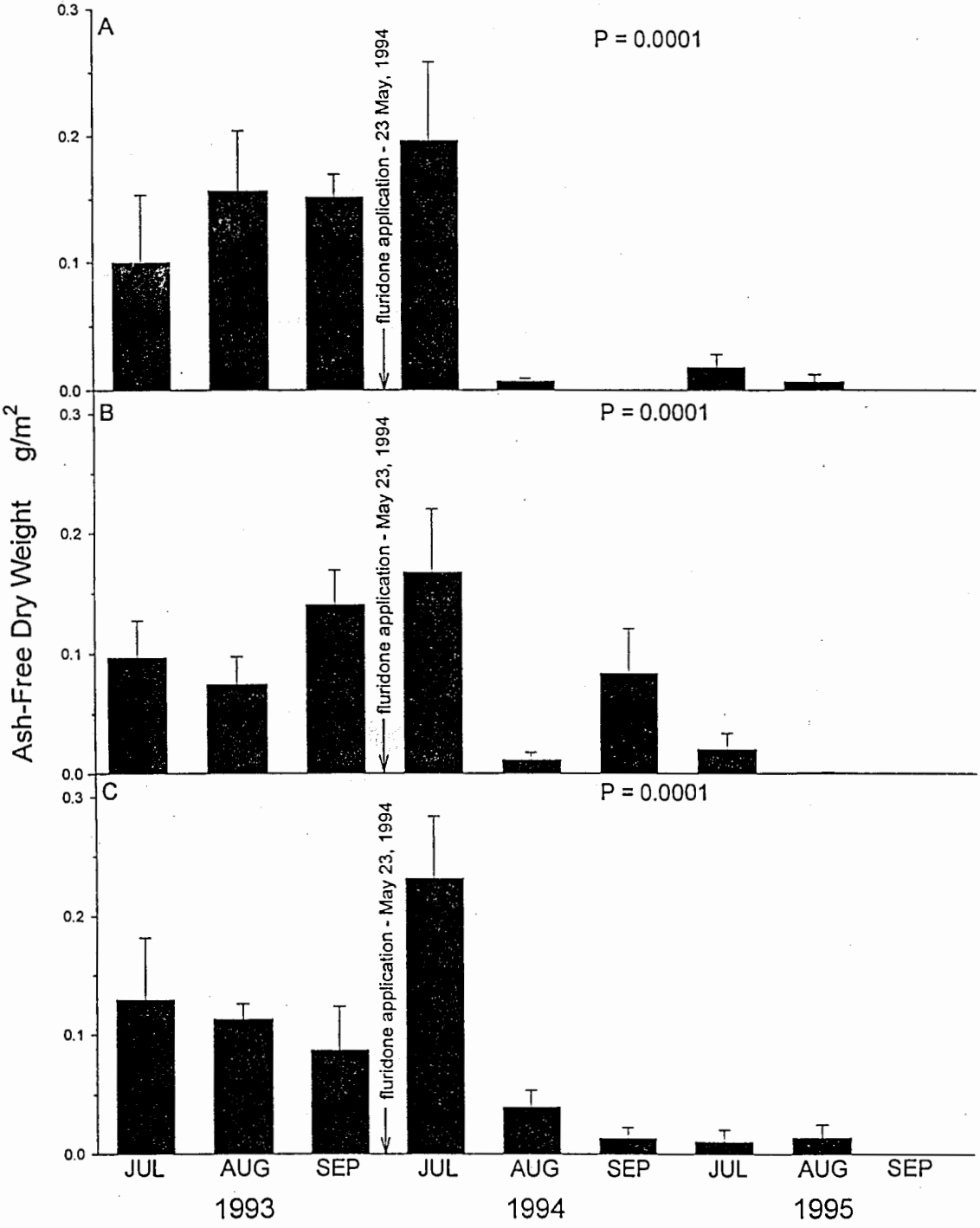

Fig. 2.5. Mean macroinvertebrate AFDW (g/m^2) at three sites in Zumbra Lake: A, "*M. spicatum*" site; B, "mixed" site; and C, "native" site. Six samples were taken from each site on each sampling date. Error bars are one standard error. P values are from a Kruskal-Wallis test for differences within sites over time.

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.

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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 Auburn 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 m^2 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 MACROTHE 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
CYRNFRAT NEURECSP POLYCNSP AGRYPNIA TIPULARV CHIRONOM CHIRONAE
TANYPNAE ORTHONAE PROBGLAB CULCOIDE MUSCPUPA CERATPUP MPIDIDA CHIRPUPA
HEMERODR HYALAZTE ACARIxxx COPEPODA HYDRASPx CLADOCER NEMATODA
OLIGOCHA MENETUSS PHYSELLA FERRISIA DUGESIAS HSTAGNAL HELOBDEL HELONGAT
PMULTILI PORNATA OTRANSLU PPARASIT AHETEROC MLUCIDIA MFERIDIA EPUNCTAT
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.
*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 IMMOBILIS
*LEPTAMER = LEPTOCERUS AMERICANUS
*OCINERAS = OECETIS CINERASCENS
*TRITARDA = TRIANODES TARDA
*TRINJUST = TRINANODES INJUSTA
*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
*HYDROPSP = 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.
*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.
*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
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;
```

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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 EMPIDIDA = 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 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 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 = 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;
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/m^2 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 NEHLENIA SOMATOSP
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 POLYCINE POLYREMO POLYINTR
CYRNFRAT NEURECSP POLYCNSP AGRYPNIA TIPULARV CHIRONOM CHIRONAE
TANYPNAE ORTHONAE PROBGLAB CULCOIDE MUSCPUPA CERATPUP EMPIDIDA
CHIRPUPA HEMERODR HYALAZTE ACARIxxx COPEPODA HYDRASPx CLADOCER
NEMATODA OLIGOCHA MENETUSS PHYSELLA FERRISIA DUGESIAS HSTAGNAL
HELOBDEL HELONGAT PMULTILI PORNATA OTRANSLU PPARASIT AHETEROC MLUCIDIA
MFERIDIA EPUNCTAT 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.
*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 IMMOBILIS
*LEPTAMER = LEPTOCERUS AMERICANUS
*OCINERAS = OECETIS CINERASCENS
*TRITARDA = TRIANODES TARDA
*TRINJUST = TRINANODES INJUSTA
*TRIADA = TRIANODES ABA
*TRIANODE = TRIANODES SP.
*NECTALBI = NECTOPSYCHE ALBIDA
*CERGLGMS = CERACLEA GLAGMUS
*LEPTOCSP  = LEPTOCERUS SP.
*LEPTPUPA = LEPTOCERUS SP. PUPAE
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*NECTOPSY = NECTOPSYCHE SP.
*OECETISP = OECETIS SP.
*OXYETHSP = OXYETHIRA SP.
*ORTHOTSP = ORTHOTRICHIA SP.
*HYDROPSY = HYDROPSYCHIDAE .
*HYDROPSP = 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.
*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.
