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The Influence of Aquatic Vegetation Upon Zooplankton and Benthic Macroinvertebrates in Orange Lake, Florida[1]

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ABSTRACT

Zooplankton and benthic macroinvertebrate communities were compared between vegetated and non-vegetated lake regions and among three plant communities (*Nuphar luteum* (L.), *Panicum* sp., and *Hydrilla verticillata* (L.F.) Royle), in Orange Lake, Florida from January 1979 through December 1981. Crustacean zooplankton and benthic macroinvertebrates seemed to prefer the vegetated lake regions, and rotifer zooplankton the non-vegetated limnetic area. The greatest variet yof invertebrates were collected from vegetated lake regions. Among vegetated habits, *Hydrilla* supported a significantly ($P < 0.05$) greater number of benthic macroinvertebrates than any other habitat. Although aquatic vegetation appears important for aquatic invertebrates, overgrowth and some growth forms (eg. *Hydrilla*) may reduce their vulnerability as prey items for fish and other predators.

Key words: Hydrilla, zooplankton, benthic macroinvertebrate, littoral, profundal, habitats.

INTRODUCTION

Aquatic invertebrates are an important component in the freshwater biotic community. Some function as decomposers, recycling nutrients in detritus and the sediments to primary producers, and some species serve as indicators of environmental disturbances. Most are the primary food items for forage and sport fish. Community composition, distribution, and abundance of invertebrates appear to be regulated by water chemistry, substrate (bottom) type, depth and the presence or absence of aquatic vegetation (Eggleton 1931, Andrews and Hasler 1943, Pennak and Van Gerpen 1947, Smyly 1952, Hutchinson 1967, and Quade 1968).

Aquatic vegetation offers protection, support, and food, both directly and through grazing of aufwuchs. The abundance and diversity of aquatic invertebrate populations are directly influenced by the amount and species of aquatic plants present. Smyly (1952) and Straskraba (1964) noted that an increase in abundance and productivity of littoral, vegetation inhabiting zooplankton coincided with an increase in the level of aquatic vegetation. Cowell and Hudson (1967) found 7 to 30 times greater production of macroinvertebrates in the vegetated versus non-vegetated profundal region. MacLachlan (1969) noted an increase in the abundance, biomass, and variety of benthic macroinvertebrates accompanied an increase in aquatic macrophytes. Numerous authors (Krecker and Lancaster 1933, Frohne 1938, Smyly 1952, Straskraba 1964) have demonstrated that a preference exists among both zooplankton and benthic macroinvertebrates for a number of aquatic plant species.

The topography and climate in Florida and much of the southeast is conducive to luxurious growths of aquatic plants, especially exotic plants such as *Hydrilla*. Interest into their role upon aquatic biota has been of increasing concern in recent years. It was the objective of this study to examine what influence aquatic vegetation had upon invertebrate distribution and abundance, and to study whether any habitat preferences could be ascertained.

STUDY AREA

Orange lake, a 4921 ha lake is located in north central Florida bordering Alachua and Marion counties (29°25′ north latitude, 82°10′ west longitude). Maximum depth is 4.9 m and the mean depth is 2.9 m. The lake bottom is composed of a vegetative detrital-muck layer in the littoral zone and flocculant muck layer up to 1 m deep in the profundal region. Nineteen species of aquatic macrophytes are common and cover approximately 60% of the lake. Dominant aquatic macrophytes are *Nuphar* (48% cover), *Panicum hemitomon* Schult. and *Panicum geminatum Forsk.* (4% cover), and *Hydrilla* (22% cover).

MATERIALS AND METHODS

Aquatic invertebrates were collected monthly from January 1979 through December 1981 from four habitats, *Nuphar, Panicum, Hydrilla* and the non-vegetated profundal area (open water). Zooplankton were collected with a #20 Wisconsin type plankton net (16 cm diameter). Three replicate vertical tow samples were collected monthly from each habitat and were immediately placed into 75 ml plastic vials and preserved with a 10% solution of formaldehyde stained with rose bengal. Benthic macroinvertebrates were collected using a petite ponar dredge (232.5 cm^2). Three replicate bottom samples were collected monthly from each habitat and were immediately preserved with a 10% solution of formaldehyde stained with rose bengal. Samples were washed through a number 30 mesh sieve (0.36 mm openings) and organisms were removed with the aid of a lighted magnifying lens. Organisms other than flatworms were identified through genera and to species where possible and counted under a binocular microscope.

