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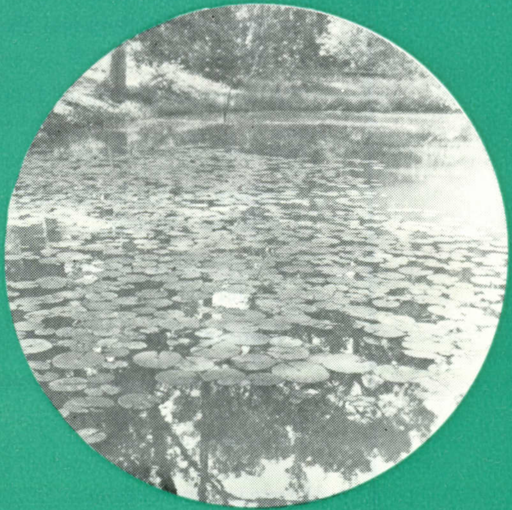

Competition for Light by Aquatic Plants in Fish Ponds

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FIRST PRINTING 3M, JUNE 1975

COMPETITION FOR LIGHT BY AQUATIC PLANTS

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INTRODUCTION

UNMANAGED PONDS in most areas of Alabama often have relatively clear water and are therefore excellent habitats for growth of underwater and emergent plants. These plants cause unbalanced fish populations, interfere with fishing and fish harvest, favor mosquito production, and compete with phytoplankton for light and nutrients *(5)*. Early studies on fertilization of fish ponds revealed that additions of inorganic nutrients increased phytoplankton production and fish yield. The resulting phytoplankton turbidity also shaded and eliminated underwater weeds from ponds (15, 16).

Small, sheltered fish ponds with waters rich in organic matter are often infested with duckweeds *(6,8,13)*. These plants grow on pond surfaces and interfere with gas exchange between water and atmosphere, inhibit photosynthesis by underwater plants, and cause low oxygen tensions in waters beneath *(7)*. Fertilization is not effective in controlling duckweeds.

The early studies of pond fertilization were primarily concerned with immediate means of increasing fish production, but through necessity, a number of practical generalizations were made on the ecology of aquatic weeds in ponds *(14,15,16,18,19)*. Unfortunately, many of the observations on the ecology of aquatic weeds have never been substantiated with data and are open to criticism. The present report contains data on competition between aquatic plants for light and the influence of this competition on the pond environment.

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MATERIALS AND METHODS

Effect of Light Intensity on Photosynthesis by Aquatic Weeds

Nutrient solutions were prepared from well water which had been heated with stirring to reduce its dissolved oxygen content. Lowering of the dissolved oxygen content was necessary to prevent supersaturation of water with dissolved oxygen during photosynthesis experiments *(10)*. After cooling, ammonium nitrate and potassium dihydrogen phosphate were added to raise concentrations of nitrogen and phosphorus to 1.0 and 0.25 parts per million, respectively. Available carbon in different batches was similar; pH (6.95 to 7.25), total alkalinity (41.7 to 43.8 parts per million), and carbon dioxide (5.3 to 8.4 parts per million). Dissolved oxygen concentrations in different batches ranged from 4.0 to 5.5 parts per million. An analysis of well water by atomic absorption spectrophotometry gave the following results in parts per million; calcium 4.0, magnesium 2.8, sodium 6.5, potassium 1.1, iron 3.4, manganese 0.05, zinc 0.29, and copper 0.05. Aquatic weeds were collected from depths of 1 to 3 feet in ponds on the Fisheries Research Unit of the Auburn University Agricultural Experiment Station, Auburn, Alabama. In each series of photosynthesis measurements, fresh 1.0-gram samples of plants were placed in each of 15 standard BOD bottles. The bottles were put in a dark box and transported to a nearby pond. Nutrient solution was introduced through a siphon tube which discharged at the bottom of bottles. Bottles were allowed to overflow for one complete exchange of water, stoppered, and returned to the dark box. Eleven BOD bottles were attached horizontally by universal clamps at 10-inch intervals along a metal rod. The rod was then suspended vertically so that bottles were positioned at 10-inch intervals from the surface to 8.3 feet. Two bottles (dark bottles) were wrapped in aluminum foil and suspended at depths of 1 and 4 feet. As soon as light and dark bottles were in place, nutrient solution from the two remaining bottles (initial bottles) was siphoned into 60-milliliter bottles for dissolved oxygen determinations by the Winkler method *(1)*. Transfer of plant material was prevented by fitting a piece of bolting silk over the siphon intake. After 1-hour incubation, light and dark bottles were quickly placed in the dark. Bottles were then removed one at a time and nutrient solution siphoned to 60-milliliter bottles for dissolved oxygen analysis. Dark bottles were always siphoned last and the time of dark storage (5 to 15 minutes) between the end of incubation and siphoning recorded. Rates of respiration and net photosynthesis per gram fresh plant material were calculated from the following equations.

