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ACKNOWLEDGMENT

The author expresses his sincere appreciation to Mr. Wesley Fish, Fla. Game & Fish Commission, for his worthy assistance throughout the project.

EFFECT OF WATER HYACINTHS AND FERTILIZATION ON FISH-FOOD ORGANISMS AND PRODUCTION OF BLUEGILL AND REDEAR SUNFISH IN EXPERIMENTAL PONDS [1]

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ABSTRACT

Eighteen 0.1-acre ponds at the Auburn University Fisheries Research Unit, Auburn, Alabama, were used from April 5 through November 20, 1967. Both species of fishes were stocked together randomly at a rate of 4,000 fingerlings per acre. The experimental design consisted of three control ponds without fertilization or hyacinths; three control ponds without fertilization, but with hyacincths; three ponds with 0-8-0 (N,P,K) fertilization, but no hyacinths; three ponds with 0-8-0 fertilization, but with hyacinths; three ponds with 8-8-0 fertilization, but no hyacinths; and three ponds with 8-8-0 fertilization, but with hyacinths. The fertilizers were applied to stimulate the growth of hyacinths and fish-pond organisms.

Greater numbers and dry weights of fish-food organisms were associated with roots of water hyacinths in control ponds than in fertilized ponds. Snails and odonate numphs were dominant in control ponds but were not important in fertilized ponds. Dry weight of am-

[1] This research was supported in part by Rockefeller Foundation Grant RF 65061.

[2] This paper is based on a thesis submitted to the Graduate Faculty of Auburn Univ. in partial fulfillment of the requirements for the M.S. Degree.

phipods and midge larvae did not differ significantly between the control and two fertilizer treatments. Low numbers and dry weights of fish-food organisms in fertilized ponds containing hyacinths was probably due to heavy predation by the sunfishes. Upon draining the fish production was greater in fertilized ponds containing plants compared to control hyacinth ponds. In the unfertilized ponds the mean standing crop of fish at draining time was approximately the same in both hyacinth and non-hyacinth ponds. The mean standing crop from fertilized ponds was at least twice as great in non-hyacinth ponds as in hyacinth ponds. The reduced fish production in hyacinth ponds was probably a result of competition for nutrients between the water hyacinths and plankton food-chain, and of the reduction of "edge" for fish-food organisms on the roots.

INTRODUCTION

The water hyacinth, *Eichhornia crassipes* (Mart.) Solms, has become a pest in many areas of the Gulf Coast because it obstructs navigable waterways, and its extensive growth has a detrimental effect on fishing and use of wetlands for wildlife. Yet, the water hyacinth's root system provides a habitat for many fish-food organisms. Thus under proper management control, it may be possible to use these plants in fish culture.

A review of the literature revealed no articles reporting attempts to manage the water hyacinth in small impoundments or lakes to increase fish production. Dendy and Swingle (personal communication) observed water hyacinth rafts within enclosures of rope and bamboo stakes in large lakes of several Asian countries. The rafts were used to attract fish which were captured in traps, nets or by hook and line. Burgess (1965) stated that the use of water hyacinths as a suitable substrate for invertebrate forage (for fish) may be more a topic of academic interest than of a practical nature. Katz (1967) reported that studies carried out in connection with controlled spraying of hyacinths have indicated that the amount of natural shelter provided by floating vegetation, such as water hyacinths, has an effect upon the size and ratio of forage fish to predatory fish. She further stated that all hyacinth samples collected contained small fish of various species which supports her contention that these fish seek out hyacinth mats for food and shelter.

The author postulated that by stimulating the growth of water hyacinth roots with different fertilizers, increased surface area of favorable habitat would result in greater numbers of fish-food organisms and increased fish production. It was also assumed that a surface coverage of approximately 10% of the 0.1-acre pond (4,356 ft^2 or 405 m^2 by a water hyacinth raft (484 ft^2 or 45 m^2), as opposed to open water would show an effect on the fish production.

