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Effects of Waterhyacinth on the Physicochemistry of a South Georgia Pond

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ABSTRACT

Changes in the aquatic environment due to the presence of waterhyacinth in chemically treated and uncontrolled stands were studied in a south Georgia pond. Vertical stratification and daily fluctuations of temperature, dissolved oxygen, dissolved carbon dioxide, pH, Eh and phosphorus were measured in relation to plant biomass and detritus. Water below untreated plants indicated a decreased O_2, pH and Eh, and an increased CO_2, apparently as detritus accumulated. Herbicide application may have temporarily resulted in decreased O_2 and increased CO_2 and available nutrients due to plant decomposition, but little detrital accumulation occured in treated areas and physiocochemical conditions were similar to those of open water.

INTRODUCTION

In addition to purely mechanical obstruction of waterways caused by its rapid growth, waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) causes significant physicochemical changes in aquatic environments where it has been introduced. Penfound and Earle (5) reported more uniform water temperatures, higher acidity and dissolved carbon dioxide (CO_2), and lower dissolved oxygen (O_2) under a waterhyacinth mat as compared with an equivalent location in open water.

Timmer and Weldon (10) reported increases in optical density, turbidity, color, and the amount of tannin and lignin in ponds containing waterhyacinth as compared to control ponds. Over a period of 6 months, they reported the accumulation of 18 cm of dead plant material in a pool 61 cm deep.

McVea and Boyd (4) studied some chemical and biological effects of different amounts of waterhyacinth cover using small ponds. pH was highest in control ponds (without waterhyacinth) and lowest in ponds with 10 and 25% waterhyacinth cover. These differences were attributed to the different rates of removal of CO_2 by phytoplankton during photosynthesis under the different amounts of macrophyte cover. Dissolved oxygen concentrations were generally lower under waterhyacinth cover, although O_2 levels were never so low as to threaten fish survival.

Ultsch (11) reported that while surface and bottom temperatures were similar in a pond regardless of the presence of waterhyacinth, there was a more rapid drop in temperature with depth beneath a waterhyacinth mat due to its insulating effect. Similarly, O_2 decreased more rapidly and CO_2 increased more rapidly under waterhyacinth as compared to open water. On a daily basis, temperature and O_2 most often reached minimum values at sunrise when CO_2 was at its peak in both areas. Generally, in all areas of measurement, O_2 and pH were lowest during summer months when CO_2 was at its peak. Biomass and detritus were not quantified by Ultsch although he found lower O_2 levels and higher CO_2 levels beneath "thick" hyacinth mats which contained a considerable amount of detritus in the root mass.

Rai and Munshi (6) reported lower O_2, pH and temperature fluctuations and high CO_2 under waterhyacinth covered areas than in open water of a small pond. They suggested that this difference was related to decaying leaves and detritus and decreased aquatic photosynthesis beneath waterhyacinth covered areas. However, variability within plant covered areas was not considered nor related quantitatively to plant biomass and detritus.

Previous work has indicated that introduction of waterhyacinth into aquatic systems causes undesirable physicochemical changes. In this paper, waterhyacinth biomass and detritus were measured in conjunction with the condition of the aquatic environment. Measurements were made in a natural system in south Georgia containing waterhyacinth; these measurements were made in relatively undisturbed areas as well as in areas subject to periodic chemical control.

MATERIALS AND METHODS

This study was conducted during the summer of 1977 at Grassy Pond (30° 39′ N, 83° 14′ W), about 19 km south of Valdosta, Georgia. Grassy Pond is a soft water, low conductivity (25 to 35 μS/cm), sinkhole basin with a mean depth of about 2 m and an area of 97 ha. The pond is used primarily for recreational fishing and had about 15% coverage by waterhyacinth at the time of this study. However, *Cabomba* (fanwort), *Ceratophyllum* (coontail), and *Utricularia* (bladderwort) grew to the surface in much of the open water, especially during the late summer months. Herbicide treatment for waterhyacinth control was undertaken intermittantly during the summer months (with 2,4-Dichlorophenoxy acetic acid during the period of this study.) The eastern side of the pond was treated several times during the growing season, while most of the western side had been undisturbed for several years, permitting extensive development of waterhyacinth mats extending up to 75 m from shore. Environmental parameters were measured in herbicide-treated areas and across an undisturbed waterhyacinth mat from near shore to open water (Fig. 1). This study was conducted during summer months (June - August) when physicochemical conditions were expected to be most severe (i.e., low O_2, high CO_2) and when macrophyte biomass was expected to be greatest. Diel measurements for O_2, pH, temperature and redox potential (Eh) were made in Grassy Pond at a depth of 25 cm with a Hydrolab Surveyor (Model 6D) water quality analyzer. Dissolved oxygen and temperature profiles were determined *in situ* at 10 to 20 cm intervals with a YSI oxygen meter (model 51B) and water samples were collected at various depths for determination of pH, CO_2, ortho-phosphate and total phosphorus. Samples were stored in an ice chest and prepared for analysis or were frozen within 3 hours. All measurements were made on sunny days to preclude effects of cloud cover on comparisons between different areas. Chemical analyses were performed according to standard methods (1, 8).

