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WASHINGTON, D. C. 20523

**BIBLIOGRAPHIC INPUT SHEET**

Batch 74

| | | |
|---|---|---|
| 1. SUBJECT CLASSIFICATION | A. PRIMARY<br>Food production and nutrition | AM40-0000-0000 |
| | B. SECONDARY<br>Aquatic biology | |

2. TITLE AND SUBTITLE

Effects of waterhyacinth cover on water chemistry,phytoplankton,and fish in ponds

3. AUTHOR(S)

McVea,Charles; Boyd,C.E.

| 4. DOCUMENT DATE | 5. NUMBER OF PAGES | 6. ARC NUMBER |
|---|---|---|
| 1975 | 5p. | ARC |

7. REFERENCE ORGANIZATION NAME AND ADDRESS

Auburn

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)

(In J.of Environmental Quality,v.4,no.3,p.375-378)

9. ABSTRACT

Use abstract with article

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10. CONTROL NUMBER

PN-AAF-076

11. PRICE OF DOCUMENT

12. DESCRIPTORS

Aquatic weeds
Fresh water fishes
Hyacinth?
Phytoplankton
Ponds
Water quality

13. PROJECT NUMBER

14. CONTRACT NUMBER

CSD-2780 211(d)

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

Reprinted from the *Journal of Environmental Quality*
Vol. 4, no. 3, July-Sept. 1975, Copyright © 1975, ASA, CSSA, SSSA
677 South Segoe Rd., Madison, Wis. 53711 USA

# Effects of Waterhyacinth Cover on Water Chemistry, Phytoplankton, and Fish in Ponds[1]

Charles McVea[2,3] and Claude E. Boyd[2]

## ABSTRACT

Waterhyacinth [*Eichhornia crassipes* (Mort.) Solms] cover of 0, 5, 10, or 25% surface was established in fertilized ponds stocked with the fish, *Tilapia aurea* (Steindachner), at Auburn, Alabama. Measurements of water chemistry, phytoplankton density, and fish production were made during the 1973 growing season.

Phytoplankton production was less in ponds with 10 and 25% cover by waterhyacinth than in ponds with 0 and 5% cover. Competition of waterhyacinth with phytoplankton involved shading and removal of phosphorus from the water.

Concentrations of dissolved oxygen were lowest in ponds with 25% cover, but oxygen tensions in all ponds were adequate for survival and growth of fish.

Reduction in phytoplankton growth in ponds with 10 and 25% cover resulted in much lower fish production. The presence of 5% cover by waterhyacinth did not significantly affect fish production.

Additional Index Words: aquatic weeds, plant competition.

Catastrophic consequences of rampant growth for *Eichhornia crassipes* (Mart.) Solms (waterhyacinth) in freshwater habitats are well known. Extensive stands of waterhyacinth impede navigation, interfere with hydroelectric generation, reduce flow in drainage and irrigation canals, cause floods, and harbor insect vectors of human and animal diseases (11, 19, 22, 24). Water losses are greater from surfaces covered by waterhyacinth because of high rates of evapotranspiration (7, 14, 19, 22, 27). Waterhyacinths also interfere with fish production and fishing (13, 16). Cover by waterhyacinth decreases phytoplankton production by shading and thereby reduces the food base for fish production (4, 11, 13, 15). Water beneath mats of waterhyacinth usually has low oxygen tension and is an unfavorable habitat for fish (16). However, the amount of cover by waterhyacinth necessary for adverse effects on fish produciton is not known.

The present investigation concerns the effect of various

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[1] Research supported by Hatch Project Alabama No. 287 and Project AID/csd 2780 to the International Center for Aquaculture, Auburn University. Received 10 Dec. 1974.

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phytoplankton production, and water quality.

