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Aquatic Plant Control Research Program

Effects of Three Species of Aquatic Plants on Macroinvertebrates in Lake Seminole, Georgia

by Richard Peets, Andrew C. Miller, WES

David C. Beckett, University of Southern Mississippi

WES

Prepared for Headquarters, U.S. Army Corps of Engineers

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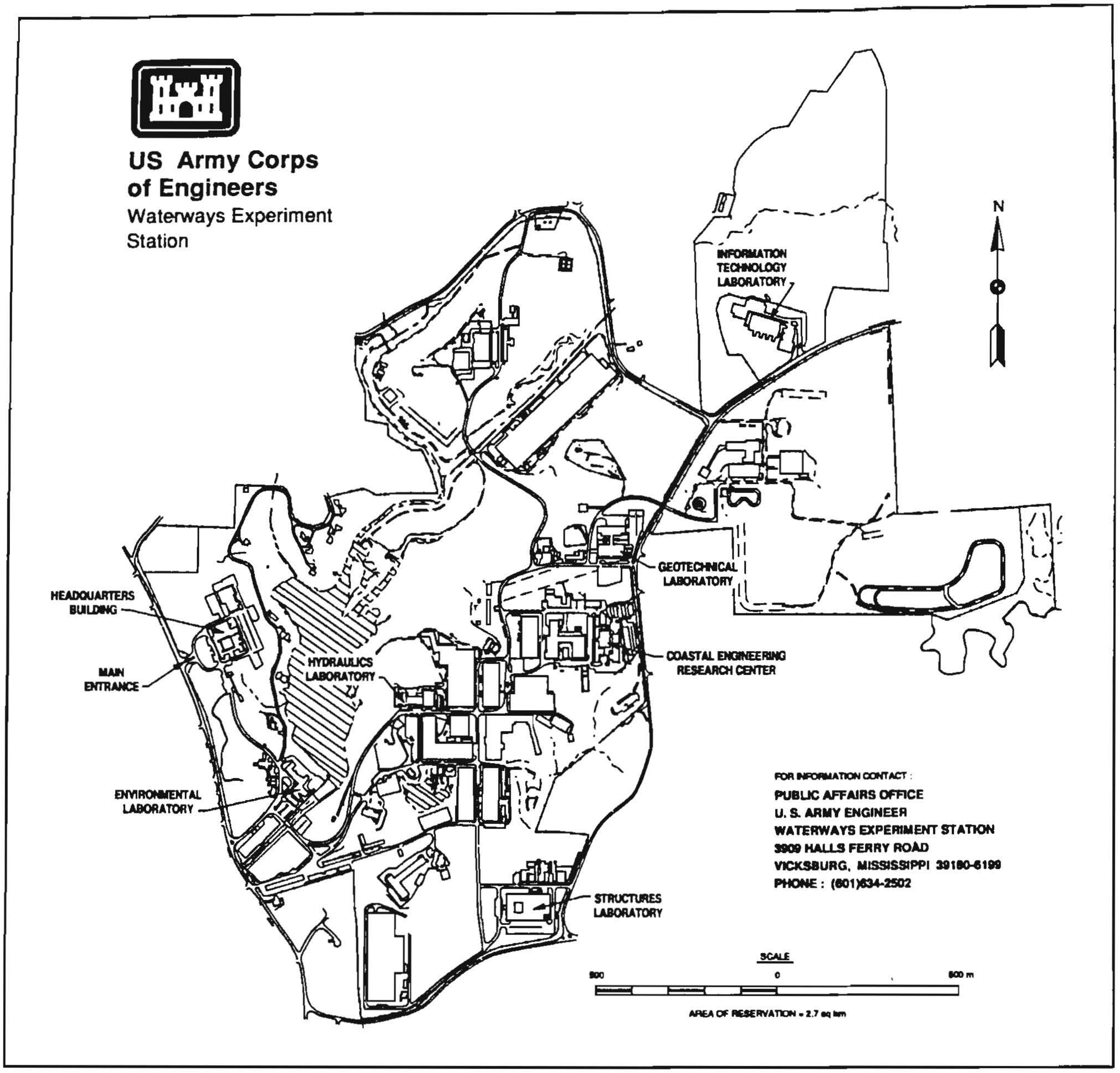

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Contents

Preface

The work reported herein was conducted as part of the Aquatic Plant Control Research Program (APCRP), Work Unit 32505. The APCRP is sponsored by the Headquarters, U.S. Army Corps of Engineers (HQUSACE), and is assigned to the U.S. Army Engineer Waterways Experiment Station (WES) under the purview of the Environmental Laboratory (EL). Funding was provided under Department of the Army Appropriation No. 96X3122, Construction General. The APCRP is managed under the Environmental Resources Research and Assistance Programs (ERRAP), Mr. J. L. Decell, Manager. Mr. Robert C. Gunkel was Assistant Manager, ERRAP, for the APCRP. Technical monitor during this study was Ms. Denise White, HQUSACE.

This report was prepared by Mr. Richard Peets, a graduate student at the University of Southern Mississippi (USM), Hattiesburg, MS, who was working as a contract student for EL, Dr. Andrew C. Miller, Aquatic Ecology Branch, (AEB), Ecological Research Division (ERD), EL, and Dr. David C. Beckett, USM.

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1 Introduction

Macrophytes and Benthic Macroinvertebrates

Aquatic macrophytes affect limnological processes in lentic and lotic habitats (Carpenter and Lodge 1986). Carter et al. (1988) showed that macrophytes affected flow, water temperature, and clarity in the Potomac River in Maryland. In lacustrine systems, aquatic macrophytes increase sediment deposition and substratum stability (Carpenter and Lodge 1986; McDermid and Naiman 1983). Decayed macrophytes have been shown to be an important source of detritus and nutrients to benthic macroinvertebrates (Carpenter and Lodge 1986).

Macrophytes can also affect benthic macroinvertebrate abundance and density. Engel (1988) reported that aquatic macrophytes increased benthic macroinvertebrate abundances in Lake Halverson, a Wisconsin lake. Over 75 percent of benthic organisms from the lake were collected beneath macrophyte beds. Beckett, Aatila, and Miller (1991a) reported benthic densities were seven times greater in vegetated as compared with nonvegetated sediments in Eau Galle Lake, WI. Dvorak and Best (1982) reported higher benthic macroinvertebrate densities in vegetated sediments than in nonvegetated sediments in Lake Vechten, Holland. Soszka (1975) reported higher densities beneath macrophyte beds in Lake Milolasjkie, Poland. Vegetated areas with similar substratum in Orange Lake, FL, were shown to support higher macroinvertebrate densities than nonvegetated areas (Schramm and Jirka 1989).

Macrophytes and Epiphytic Macroinvertebrates

Aquatic macrophytes provide additional colonizable substratum in the littoral zone than afforded by sands and silts in the lake bottom. This substratum is often more complex than the more homogenous benthic substratum (Minshall 1984). Aquatic macrophytes have been shown to support high macroinvertebrate densities (Krecker 1939; Andrews and Hasler 1943; Gerking 1957; Soszka 1975; Engel 1988) and support more diverse taxa than adjacent benthic habitats. Krecker (1939), Rosine (1955), Dvorak and Best (1982), and Rooke (1984) found that aquatic macrophyte species that have complex morphological structure support high macroinvertebrate densities because of the great amount of available surface area. Filter-feeding macroinvertebrates attach to macrophytes and feed in the water column. Other macroinvertebrate groups such as Odonata and Hemiptera cling to macrophytes while searching for prey (McDermid and Naiman 1983). Epiphytic algae, bacteria, and diatoms that attach to stems and leaves of macrophytes are grazed by macroinvertebrate taxa such as chironomids and snails. Some macroinvertebrate taxa (certain chironomid taxa and aquatic lepidoptera) are phytophilous and feed on aquatic plants (McGaha 1952). Macrophytes serve as places of refuge from predation by fish. Crowder and Cooper (1982) note that macrophyte complexity and prey density are interactions to be considered in resource utilization by fishes.

Macrophytes are used by macroinvertebrates that oviposit on macrophytic tissue (Berg 1949; Gerrish and Bristow 1979). Macroinvertebrates can use rooted macrophytes for protection from unfavorable conditions such as anoxic lake sediments or an unstable lake bottom (Kibret and Harrison 1989). McLachlan (1975) reported floating and emergent plants were used by aquatic insects such as Odonata and Ephemeroptera to transform into adults. In unstable substratum of streams and rivers, macrophytes can provide a stable platform for macroinvertebrates (Tokeshi and Pinder 1985). Schramm and Jirka (1989) found that macroinvertebrate density and biomass were greater in benthic communities with firm substratum when compared with macroinvertebrate density and biomass in soft, unstable substratum.

All macrophytic and macroinvertebrate associations are not positive. Macrophytes such as *Potamogeton crispus* and *Myriophyllum spicatum* contain toxic compounds such as alkaloids (Ostrofsky and Zettler 1986). However, Hutchinson (1981) reported that little is known about the inhibitory effect of macrophytic-produced chemicals on macroinvertebrates.

Macrophytes are important to vertebrates. By forming dense beds, macrophytes provide a refuge for larval fishes where they can be protected from predation by larger organisms (Chilton 1990). Epiphytic macroinvertebrates are an important food source for fishes (Schramm, Jirka, and Hoyer 1987). Waterfowl have been shown to feed on macrophyte tissue and epiphytic macroinvertebrates (Krull 1970).

Purpose

The purpose of this research was to analyze the effects of three species of aquatic macrophytes (*Hydrilla verticillata, Potamogeton nodosus*, and *Nymphaea odorata*) on macroinvertebrate density and community composition in Lake Seminole, GA. The study considered both epiphytic (attached to plant surfaces) and benthic organisms (living on or just beneath the sediment surface).

2 Study Area and Methods

Study Area

Background on study area

Lake Seminole, located in southeastern Georgia and northwestern Florida, was created in 1954 by construction of Jim Woodruff Lock and Dam at the confluence of the Flint and Chattahoochee Rivers (Figure 1). At normal pool elevation of 23.5 m, the total watershed measures 15,297 ha. The majority of the lake is 2.1 m deep or less. The watershed extends 80.5 km up the Chattahoochee River and 75.6 km up the Flint River. The total drainage area above the lock and dam is 44,626 sq km. The climate in the area is mild; the annual temperature is 20 °C, and the growing season lasts from the middle of March to the end of October.

As of 1990, Lake Seminole contained approximately 220 species of macrophytes and three species of epiphytic algae. Macrophytes covered approximately 60 percent of the lake.[1]

Sites for macroinvertebrates studies

The benthic habitats on the lake bottom were divided into vegetated and nonvegetated areas. Vegetated areas consisted of a bed of *Hydrilla verticillata* and a mixture of *H. verticillata* and *Potamogeton nodosus* (Figure 1). The two nonvegetated habitats were located near a cove in Seminole Park.

Characteristics of plants where macroinvertebrates were collected

Three aquatic macrophyte species were examined in this study: *Hydrilla verticillata* (L.f.) Royle, *Nymphaea odorata* Ait., and *Potamogeton nodosus* Poir.

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[1] Personal Communication, 1991, Joseph Kight, Biologist, Florida Department of Natural Resources, Tallahassee, FL.

Hydrilla verticillata is a rooted aquatic macrophyte with opposite leaves, three to five per node (Figure 2). This species is characterized by serrated leaf margins and a midrib that runs the length of the leaf. It can spread rapidly throughout a water body by formation of seeds, stolons, and rhizomes and by fragmentation. This species is found in clear, turbid, soft or hard water (Tarver et al. 1978; Godfrey and Wooten 1979). *Hydrilla verticillata* can grow in 0.5 to 0.75 percent sunlight, whereas other macrophytes require at least 1.5 percent sunlight. The ability to exist at lower light levels enables this species to grow earlier in the day and at greater depths, up to 15 m, than many other plant species. *Hydrilla verticillata* can branch repeatedly and quickly reaches the surface, often preventing other plants from becoming established (Tarver et al. 1978). This species originated in the Old World and is now ubiquitous and considered a nuisance in the southern United States.

Nymphaea odorata is a rooted aquatic macrophyte that grows in lakes, reservoirs, and slow-moving streams. Known as the fragrant water lily, *N. odorata* is characterized by a single, floating orbicular leaf that has a diameter of 15 to 30 cm, with a deep cleft present in the leaf (Figure 3). Only a single cylindrical stem is present. The dorsal side of the leaf is greenish, and the ventral side is reddish-purple. This species receives its name from the fragrance of its floating flower, which is attached with a slender peduncle. This plant grows in 0.1- to 2.5-m-deep water.

Potamogeton nodosus Poir., also known as the American pondweed, is a rooted emersed plant that has both floating and submersed leaves (Figure 4). The floating leaves are lenticular to elliptical in shape and firm in texture. The submersed leaves are linear to lanceolate and more membranous than the floating leaves (Godfrey and Wooten 1979).

Methods

Collection of benthic macroinvertebrates

Benthic samples were collected in July 1987. Three sites (A, B, and C) were sampled within each of the four habitat types (NVL, NVC, HYD, and PTM/HYD, Figure 1). Five samples were taken at each site. Samples were collected with a hand-held coring device (Miller and Bingham 1987). This device can penetrate mats of plants and obtain sediment without collecting macrophytes or macroinvertebrates in the water column.

Core samples were preserved in the field in 5-percent Formalin solution and transported to the University of Southern Mississippi where they were stained with Rose Bengal to aid in macroinvertebrate identification (Mason and Yevich 1967). In the laboratory, sediments were washed through a 250-µm mesh screen. Macroinvertebrates retained on the sieve were stored in 80-percent alcohol. The macroinvertebrates were initially sorted into three major groups:

Oligochaeta, Chironomidae, and others. The latter group was separated into eight major taxonomic groups: Ostracoda, Nematoda, Hydracarina, Copepoda, Cladocera, Platyhelminthes, Microcrustaceans, and Trichoptera. Chironomids and oligochaetes were mounted for identification following the procedure of Beckett and Lewis (1982).

Collection of epiphytic macroinvertebrates

Macrophytes were collected in Lake Seminole, GA, in July 1987. Three species of macrophytes were obtained at each of three sites (A, B, and C, Figure 1). Five samples were taken at each site; therefore, 15 individuals of each species were collected. Since *H. verticillata* grows in tangled masses, it was not possible to collect an entire plant. Therefore, only a single section of each stem was taken for analysis. For *N. odorata* and *P. nodosus*, a sample consisted of an entire plant exclusive of any portions in the sediment. These plants were snipped at the substratum-water interface and placed into a sample container in 5-percent Formalin solution.

Total stem length of each *H. verticillata* was measured in the laboratory. The surface area of a leaf was estimated using the formula for the ellipse. Total surface area of each plant was determined by multiplying surface area of an average leaf by the estimated number of leaves per stem and adding this to the surface area of the stem. The number of leaves per stem was estimated based upon examination of other plants taken in qualitative sampling.

The formula for an ellipse was used to determine the surface area of *N. odorata* leaves. Surface area for only one side was calculated, since macroinvertebrates were found only on the ventral leaf surface. The formula for a cylinder was used to estimate the surface area of the stem of *N. odorata*. Leaf and stem surface areas were summed to obtain a total surface area for this species.

The major and minor axis of the blade of each floating leaf was measured, and the formula for an ellipse was used to estimate surface area of *P. nodosus*. Since only the ventral leaf of the floating leaves are used by aquatic macroinvertebrates, surface area was calculated accordingly. The blades of submersed leaves of *P. nodosus* were considered to consist of two isosceles triangles with the bases contiguous to each other. Since both the upper and lower surfaces of leaves of this species were available for colonization, the surface area of each side was determined. The formula for a cylinder was used for computing the surface area of *P. nodosus* stems and leaf petioles.

Statistical methods

A stratified sampling design was used to sample the macrophyte beds and benthic macroinvertebrates. A one-way analysis of variance was used to test for density differences among the four benthic habitats or among the three plant species. If significant differences were found, then pair-wise tests were made with Duncan's multiple range test. Correlation coefficients were calculated for total individuals (Y) versus surface area of each plant species (X).

The relationship between macroinvertebrate communities on *H. verticillata*, *N. odorata*, and *P. nodosus* was analyzed with a polar ordination procedure that is an indirect form of gradient analysis (Smith 1980). Programs developed by Ludwig and Reynolds (1988) were used to construct the polar ordination.

3 Results

Benthic Macroinvertebrates

A total of 15 macroinvertebrate taxonomic groups were identified from four different habitat types in Lake Seminole (Table 1). Mean total macroinvertebrate density was greatest in sediments in the nonvegetated cove (4,638.0 individuals/square meter) and least in sediments beneath *H. verticillata* (1,480.2 individuals/square meter) (Figure 5). Oligochaeta and Chironomidae had the greatest taxa richness of all groups present; a total of nine oligochaete and 14 chironomid taxa were identified. The only bivalve mollusc identified was the Asian clam *Corbicula fluminea*, and only two genera of gastropods were collected (*Gyraulus* sp. and *Physa* sp.).

The Oligochaeta and Chironomidae dominated numerically in the sediments and comprised 32.2 to 53.2 percent and 13.3 to 37.7 percent of the fauna, respectively (Table 2). Ostracods were absent from sediments beneath *H. verticillata* and the *P. nodosus/H. verticillata* mixture. In the nonvegetated cove, Ostracoda comprised 13.5 percent of the fauna (Tables 1 and 2). Hydracarina was present in three habitats, but was absent in *P. nodosus/H. verticillata* sediments. Copepoda and Cladocera were absent in the nonvegetated littoral zone but were common in the other three habitat types. Chaoboridae were present only in *P. nodosus/H. verticillata* sediments where they comprised 4.2 percent of the macroinvertebrate fauna.

Analysis of variance was performed to test for significant differences among density of Chironomidae, Oligochaeta, and other macroinvertebrate groups in each habitat type (Table 3). Duncan's multiple range test revealed that chironomid density in *H.* verticillata (197 individuals/square meter) was significantly less than density in the nonvegetated cove (1,315 individuals/square meter) and nonvegetated littoral zone (953 individuals/square meter) (Table 4). Mean density of Chironomidae in the *P. nodosus/H. verticillata* (427 individuals/square meter) was less than density for the nonvegetated cove sediments. There were significant density differences for *Dugesia tigrina* (Turbellaria) between *P. nodosus/H. verticillata* and the other three benthic habitat types (Table 4). Duncan's multiple range test also indicated a difference between Trichopteran densities in *P. nodosus/H. verticillata* (197 individuals/square meter) and the three remaining habitat types (Table 4).