MATERIALS AND METHODS

Description of Ponds

The ponds (60 x 72.5 ft.) were constructed in sandy clay and had sloping banks. The depth of water upon filling varied from approximately 1 1/2 ft. at the shore to approximately 6 ft. at the standing drain pipe. The ponds were arranged in two "L-shaped" parallel rows. Water entered the pond from a diversion ditch by a 2-inch-diameter PVC plastic pipe system. Each pond's water inlet consisted of a gate value to regulate flow and an attached Saran sock (36 inches long x 4 inches diameter) supported by a wooden trough platform 4 feet long. The purpose of the Saran screen sock was to prevent the entry of wild fish and fish eggs. Individual ponds were drained separately by rotating the 4-inch diameter standing drain pipe on an elbow at the bottom.

Fertilizer Treatments

Treatment	Number of Ponds Hyacinths	No. Hyacinths
0-0-0	3	3
0-8-0	3	3
8-8-0	3	3

The ratios represent the weights of nitrogen, potassium, phosphate, respectively, in the fertilizer applied. Nitrogen was provided in the form of ammonium nitrate (33.5% N). Phosphate was provided in the form of triple superphosphate (54% P). The fertilizers were applied at the rate of 100 pounds per acre per application for 10 applications. They were applied at two-week intervals from April 5, 1967, until May 19, 1967, when a heavy plankton bloom occurred in several ponds. At that time it was decided to extend the interval between fertilizer applications to four weeks.

Water Hyacinth Rafts

The hyacinth enclosures consisted of a rough-cut 1 x 6 inch pine boards nailed together to form a 22 x 22 foot square. The rafts were held stationary in the center of the pond by 1 x 6 inch rough pine boards which were driven into the pond bottom and railed to the raft. Each of the rafts in the nine ponds containing hyacinths was filled to one-third surface area capacity with plants (approximately 1,400 plants) of uniform size on April 19-20, 1967. The hyacinths were obtained from Lake Seminole, Georgia. The remaining two-thirds capacity provided for growth in response to the fertilizer treatments. The term "edge" refers to the amount of open water between the plants and between roots where light can penetrate.

Fish Stocking

The bluegill sunfish, *Lepomis macrochirus* Rafinesque, was chosen as the experimental special because it feeds extensively on macroinvertebrates as shown by the food habit studies of Applegate et al., (1966), Chable (1947), Dendy (1956), Gerking (1964), Howell et al., (1941), Huish (1957) and Schneider (1962). A supply of 1 to 3-inch fingerling bluegills were obtained from the National Fish Hatchery, Marion, Albama. This supply was found to be contaminated with redear sunfish, *Lepomis microlophus* (Gunther). Both species of sunfishes were stocked because identification through handling could result in high mortality and they were difficult to separate at a small size. Prior to being stocked, the fish were treated with formalin at 20 ppm for three hours to remove external parasites. In this paper, standing crop and final production are synonymous.

Sampling Methods and Analysis

All ponds with hyacinth rafts were sampled at monthly intervals for production of fish-food organisms. The sampling device (0.9 ft. or 0.1 m^2 surface area at mouth) consisted of a galvanized bucket (13 1/2 inches mouth diameter x 8 inches deep x 11 1/8 inches bottom diameter), with a perforated bottom. The perforated bottom was covered with an inside lining of No. 50 brass screen. The screen was soldered to the bottom at the edge and at several places near the middle.

The sampling technique consisted of swimming underneath the hyacinth raft and randomly surfacing under the hyacinth roots with the sampling bucket's mouth upward. All hyacinth parts hanging outside the bucket were removed and all parts within the bucket were quickly transferred to large labeled plastic bags. Any macroinvertebrates found inside the bucket were also transferred to the hyacinth sample bag by means of several water washings, and the bag was closed with a large rubber band. Three samples per raft per month (0.55% surface area) were taken in this manner in each hyacinth pond. The hyacinth samples were refrigerated at 60°F until they could be processed in the laboratory.

