BENTHIC MACROINVERTEBRATE RESPONSE TO GRASS CARP INTRODUCTION IN THREE FLORIDA LAKES

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Abstract: Three natural lakes were studies to determine effects of grass carp (*Ctenopharyngodon idella* Val.) introduction on invertebrates. Benthic macroinvertebrate populations were changed after the introduction of grass carp changed the existing habitat in the 3 natural lakes. Species diversity (d), number of taxa and pollution-intolerant organisms decreased in all lakes after grass carp introduction. Macrophytes were also reduced in all study areas and several native species were eliminated. Changes in benthos corresponded to changes in water quality and aquatic vegetation.

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Management of lakes must be carefully planned to sustain good water quality, intensive public use and high yields of fish and wildlife resources. Introductions of exotic plants and animals and urbanization of drainage basins complicate management problems and should not be done without careful evaluation. Unfortunately, some exotic organisms are established and we cannot adequately control their spread. Exotic aquatic plants presently dominate the flora of some lakes creating public use problems.

Florida elodea (*Hydrila verticillata*, Royle) is one of the plants of primary concern. Infestation of several lakes has been rapid, and some have recommended grass carp to control *Hydrilla*.

Grass carp's ability to eat and control aquatic vegetation, and its life history have been well documented (Lin 1935; Nikol'skii 1956; Stroganov 1961; Aliev 1963; Avault 1965; Hickling 1966; Krapauer 1968). Several authors have reported the fish to eat all kinds of vegetation in its presence (Avault 1965; Avault et al. 1968; Terrell and Fox 1974).

Kilgen and Smitherman (1971) concluded that grass carp did not compete with game fishes for food organisms. Several authors (Tang 1970; Fisher 1973; and Stanley 1974) emphasized the physiological needs of grass carp for animal food. Tang (1970) evaluated grass carp feeding habits and food availability in ponds with several fish species and reported that the macrophyte complex composed of plants, periphyton, and aquatic invertebrates is much more nutritious than macrophytes alone.

The purpose of this research was to define the effects of grass carp introduction on benthic macroinvertebrate populations in 3 Florida lakes. These populations are important fish foods as well as essential converters of detrital and plant material to animal matter. Macroinvertebrate populations may serve as indicators of water quality.

MATERIALS AND METHODS

In 1972, the Florida Game and Fresh Water Fish Commission and the Florida Department of Natural Resources jointly began a study on 3 small lakes. Study sites with diverse physiography and variable physical and chemical characteristics were chosen. The northernmost 2 sites, Suwannee Lake and Madison Pond, were similar in geographic location and chemical characteristics with pH between 6.0 and 7.0, but differed biologically. Suwannee Lake located on the University of Florida Agricultural Experiment Station had a drainage area of approximately 65 ha, which was a mixture of upper coastal plain flatwoods and agricultural land. It was the largest water body studied, with a surface area of 12.2 ha. the lake was only moderately vegetated. Marginal vegetation included panic grass (*Panicum hemitomon*) and floating pad communities of floating heart (*Nymphoides aquaticum*), spatterdock (*Nyphar macrophylla*), watershield

(*Brasenia schreberi*) and fragant waterlily (*Nymphaea odorata*). Slender spikerush (*Eleocharis acicularis*) formed a carpet on the lake bottom, extending lakeward from the shoreline.

Madison Pond was smaller, approximately 3.4 ha, with a drainage area of approximately 185 ha consisting of woods and agricultural land. A densely matted periphery dominated by panic grass and alligatorweed (*Alternanthera philoxeroides*) extended from 9 m to 21 m lakeward from shore. the pond middle was densely vegetated with cabomba (*Cabomba caroliniana*) interspersed with bladderwort (*Utricularia gibba-fibrosa*). Both Suwannee Lake and Madison Pond were located in Atlantic coastal plain pine flatwoods habitat.

Pasco Pond in West Central Florida was a 2.6 ha pond having practically no drainage area and a very low pH (4.5 - 5.5). Cypress trees (*Taxiodium* sp.) fringed the pond. Dominant aquatic vegetation included slender spikerush (*Eleocharis vivipara*), water shield, floating heart, spatterdock and bladderwort (*Utricularia purpurea vulvaris*). Pasco was intermediate between Madison and Suwannee in degree of aquatic vegetation coverage.

A 3 year sampling program was designed with the first year (1972) to serve as a control (without grass carp). Each site was stocked with 67 kg per ha of grass carp. Because of differences in the size of fish, Suwannee was stocked with 298 fish per ha, Madison with 51 fish per ha, and Pasco with 185 fish per ha.