*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;
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;
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;

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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;
CERATPUm = 10.74*CERATPUP;
EMPIDIDm = 10.74*EMPIDIDA;
CHIRPUPm = 10.74*CHIRPUPA;
HEMERODm = 10.74*HEMERODR;
HYALAZTm = 10.74*HYALAZTE;
ACARIxxm = 10.74*ACARIxxx;
COPEPODm = 10.74*COPEPODA;
HYDRASPm = 10.74*HYDRASPx;
CLADOCEm = 10.74*CLADOCER;
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;
PPARASIm = 10.74*PPARASIT;
AHETEROm = 10.74*AHETEROC;
MLUCIDIm = 10.74*MLUCIDIA;
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*STENOPEL;
HYPERODm = 10.74*HYPERODE;
CURCLARm = 10.74*CURCLARV;
CORILARm = 10.74*CORILARV;
CORIXIDm = 10.74*CORIXIDA;
PELTODYm = 10.74*PELTODYT;
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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+
    ISCHNURm+ARGIAm+GOMPHIDm+NEHLENIm;
TRICHOP = HSIMULAm+HYDRORRm+CHEUMATm+IMOBILUm+LEPTAMEm+OCINERAm+
    TRITARDm+TRINJUSm+NECTALBm+LEPTOCSm+LEPTPUPm+NECTOPSm+OECETISm +
    OXYETHSm+ORTHOTSm+HYDROPSm+HYDROPm+HYDRPUPm+HYTILASm+POLYCINm
    +POLYCENm+NEURECSm+CYRNFRAm+POLYCNSm+TRIADAm+TRIANODm+
    CERGLGMm+POLYREMm+POLYINTm+AGRYPNIm;
DIPTERA = CHIRONDm+PROBGLAm+CULCOIDm+CERATPUm+CHIRPUPm+TIPULARm+
    MUSCPUPm+EMPIDIDm+HEMERODm+ATOCHAm;
CRUSTAC = HYALAZTm+COPEPODm+CLADOCEm+OSTRACOm+ISOPODAm;
ANNELID = HSTAGNAm+PMULTILm+OTRANSLm+PPARASIm+AHETEROm+MLUCIDIm+
    EPUNCTAm+ERPOBDEm+BPALUDOm+PMARAMOm+OLIGOCHm+HELOBDEm+
    HELONGAm+PORNATAm+MFERIDIm+BPICTAm;
OTHER = ACARIxxm+HYDRASPm+NEMATODm+DUGESIAm+CORILARm+CORIXIDm;
COLEOP = STENOPEm+HYPERODm+CURCLARm+LIXUSSPm+PELTODYm;
LEPIDOP = ACENTRIm+PARAPYNm+SPHINGIm+LEPIDPUm;
GASTRO = MENETUSm+PHYSELLm+FERRISIm;
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/m^2) 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 m^2 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";
     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 HYDROPSY
HYDROPSP HYDRPUPA HYTILASP POLYCENT POLYCINE POLYREMO POLYINTR
CYRNFRAT NEURECSP POLYCNSP
AGRYPNIA TIPULARV CHIRONOM CHIRONAE TANYPNAE ORTHONAE PROBGLAB
CULCOIDE MUSCPUPA CERATPUP EMPIDIDA CHIRPUPA HEMERODR HYALAZTE ACARIxxx
COPEPODA HYDRASPx CLADOCER NEMATODA OLIGOCHA MENETUSS PHYSELLA
FERRISIA DUGESIAS HSTAGNAL HELOBDEL HELONGAT PMULTILI PORNATA OTRANSLU
PPARASIT AHETEROC MLUCIDIA MFERIDIA EPUNCTAT 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.
*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 IMMOBILIS
*LEPTAMER = LEPTOCERUS AMERICANUS
*OCINERAS = OECETIS CINERASCENS
*TRITARDA = TRIANODES TARDA
*TRINJUST = TRINANODES INJUSTA
*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
*HYDROPSP = 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.
*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.
*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
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;
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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 EMPIDIDA = 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 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 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 = 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;
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/m^2 among the "*M. spicatum*," "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 NEHLENIA SOMATOSP
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 POLYCINE POLYREMO POLYINTR
CYRNFRAT NEURECSP POLYCNSP AGRYPNIA TIPULARV CHIRONOM CHIRONAE
TANYPNAE ORTHONAE PROBGLAB CULCOIDE MUSCPUPA CERATPUP EMPIDIDA
CHIRPUPA HEMERODR HYALAZTE ACARIxxx COPEPODA HYDRASPx CLADOCER
NEMATODA OLIGOCHA MENETUSS PHYSELLA FERRISIA DUGESIAS
HSTAGNAL HELOBDEL HELONGAT PMULTILI PORNATA OTRANSLU PPARASIT AHETEROC
MLUCIDIA MFERIDIA EPUNCTAT 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.
*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 IMMOBILIS
*LEPTAMER = LEPTOCERUS AMERICANUS
*OCINERAS = OECETIS CINERASCENS
*TRITARDA = TRIANODES TARDA
*TRINJUST = TRINANODES INJUSTA
*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
*HYDROPSP = 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.
*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.
*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;
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;
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;

```
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;
CERATPUm = 10.74*CERATPUP;
EMPIDIDm = 10.74*EMPIDIDA;
CHIRPUPm = 10.74*CHIRPUPA;
HEMERODm = 10.74*HEMERODR;
HYALAZTm = 10.74*HYALAZTE;
ACARIxxm = 10.74*ACARIxxx;
COPEPODm = 10.74*COPEPODA;
HYDRASPm = 10.74*HYDRASPx;
CLADOCEm = 10.74*CLADOCER;
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;
PPARASIm = 10.74*PPARASIT;
AHETEROm = 10.74*AHETEROC;
MLUCIDIm = 10.74*MLUCIDIA;
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*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+STENOINm+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+POLYCENm+
     POLYCINm+NEURECSm+CYRNFRAm+POLYCNSm+TRIADAm+TRIANODm+CERGLGMm+
     POLYREMm+POLYINTm+AGRYPNIm;
DIPTERA = CHIRONDm+PROBGLAm+CULCOIDm+CERATPUm+CHIRPUPm+TIPULARm+
     MUSCPUPm+EMPIDIDm+HEMERODm+ATOCHAm;
CRUSTAC = HYALAZTm+COPEPODm+CLADOCEm+OSTRACOm+ISOPODAm;
ANNELID = HSTAGNAm+PMULTILm+OTRANSLm+PPARASIm+AHETEROm+MLUCIDIm+
     EPUNCTAm+ERPOBDEm+BPALUDOm+PMARAMOm+OLIGOCHm+HELOBDEm+HELONGA
     m+ PORNATAm+MFERIDIm+BPICTAm;
OTHER = ACARIxxm+HYDRASPm+NEMATODm+DUGESIAm+CORILARm+CORIXIDm;
COLEOP = STENOPEm+HYPERODm+CURCLARm+LIXUSSPm+PELTODYm;
LEPIDOP = ACENTRIm+PARAPYNm+SPHINGIm+LEPIDPUm;
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/m^2) 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 m^2 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 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 HYDROPSY HYDROPSP
HYDRPUPA HYTILASP POLYCENT POLYCINE POLYREMO POLYINTR CYRNFRAT
NEURECSP POLYCNSP
AGRYPNIA TIPULARV CHIRONOM CHIRONAE TANYPNAE ORTHONAE PROBGLAB
CULCOIDE MUSCPUPA CERATPUP EMPIDIDA CHIRPUPA HEMERODR HYALAZTE ACARIxxx
COPEPODA HYDRASPx CLADOCER NEMATODA OLIGOCHA MENETUSS PHYSELLA
FERRISIA DUGESIAS
HSTAGNAL HELOBDEL HELONGAT PMULTILI PORNATA OTRANSLU PPARASIT AHETEROC
MLUCIDIA MFERIDIA EPUNCTAT 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.
*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 IMMOBILIS
*LEPTAMER = LEPTOCERUS AMERICANUS
*OCINERAS = OECETIS CINERASCENS
*TRITARDA = TRIANODES TARDA
*TRINJUST = TRINANODES INJUSTA
*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
*HYDROPSP = 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.