Nematode density in *H. verticillata* sediments (164.4 individuals/square meter) was significantly greater than beneath *P. nodosus/H. verticillata* (0.0 individuals/square meter).

Fourteen taxa of chironomids were collected form sediments in the four habitat types (Table 5). In the sediments supporting *H. verticillata*, only three chironomid taxa were found, whereas eight taxa were found in sediments supporting *P. nodosus* and *H. verticillata.* The number of taxa collected from the two nonvegetated habitats (nonvegetated cove and nonvegetated littoral zone) were approximately equal (seven and six taxa, respectively). In the nonvegetated sediments, one chironomid (*Cladotanytarsus* sp.) comprised over 50 percent of total abundance. *Tanytarsus* sp. was the most abundant taxon in nonvegetated littoral sediments, although fairly uncommon in *P. nodosus/ H. verticillata* sediments and in the nonvegetated littoral zone.

Of the fourteen chironomid taxa identified among the four benthic habitats in Lake Seminole, nine taxa were habitat specific. *Djalmabatista pulcher* and *Labrundinia neopilosella* were collected only in sediments in the nonvegetated littoral zone. *Endochironomus* sp., *Thienemanniella* nr. *fusca,* and *Procladius* sp. were collected only in the *P. nodosus/H. verticillata* sediments, whereas *Thienemanniella* nr. *xena* was collected only from *H. verticillata. Cryptochironomus* sp., *Larsia* sp., and *Ablabesmyia peleensis* were only found in the nonvegetated cove. Only two chironomid taxa were common to all four benthic habitat types; these were *Tanytarsus* sp. and *Pseudochironomus* sp.

Oligochaetes were represented by the families Naididae and Tubificidae (Table 6); of the nine oligochaete species collected, five were naidids. The naidid *Dero pectinata* comprised over half of this group found in sediments beneath *H. verticillata*, whereas *Pristina leidyi* made up over half of the oligochaetes present beneath *P. nodosus/H. verticillata. Dero trifida* was found only in one habitat type (the nonvegetated littoral zone), where it comprised 51.5 percent of the oligochaetes.

The relationship between cumulative species of oligochaetes (Y) and cumulative individuals (X) was plotted for all benthic habitats combined (Figure 6). For oligochaetes, the curve was still climbing after nearly 100 individuals were identified. For Chironomidae, the curve rose steeply until approximately 20 individuals were identified. Then it leveled off quickly but did not plateau even after nearly 100 individuals were found and identified. Since neither curve became level, it is likely more oligochaete and chironomid species were at these sites than were identified during this survey.

Epiphytic Macroinvertebrates

A total of 16 taxonomic groups were identified on three species of macrophytes in Lake Seminole (Table 8). Total macroinvertebrate density was greatest on *H. verticillata* (12,855 individuals/square meter) and least on *N. odorata*

(5,931 individuals/square meter). Fourteen taxonomic groups were common to the stems and leaves of these three macrophyte species and the benthic sediments (compare Table 1 with Table 7). Hydracarina, copepods, ostracods, and cladocerans were common in the benthos. Two coleopteran taxa were present on macrophytes, compared with only one taxon from the sediments. Diptera and Oligochaeta were also common in sediments and on plants. Two groups (Bivalvia and Amphipoda) were found only in sediments, and two groups (Lepidoptera and Cnidaria) were only on macrophytes.

Chronomids comprised over 50 percent of the fauna on *P. nodosus*, but less than 10 percent on *N. odorata* (Table 9). Oligochaete abundance ranged from a high of 32.2 percent on *H. verticillata* to a low of 12.7 percent on *N. odorata*. When Nematoda, Oligochaeta, and Chironomidae abundances were pooled, they comprised 93 percent of the macroinvertebrates on *H. verticillata* and 85 percent of the macroinvertebrates on *P. nodosus*. However, on *N. odorata*, these three taxonomic groups comprised only 50 percent of the fauna. Hydracarina and Ostracoda comprised 1.4 and 0.9 percent on *H. verticillata* and 4.9 and 2.4 percent on *P. nodosus*; but on *N. odorata*, these groups comprised 27.7 and 17.4 percent of the macroinvertebrate fauna, respectively.

Five groups (Chironomidae, Oligochaeta, Hydracarina, Nematoda, and Ostracoda) exhibited comparatively high densities on macrophytes (Table 8). Chironomid density ranged from a high of 5,469 individuals/square meter on *P. nodosus* to a low of 425 individuals/square meter on *N. odorata*. Nematoda density ranged from a high of 4,459 individuals/square meter on *H. verticillata* to a low of 879 individuals/square meter on *P. nodosus*. Oligochaeta density ranged from a high of 4,138 individuals/square meter on *H. verticillata* to a low of 760 individuals/square meter on *N. odorata*. Hydracarina and Ostracoda had high densities, 1,590 individuals/square meter and 1,038 individuals/square meter, on *H. verticillata* and low densities, 178 individuals/square meter and 1,220 individuals/square meter, on *N. odorata*. The remaining groups comprised less than 5 percent of the assemblage on *H. verticillata*, 7.5 percent on *P. nodosus*, and 4.2 percent on *N. odorata*. Density of Chironomidae on *N. odorata* (425 individuals/square meter) was significantly less than on *P. nodosus* (5,469 individuals/square meter) or *H. verticillata* (3,347 individuals/square meter) (Tables 10 and 11 and Figure 7). There was a density difference between Oligochaeta on *H. verticillata* (4,138 individuals/square meter) and on *N. odorata* (1,906 individuals/square meter) and *P. nodosus* (761 individuals/square meter) (Tables 10 and 11 and Figure 7).

Hydracarina were nine times more abundant on *N. odorata* than on *H. verticillata*. Density of this group on *N. odorata* (1,590 individuals/square meter) was greater than on *P. nodosus* (473 individuals/square meter) and on *H. verticillata* (178 individuals/square meter) (Tables 10 and 11 and Figure 5). Coleopteran densities on *H. verticillata* (55 individuals/square meter) were significantly greater than on *N. odorata* or *P. nodosus* (Tables 10 and 11 and Figure 5). Trichopteran densities on *P. nodosus* (263 individuals/square meter) were greater than on *H. verticillata* (35 individuals/square meter) and *N. odorata* (1.0 individuals/square meter) (Tables 10 and 11 and Figure 8).

Ostracoda density on *N. odorata* (1,038 individuals/square meter) was significantly greater than on *H. verticillata* (122 individuals/square meter) or *P. nodosus* (231 individuals/square meter, tables 10 and 11, Figure 9). Nematoda density on *H. verticillata* (4,459 individuals/square meter) was significantly greater than on *N. odorata* (1,849 individuals/square meter) or *P. nodosus* (879 individuals/square meter) (Tables 10 and 11 and Figure 10). The total number of macroinvertebrates was significantly greater on *H. verticillata* than on *N. nodosus* or *P. nodosus* (Figure 10).

Each species of macrophytes was dominated by a different species of chironomid. On *H. verticillata*, four chironomid genera in descending order of abundance were *Tanytarsus* sp., *Pseudochironomus* sp., *Parakiefferiella* sp., and *Psectrocladius* sp., which together comprised 81.4 percent of this family (Table 12). The four most abundant chironomid taxa, in descending order of abundance, on *N. odorata* were *Polypedilum illinoense*, *Polypedilum laetum*, *Ablabesmyia peleensis*, and *Parachironomus abortivus* group, which together comprised 84.5 percent of the family. On *P. nodosus*, two genera, *T.* nr. *fusca* and *Psectrocladius* sp., comprised 79.7 percent of the assemblage (Table 12).

When the percentage composition of the identifiable species of Chironomidae from the three species of plants were plotted, all curves were similar and showed no strong dominance by any single species. On each macrophyte, the percent abundance of the Chironomidae spanned three orders of magnitude. The fauna on *N. odorata* displayed a minor break between five fairly common and eight uncommon species (Figure 11).

Ten species of oligochaetes were identified on plants (Tables 7 and 13). Two naidid species, *Allonais pectinata* and *P. leidyi*, comprised over 75 percent of the oligochaetes collected on *H. verticillata*. *Dero pectinata*, *A. pectinata*, and *P. leidyi* made up over 90 percent of the fauna on *N. odorata*. On *P. nodosus*, three naidid species (*A. pectinata*, *Nais pardalis*, and *D. pectinata*) accounted for 75 percent of the fauna. On each species of plant, the distribution of Oligochaeta was evenly distributed (Figure 12).

The relationship between cumulative species (Y) and cumulative individuals (X) was plotted for Chironomidae (Figure 13) and Oligochaeta (Figure 14) for each macrophyte species. The curves for Chironomidae on *N. odorata* and *P. nodosus* were similar. They quickly plateaued at 10 species after approximately 25 individuals were identified. The curve for Chironomidae on *H. verticillata* did not plateau until approximately 1,500 individuals were examined and 15 species had been identified (Figure 13). On *H. verticillata*, seven of the nine oligochaete species were identified after 100 individuals were examined, after which the curve plateaued (Figure 14).

For Oligochaeta, on *N. odorata*, all seven species were found after 200 individuals were collected. The curve for *P. nodosus* did not plateau until 550 of all collected individuals were examined and 10 species were collected (Figure 14).

There were significant positive correlations ($P < 0.05$) between plant surface area and total density for nine macroinvertebrate groups (Table 14, Figures 15-21). Chironomids were positively correlated to the surface area of *H. verticillata*, but negatively correlated to surface area of *P. nodosus* (-0.82). Densities of Hydracarina and Ostracoda were negatively correlated to surface area of *Hydrilla* (-0.71 and -0.70, respectively). Only the Ostracoda showed a significant positive correlation with total surface area of *N. odorata* (-0.83). All significant correlations on *P. nodosus* (except chironomids which exhibited a strong negative correlation, -0.82) were positive. Density of oligochaetes was significantly correlated only to surface area of *H. verticillata*.

Composition of the macroinvertebrate community was similar on each macrophyte species (Figure 22). Each plant had a specific and characteristic macroinvertebrate fauna, regardless of where it was physically located.

4 Discussion

Benthic Macroinvertebrates

Density

Scott and Osborne (1981) studied benthic macroinvertebrates from sediments beneath *H. verticillata* in Little Lake Barton in central Florida. They reported that mean benthic density in July equaled 323 individuals/square meter. The results of the present study were similar to theirs, although macroinvertebrate density below *H. verticillata* in Lake Seminole was approximately 4.5 times greater (1,480.2 individuals/square meter) than in Little Lake Barton. Scott and Osborne (1981) collected a total of 54 benthic taxa from all of Little Lake Barton; however, in July they collected only 15 total taxa in sediments beneath *H. verticillata*. In this study, a similar number of benthic taxa (16) were collected from sediments beneath *H. verticillata* in July, with a total of 45 benthic macroinvertebrate taxa from the entire lake. Oligochaete densities in Little Lake Barton were quite low (11 individuals/square meter) and consisted only of *Nais* sp. and no Tubificidae (Scott and Osborne did not identify any worms in the genus *Nais* to the species level). Densities of oligochaetes in sediments beneath *H. verticillata* in Lake Seminole were 67.9 individuals/square meter, and five species of Naididae and four species of Tubificidae were identified. In Lake Seminole, oligochaete densities in *H. verticillata* sediments were approximately six times greater than in Little Lake Barton.

Engel (1985) studied macrophyte-invertebrate relationships in Lake Halverson, WI. In sediments beneath *Potamogeton* sp. and *Heatheranthia dubia*, he reported densities of 4,800 and 7,700 individuals/square meter, respectively. Densities in sediments below the two plant beds species in Lake Seminole were lower. Mean benthic macroinvertebrate density in sediments below *H. verticillata* was 1,480 individuals/square meter, whereas mean macroinvertebrate density below a mixture of *H. verticillata* and *P. nodosus* was 2,368.3 individuals/square meter. Engel (1985) reported that 75 percent of all the macroinvertebrates in Lake Halverson occurred below macrophyte beds. In contrast, only 34.9 percent of all bottom fauna in Lake Seminole were collected in sediments below *H. verticillata* and *P. nodosus/H. verticillata*.

Beckett, Aartila, and Miller (1991a) studied benthic macroinvertebrates in *P. nodosus* and *Ceratophyllum demersum* beds and in adjacent nonvegetated zones in Eau Galle Lake, WI. They reported that the highest macroinvertebrate densities were below *C. demersum* (35,260 macroinvertebrates/square meter); whereas, the lowest densities were found in nonvegetated areas (2,730 macroinvertebrates/square meter). During July, August, and September, macroinvertebrate densities in Little Lake Barton declined to less than 2 percent of annual mean density (Scott and Osborne 1981). These workers reported that reduced dissolved oxygen (≤ 2.0 ppm) was responsible for this decline in macroinvertebrate densities during the summer. Osborne, Wanielista, and Yousef (1976) reported that dissolved oxygen concentrations for six Florida lakes in July 1975 ranged from a high of 4.7 mg/l to a low of 2.5 mg/l. Dissolved oxygen at the surface, middle, and bottom were measured in *H. verticillata* beds in Lake Seminole, August 1988. Dissolved oxygen values near the lake bottom ranged from a high of 7.8 mg/l in late afternoon to a low of 1.9 mg/l in early morning. Low dissolved oxygen probably negatively affected benthic macroinvertebrates in Lake Seminole. Wetzel (1975) reported that 2 mg/l or less for extended periods of time can cause mortality of most species of macroinvertebrates.

Substratum type also affects benthic macroinvertebrate density. Kibret and Harrison (1989) studied the relationship between aquatic macrophytes and benthic fauna in Lake Chilwa, located in eastern Africa. In Lake Chilwa, macroinvertebrates were absent from flocculent mud substratum, which comprised a large portion of the sublittoral zone less than 6 m deep. Kibret and Harrison (1989) suggested that the flocculent character of the substratum influenced macroinvertebrate benthic density, since dissolved oxygen was adequate at approximately 4 mg/l. Sediments in Lake Seminole consisted of firmly packed fine-grain sands and silts. Therefore, low macroinvertebrate densities were probably not a function of unsuitable substratum.

Community composition

The benthic macroinvertebrate fauna in Lake Seminole was dominated by Oligochaeta and Chironomidae. Combined abundance of these two taxonomic groups ranged from a low of 57.7 percent in sediments below *H. verticillata* to a high of approximately 91 percent in sediments of the nonvegetated littoral zone. Scott and Osborne (1981) also reported that the Chironomidae and Oligochaeta were numerical dominants in the sediments of Little Lake Barton, FL. In that lake, chironomids comprised 60 percent, whereas oligochaetes comprised approximately 21 percent of total annual abundance.

In Lake Halverson, WI, Engel (1988) reported that molluscs dominated sediments in nonvegetated and vegetated areas. Benthic samples from four inshore benthic sites not beneath macrophyte beds had molluscan abundances of 68.8, 63.9, 45.6, and 60.3 percent. In contrast, molluscs were not abundant in Lake Seminole sediments. In *P. nodosus/H. verticillata* sediments, gastropod abundance was approximately 3.6 percent of all the macroinvertebrates collected, represented by only two taxa (*Physa* sp. and *Gyraulus* sp.). In the nonvegetated littoral zone at Lake Seminole, gastropods comprised only 1.3 percent of total abundance, with one taxa present (*Gyraulus* sp.). One bivalve, *Corbicula fluminea*, was collected in Lake Seminole. Scott and Osborne (1981) reported four gastropod taxa from Little Lake Barton, FL, (*Gyraulus* sp., *Physa* sp., *Heliosoma* sp., and *Viviparus georgianus wareanus*).

Chironomid species composition

Scott and Osborne (1981) reported that chironomids collected from sediments beneath *H. verticillata* in Little Lake Barton were composed of 27 species, whereas over three chironomid taxa were collected beneath *H. verticillata* beds in Lake Seminole. Core samples from beneath *H. verticillata* in Lake Seminole consisted mainly of leaves and stems from water above the sediments.

Carpenter and Lodge (1986) reported that large deposits of detritus were probably responsible for oxygen depletion, and it is likely that oxygen depletion in *H. verticillata* sediments affected chironomid distribution in Lake Seminole. Scott and Osborne (1981) postulated that reduced dissolved oxygen in Little Lake Barton was responsible for low chironomid density. Low oxygen levels could explain the low number of benthic chironomid taxa in *H. verticillata* in Lake Seminole.

Oligochaete composition

Oligochaetes comprised approximately 21 percent of the total benthic macroinvertebrates in Little Lake Barton, FL (Scott and Osborne 1981). However, in July, oligochaetes comprised only 3.5 percent of the total macroinvertebrates in Lake Seminole. Scott and Osborne (1981) reported only one tubificid species (*Limnodrilus hoffmeisteri*) and no naidid species. In contrast, oligochaetes numerically dominated sediments of Lake Seminole. Beckett, Aartila, and Miller (1991a) reported oligochaetes comprised 20.2, 39.2, and 32.5 percent of the macroinvertebrates beneath *Ceratophyllum demersum*, *Potamogeton* sp., and a nonvegetated zone, respectively, in Eau Galle Lake, WI. In Lake Seminole, oligochaetes comprised 44.4 and 47.2 percent of the macroinvertebrates in sediments beneath *H. verticillata* and a mixture of *H. verticillata* and *P. nodosus*, respectively.