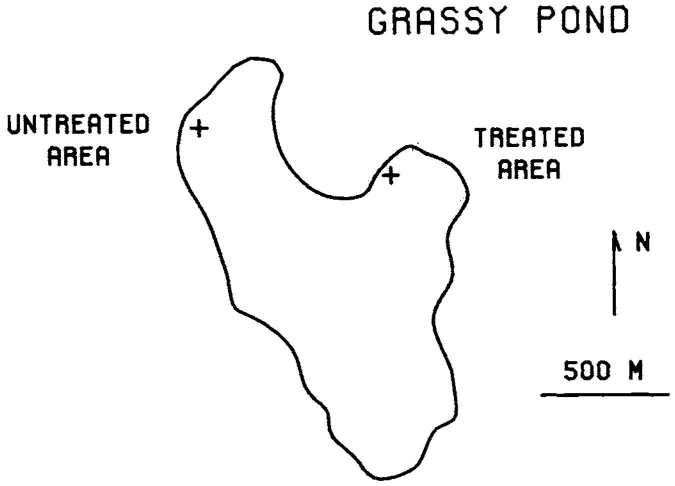

Figure 1. Map of Grassy Pond, Georgia, showing location of sampling stations.

Waterhyacinth biomass and detritus were measured in: (1) an old undisturbed mat 52 m from open water (13 m from shore), (2) at the edge of an undisturbed mat (64 m from shore) and (3) in herbicide-treated areas following regrowth of macrophytes. Three 0.25 m² samples were collected in each area. Detritus was separated from the plants and samples were returned to the laboratory and dried at 105 C for 48 h.

RESULTS AND DISCUSSION

Waterhyacinth biomass and floating detritus in the sampling areas are shown in Table 1. The area 52 m from open water had not been treated for at least 2 years and represents the relatively older area of the mat (old mat); the area 1 m from open water represents the edge of the expanding mat (mat edge). (There is, of course, considerable variability in the size of the mat from shore to open water around Grassy Pond, but the relationships described generally hold true around the undisturbed areas of the pond). One location was sampled in the managed area of the pond 6 weeks after herbicide had been applied; by this time plants were recolonizing the area, and the mat extended 2 to 3 m from shore.

There was over 2.5 times as much dry weight biomass in the old mat as compared to the young recolonizing stand (6 weeks post treatment) but there was over 30 times as much

TABLE 1. WATERHYACINTH BIOMASS AND DETRITUS IN GRASSY POND, JULY-AUGUST, 1977. DATA REPORTED AS THE MEAN OF THREE SAMPLES ± 1 STANDARD ERROR. FLOATING DETRITUS INCLUDES DEAD PLANT MATERIAL IN MAT BUT EXCLUDES DETRITUS ON THE BOTTOM.

Location	Dry Weight kg/m²	
Living Hyacinth		% Water
old mat	0.99 ± 0.02	93.7
mat edge	0.83 ± 0.07	94.3
6 wks post treatment	0.39 ± 0.02	95.9
Floating Detritus		% Living
old mat	1.14 ± 0.01	46
mat edge	0.11 ± 0.01	86
6 wks post treatment	0.03 ± 0.01	93

