Comparison of Periphyton and Invertebrates on Three Species of Macrophytes

BIOS 569 - Practicum in Aquatic Biology

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1991

Abstract

Macrophytes serve as habitat to many invertebrates. The number and diversity of invertebrates depends on a number of factors, including protection, space, and food availability. With field sampling, I compare the densities per unit surface area of invertebrate taxa found on three species of macrophytes, *Nuphar variegatum*, *Sparganium fluctuans*, and *Isoetes braunii* from Long Lake in Gogebic Co., Michigan. Significantly higher densities of algal biomass, total invertebrates, and several specific invertebrate taxa, including Cladocera and Diptera of the family Chironomidae, occurred on Isoetes relative to the other two species (ANOVA, $p < 0.05$). This result may have been the consequence of habitat preference due to the architecture (size, leaf dissection, etc.), of the *Isoetes* plants. Apparent preferences may also have been spurious, however, because the *Isoetes* samples contained a large amount of detritus from the lake bottom that inflated algal biomass and may have also added invertebrates to the samples. Also, high densities of Hemiptera of the genus *Plea* were found on the *Nuphar*, but the reasons for this are unclear.

Introduction

Macrophytes serve several important functions in benthic communities. They produce oxygen and biomass through photosynthesis. Rooted macrophytes anchor sediments and transport nutrients, such as phosphorus, out of the sediments and into the open water during both active growth (Twilley et al. 1977) and decay (Carpenter 1980).

In addition, macrophytes serve as habitat for littoral zone invertebrates. The dynamics of macrophyte- invertebrate interactions have been the subject of a number of studies, and may be the result of factors such as predator avoidance, food availability, and living space (Riemer 1984).

Many experiments have sought to dissect the importance of these factors. For instance, Benke (1976) has suggested that voracious predators such as dragonflies can annihilate prey populations unless their prey species can find protective cover. Gilinsky (1984) also observed that, in areas of bluegill predation, "The presence of plants led to increases both in species richness and in density of most macroinvertebrates." She suggests that the macrophytes provide refuges for the macroinvertebrates and interfere with the foraging efficiency of the predator.

Some experiments have suggested evidence to the contrary. Bell and Westoby (1986) thinned sea grass densities in cages and monitored changes in density of the organisms in the cages. They found that invertebrate densities varied equally among cages that excluded predators as those that included predators. This suggests that predation avoidance is not the most important reason for invertebrates finding cover among macrophytes.

In addition to refuge, macrophytes provide invertebrates with oxygen, an ammonia sink (Lodge et al. 1988), and a food source either directly (Carpenter and Lodge 1986) or via the periphyton on the surface of the macrophytes (Lamberti and Moore 1984).

Some evidence has suggested that many of these factors are related to the complexity of the macrophyte in question. For instance, the amount of leaf dissection may play a role in habitat preference by invertebrates. Cyr and Downing (1988) credit Krecker (1939) with the suggestion, "from qualitative observations, that plants with finely dissected leaves support systematically more invertebrates than plants with broad leaves." The dissection of the leaves primarily acts to increase the surface area of the leaf, allowing more space for periphyton growth and increased living space for invertebrates. In addition, the dissected leaves can catch small detrital particles that also serve as food for invertebrates, and the complexity of the finely dissected leaves may offer more protection than the flat blades of broader leaves.

When Cyr and Downing (1988) tested this model, however, they found that highest invertebrate densities occurred on both the most and least dissected plants, and that greater variation in invertebrate abundance occurred among broad-leaved plants than between the broad and dissected leaved categories. This suggests that leaf dissection is not the most important factor in abundance, particularly when some invertebrates are too large to be supported by the fragile, dissected leaves.

Substrate architecture, however, encompasses more characteristics that simply leaf dissection, and Kershner and Lodge (1990) found significant differences in snail colonization of balsa wood substrates when they tested for dissection, bottom contact, and usable surface area. This indicates that substrate architecture is one of the factors influencing abundance, and that this category itself consists of several components.

This experiment looks at invertebrate and periphyton densities on three species of macrophytes with different shapes: Nuphar variegatum, Sparganium fluctuans, and Isoetes braunii. It is meant as a comparison to another project (Garlitz, unpublished data) that tests the same factors on artificial macrophytes. The real and artificial macrophytes should produce similar colonization results, as macrophytes appear to be more important as a source of physical support for the periphyton community rather than a source of nutrients (Carignan and Kalff, 1982).

Specifically, I ask if different species of macrophytes support specific or characteristic abundances of invertebrates. Do certain invertebrate species or feeding groups exhibit preference for a certain species or shape of macrophyte? Do densities per unit area vary significantly between types of plants?

Materials and Methods

The plants were sampled from Central Long Lake on July 15, 1991, from 8:15 to 10:00 AM. The plants were collected near the south shore, at depths of .5m-1m. I snorkeled to reach the plants with minimum benthic disturbance. Plants were collected by slipping a plastic bag over the top of each plant, then extending the bag downwards to the base of the plant, while trying to disturb the periphyton and surrounding plants as little as possible. Nine samples of Nuphar, nine samples of Sparganium, and seven samples of Isoetes were collected. A sample consisted of one entire plant. The short height of the Isoetes and the deep and flocculent sediments made it very difficult to collect the Isoetes samples. Many contained a lot of lake-bottom detritus that was impossible to separate from the periphyton that actually occurred on the samples.

After the plants were collected, the bagged samples were processed in the lab. First, the contents of the bag were run through a 1mm sieve, and the water was collected. Then, the plants were rinsed through the sieve, and the periphyton was removed by hand. The sampled plants themselves were returned to labeled plastic bags and frozen. The invertebrates were picked out of the sample and preserved in vials of 90% ethanol. The volume of the water samples was measured, homogenized by mixing, and two subsamples, each 70ml, were filtered onto 4.7cm Whatman GF/F Glass Microfibre Filters of pore size 0.7 micrometers, using a filter pump. The amount of detritus in the Isoetes samples made it difficult to see organisms and inflated the filtration weights for the samples.

In September, the invertebrates in the vials were identified to family and recorded. The filters, which were dried both at UNDERC and on campus, were weighed, and periphyton biomass was estimated based on the volume of water in the total sample and an average filter weight of .1275g, an average of the weights of 99 filters of that size. The Nuphar samples were thawed, photocopied, and digitized using Sigma Scan software in order to get an accurate area accounting for the irregular shapes of and holes in the leaves. The areas of the Nuphar stems were calculated using the assumption that the stems were half-circular in cross section. The Sparganium and Isoetes plants were thawed and measured individually. The total area of the Isoetes was calculated assuming cylindrical blades and disregarding the tapering of the tips.

The area of the Sparganium was calculated by doubling the total measured length times and average width based on four measurements. An estimate of the floating portion of the Sparganium was made by counting the number of blades in each sample, and subtracting that area based on the assumption that 20cm of each blade was afloat and therefore had no periphyton growing on the top side. This was the closest estimate I could get from memory of the field work. This estimate, of course, could be incorrect, leading to incorrect reported areas.