Modified line transects were run quarterly on each site beginning in October, 1972. In Madison and Pasco, transects traversed the pond; however, in Suwannee Lake transects were confined to vegetated littoral zones only. Permanent markers were established and a rope marked in 1.5 m intervals was stretched between markers. At each rope mark, a wooden pole was submerged and plants that touched were recorded. At each 9.1 m interval, a frame (1 m^2) was lowered to the water and coverage of each vegetation species within the frame recorded. From these data, percentage frequency of occurrence and percentage relative cover were calculated for each plant species. Control exclosures were constructed in each pond by screening an area to prevent disturbances of the plant communities by grass carp. Experimental remote sensing photography was also used to detect gross changes.

Four fixed sampling station, 2 shallow-water stations and 2 deep water stations were set up in Madison and Pasco Ponds to sample benthic organisms. Six stations (3 shallow and 3 deep) were set up in Suwannee Lake due to its larger size. Organisms were collected monthly at each station with a 15 by 15 cm Ekman dredge. Samples were sieved using a U.S. series No. 39 sieve in the field and taken to Rollins college, Winter Park, Florida, for identification and counting. Organisms were identified to genus and counted by Rollins College staff.

Means and ANOVA were computed using an IBM 370/165 computer at the University of Florida and SAS program language (Barr and Goodnight 1972). Technical assistance was provided by Mr. Paul Geissler with the North Carolina State Cooperative Statistics Unit. A split plot design was used with Madison, Suwannee and Pasco Ponds being replications and years being the plot. The treatment considered was stocking grass carp and objectives were to measure significantly affected responses. We transformed benthic data to a logarithmic scale.

RESULTS

Suwannee Lake has a diverse flora with 23 species encountered in first year transects. Spikerush and maidencane were dominant aquatic vegetation in the control year (Table 1). Some common floating pads found in the pond were watershield, floating heart and fragant waterlily. By the end of the first treatment year (after grass carp introduction), spikerush was eliminated from transects. Emergent vegetation showed slight change.

TABLE 1. Mean percentage frequency of occurrence and mean percentage relative cover of dominant aquatic plants found in each of the 3 ponds.

Pond	Dominant Plant	Mean percent frequency Pre-stocking Year 1	Year 2	Year 3	Mean percent cover Pre-stocking Year 1	Year 2	Year 3
Suwannee	Spikerush	53.14	20.44	0.00[a]	40.93	2.96	0.00[a]
	Umbrella Grass	13.36	2.14	0.00	7.46	0.14	0.00
	Maidencane	18.74	18.04	16.74	3.00	4.43	3.18
Madison	Alligatorweed	30.58	32.32	27.21	23.19	22.49	13.99
	Cabomba	63.32	55.31	35.29	59.72	37.90	13.42
	Bladderwort	39.17	34.30	8.83	14.69	18.39	4.33
Pasco	Spikerush	37.46	2.48	0.00	26.15	0.11	0.00
	Bladderwort	15.86	12.60	0.21	3.11	4.46	0.00
	Watershield	24.72	7.33	0.00	10.72	1.43	0.00
	Floating heart	5.44	4.47	0.94	1.32	1.43	0.43
	Fragrant Waterlily	6.04	3.20	1.55	3.04	2.84	0.35
	Spatterdock	8.07	7.00	4.67	4.41	3.91	1.33

[a]A small amount of spikerush was encountered along the transects; however, it was found only on exposed shoreline areas and was not found in the water where it would have been available to the grass carp.

Watershield declined in mean percentage cover of occurrence from .63 % in the control year to .03%. Percentage frequency of occurrence also declined from 3.2% to .01%. Floating heart was more abundant in the first treatment year. Mean percentage cover increased from 1.34% to 2.26%. Mean frequency of occurrence increased from 2.49% in the control year to 6.68%. Fragrant waterlily changed very little in mean percent cover with 1.48% the control year and 1.58% the first treatment year. Mean percentage frequency of occurrence increased from 2.50% to 4.03%.

Water level fluctuation probably contributed to some third-year changes in the plant community; however, most vegetation had been removed along transects by the end of the study. Mean percentage cover and mean frequency of occurrence was reduced to zero by the third year for watershield and floating heart. Fragrant waterlily was reduced to .65 mean percent cover. Mean percent frequency of occurrence increased to 5.30%. Figure 1 shows effects of grass carp introduction on the total aquatic plant community of the lake. Submerged aquatic vegetation was totally eliminated. Aquatic vegetation in the screened exclosure remained intact.

In Madison Pond, 18 aquatic plant species were found along transects the control year. Dominant plants included alligatorweed, cabomba, and bladderwort (Table 1). The dense alligatorweed mat surrounding the pond periphery harbored an associated plant community which was not readily accessible to grass carp upon introduction. The first year after introduction, cabomba and bladderwort were substantially reduced as reflect by change in mean percentage cover. The alligatorweed mat and associated community remained essentially unchanged.

Substantial reduction in the cabomba-bladderwort community continued the third year. The alligatorweed community showed some decline. With exception of a large open water area in the center of the pond, the vegetation community was largely intact the end of the third year. The screened exclosure also supported substantial aquatic vegetation. Reduction of the aquatic vegetation community occurred gradually (Fig. 1) and would likely have continued if grass carp had not been removed the end of the year 3.