For statistical analysis, all data were logarithmically transformed to stabilize the variability within the data, and analyses were conducted at each taxonomic level: phylum, class, order, family, genus and species where applicable.

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To determine whether significant differences in numbers existed between vegetated and non-vegetated habitats, all vegetated samples were pooled and a Students t-test was employed. To determine if significant numerical differences existed among the four habitats, an analysis of variance was conducted and a Duncan's multiple range test was used to rank mean abundance among habitats. All statistical analyses were accomplished using the Statistical Analysis System (Barr et al. 1978). The term "significant" is used when a statistical test indicated significance at $P < 0.05$.

RESULTS

Littoral vs. Profundal Zones

A total of 79 different invertebrate taxons were collected (Table 1), from the vegetated region and 51 taxons (65%) were collected from the profundal area.

TABLE 1. A CHECKLIST OF ZOOPLANKTON AND BENTHIC MACROINVERTEBRATES COLLECTED FROM ORANGE LAKE, FLORIDA, JANUARY 1979 THROUGH DECEMBER 1981.

TAXON		COMMON NAME
Zooplankton		
Arthropoda		
Crustacea		
Cladocera		Water flea
Sididae	*Sida crystallina*	
	Diaphanosoma brachyurum	
	Latonopsis occidentalis	
Holopedidae	*Holopedium gibberum*	
Daphnidae	*Daphnia ambigua*	
	Simocephalus vetulus	
	Ceriodaphnia reticulata	
Chydoridae	*Chydorus sphaericus*	
	C. hybridus	
	Alona rectangula	
	A. guttata	
	A. affinis	
	A. monacantha	
	Dunhevedia crassa	
	D. serrata	
	Kurzia latissma	
	Eurycercus lamellatus	
	Illocryptus spinifer	
	Graptoleberis testudinaria	
	Camptocercus rectirostris	
	Pleuroxus denticularis	
Bosminidae	*Eubosmina tubicen*	
Macrothricidae	*Macrothrix rosea*	
	M. laticornis	
Copepoda		Copepods
Diaptomidae	*Diaptomus floridanus*	
Cyclopidae	*Cyclops* sp.	
Rotifera		Rotifers
Digononta		
Bdelloidea		
Philodinidae	*Philodina* sp.	
	Pleuretra sp.	
Monogonata		
Ploima		
Brachionidae		
Brachioninae	*Brachionus havanaensis*	
	Brachionus angularis	
	B. quadridentata	
	B. caudatus	
	Keratella cochlearis	
	Kellicottia sp.	
	Platias patulus	
	P. quadricornis	
	Euchlanis sp.	
	Manfredium sp.	
	Mytilina sp.	
	Macrochaetus sp.	
	Tricotria sp.	
Lecaninae	*Lecane* sp.	
	Monostyla sp.	
Colurinae	*Lepadella* sp.	
Synchaetidae	*Polyarthra* sp.	
	Synchaeta sp.	
Asplanchnidae	*Asplanchna* sp.	
Tricocercidae	*Trichocerca* sp.	
Hexarthridae	*Hexarthra* sp.	
Notommatidae	*Cephalodella* sp.	
	Monommata sp.	
	Scaridium sp.	
Ploesomatidae	*Ploesoma* sp.	
Flosculariacea		
Testudinellidae	*Testudinella* sp.	
Filiniidae	*Filina* sp.	
	Pedalia sp.	
Conochilidae	*Conochilus* sp.	
Benthic Macroinvertebrates		
Platyhelminthes		
Turbellaria		
Planariidae		Flatworms
Nematoda		Roundworms
Adenophorea		
Dorylaimidae	*Eudorylaimus* sp.	
Annelida		Aquatic earthworms
Oligochaeta		
Plesiopora		
Tubificidae	*Limnodrillus* sp.	
Hirudinea		Leeches
Rhynchobdellida		
Glossiphoniidae	*Helobdella* sp.	
Arthropoda		
Crustacea		
Decapoda		
Palaemonidae	*Palaemonetes paludosus*	Grass Shrimp
Amphipoda		
Talitridae	*Hyalella azteca*	Scuds
Insecta		
Ephemeroptera		Mayflies
Baetidae	*Callibaetis* sp.	
Odonata		Dragonflies
Libellulidae	*Erythemis* sp.	
	Pachydiplax sp.	
	Paraponyx sp.	
	Canacria sp.	
Coenagriidae	*Enallagma* sp.	Damselflies
Tricoptera		Caddis flies
Hydroptilidae	*Orthotrichia* sp.	
	Oxyethira sp.	
	Oecetis sp.	
Hemiptera		Water bugs
Nocoridae	*Pelocoris* sp.	
Lepidoptera		Aquatic caterpillar
Leutoceridae	*Leptocerus* sp.	
Hymphulidae	*Paraponx* sp.	
Coleoptera		Beetles
Chrysomelidae	*Donacia* sp.	
Diptera		
Chironomidae		Midges
Chaoboridae	*Chaoborus* sp.	Phantom midges
Ceratopogonidae		Biting midges
Tabanidae	*Tabanus* sp.	Horse flies
Mollusca		
Gastropoda		
Pulmonata		
Ancylidae	*Ferissia* sp.	Limpets
Planorbidae	*Gyraulus* sp.	Orb snails
	Helisoma sp.	
Physidae	*Physa* sp.	
Ctenobranchiata		
Viviparidae	*Viviparous* sp.	Pouch snails
Pelecypoda		
Eulamellibranchia		
Sphaeridae	*Musculium* sp.	Freshwater mussel
	Pisidium sp.	