## MATERIALS AND METHODS

Treatment replication and control was achieved by use of 12 0.04-ha ponds at the Fisheries Research Unit, Auburn University, Auburn, Ala. Depths of water averaged 0.9 m and varied from 0.3 m near edges to 1.5 m at the deepest points. Waterhyacinth was contained within bouyant rectangular frames made of 5.1-cm polyvinylchloride pipe and attached to metal posts in center of ponds (29). These enclosures measured 3.18 m by 6.36 m, 4.50 m by 9.00 m, and 7.12 m by 14.21 m to correspond to 5, 10, and 25% of pond areas, respectively. Three replications of 0, 5, 10, and 25% cover by waterhyacinth were randomly assigned to the 12 ponds. Small waterhyacinth plants were obtained from Lake Seminole, Chattahoochee, Florida, on 22 April 1973. These plants were placed in a concrete tank and fish eggs on roots killed by application of rotenone. On 1 May 1973, 500, 750, and 1,250 plants were stocked in 5, 10, and 25% enclosures, respectively.

Table 1–Total dry matter production and N and P uptake by waterhyacinth at three levels of cover in 0.04-ha ponds

| Cover by waterhyacinth | Dry matter production | | Nutrient uptake | |
|---|---|---|---|---|
| | | | Nitrogen | Phosphorus |
| % | kg/m²* | kg/enclosure* | | |
| 5 | 2.58a | 52.2a | 0.91a | 0.11a |
| 10 | 2.25a | 91.8b | 1.37b | 0.20b |
| 25 | 1.97a | 201.8c | 2.57c | 0.36c |

* Values having the same letter in each column are not significantly different at the 5% level, as indicated by Duncan's Multiple Range Test.

Table 2–Averages for pH and concentrations of soluble inorganic P, total P, nitrate, and chemical oxygen demand (COD) in waters of 0.04-ha ponds with four different levels of waterhyacinth cover

| Measurement | Percent cover by waterhyacinth | Date* | | | | | |
|---|---|---|---|---|---|---|---|
| | | 17 May | 15 June | 13 July | 3 Aug. | 17 Aug. | 7 Sept. |
| pH | 0 | 8.3ab | 9.1a | 8.8ab | 7.8a | 8.7a | 9.1a |
| | 5 | 8.8a | 7.3b | 9.7a | 7.3b | 9.1a | 8.2b |
| | 10 | 8.2ab | 7.1b | 8.4bc | 7.0bc | 7.4b | 7.9b |
| | 25 | 7.5b | 7.5b | 7.4c | 6.8c | 7.0b | 7.0c |
| $PO_4$-P (mg/liter) | 0 | 0.07a | 0.01a | 0.06a | 0.01a | 0.06a | 0.08a |
| | 5 | 0.02a | 0.01a | 0.08a | 0.01a | 0.03a | 0.06a |
| | 10 | 0.09a | 0.08a | 0.07a | 0.01a | 0.03a | 0.02b |
| | 25 | 0.12a | 0.01a | 0.08a | 0.01a | 0.01a | 0.01b |
| Total P (mg/liter) | 0 | 0.20a | 0.15a | 0.20a | 0.13a | 0.35a | 0.32a |
| | 5 | 0.11a | 0.10a | 0.20a | 0.06b | 0.27ab | 0.21b |
| | 10 | 0.15a | 0.09a | 0.17a | 0.06b | 0.11bc | 0.13bc |
| | 25 | 0.22a | 0.02a | 0.11a | 0.02c | 0.07c | 0.12c |
| $NO_3$-N (mg/liter) | 0 | 0.17a | 0.19a | 0.29a | 0.19a | 0.08a | 0.01a |
| | 5 | 0.17a | 0.18a | 0.16a | 0.12a | 0.08a | 0.02a |
| | 10 | 0.24a | 0.16a | 0.19a | 0.08a | 0.01a | 0.01a |
| | 25 | 0.26a | 0.13a | 0.26a | 0.09a | 0.02a | 0.01a |
| COD (mg/liter) | 0 | 13.8a | 13.9a | 19.6a | 54.2a | .. | 30.7a |
| | 5 | 20.9a | 21.2a | 25.6a | 45.7a | .. | 30.9a |
| | 10 | 15.4a | 15.4a | 17.3a | 34.8a | .. | 18.9b |
| | 25 | 14.6a | 13.7a | 26.5a | 33.0a | .. | 11.3b |

* Values having the same letter in each column are not significantly different at the 5% level.