Epiphytic Macroinvertebrates

Density

Krecker (1939) and Rosine (1955) reported dissimilar macroinvertebrate densities among macrophyte species with different morphologies. Their findings indicate that macrophytes with highly dissected leaves support higher densities than plants with more simple leaf structure. Soszka (1975), Dvorak and Best (1982), and Gerking (1957) reported similar results. Beckett, Aartila, and Miller (1991b) studied macroinvertebrate colonization on *P. nodosus* in Eau Galle Lake in Wisconsin and reported number of macroinvertebrates per *P. nodosus* plant and per square centimeter of plant surface area. For June, in Eau Galle Lake, the mean macroinvertebrate density was 154 individuals per mean surface area of 1,222 sq cm. For August, Beckett, Aartila, and Miller (1991b) reported a mean of 127 macroinvertebrates per mean surface area of 183 sq cm. Although Lake Seminole and Eau Galle Lake are geographically distant, *P. nodosus* was studied at both lakes. In Lake Seminole, mean total macroinvertebrates was 12,676 individuals/square meter in June 1987 on *P. nodosus*. Chironomid density in Lake Seminole was 1.8 times greater than the chironomid density in Eau Galle Lake (6,187 individuals/square meter). Oligochaeta density on *P. nodosus* in Lake Seminole in June was 1.1 times the density on this plant in Eau Galle Lake (2,012 individuals/square meter).

Growth pattern of macrophytes will influence macroinvertebrate density. Since *H. verticillata* is branched, a vast interconnecting macrophyte bed can be formed. Rooke (1986) reported that complex growth pattern can lead to high macroinvertebrate density, since macroinvertebrate density of the three species of plants in Lake Seminole was on *H. verticillata,* which has a complex growth pattern.

Elakovitch and Wooten (1989) reported that *N. odorata* leaves and stems possessed allelopathic activity. Their experiments did not include macroinvertebrates, but it is likely that exuded compounds can negatively affect colonization by most aquatic organisms (Hutchinson 1981; Carpenter and Lodge 1986).

Bekett, Aartila, and Miller (1991b) reported that the degree of senescence in *P. nodosus* influenced macroinvertebrate density in Eau Galle Lake. In Lake Seminole, *H. verticillata* and *N. odorata* did not exhibit marked senescence, whereas submersed leaves of *P. nodosus* occasionally displayed some degree of senescence. Naidids were present on partially decaying submersed leaves of *P. nodosus* more commonly than on nonsenescent leaves. Although this senescence on *P. nodosus* was not quantitatively measured, it is possible that senescence, in conjunction with macrophytically produced compounds, is important in influencing macroinvertebrate colonization of the macrophytes in Lake Seminole. Studies by Smock and Stoneburner (1980) as well as Beckett, Aartila, and Miller (1991b) indicated that plant condition is an important factor in the determination of macroinvertebrate abundance on macrophytes.

Condition *P. nodosus* probably affected macroinvertebrate abundance in Lake Seminole.

Percent composition of major macroinvertebrate groups

In Lake Seminole, the dominant taxonomic groups found on *H. verticillata, N. odorata,* and *P. nodosus* were Chironomidae, Nematoda, Oligochaeta, Hydracarina, and Ostracoda (Table 9). Martin and Shireman (1976) studied Lake Wales, a lake in central Florida. They reported chironomids and oligochaetes comprised over 80 percent of total macroinvertebrates collected from *H. verticillata.* A snail (*Gyraulus* sp.) comprised 9.8 percent of total macroinvertebrates, and Ephemeroptera comprised 3.1 percent. Abundances of major taxonomic groups on *H. verticillata* in Lake Seminole were different from those in Lake Wales. Chironomidae and Oligochaeta comprised only 57 percent of total macroinvertebrate collected on *H. verticillata* in Lake Seminole, but Gastropoda and Ephemeroptera in Lake Seminole had abundances of less than 1 percent.

Chironomid species percentage

The chironomid community on the three macrophyte species from Lake Seminole consisted of a total of 17 taxa, with three different chironomid taxa dominating each of the three macrophyte species. Miller et al. (1989) reported 21 chironomid taxa from *C. demersum*, a dominant macrophyte in Eau Galle Lake, WI. *Ceratophyllum demersum* is a macrophyte similar in complexity to *H. verticillata*, the dominant macrophyte species in Lake Seminole. Chironomidae collected from *P. nodosus* in Lake Seminole comprised over 56 percent of chironomids, but this group was only 26 percent of total chironomids collected on *H. verticillata.* Two chironomid taxa, *T.* nr. *fusca* and *Psectrocladius* sp., comprised over 79 percent of all chironomids collected on *P. nodosus.* Both of these taxa belonged to Orthocladiinae, which are scrapers (Merritt and Cummins 1978). The dominant chironomid on *H. verticillata* was *Tanytarsus* sp., a collector, and comprised 37.7 of the total chironomid fauna.

Oligochaete species composition

Ten naidid taxa were collected from *P. nodosus* in Eau Galle Lake, WI (Miller et al. 1989), and Lake Seminole, GA, in the present study. The dominant naidid species on *P. nodosus* in Eau Galle Lake was *Nais pardalis*, which comprised 60 percent of all naidids collected. *Nais pardalis* was the second most abundant naidid on *P. nodosus* in Lake Seminole, where it comprised 21.1 percent of the naidids. The most abundant naidid on *P. nodosus* and on *H. verticillata* in Lake Seminole was *A. pectinata*, a species not collected in Eau Galle Lake. *Potamogeton nodosus* supported a diverse naidid taxa in both Wisconsin and Georgia. However, total naidid densities were highest on

H. verticillata, a plant morphologically much different from *P. nodosus*. When examined under the dissecting microscope, some *H. verticillata* samples were found to contain abundant detritus. Those *H. verticillata* specimens would always contain a large number of naidids. Although this is only a qualitative observation, it could suggest an answer for difference observed in density and abundance of naidids in Lake Seminole.

Community characteristics

Rosine (1955) studied macroinvertebrate densities on three macrophyte species in a Colorado lake. He concluded that surface area was directly and positively related to macroinvertebrate density. Plants with large surface area would support higher densities than a species with smaller surface area. Bolchino and Bolchino (1979) studied the relationship between macroinvertebrate density and two variables: plant biomass and plant surface area. They concluded that surface area was significantly correlated to macroinvertebrate density.

A total of thirteen significant correlations existed between macroinvertebrate densities and three aquatic macrophyte species; all but three were positive (Table 14). Total macroinvertebrate numbers were positively and significantly correlated with *H. verticillata* and *P. nodosus*. *Hydrilla verticillata*, depending on stem length, can provide macroinvertebrates with a large amount of colonizable substratum. Naidid density was significantly correlated to *H. verticillata*. Perhaps this correlation is due to greater amount of detritus trapped by *H. verticillata*. Rooke (1986) reported that macrophytes that possessed a complex growth pattern could trap detritus. *Hydrilla verticillata*, which is structurally complex, possessed more detritus than *P. nodosus* or *N. odorata*. It is likely that a combination of morphological complexity and surface area, with subsequent detrital accumulation, explains the presence of Oligochaeta on *H. verticillata*. There were no significant positive correlations between surface area and density of any macroinvertebrate group for *Nymphaea odorata*. This broad leaf with little structural complexity did not trap detritus or provide many areas suitable for hiding or attachment.

Individual sites in Lake Seminole were similar in substratum composition and water depth. The macroinvertebrate community was similar within each plant type. This is consistent with findings from workers (Rosine 1955; Gerking 1957; and Soszka 1975) who have remarked on the existence of specific macroinvertebrate fauna on a particular macrophyte species. Ordination is well suited for analysis of community structure since it provides much information about community composition and the relationship of individual units (sites) to one another. A community that is similar in composition to another will be closer spatially on the polar ordination graph. Conversely, a community that is dissimilar in faunal composition from the other will be more distant from the other (Smith 1980). The ordination of the macroinvertebrate species collected in Lake Seminole from *H. verticillata*, *N. odorata*, and *P. nodosus* revealed the existence of three dissimilar macroinvertebrate communities on each of the three respective macrophyte species (Figure 22). The dissimilarity is easily seen since the graph shows the spatial position of each macroinvertebrate community to be quite separate from each other.

Summary

As prominent features of the littoral zones of lakes and many river channels, submersed macrophytes have the capacity to alter the physical environment by changing the velocity of waves and currents, modifying sedimentation patterns and substrates, stabilizing habitats, reducing erosion, altering temperature regimes, and influencing available light. Dense populations of macrophytes in rivers reduce current velocities and flow patterns and physically alter the environment by reducing water movement and causing a higher retention of silt, sand, and particulate organic matter. Beds of macrophytes in the littoral zones of lakes modify water circulation patterns by reducing the velocity and changing direction of flow.

The complex morphological characteristics and densities of plants enable them to function as mechanical filters of suspended matter and act as a barrier to the entry of pollutants into the ecosystem. Submersed macrophytes may also establish a gradient of physical parameters including light and temperature. Colonization and subsequent modifications of the habitat may bring about a succession of other macrophyte species resulting in further changes in the physical environment and associated epiflora and epifauna. Submersed macrophytes undergo complex interactions with abiotic and biotic components and can cause wide diurnal fluctuations in dissolved oxygen, carbon dioxide, and pH. The effects of submersed macrophytes on the nutrient cycles of aquatic habitats are varied and related in part to macrophyte morphology and the hydrochemistry of the environment.

The relationships between submersed macrophyte communities and macroinvertebrates include complex interactions relating to macrophyte morphology, invertebrate behavior, life cycles, and predator-prey relationships. Invertebrate abundances on submersed macrophytes tend to be related to plant morphology and physicochemical or environmental factors. The most common invertebrates colonizing submersed macrophytes include crustaceans, midges, oligochaetes, and gastropods. Of the insects that are adapted to live part or all of their lives in aquatic habitats, many species have adapted to the habitats provided by submersed macrophytes. Submersed macrophytes provide valuable substrates to aquatic habitats for direct colonization by invertebrates, and numerous studies have documented the importance of submersed macrophytes to macroinvertebrate communities.

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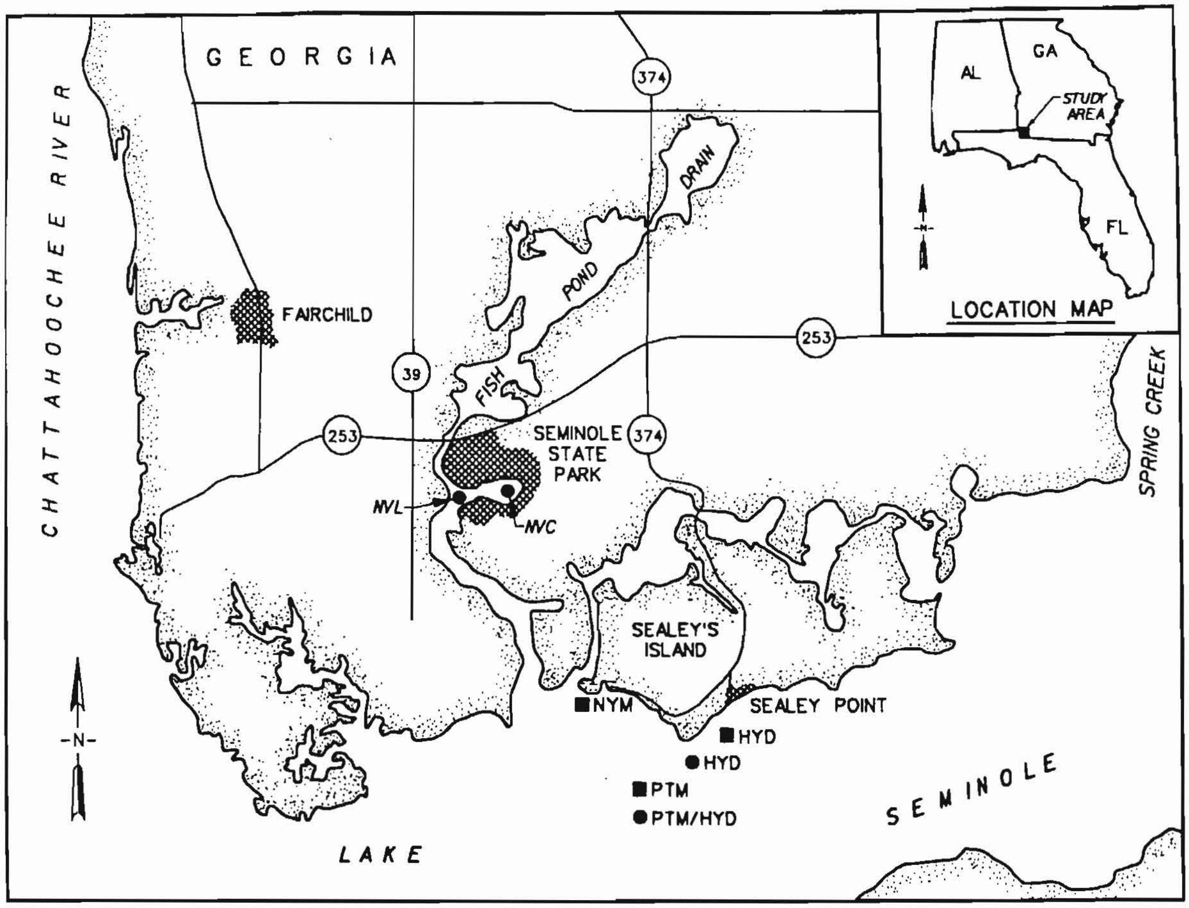