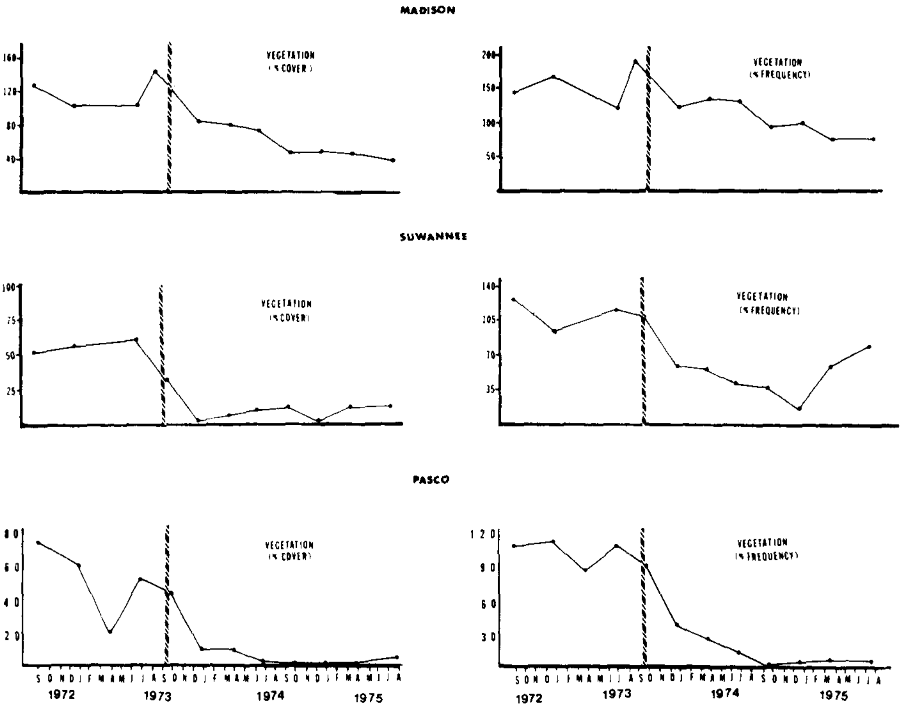

Fig. 1. Mean percentage frequency of occurrence and mean percent cover for aquatic vegetation in the 3 study ponds through the study period. The broken line indicates where grass carp were stocked.

Sixteen plant species were encountered along transects in Pasco Pond the control year. Spikerush, bladderwort and watershield were the most commonly occurring plants (Table 1). These 3 plants were totally eliminated from the pond as well as along the transects by the end of the second year. The entire aquatic plant community was substantially reduced by the end of the year 3 (Fig. 1). By 1975, fish entered the exclosure, but this had no serious impact on the study at this time.

Reduction in benthic invertebrates corresponded to aquatic vegetation reduction (Table 2). In Suwannee Lake, 16 genera representing 11 orders were considered prominent because they occurred in 20% or more of the months sampled during the prestocking year. This decreased to 10 genera representing 5 orders the first treatment year, then to 6 genera representing 4 orders the second year after grass carp introduction. The oligochaete, *Chaetogaster*, and two diptera, *Chaoborus* and *Chironomus*, increased in number after introduction. *Ephemera* declined after introduction but recovered the third year.

In Madison Pond, 7 genera representing 5 orders occurred in 20% or more of the months sampled the first year. This decreased to 6 genera representing 3 orders the second treatment year. *Chaetogaster*, *Chaoborus*, and *Chironomus* remained along with *Arrenurus* and *Limnochares*. *Chaoborus* was high in numbers, but other genera were greatly reduced. The *Chironomus* population in the third year was greatly reduced when compared to the control year.

TABLE 2. Percentage frequency of occurrence of prominent benthic invertebrates for the 3 ponds studied.

Organism	Madison Year 1	Madison Year 2	Madison Year 3	Suwannee Year 1	Suwannee Year 2	Suwannee Year 3	Pasco Year 1	Pasco Year 2	Pasco Year 3
Vorticella	0	0	0	25	0	0	0	0	0
Nematoda	0	0	0	25	0	0	*	0	0
Chaetogaster	23	33	40	33	41	27	38	50	*
Nais	23	0	0	0	*	0	*	0	0
Stylaria	0	0	0	0	0	0	0	0	0
Helobidella	0	*	0	33	*	*	0	*	*
Cladocera	*	*	*	25	*	0	0	0	0
Ostracoda	*	0	0	58	0	0	0	0	0
Copepoda	31	0	0	25	0	23	23	0	0
Hyalella	38	42	*	41	41	0	61	*	*
Palaemonetes	0	0	0	0	0	0	*	25	0
Ephemera	0	0	0	58	41	64	0	0	0
Tricorythodes	0	*	0	0	*	0	30	0	27
Leucorrhina	0	0	0	25	0	0	0	*	0
Clinotanypus	*	0	0	58	33	0	24	*	*
Chaborus	77	75	100	91	100	100	92	100	100
Palpomyia	*	0	0	41	33	*	23	25	0
Chironomus	54	50	70	100	100	90	60	67	27
Arrenurus	*	50	*	66	41	*	*	33	0
Eylas	*	0	*	0	0	0	30	*	0
Limnochares	85	67	40	66	61	45	85	33	0
Mideopsis	23	*	0	75	41	27	30	25	0
Gyraulus	*	0	0	0	0	0	0	*	0
Physa	0	*	0	0	0	0	0	0	0