An analysis of variance (ANOVA) compared the three sample plant species for ten different responses: periphyton biomass (g/m^2), total invertebrates ($individuals/m^2$), Cladocera ($individuals/m^2$), Coleoptera ($individuals/m^2$), Diptera ($individuals/m^2$), Hemiptera ($individuals/m^2$), mites ($individuals/m^2$) Odonata ($individuals/m^2$), Trichoptera ($individuals/m^2$), and other taxa ($individuals/m^2$).

Results

The plants sampled were of distinctly different shapes. *Nuphar* is a water lily composed of a .5-1m long semicircular blade with a 10-20cm peltiform floating leaf. A *Sparganium* plant consists of four to six flat blades, each roughly .75m long and 1cm wide. *Isoetes* is a submersed plant with about 30 cylindrical blades averaging 7cm long and 1mm wide.

ANOVA showed a significantly greater amount of periphyton biomass on the *Isoetes* plants relative to either the *Sparganium* or *Nuphar*, but no significant difference between the *Nuphar* and *Sparganium* (Fig 1). Significant differences in total invertebrates density were also found on *Isoetes* relative to *Nuphar* and *Sparganium* (Fig. 2). Significant differences in cladoceran density were found between *Isoetes* and *Nuphar* (Fig. 3A), in dipteran densities between *Isoetes* and *Sparganium* (Fig. 3C). Also, *Nuphar* had significantly higher densities of hemiptera, which were mostly of the genus *Plea*, relative to *Sparganium* and *Isoetes*, which contained no hemipterans. (Fig. 3D). There were no significant differences between densities on any of the other taxa (Figs. 3B, 3E-H). Dipterans of the family Chironomidae dominated the samples of each type of plant (Figs. 4-6).

Discussion

The results indicate that *Isoetes* differs from *Sparganium* and *Nuphar* in densities of some invertebrates, and that *Nuphar* and *Sparganium* do not differ significantly from each other. These results may be the consequence of the sampling procedure; specifically, the inclusion of lake-bottom detritus in the *Isoetes* samples. As mentioned earlier, a large amount of detritus was readily visible in the plastic sampling bags and on the filters, and much of this occurred around, rather than on, the Isoetes plants. This detritus contributed to the larger biomass values for the Isoetes samples. Although fewer organisms generally live on benthic sediments than on macrophytes (Riemer 1984), it is possible that invertebrates from the sediments were inadvertently included in the samples. Obviously, this would skew the results in favor of higher Isoetes densities.

If, however, the inclusion of sediments is not the cause of differences in invertebrate densities, substrate architecture may play a role. Sparganium and Nuphar are fairly similar in their size and lack of leaf dissection. Isoetes is much smaller, closer to the bottom, and more finely dissected than either of the other two plants. These differences could affect invertebrate densities in a number of ways. First of all, the dissection of the leaves of Isoetes could offer more hiding places for refuge from predators than the other types of plants. Second, the large amount of periphyton and detritus on and near the Isoetes plants a a richer food source than is available on the other plants. Third, the short stature and proximity to the bottom of the Isoetes might make them a more convenient habitat, since less climbing is required to find food and living space.

Predator avoidance is often cited as a major factor in invertebrate use of spatial heterogeneity. In this context, McPeek (1990) asserts "For a prey species to coexist with a predator in a given habitat, the prey species must possess morphological, physiological, or behavioral traits (i.e., antipredator defenses) that reduce the impact of that predator to levels where the prey species can maintain a population." One of these antipredator responses is hiding from predators. In the case of particularly voracious predators, seeking refuge in areas of high spatial heterogeneity is sometimes the only way that an organism can survive (Benke 1976). Predator avoidance, however, may not have been a factor in invertebrate preference of Isoetes in this case, because at the time of collection, there were few predators at the site. All fish had been removed from the lake six weeks prior to sampling as part of the Cascading Trophic Interactions project. In addition, collection revealed no sign of large predatory insects, such as odonates. Odonate densities were fairly low, although insignificantly higher on Isoetes. None of the odonates found were significantly larger than 1cm in length, however, so their threat to the other invertebrates is questionable. Consequently, hiding behavior of the invertebrates might disappear in these conditions.

Food availability is another possible cause for invertebrate preference of a particular substrate. Chironomids have been found to decrease the algal standing crop in outdoor artificial streams (Eichenberger and Shlatter 1978). Many cladocerans, such as Daphina, also use algae as a food source (Balcer, et. al. 1984). Many chironomids also feed by collecting detrital fine particulate organic material (Coffman and Ferrington 1984), which dominated the filtered samples of material on and around the Isoetes samples. Thus, the abundance of possible food items might be partly responsible for the higher number of insects on Isoetes.

In addition, positive correlations have been found between the amount of bottom contact of a substrate and the number of invertebrates (snails) colonizing it (Kershner and Lodge, 1990). While the actual amount of bottom contact of each sample was not measured, the Isoetes plants' small stature and number of small blades may facilitate colonization by organisms from in and on the sediments.

Hemiptera, primarily of the genus Plea, were found exclusively on the Nuphar plants. Plea are predaceous on microcrustecea and prefer dense stands of vegetation (Polhemus 1984). It is unknown why they occurred on the Nuphar samples.

In conclusion, architecture of a macrophyte, including its size, shape, dissection, and amount of bottom contact, may affect the numbers and types of invertebrates that live on the plant. Architecture may also contribute to other factors that influence the survival of an invertebrate, such as food availability and protection from predators.

Acknowledgments

I thank The Bernard J. Hank Family Endowment for the opportunity to study at UNDERC, David M. Lodge for advice and instruction, and Cristopher Garlitz for field work assistance on this project.

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Fig. 4. Percent abundances of taxa on *Isoetes*.

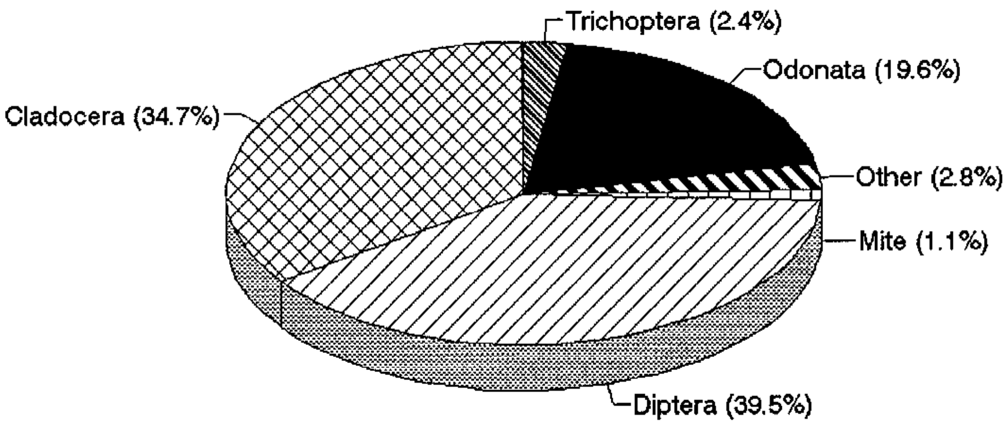


Fig. 5. Percent abundances of taxa on *Nuphar*.

