PRELIMINARY STUDY ON THE EFFECTS OF WATER HYACINTHS ON WATER QUALITY AND PRODUCTION OF TILAPIA RECEIVING FEEDS IN PONDS

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ABSTRACT

Water hyacinth [*Eichhornia crassipes* (Mart.) Solms] was used in an attempt to control phytoplankton abundance through nutrient and sunlight competition to increase oxygen levels in warm w ponds without the need of water exchange or aeration. Measurements of phytoplankton densities, water quality, and fish production were compared among ponds with hyacinth covers of 0, 5, and 25 % over the six months of the study. Male tilapia [*Oreochromis niloticus* (Trewavas)], average weight 28 g, were stocked at a density of 3/m2. Regression analysis indicated a signifie in chlorophyll-a concentrations in ponds with 0, 5, 10, and 15 % cover over time, chlorophyll-a concentrations in ponds with 20 and 25 % cover did not significantly change. Average ch concentrations were negatively correlated but did not significantly decrease with increasing plant cover. Weekly average oxygen levels decreased significantly in all ponds over time, but concentrations were not significantly different among them. Total ammonia concentrations significantly increased over time in the 0 % cover pond. Total pond production did not significantly increasing plant cover, but increasing plant cover resulted in significantly greater production of larger fish (25-27 cm total length). The results suggest that to partially cover the area of a warm water production pond with water hyacinths may improve the water quality of the pond and in turn have beneficial effects on the fish production.

KEY WORDS: plant competition, phytoplankton densities.

INTRODUCTION

The high feeding levels necessary to sustain semi-intensive and intensive fish culture systems contribute large amounts of nutrients to the water. These nutrients are available to the phynd enhance their proliferation (Boyd 1990).

However, dense phytoplankton populations have adverse effects upon the water quality and fish production in ponds (Swingle 1947, Boyd et al. 19and Boyd 1978, Lovell 1983). Thus, intermediate densities of phytoplankton should be developed, because this has shown a greater potential to produce higher dissolved oxygen concentrationr high densities (Smith and Piedrahita 1988). The vascular floating aquatic plant water hyacinth [Eichhornia crassipes (Mart.) Solms] has shown high levels of nitrogen and phosphorus uptake (Dunigan et al. 1975, Boyd 1976) and has beenpete with the phytoplankton to control its densities (McVea and Boyd 1975, Costa-Pierce et al. 1985). However, no information is available about integrated systems of fish and water hyaci water earthen ponds receiving dry feeds. The present study reports on the effect of different water hyacinth covers in eutrophic ponds on phytoplankton densities, water quality, and fish production.

MATERIALS AND METHODS

The investigation was conducted at the Aquaculture Experimental Station of the Department of Marine Sciences, University of Puerto Rico, Mayaguez Campus, located in the Lajas Valley, Puerto Rico May 5 to October 21, 1992. Six earthen ponds of 200 m2 each were used. The ponds averaged 1 m in depth with an internal 2-to-1 slope and a depth of 0.3 m near the edges. The inflow piped ward side of the ponds had a Saran filter to prevent the entrance of any wild fish from the reservoir lake. Water was supplied to the ponds at a rate of two liters per minute to maintain level.

Male tilapia fingerlings [*Oreochromis niloticus* (Trewavas 1982)], average weight 28 g, were manually selected and stocked at a density of 3 fish / m2. The ponds were covered at 0, 5, 10, 15,25 % of their area with water hyacinths obtained from Guanajibo River at a density of 15 plants / m2 after treatment with pressurized chlorinated water to remove any eggs or animals attached. The water hyacinths were contained within rectangular floating frames of polyvinylchloride (PVC) pipe (5 cm in diameter) and anchored rope placed at the four corners of each pond. All d a width of 2.00 m and varying lengths of 1.25 m, 2.50 m, 3.50 m, 5.00 m, and 6.25 m to provide the desired cover for the ponds. Water hyacinths were manually taken out of the ponds as requared to maiintain the percentage cover. To standardize the pond area available to bird predation, a plastic screen of wide mesh size was used over the areas not covered with plants up to the maximum level of 25% plant cover.