$$(1)\ \text{Respiration } (\mu MO_2/hr) = \frac{\mu MO_2\ I.B. - \mu MO_2\ D.B.}{1\ hr. + t}$$

$$(2)\ \text{Net photosynthesis } (\mu MO_2/hr) = \mu MO_2\ L.B. - \mu MO_2\ I.B. + (t)\ (\text{Respiration})$$

Where: $\mu MO_2/hr$ = micromoles of oxygen per hour, t = time of dark storage in hours, I.B. = initial bottle, L.B. = light bottle, and D.B. = dark bottle, and 1 hour = time of incubation.

The 1-hour incubations were conducted within the periods 8:30 a.m. to 10:30 a.m. and 1:00 p.m. to 4:00 p.m. on clear, calm days during June and July, 1974. Intensity of light was measured at 10-inch depth intervals with a Tsurumi-Seiki submarine illuminance meter.[1] Measurements were repeated every 15 minutes during each incubation period. Approximately 93 percent of the light passed through one side of the BOD bottles, so all measured light intensities were multiplied by a factor of 0.93.

Competition Between Phytoplankton and Underwater Weeds

The extent of coverage by aquatic weeds of some ponds on the Fisheries Research Unit and in the vicinity was estimated during June and July, 1972. Estimates of turbidity were by Secchi disk visibility.[2] Phytoplankton density was estimated from chlorophyll *a* analysis *(20)* and from primary productivity determinations by the oxygen light-dark bottle technique *(1)*. In two ponds, measurements of Secchi disk visibility, chlorophyll *a* content of water, and cover of bottom by macrophytes were made at biweekly intervals from February 14 until August 31, 1973. Concentrations of soluble inorganic and total phosphorus in water samples were measured by standard techniques *(1)*.

To estimate standing crops of macrophytic algae, an open-ended plastic cylinder (10-inches in diameter) was pressed into the mud. Enclosed plant material was either hand-picked or removed with a dip net. All debris was removed and algae dried at 220° Fahrenheit. Three to five, 10-inch diameter circles of algae were harvested from each pond.

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[1] An underwater light meter.

[2] The depth at which an 8-inch diameter disk with two black and two white quadrants disappeared from view.

Ecological Effects of Duckweeds

Twelve circular pools (10 feet in diameter) were built in an unshaded area on the Fisheries Research Unit; they consisted of vinyl plastic liners attached to corrugated steel siding. The bottom of each pool was filled to 3-inch depth with a Cecil sandy loam top soil and water was maintained at depths of 20 to 24 inches by periodic additions or removals. On August 20, 1974, *Spirodela polyrhiza* and *Wolffia columbiana* were added to cover the surfaces of each of four pools, respectively. Four pools were maintained as controls. Fertilizer (3 ounces of a 20-20-5 mixture) was added to each pool on August 20, 1974, and again on September 10.

Changes in water levels caused by evaporation and evapotranspiration were measured daily from August 23 to September 25, 1974, with a hook gage. A rain gage was positioned beside pools for correction of data on water level changes during days when it rained. Maximum-minimum air temperatures were obtained daily from thermometers mounted in a Weather Bureau-type instrument shelter. Water temperature and dissolved oxygen concentrations were measured daily between 2:00 and 2:30 p.m. at 0, 3, 10, and 20-inch depths with a submersible thermister and a polarographic oxygen meter. Light penetration measurements were made near noon with a submersible photometer. Gross photosynthesis was measured on three dates by the oxygen light-dark bottle technique *(1)*. Bottles were incubated at 10-inch depth. On September 20, water samples were collected from a depth of 10 inches for phytoplankton enumeration and chemical analysis *(1)*.