Zooplankton numbers were not significantly different between the two areas. Among the classes of zooplankton, Crustacea were more abundant in the vegetated areas while Monogonata (rotifers) were more numerous in open water (Table 3). Copepods and over 50% of all cladocerans were collected at significantly greater numbers from vegetated areas.

Aquatic vegetation appears to have a greater influence upon benthic macroinvertebrates than upon zooplankton. In Orange Lake, the vegetated area supported a significantly greater density (organisms/m^2) of benthic macroinvertebrates than the non-vegetated area (Table 2). All classes of benthic macroinvertebrates were collected in significantly greater numbers from vegetation (Table 3). Approximately 85% of the profundal macroinvertebrates collected were burrowers, living in the bottom substrate, while less than 65% of the vegetative inhabiting macroinvertebrates were burrowing forms. All families except Chironomidae and Chaoboridae and over 50% of the genera tested were collected at significantly greater numbers in vegetation .

Plant Habitats

Among the four habitats, *Nuphar* supported the greatest number of taxa (77) followed by *Panicum* (68), *Hydrilla* (67), and open water (51). Arthropod zooplankton comprised the greatest percentage of the plankton collected from all three vegetated in habitats, while rotifers comprised the greatest percentage collected from open water (Figure 1). Neither zooplankton numbers (collectively) nor crustaceans or rotifers exhibited a significantly greater abundance among habitats. One family and four species of zooplankton were collected at significantly greater numbers from vegetative habitats (Table 4).

Table 2. Mean total number zooplankton per cubic meter and benthic macroinvertebrates per square meter collected from Orange Lake, Florida (± 95% confidence interval).

POOLED HABITATS	ZOOPLANKTON	BENTHOS
Vegetated	216718.7 ± 31901.0	1069.7 ± 477.3
Nonvegetated	177601.0 ± 14965.3	2867.9 ± 352.3

Table 3 Mean number of zooplankton per cubic meter and benthic macroinvertebrates per meter square by class, between vegetated and nonvegetated regions in Orange Lake, Florida (± 95% confidence interval).

TAXON	VEGETATED	NON VEGETATED
Zooplankton		
Crustacea	109832.0 ± 10819.2	97756.3 ± 13753.9
Monogonata	67769.1 ± 7208.5	118962.4 ± 28863.0
Benthos		
Turbellaria	126.2 ± 32.5	22.3 ± 24.7
Adenophorea	88.8 ± 9.1	65.8 ± 8.3
Oligochaeta	1317.8 ± 223.8	247.5 ± 188.4
Hirudinea	190.5 ± 52.3	62.3 ± 61.9
Crustacea	412.0 ± 108.6	111.5 ± 88.4
Insecta	688.0 ± 122.1	454.1 ± 82.7
Gastropoda	26.5 ± 10.2	1.8 ± 0.9
Pelecypoda	9.9 ± 4.0	2.0 ± 0.8

Table 4. Mean number of zooplankton per cubic meter and benthic macroinvertebrates per meter square in Orange Lake, Florida (values in a row followed by the same letter have overlapping 95% confidence intervals).