Fish-food macroinvertebrates were removed by dipping the water hyacinth roots in a plastic wash basin of scalding water (approximately 176°F) for approximately one minute. The whole plant was quickly removed and placed in another basin so that any dead organisms that might have remained on the roots could be sorted out. The resulting mixture of hot water, macroinvertebrates and detritus was poured through a No. 25 mesh sieve and washed to remove all silt. This sample material was transferred to a sorting tray. Any remaining debris in the sieve was also washed into the sorting tray. The sample was placed under an illuminated magnifier and all macroinvertebrates were removed to sample jars, preserved in 70% ethyl alcohol and labeled according to pond, month sampled and particular sample (e. g. first, second and third sample). Macroinvertebrates remaining on the hyacinth roots turned white upon scalding, therefore they were easily visible against the black background of the roots. These organisms were placed in their respective sample jars with the previously sorted macroinvertebrates and put aside for future identification and enumeration. Due to the extensive time necessary for sampling and sorting, macroinvertebrates collected in a given month for the nine hyacinth rafts required five to seven days to process.

Only fish-food organisms large enough to be observed under a binocular dissection microscope (10X) were saved. These were identified to order, and in several cases to family, by use of keys by Borrer and DeLong (1964), Pennak (1953) and Usinger (1963). All organisms were counted, but only aquatic forms and stages were included in the total sample count.

Dry weights of the macroinvertebrates were used to reduce the bias resulting from water and alcohol preservative. All weights were read on a Mettler Balance [1] to the nearest 0.0001 g. Plastic sandwich boxes with lids (4½ x 4 x 1¼ inches), which previously had several holes drilled through the sides for heat circulation, were used to hold the samples for drying. A numbered grid was drawn on the outside bottom of each box. Each sample was placed on a previously weighed aluminum foil planchet (Dendy, personal communication) which had been assigned to a numbered block on the grid. The boxes containing the samples were placed in a drying oven, with the lid slightly ajar, at 140°F for 24 hours. They were then removed and allowed to cool in desiccators until weighed. The weight differences between the planchet and the planchet with sample was recorded as the sample dry weight.

Because of the variable growth of the hyacinths in response to a fertilizer treatment, it was extremely difficult to sample a given area of hyacinth roots. Therefore the dry weights of organisms are expressed as dry weight per m^2 of water hyacinths based on three 0.1 m^2 samples.

Statistical Analysis

Analyses of variance were computed to gain insight into the main effects and interactions occurring within the hyacinth ponds. The three main effects used were fertilizers, dates sampled and presence of water hyacinths. The dependent variables used included the number of macroinvertebrates, dry weight of macroinvertebrates, combined net production of bluegill and redear sunfishes, and standing crop of wild fishes. Caution must be used when there is interaction between two independent variables. If the probability value for the effect of interaction is significant, then a comparison within the main effects is not valid. In this situation the interaction is no longer independent but acts as a dependent factor.

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1 Mettler Instrument Corp., Hightstown, New Jersey.

RESULTS AND DISCUSSION

MACROINVERTEBRATES

Twenty-four different groups of organisms were collected from the hyacinth roots in the experimental ponds (Table 1). Final enumeration of macroinvertebrates was reported as mean number of organisms on roots per m^2 of water hyacinths (Figure 1). Numbers of organisms in the first samples during May were greater in 0-8-0 and 8-8-0 ponds than in 0-0-0 ponds. As the season progressed, greater numbers of fish-food organisms occurred in the control (0-0-0) hyacinth ponds while a decline was evident in 0-8-0 and 8-8-0 ponds. Heavy cropping by stocked fish and the reduction of "edge" within the hyacinth rafts receiving 0-8-0 and 8-8-0 treatments could have drastically affected the numbers appearing in the samples. The effect of fertilization, dates sampled, and interaction upon the numbers of fish-food organisms was highly significant. Due to the highly significant effect of interaction, a monthly comparison was made of the fertilization effect on the number of organisms. The monthly differences in numbers of macroinvertebrates in fertilized ponds, and in unfertilized ponds was statistically significant. The monthly fluctuations in numbers of organisms associated with hyacinth roots was attributed directly to the individual fertilizer treatments.