Standing crops of *W. columbiana* and *S. polyrhiza* were determined on two dates. Plants were collected by placing a fine-mesh, 8-inch diameter sieve beneath the mats of duckweeds and then lifting the sieve. Fronds were removed from the sieve and dried at 220° F to constant weight.

RESULTS AND DISCUSSION

Effects of Light Intensity on Photosynthesis by Aquatic Weeds

Relationships between light intensity and net photosynthesis in eight species of macrophytic algae and five species of submersed higher aquatic plants are presented in figures 1 and 2. All regression equations were quadratic and correlations between

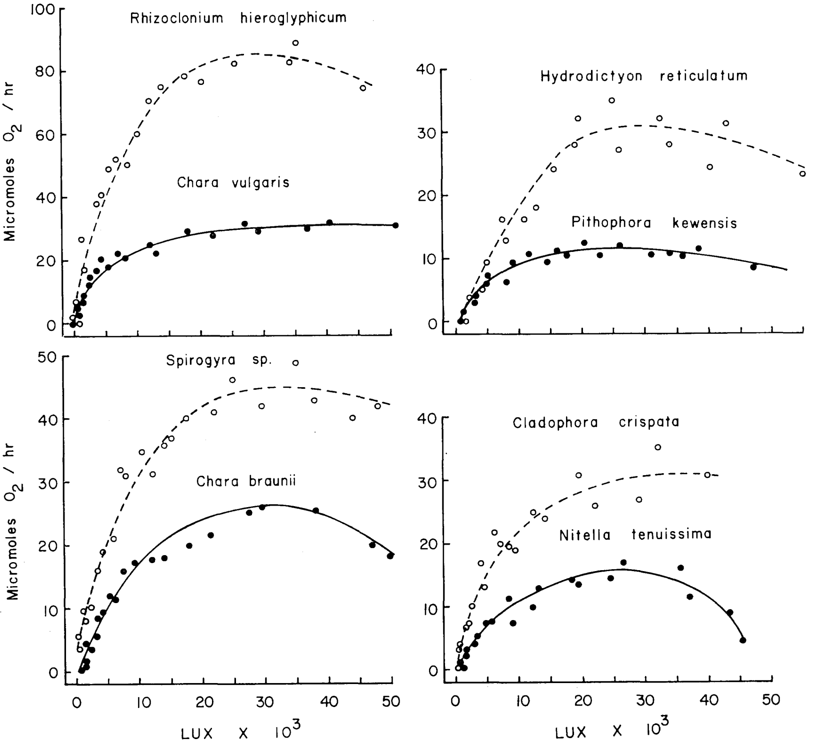

FIG. 1. Net photosynthesis by 1-gram samples of eight species of macrophytic algae which were incubated for 1 hour at different light intensities.

light intensity and net photosynthesis were significant at the 0.01 level of probability. Maximum rates of net photosynthesis in algae occurred between 20,000 and 35,000 lux, but light intensities above 35,000 lux were inhibitory to all algae except *Chara vulgaris* and *Cladophora crispata.* Photosynthesis by algae was measureable at light intensities below 2,000 lux, and 50 percent of maximum net photosynthesis was attained at light intensities between 4,000 and 9,000 lux. The higher plants had slightly lower light requirements for photosynthesis than did macrophytic algae. Maximum rates of net photosynthesis in higher plants were recorded at light intensities of 10,000 to 20,000 lux. A 50 percent reduction in photosynthesis was not affected until light intensities dropped below 2,000 to 5,000 lux. These data, figures 1 and 2, suggest that macrophytic algae and submersed angiosperms have rather low requirements for light and that the requirements for different species do not differ greatly.