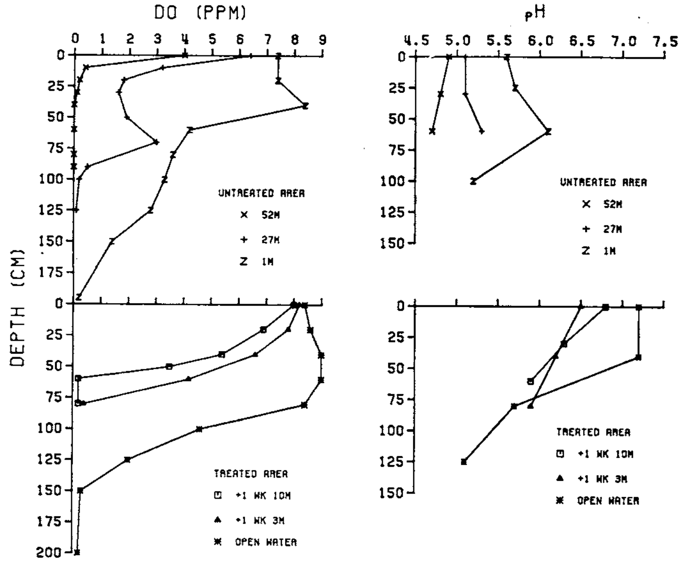

Figure 2. Depth profiles of dissolved oxygen (DO) and pH in Grassy Pond in mid July. Untreated areas and open water sampled 1330-1500 hrs; treated areas sampled 1700-1800 hrs. Locations reported as distance from open water in meters.

detritus in this older stand as compared to the young stand. The edge of the undisturbed mat was similar in terms of biomass but had considerably less detritus than the older area of the mat; the continuous leaf turnover by waterhyacinth during the growing season and winter dieback converts most of the leaf biomass into the next season's detritus.

In comparison with the 8 year old mat described by Penfound and Earle in Louisiana (5), there was less dry weight biomass but possibly more detritus in the 2 to 3 year old mat of Grassy Pond. There was, however, considerable seasonal variability in the data of Penfound and Earle. The amount of living material in the old mat of Grassy Pond was lower than that in Louisiana during the summer months. The average of the oldest and youngest areas of the old mat of Grassy Pond (66% living) was similar to the average for the Louisiana site for the months of May through September (63% living).

Depth profiles of O_2 and pH in various areas of Grassy Pond are shown in Fig. 2. (For brevity, only PM readings of O_2 and pH are shown; PM profiles of temperature and CO_2 and AM readings of all parameters are reported elsewhere[1].) Physicochemical conditions across the undisturbed mat corresponded to the continuum of biomass and detritus across this area. The insulating capacity of the mat was greatest toward shore as indicated by lower overall temperature in this area as well as by a rapid decline in temperature with depth. This insulating capacity decreased toward open water as indicated by a reversal of these trends. However, temperature profiles and other parameters were influenced not only by the thickness of the mat but also by proximity to open water where exchange currents with open water could influence these profiles.

Dissolved oxygen dropped to less than 1 ppm at a depth of only 10 cm in midafternoon in the undisturbed area near shore. Toward the edge of the mat in both morning and afternoon the O_2 conditions became less extreme and approached those of open water. Oxygen production occurred mostly in the top 100 cm. Dissolved oxygen readings in an area 1 week after treatment indicated somewhat steeper O_2 gradients, in part due to shallow depth in these areas compared to open water and the undisturbed mat. There appeared to be greater O_2 productivity in the treated area although comparison of afternoon data must be made cautiously since measurements were obtained 3 to 4 hours later than in the undisturbed mat.

pH profiles in Grassy Pond were inversely related to the relative amount of CO_2 and depth profiles of CO_2 generally showed trends opposite those of pH and O_2. In the older mat, CO_2 ranged from about 30 to 45 ppm while pH was less than 5. Dissolved CO_2 decreased to less than 10 ppm and pH increased to greater than 5.5 at the mat edge except near the pond bottom. There was a wider range of CO_2 and pH values in the open water and in the treated areas, reflecting primary production in the surface regions by submersed macrophytes and algae, and decomposition of dead plant parts near the pond bottom.

Diel measurements of O_2, pH, temperature, and Eh in various areas of Grassy Pond at a depth of 25 cm are shown in Fig. 3. Diel temperature fluctuations indicated results similar to those of depth profiles; the least diel range in temperature (1.6 C) occured 52 m from open water under the older mat, while the greatest range (4.1 C) occured 1 week after treatment where floating dead plant parts absorbed radiation during the day and appeared to prevent heat loss at night. An area 6 weeks after treatment and an area of the undisturbed mat nearer to open water, both with intermediate macrophyte biomass, showed temperature fluctuations of 3.3 C.

Dissolved oxygen never exceeded 1 ppm in the older mat 52 m from open water while 8 m from open water O_2 ranged from 2.0 to 7.7 ppm over the 24 hour measurement period. In the treated area, O_2 ranged from 2.8 to 7.3 ppm one week after treatment and from 4.0 to 6.6 ppm six weeks after treatment.

The diel ranges of pH values were similar to depth profiles of pH and were inversely related to the relative

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[1] Schreiner, S.P. 1978. Investigations of the Environmental Consequences of *Eichhornia crassipes* in Aquatic Ecosystems. M.S. Thesis, University of Georgia, Athens.