Table 3–Average concentrations of dissolved oxygen on selected dates in waters of 0.04-ha ponds with four different levels of waterhyacinth cover

| Date | Percent cover by waterhyacinth | | | |
|---|---|---|---|---|
| | 0 | 5 | 10 | 25 |
| | mg/liter* | | | |
| 25 July | 10.8a | 10.4a | 9.9a | 7.7a |
| 30 July | 8.5a | 7.3a | 7.4a | 5.5a |
| 6 Aug. | 8.4a | 7.8a | 7.0a | 5.2a |
| 13 Aug. | 9.9a | 8.4ab | 7.8b | 5.5c |
| 17 Aug. | 8.3a | 7.1a | 7.6a | 6.0b |

* Values having the same letter in each line are not significantly different at the 5% level.

Sixteen applications of 1.1 kg ammonium nitrate (34% N) and 0.8 kg triple superphosphate (22% P) were broadcast over ponds at 2-week intervals between 5 February and 9 September 1973. One-hundred *Tilapia aurea* (5–12 cm long) were stocked in each pond on 4 April 1973.

Standing crops of waterhyacinths were determined periodically by harvesting 0.25 $m^2$ quadrats (6). Plant samples for tissue analysis were dried to constant weight at 80C and pulverized in a Wiley mill to pass a screen with 0.42-mm openings. Nitrogen analyses were by the micro-Kjeldahl technique (2). The vanodomolybdophosphoric acid method was used to determine phosphorus in 0.5*N* nitric acid extracts of plant ash (12).

Water samples for chemical and phytoplankton analyses were obtained with a 90-cm water column sampler (5). Samples were collected within 2 hours of sunrise from deep ends of ponds. Procedures of the American Public Health Association (1) were used for analyses of total alkalinity, total hardness, nitrate, soluble orthophosphate, total phosphorus, and chemical oxygen demand. A glass electrode was used to measure pH. Dissolved oxygen determinations were made between 0800 and 0900 hours at depths of 0, 0.5, and 1.0 m with a polarographic oxygen meter. Phytoplankton was removed from water by filtration through a 0.45-μ millipore filter. Chlorophyll *a* was extracted from phytoplankton with 90% acetone and measured spectrophotometrically (28). Phytoplankton concentrated by centrifugation was counted in a Sedgwick-Rafter chamber under a microscope fitted with a Whipple disk micrometer (1).

Ponds were drained and fish harvested between 28 Sept. and 5 Oct. 1973.

## RESULTS AND DISCUSSION

### Production of Waterhyacinth

The initial stock of plants filled only about one-third of the space in enclosures. Vegetative reproduction by means of offsets was rapid and by early June all enclosures were filled with small plants. Growth continued throughout summer as plants increased in height. Periodic sampling revealed that rates of growth and uptake of nitrogen and phosphorus were relatively uniform throughout the study. Although there were no great differences in production of waterhyacinth per unit area in enclosures of different sizes, the total production of waterhyacinth increased with population size (Table 1). Ponds with 25% cover produced roughly four times more waterhyacinth by weight than ponds with 5% cover and two times more than ponds with 10% cover. Removal of nitrogen and phosphorus from pond water was correlated positively with amount of cover by waterhyacinth (Table 1). The observation that waterhyacinth in enclosures absorbed large amounts of nitrogen and phosphorus corroborates claims that this species could be cultivated to remove nitrogen and phosphorus from excessively eutrophic water (4, 14, 23, 25, 30).