TAXON	NUPHAR	PANICUM	HYDRILLA	OPEN WATER
Zooplankton				
Cladocera				
Sididae (Family)	2138.0a	1614.7a	4879.0b	333.0c
Diaphanosoma brachyurum	1640.0a	1037.0a	1953.7a	314.6b
Macrothrix rosea	343.0a	16.7b	223.6a	4.2b
Camptocercus rectirostris	214.0a	270.0b	1000.0b	11.5c
Rotifera				
Monostyla sp.	4129.0a	948.0b	4885.0a	637.5b
Keratella cochlearis	10025.0a	15154.2b	9517.2a	40777.0c
Benthos				
Annelida				
Hirudinea (Class)	75.5a	230.0b	257.8c	62.3d
Oligochaeta (Class)	916.0a	1168.3b	1860.7b	247.5c
Crustacea				
Palaemonetes paludosus	8.2a	2.4b	4.6ab	0.0c
Total benthic macroinvertebrates	2244.0a	2586.4a	3752.3b	1067.2c

Among benthic macroinvertebrates, annelids comprised the greater percentage from *Panicum* and *Hydrilla* habitats while arthropods comprised the greater percentage from *Nuphar* and open water (Figure 2). Significantly greater numbers of benthic macroinvertebrates were collected from *Hydrilla* and significantly fewer from open water (Table 4); however, only two classes (Hirudinea and Oligochaeta) and one species (*Palaemonetes paludosus*) were significant among habitats (Table 4).

DISCUSSION

Aquatic plants afford niches for the existence of animal species, and as aquatic flora increases in abundance and variety, the associated fauna also increases (Rosine 1955, Mclachlan 1969, Quade 1968). Numerous authors have also demonstrated that preferences exist for vegetation types, by both zooplankton and benthic macroinvertebrates (Krecker and Lancaster 1933, Frohne 1938, Smyly 1952, Straskraba 1964). Similarly, our results indicate in Orange Lake that differences in number and variety of invertebrates among habitats and between the vegetated and non-vegetated regions existed.

Among zooplankton, those cladocera and copepod taxa which preferred aquatic plants are forms which either feed among them, or owing to their larger size avoid open water, and use aquatic plants to avoid predation (Green 1967, Hutchinson 1967, Whiteside and Harmsworth 1967). The preference of rotifiers for the non-vegetated lake region may be due to their ability to avoid predation, owing to their smaller size, or physiological avoidance of aquatic plants (Hutchinson 1967, Hasler and Jones 1949).

The greater number and variety of benthic macroinvertebrates in the vegetated region of Orange Lake is similar to results of other studies. Muttowski (1918) and Eggleton (1931) noted that the profundal region supported fewer numbers and variet yof benthic macroinvertebrates than littoral habitats. In their studies, the profundal region was