Pasco had 6 prominent order represented by 12 genera the control year. The first year after stocking carp 5 orders were prominently represented by 9 genera. In the final year, 3 orders represented by 4 prominent genera were found. *Chaoborus* was the only genus well represented at the end of the third year. The initial diverse benthic population was greatly reduced.

At study initiation, all 3 ponds had diverse benthic invertebrate populations. Oligochaeta, Amphipoda, Ephemeroptera, Odonata, Trichoptera, Diptera and Hydracarina were among prominent major groups represented. An analysis of variance for Diptera, Hydracarina, Ehemeoptera, and Odonata is represented in Tables 3 & 4. The statistical analysis was applied to 3 ponds, 3 years (1 control and 2 treatment), months (12 to partition seasonal influence) and stations (classified as deep and shallow). Only Ephemeroptera varied significantly ($P > .05$) among sites due to the presence of the burrowing genus *Ephemera* in Suwannee Lake. This genera was prominent in Suwannee Lake the third year as well. Ephemeroptera, Odonata and Hydracarina varied significantly ($P > .05$) in control year versus treatment years comparison. All decreased in abundance after grass carp introduction. Amphipoda also decreased and varied

TABLE 3. Analysis-of-variance for Odonata and Ephemeroptera. Asterisks denote significance at $P > .05$ (*) or $P > 0.01$ (**); unmarked values represent non-significant differences. All data were tranformed to logarithmic scale.

Source of variation	Odonata			Ephemeroptera		
	Degrees of Freedom	Mean Square	F	Degrees of Freedom	Mean Square	F
Ponds (Madison, Suwannee, Pasco)	2	.00078	.4148	2	.20123	107.0372**
Madison vs. Suwannee and Pasco	1	.0023	.1223	1	.14132	75.1223**
Suwannee vs. Pasco	1	.00120	.6383	1	.21831	116.1223**
Years (control, treatment year 1, treatment year 2)	2	.01105	5.8777	2	.01104	5.8723
Control vs. treatment years	1	.01733	9.2180*	1	.01733	9.2181*
Treatment year 1 vs. treatment year 2	1	.00476	2.5319	1	.00476	2.5319
Ponds across Years	4	.00188	Error ↑	4	.00188	Error ↑
Season (months)	11	.00325	1.7956	1	.03008	2.6643
Season interaction with control vs. treatment years	11	.00640	3.5359*	11	.01010	.8946
Season interaction with treatment year 1 vs. treatment year 2	11	.00181	Error ↑	11	.01129	Error ↑
Deep water stations vs. shallow water stations with control vs. treatment years	1	.03422	31.981	1	.08321	2.65
Deep water stations vs. shallow water interaction with year 2	1	.0107	Error ↑	1	.03140	Error ↑

significantly in the months and years interaction. Diptera genera compensated each other with an increase in *Chaborus* and a decrease in other genera. No significant variation was found for this group in the years comparisons; however, Diptera and Amphipoda showed significant ($P > .05$) differences in the seasonal tests. Months and the interaction of months with control years versus treatment years was highly significantly ($P > 0.01$) different.

A problem with using the 3 natural lakes as replications is that some organisms do not occur in all lakes. Those commonly occurring genera were tested, using analysis of variance. Among ponds, only *Tricorythrodes* was significantly different.

Nais showed significant variation among years and between control and treatment years comparisons. It decreased in all ponds after the first year of the study. *Chaoborus* had a high F value but was not significantly different at the 0.05 level. Seasonal differences were significant for *Clinotanypus*, an unidentified copepoda, *Hyalella* and *chironomus*. *Clinotanypus*, Copepoda and *Hyalella* significantly changed when season interacts with the control year versus the treatment years. All decreased after grass carp introduction.

Distribution of benthic invertebrate communities often differs between littoral and limnetic areas of a lake. *Clinotanypus*, an unidentified Copepoda, *Mideopsis* and *Nais* displayed significant differences when deep water samples were compared with open water samples in the years interaction. This may reflect the removal of littoral vegetation and a food chain interruption.