*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.
*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
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 EMPIDIDA = 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 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 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 = 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;
*CRUSTAC = DDD+FFF+HHH+LLLL+RRRR;
*ANNELID = JJJ+OOO+PPP+QQQ+RRR+SSS+TTT+UUU+VVV+XXX+YYY+ZZZ+
      AAAA+BBBB+CCCC+DDDD;
*OTHER = EEE+GGG+III+NNN+HHHH+IIII;
*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 NPAR1WAY 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/m^2 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 NEHLENIA SOMATOSP
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 POLYCINE POLYREMO POLYINTR
CYRNFRAT NEURECSP POLYCNSP AGRYPNIA TIPULARV CHIRONOM CHIRONAE
TANYPNAE ORTHONAE PROBGLAB
CULCOIDE MUSCPUPA CERATPUP EMPIDIDA CHIRPUPA HEMERODR HYALAZTE ACARIxxx
COPEPODA HYDRASPx CLADOCER NEMATODA OLIGOCHA MENETUSS PHYSELLA
FERRISIA DUGESIAS HSTAGNAL HELOBDEL HELONGAT PMULTILI PORNATA OTRANSLU
PPARASIT
AHETEROC MLUCIDIA MFERIDIA EPUNCTAT 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.
*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 IMMOBILIS
*LEPTAMER = LEPTOCERUS AMERICANUS
*OCINERAS = OECETIS CINERASCENS
*TRITARDA = TRIANODES TARDA
*TRINJUST = TRINANODES INJUSTA
*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
*HYDROPSP = 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.
*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.
*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;
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;
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;
```

```
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;
CERATPUm = 10.74*CERATPUP;
EMPIDIDm = 10.74*EMPIDIDA;
CHIRPUPm = 10.74*CHIRPUPA;
HEMERODm = 10.74*HEMERODR;
HYALAZTm = 10.74*HYALAZTE;
ACARIxxm = 10.74*ACARIxxx;
COPEPODm = 10.74*COPEPODA;
HYDRASPm = 10.74*HYDRASPx;
CLADOCEm = 10.74*CLADOCER;
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;
PPARASIm = 10.74*PPARASIT;
AHETEROm = 10.74*AHETEROC;
MLUCIDIm = 10.74*MLUCIDIA;
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*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+STENOINm+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+POLYCEN
      m+POLYCINm+NEURECSm+CYRNFRAm+POLYCNSm+TRIADAm+TRIANODm+CERGLG
      Mm+POLYREMm+POLYINTm+AGRYPNIm;
DIPTERA = PROBGLAm+CULCOIDm+CERATPUm+CHIRPUPm+TIPULARm+MUSCPUPm+
      EMPIDIDm+HEMERODm+ATOCHAm+CHIRONDm ;
CRUSTAC = HYALAZTm+COPEPODm+CLADOCEm+OSTRACOm+ISOPODAm;
ANNELID = HSTAGNAm+PMULTILm+OTRANSLm+PPARASIm+AHETEROm+MLUCIDIm+
      EPUNCTAm+ERPOBDEm+BPALUDOm+PMARAMOm+OLIGOCHm+HELOBDEm+HELON
      GAm+PORNATAm+MFERIDIm+BPICTAm;
OTHER = ACARIxxm+HYDRASPm+NEMATODm+DUGESIAm+CORILARm+CORIXIDm;
COLEOP = STENOPEm+HYPERODm+CURCLARm+LIXUSSPm+PELTODYm;
LEPIDOP = ACENTRIm+PARAPYNm+SPHINGIm+LEPIDPUm;
GASTRO = MENETUSm+PHYSELLm+FERRISIm;
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 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/m^2) 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 = 1993;
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 m^2 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 MACROTHE 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
CYRNFRAT NEURECSP POLYCNSP AGRYPNIA TIPULARV CHIRONOM CHIRONAE
TANYPNAE ORTHONAE PROBGLAB CULCOIDE MUSCPUPA CERATPUP EMPIDIDA
CHIRPUPA HEMERODR HYALAZTE ACARIxxx COPEPODA HYDRASPx CLADOCER
NEMATODA OLIGOCHA MENETUSS PHYSELLA FERRISIA DUGESIAS HSTAGNAL
HELOBDEL HELONGAT PMULTILI PORNATA OTRANSLU PPARASIT AHETEROC MLUCIDIA
MFERIDIA EPUNCTAT 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.
*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 IMMOBILIS
*LEPTAMER = LEPTOCERUS AMERICANUS
*OCINERAS = OECETIS CINERASCENS
*TRITARDA = TRIANODES TARDA
*TRINJUST = TRINANODES INJUSTA
*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
*HYDROPSP = 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.
*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.
*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
IF CAENISSP = 0 THEN A = 0; ELSE A = I;
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 = I;
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 EMPIDIDA = 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 = I;
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 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 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 = 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;
*CRUSTAC = DDD+FFF+HHH+LLLL+RRRR;
*ANNELID = JJJ+OOO+PPP+QQQ+RRR+SSS+TTT+UUU+VVV+XXX+YYY+ZZZ+
      AAAA+BBBB+CCCC+DDDD;
*OTHER = EEE+GGG+III+NNN+HHHH+IIII;
*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 = 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 NUMTAXA;
PROC CHART;
BY LAK SITE;
VBAR MONTH/DISCRETE SUMVAR = NUMTAXA TYPE=MEAN;
PROC NPAR1WAY ANOVA WILCOXON;
BY LAK SITE;
CLASS MONTH;
VAR NUMTAXA;
```

APPENDIX K: Statistacal analysis system (SAS) program used in Chapter Two to analyze for differences in aquatic macroinvertebrate densities/m^2 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 HYDROPSY
HYDROPSP HYDRPUPA HYTILASP POLYCENT POLYCINE POLYREMO POLYINTR
CYRNFRAT NEURECSP POLYCNSP AGRYPNIA TIPULARV CHIRONOM CHIRONAE
TANYPNAE ORTHONAE PROBGLAB CULCOIDE MUSCPUPA CERATPUP EMPIDIDA
CHIRPUPA HEMERODR HYALAZTE ACARIxxx COPEPODA HYDRASPx CLADOCER
NEMATODA OLIGOCHA MENETUSS PHYSELLA FERRISIA DUGESIAS HSTAGNAL
HELOBDEL HELONGAT PMULTILI PORNATA OTRANSLU PPARASIT AHETEROC MLUCIDIA
MFERIDIA EPUNCTAT 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.
*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 IMMOBILIS
*LEPTAMER = LEPTOCERUS AMERICANUS
*OCINERAS = OECETIS CINERASCENS
*TRITARDA = TRIANODES TARDA
*TRINJUST = TRINANODES INJUSTA
*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
*HYDROPSP = 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.
*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.