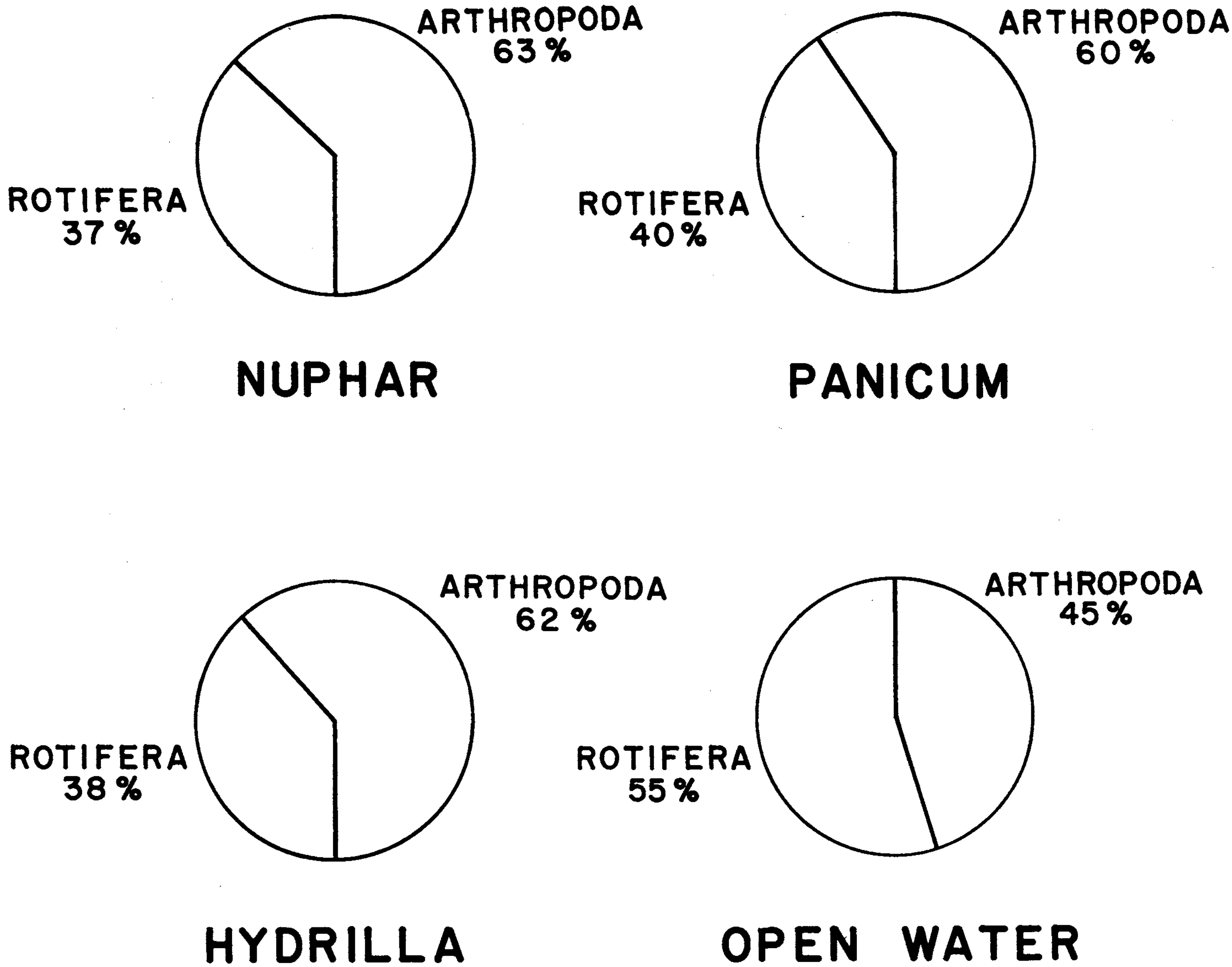

Figure 1. Percent composition of Arthropod and Rotifer zooplankton collected from four habitats within Orange Lake Florida.

inhabited by predominantly burrowing, substrate inhabiting forms, while the littoral region supported motile rapacious forms which is similar to our findings. As the greater variety of macroinvertebrates collected in our study were shredders, collectors or scrapers (Cummings 1973) and potentially more subject to predation due to size, Werner and Hall (1974), Kislalioglu and Gibson (1976) and O'Brien et al. (1976), both food and predation are probably the main factors influencing their distribution.

The greater number of benthic macroinvertebrates collected from *Hydrilla* samples might be attributed to plant morphology. Krecker and Lancaster (1939) and Andrew and Hasler (1943) found that plants with greater leaf dissection, and hence greater surface area harbored greater numbers of macroinvertebrates. *Hydrilla* has numerous small leaves on a central stem which offers attachment sites. *Hydrilla* also forms very dense stands which affort greater attachment sites for aufwuchs and grazing macroinvertebrates.

Although dense stands of aquatic vegetation, especially *Hydrilla,* provides for greater abundance and variety of benthic macroinvertebrates, excessive growth may be detrimental to forage and sport fish. Colle and Shireman (1980) and Maceina and Shireman (1982) hypothesized that growth, numbers and biomass of sport fish may have been reduced in *Hydrilla* infested lakes owing to reduced availability of prey. In these studies and others, fish stunted at a size where they had advanced from feeding primary upon zooplankton to benthic macroinvertebrates. Our findings indicate aquatic vegetation had a greater influence upon benthic macroinvertebrates than upon zooplankton.