TABLE 1. List of Organisms Collected from Hyacinth Roots from May Through October 1967

Platyhelminthes	Crustacea (continued)
Turbellaria	Amphipoda—Grammaridae
Annelida	—Talitridae
Oligochaeta	Insecta
Hirudinea	Ephemeroptera—Baetidae
Mollusca	Hemiptera—Belostomatidae
Gastropoda—Physidae	Odonata
—Planorbidae	Anisoptera—Libellulidae
Pelecypoda—Sphaeriidae	Zygoptera—Coenagrionidae
Acarina	Coleoptera—Dytiscidae
Hydracarina	—Gyrinidae
Crustacea	—Hydrophilidae
Ostracoda	Trichoptera
Copepoda	Lepidoptera—Pyralidae
Cladocera	Diptera—Tipulidae
	—Culicidae
	—Chironomidae

Both numbers and dry weight of organisms on roots were based on a m^2 of water hyacinths rather than on dry weight of hyacinth roots because the ratio of organism numbers and weight to root weight were not correlated between treatments when plotted on graphs.

Monthly dry weights of macroinvertebrates are presented in Figure 2. Macroinvertebrate biomass decreased drastically on hyacinth roots in 0-8-0 and 8-8-0 ponds while an increase occurred in control ponds. This phenomenon could be attributed to the reduction of "edge" brought about by increased growth of hyacinths receiving 0-8-0 and 8-8-0 treatments. The effect of fertilization, sampling date, and interaction on the dry weight of macroinvertebrates was highly significant. The effect of fertilizer treatment on dry weight of macroinvertebrates from monthly samples associated with the hyacinth roots was not significant from July through October. The non-significant effect of fertilization on macroinvertebrate dry weight during May and June could be associated with the small variation which occurred between treatments (Figure 2).

Katz (1967) reported that the amphipod, *Hyalella azteca*, was the most abundant organisms associated with water hyacinth roots, followed by chironomid larvae. In control ponds, snails comprised the largest portion of biomass. Odonate nymphs ranked second, followed by amphipods and midge larvae. It was difficult to rank the organisms in 0-8-0 and 8-8-0 ponds associated with roots because of the wide variation in estimated dry weights of these dominant organisms. Yet, odonate nymphs seemed to comprise the greatest weight.

Fish Production

Upon draining the ponds, a number of wild fish species were found in the ponds and were recorded along with the bluegill and redear sunfish data. Table 2 illustrates the condensed results of the bluegill and redear sunfish production. The absence of small individuals of bluegill and redear sunfish in several of the ponds was possibly due to crowding and not to the harmful effect of free-floating hyacinths drifting over nets and disturbing spawning fish as reported by Lynch et al., (1947). There was no correlation between the variable stocking weight and the final production and net production of bluegills and redears. Yet, several of the ponds (R-13, R-15, R-18) which received low stocking weights had the highest percentage survival. In determining percentage survival, fish three inches or larger in length were assumed to have been stocked and not reproduced. Percentage survival averaged higher in non-hyacinth ponds (76%) than in hyacinth ponds (61%). Within fertilizer treatments, average percentage survival was greater when hyacinth rafts were absent. Final standing crop and net production were lower in ponds with hyacinths than without the plants, except where fertilizer was not applied (0-0-0 ponds). The fish production was approximately the same in the control ponds. In 0-8-0 ponds the average standing crop was 2.5 times greater and the net production was 3.0 times greater in non-hyacinth ponds than in hyacinth ponds. The average standing crop in the 8-8-0 ponds was 2.1 times greater and the net production was 2.5 times greater in non-hyacinth ponds. There was an approximate average net increase of 20 pounds per acre in standing crop and 28 pounds increase in net production which was brought about by increasing the level of fertilization from 0-8-0 to 8-8-0 in the absence of water hyacinths. With hyacinths present, there was an average net increase of 19 pounds per acre and 22 pounds per acre increase in final production with higher levels of fertilization (0-8-0 to 8-8-0). In comparing the weight of wild fish and weight of bluegill and redear sunfish, no correlation could be seen that indicated influence of competition.

The effect of fertilization and water hyacinths on the final bluegill and redear sunfish net production was highly significant; also the effect of their interaction was significant. From these data it is concluded that the low net production of bluegill and redear in hyacinth ponds was due to the effect of water hyacinths and fertilization. Likewise the high production in non-hyacinth ponds was associated with different treatments of fertilization. The effect of fertilization, hyacinths and their interaction on the production of wild fish was not significant.