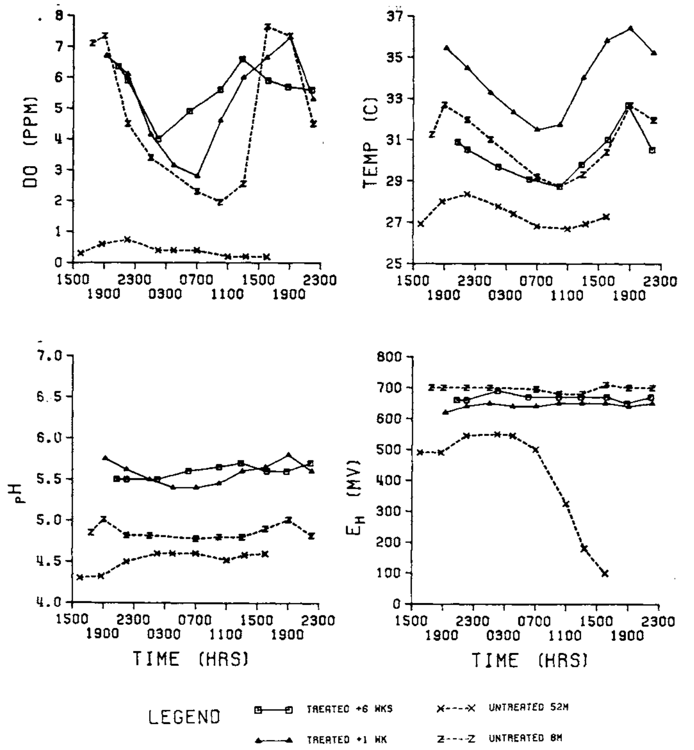

Figure 3. Daily cycles of dissolved oxygen (DO), temperature, pH, and Eh in Grassy Pond in summer at a depth of 25 cm. Locations reported as distance from open water in meters.

amounts of CO_2 present in the area. pH ranged from 4.3 to 4.6 in the older mat (52 m) and from 4.8 to 5.0 in the undisturbed mat nearer to open water (8 m). Changes over the 24 hour period in these areas were more likely due to physical mixing events both in the pond system and due to the stirring mechanism of the sampling equipment. pH ranged from 5.4 to 5.8 one week after treatment and from 5.5 to 5.7 six weeks after treatment. In these areas, minimum pH occured toward the end of nighttime CO_2 production, while maximum pH tended to occur toward the end of daytime CO_2 utilization, although there was also some variability due to mixing events. As with O_2 measurements, there was less fluctuation 6 weeks after treatment as compared to 1 week after treatment.

Results of Eh measurements can only be used qualitatively since there are many redox reactions in natural systems which do not show reversible electrode potentials (9). Diel measurements generally reflected relatively oxidizing conditions (620-710 mv) in all areas except the older mat. In this area, Eh ranged from 500 to 635 mv during all but the last 9 hours of measurement when there was a drop to 100 mv. This effect occured in the same area the previous year, also toward the end of a 24-hour measurement period, suggesting the occurence of a slow reducing reaction in this poorly oxygenated area (9).

Results of phosphorus measurements in various areas of Grassy Pond are shown in Table 2; these data are primarily useful in indicating nutrient regeneration due to senescence or herbicide treatment. In general, lowest nutrient values for both total phosphorus and ortho-phosphate were found on the edge (1 m) and in the middle of the mat. In these areas waterhyacinth was growing most rapidly and therefore was more likely to be accumulating nutrients (2). Higher phosphorus levels were found in the older portion of the mat near shore (52 m) where levels of detritus were greatest; plants in this area were senescent as indicated by lower leaf chlorophyll and greater amounts of pheophytin as compared to plants at the mat edge.[1]

Table 2. Total and ortho-phosphorus in Grassy Pond, July 1977. Mean of three vertical samples ± 1 standard error reported.

Location	Total P µg P/l	Ortho-P µg P/l	% Ortho-P
Old Mat	123 ± 28	30 ± 9	19 ± 1
Mat Edge	27 ± 15	5 ± 2	14 ± 8
1 Wk Post Treatment	151 ± 73	22 ± 10	13 ± 1

Nutrient regeneration was presumably induced in the treated area as killed plants were decomposed (3, 7); the greatest portion of this regeneration occurred closer to the pond bottom as indicated by increasing nutrient concentration with depth, even though treated plants remained floating for several days before eventually sinking. Between 13% and 21% of the total phosphorus was in the form of orthophosphate, presumably the most available form for uptake by algae and macrophytes.

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