### Water Chemistry

Experimental ponds contained soft water of low alkalinity. Total alkalinity varied from 11.6 to 24.5 mg/liter and total hardness from 4.6 to 16.4 mg/liter in ponds of various treatments. There was no obvious difference

Table 4—Estimate of phytoplankton production by three techniques in waters of 0.04-ha ponds with four different levels of waterhyacinth cover

| Determination | Percent cover by waterhyacinth | Date* | | | | | |
|---|---|---|---|---|---|---|---|
| | | 17 May | 15 June | 13 July | 3 Aug. | 17 Aug. | 7 Sept. |
| Secchi disk visibility (m) | 0 | 1.20a | 0.42a | 0.55a | 0.38a | 0.38a | 0.45a |
| | 5 | 0.70ab | 0.72ab | 0.58a | 0.78b | 0.68b | 0.50a |
| | 10 | 0.62ab | 0.88bc | 0.82ab | 1.12c | 1.23c | 0.88b |
| | 25 | 0.48b | 1.17c | 1.17b | 1.28c | 1.25c | 1.18b |
| Chlorophyll *a* (μg/liter) | 0 | 9.5a | 83.1a | 65.4a | 74.1a | 77.4a | 128.9a |
| | 5 | 17.2a | 19.6b | 68.5a | 46.6ab | 55.9a | 68.6ab |
| | 10 | 14.6a | 26.0b | 40.6b | 23.5b | 27.9b | 42.5b |
| | 25 | 5.7a | 7.6b | 17.1c | 16.7b | 17.8b | 26.7b |
| Phytoplankton (No./ml × $10^3$) | 0 | -- | -- | -- | 12.2a | 33.1a | 37.9a |
| | 5 | -- | -- | -- | 5.5b | 8.7b | 19.2a |
| | 10 | -- | -- | -- | 4.2b | 5.3b | 7.4b |
| | 25 | -- | -- | -- | 3.6b | 2.9b | 6.0b |

* Values having the same letter in each column are not significantly different at the 5% level.

in hardness and alkalinity between treatments, but in all ponds there was a gradual increase in total hardness from calcium introduced in triple superphosphate.

Values for pH were normally highest in control ponds (0% cover) and lowest in ponds with 10 and 25% cover (Table 2). Differences in pH were related to different rates of removal of carbon dioxide by phytoplankton during photosynthesis as evident from the positive relationship between pH (Table 2) and phytoplankton abundance as estimated by three methods (Table 4).

Concentrations of soluble orthophosphate in waters of various treatments differed significantly only on 7 Sept. (Table 2). On August and September sampling dates, total phosphorus concentrations generally decreased in order of increasing waterhyacinth cover (Table 2). These differences were related to greater phytoplankton biomass and constituent phosphorus in ponds with less cover. Nitrate concentrations did not differ with treatment (Table 2). Plants (phytoplankton, waterhyacinth, or both) absorbed considerable quantities of nitrogen and phosphorus. Considerable phosphorus was lost to adsorption by muds (10) and some nitrogen was lost by denitrification in muds (3, 21) and ammonia volatilization (21).

Chemical oxygen demand (COD) was similar for waters of all ponds in May, June, and July (Table 2). Apparent differences in COD values were not significant on 17 Aug. but on 7 Sept. water from ponds with 0 and 5% cover had greater COD values than those from ponds with 10 and 25% cover. These differences also reflect phytoplankton abundance.

For brevity only a few selected, but representative, data on dissolved oxygen concentrations are presented (Table 3). Variations in oxygen concentrations of different ponds within a particular treatment were great on all dates. However, averages for treatments generally declined with increasing waterhyacinth cover and on two dates dissolved oxygen concentrations were significantly lower at 25% cover than in other treatments (Table 3). Lower oxygen tensions resulted from reduced rates of photosynthesis in ponds with 25% cover. Oxygen determinations were made in early morning when concentrations are normally lowest. Therefore, up to 25% cover by waterhyacinth did not cause dangerously low oxygen tensions and threaten fish survival.