Since the ponds used in this experiment were newly constructed, there was no opportunity for organic matter to accumulate in pond bottoms and to provide a more favorable habitat for benthic fish-food organisms. Although the abundance of plankton was not determined, observations on the color of the pond water showed that non-hyacinth ponds receiving fertilizer usually had a good plankton bloom (dark green) while hyacinth ponds receiving fertilizer had a poor plankton bloom (light green to clear). The reduced production of plankton in hyacinth ponds was probably due to competition for fertilizer between the water hyacinths and phytoplankton. In other words, the food chain starting with phytoplankton and going through the different levels of zooplankton provides more fish-food than do the organisms associated with the hyacinth roots.

There were greater numbers and dry weight of macroinvertebrates (Figures 1 and 2) along with the lowest fish production (Table 2) in

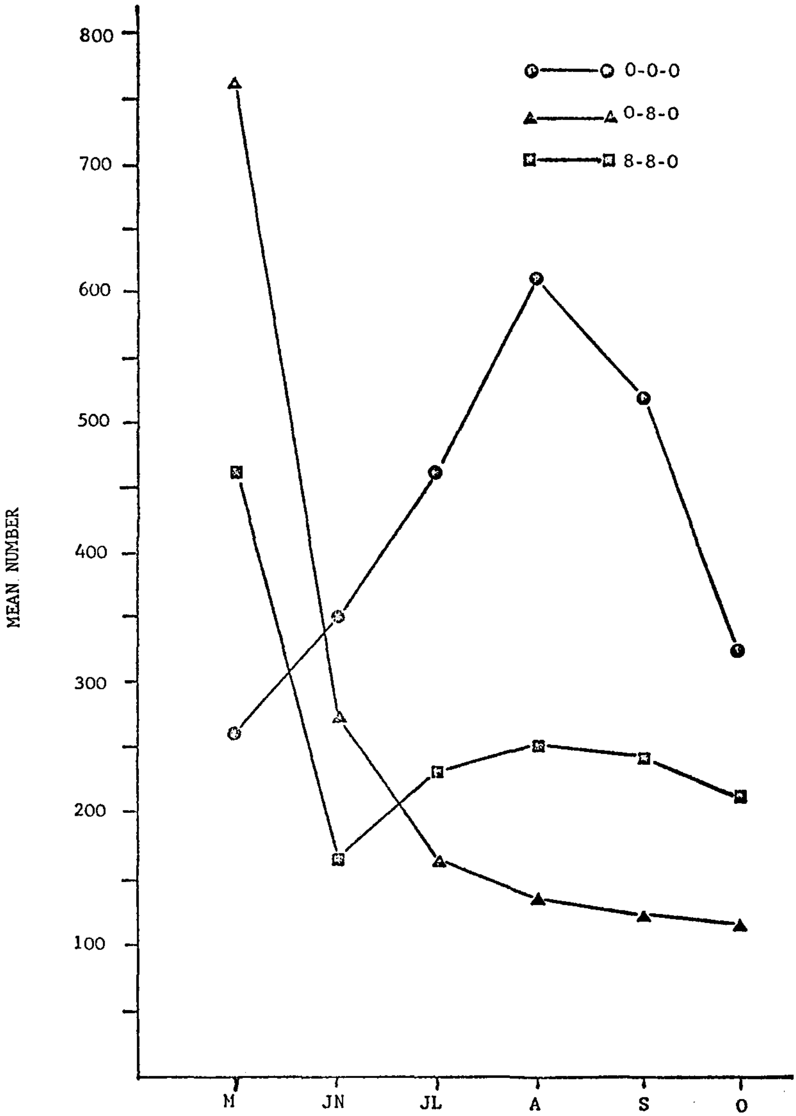

FIGURE 1. MONTHLY MEAN NUMBER OF MACROINVERTEBRATES ON ROOTS PER M^2 OF WATER HYACINTHS

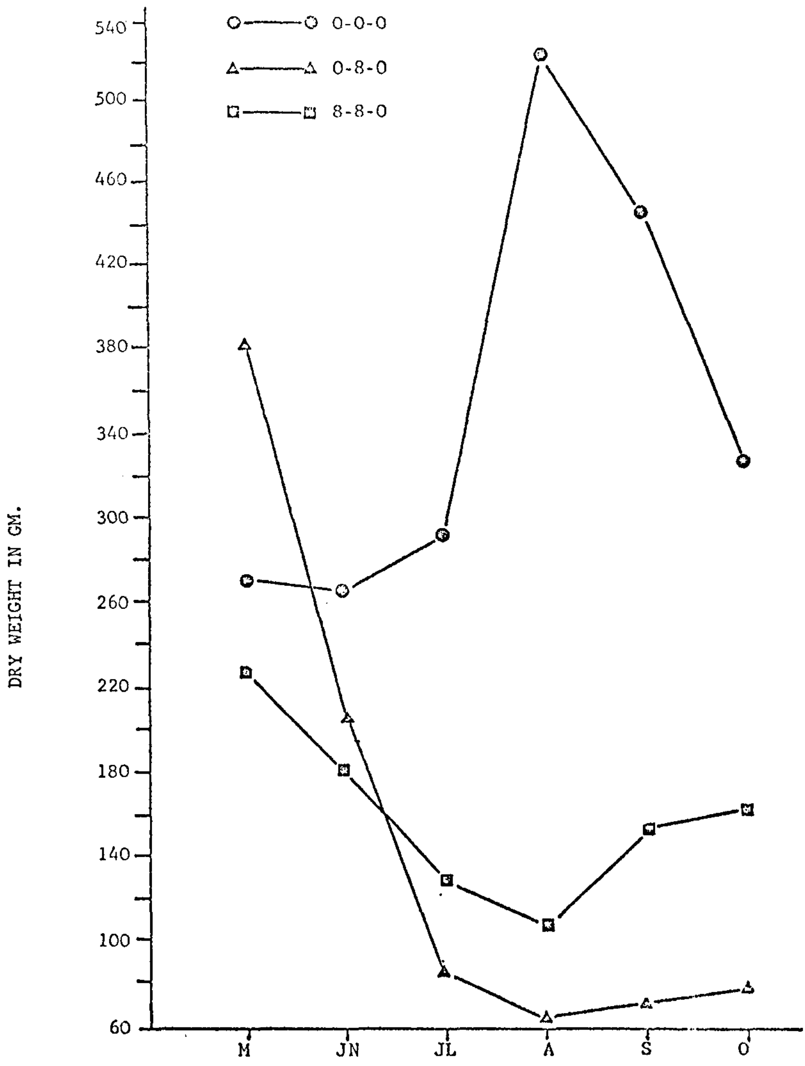

FIGURE 2. MONTHLY MEAN DRY WEIGHTS OF MACROINVERTEBRATES ON ROOTS PER M^2 OF WATER HYACINTHS