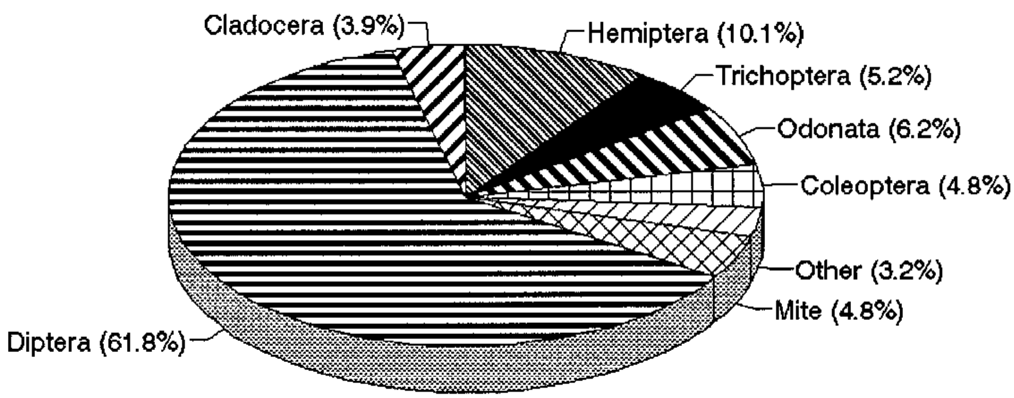
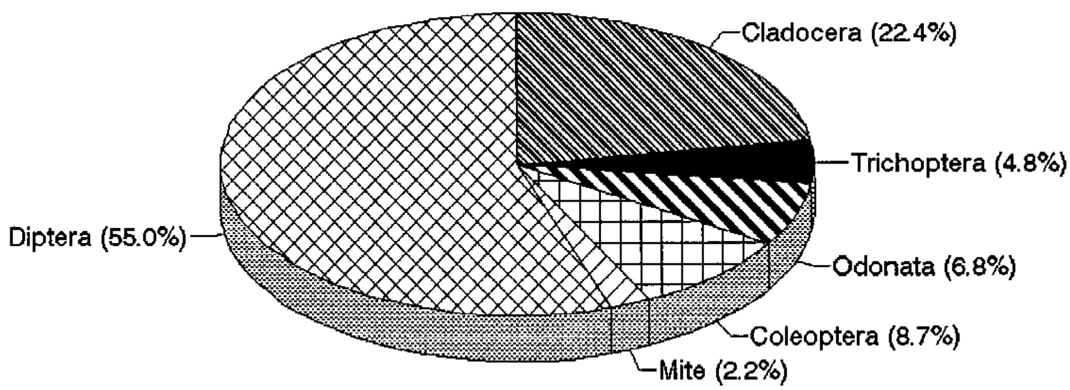


Fig. 6. Percent abundances of taxa on *Sparganium*.



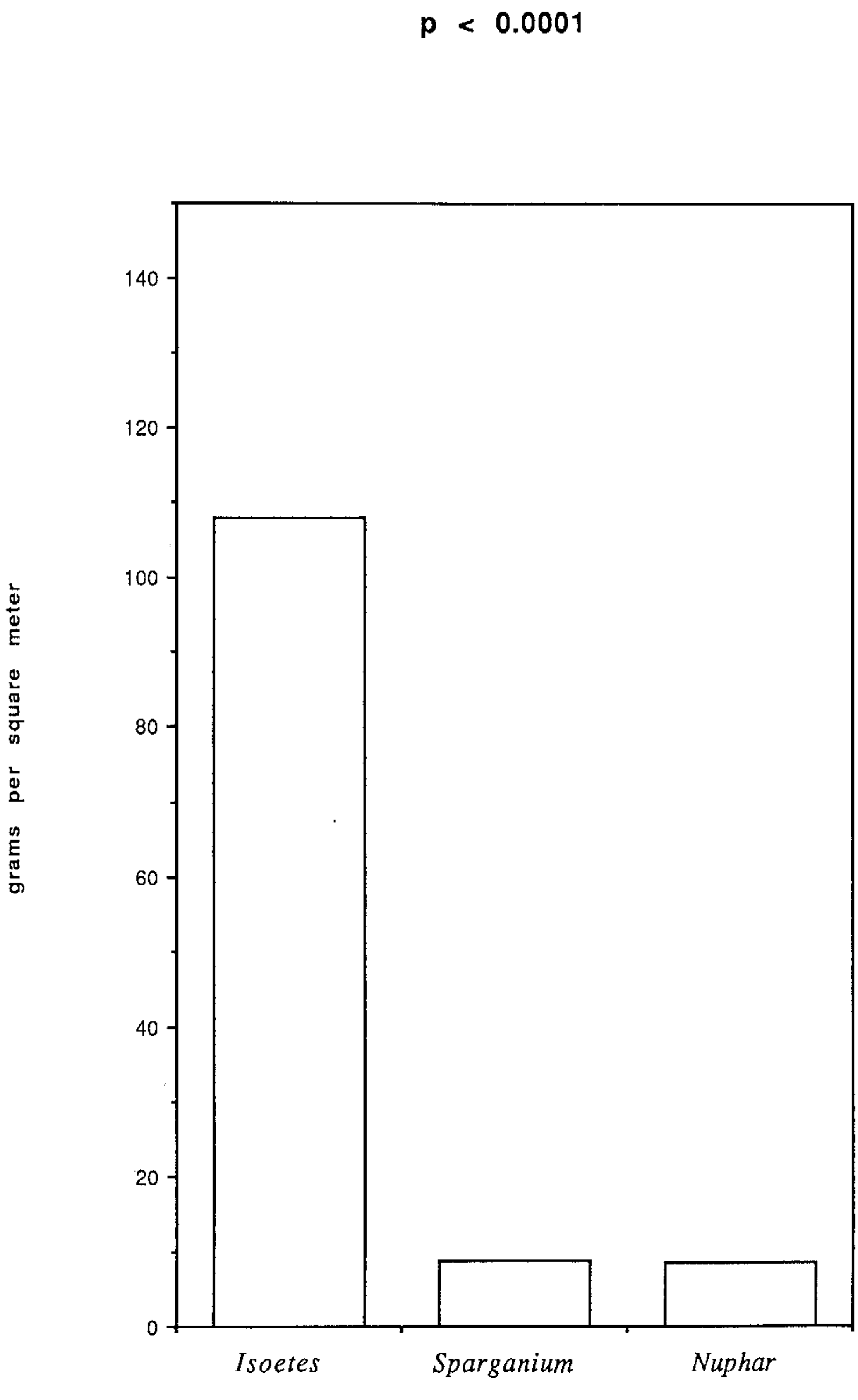


Fig. 1. Histogram of algal biomass on macrophyte species. Values are statistically significant ($p < 0.05$, Tukey's test) when not connected by a line.