Figure 1. Lake Seminole, GA

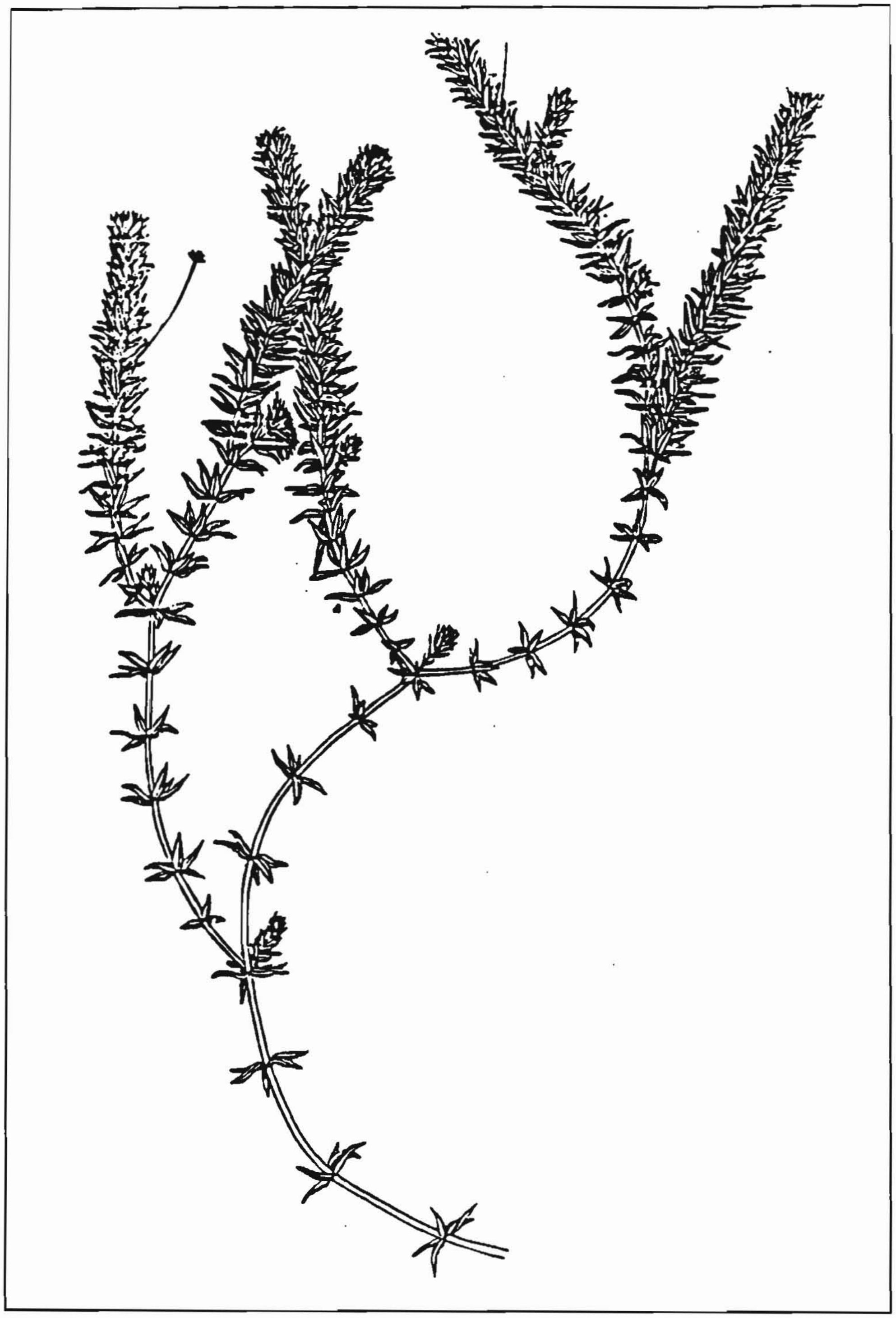

Figure 2. *Hydrilla verticillata*

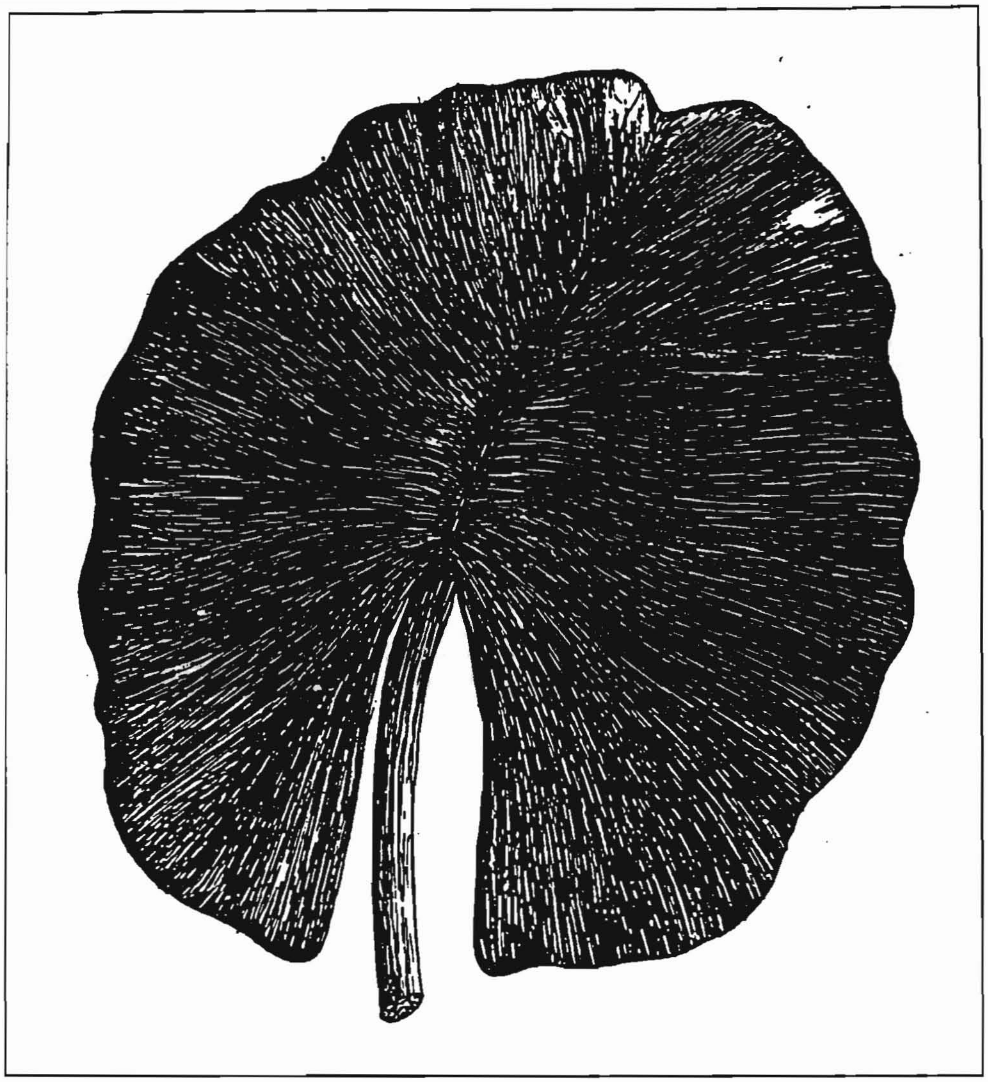

Figure 3. *Nymphaea odorata*

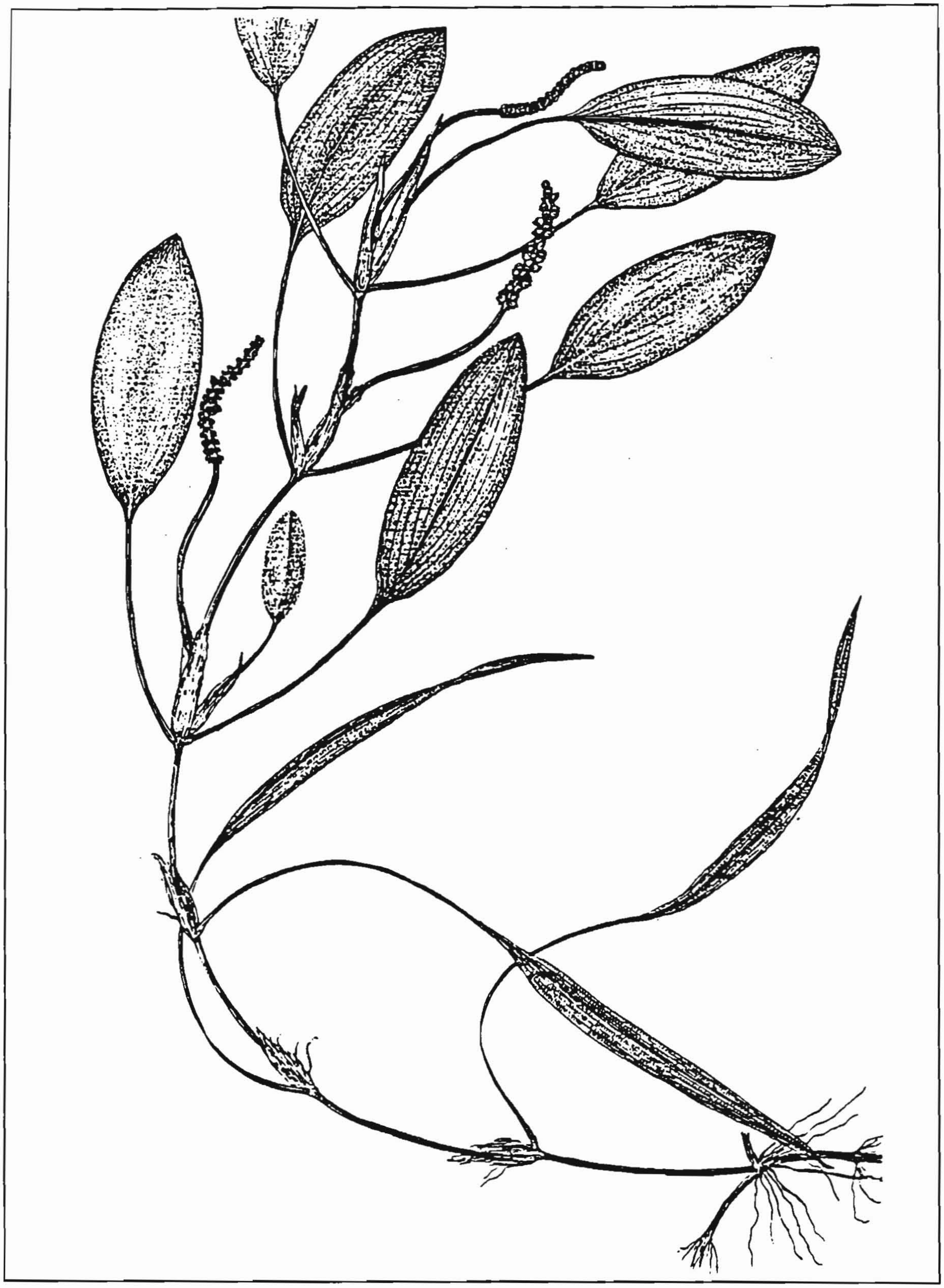

Figure 4. *Potamogeton nodosus*

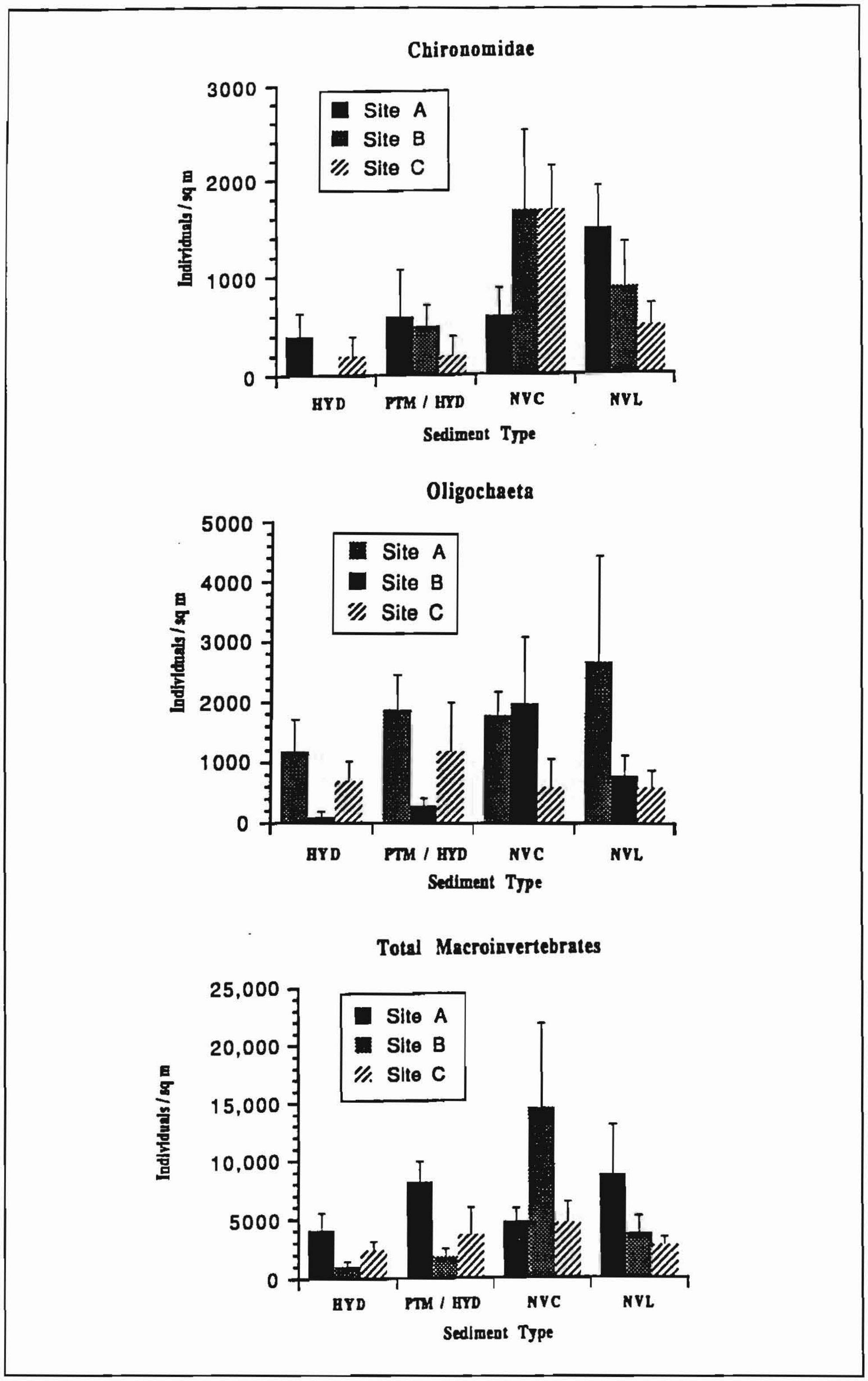

Figure 5. Density values for Chironomidae, Oligochaeta, and total macroinvertebrates from four benthic habitats

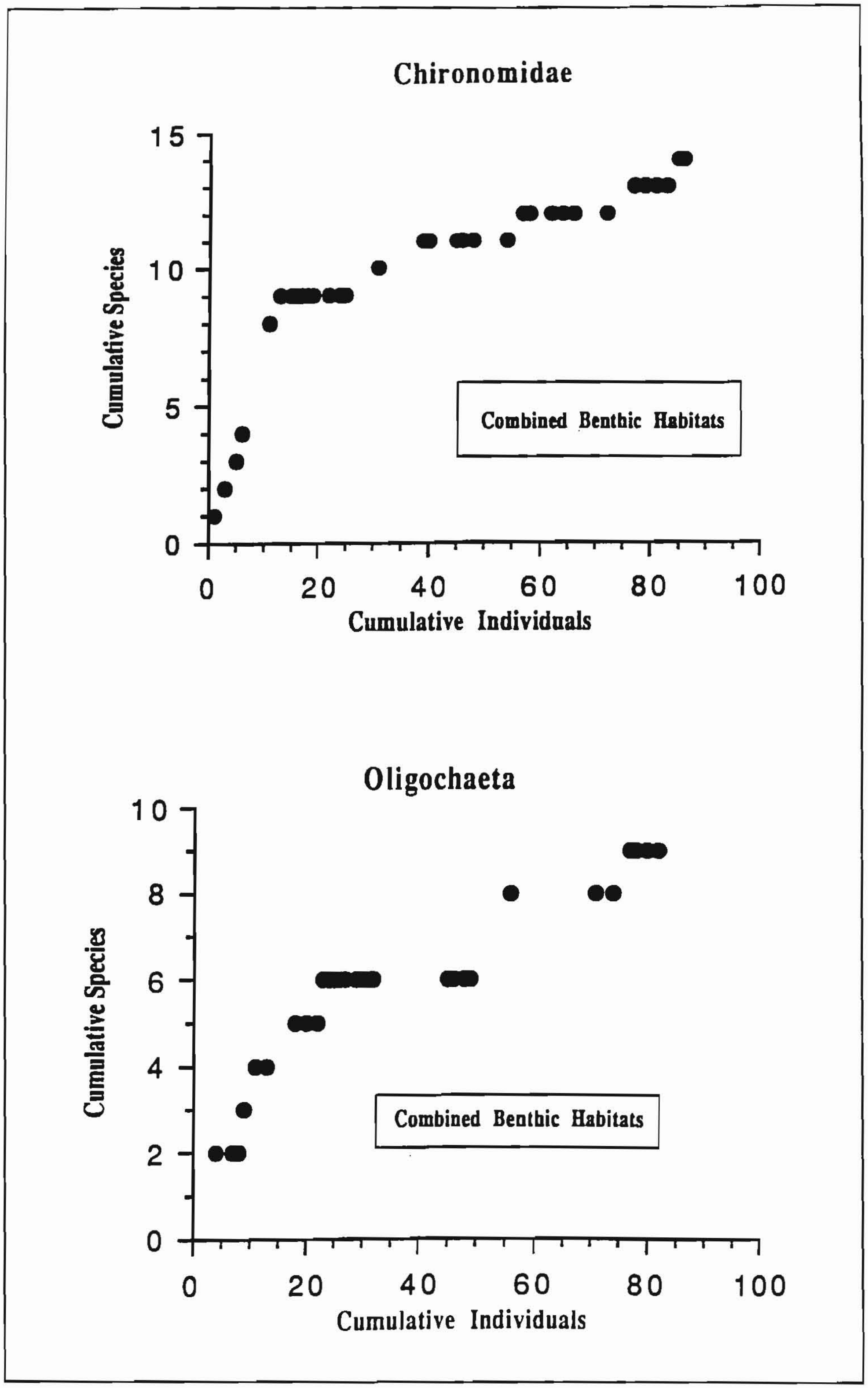

Figure 6. Relationship between cumulative species (Y) and cumulative individuals (X) for benthic Chironomidae and Oligochaeta

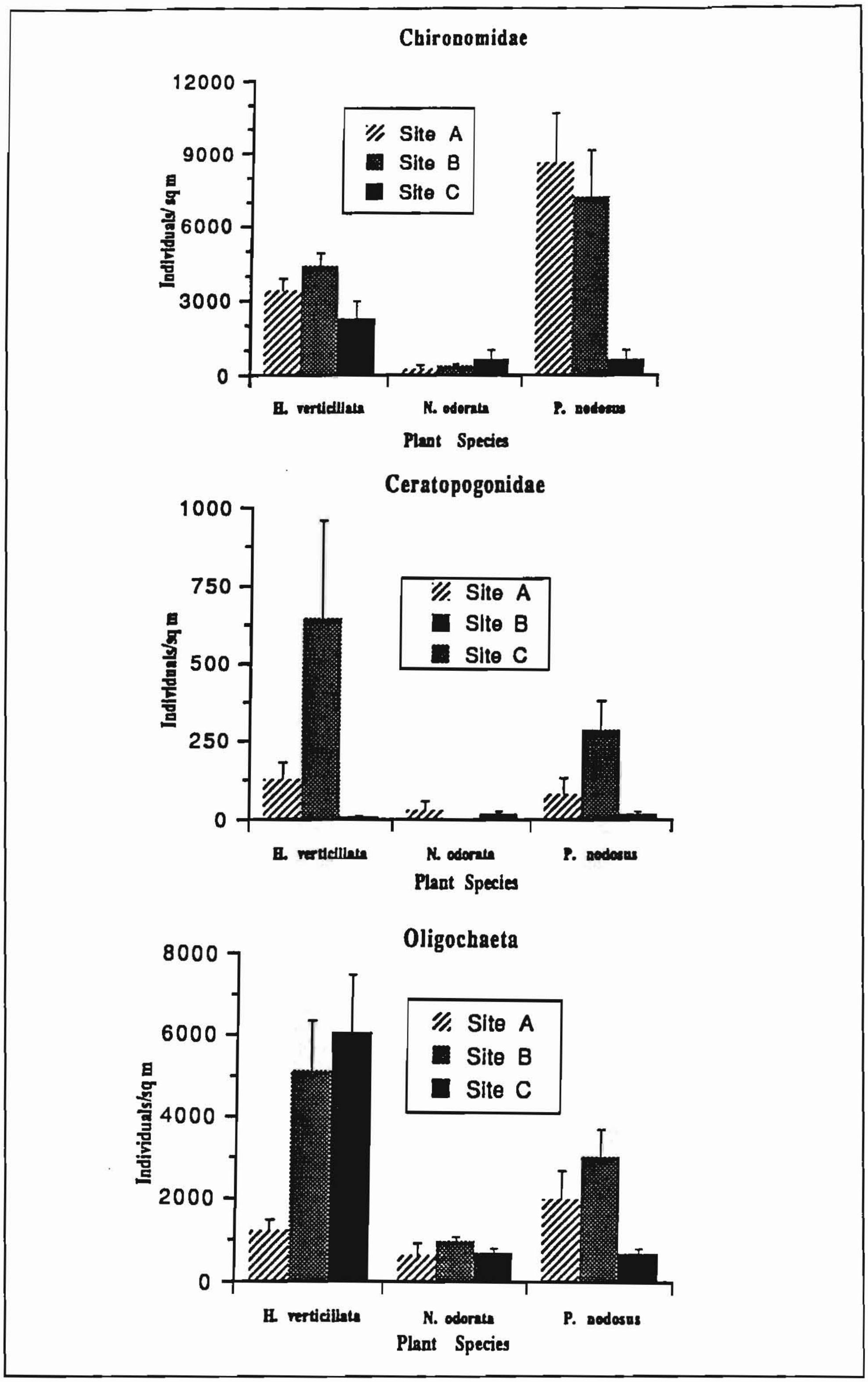

Figure 7. Density values for Chironomidae, Ceratopogonidae, and Oligochaeta from three macrohyte species