The fish were fed with a commercially available sinking pellet once a day, five days a week. The feed was guaranteed by the manufacturing company (Molinos de Puerto Rico, Inc., San Juan, Pue to contain a minimum of 30% crude protein and 3% crude fat, and a maximum of 8% crude fiber and 1.23% phosphorus.

The initial feeding rate was 5% of body weight, this percentage decreased wasing fish weight to 3% in 30 days, 2.5% in 61 days, 2.2% in 91 days, and 2% in 122 days. The 2% feeding rate was maintained until harvesting time. Feeding was suspended for all ponds when oxygen levels below 1 mg/L were recorded for any of the ponds. Monthly samplings were conducted using a casting net to obtain fish weights on a Detecto Seales Inc. scale, Model 31S, and fish immediately returned to the pond. The computer feeding program developed and used at the Aquaculture Experimental Station served to make feeding adjustments. At final harvest, fish were weighed on an Accuweigh scale, Model BD-200/PK, by size groups.

Measurements for pH, surface and bottom water temperature and dissolved oxygen were taken in situ prior to the morning feeding, between 0630 and 0700, at the deep side of the ponds at least es a week. A temperature compensated dissolved oxygen meter, YSI (Yellow Spring Instrument) Model 50B, was used to measure temperature and dissolved oxygen; pH was measured with a Hanna Instodel pHep pH meter. Water samples for ammonia and nitrite analyses were obtained monthly at the center of the ponds, approximately 10 cm from the bottom. Collection bottles were immediately ed to the laboratory and analyzed. Triplicate water samples were used to determine ammonia and nitrite concentrations using a fluid injector analyzer, Lachat Quickchem FIA 1000 Automatic Floon Analyzer (Parsons et al., 1989). The absorbance peaks were recorded on a Fisher-Recordall Model 5000 recorder. Water samples for chlorophyll-a analyses were obtained monthly at the centeponds from the surface to a depth of approximately 25 cm with a water column sampler made of PVC pipe to estimate phytoplankton abundance. The water samples were immediately transported to ttory and kept in a refrigerator for 24 hours. Triplicate water samples were used to measure chlorophyll-a concentrations with a fluorometer, Turner 111, to determine phytoplankton density (nd Yentsch, 1985). Samples of pond soil were collected at the beginning and at the end of the experiment and analyzed by the Soil Testing Laboratory of the Department of Agronomy and Soils of the University ofPuerto Rico, Mayagƒez Campus, for available phosphorus (Olsen and Sommers, 1982) and pH (McLean, 1982).

Ponds were harvested on 20 and 21 October to determine fish production, mortality, percentage of crop above a 100 g (At value) (Swingle 1960), and feed conversion rate (S) (Swingle 1958 Water hyacinths harvested during and at the end of the experiment were used to determine plant production. Production was determined on a wet and dry weight basis. The plants in one squ weighed on a Detecto Seales Inc. scale, Model 31S, and this weight was extrapolated according to the total area covered by the plant in each pond to obtain the total plant wet weight fPlant dry weight was calculated determining the percent water composition, by placing the plants in a DESPATCH oven, Model LEB-1-27, at 80 íC for 24 hours. Initial and final plant weighed using a Mettler analytical balance, Model 10 Tw. The results, reported at a 95% confidence level, obtained from the randomized design with six treatments were statistically analyzed by comparing regression curves using the t-test to deatment responses were different. Pearson correlations among environmental variables were used to compare ponds (Steel and Torrie 1988). The statistical program MSTAT-C, version 1.4 (Crience Department, Michigan State University) was used to perform the statistical analyses.

RESULTS AND DISCUSSION

Phytoplankton densities

Analysis of chlorophyll-a concentrations measured on selected days (Table 1) indicated a significant increase only in ponds with 0 (P = 0.033), 5 (P = 0.003), 10 (P = 0.002), and 15 (P per cent cover over time. Chlorophyll-a concentrations for ponds with 20 (P = 0.158) and 25 (P = 0.090) per cent cover did not significantly change over time. However, the pond with 20 % cohe highest chlorophyll-a concentration, recorded on day 168, of 85.9 mg/L which contributed to the high average concentration in this pond. The average chlorophyll-a concentration did not sily decrease with increasing plant cover although the slope of the linear regression was negative. These data indicate that phytoplankton production may decrease with increasing plant cover ids, probably through nutrient and sunlight competition (Boyd 1969, Steward 1970, Rogers and Davis 1972). The high chlorophyll-a concentration found in the 20 % cover pond on the last sampliy have been due to a phytoplankton bloom at the moment of sampling. Although an increase in chlorophyll-a concentrations was observed towards the last weeks of the study, when larger amounts of feed were given, ponds with 20 and 25 % plant cover could maintain controlled phytoplankton populations.