## Phytoplankton Production

None of the three methods of estimating phytoplankton abundance give a true measure of phytoplankton biomass and correlations between estimates by the different methods are weak (8, 15, 20). However, examined collectively, means and statistical analyses of estimates of phytoplankton abundance suggest (i) although values were normally greatest in control ponds, differences in values for ponds with 0 and 5% cover were often not significant; (ii) ponds with 10 and 25% cover produced markedly less phytoplankton than ponds with 0 and 5% cover; and (iii) the magnitude of phytoplankton production was similar in ponds with 10 and 25% cover.

Waterhyacinth competed with phytoplankton for light by shading 5, 10, or 25% of the pond surfaces. Cover by waterhyacinth also resulted in greater removal of nitrogen and phosphorus from the water. Each pond exhibited a high degree of individuality and concentrations of nutrients and phytoplankton production varied greatly between ponds within each treatment on each date. Therefore, concentrations of nitrate, soluble orthophosphate,

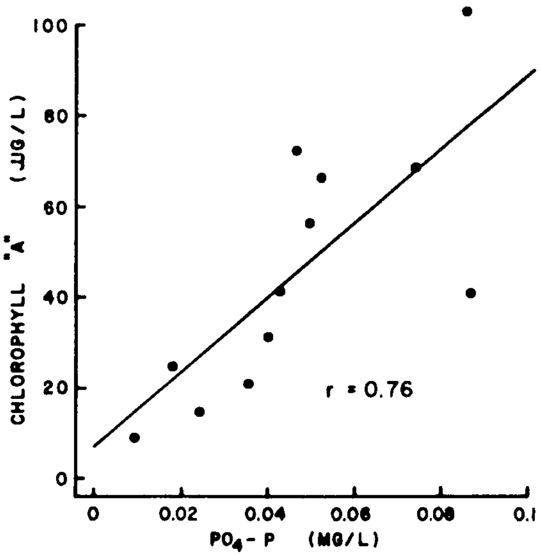

Fig. 1—Relationship between seasonal averages for soluble inorganic P concentrations and chlorophyll *a* in 12, 0.04-ha ponds. ($r = 0.76$; $P < 0.01$).

Table 5—Average net production of fish, *Tilapia aurea*, in 0.04-ha ponds with four different levels of waterhyacinth cover

| Cover by waterhyacinth | Net production of *Tilapia aurea* |
|---|---|
| % | kg/ha* |
| 0 | 905a |
| 5 | 848a |
| 10 | 496b |
| 25 | 281b |

* Values having the same letter are not significantly different at the 5% level.

and chlorophyll *a* for each pond were averaged across all sampling dates. Regression coefficients between chlorophyll *a* and concentrations of nitrate and soluble orthophosphate were obtained. Chlorophyll *a* concentrations in the 12 ponds were not related to variations in nitrate concentrations ($r = 0.15$; $P > 0.05$). There was a positive correlation between concentrations of soluble orthophosphate and chlorophyll *a* (Fig. 1). This relationship suggests that removal of phosphorus by waterhyacinth deprived phytoplankton of this nutrient and adversely affected their growth. The possibility that substances toxic to phytoplankton were excreted by waterhyacinth could not be tested by the experimental design.

## Fish Production

Production of *Tilapia aurea* was not reduced appreciably by 5% cover with waterhyacinth (Table 5), but 10 or 25% waterhyacinth cover reduced fish production by about 50% of production in control ponds. Differences in fish production exhibited the same general relationship to treatment as did phytoplankton production. McBay (17) reported that *T. aurea* fed primarily on phytoplankton. Therefore, waterhyacinth affected fish production indirectly through competition with phytoplankton. Other workers have demonstrated a direct relationship between phytoplankton production and the production of fish (9, 18, 26).

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