

The Influence of Aquatic Vegetation Upon Zooplankton and Benthic Macroinvertebrates in Orange Lake, Florida¹

CURTIS E. WATKINS II, JEROME V. SHIREMAN
AND WILLIAM T. HALLER²

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 variety of 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 1981, 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 cm²). 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.

¹Journal Series Number 4668 of the Florida Agricultural Experiment Station.

²Center for Aquatic Weeds, 7922 N.W. 71 Street, Gainesville, Florida 32601.

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

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/m²) 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 (\pm 95% CONFIDENCE INTERVAL).

POOLED HABITATS	ZOOPLANKTON	BENTHOS
Vegetated	216718.7 \pm 31901.0	1069.7 \pm 477.3
Nonvegetated	177601.0 \pm 14965.3	2867.9 \pm 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 (\pm 95% CONFIDENCE INTERVAL).

TAXON	VEGETATED	NON VEGETATED
Zooplankton		
Crustacea	109832.0 \pm 10819.2	97756.3 \pm 13753.9
Monogonata	67769.1 \pm 7208.5	118962.4 \pm 28863.0
Benthos		
Turbellaria	126.2 \pm 32.5	22.3 \pm 24.7
Adenophorea	88.8 \pm 9.1	65.8 \pm 8.3
Oligochaeta	1317.8 \pm 223.8	247.5 \pm 188.4
Hirudinea	190.5 \pm 52.3	62.3 \pm 61.9
Crustacea	412.0 \pm 108.6	111.5 \pm 88.4
Insecta	688.0 \pm 122.1	454.1 \pm 82.7
Gastropoda	26.5 \pm 10.2	1.8 \pm 0.9
Pelecypoda	9.9 \pm 4.0	2.0 \pm 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)	2138.0 ^a	1614.7 ^a	4879.0 ^b	333.0 ^c
<i>Diaphanosoma brachyurum</i>	1640.0 ^a	1037.0 ^a	1953.7 ^a	314.6 ^b
<i>Macrothrix rosea</i>	343.0 ^a	16.7 ^b	223.6 ^a	4.2 ^b
<i>Camptocercus rectirostris</i>	214.0 ^a	270.0 ^b	1000.0 ^b	11.5 ^c
Rotifera				
<i>Monostyla</i> sp.	4129.0 ^a	948.0 ^b	4885.0 ^a	637.5 ^b
<i>Keratella cochlearis</i>	10025.0 ^a	15154.2 ^b	9517.2 ^a	40777.0 ^c
Benthos				
Annelida				
Hirudinea (Class)	75.5 ^a	230.0 ^b	257.8 ^c	62.3 ^d
Oligochaeta (Class)	916.0 ^a	1168.3 ^b	1860.7 ^b	247.5 ^c
Crustacea				
<i>Palaemonetes paludosus</i>	8.2 ^a	2.4 ^b	4.6 ^{ab}	0.0 ^c
Total benthic macroinvertebrates	2244.0 ^a	2586.4 ^a	3752.3 ^b	1067.2 ^c

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 rotifers 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 variety of benthic macroinvertebrates than littoral habitats. In their studies, the profundal region was