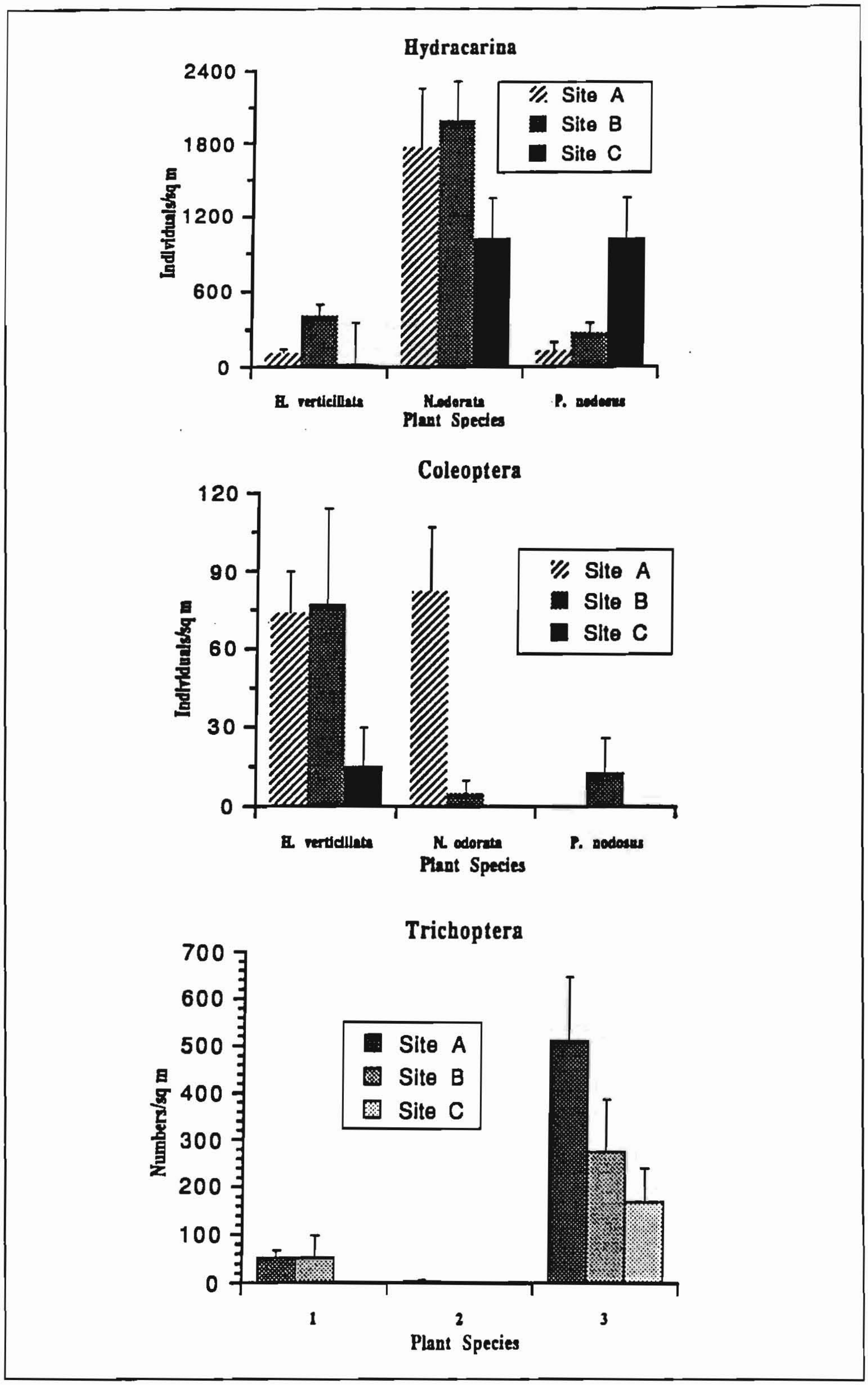

Figure 8. Density values for Hydracarina, Coleoptera, and Trichoptera from three macrophyte species

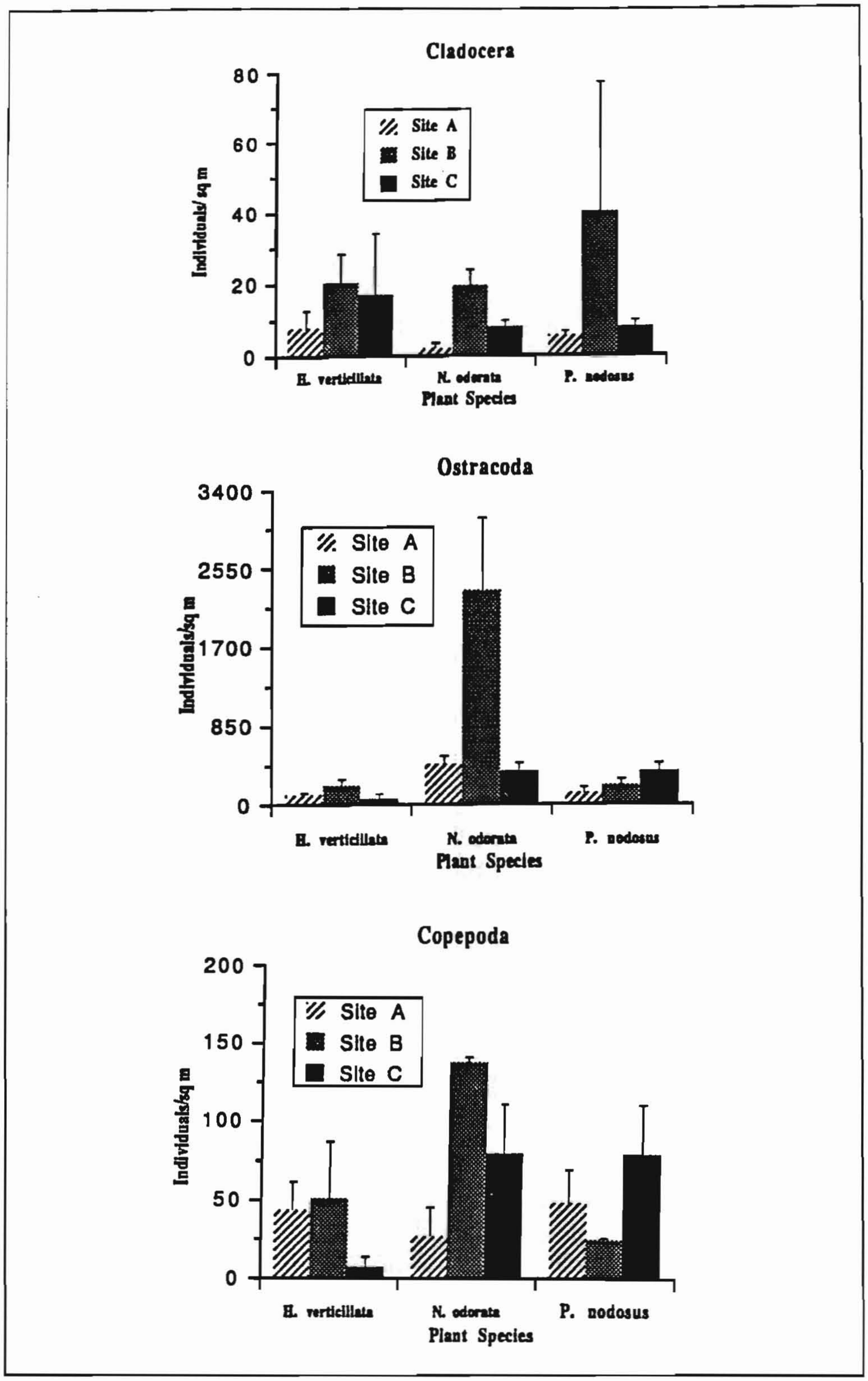

Figure 9. Density values for Cladocera, Copepoda, and Ostracoda from three macrophyte species

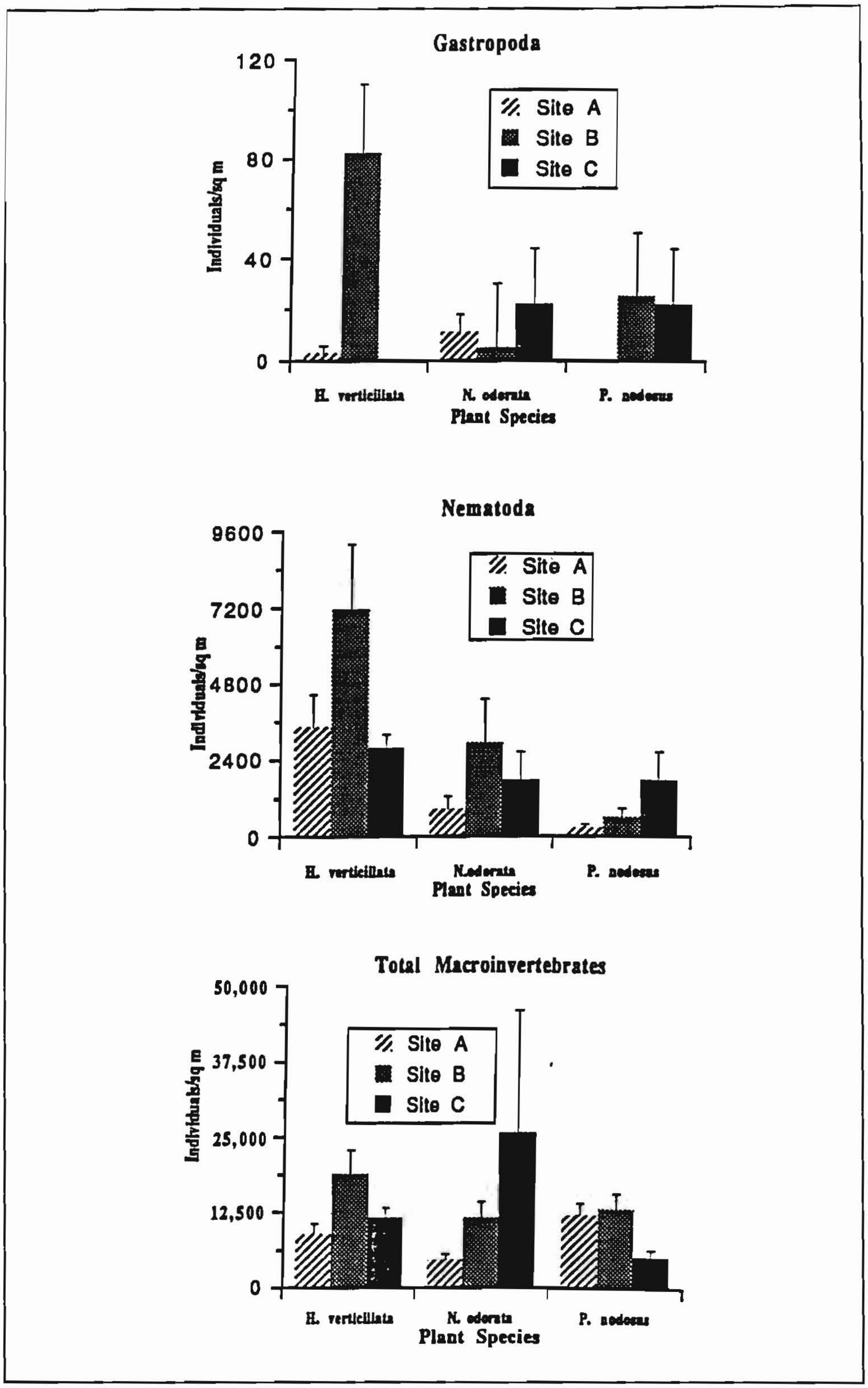

Figure 10. Density values for Gastropoda, Nematoda, and total macroinvertebrates from three macrophyte species

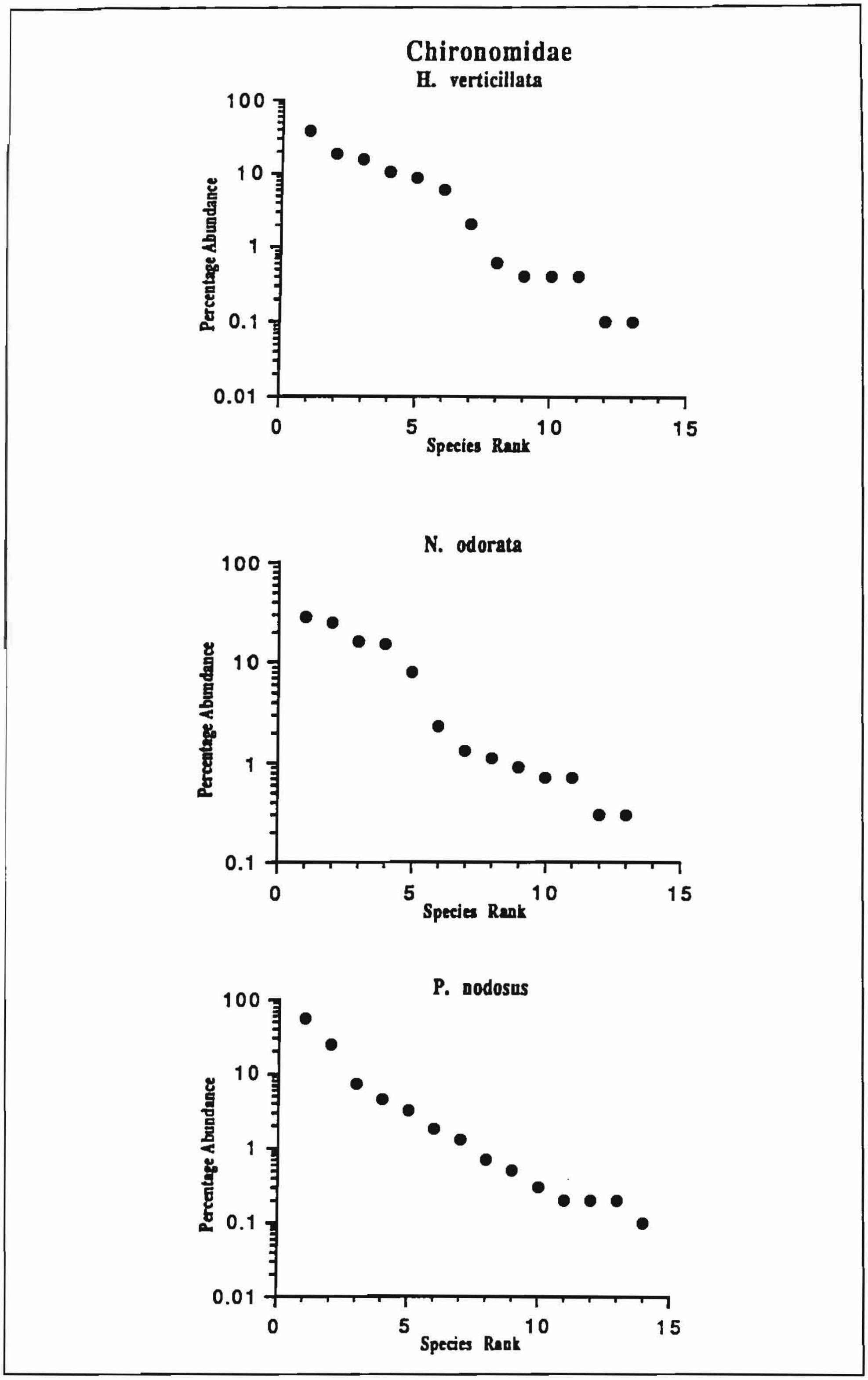

Figure 11. Relationship between percentage of abundance (Y) and species rank (X) of Chironomidae collected from three macrophyte species

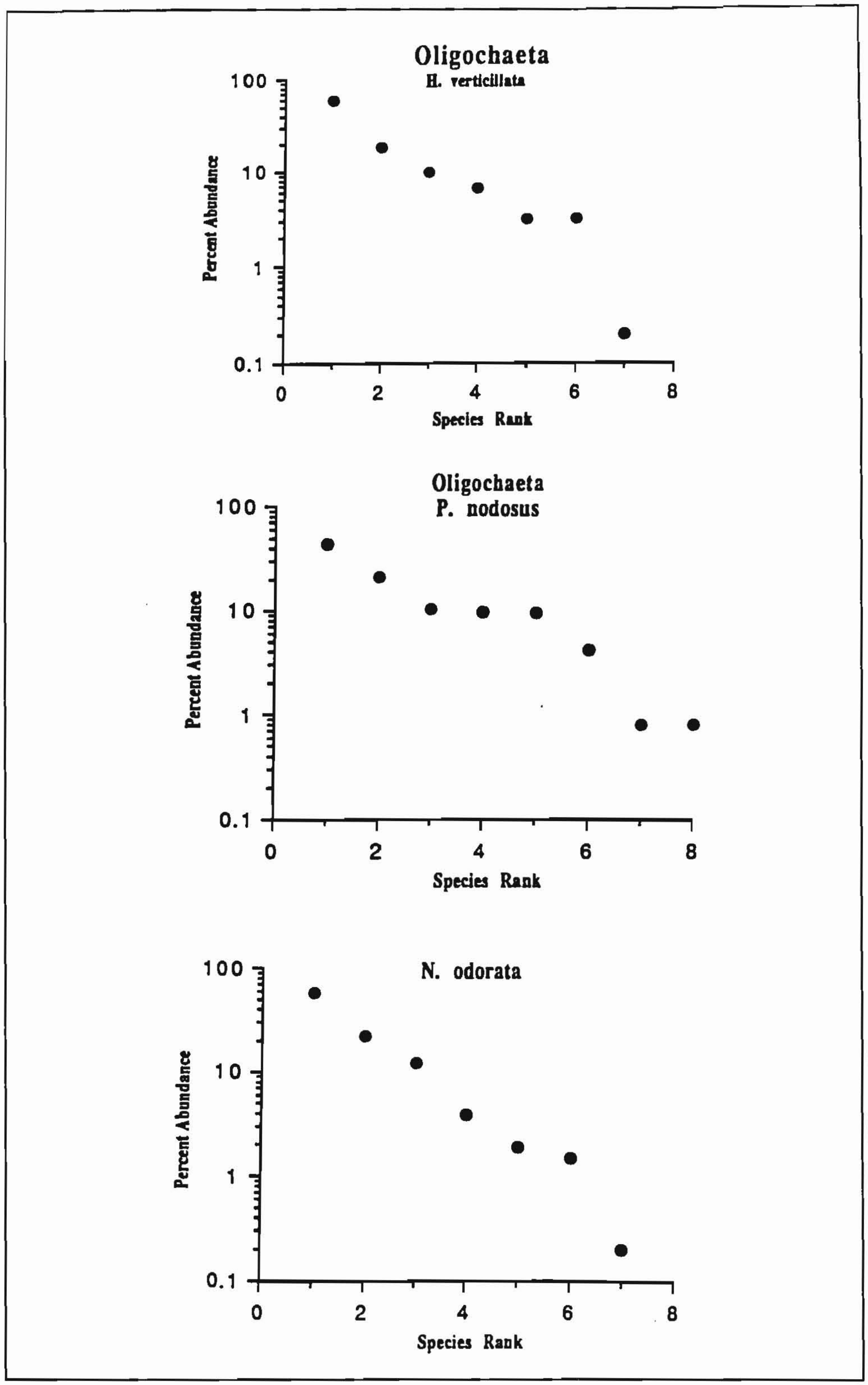

Figure 12. Relationship between percentage of abundance (Y) and species rank (X) of Oligochaeta collected from three macrophyte species