*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;
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;
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;
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;
CERATPUm = 10.74*CERATPUP;
EMPIDIDm = 10.74*EMPIDIDA;
CHIRPUPm = 10.74*CHIRPUPA;
HEMERODm = 10.74*HEMERODR;
HYALAZTm = 10.74*HYALAZTE;
ACARIxxm = 10.74*ACARIxxx;
COPEPODm = 10.74*COPEPODA;
HYDRASPm = 10.74*HYDRASPx;
CLADOCEm = 10.74*CLADOCER;
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;
PPARASIm = 10.74*PPARASIT;
AHETEROm = 10.74*AHETEROC;
MLUCIDIm = 10.74*MLUCIDIA;
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*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+STENOINm+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+POLYCENm+
    POLYCINm+NEURECSm+CYRNFRAm+POLYCNSm+TRIADAm+TRIANODm+CERGLGMm+
    POLYREMm+POLYINTm+AGRYPNIm;
DIPTERA = PROBGLAm+CULCOIDm+CERATPUm+CHIRPUPm+TIPULARm+MUSCPUPm+
    EMPIDIDm+HEMERODm+ATOCHAm+CHIRONDm;
CRUSTAC = HYALAZTm+COPEPODm+CLADOCEm+OSTRACOm+ISOPODAm;
ANNELID = HSTAGNAm+PMULTILm+OTRANSLm+PPARASIm+AHETEROm+MLUCIDIm+
      EPUNCTAm+ERPOBDEm+BPALUDOm+PMARAMOm+OLIGOCHm+HELOBDEm+HELON
      GAm+PORNATAm+MFERIDIm+BPICTAm;
OTHER = ACARIxxm+HYDRASPm+NEMATODm+DUGESIAm+CORILARm+CORIXIDm;
COLEOP = STENOPEm+HYPERODm+CURCLARm+LIXUSSPm+PELTODYm;
LEPIDOP = ACENTRIm+PARAPYNm+SPHINGIm+LEPIDPUm;
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/m^2) 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 m^2 and total densities/m^2 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.

AUB 1 1 1 1 71593 1 1 1 0 0 0 12 0 0 0 0 0 0 0 0 0 0 0 0 0 3 0 2 0 2 0 0 0 0 0 0 0 0 0 6 8 0 1 2 0 0 0 0 0 0 0
0 0 0 0 124 14 54 56 1 0 0 0 0 12 0 136 32 0 0 0 0 5 37 4 0 7 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
2 1 0 0 0
AUB 1 1 1 2 71593 1 1 90 0 0 0 16 0 0 0 0 0 0 0 0 0 0 0 0 0 25 0 1 0 0 1 0 0 0 0 2 0 0 13 32 0 0 8 0 0 0
0 0 0 0 0 4 0 1220 890 130 200 12 0 0 2 0 37 0 801 32 0 0 0 0 1 145 11 0 11 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0
2 0 0 0 0 0 1 0 5 0 0 0 0
AUB 1 1 1 3 71593 1 1 38 0 0 0 8 0 0 0 0 0 0 0 0 0 0 0 0 0 4 0 0 1 0 0 0 0 0 0 4 0 0 2 7 0 0 0 0 0 0 0 0 0
0 0 0 0 253 186 33 34 6 0 0 0 0 8 0 163 12 0 0 0 0 1 46 12 0 8 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0
1 0 0 0 0
AUB 1 1 2 1 71593 1 1 10 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 11 0 1 0 0 0 0 0 0 0 0 0 0 23 14 0 0 2 0 0 0 0
0 0 0 0 0 0 406 384 0 22 1 0 0 0 0 8 0 4 11 0 0 0 0 0 11 0 2 8 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0
AUB 1 1 2 2 71593 1 1 92 0 0 0 15 0 0 0 0 0 0 0 0 0 0 0 0 0 30 1 9 0 0 0 0 0 0 1 3 0 0 20 22 0 0 3 2 0 0
0 0 0 0 0 0 0 1088 1012 22 54 8 0 0 1 0 4 0 73 3 0 0 0 0 0 126 6 1 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 8 0 0 0
1 0 0 0 0 0 0 0
AUB 1 1 2 3 71593 1 1 2 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 13 0 0 0 0 0 0 0 0 0 0 0 1 15 11 0 0 0 0 0 0 0
0 0 0 0 0 0 534 496 6 32 0 0 0 0 0 8 0 6 0 0 0 0 0 0 1 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 1 0
0 0 0
AUB 1 2 1 1 71593 1 1 87 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 6 0 0 0 0 0 0 0 0 1 1 0 0 8 0 0 0 2 2 0 0 0 0 0
0 0 0 0 363 279 40 44 0 0 0 0 4 0 238 18 4 0 0 0 0 37 1 0 3 4 0 0 0 0 0 0 38 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0
1 0 0 0 0
AUB 1 2 1 2 71593 1 1 30 0 0 0 3 0 0 0 0 0 0 0 0 0 0 0 0 0 9 0 0 2 0 0 0 0 0 0 1 0 0 14 29 5 0 0 0 6 14 0
0 0 2 1 0 0 451 361 25 65 3 0 0 0 0 5 0 84 15 0 0 0 0 0 58 1 0 2 5 0 0 0 0 0 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 1
0 2 0 0 0 0
AUB 1 2 1 3 71593 1 1 3 0 0 0 12 0 0 0 0 0 0 0 0 0 0 0 0 0 15 0 2 0 0 0 0 0 0 0 0 0 1 7 9 0 0 4 0 7 13 0
0 0 0 0 0 0 366 278 44 44 6 0 0 0 0 16 0 123 6 0 0 0 0 1 40 1 0 1 5 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 1 1 0 0 0 0
AUB 1 2 2 1 71593 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
AUB 1 2 2 2 71593 1 1 9 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 0 3 0 0 0 0 0 0 0 0 1 0 0 5 3 0 0 0 0 0 0 0 0 0
0 4 0 0 126 113 6 7 1 0 0 0 0 9 0 72 7 0 0 0 0 0 11 2 0 1 10 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0
AUB 1 2 2 3 71593 1 1 1 0 0 0 3 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 3 7 0 0 0 0 0 0 0 0 0
2 0 0 0 406 386 4 16 1 0 0 0 0 16 0 68 16 2 0 0 0 3 5 2 0 1 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0
AUB 1 3 1 1 71593 1 1 16 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 6 0 0 1 2 0 0 0 0 0 0 0 0 4 2 0 1 0 0 2 0 0 0 0
1 0 0 0 162 134 17 11 0 0 0 0 0 3 0 94 3 0 0 0 0 0 8 5 0 1 22 0 0 0 0 0 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0
0 0 0
AUB 1 3 1 2 71593 1 1 12 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 0 0 0 0 0 0 0 0 0 0 0 0 11 32 0 0 1 1 0 1 0
0 0 1 0 0 0 553 483 35 35 0 0 0 0 0 19 0 198 35 0 0 1 0 6 25 14 0 5 20 0 0 0 0 0 0 3 0 1 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0
AUB 1 3 1 3 71593 1 1 8 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1 0 3 0 0 0 0 1 0 0 0 0
5 1 0 0 95 89 6 0 0 0 0 0 0 6 0 25 10 0 0 0 0 2 4 2 0 0 3 0 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0

AUB 1 3 2 1 71593 1 1 0 0 0 0 2 0 0 0 0 0 0 0 0 0 0 0 0 12 0 1 1 0 0 0 0 0 0 0 0 0 28 2 0 0 0 0 1 0 0 0
0 2 0 0 0 456 438 10 8 0 0 0 0 0 12 0 43 10 0 0 0 0 0 8 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0

AUB 1 3 2 2 71593 1 1 20 0 0 0 4 0 0 0 0 0 0 0 0 0 0 0 0 3 0 0 0 0 0 0 0 0 1 0 0 0 12 5 0 0 0 0 0 0 0 0
0 4 2 0 0 406 388 4 14 1 0 0 0 0 21 0 57 13 0 0 2 0 0 16 2 0 4 5 0 0 0 0 0 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0