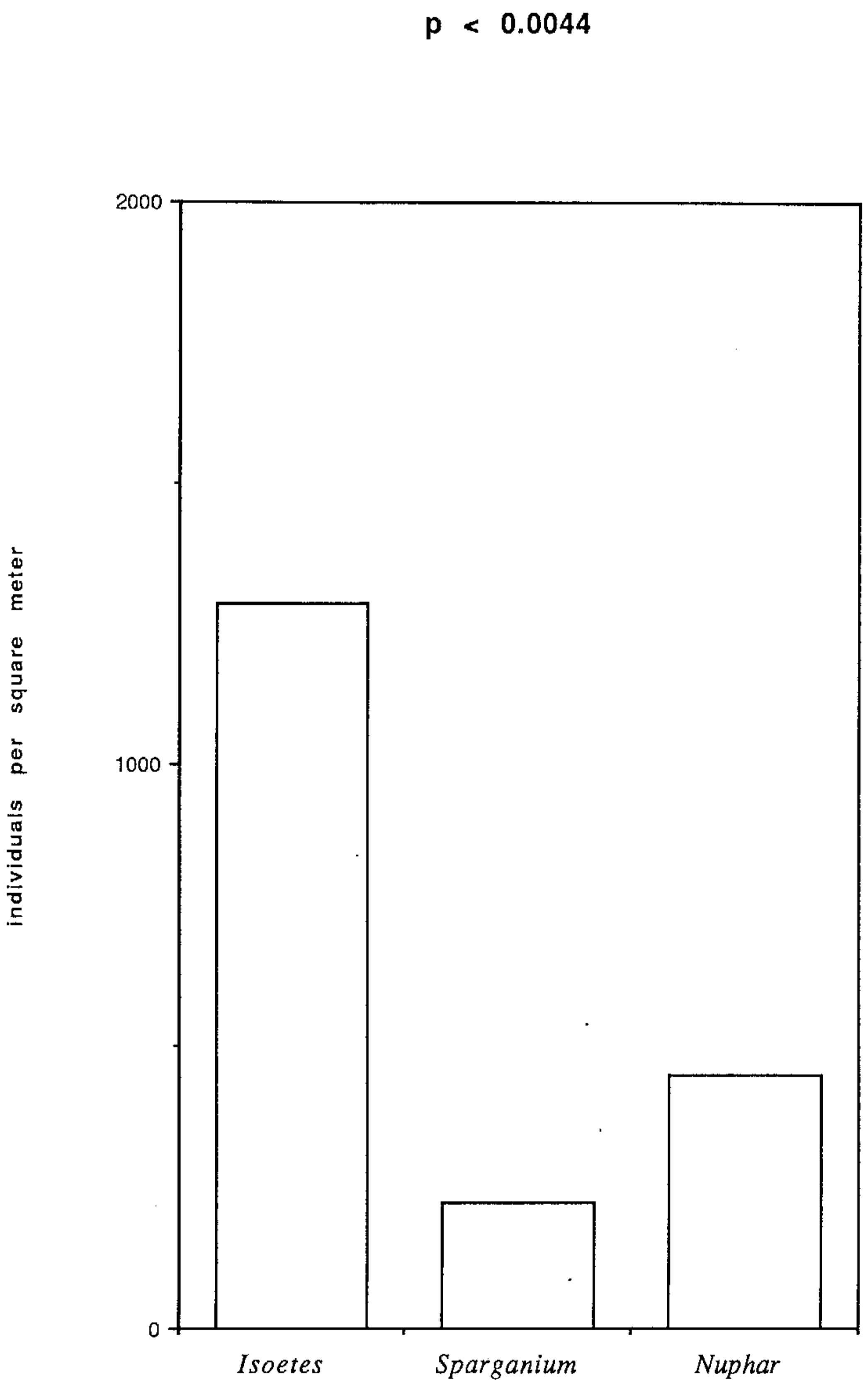


Fig. 2. Histogram of total invertebrate densities on three macrophyte species. Values are statistically significant ($p < 0.05$, Tukey's test) when not connected by a line.

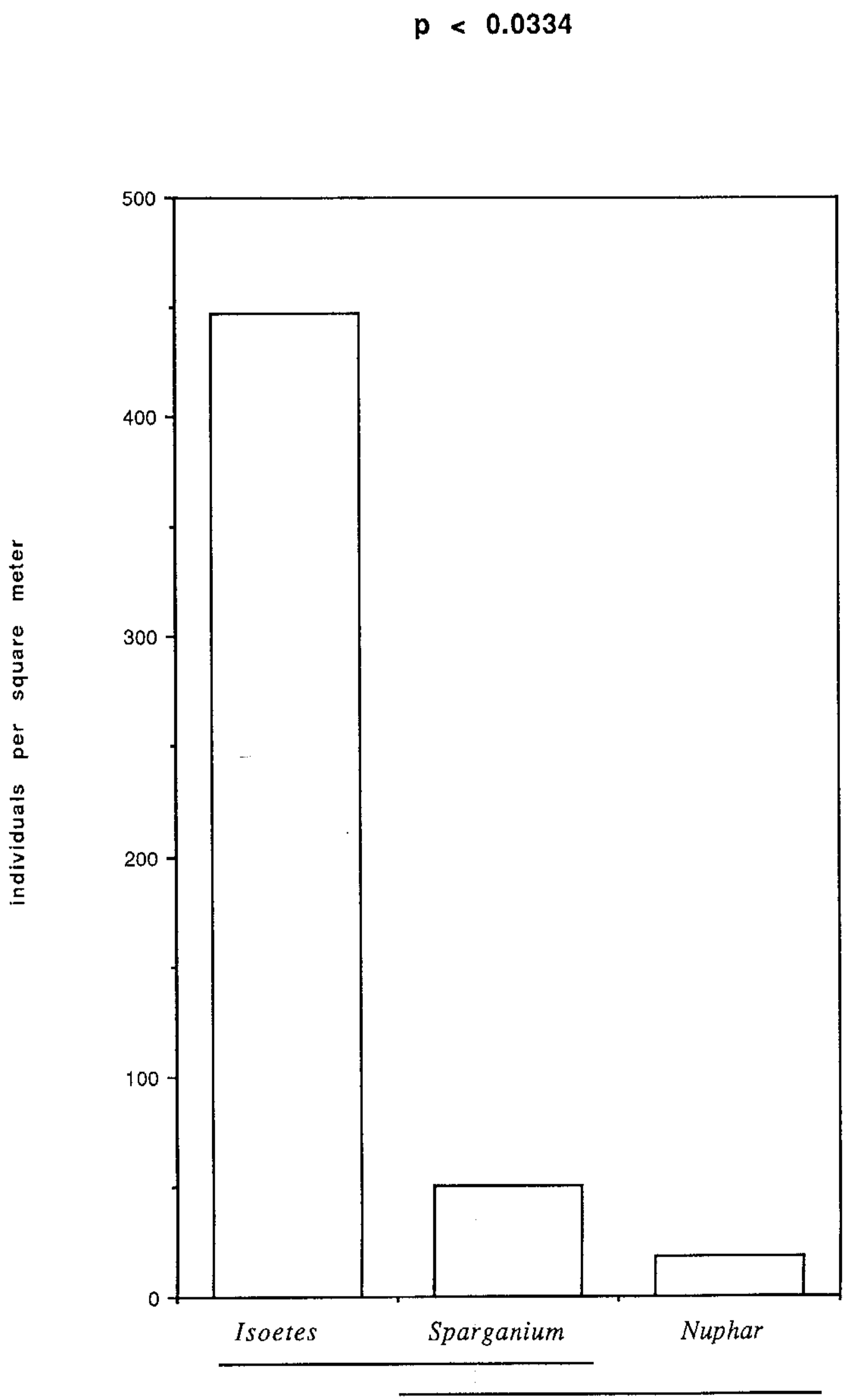


Fig. 3A. Histogram of cladoceran densities on three macrophyte species.