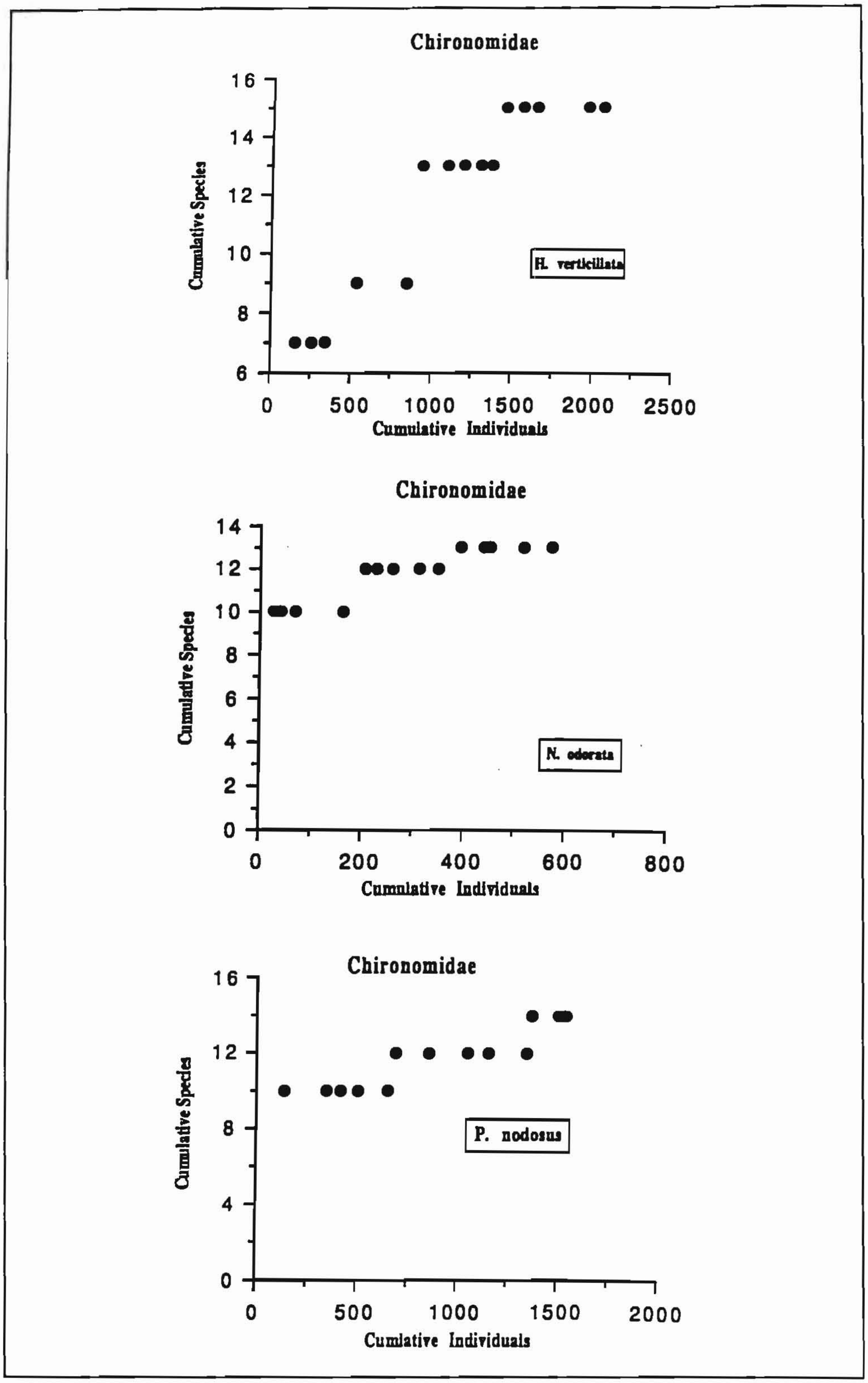

Figure 13. Relationship between cumulative species (Y) and cumulative individuals (X) for Chironomidae collected from three macrophyte species

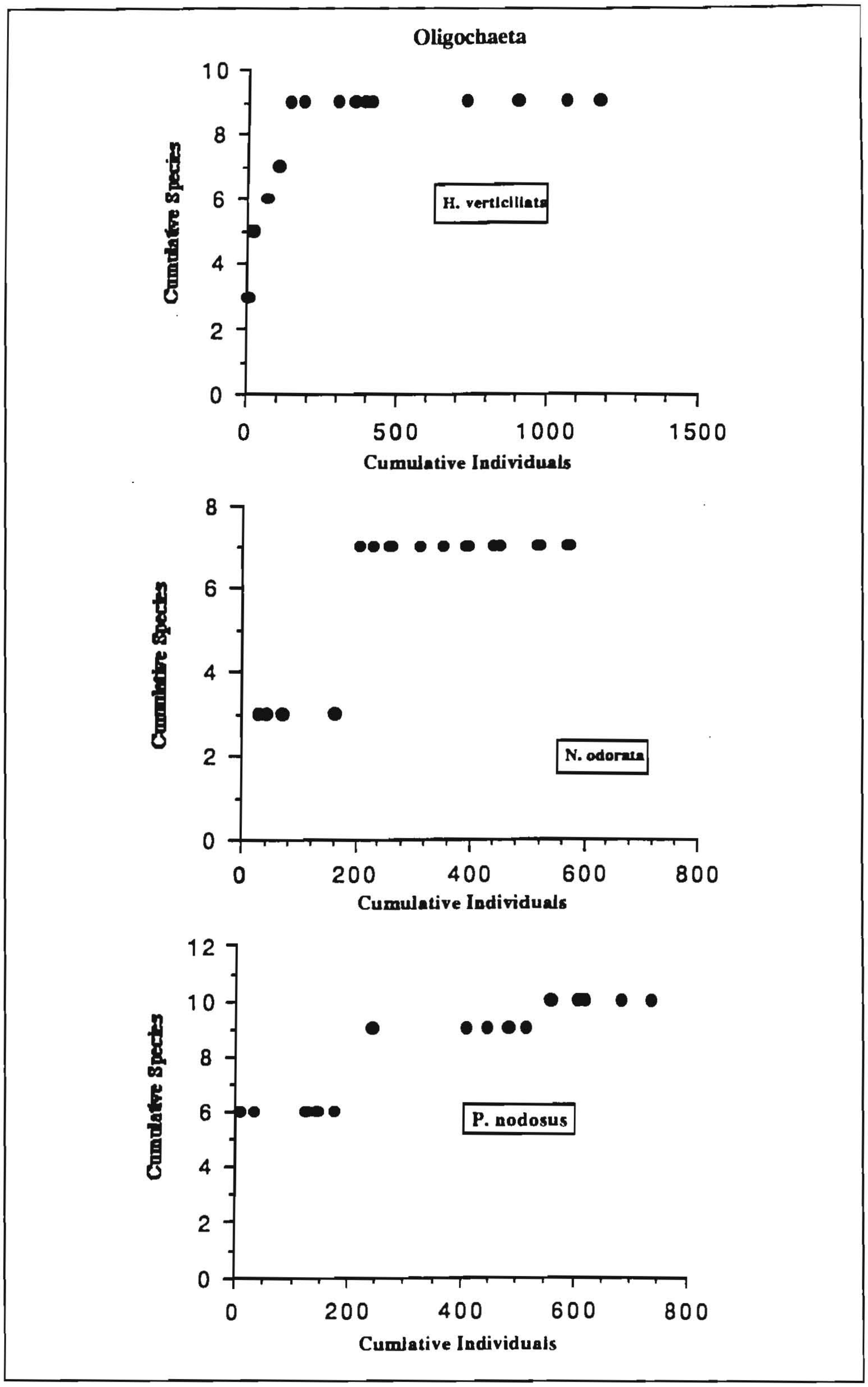

Figure 14. Relationship between cumulative species (Y) and cumulative individuals (X) for Oligochaeta collected from three macrophyte species

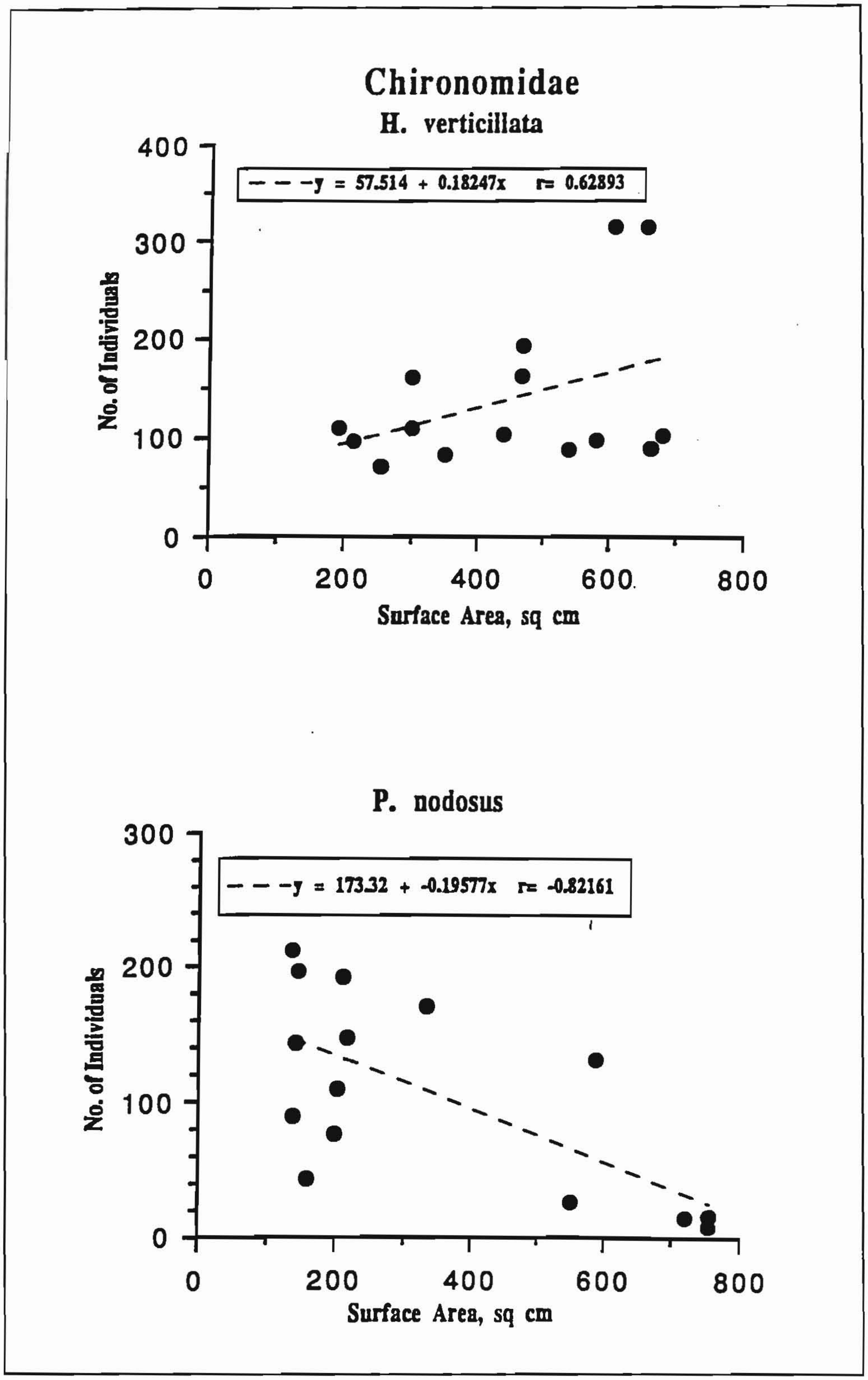

Figure 15. Relationship between surface area and number of Chironomidae collected from two macrophyte species

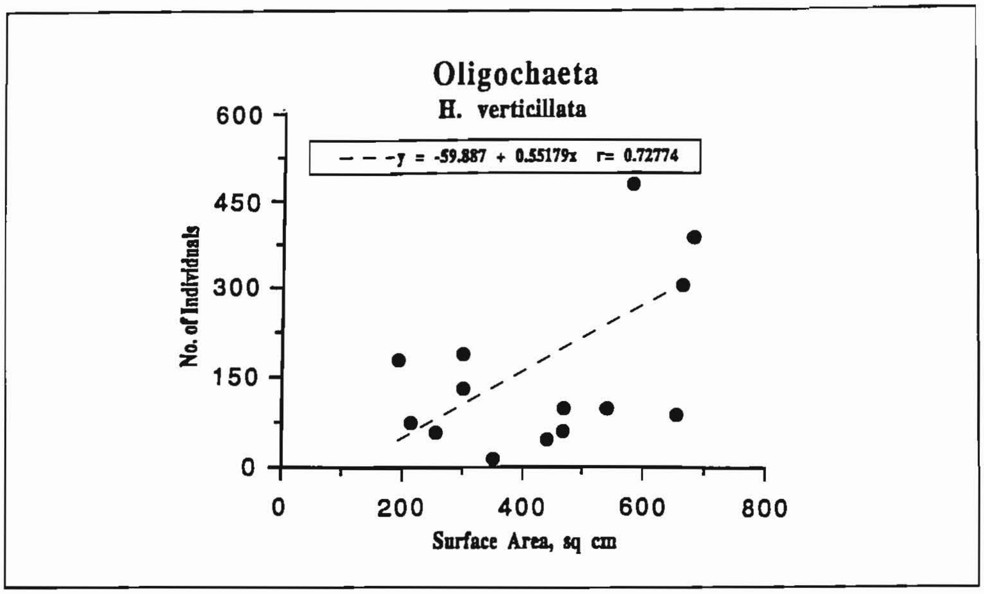

Figure 16. Relationship between surface area and number of Oligochaeta collected from one macrophyte species

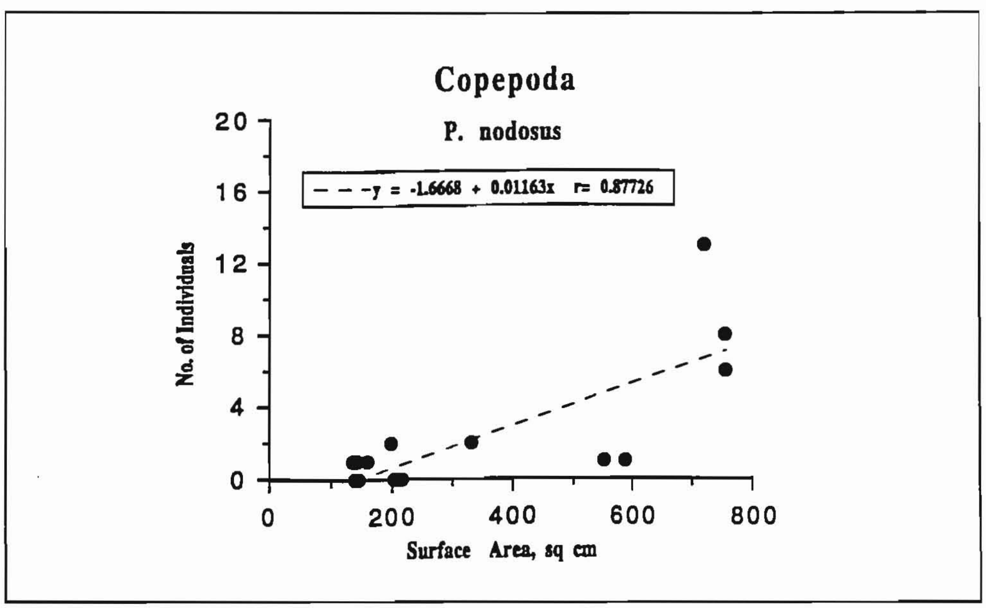

Figure 17. Relationship between surface area and number of Copepoda collected from one macrophyte species