AUB 1 3 2 3 71593 1 1 5 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 9 0 0 0 2 0 0 0 0 0 0 0 0 50 9 0 0 4 0 0 0 0 0 0
2 0 0 1 1306 1210 64 32 0 0 1 0 0 1 0 138 19 0 0 0 0 0 10 0 0 0 20 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0

ZUM 1 2 1 1 71593 1 1 9 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 11 0 0 0 0 0 0 0 0 2 0 0 0 9 0 0 0 0 0 0 0 0 0
0 0 0 0 0 101 82 16 3 0 0 0 0 0 3 0 7 3 0 0 0 0 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0

ZUM 1 2 1 2 71593 1 1 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 0 0 0
0 0 0 0 146 132 14 0 0 0 0 0 0 0 0 18 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0

ZUM 1 2 1 3 71593 1 1 9 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 4 0 0 1 0 0 0 0 0 0
0 0 0 0 89 71 17 1 0 0 0 0 0 3 0 0 3 0 0 0 0 0 1 0 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

ZUM 1 2 2 1 71593 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0 0 0 1 0 0 0 0 0
0 0 0 0 25 13 2 10 0 0 0 0 0 0 0 0 5 0 0 0 0 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

ZUM 1 2 2 2 71593 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

ZUM 1 2 2 3 71593 1 1 7 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 2 0 0 0 0 0 0 0 0 0 1 0 0 5 0 0 0 0 0 0 0 0 0 0
0 0 0 0 71 71 0 0 0 0 0 0 0 0 0 28 6 0 0 0 0 0 1 0 0 0 6 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

ZUM 1 1 1 1 71593 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0
0 0 0 0 31 23 7 1 0 0 0 0 0 0 0 36 3 0 0 0 0 1 24 0 1 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0

ZUM 1 1 1 2 71593 1 1 4 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 17 0 0 0 1 0 0 0 0 0
0 0 0 0 0 171 122 44 5 4 0 0 0 0 6 0 125 22 0 0 0 0 0 55 11 0 0 6 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0

ZUM 1 1 1 3 71593 1 1 6 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 0 0 0 0 0 0 0 0 0 0
0 0 0 0 36 18 15 3 0 0 0 0 0 0 0 36 0 0 0 0 0 0 13 4 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0

ZUM 1 1 2 1 71593 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 12 0 0 0 0 0 0 0 0 0
0 0 0 0 0 98 90 3 5 6 0 0 0 0 0 0 11 0 0 0 0 0 20 9 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0

ZUM 1 1 2 2 71593 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

ZUM 1 1 2 3 71593 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

ZUM 1 3 1 1 71593 1 1 5 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 0 0 0 0 0 1 19 0 0 0 1 0 0 0 0
0 0 0 0 0 545 490 10 45 19 0 0 1 6 0 0 7 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0

ZUM 1 3 1 2 71593 1 1 5 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 3 0 4 0 3 1 0 0 0 0 0 0 0 0
0 0 0 0 40 40 0 0 0 0 0 0 0 0 3 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

ZUM 1 3 1 3 71593 1 1 21 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 6 0 0 0 0 0 0 0 0 0 1 0 0 45 0 0 0 7 0 0 0 0 0
0 0 0 0 0 493 402 71 20 8 0 0 0 0 24 0 113 13 0 0 0 0 1 11 0 1 1 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0

ZUM 1 3 2 1 71593 1 1 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 5 0 0 0 2 0 0 0 0 0 0
0 0 0 0 88 76 6 6 0 0 0 0 0 0 0 0 2 0 0 0 0 1 11 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

ZUM 1 3 2 2 71593 1 1 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 6 0 0 0 5 0 0 0 0 0 0 0 0 0 0 180 141 11 28 3 0 0 0 0 10 0 4 6 0 0 0 0 1 7 1 1 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

ZUM 1 3 2 3 71593 1 1 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 16 1 0 0 14 0 0 0 0 0 0 0 0 0 0 250 208 11 31 9 0 0 0 0 1 0 1 1 0 0 0 0 3 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

AUB 1 1 1 1 80993 2 1 24 0 0 0 36 0 0 0 0 0 0 0 0 0 0 0 0 0 18 13 2 1 0 0 0 0 0 0 2 0 1 31 14 0 0 16 0 0 0 0 0 0 0 0 0 0 3312 3030 58 224 4 1 0 1 0 24 0 167 24 7 152 3 0 219 40 3 0 379 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

AUB 1 1 1 2 80993 2 1 19 1 0 0 21 0 2 0 0 0 0 0 0 0 0 0 0 0 1 1 5 1 0 0 0 0 0 0 0 0 0 8 17 0 0 0 0 0 0 0 0 0 0 0 0 0 480 452 8 20 3 0 0 0 0 8 0 93 7 0 1 1 0 0 11 5 0 32 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

AUB 1 1 1 3 80993 2 1 18 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 10 3 0 2 0 0 0 0 0 0 2 0 0 1 6 0 0 0 0 0 0 0 0 0 0 0 0 0 622 516 24 82 4 0 0 0 0 15 0 115 2 0 0 0 0 0 56 11 1 0 0 0 0 0 0 0 0 0 5 0 0 0 0 0 0 0 1 0 0 1 0 0 0 0 0 0 0 0 0

AUB 1 1 2 1 80993 2 1 11 1 0 0 9 0 0 0 0 0 0 0 0 0 0 0 0 0 22 0 0 1 0 0 0 0 0 21 2 0 0 13 3 0 0 0 0 0 0 0 0 0 0 0 0 0 832 756 32 44 1 0 0 0 0 6 0 77 28 0 0 0 0 3 29 0 1 6 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0 0 0 0 5 0 0 0 0 0 0

AUB 1 1 2 2 80993 2 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 4 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 16 16 0 0 0 0 0 0 0 0 0 8 0 0 0 0 0 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

AUB 1 1 2 3 80993 2 1 27 0 0 0 25 0 0 0 0 0 0 0 0 0 0 0 0 0 22 1 4 0 0 0 0 0 0 0 0 0 0 0 33 6 0 0 7 0 0 0 0 0 0 0 0 0 0 1266 1238 20 8 0 0 0 0 0 0 0 0 21 10 0 0 0 0 0 53 1 1 1 7 0 0 1 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

AUB 1 2 1 1 80993 2 1 29 0 0 0 15 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 1 4 0 0 0 0 0 1 0 0 0 11 0 0 0 293 218 27 48 5 0 0 0 0 0 0 0 179 16 0 0 0 0 0 10 0 0 0 11 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0

AUB 1 2 1 2 80993 2 1 33 0 0 0 12 0 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 0 0 5 0 0 0 3 11 0 0 0 0 0 0 4 0 0 0 8 0 0 0 298 219 47 32 1 0 0 0 0 0 0 0 547 39 0 0 0 0 0 5 3 0 0 8 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0