Water quality

Average surface and bottom water temperatures in all ponds ranged between 27.7 C and 28.1 C and pH values averaged between 7.2 and 7.4 (Table 2). There were no significant differences i and pH among ponds. Early morning dissolved oxygen concentrations in the ponds varied between 5.0 and 0.5 mg/L, with lower oxygen levels recorded during the last weeks of the study. Wdissolved oxygen concentrations decreased significantly (P = 0.002) in all ponds over time. The average dissolved oxygen levels ranged between 2.2 and 1.1 mg/L (Table 2), and were not sifferent (P =0.620) among ponds, but were below the required level for optimum fish growth (Chervinski, 1982). This contrasts with the results of

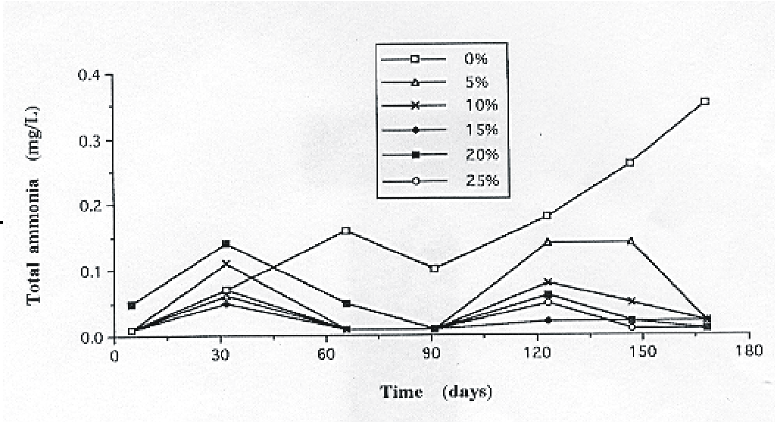

Figure 1. Total ammonia concentration measured on selected days during the 170 days of the study in waters of 0.02 ha ponds with six different levels of water hyacinth cover

McVea and Boyd (1975) who reported low oxygen levels in higher per cent plant cover ponds. The pond with 20 % cover most often seemed to reach oxygen levels below 1 mg/L. This condition may have been caused by the filling with king of fish in this pond without allowing the pond bottom to dry and crack to oxidize the organic components left from the previous culture cycle. A higher level of organic matter ini in this pond may have increased oxygen demand from heterotrophic bacteria. Total ammonia concentrations, measured on selected days during the study (Figure 1) significantly increased (P = 0.002) over time in the 0 % cover pond. The other five ponds did not shot change (P = 0.326, P = 0.942, P = 0.782, P = 0.155, and P = 0.600 for the 5, 10, 15, 20, and 25 % cover ponds, respectively) in total ammonia concentrations over time. Analyses of the concentrations indicated that there was not a significant change (P = 0.055, P = 0.111, P = 0.406, P = 0.120, P =0.319, and P = 0.078, respectively, with increasing per cent cover) over time ponds. Average total ammonia (P = 0.076) and nitrite (P = 0.066) concentrations did not significantly change with increasing plant cover although the slopes of the linear regression live in both cases.

Total ammonia concentrations were initially higher in the pond with 20 % cover (Figure 1). The higher initial ammonia and nitrite concentrations in this pond also sup of a higher oxygen demand by nitrifying bacteria to oxidize these compounds present from the previous culture. Total ammonia and nitrite concentrations were always below toxic levels f all ponds during the study. However, levels of total ammonia and nitrite in the pond with 0 % cover were considerably higher than those in any of the other ponds, and they were lowest th 25 % cover. This suggests that the presence of water hyacinths in the ponds contributes to the removal of nitrogenous compounds.