Several genera showed significantly different responses in ponds comparisons interact with control versus treatment years. *Arrenurus*, an unidentified Copepoda, *Limnochares* and *Nais* were significantly different when Madison was compared to Pasco interacting with the control versus treatment years.

TABLE 4. Analysis-of-variance for Diptera and Hydracarina. Asterisks denote significance at P > .05 (*) or P > .0.01 (**); unmarked values represent non-significant differences. All data were transformed to logarithmic scale.

	Diptera			Hydracarina		
Source of variation	Degrees of Freedom	Mean Square	F	Degrees of Freedom	Mean Square	F
Ponds (Madison, Suwannee, Pasco)	2	.20943	.36923	2	.18707	.55230
Madison vs. Suwannee and Pasco	1	.30782	.54270	1	.01538	.04540
Suwannee vs. Pasco	1	.15322	.27013	1	.33871	4.3897
Years (control, treatment year 1, treatment yer 2)	2	.33145	.58436	2	2.95490	9.57301*
Control vs. treatment year	1	.64551	1.1380	1	5.55412	17.99371*
Treatment year 1 vs. treatment year 2	1	.01830	.03226	1	.35570	1.5236
Ponds across Years	4	.56720	Error ↑	4	.30867	Error ↑
Season (months)	11	.87523	11.39622**	11	.04966	.67990
Season interaction with control vs. treatment years	11	.70125	9.13086**	11	.15557	2.12992
Season interaction with treatment year 1 vs. treatment year 2	11	.07680	Error ↑	11	.07304	Error ↑
Deep water stations vs. shallow water stations with control vs. treatment years	1	.75952	16.07055	1	.52112	111.11
Deep water stations vs. shallow water interaction with treatment year 1 vs. treatment year 2	1	.04735	Error ↑	1	.00469	Error ↑

Several authors have investigated feeding of sport fishes in Florida (Ware 1966; Welch 1967; Wilbur 1969; Chew 1974). Abundance of benthic organisms in food habits suggests they are essential for sport fish production. Benthic organisms were classified into categories according to the afore-mentioned reports. Those which were reported to have percentage frequency of occurrence in fish stomachs greater than 20% in the above-referenced works classified as fish food organisms. These include the following: *Hyalella Baetis*, *Palaemonetes*, *Ephemera*, *Ischnura*, *Ephemerella*, *Hexagenia*, *Tricorythodes*, *Erythemis*, *Gomphoides*, Coeagrionidae, *Lestes*, *Leucorrhina*, *Libellula*, *Pachydiplax*, *Taeniogeter*, Tendipedidae, *Tendipes*, *Arrenurus*, *Limnochares*, *Eylas* and *Mideopsis*. Other organisms found could possibly be utilized by fishes but these are representatives presented in published literature, either as major groups or genera. Fig. 2 illustrates changes in fish food organisms through the study.

An analysis of variance revealed a significant difference in fish food organisms when the control year was tested against the two treatment years (Table 5). Fish food organisms were reduced after grass carp stocking. No significant difference were found among ponds or in pond comparisons. Significant differences were found among months and the months interaction with the control year versus the treatment years. Seasonal effect seems to be present with high numbers of fish food organisms occurring winter and early spring and lower numbers occurring in summer and early fall. Many of the high numbers present in winter are due to *Hyalella asteca*, an important fish food organism.

Fish food organisms were reduced somewhat in all ponds the first year after introduction of grass carp. Slight recovery occurred in Suwannee the third year of the study. *Ephemera* and *Tendipes* were well numerically represented in Suwannee Pond in the first year and third year of the study. Pasco and Madison food organisms remained depressed through the third year.