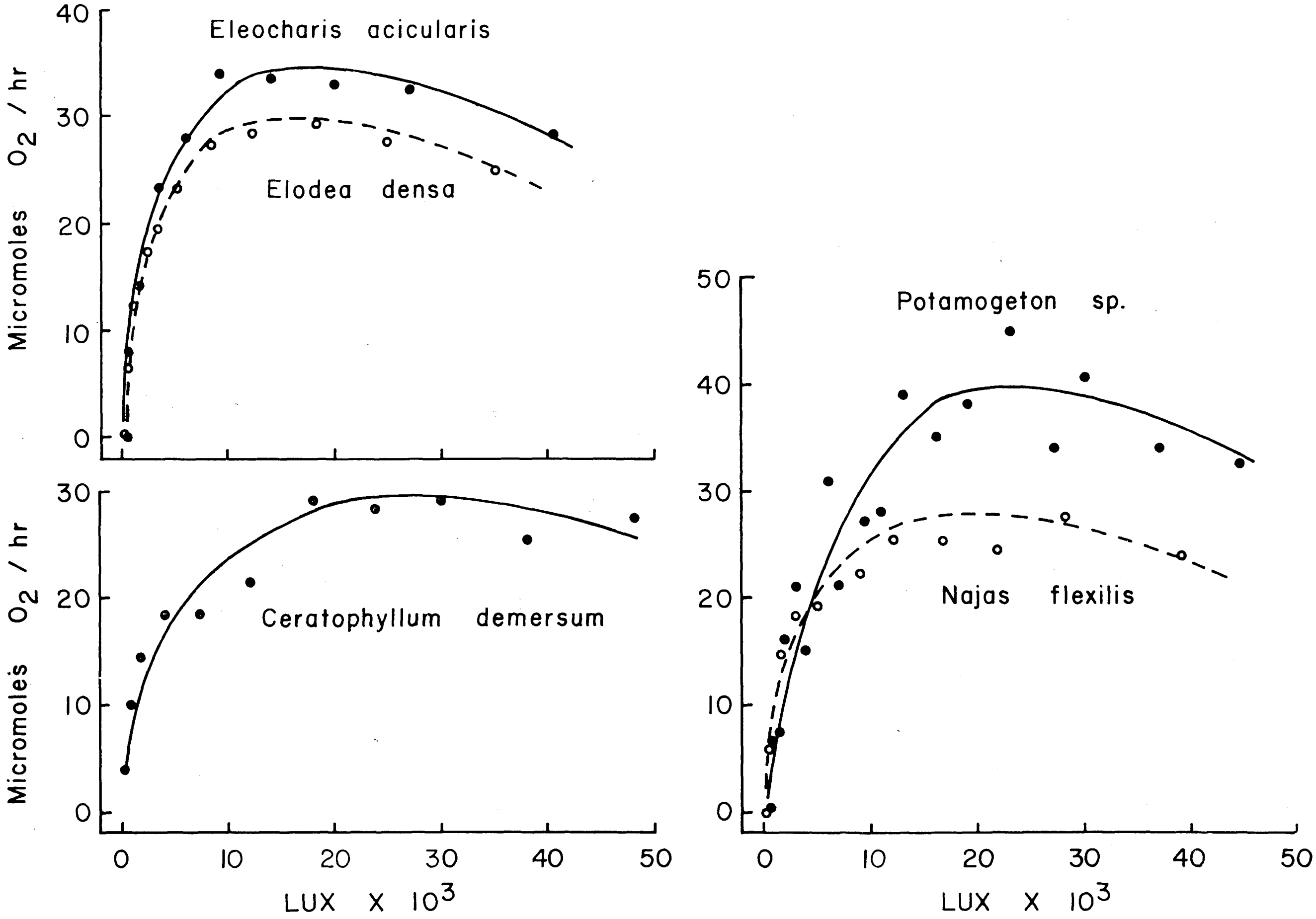

FIG. 2. Net photosynthesis by 1-gram samples of five species of submersed angiosperm aquatic weeds which were incubated for 1 hour at different light intensities.

Transparency of water in the pond where samples were incubated did not change appreciably during the study. Secchi disk visibilities for different days averaged 38.6 inches with a standard error of ± 0.24 inches. The maximum depth of immersion at which net photosynthesis was detectable ranged from 6.6 to 7.4 feet or roughly twice the Secchi disk visibility. Plants must produce enough extra photosynthate during daylight to supply carbohydrate for night time respiration. Therefore, the actual depth to which plants can occur will be somewhat less than twice the Secchi disk visibility.

The usual recommendations hold that weed control can be affected by deepening pond edges to 2 feet and adding fertilizer at a rate sufficient to restrict underwater visibility (or Secchi disk visibility) to 12 inches (9, 19). Findings reported above concur that underwater weeds could not grow in waters deeper than 2 feet which have Secchi disk visibilities of 12 inches or less. In fact, it appears from the photosynthesis experiments that even greater Secchi disk visibilities would be permissible without encouraging weed growth.