AUB 1 2 1 3 80993 2 1 32 0 0 0 9 0 0 0 0 0 0 0 0 0 0 0 0 0 8 6 0 0 4 2 0 0 0 0 0 0 0 0 0 0 0 0 3 0 0 0 3 0 0 0 8 6 0 0 242 147 52 43 0 0 0 0 0 0 0 0 11 0 0 0 5 0 0 9 1 0 13 6 0 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

AUB 1 2 2 1 80993 2 1 10 0 0 0 11 0 0 0 0 0 0 0 0 0 0 0 0 0 6 41 3 0 0 0 0 0 0 0 0 0 0 0 20 13 0 0 0 0 0 0 1 1 0 0 18 0 0 0 554 522 2 30 12 0 0 0 0 0 0 0 144 16 0 6 0 0 50 8 0 0 191 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

AUB 1 2 2 2 80993 2 1 7 0 0 0 16 0 0 0 0 0 0 0 0 0 0 0 0 0 2 33 0 0 0 0 0 0 0 0 0 0 0 0 13 17 0 3 6 0 0 0 0 0 0 0 1 0 0 648 610 28 10 9 0 1 3 0 1 0 209 20 0 32 0 0 260 3 0 0 176 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0

AUB 1 2 2 3 80993 2 1 11 0 0 0 11 0 0 0 0 0 0 0 0 0 0 0 0 0 41 1 0 0 0 0 0 0 0 0 0 0 0 5 1 0 0 2 1 0 1 0 0 0 2 1 0 0 224 204 18 2 3 0 0 2 0 3 0 117 32 1 27 2 0 129 7 0 1 89 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

AUB 1 3 1 1 80993 2 1 16 0 0 0 18 0 0 0 0 0 0 0 0 0 0 0 0 0 4 0 0 1 0 0 0 0 0 1 0 6 0 13 0 0 10 0 0 0 0 0 0 0 0 0 0 230 124 22 84 4 0 0 1 0 6 0 0 28 8 0 0 0 2 54 21 0 0 5 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0 0 0

AUB 1 3 1 2 80993 2 1 27 0 0 0 16 0 0 0 0 0 0 0 0 0 0 0 0 0 4 4 0 0 0 0 0 0 0 0 1 3 0 0 5 11 0 0 0 0 0 0 0 0 0 0 2 0 0 131 77 12 42 0 0 0 1 0 3 0 132 9 1 3 2 0 2 23 3 0 5 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0 2 4 0 0 0 0 0 0 0 0 0 0 0

AUB 1 3 1 3 80993 2 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 32 0 0 0 0 0 0 0 0 0 0 0 0 0 80 40 4 32 0 0 0 0 0 0 0 28 0 0 0 0 0 0 76 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 4 0 0 0 8 0 0 0 0 0 0 0

AUB 1 3 2 1 80993 2 1 9 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 4 9 0 0 0 0 0 0 0 0 0 1 0 1 3 0 0 0 0 0 0 0 0 0 0
0 0 0 184 179 1 4 1 0 0 0 0 2 0 32 12 0 0 0 0 1 8 1 0 1 7 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0

AUB 1 3 2 2 80993 2 1 4 0 0 0 8 0 0 0 0 0 0 0 0 0 0 0 0 0 3 0 0 0 0 0 0 0 0 0 9 7 0 30 0 12 0 2 6 1 0 0 0 0
0 0 0 0 0 1507 1466 8 33 0 0 0 5 0 5 0 13 2 0 0 1 0 2 4 0 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0

AUB 1 3 2 3 80993 2 1 14 0 0 0 9 0 0 0 0 0 0 0 0 0 0 0 0 5 5 1 0 1 0 0 0 0 0 0 0 0 5 7 9 0 1 6 0 0 1 0 0 0
2 0 0 0 336 328 2 6 1 0 0 0 0 4 0 30 6 1 44 2 0 36 8 1 0 104 3 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0

ZUM 1 2 1 1 80993 2 1 12 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 11 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 296 284 8 4 4 0 0 0 0 0 8 0 19 1 1 0 0 0 5 1 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0

ZUM 1 2 1 2 80993 2 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0
0 0 0 0 120 110 6 4 0 0 0 0 0 0 0 0 0 0 0 0 6 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0

ZUM 1 2 1 3 80993 2 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 0 0
0 0 0 0 70 66 4 0 6 0 0 0 0 0 0 2 0 0 0 0 0 10 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

ZUM 1 2 2 1 80993 2 1 3 0 0 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 5 1 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0
0 0 0 0 68 60 8 0 0 0 0 0 0 0 0 4 0 0 0 0 0 0 3 0 0 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

ZUM 1 2 2 2 80993 2 1 0 0 0 0 6 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0 0
0 0 0 0 22 22 0 0 4 0 0 0 0 0 0 0 16 0 0 0 10 0 4 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0

ZUM 1 2 2 3 80993 2 1 1 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0
0 0 0 0 69 67 2 0 0 0 0 0 0 2 0 1 1 0 0 0 0 3 0 0 0 6 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

ZUM 1 1 1 1 80993 2 1 12 2 0 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 636 608 8 20 4 0 0 0 0 0 0 6 0 0 0 0 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0

ZUM 1 1 1 2 80993 2 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 300 267 6 27 1 0 0 0 0 0 0 0 0 0 0 0 0 0 45 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0

ZUM 1 1 1 3 80993 2 1 0 2 0 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 436 364 24 48 4 0 0 0 0 0 0 22 0 0 0 0 0 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0

ZUM 1 1 2 1 80993 2 1 0 0 0 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 147 133 6 8 2 0 0 0 0 0 0 0 0 0 0 0 0 1 9 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0

ZUM 1 1 2 2 80993 2 1 2 1 0 0 17 0 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 13 2 0 0 0 0 0 0 0 0
0 0 0 0 0 293 256 13 24 19 0 0 2 0 1 0 10 0 0 1 9 0 31 9 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0

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AUB 1 1 1 1 71294 5 1 38 0 0 0 6 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0 0 0
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AUB 1 1 2 1 71294 5 1 16 0 0 0 22 0 0 0 0 0 0 0 0 0 0 0 0 2 0 2 0 0 2 0 0 0 0 0 0 2 0 0 0 0 0 0 0 0 0 0
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AUB 1 1 2 2 71294 5 1 168 0 0 0 8 0 0 0 0 0 0 0 0 0 0 0 0 6 3 0 0 0 0 0 0 0 0 0 0 0 4 23 0 0 0 0 1 0 0
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AUB 1 2 1 1 71294 5 1 4 0 0 0 4 0 0 0 0 0 0 0 0 0 0 0 0 36 0 0 0 0 8 0 0 0 0 0 0 4 0 0 0 0 0 0 12 0 0 0
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ZUM 1 3 1 3 80195 10 1 12 2 0 0 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 0 0 1 0 0 0 0 0 0
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AUB 1 1 1 1 90795 11 1 256 0 0 0 248 0 0 0 0 0 8 0 0 0 0 0 0 80 132 0 16 0 0 0 0 0 0 0 0 0 0 8 0 0 0
0 0 16 0 0 0 0 0 0 476 432 24 20 0 0 0 0 0 0 1320 112 0 0 0 0 0 8 24 0 16 8 0 0 0 0 0 0 0 16 0 0 0 0 0