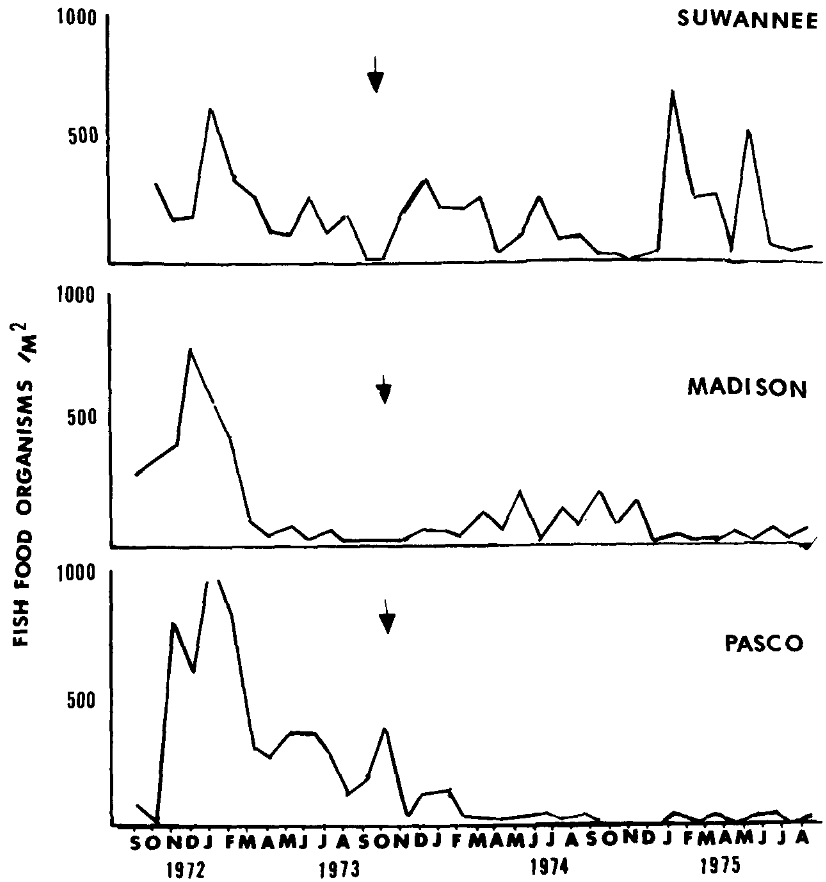

Fig. 2. Number of fish food organisms per square meter for each of the 3 ponds through through the study period. The arrows (↓) indicate where grass carp were stocked.

Authors (Mackentham 1966; Wilhm 1967; Cairns and Dickson 1971; Weber 1973) have suggested benthic invertebrate populations as pollution indicators. The concensus is that benthic macroinvertebrates are particularly useful because habitat preference and low mortality cause them to be affected directly by major water quality changes. These offer an advantage to scientists who sample the environment because other indicators such as phytoplankton populations and water chemistry criteria vary dramatically during the day and over a short time period.

Changes in macroinvertebrate water quality indicator organisms were evaluated using three published techniques. Diversity indices (Wilhm and Dorris 1969) were calculated for each sample period using the formula:

$$\bar{d} = \sum_{i=i}^{s} \frac{ni}{n} \log_2 \frac{ni}{n}$$

where
ni = number of individuals per taxa
n = total number of individuals
s = total number of taxa in the sample of the
d = a mẹasure of species diversity

Stations sampled were pooled by pond and sample period to represent the benthic community. Fig. 3 shows results of these calculations. Wilhm and Dorris found that values for d are usually less than 1 for areas of heavy pollution, from1 to 3 in areas of moderate pollution and greater than 3 in clean water areas. Data collected from waters of the southeastern United States have shown that where degradation is at slight or moderate levels, d lacks sensitivity to demonstrate differences (Weber 1973); however, this was not the case with these data.

TABLE 5. Analysis-of-variance for pollution intolerant organisms and fish food organisms. Asterisks denote Significance at P > .05 (*) or P > 0.01 (**); unmarked values represent non-significant differences. All data were transfomed to logarithmic scale.

	Pollution intolerant organisms			Fish food organisms		
Source of Variation	Degrees of Freedom	Mean Square	F	Degrees of Freedom	Mean Square	F
Ponds (Madison, Suwannee, Pasco)	2	.01338	.05205	2	.23894	.25452
Madison vs. Suwannee and Pasco	1	.01557	.06057	1	.29706	.31644
Suwannee vs. Pasco	1	.01410	.05485	1	.13222	.14085
Years (control, treatment year 1, treatment year 2)	2	3.08846	12.01408*	2	6.40863	6.82670
Control vs. treatment year	1	5.69160	22.14027**	1	11.86264	12.63650*
Treatment year 1 vs. treatment year 2)	1	.18379	.71494	1	.95464	1.01692
Ponds across Years	4	.25707	Error↑	4	.93876	
Season (months)	11	.07663	.86412	11	.58107	11.40919**
Season interaction with control vs. treatment years	11	.16527	1.86367	11	.47073	9.24269**
Season interaction with treatment year 1 vs. treatment year 2	11	.08868	Error↑	11	.05093	Error↑
Deep water stations vs. shallow water stations with control vs. treatment years	1	.60844	112.25830	1	.38309	10.45837
Deep water stations vs. shallow water interaction with treatment year 1 vs. treatment year 2	1	.00542	Error↑	1	.03663	Error↑

Further evaluation was done using an indicator-organism scheme and tables presented by Weber (1973) with modificiations based on Florida's freshwater systems and other literature (Beck, 1957). As illustrated by Cairns and Dickson (1971), tolerant organisms are found in both clean and polluted situations and that their presence does not mean a body of water is polluted; however, a population of tolerant organisms combined with an absence of intolerant organisms is a good indication of pollution. Fig. 4 illustrates changes in organisms through time. For the purpose of this phase of evaluation, *Hexagenia*, *Baetis*, all general of Hydracarina, *Hydroptila*, *Psychomyia* and *Leptocercus* were considered pollution intolerant organisms. Other genera were considered facilitative or tolerant based on previously cited literature. Several organisms present in this research have not been classified by any pollution standards.