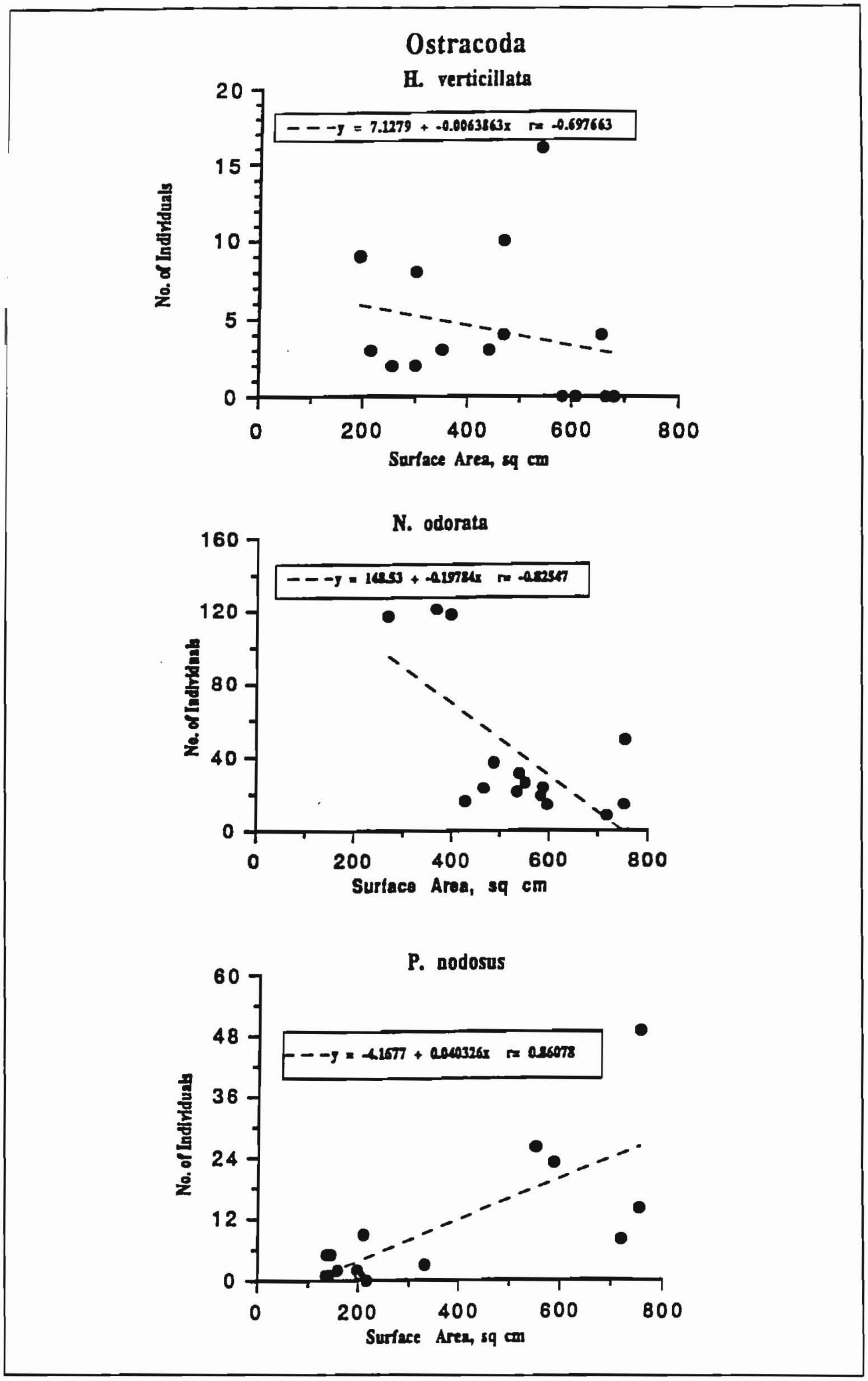

Figure 18. Relationship between surface area and number of Ostracoda collected from three macrophyte species

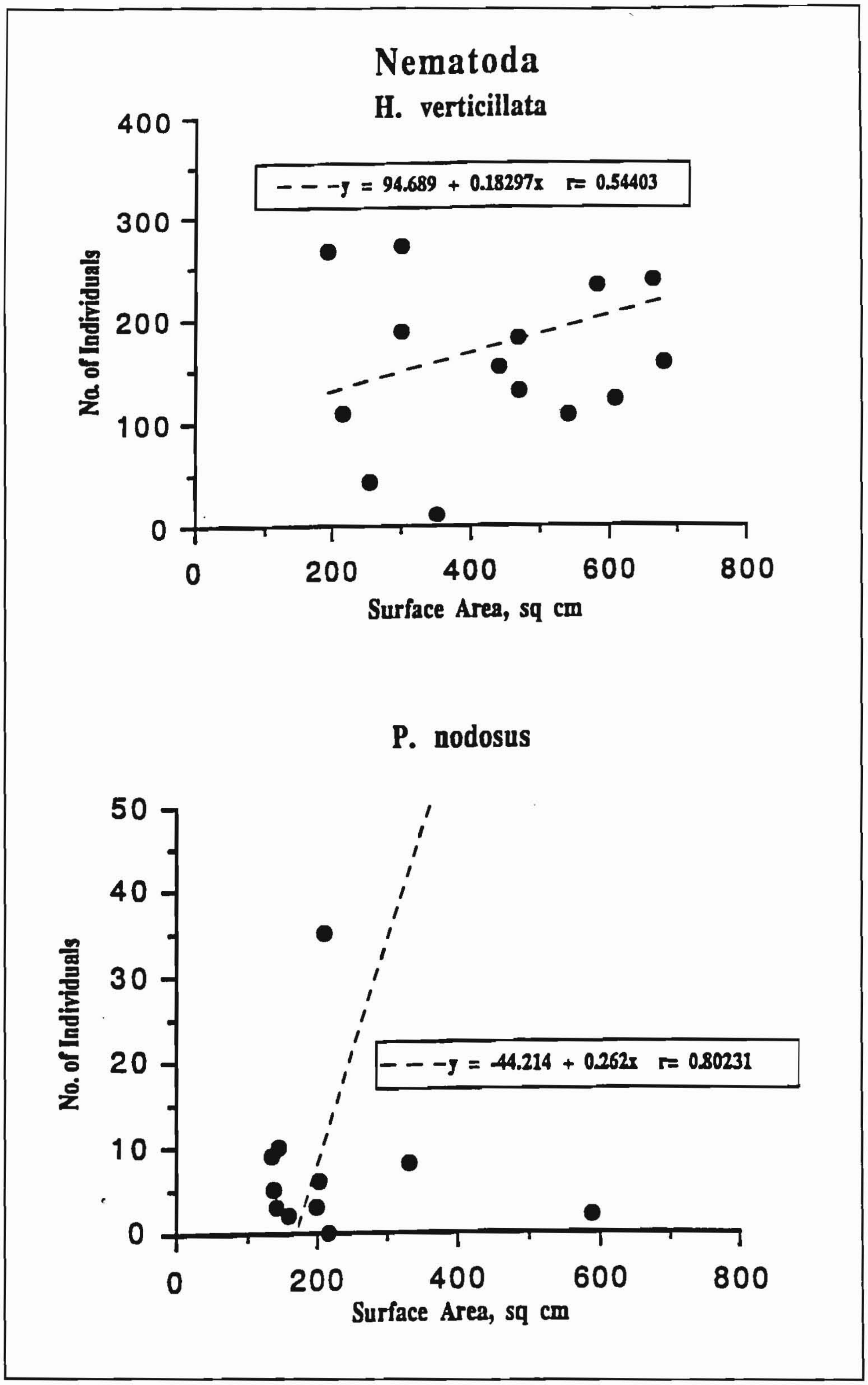

Figure 19. Relationship between surface area and number of Nematoda collected from two macrophyte species

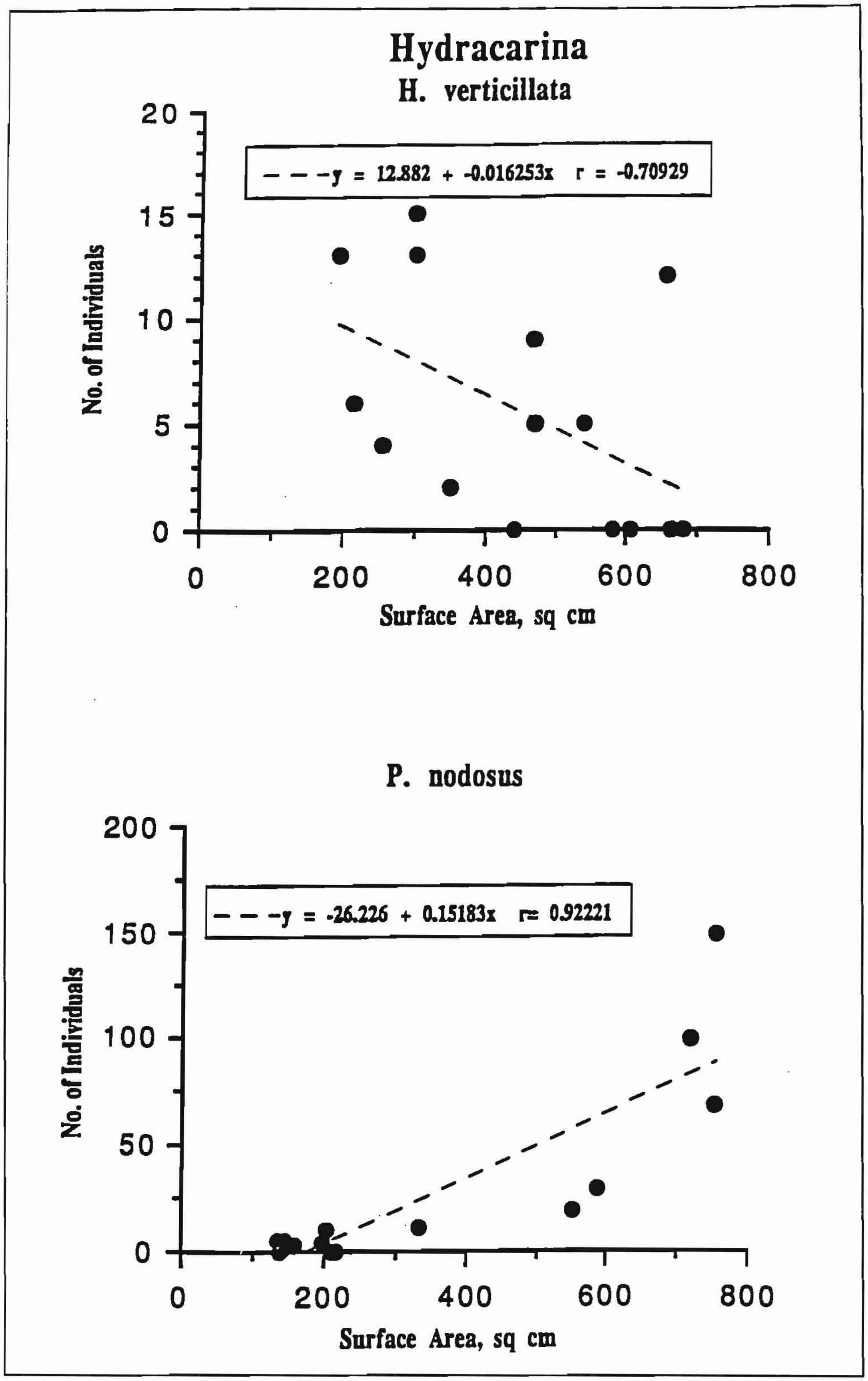

Figure 20. Relationship between surface area and number of Hydracarina collected from two macrophyte species

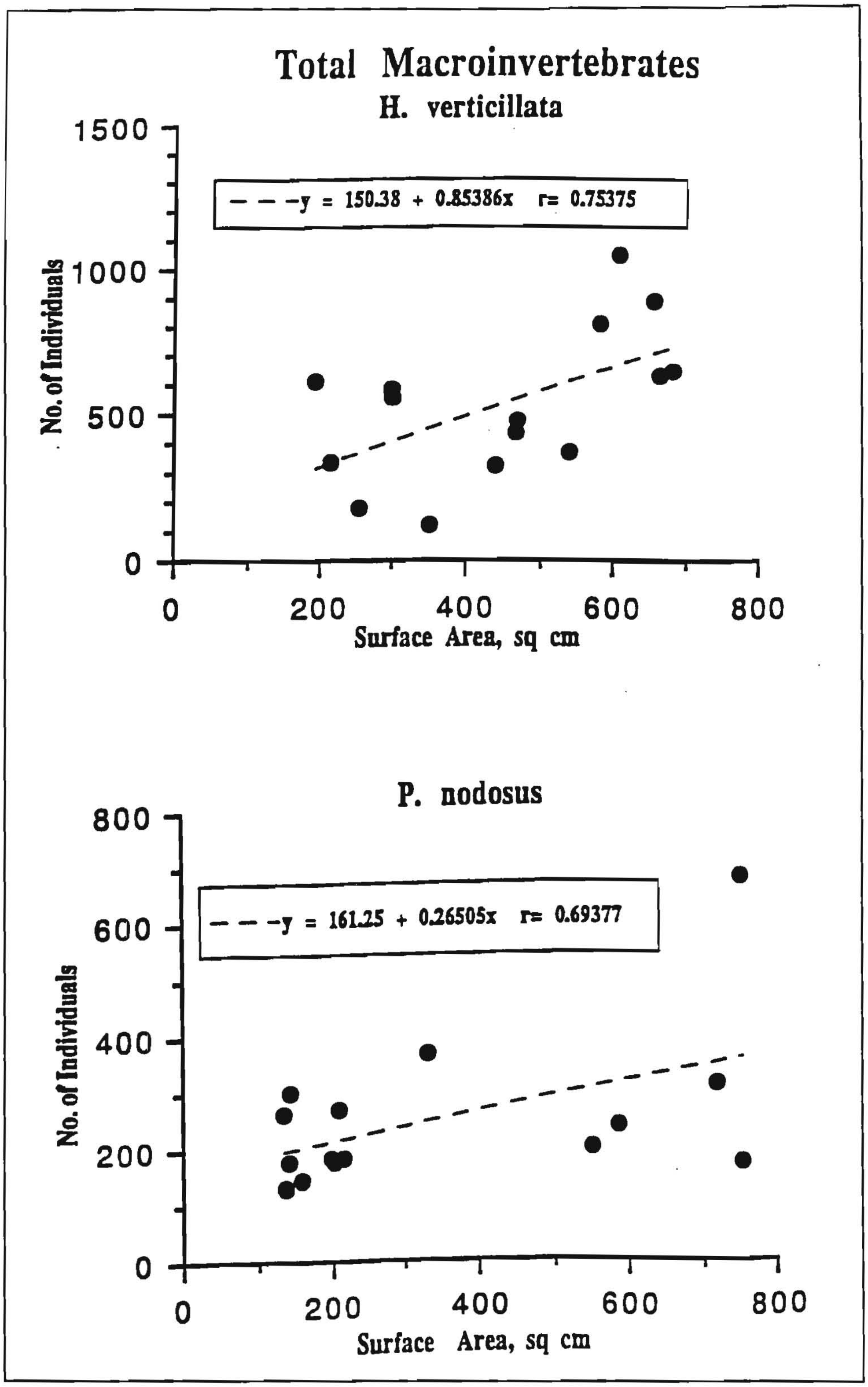

Figure 21. Relationship between surface area and number of total macroinvertebrates collected from two macrophyte species

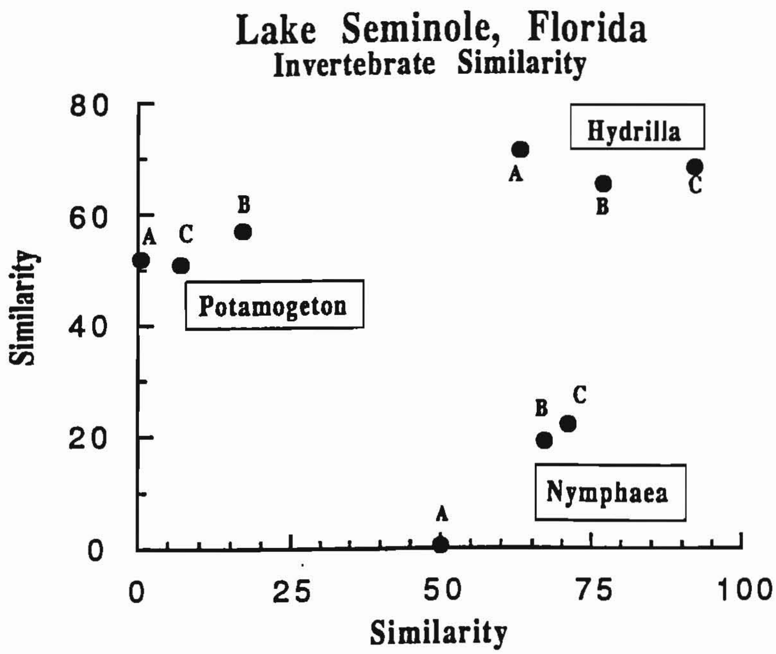

Figure 22. Ordination diagram of the relationships between the macroinvertebrate communities present on three macrophyte species

Table 1
Mean Density (number/square meter) of Macroinvertebrates Collected in Sediments in a Bed of *H. verticillata* (HAD), a Mixture of *P. nodous* and *H. verticillata* (PTM/HAD), a Nonvegetated Cove (NVC), and a Nonvegetated Littoral Area (NVL) in Lake Seminole, Georgia, July 14, 1987

Taxon	HAD	PTM/HAD	NVC	NVL
Turbellaria				
Dugesia tigrina		197.4		
Nematoda	164.5		32.9	32.9
Copepoda	164.5	32.9	723.7	
Ostracoda			625.0	
Cladocera	164.5	65.8	98.7	
Amphipoda				
Hyalella azteca		65.8		
Hydracarina	65.8		230.3	32.9
Odonata (e.i)[1]		65.8	65.8	
Ephemeroptera				
Caenis sp.	32.9			
Hemiptera				
Merragata sp.			32.9	
Trichoptera				
Orthotrichia sp.		32.9		32.9
Oxyethira sp.		98.7		
Polycentropus sp.		65.8		
Coleoptera				
Bidessini	32.9			
Mollusca				
Gyraulus sp.		65.8		32.9
Physa sp.		32.9		
Pelecypoda				
Corbicula fluminea			65.8	65.8
Oligochaeta				
Allonais pectinata	131.6	32.9	328.9	65.8
Aulodrilus pigueti				32.9
Branchiura sowerbyi				263.1
Dero pectinata	230.3	32.9	65.8	32.9
Dero trifida				559.2
Limnodrilus hoffmeisteri		65.8	164.5	32.9
Limnodrilus udekemianus	32.9			
Pristina leidyi	32.9	230.3	197.4	32.9
Stylaria lacustris		65.8		65.8

(*Continued*)

Note: Fifteen replicates were taken from each habitat type.
[1] Early instar, not identifiable to genus.

Table 1 (Concluded)

Taxon	HAD	PTM/HAD	NVC	NVL
Tubificidae- No Capilliforms[2]	32.9	526.3	625.0	65.8
Tubificidae-Capilliforms[3]	197.4	164.5	65.8	197.4
Diptera (Chironomidae)				
Ablabesmyia peleensis			32.9	
Cladotanytarsus sp.		65.8	756.5	131.6
Clinotanypus sp.		98.7		32.9
Cryptochironomus sp.			65.8	
Djalmabatista pulcher				32.9
Endochironomus sp.		32.9		
Larsia sp.			131.6	
Labrundinia neopilosella				32.9
Polypedilum illinoense		65.8	197.4	
Procladius sp.		32.9		
Pseudochironomus sp.	32.9	65.8	32.9	328.9
Tanytarsus sp.	98.7	32.9	65.8	394.7
Thienemanniella nr. *fusca*		32.9		
Thienemanniella nr. *xena*	32.9			
Tanypodinae[1]	32.9		32.9	
Other Diptera				
Chaoborus sp.		98.7		
Dasyhelea sp.				32.9
Total density	1,480.2	2,368.3	4,638.0	2,532.8

[2] Immature tubificidae without capilliform chaetae.
[3] Immature tubificidae with capilliform chaetae.