TABLE 2. Production of Bluegill and Redear Sunfish Upon Draining

Pond number	Stocking weight (lbs/A)	Reproduction	Percent survival	Mean	Final standing crop (lbs/A)	Mean	Net production (lbs/A)	Mean	Wild fish (lbs/A)	Mean
0-0-0 Fertilization Without Hyacinths										
R-11	4.4	No	74		43.7		39.3		15.0	
R-26	23.1	Yes	50		33.5		10.4		0.3	
R-30	6.3	Yes	81	68	45.8	41.0	39.5	29.7	3.5	6.3
0-0-0 Fertilization With Hyacinths										
R-6	5.6	Yes	26		23.9		18.3		31.4	
R-16	7.5	No	65		77.5		70.0		13.3	
R-21	21.3	Yes	53	48	34.2	45.2	12.9	33.7	13.8	19.8
0-8-0 Fertilization Without Hyacinths										
R-18	16.3	Yes	85		151.7		135.4		48.6	
R-20	31.9	Yes	75		104.9		73.0		7.5	
R-22	20.0	Yes	78	79	136.5	131.0	116.5	108.3	61.6	39.2
0-8-0 Fertilization With Hyacinths										
R-17	12.5	No	63		35.7		23.2		51.3	
R-25	21.3	Yes	61		56.7		35.4		5.6	
R-27	11.3	Yes	55	60	61.5	51.3	50.2	36.3	0.1	19.0
8-8-0 Fertilization Without Hyacinths										
R-15	4.4	Yes	88		146.4		142.0		209.4	
R-23	18.8	Yes	80		155.2		136.4		1.7	
R-24	21.3	Yes	76	81	151.0	150.9	129.7	136.0	16.7	75.9
8-8-0 Fertilization With Hyacinths										
R-13	7.5	No	89		93.0		85.8		9.0	
R-19	23.8	Yes	70		74.8		51.0		24.9	
R-28	21.3	Yes	70	76	50.7	72.9	29.4	55.4	15.5	16.5