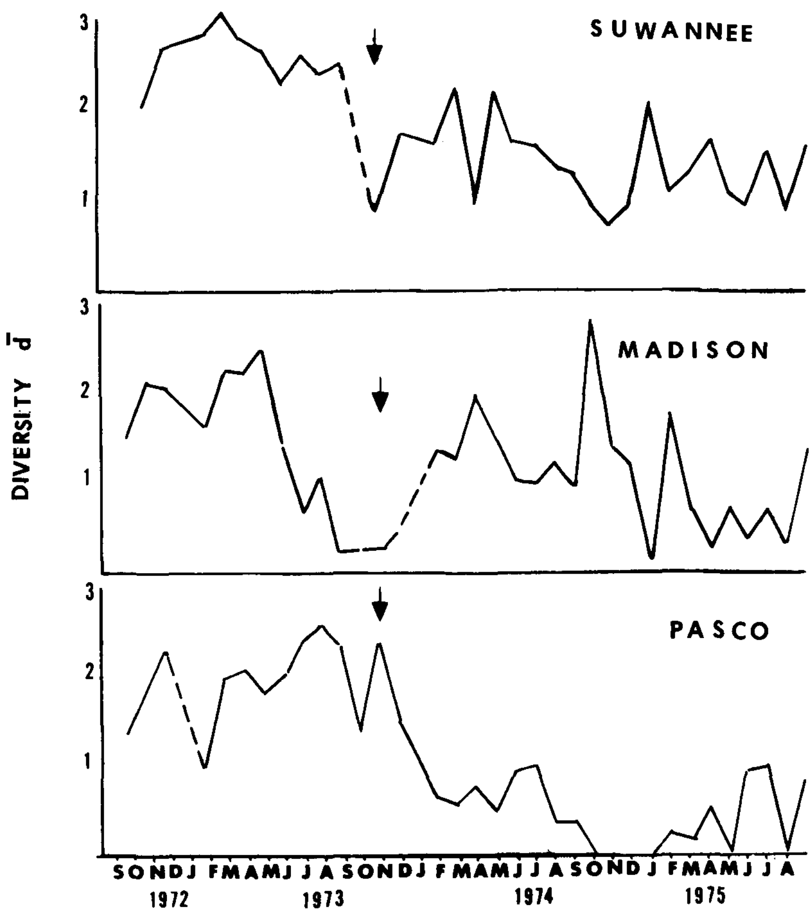

Fig. 3. Species diversity (d) for benthic macroinvertebrates for each of the 3 ponds through the study period. The arrows (↓) indicate where grass carp were stocked.

Significant differences in pollution intolerant organisms were indicated by an analysis of variance. No difference was indicated among ponds. Significant differences did occur among years. When the control year was compared to treatment years, pollution intolerant organisms decreased after grass carp introduction. Significant seasonal influence was indicated by differences among months and as months interacted with the control year versus treatment years (Table 5). The final method used is simply number of species present. Decreases occured in all ponds.

CONCLUSIONS

Publishes works on the effects of grass carp introduction on water quality are few. Conflicting reports are found in other literature. Some authors (Prowse 1969; Bailey and Boyd 1970: Cagni et al. 1971) stated that grass carp will lessen the rate of eutrophication; however, grass carp are reported to cause algal blooms and organically stained water (Straoganov 1968; Avault et al. 1968; Opuszynski 1972; Chittum 1974). Major changes in water quality have been reported (Michewicz et al. 1972; Stanley 1974) as a result of grass carp feeding in laboratory environments.