Table 2
Mean Density (number/square meter) and Percentages of Macro-invertebrates Collected in Sediments in a Bed of *H. verticillata* (HAD), a Mixture of *P. nodous* and *H. verticillata* (PTM/HAD), a Nonvegetated Cove (NVC), and a Nonvegetated Littoral Area (NVL) in Lake Seminole, Georgia, July 14, 1987

	HYD		PTM/HYD		NVC		NVL	
Taxon	Density	%	Density	%	Density	%	Density	%
Amphipoda			65.8	2.8				
Bivalvia					65.8	1.4	65.8	2.6
Heleidae							32.9	1.3
Chaorboridae			98.7	4.2				
Chironomidae	197.4	13.3	427.6	18.1	1317.2	28.4	953.9	37.7
Coleoptera	32.9	2.2						
Hemiptera					32.9	0.7		
Hydracarina	65.8	4.4			230.3	5.0	32.9	1.3
Odonata			65.8	2.8	65.8	1.4		
Oligochaeta	678.0	44.4	1118.4	47.2	1447.3	31.2	1348.6	53.2
Turbellaria			197.4	8.3				
Trichoptera	32.9	2.2	197.4	8.3			32.9	1.3
Copepoda	164.5	11.1	32.9	1.4	723.7	15.6		
Ostracoda					625.0	13.5		
Cladocera	164.5	11.1	65.8	2.8	98.7	2.1		
Nematoda	164.5	11.1			32.9	0.7	32.9	1.3
Total Density	1,480.5		2,386.3		4,638.0		2,532.8	

Note: Fifteen replicates were taken from each habitat type.

Table 3
Results from an Analysis of Variance of Invertebrate Densities (individuals/square meter) for Macroinvertebrates Collected in Sediments in a Bed of *H. vertilliata* (HAD), a Mixture of *P. nodous* and *H. verticillata* (PTM/HYD), a Nonvegetated Cove (NVC), and a Nonvegetated Littoral Area (NVL) in Lake Seminole, Georgia, July 14, 1987

Taxon	F ratio	F probability
Chironomidae	4.92	0.0042**
Oligochaeta	0.65	0.5886
Turbellaria	3.38	0.0245*
Trichoptera	2.89	0.0433*
Chaorboridae	3.50	0.0212*
Nematoda	2.55	0.0649
Total Invertebrates	1.37	0.2616

Note: Fifteen replicates were collected from each habitat type. Significance less than 0.05 is indicated by *, and significance less than 0.001 is indicated by **.

Table 4
Results from Duncan's Multiple Range Test for Macroinvertebrates (number/square meter) Collected in Sediments Among *H. verticillata* (HAD), a Mixture of *P. nodous* and *H. verticillata* (PTM/HAD), a Nonvegetated Cove (NVC), and a Nonvegetated Littoral Area (NVL) in Lake Seminole, Georgia, July 14, 1987

	Habitat Type			
Group	HAD	PTM/HAD	NVC	NVL
Chironomidae	197.4^{c}	427.5^{bc}	$1,315.6^{a}$	953.9^{ba}
Oligochaeta	657.7^{a}	$1,118.3^{a}$	$1,447.3^{a}$	$1,348.6^{a}$
Turbellaria	32.9^{b}	164.4^{a}	0.0^{b}	0.0^{b}
Trichoptera	32.9^{b}	197.3^{a}	0.0^{b}	32.9^{b}
Nematoda	164.4^{a}	0.0^{b}	32.9^{ba}	32.9^{ba}
Total	$1,842^{a}$	$2,434^{a}$	$6,085^{a}$	$2,533^{a}$

Note: Fifteen replicates were taken from each habitat type. Values with dissimilar superscripts were significantly different ($P > 0.05$).

Table 5
Percentages of Chironomidae Collected in Sediments in a Bed of *H. verticillata* (HAD), a Mixture of *P. nodous* and *H. verticillata* (PTM/HAD), a Nonvegetated Cove (NVC), and a Nonvegetated Littoral Area (NVL) in Lake Seminole, Georgia, July 14, 1987

Taxon	HAD	PTM/HAD	NVC	NVL
Ablabesmyia peleensis			2.6	
Cladotanytarsus sp.		15.4	59.0	13.8
Clinotanypus sp.		23.1		3.4
Cryptochironomus sp.			5.1	
Djalmabatista pulcher				3.4
Endochironomus sp.		7.7		
Labrundinia neopilosella				3.4
Larsia sp.			10.3	
Polypedilum illinoense		15.4	15.4	
Procladius sp.		7.7		
Pseudochironomus sp.	20.0	15.4	2.6	34.5
Tanytarsus sp.	60.0	7.7	5.1	41.4
Thienemanniella nr. *xena*	20.0			
Thienemanniella nr. *fusca*		7.7		
Total density	164.5	427.6	1,282.8	953.9

Note: Fifteen replicates were taken from each habitat type.

Table 6
Percentages of Species of Oligochaetes Collected Among *H. verticillata* (HAD), a Mixture of *P. nodous* and *H. verticillata* (PTM/HAD), a Nonvegetated Cove (NVC), and a Nonvegetated Littoral Area (NVL) in Lake Seminole, Georgia, July 14, 1987

Taxon	HAD	PTM/HAD	NVC	NVL
Allonais pectinata	30.8	7.7	43.5	6.1
Aulodrilus pigueti				3.0
Branchiura sowerbyi				24.2
Dero trifida				51.5
Dero pectinata	53.8	7.7	8.7	3.0
Limnodrilus udekemianus	7.7			
Limnodrilus hoffmeisteri		15.4	21.7	3.0
Pristina leidyi	7.7	53.8	26.1	3.0
Stylaria lacustris		15.4		6.1
Total density	427.6	427.6	756.5	1,085.5

Note: Fifteen replicates were taken from each habitat type.

Table 7
Total Mean Densities (per square meter of plant surface area) of Major Macroinvertebrate Groups Collected from Individual Plants of *H. verticillata* (HAD), *N. odorata* (NYM), and *P. nodous* (PTM) at Lake Seminole, Georgia, July 14, 1987

Taxon	HAD	NYM	PTM
Cnidaria			
Hydra sp.			27
Turbellaria			
Dugesia tigrina	3		5
Nematoda	4,459	1,849	879
Oligochaeta			
Aeolosomatidae		15	3
Allonais pectinata	2,438	166	823
Chaetogaster diaphanus	129	14	79
Dero furcata		11	10
Dero nivea	272	2	15
Dero pectinata	403	434	196
Nais pardalis	129		402
Nais simplex	8		180
Pristina aequiseta	1	29	14
Pristina leidyi	757	90	181
Stylaria lacustris	1		4
Cladocera	150	97	176
Ostracoda	122	1,038	231
Copepoda	34	82	51
Hydracarina	178	1,590	473
Ephemeroptera			
Caenis sp.	20		4
Cloeon sp.	19		
Odonata			
Enallagma sp.			
Ischnura complex	6		
Coenagrionidae[1]	8		
Hemiptera			
Merragata sp.	6	4	
Trichoptera			
Orthotrichia sp.			9
Oxyethira sp.	15	1	250
Lepidoptera			
Pyralidae		29	47

(Continued)

Note: Fifteen replicates were taken from each macrophyte species.
[1] Early instar, not identifiable to genus.

Table 7 Concluded

Taxon	HAD	NYM	PTM
Coleoptera			
Bidesinni	52	7	4
Notomicrus nanulus	3	8	
Diptera (Chironomidae)			
Ablabesmyia peleensis	14	63	27
Cricotopus sp.	3		11
Dicrotendipes sp.	64		13
Endochironomus sp.		1	
Labrundinia neopilosella	12	4	5
Larsia sp.	194	31	36
Nanocladius sp.	3		
Nilothauma sp.	1		
Parachironomus abortivus gr.	15	60	72
Parakiefferiella sp.	501	3	18
Polypedilum bergi		1	9
Polypedilum illinoense	21	112	388
Polypedilum laetum		99	98
Psectrocladius sp.	342	3	1,324
Pseudochironomus sp.	601	5	240
Tanytarsus sp.	1,245	3	169
Thienemanniella nr. *fusca*	284	9	2,945
Chironomoni[1]	27	18	76
Orthocladiinae[1]			20
Tanypodinae[1]	5	9	7
Other Diptera			
Bezzia complex	177	11	107
Dasyhelia sp.	81	1	5
Hydrellia sp.		2	14
Heleidae pupae	1	4	17
Chironomidae Pupae	14	3	13
Mollusca			
Gyraulus sp.	28	3	10
Physa sp.		8	5
Lymnaea sp.		1	1
Total mean density	12,846.0	5,931.0	9,732.0

Table 8
Total Mean Densities (per square meter of plant surface) of Major Macroinvertebrate Groups Collected from Individual Plants of *H. verticillata* (HAD), *N. odorata* (NYM), and *P. nodous* (PTM) at Lake Seminole, Georgia, July 14, 1987

Taxon	HAD	NYM	PTM
Chironomidae	3,347	425	5,469
Nematoda	4,459	1,849	879
Oligochaeta	4,138	760	1,906
Hydracarina	178	1,590	473
Ostracoda	122	1,038	231
Caldocera	150	97	176
Ceratopogonidae	260	16	129
Trichoptera	35	1	263
Copepoda	34	82	51
Lepidoptera		29	47
Coleoptera	55	15	4
Gastropoda	28	13	16
Hydra			27
Ephemeroptera	19		
Diptera (non chironomids)		2	14
Hemiptera	6	4	
Odonata	8		
Turbellaria	3		5
Mean density	12,843	5,922	9,689

Note: Fifteen replicates were taken from each macrophyte species.

Table 9
Percentages of Major Macroinvertebrate Groups Collected from Individual Plants of *H. verticillata* (HAD), *N. odorata* (NYM), and *P. nodous* (PTM) at Lake Seminole, Georgia, July 14, 1987

Taxon	HAD	NYM	PTM
Chironomidae	26.1	7.5	56.4
Nematoda	34.7	30.5	9.1
Oligochaeta	32.2	12.7	19.7
Hydracarina	1.4	27.7	4.9
Ostracoda	0.9	17.4	2.4
Cladocera	1.2	1.6	1.8
Ceratopogonidae	2.0	0.3	1.3
Trichoptera	0.3	--	2.7
Copepoda	0.3	1.4	0.5
Lepidoptera	--	0.5	0.5
Coleoptera	0.4	0.2	--
Gastropoda	0.2	0.2	0.2
Hydra	--	--	0.3
Diptera (others)	--	--	0.1
Ephemeroptera	0.1	--	--
Hemiptera	--	0.1	--
Odonata	0.1	--	--
Turbellaria	<0.1	--	<0.1
Mean density	12,843	5,922	9,689

Note: Fifteen replicates were taken from each macrophyte species.

Table 10
Results from an Analysis of Variance of Total Macroinvertebrate Densities (individuals/square meter) Obtained from Three Aquatic Macrophyte Species from Lake Seminole, Georgia, July 14, 1987

Taxon	F ratio	F probability
Chironomidae	10.78	0.0002**
Oligochaeta	10.70	0.0002**
Hydracarina	21.90	0.0001**
Cladocera	0.26	0.7741
Copepoda	2.33	0.1099
Ceratopogonidae	2.58	0.0879
Coleoptera	6.52	0.0034**
Gastropoda	0.60	0.5540
Trichoptera	9.63	0.0004**
Ostracoda	6.15	0.0045**
Nematoda	8.45	0.0008**
Total	5.85	0.0058**

Note: The aquatic macrophytes were *H. verticillata*, *N. odorata*, and *P. nodous*. Fifteen replicates were collected form each macrophyte species. A significance of $P < 0.001$ is represented by **.

Table 11
Results from Duncan's Multiple Range Test of Mean Total Macroinvertebrate Densities Collected from *H. vertilliata* (HAD), *N. odorata* (NYM), and *P. nodous* in Lake Seminole, Georgia, July 14, 1987

Taxon	HAD	NYM	PTM
Chironomidae	3,347.0^{a}	425.0^{b}	5,469.0^{a}
Oligochaeta	4,138.0^{a}	761.0^{b}	1,906.0^{b}
Hydracarina	178.3^{3}	1,590.0^{b}	473.0^{a}
Cladocera	178.0^{b}	97.0^{a}	176.0^{b}
Copepoda	33.8^{a}	81.9^{a}	51.3^{a}
Ostracoda	121.9^{b}	1,037.9^{a}	230.6^{ba}
Nematoda	4,459.4^{a}	1,848.7^{b}	878.7^{b}
Trichoptera	35.1^{b}	1.4^{b}	263.1^{a}
Coleoptera	55.3^{a}	14.9^{b}	4.2^{b}
Total	12,843.0^{a}	5,922.0^{b}	9,689.0^{ba}

Note: Fifteen replicates were taken from each macrophyte species. Densities with dissimilar superscripts are significantly different ($P < 0.05$).

Table 12
Percentages of Species of Chironomidae Collected from Individual Plants of *H. verticillata* (HAD), *N. odorata* (NYM), and *P. nodous* (PTM) at Lake Seminole, Georgia, July 14, 1987

Taxon	HAD	NYM	PTM
Ablabesmyia peleensis	0.4	16.0	0.5
Cricotopus sp.	0.1		0.2
Dicrotendipes sp.	2.0		0.2
Endochironomus sp.		0.3	
Labrundinia neopilosella	0.4	1.1	0.1
Larsia sp.	5.9	7.9	0.7
Nanocladius sp.	0.1		
Nilothauma sp.	1.0		
Parachironomus abortivus gr.	0.4	15.1	1.3
Parakiefferiella sp.	15.2	0.7	0.3
Polypedilum laetum		25.1	1.8
Polypedilum illinoense	0.6	28.3	7.3
Polypedilum bergi	0.0	0.3	0.2
Psectrocladius sp.	10.3	0.9	24.7
Pseudochironomus sp.	18.2	1.3	4.5
Tanytarsus sp.	37.7	0.7	3.2
Thienemanniella nr. *fusca*	8.6	2.3	55.0

Note: Fifteen replicates were taken from each macrophyte species.

Table 13
Percentages of Oligochaeta Species Collected from Individual *H. verticillata* (HAD), *N. odorata* (NYM), and *P. nodous* (PTM) at Lake Seminole, Georgia, July 14, 1987

Taxon	HAD	NYM	PTM
Allonais pectinata	58.9	22.2	43.2
Chaetogaster diaphanus	3.1	1.9	4.1
Dero furcata		1.5	0.5
Dero pectinata	9.7	58.2	10.3
Dero nivea	6.6	0.2	0.8
Nais pardalis	3.1		21.1
Nais simplex	0.2		9.4
Pristina leidyi	18.3	12.1	9.5
Pristina aequiseta		3.9	0.8
Stylaria lacustris			0.2

Note: Fifteen replicates were taken from each macrophyte species.

Table 14
Correlation Coefficients Relating Macrophyte Surface Areas (square meters) for *H. verticillata*, (HAD) *N. odorata* (NYM), and *P. nodous* (PTM) with Total Density for Selected Macroinvertebrate Groups

Taxon	HAD	NYM	PTM
Chironomidae	0.63*	0.26	-0.82**
Cladocera	0.26	-0.18	0.36
Copepoda	-0.27	0.51	0.88**
Hydracarina	-0.71**	0.45	0.92**
Nematoda	0.54*	0.45	0.80*
Oligochaeta	0.73*	0.38	0.27
Ostracoda	-0.70**	-0.83**	0.86**
Total	0.75*	0.25	0.69**

Note: Samples were collected from Lake Seminole, Georgia, July 14, 1987. Significant at the 0.05 level is denoted with *, and significant at the 0.01 level is denoted with **.

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13. ABSTRACT *(Maximum 200 words)*
In July 1987, entire plant samples and quantitative total substratum samples were collected in Lake Seminole, Florida, to analyze the effects of three species of plants (*Hydrilla verticillata*, *Potamogeton nodosus*, and *Nymphaea odorata*) on macroinvertebrate density and community composition. The study was designed to examine epiphytic (attached to plant surfaces) as well as benthic organisms (living on or just beneath the sediment surface).

Fifteen macroinvertebrate taxonomic groups were identified from four different habitat types in Lake Seminole. Mean total macroinvertebrate density was greatest in sediments in the nonvegetated cove (4,638.0 individuals/square meter) and least in sediments beneath *H. verticillata* (1,480.2 individuals/square meter). Oligochaeta and Chironomidae had the greatest taxa richness of all groups present; a total of nine oligochaete and 14 chironomid taxa were identified. The only bivalve mollusc identified was the Asian clam *Corbicula fluminea*, and only two genera of gastropods were collected (*Gyraulus* sp. and *Physa* sp.). Duncan's multiple range test revealed that chironomid density in *H. verticillata* (197 individuals/square meter) was significantly less than density in the nonvegetated cove (1,315 individuals/square meter) and nonvegetated littoral zone (953 individuals/square meter).

A total of 16 taxonomic groups were identified on three species of macrophytes in Lake Seminole. Total macroinvertebrate density was greatest on *H. verticillata* (12,855 individuals/square meter) and least on *N. odorata*

(Continued)

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(5,931 individuals/square meter). Fourteen taxonomic groups were common to the stems and leaves of these three macrophyte species and the benthic sediments. There were significant positive correlations ($P < 0.05$) between plant surface area and total density for nine macroinvertebrate groups. Chironomids were positively correlated to the surface area of *H. verticillata* but negatively correlated to surface area of *P. nodosus* (-0.82). Densities of Hydracarina and Ostracoda were negatively correlated to surface area of *Hydrilla* (-0.71 and -0.70, respectively). Each plant species had a specific and characteristic macroinvertebrate fauna, regardless of where it was physically located.