the 0-0-0 ponds with hyacinths. This may be attributed to one or a combination of four factors: (1) the dominant organisms (microcrustacea, molluscs, and insect larvae and nymphs) were not desirable as fish-food; (2) sampling error; (3) an absence or shortage of plankton to feed desirable fish-food organisms and to supplement the diet of the fish; (4) the sparse root system of the non-fertilized hyacinths did not provide a desirable habitat for preferred fish-food organisms. Also the high fish production and corresponding low number of organisms in 0-8-0 and 8-8-0 ponds with hyacinths could reflect heavy predation on the organisms (Figure 3). These harvested fish-food organisms would not be evident in the monthly root samples. Higher fish production in

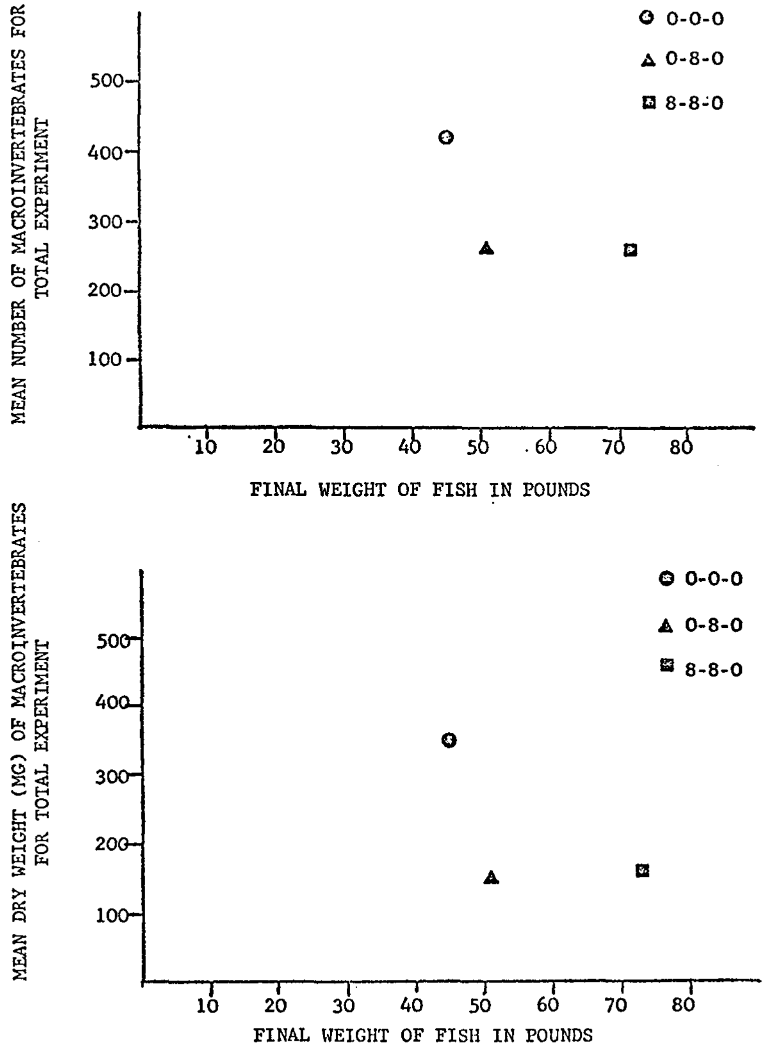

FIGURE 3. COMPARISON OF MACROINVERTEBRATES PER M^2 OF WATER HYACINTHS TO FINAL PRODUCTION OF BLUEGILL AND REDEAR SUNFISH.

non-hyacinth ponds is probably due to the greater amount of fish-food organisms available through the fertilizer-plankton food chain as opposed to the fertilizer-hyacinth roots-associated macroinvertebrates food chain in hyacinth ponds.