p < 0.1560

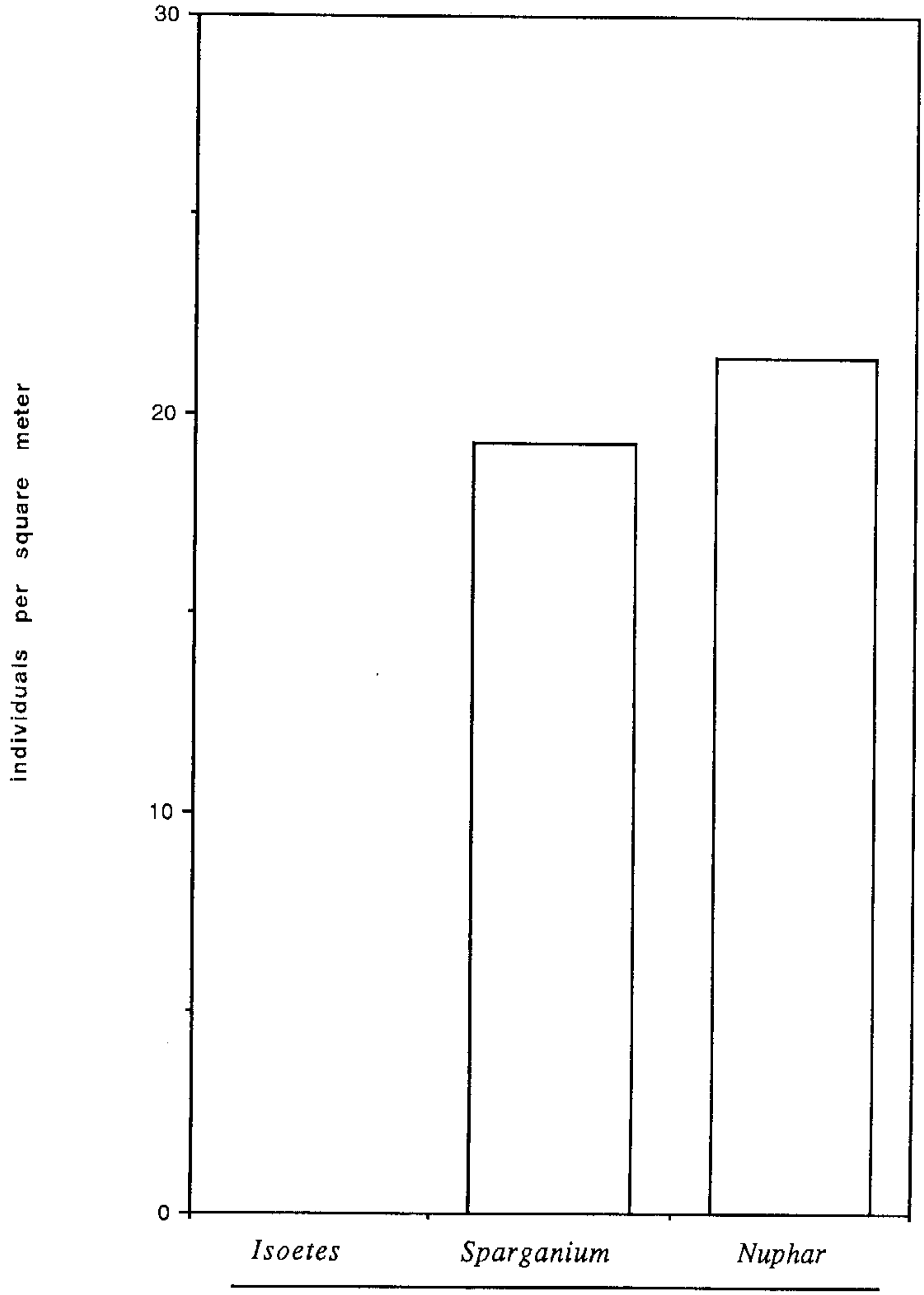


Fig. 3B. Histogram of coleopteran densities on three macrophyte species.