Competition Between Phytoplankton and Underwater Weeds

Fish ponds which were turbid with plankton were essentially free of underwater weeds, Table 1. Secchi disk visibilities averaged 5.7 feet in ponds which were infested with weeds, but only 1.4 feet in ponds which were essentially free of weed problems. Data on gross photosynthesis and chlorophyll *a* concentrations, Table 1, confirm that the differences in turbidity resulted from differences in phytoplankton abundance between the two groups of ponds. Furthermore, ponds with aquatic weed problems had much lower concentrations of soluble inorganic phosphorus and total phosphorus than ponds with phytoplankton blooms. This was not surprising because most of the ponds with phytoplankton blooms had been fertilized, while most of the ponds with weed infestations had not been fertilized.

More direct evidence of the influence of turbidity on macrophytic algae is illustrated, Figure 3. *Spirogyra* sp. and *Hydrodictyon reticulatum* grew well in two ponds from mid-February until early June when phytoplankton was scarce and waters transparent. Turbidity increased in early June, following a burst of phytoplankton growth. Macrophytic algae essentially disappeared from both ponds by early July and did not reappear during restriction of light penetration.

Recommendations on the use of fertilizers for weed control in fish ponds stress that fertilization programs be initiated only when underwater weed populations are at low abundance; usually in late winter *(15,16)*. Otherwise, fertilizer will stimulate additional aquatic weed growth and prevent the development of a plankton turbidity sufficient to shade the weeds. Data in Table 2 illustrate that shading within dense populations of weeds will greatly restrict phytoplankton photosynthesis as compared to photosynthesis in open water areas of the same pond.

Ponds with waters turbid from suspended soil particles or humic substances are often not troubled by underwater weeds. However, the turbidity of such ponds also restricts phytoplankton growth and prevents good fish production.

Although fertilization is an effective means of increasing fish production and controlling weeds, excessive fertilization is wasteful, expensive, and may cause too much plankton growth. Beasley *(2)* demonstrated that the depth of penetration of adequate

TABLE 1. LIMNOLOGICAL DATA FOR PONDS WITH PHYTOPLANKTON BLOOMS OR COMMUNITIES OF AQUATIC WEEDS. SEVEN PONDS OF EACH TYPE WERE USED FOR GROSS PRIMARY PRODUCTIVITY MEASUREMENTS. FOR OTHER DETERMINATIONS, SAMPLE SIZE WAS 20 AND 22 FOR PONDS WITH PHYTOPLANKTON BLOOMS AND PONDS WITH WEED PROBLEMS, RESPECTIVELY

Measurement[1]	Ponds with less than 5% of bottoms covered by aquatic weeds	Ponds with 10 to 100% of bottoms covered by aquatic weeds
Secchi disk transparency (in)	16 ± 3	69 ± 13
Chlorophyll *a* (ppb)	86 ± 16	13 ± 5
Gross primary productivity (ppm oxygen/day)	6.4 ± 1.0	1.5 ± 0.3
Soluble inorganic phosphorus (ppm)	0.050 ± 0.031	0.011 ± 0.003
Total phosphorus (ppm)	0.151 ± 0.048	0.042 ± 0.012

[1] Averages ± two standard errors.

TABLE 2. GROSS PHOTOSYNTHESIS BY PHYTOPLANKTON BENEATH MATS OF *Pithophora kewensis* AND WITHIN STANDS OF *Chara braunii* AND IN OPEN WATER AREAS OF THE SAME PONDS

Depth (ft)	Gross photosynthesis (ppm O_2/hr)			
	Beneath mat of *Pithophora*	Open water	Within stand of *Chara*	Open water
0	0.02	0.08	0.04	0.05
0.7	0.02	0.12	0.04	0.06
1.4	0.02	0.09	0.03	0.05
2.1	0.01	0.09	0.01	0.05
2.8	0.01	0.08	0.01	0.04
3.5	0.01	0.04	----	----
4.2	0.0	0.02	----	----
4.9	----	0.0	----	----