Among the many factors which influence invertebrate populations, the type and density of vegetation has often been ignored, but is apparently a very important effect. It is evident that the lack of vegetation, or too much vegetation, directly influences invertebrates and ultimately influences fish production. Consequently, management of aquatic plants should be directed toward encouraging growth of those plants with an open growth form (e.g. *Panicum* and *Nuphar*) and limiting those submersed plants

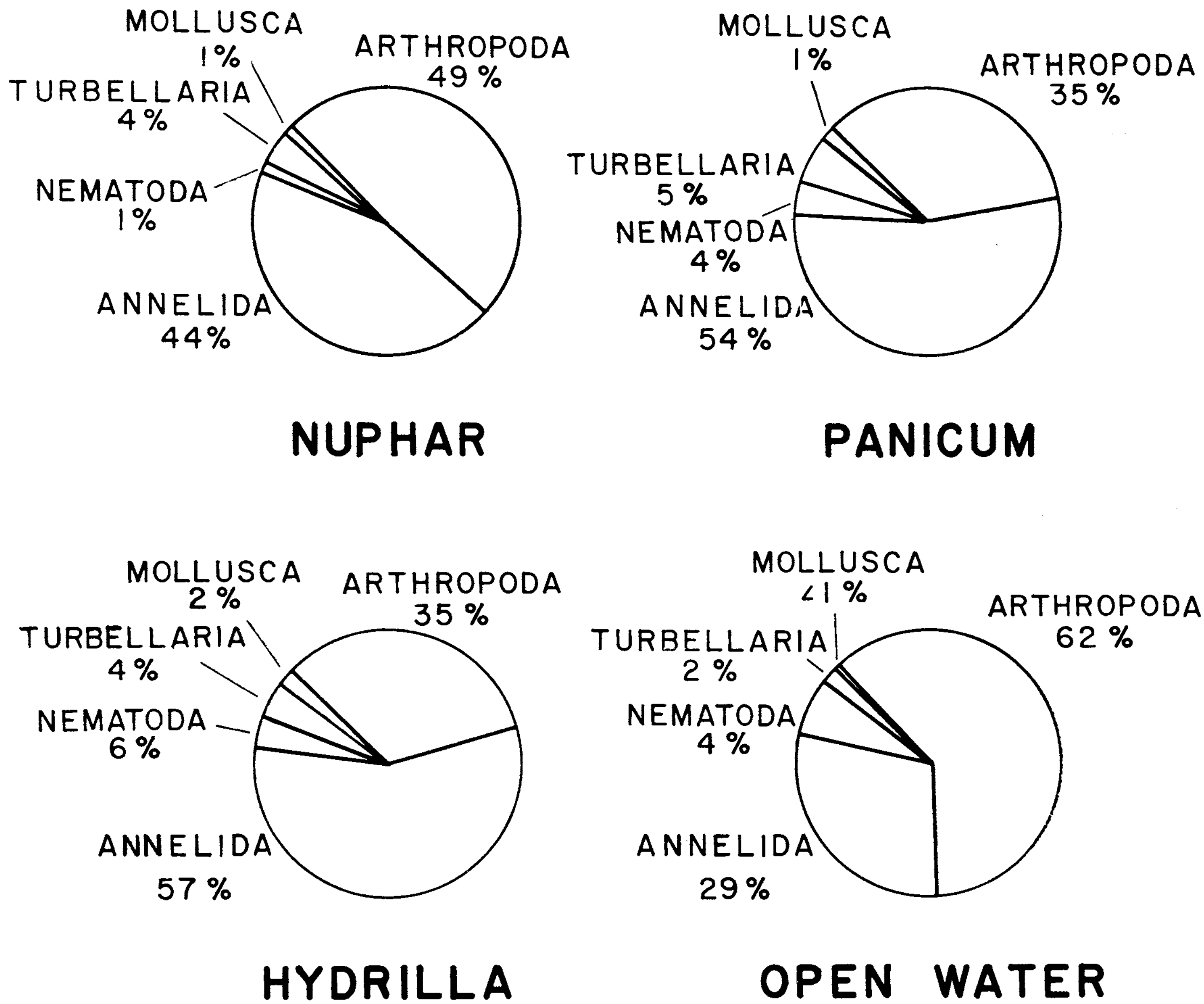

Figure 2. Percent composition of benthic macroinvertebrates collected from four habitats within Orange Lake Florida.

which produce extensive dense mats of vegetation, where although a greater number of macroinvertebrates may be present, they are apparently less available to predation.

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