p < 0.0104

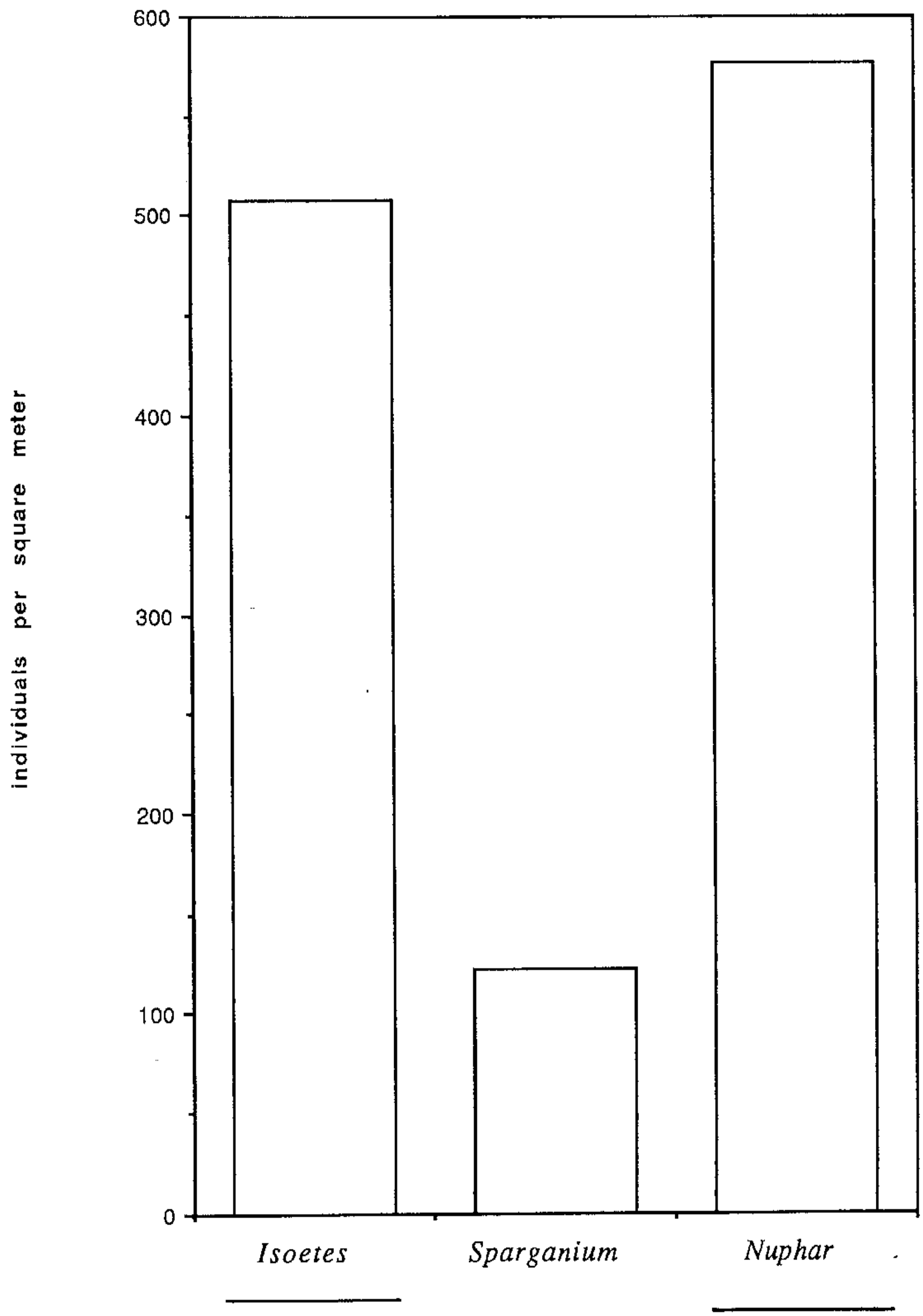


Fig. 3C. Histogram of dipteran densities on three macrophyte species.

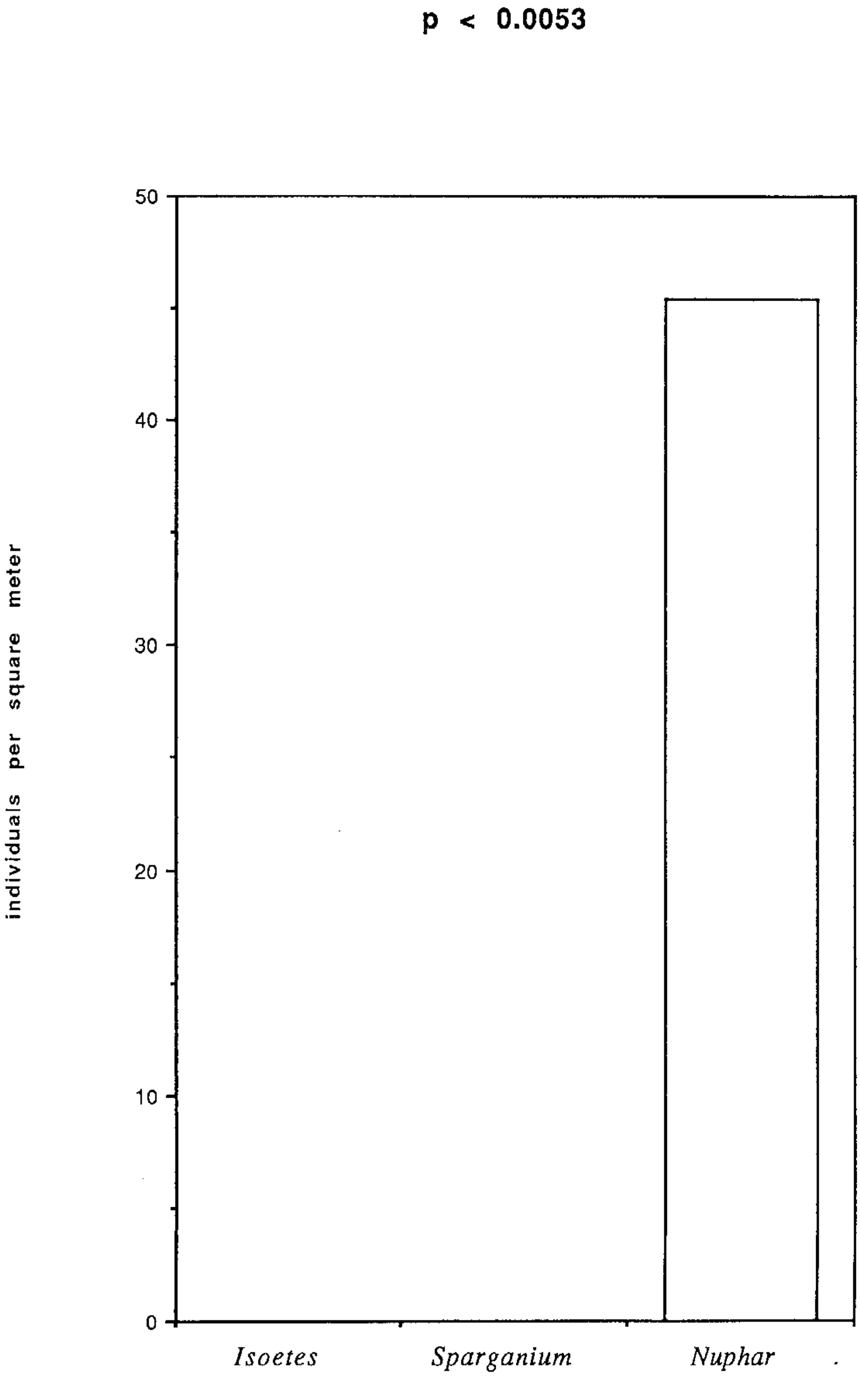


Fig. 3D. Histogram of hemipteran densities on three macrophyte species.