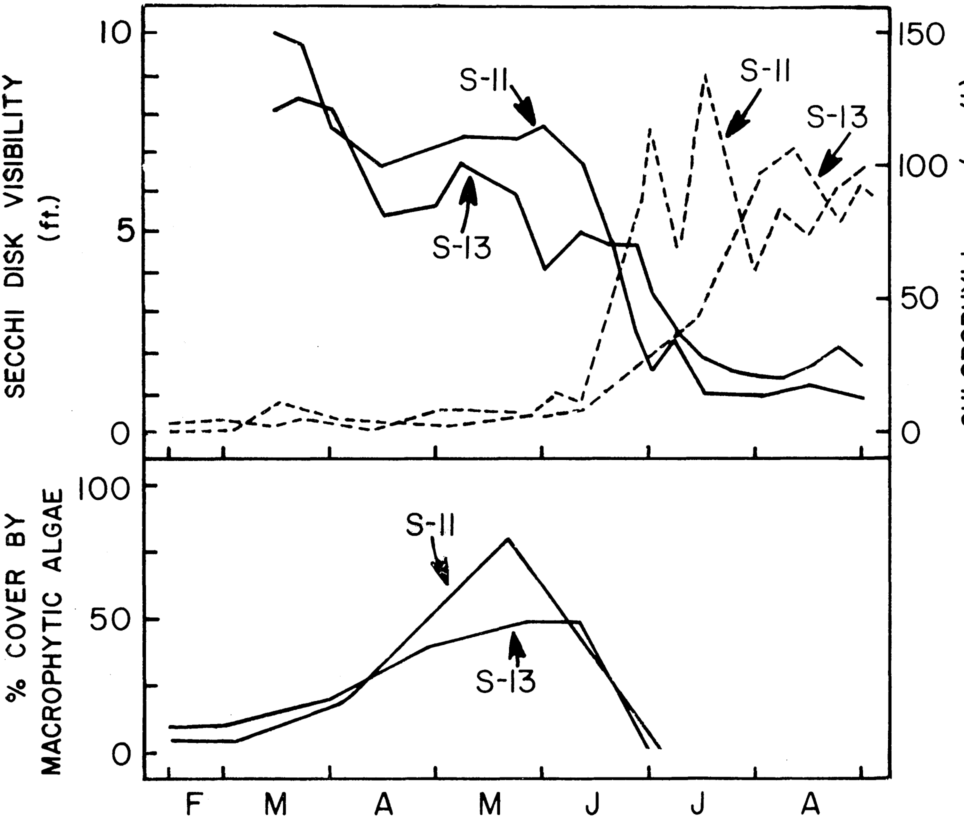

FIG. 3. Upper: Relationships between chlorophyll a concentrations (dashed lines) and Secchi disk visibility (solid line) in two ponds. Lower: Abundance of macrophytic algae for comparison with data in upper portion of figure.

light for photosynthesis by phytoplankton was inversely related to phytoplankton density. He also found that the depth of water containing enough dissolved oxygen for fish survival corresponded with the zone in which there was adequate light for photosynthesis. In response to low light intensity, blue-green algae form gas vacuoles and rise to areas of greater light intensity. Therefore, excessive phytoplankton growth usually results in surface scums of algae and shallow thermal and chemical stratification *(4)*. Heavy scums of phytoplankton cause a number of problems including odors, off-flavor in fish, and direct toxicity to aquatic organisms *(4)*. Under certain conditions, blooms of blue-green algae suddenly die and their decomposition leads to oxygen depletion and fish mortality *(4,17)*. Therefore, only enough fertilizer should be added to ponds to produce sufficient plankton to affect underwater weed control and the desired level of fish production.

Standing Crops of Aquatic Weeds

As stated previously, aquatic weeds may completely dominate plant communities of ponds and cause serious fish management problems. Weed populations may blanket the surface, cover the bottom, or completely fill the water column. These weed infestations appear to contain a large amount of plant material, but findings reported in tables 3 and 4 reveal that standing crops of weeds in Alabama fish ponds are generally below 2,500 pounds per acre dry weight. Emergent aquatic weeds which often occur

TABLE 3. AVERAGES ± ONE STANDARD ERROR FOR DRY MATTER STANDING CROPS OF NINE SPECIES OF ALGAE IN PONDS

Species	No of samples[1]	Average standing crop (Lb/A)
Spirogyra spp.	6	526 ± 80
Rhizoclonium hieroglyphicum	4	1,383 ± 285
Pithophora kewensis	6	1,160 ± 196
Chara fibrosa	5	1,124 ± 223
Chara vulgaris	4	1,383 ± 214
Chara braunii	3	928 ± 223
Nitella teniussima	1	535
Hydrodictyon reticulatum	1	482
Cladophora crispata	1	571

[1] Each sample represents the average of 3 to 5 subsamples from individual ponds.