Fish Production

Mortality rates of about 15 % were found for all ponds except for the pond with 10 % cover, which had a mortality closer to 25 %. No evidence of any probable cause for the high mortality rer this pond was found. Fish mortality did not significantly change (P = 0.735) with increasing plant cover, although the pond with 25 % cover had the lowest mortality. García (1993) found sitality values in similar ponds at the Aquaculture Experimental Station stocked at a density of 1 fish / m2, indicating that fish density may not be a detrimental factor in the production of / m2. At values above 90 % were found for all ponds. This suggests that the stocking of ponds with 3 fish per m2 may be a feasible practice in ponds without water exchange or aeration if appropriate managerial techniques are used.

The fish were fed a total of 115 days during the study. Feed conversion rates ranged between 1.7 for the pond with 10 % cover and 1.5 for the 25 % cover pond. García (1993) obtained similar in ponds stocked at a density of 1 fish / m2. The higher feed conversion rate found in the pond with 10 % cover is probably due to the high mortality that occurred in this pond while maintaining equal feeding rates during the study for all ponds.

Fish net weight gain did not significantly change (P = 0.109) with increasing plant cover (Table 3). This result contrast with McVea and Boyd?s (1975) findings of 50% and 70% reduction ponds with 10% and 25% cover, respectively. Moreover, fish production in our study was between 456% to 528% higher than the highest production level obtained by McVea and Boyd (1975).

Distribution of the fish by total length in centimeters (Swingle 1968) indicated that there was not a significant change in the production of fish of the size groups 19-21 cm (P = 0.130), 21-23 cm55), or 23-25 cm (P = 0.118). The production of fish of the size group 17-19 cm, however, significantly decreased (P

= 0.025) and fish of the size group 25-27 cm significantly increased (P =ith increasing plant cover. Average fish weight ranged between 169.8 g for the pond with 0 % cover and 184.0 g for the pond with 25 % cover. The pond with 25 % cover had the highest fish proith 4777 kg/ha, and the largest fish with a 16.4 % of the total net weight from fish harvested in the 25-27 cm size group. The improved water quality condition found in the pond with 25 % originate by the higher dissolved oxygen concentrations and lowest total ammonia and nitrite concentrations, was probably the cause for the larger size fish and production in this pond. Fish would have probably been greater in this pond if the feeding regime had not been suspended because of the low dissolved oxygen levels in other ponds.

Soil phosphorus and pH

Although an increase in available phosphorus was observed at the end of the study, it did not significantly change (P = 0.126) among ponds with increasing plant cover. The lowest increment ile phosphorus was found in the 25 % cover pond, with an increase of 1.8 mg/g. The water hyacinths probably contributed to the removal of phosphorus which accumulated in lesser quantities by n in the pond muds (Hepher 1958) in the ponds with higher percentage plant cover. Soil pH was not significantly different (P = 0.626) among ponds.

Water hyacinth production

Water hyacinths were found to contain between 90 and 92 % water in their tissue, as indicated by Little and Henson (1967). The initial stock of water hyacinths did not completely fill the areas but, by vegetative reproduction, the enclosures were filled with small plants in a few weeks. Growth continued as the plants increased in height to obtain sunlight. Most of the water hin the 25 % cover pond developed a yellow color on the leaves during the first 4 weeks of the experiment, probably due to a limiting nutrient(s). The leaves regained their normal coloration r as more feed was introduced to the pond. The plants were easily maintained within the enclosures and did not propagate to adjacent ponds. Total dry weight production increased with increasing percentage cover as more pond surface area was available for the plant. The estimated total wet and dry weight production of water hyacinths harvested during the study is given in Table 4.

CONCLUSION

The vascular floating aquatic plant water hyacinth [*Eichhornia crassipes* (Mart.) Solms] has demonstrated a positive effect on the water quality in a pond receiving dry feeds when allowed ween 20 and 25 % of the pond area. Water quality was improved by maintaining stable phytoplankton populations and low total ammonia and nitrite concentrations which translated into larger fish production. Based on these results, the authors recommend further investigation of in-pond integrated plant and fish culture systems receiving dry feeds.

LITERATURE CITED

Almazan, G. and C.E. Boyd. 1978. Plankton production and tilapia yield in ponds. Aquaculture. 15: 75-77.

Boyd, C.E. 1969. Vascular aquatic plants for mineral nutrient removal from polluted waters. Econ. Bot. 23: 95-103.