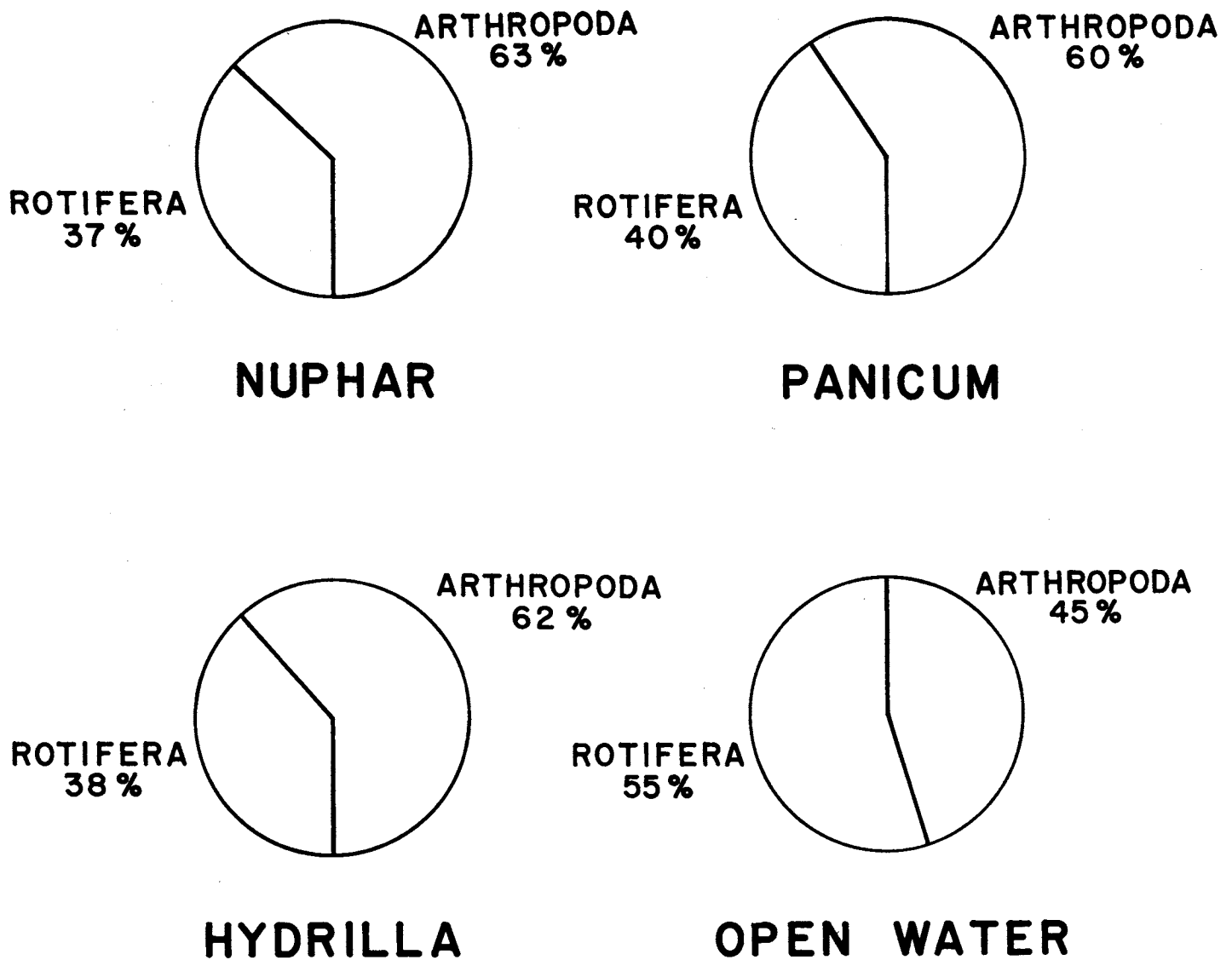


Figure 1. Percent composition of Arthropod and Rotifer zooplankton collected from four habitats within Orange Lake Florida.

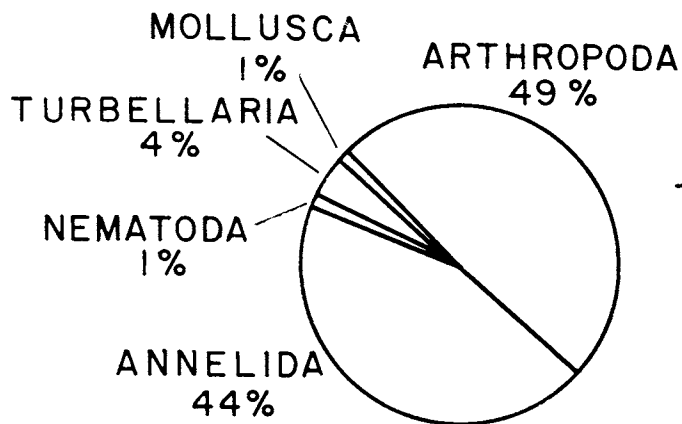
inhabited by predominantly burrowing, substrate inhabiting forms, while the littoral region supported motile rapacious forms which is similar to our findings. As the greater variety of macroinvertebrates collected in our study were shredders, collectors or scrapers (Cummings 1973) and potentially more 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. Kreckler 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 afford greater attachment sites for aufwuchs and grazing macroinvertebrates.