TABLE 4. AVERAGES ± ONE STANDARD ERROR FOR DRY MATTER STANDING CROPS OF 12 SPECIES OF AQUATIC WEEDS IN PONDS

Species	No. of samples[1]	Average standing crop (Lb/A)
Najas guadalupensis	6	937 ± 152
Potamogeton diversifolius	6	1,124 ± 205
Eleocharis acicularis	6	2,069 ± 562
Heteranthera dubia	1	1,650
Myriophyllum heterophyllum	1	731
M. brasilensis	1	3,559
Ceratophyllum demersum	1	651
Jussiaea repens	6	3,675 ± 232
Brasenia schreberi	4	1,365 ± 535
Herpestris sp.	3	1,971 ± 134
Wolffia columbiana	8	598 ± 62
Spirodela polyrhiza	4	491 ± 71

[1] Each sample represents the average of 3 to 5 subsamples from individual ponds.

around the shallow edges of fish ponds produce more impressive standing crops of 8,000 to 20,000 pounds per acre *(12)*. Some of the larger floating plants, e.g. *Eichhornia crassipes* of tropical and subtropical regions, may also produce standing crops greater than 10,000 pounds per acre dry weight *(21)*.

Plankton densities in fertilized ponds usually range from 20 to 40 ppm dry weight *(18)*. In a pond with an average depth of 6 feet, the plankton crop will weigh about 360 to 720 pounds per acre. The average life of plankton organisms is brief (a few weeks or less), but there is a continuous replenishment by new growth. Aquatic weeds live longer and many of the individual plants present in the spring will survive until fall or winter. Therefore, production by plankton in fertilized ponds greatly exceeds the production of weeds in unmanaged ponds.

Ecological Effects of Duckweeds

Weather conditions during the study were normal for the locality and time of year. Skies were clear or partly cloudy, except for the period September 4 to 13, when a hurricane over the Gulf of Mexico caused cool, overcast conditions. Daily minimum air temperatures ranged from 52 to 68° F while the daily maximum values varied from 77 to 97° F. Rainfall occurred on 7 days, but at no time did 24-hour totals exceed 1 inch.

Averages ± one standard error for standing crops of dry matter in pools on August 28 and September 23 were 1,052 ± 169 and 803 ± 71 pounds per acre for S. *polyrhiza* and 312 ± 45 and 196 ± 9 pounds per acre for W. *columbiana*. Amounts of duckweed were adequate to cover surfaces of pools. Plants shaded pools and less light penetrated to a given depth in pools with duckweed than in control pools, Table 5. Larger S. *polyrhiza* fronds formed a more tightly massed assemblage and reflected and absorbed more light than did W. *columbiana*.

Diurnal changes in temperature at different depths are illustrated in Figure 4. Temperatures in all pools increased from dawn until afternoon and then decreased with lowest temperatures occurring just before the next dawn. There was, however, a marked difference between temperature patterns in control and duckweed covered pools. The water column heated more uniformly in control pools during daylight hours and the temperature differential between top and bottom seldom exceeded 5° F. Duckweeds absorbed heat during daylight hours and surface waters were 5 to 7° F warmer than in control pools. Waters at