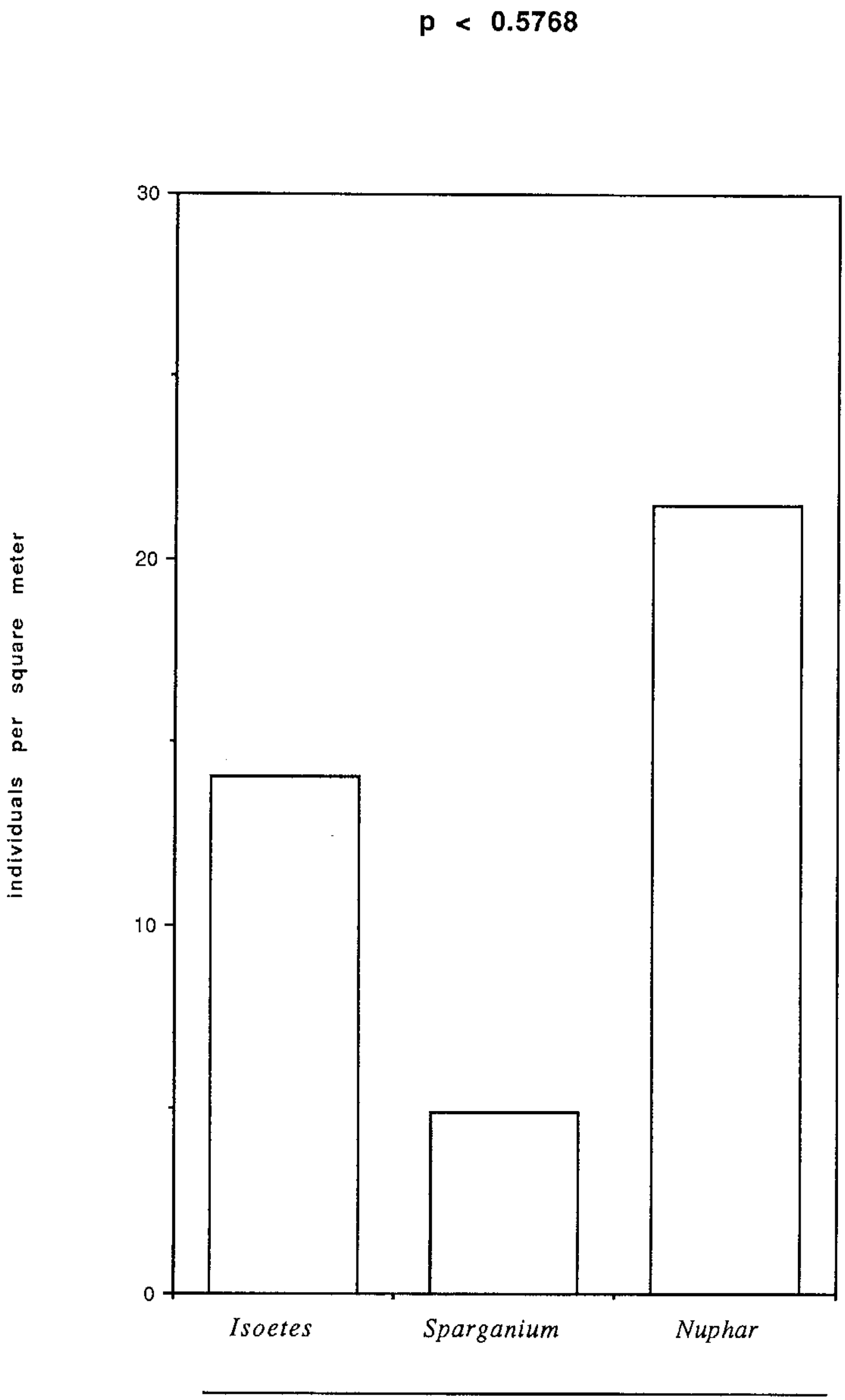


Fig. 3E. Histogram of mite densities on three species of macrophyte.

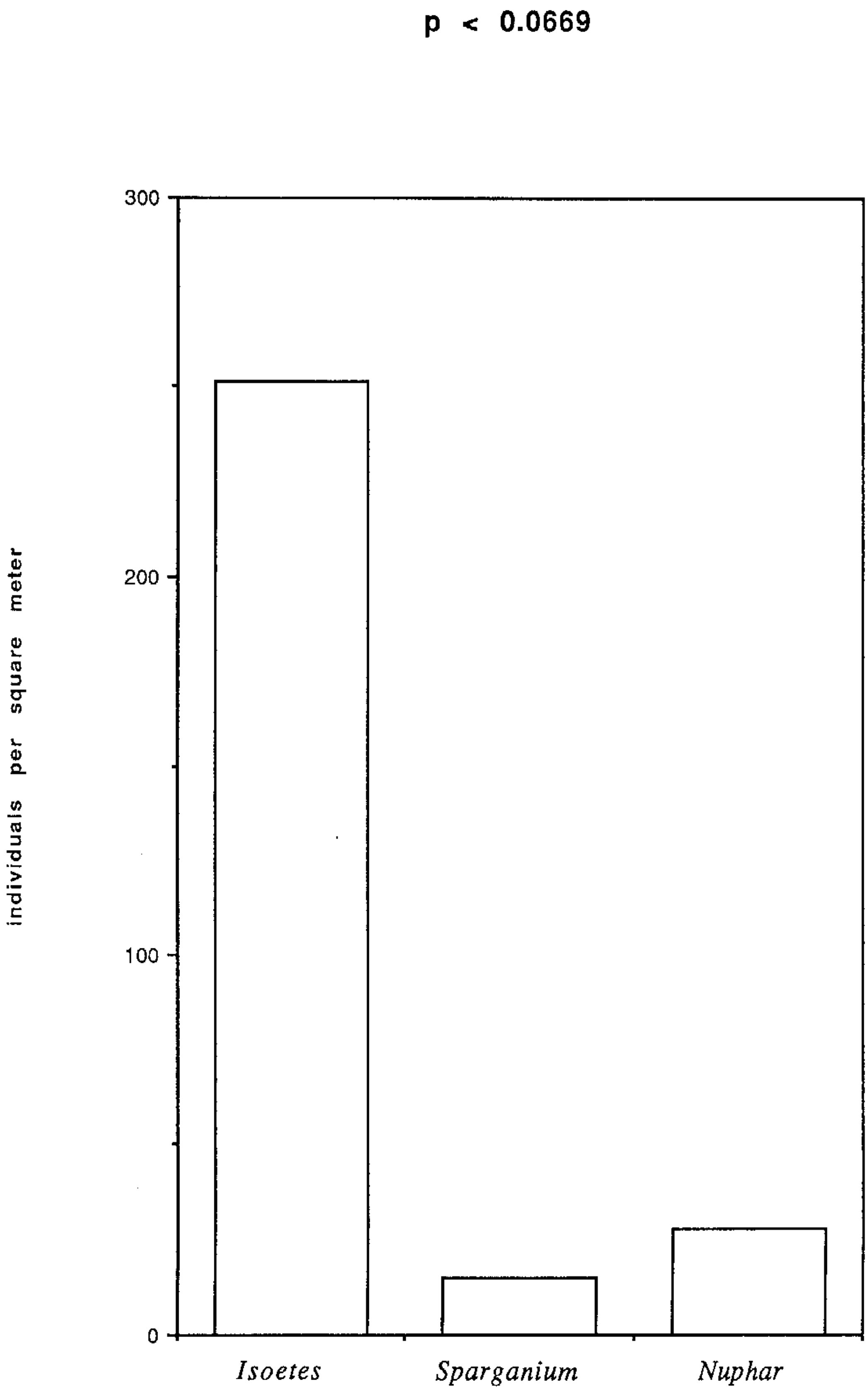


Fig. 3F. Histogram of odonate densities on three macrophyte species.