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AUB 1 1 1 2 90795 11 1 20 0 0 0 32 0 0 0 0 0 0 0 0 0 0 0 0 0 20 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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AUB 1 1 1 3 90795 11 1 64 0 0 0 32 0 0 0 0 0 0 0 0 0 0 0 0 0 24 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 4 0
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AUB 1 1 2 1 90795 11 1 44 0 0 0 188 0 0 0 0 0 0 0 0 0 0 0 0 0 44 24 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
12 0 0 0 0 0 0 0 388 372 8 8 0 0 0 0 0 0 200 0 0 0 0 0 0 16 8 0 0 128 0 0 0 0 0 0 0 0 0 0 0 0 0 4 0 0 0
0 0 0 0 0 0 0 0 0 0
AUB 1 1 2 2 90795 11 1 32 0 0 0 172 0 0 0 0 0 0 0 0 0 0 0 0 0 28 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
20 0 0 0 0 0 0 0 120 120 0 0 0 0 0 0 0 0 164 0 0 0 0 0 0 12 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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AUB 1 1 2 3 90795 11 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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AUB 1 2 1 1 90795 11 1 32 0 0 0 52 0 0 0 0 0 0 0 0 0 0 0 0 92 8 0 0 0 0 0 24 0 0 0 0 0 0 24 0 0 0 0 0
12 0 0 0 0 0 0 0 240 48 72 120 0 0 0 0 0 32 0 1296 12 0 0 0 0 0 68 8 0 0 8 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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AUB 1 2 1 2 90795 11 1 16 0 0 0 12 0 4 0 0 0 0 0 0 0 0 0 0 88 0 0 0 0 0 0 48 0 0 0 0 0 0 0 0 0 0 0 0 4
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AUB 1 2 1 3 90795 11 1 384 0 0 0 52 0 0 0 0 0 0 0 0 0 0 0 0 20 0 8 4 0 0 0 0 0 0 0 0 0 0 4 0 0 0 0 0 0
0 0 0 0 0 0 0 3216 2146 468 602 0 0 0 0 0 16 0 88 0 0 0 8 0 0 4 4 0 20 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0
AUB 1 2 2 1 90795 11 1 12 0 0 0 20 0 0 0 0 0 0 0 0 0 0 0 0 0 20 32 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 28 20 4 4 0 0 0 0 0 0 0 40 0 0 0 0 0 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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AUB 1 2 2 2 90795 11 1 27 0 0 0 17 0 0 0 0 0 0 0 0 0 0 0 0 2 20 17 1 0 0 0 0 0 0 0 0 0 0 2 0 0 0 1 2 0
0 0 0 0 0 0 0 275 243 12 20 0 0 0 0 0 0 0 17 3 0 0 0 0 0 1 0 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0

AUB 1 2 2 3 90795 11 1 44 0 0 0 28 0 0 0 0 0 0 0 0 0 0 0 0 24 4 0 0 0 0 0 0 0 0 0 0 0 0 4 0 0 0 0 0 4 0
0 0 0 0 0 0 124 100 8 16 0 0 0 0 0 4 0 188 12 0 0 0 0 72 4 0 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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AUB 1 3 1 1 90795 11 1 12 0 0 0 44 0 0 0 0 0 0 0 0 0 0 0 0 0 48 0 0 0 0 0 0 0 0 0 0 0 0 0 0 4 0 0 0 0 0 0 0
0 0 0 0 0 0 504 432 56 16 0 0 0 0 0 0 0 212 0 0 8 0 0 32 8 8 0 8 4 0 0 0 0 0 0 0 0 0 4 0 0 0 0 0 0 0 0 0 0
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AUB 1 3 1 2 90795 11 1 0 0 0 0 16 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 58 0
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AUB 1 3 1 3 90795 11 1 0 0 0 0 12 0 0 0 0 0 0 0 0 0 0 0 0 0 60 4 20 0 0 0 0 0 0 0 0 0 0 0 0 0 8 0 0 0 0 0 8 0
0 0 0 0 0 0 276 252 20 4 0 0 0 0 0 0 0 112 0 0 0 0 0 36 28 0 0 40 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0

AUB 1 3 2 1 90795 11 1 104 0 0 4 36 0 0 0 0 0 0 0 0 0 0 0 0 0 48 76 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 8 0
44 0 4 0 0 0 0 0 992 828 116 48 4 0 0 0 0 20 0 636 8 0 0 8 0 0 12 0 0 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0

AUB 1 3 2 2 90795 11 1 4 0 0 0 8 0 0 0 0 0 0 0 0 0 0 0 0 0 16 0 0 0 0 0 0 0 8 0 0 0 0 0 0 0 0 0 0 0 0 0 4 0 0
0 0 0 0 0 76 64 0 12 4 0 0 0 0 4 0 304 4 0 0 0 0 0 8 4 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 4 0 0 0 0 0 0 0 0
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AUB 1 3 2 3 90795 11 1 36 0 0 0 36 0 0 0 0 0 0 0 0 0 0 0 0 0 32 12 20 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
12 0 0 0 0 0 0 0 512 444 52 16 0 0 0 0 0 0 0 368 12 0 0 0 0 12 0 0 0 16 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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ZUM 1 2 1 1 90795 11 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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ZUM 1 2 1 2 90795 11 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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ZUM 1 2 2 1 90795 11 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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ZUM 1 1 1 1 90795 11 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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ZUM 1 1 1 3 90795 11 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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ZUM 1 1 2 1 90795 11 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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ZUM 1 1 2 3 90795 11 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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ZUM 1 3 1 1 90795 11 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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ZUM 1 3 1 2 90795 11 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 00 0 0 0 0 0 0 0 0 0 0 0 0
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APPENDIX N: "Biomass" data set used to estimate and analyze epiphytic macroinvertebrate AFDW (g/m^2) 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.

AUB	1	1	1	1	71593	1	1	0.04063
AUB	1	1	1	2	71593	1	1	0.06197
AUB	1	1	1	3	71593	1	1	0.06364
AUB	1	1	2	1	71593	1	1	0.01274
AUB	1	1	2	2	71593	1	1	0.01462
AUB	1	1	2	3	71593	1	1	0.01701