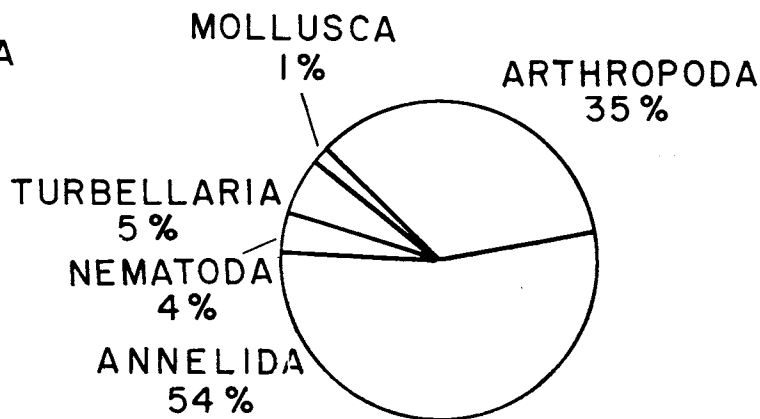
Although dense stands of aquatic vegetation, especially

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.

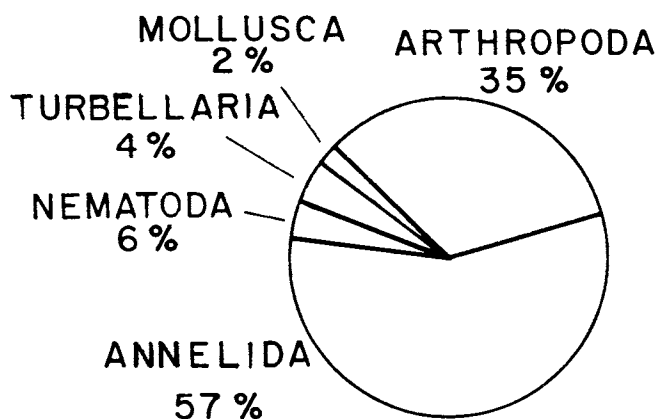
Among the many factors which influence invertebrate populations, the type and density of vegetation has often been ignored, but is apparently a very important effect. It is evident that the lack of vegetation, or too much vegetation, directly influences invertebrates and ultimately influences fish production. 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



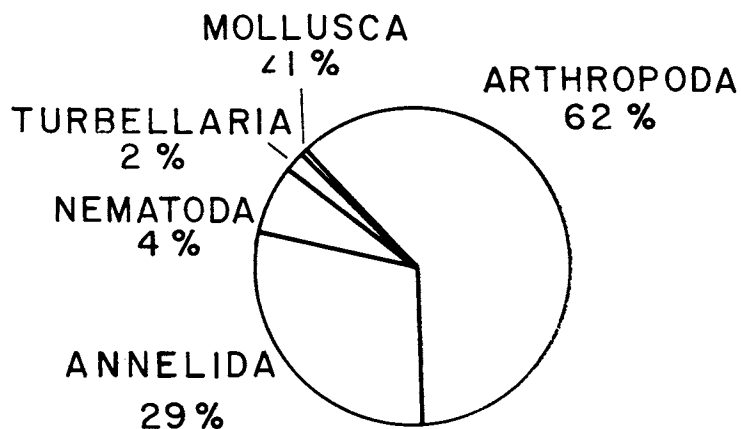
NUPHAR



PANICUM



HYDRILLA



OPEN WATER

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.

ACKNOWLEDGMENT

We wish to thank Drs. G. B. and E. S. Deevy, Dr. M. J. Westfall Jr. and Dr. R. A. Dunn for their assistance with invertebrate identification. Primary funding for this research project was provided by the Office of Research and Development, U.S. Environmental Protection Agency, under grant number R-905497. Additional funding was provided by the Center for Aquatic Weeds, University of Florida. The U.S. Environmental Protection Agency does not necessarily endorse any commercial products used in the study and the conclusions represent those of the authors which do not necessarily represent the opinions, policies, or recommendations of the U.S. Environmental Protection Agency.

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