Boyd, C.E. 1976. Accumulation of dry matter, nitrogen and phosphorus by cultivated water hyacinths. Econ. Bot. 30: 51-56. Boyd, C.E. 1990. Water quality in ponds for aquaculture. Birmingham Publishing Co. Birmingham, Alabama. 482 pp.

Boyd, C.E., E.E. Prather, and R.W. Parks. 1975. Sudden mortality of a massive phytoplankton bloom. Weed Sci. 23: 61-67. Chervinski, J. 1982. Environmental physiology of tilapias. Pages 119-128 in R.S.V. Pullin and R.H. Lowe-McConnell, eds. The biology and culture of tilapias. ICLARM Conference Proceedings. Manila, Philippines.

Costa-Pierce B.A., S.R. Malecha, and E.A. Laws. 1985. Effects of polyculture and manure fertilization on water quality and heterotrophic productivity in *M. rosenbergii* ponds. Trans. Amer. Fi114: 826-836.

Dunigan, E.P., R.A. Phelan, and Z.H. Shamsuddin. 1975. Use of water hyacinths to remove nitrogen and phosphorus from eutrophic waters. Hyacinth Control J. 13: 59-61.

García, A. 1993. Producciùn de un monocultivo del camarón de agua dulce, *Macrobrachium rosenbergii,* sembrado a densidad comercial y de un policultivo con tilapia, Oreochromis niloticus. M.S.Thesis. Dept. of Marine Sciences, University of Puerto Rico, Mayaguez, P.R.70 pp.

Hepher, B. 1958. On the dynamics of phosphorus added to fish ponds in Israel. Limnol. Oceanogr. 3: 84-100.

Little, E.C.S. and I.E. Henson. 1967. The water content of some important tropical water weeds. Pest Artic. News Sum. 13: 223-227.

Lovell, R.T. 1983. New off-flavors in pond-cultured channel catfish. Aquaculture. 30: 329-334.

McLean, E.O. 1982. Soil pH and lime requirement. Pages 199-224 in A. L. Page, ed. Methods of soil analysis, chemical and microbiological properties. American Society of Agronomy and Soil Society of America, Madison, Wisconsin.

McVea, C. and C.E. Boyd. 1975. Effects of water hyacinth cover on water chemistry, phytoplankton, and fish in ponds. J. Environ. Qual. 4: 375-378.

Olsen, S.R. and L.E. Sommers. 1982. Phosphorus. Pages 403-430 in A. L. Page, ed. Methods of soil analysis, chemical and microbiological properties. American Society of Agronomy and Soil Science Society of America, Madison, Wisconsin.

Parsons, T.R., Y. Maita and C.M. Lalli. 1989. A manual of chemical and biological methods for seawater analysis. Pergamon Press, Inc., Elmsford, New York. 256 p.

Phinney, D.A. and C.S. Yentsch. 1985. A novel phytoplankton chlorophyll technique: toward automated analysis. J. of Plankton Research. 7: 633-642.

Rogers, H.H. and D.E. Davis. 1972. Nutrient removal by water hyacinth. Weed Sci. 20: 423-428.

Smith, D.W. and R.H. Piedrahita. 1988. The relation between phytoplankton and dissolved oxygen in fish ponds. Aquaculture. 68: 249-265.

Steel, R.G.D. and J.H. Torrie. 1988. Bioestadística: principios y procedimientos. McGraw-Hill, Naucalpan de Juçrez, MÄxico. 622 pp.

Steward, K.K. 1970. Nutrient removal potentials of various aquatic plants. Hyacinth Control J. 8: 34-35.

Swingle, H.S. 1947. Experiments on pond fertilization. Agr. Exp. Sta., Ala. Polytech. Inst., Auburn, Bull. 264. 34 pp.

Swingle, H.S. 1958. Experiments on growing fingerling channel catfish to marketable size in ponds. Pages 63-72 in Proceedings of the Eleventh Ann. Conference Southeastern Game and Fish Commissioners. Atlanta, Georgia.

Swingle, H.S. 1960. Comparative evaluation of two tilapias as pondfishes in Alabama. Trans. Am. Fish. Soc. 89: 142-148.

Swingle, H.S. 1968. Standardization of biological methods in fish culture research. Pages 422-429 in Proceedings of the World Symposium on Warm Water Pond Fish Culture. Rome, May, 1966. FAO Fish. Rep. 44.