p < 0.7008

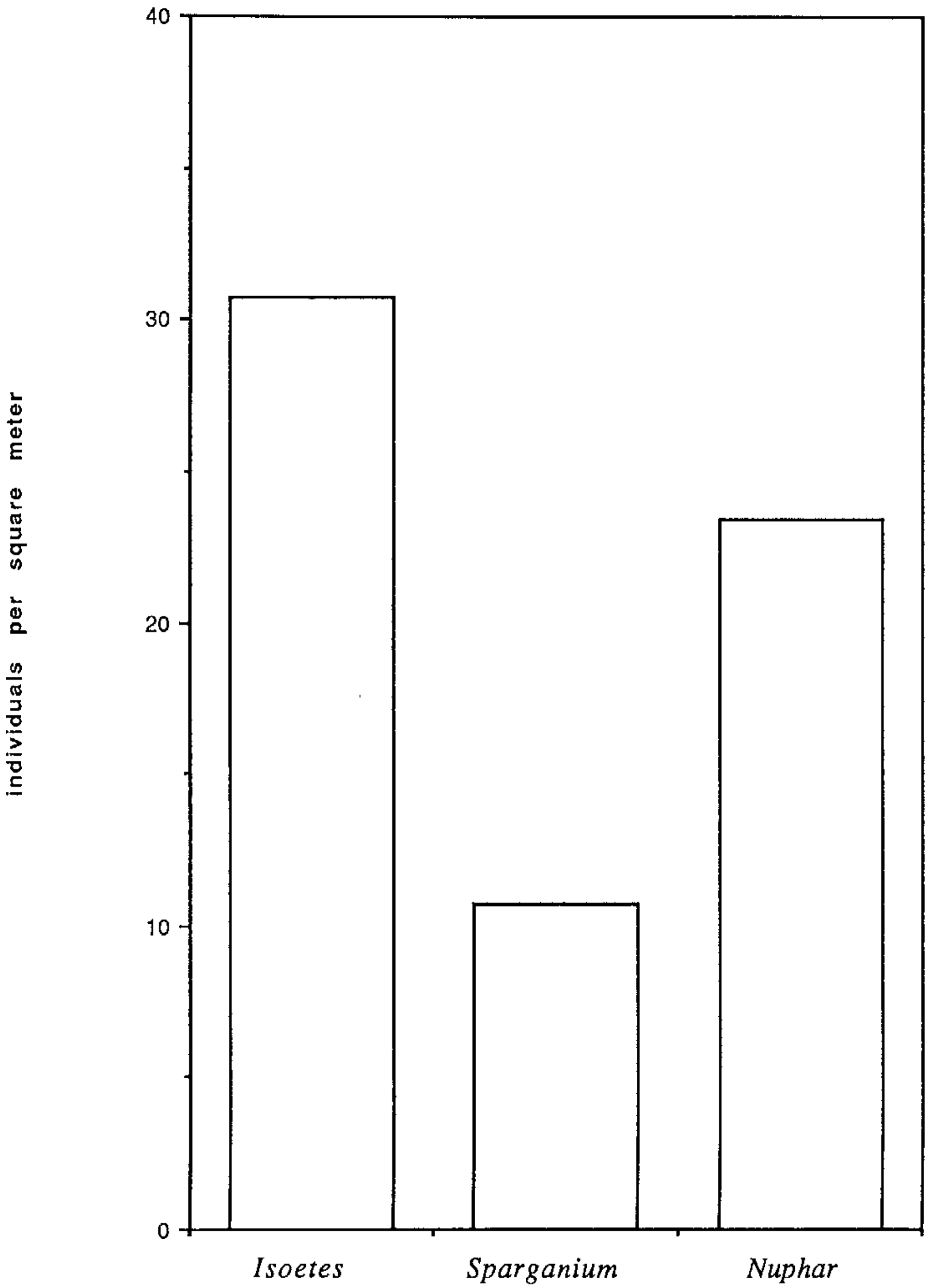


Fig. 3G. Histogram of trichopteran densities on three macrophyte species.

$p < 0.1840$

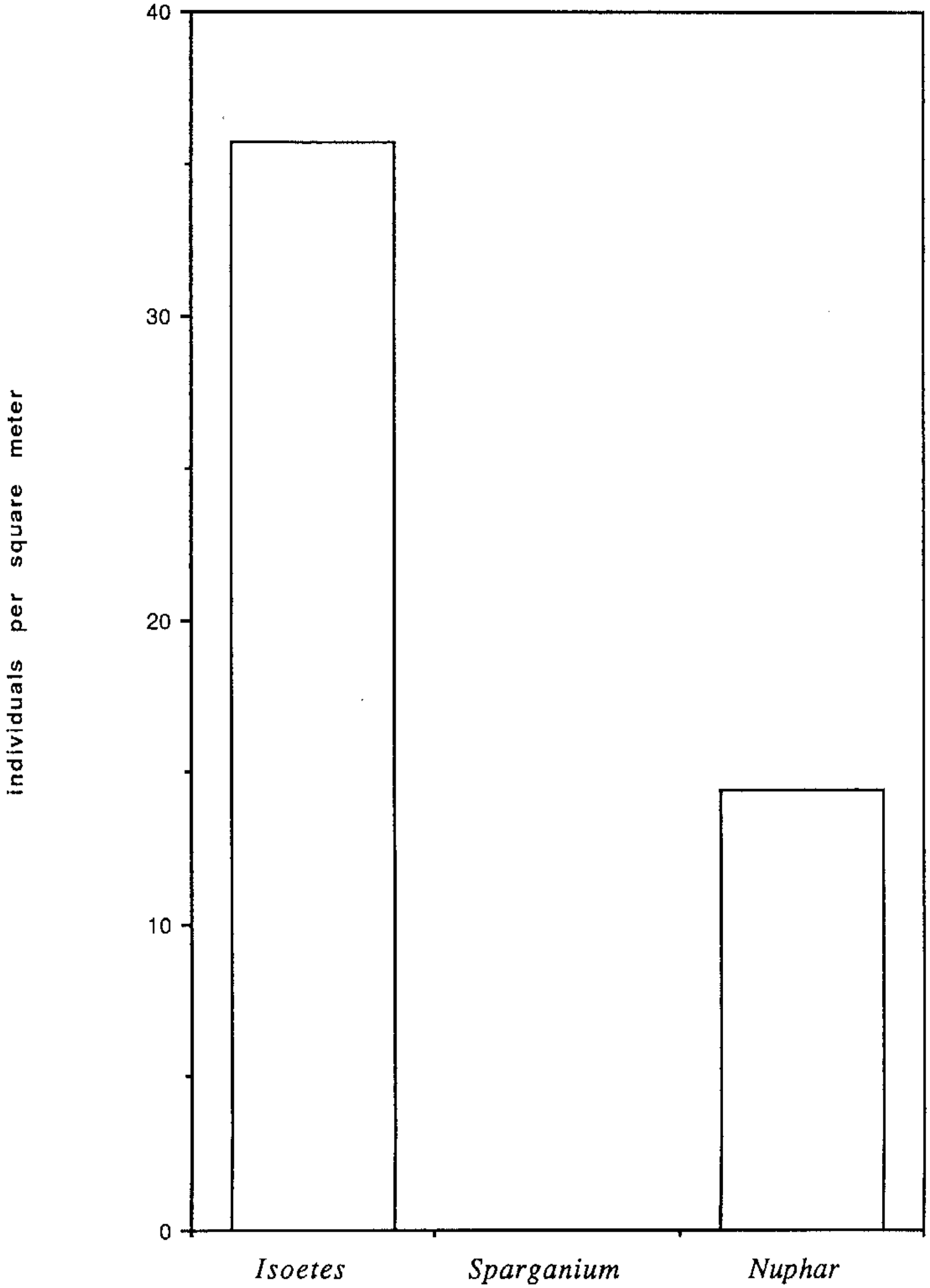


Fig. 3H. Histogram of densities of other taxa on three macrophyte species.