SUMMARY AND CONCLUSIONS

There were greater numbers and dry weights of fish-food organisms on roots per m^2 of water hyacinths in 0-0-0 ponds than in either 0-8-0 or 8-8-0 ponds. Snails and odonate nymphs were present in greater abundance in 0-0-0 ponds than in others. Amphipods and midge larvae were scarce in all ponds. In hyacinth ponds receiving 0-8-0 and 8-8-0 treatments, high fish weight was correlated with low numbers and dry weights of fish-food. This phenomenon is probably due to the reduction of "edge", and to heavy predation by bluegill and redear sunfish.

Standing crop of bluegill and redear sunfish at draining was lower in ponds with hyacinths than in ponds without the plants except where fertilizer was not applied (0-0-0 ponds). Fish production varied little among control ponds. The total weight of harvested bluegill and redear from the 0-8-0 and 8-8-0 ponds was at least twice as great in non-hyacinth ponds. The reduced fish production in hyacinth ponds was probably due to competition for fertilizer between the water hyacinths and plankton, and the reduction of "edge" for fish-food organisms. The food chain starting with phytoplankton and going through the different levels of zooplankton provided more fish-food organisms, thus more fish, than did the hyacinth roots with its associated macroinvertebrates. However, the production of bluegill and redear sunfish in the new 0.1-acre ponds without hyacinths was very low. This low production might be due to the relatively infertile bottom of the new ponds, which provided poor habitat for benthic food-organisms.

The results of this experiment do not indicate that water hyacinths complement accepted fertilizer treatments to increase fish production in the Gulf Coast States. Yet, more extensive study is necessary to evaluate the effect of water hyacinths and fertilization on fish production. By transporting the water hyacinths from their original habitat, many of the fish-food organisms were probably lost and those that remained possibly could not adjust to the pond environment.

ACKNOWLEDGMENTS

I wish to thank Dr. J. S. Dendy for his guidance and counseling in completing this project. I also wish to thank the Research Data Analysis Section of the School of Agriculture, Auburn University for computing the statistical analyses. Finally, appreciation is extended to the many graduate fisheries students at Auburn who helped me collect and transport the plants and also helped harvest them upon termination of the experiment.

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DISTRIBUTION OF JUVENILE RIVER HERRING IN THE POTOMAC RIVER

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INTRODUCTION

This report concerns the distribution of juvenile alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) in the tidal portion of the Potomac River as determined in 1968. The river courses for 100 nautical miles from the Lower Falls at Washington, D. C. to empty into the Chesapeake Bay some 60 miles from the Virginia capes. It is second only to the Susquehanna River in freshwater input to the bay, contributing 18% of the total. The salinity at the mouth is approximately 18 ppt., and salt water intrudes 70 to 75 miles. The upper tidal portion is heavily polluted by domestic wastes from the Washington Metropolitan area. Although much of the sewage is treated, overenrichment causes massive algal blooms.

METHODS

The distribution of juvenile river herring was determined by sampling at five-mile intervals with two types of trawl gear, a 30 foot semi-balloon bottom trawl and a 10 by 10 foot Cobb midwater trawl which was fished at the surface and at 15 feet of depth. The bottom trawl consisted of 1-1/2 inch mesh except that the cod end was lined with 1/2 inch mesh nylon netting. The midwater trawl had a body of 3/4 inch stretch mesh knotless nylon netting and a cod end of 1/2 inch stretch mesh knotless nylon. It was equipped with 1 1/2 inch galvanized pipe spreader bars, the lower one weighted to improve the mouth opening.

The fish from each catch were sorted by species, counted, and the fork length measured to the nearest millimeter. When catches were large only 50 of a species were measured at random. Extremely large catches were subsampled before sorting.