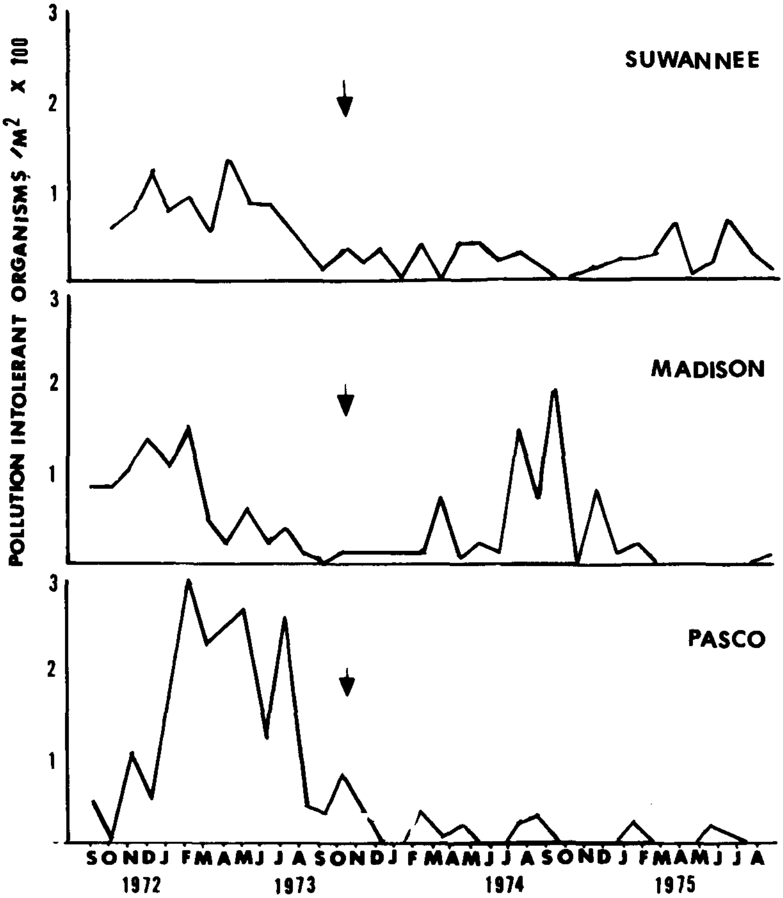

Fig. 4. Number of pollution intolerant organisms per square meter for each of the 3 ponds through the study period. The arrows (↓) indicate where grass carp were stocked.

In the ponds studies, *Chaoborus* did well at some time after grass carp introduction. Collins (1970) reported changes in benthos and phytoplankton communities when organic wastes were added to ponds. His research shows *Chaoborus* to respond well and become dominant in ponds containing large amounts of added organic matter. Other major benthic groups were depressed. Benthic population responses seen in this study are remarkably similar to those reported by Collins.

Holcomb (1969) compared 3 Florida lakes based on the trophic state of their aquatic environments as determined by weekly sampling. He concluded that Lake Dora was in the latest state of eutrophy and exhibited many undesirable characteristics. lakes Weir and Yale maintained desirable aquatic communities. Accordingly, benthic invertebrate populations were diverse in both of the latter lakes while Lake Dora's populations were dominated by *Chaoborus.*

Suwannee Lake, Madison Pond, and Pasco Pond aquatic vegetation changed dramatically after grass carp introduction. When comparing changes in benthic species diversity to vegetation changes, both occurred simultaneously after grass carp introduction in the 3 lakes studied. Change in available plant material probably contributed to some observed changes. Greatest change in benthos in each pond occurred at the time of greatest change in aquatic vegetation.

Gasaway (1976) and Gasaway and Drda (1978), reported changes in zooplankton, chlorophyll *a*, *b*, and *c* and phytoplankton. Limnetic rotifers such as *Keratella*, *Polyarthra*, *Filinia*, *Kellicotti* and *Conchilus* increased in all ponds along with significant increases in chlorophyll *a*. Shifts in the phytoplankton and zooplankton communities may have influenced changed in benthos, particularly predacious genera such as *Chaoborus*.

Grass carp growth through time for each study site was reported by Gasaway (1976). Surviving grass carp in Pasco Pond were exceptionally small and their size did not significantly change from February, 1974 to August 1975. Since these fish were from the same stock as the other 2 ponds, it is very unlikely that this is a genetic result; therefore, food supply (or the lack of it) probably was the greatest factor influencing growth. Submerged vegetation was eliminated from Pasco Pond by February, 1974.

Suwannee Lake submerged vegetation was eliminated by July, 1974. Growth was slower than in Madison Pond which was twice that of Suwannee Lake. Water temperature was significantly lower in Madison Pond. Stocking density of grass carp was also lower in Madison Pond and could have influenced growth; however, remaining submerged vegetation sustained the population.

The ponds were renovated at study termination to remove grass carp. Suwannee Lake and Pasco Pond contained 3.3 kg per ha. Pasco Pond had 17 fish and Suwannee Lake had 21 fish. There were no intensive efforts to collect grass carp in Madison Pond; however, 17 fish were collected the first day.

These data coupled with aquatic vegetation data indicate the numbers of grass carp present were influencing conditions in the pond. Therefore, the treatment (stocking of grass carp) appears valid. We believe this allows us to attribute associated changes to the actions of the fish. The aquatic vegetation community recovered in all ponds within 1 year after removal of the carp. Recent studies in Florida show grass carp display linear growth exceeding 13 kg per fish when abundant food is available.

We may conclude that introduction of grass carp into 3 Florida ponds caused changes in the benthic invertebrate community. Since this community is an important portion of the food chain, it is likely that these changes would be detrimental to some existing species of fishes and could contribute to the detrimental effects on fishes in 2 of these ponds reported by Ware and Gasaway (1977).

The cause of these changes could be related to either changes in water quality (Beach 1976; Gasaway 1976), elimination of aquatic vegetation or perhaps an overall ecosystem change. Three lakes studied were macrophyte based systems with aquatic vegetation being the major part of the ecosystems primary productivity. Changes in benthic organisms are likely to occur if grass carp are introduced into lake supporting substantial aquatic vegetation and established benthic communities.

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