AUB	1	2	1	1	71593	1	1	0.03713
AUB	1	2	1	2	71593	1	1	0.04658
AUB	1	2	1	3	71593	1	1	0.06627
AUB	1	2	2	1	71593	1	1	0.00000
AUB	1	2	2	2	71593	1	1	0.02808
AUB	1	2	2	3	71593	1	1	0.06242
AUB	1	3	1	1	71593	1	1	0.03181
AUB	1	3	1	2	71593	1	1	0.01014
AUB	1	3	1	3	71593	1	1	0.01764
AUB	1	3	2	1	71593	1	1	0.04382
AUB	1	3	2	2	71593	1	1	0.10686
AUB	1	3	2	3	71593	1	1	0.06673
ZUM	1	2	1	1	71593	1	1	0.01429
ZUM	1	2	1	2	71593	1	1	0.01710
ZUM	1	2	1	3	71593	1	1	0.00676
ZUM	1	2	2	1	71593	1	1	0.00234
ZUM	1	2	2	2	71593	1	1	0.00000
ZUM	1	2	2	3	71593	1	1	0.01360
ZUM	1	1	1	1	71593	1	1	0.00771
ZUM	1	1	1	2	71593	1	1	0.03302
ZUM	1	1	1	3	71593	1	1	0.00867
ZUM	1	1	2	1	71595	1	1	0.00641
ZUM	1	1	2	2	71595	1	1	0.00000
ZUM	1	1	2	3	71595	1	1	0.00000
ZUM	1	3	1	1	71593	1	1	0.01324
ZUM	1	3	1	2	71593	1	1	0.00119
ZUM	1	3	1	3	71593	1	1	0.03480
ZUM	1	3	2	1	71593	1	1	0.00461
ZUM	1	3	2	2	71593	1	1	0.01070
ZUM	1	3	2	3	71593	1	1	0.00775
AUB	1	1	1	1	80993	2	1	0.08841
AUB	1	1	1	2	80993	2	1	0.09480
AUB	1	1	1	3	80993	2	1	0.00822
AUB	1	1	2	1	80993	2	1	0.05480
AUB	1	1	2	2	80993	2	1	0.00548
AUB	1	1	2	3	80993	2	1	0.01791
AUB	1	2	1	1	80993	2	1	0.02123
AUB	1	2	1	2	80993	2	1	0.03410
AUB	1	2	1	3	80993	2	1	0.06218

AUB 1 2 2 1 80993 2 1 0.07816
AUB 1 2 2 2 80993 2 1 0.04843
AUB 1 2 2 3 80993 2 1 0.03918
AUB 1 3 1 1 80993 2 1 0.03965
AUB 1 3 1 2 80993 2 1 0.04371
AUB 1 3 1 3 80993 2 1 0.00638
AUB 1 3 2 1 80993 2 1 0.02291
AUB 1 3 2 2 80993 2 1 0.01526
AUB 1 3 2 3 80993 2 1 0.04014
ZUM 1 2 1 1 80993 2 1 0.01675
ZUM 1 2 1 2 80993 2 1 0.00319
ZUM 1 2 1 3 80993 2 1 0.00226
ZUM 1 2 2 1 80993 2 1 0.00600
ZUM 1 2 2 2 80993 2 1 0.00838
ZUM 1 2 2 3 80993 2 1 0.00512
ZUM 1 1 1 1 80993 2 1 0.02058
ZUM 1 1 1 2 80993 2 1 0.00660
ZUM 1 1 1 3 80993 2 1 0.03400
ZUM 1 1 2 1 80993 2 1 0.00592
ZUM 1 1 2 2 80993 2 1 0.01190
ZUM 1 1 2 3 80993 2 1 0.00823
ZUM 1 3 1 1 80993 2 1 0.01196
ZUM 1 3 1 2 80993 2 1 0.01090
ZUM 1 3 1 3 80993 2 1 0.01213
ZUM 1 3 2 1 80993 2 1 0.01435
ZUM 1 3 2 2 80993 2 1 0.00682
ZUM 1 3 2 3 80993 2 1 0.00689
AUB 2 1 1 1 83093 3 1 0.05740
AUB 2 1 1 2 83093 3 1 0.00665
AUB 2 1 1 3 83093 3 1 0.00948
AUB 2 1 2 1 83093 3 1 0.05194
AUB 2 1 2 2 83093 3 1 0.03092
AUB 2 1 2 3 83093 3 1 0.06064
AUB 2 2 1 1 83093 3 1 0.05780
AUB 2 2 1 2 83093 3 1 0.04569
AUB 2 2 1 3 83093 3 1 0.02042
AUB 2 2 2 1 83093 3 1 0.04296
AUB 2 2 2 2 83093 3 1 0.31410
AUB 2 2 2 3 83093 3 1 0.03605
AUB 2 3 1 1 83093 3 1 0.02372
AUB 2 3 1 2 83093 3 1 0.07011
AUB 2 3 1 3 83093 3 1 0.04031
AUB 2 3 2 1 83093 3 1 0.04572
AUB 2 3 2 2 83093 3 1 0.43275
AUB 2 3 2 3 83093 3 1 0.32355
ZUM 2 2 1 1 83093 3 1 0.01561
ZUM 2 2 1 2 83093 3 1 0.01932
ZUM 2 2 1 3 83093 3 1 0.01986
ZUM 2 2 2 1 83093 3 1 0.00485
ZUM 2 2 2 2 83093 3 1 0.01335
ZUM 2 2 2 3 83093 3 1 0.00551

ZUM 2 1 1 1 83093 3 1 0.01242
ZUM 2 1 1 2 83093 3 1 0.01093
ZUM 2 1 1 3 83093 3 1 0.00880
ZUM 2 1 2 1 83093 3 1 0.01982
ZUM 2 1 2 2 83093 3 1 0.01564
ZUM 2 1 2 3 83093 3 1 0.01686
ZUM 2 3 1 1 83093 3 1 0.00168
ZUM 2 3 1 2 83093 3 1 0.00115
ZUM 2 3 1 3 83093 3 1 0.02275
ZUM 2 3 2 1 83093 3 1 0.01319
ZUM 2 3 2 2 83093 3 1 0.00722
ZUM 2 3 2 3 83093 3 1 0.00234
AUB 1 1 1 1 71294 5 1 0.01248
AUB 1 1 1 2 71294 5 1 0.07840
AUB 1 1 1 3 71294 5 1 0.13468
AUB 1 1 2 1 71294 5 1 0.01022
AUB 1 1 2 2 71294 5 1 0.02397
AUB 1 1 2 3 71294 5 1 0.02072
AUB 1 2 1 1 71294 5 1 0.08380
AUB 1 2 1 2 71294 5 1 0.04356
AUB 1 2 1 3 71294 5 1 0.03204
AUB 1 2 2 1 71294 5 1 0.01062
AUB 1 2 2 2 71294 5 1 0.00166
AUB 1 2 2 3 71294 5 1 0.00288
AUB 1 3 1 1 71294 5 1 0.00800
AUB 1 3 1 2 71294 5 1 0.00990
AUB 1 3 1 3 71294 5 1 0.01212
AUB 1 3 2 1 71294 5 1 0.01118
AUB 1 3 2 2 71294 5 1 0.02544
AUB 1 3 2 3 71294 5 1 0.01852
ZUM 3 2 1 1 71294 5 1 0.00943
ZUM 3 2 1 2 71294 5 1 0.00472
ZUM 3 2 1 3 71294 5 1 0.02900
ZUM 3 2 2 1 71294 5 1 0.00075
ZUM 3 2 2 2 71294 5 1 0.02427
ZUM 3 2 2 3 71294 5 1 0.02541
ZUM 3 1 1 1 71294 5 1 0.03123
ZUM 3 1 1 2 71294 5 1 0.00381
ZUM 3 1 1 3 71294 5 1 0.01161
ZUM 3 1 2 1 71294 5 1 0.00467
ZUM 3 1 2 2 71294 5 1 0.03791
ZUM 3 1 2 3 71294 5 1 0.02022
ZUM 3 3 1 1 71294 5 1 0.01664
ZUM 3 3 1 2 71294 5 1 0.01641
ZUM 3 3 1 3 71294 5 1 0.01939
ZUM 3 3 2 1 71294 5 1 0.02216
ZUM 3 3 2 2 71294 5 1 0.00996
ZUM 3 3 2 3 71294 5 1 0.04463
AUB 1 1 1 1 81194 6 1 0.01736
AUB 1 1 1 2 81194 6 1 0.02148
AUB 1 1 1 3 81194 6 1 0.00195

AUB 1 1 2 1 81194 6 1 0.02708
AUB 1 1 2 2 81194 6 1 0.00026
AUB 1 1 2 3 81194 6 1 0.00256
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AUB	1	1	1	1	70695	9	1	0.01852
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AUB	1	1	1	3	70695	9	1	0.05172
AUB	1	1	2	1	70695	9	1	0.01744
AUB	1	1	2	2	70695	9	1	0.02212
AUB	1	1	2	3	70695	9	1	0.07884
AUB	1	2	1	1	70695	9	1	0.06404
AUB	1	2	1	2	70695	9	1	0.03340
AUB	1	2	1	3	70695	9	1	0.02272
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AUB	1	1	1	2	80195	10	1	0.00752
AUB	1	1	1	3	80195	10	1	0.01748
AUB	1	1	2	1	80195	10	1	0.02860
AUB	1	1	2	2	80195	10	1	0.01384
AUB	1	1	2	3	80195	10	1	0.01284
AUB	1	2	1	1	80195	10	1	0.02732
AUB	1	2	1	2	80195	10	1	0.02124
AUB	1	2	1	3	80195	10	1	0.04284
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AUB	1	1	1	3	90795	11	1	0.03076
AUB	1	1	2	1	90795	11	1	0.12188
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AUB	1	1	2	3	90795	11	1	0.00000
AUB	1	2	1	1	90795	11	1	0.21244
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AUB	1	2	1	3	90795	11	1	0.17592
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AUB	1	3	1	3	90795	11	1	0.03688
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AUB	1	3	2	2	90795	11	1	0.05712
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