Trewavas, E. 1982. Tilapias: taxonomy and speciation. Pages 3-13 in R.S.V. Pullin and R.H. Lowe-McConnell, eds. The biology and culture of tilapias. ICLARM Conference Proceedings. Manila, Ph.

Table 1. Chlorophyll-a concentrations in g/L during the 170 days of the study in waters of 0.02-ha ponds with six different levels of water hyacinth cover. (± s.d.).

	Percent cover by water hyacinth					
days	0%	5%	10%	15%	20%	25%
11	14 ± 3.2	10 ± 4.4	12 ± 2.3	9.2 ± 4.3	17 ± 13	8.6 ± 2.3
32	47 ± 3.2	20 ± 3.2	12 ± 3.2	13±0.9	20 ± 0.5	12 ± 2.3
66	29 ± 6.5	28 ± 5.6	37 ± 3.2	23 ± 3.2	30 ± 9.7	18 ± 5.6
91	43 ± 9.7	21 ± 3.2	29 ± 11	11 ± 9.7	54 ± 26	9 ± 3.2
123	55 ± 33.2	38 ± 5.6	54 ± 4	30 ± 5.6	19 ± 5.6	9 ± 3.2
147	50 ± 0.5	56 ± 3.2	49 ± 8.6	28 ± 5.6	25 ± 5.6	21 ± 8.6
168	73 ± 15	76 ± 5.5	80 ± 40	51± 5.5	86± 0.5	38 ± 9
Mean	43.7	35.5	38.8	23.8	35.9	16.4

Table 2. Averages for pH, temperature (°C) and dissolved oxygen concentrations (mg/L) at surface and bottom of 0.02 ha ponds with six different levels of water hyacinth cover (±s.d.).

	Percent cover by water hyacinth					
	0%	5%	10%	15%	20%	25%
ph	7.4 ± 0.4	7.4 ± 4.4	7.3 ± 0.4	7.4 ± 0.5	7.2 ± 0.4	7.4 ± 0.4

Surf. Temp	28 ± 1.3	28 ± 1.1	28 ± 1.1	28 ± 1.1	28 ± 1.0	28 ± 1.0
Bot. Temp	28 ± 1.3	28 ± 1.2	28 ± 1.2	28 ± 1.1	28 ± 1.2	28 ± 1.1
Surf. DO	2.2 ± 2.5	1.7 ± 1.7	1.6 ± 1.6	2.2 ± 1.9	1.2 ± 1.3	2.0 ± 1.9
Bot. DO	2.1 ± 2.4	1.7 ± 1.7	1.5 ± 1.6	2.1 ± 1.9	1.1 ± 1.1	1.9 ± 1.9

Table 3. Total weight in Kg/ha by fish size group, and total and net weights in Kg/ha of fish harvested from 0.02 ha ponds with six different levels of water hyacinth cover (±s.d)

length	Percent cover by water hyacinth					
class	0%	5%	10%	15%	20%	25%
17-19	210 ±26	230 ± 49	225 ± 66	190 ± 35	170 ± 23	135 ± 30
19-21	1115±249	1155 ±230	830 ± 97	950 ± 198	1020 ± 241	790 ± 165

21-23	1725±330	1790 ±376	1330 ±110	1605 ± 298	1715 ± 238	1605 ± 347
23-25	1280±235	1050±261	1430 ±145	1365 ± 207	1485 ± 415	1460 ± 250
25-27	70 ± 7	150 ± 14	325 ± 57	320 ± 72	235 ± 66	785 ±126
27-29	0	17.5	0	0	0	19
Total weight	4390±847	4392 ±930	4140±475	4430 ±810	4625 ±983	4794 ±918
Net weight	4373±847	4375 ±930	4123 ±475	4413 ±810	4608 ±983	4777 ±918

Table 4. Total wet and dry weight in kg/ha of water hyacinths harvested during the 170 days of the study from ponds with six different levels of water hyacinth cover (±s.d).

length	Percent cover by water hyacinth				
class	5%	10%	15%	20%	25%
Wet weight	25350± 4500	35250± 9000	50800± 13500	68850± 18000	81200± 22500
Dry weight	2535± 450	3525± 900	5080± 1350	6885± 1800	8120± 2250

MANAGEMENT