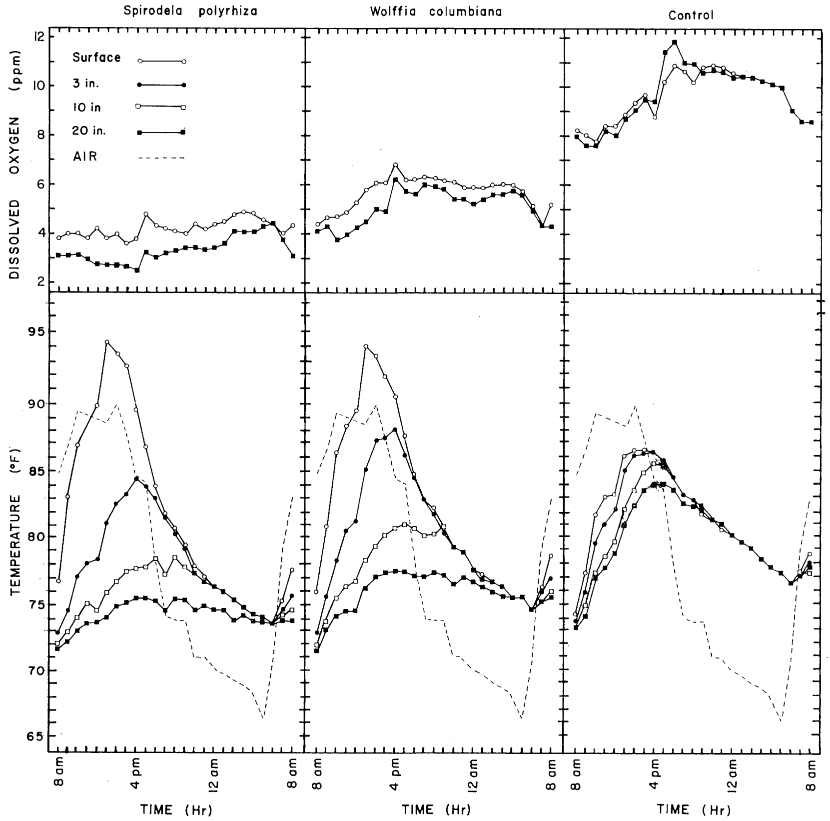

FIG. 4. Diurnal changes in dissolved oxygen and temperature in plastic pools covered with one of two species of duckweed and in control pools. Each value is the average of data from four pools.

3-inch depths were at similar temperatures in all pools during daylight hours. Temperatures at 10 and 20-inch depths were considerably lower in pools covered by *W. columbiana* and *S. polyrhiza.* Temperature differentials between top and bottom in pools with duckweeds ranged from 9 to 18° F between 10:00 a.m. and 6:00 p.m. As air temperature declined, surface waters of pools covered by duckweeds lost heat and isothermal conditions existed at dawn.

Temperature profiles recorded for 2:00 p.m. on September 10, Figure 4, were similar to profiles measured at 2:00 p.m. on other clear or partly cloudy days. During the period of cool, overcast weather (September 4 to 13), waters were isothermal, or nearly so at 2:00 p.m. in pools of all treatments. Total heat content per unit surface area (calories per inch^2) above 32° F was calculated for data collected on 5 days (2:00 p.m.) by multiplying weighted mean temperatures by mean depth *(3)*. Total heat contents were usually less in pools covered by *S. polyrhiza* and greatest in control pools, Table 6. The average in heat content of control pools exceeded that of pools with *S. polyrhiza* by 9.7 percent. Therefore, duckweed cover altered vertical distribution of heat more than it altered total heat content.

Water losses to evaporation in control pools exceeded losses by evapotranspiration in duckweed covered pools, Table 5. Complete surface coverage of pools by duckweed reduced the surface of water in direct contact with air and retarded evaporation even though surface waters were usually warmer than those of

TABLE 5. WATER LOSSES TO ATMOSPHERE, LIGHT PENETRATION, PHYTOPLANKTON DENSITY, AND GROSS PHOTOSYNTHESIS BY PHYTOPLANKTON IN CONTROL POOLS AND IN POOLS COVERED WITH ONE OF TWO SPECIES OF DUCKWEED. EACH VALUE IS THE AVERAGE OF DATA FROM FOUR REPLICATES

Measurement	Treatment[1]		
	Control	*Wolffia columbiana*	*Spirodela polyrhiza*
Total water loss by evaporation and evapotranspiration from 8/23 to 9/25 (in.)	4.75 a	4.26 b	4.06 c
% Incident light at 1 ft			
9/16	74.2 a	17.8 b	0.8 c
9/18	80.9 a	32.7 b	0.9 c
9/20	73.0 a	23.2 b	0.9 c
Phytoplankton density on 9/20 (Individuals/ml)	5,159 a	594 b	40 c
Gross photosynthesis by phytoplankton (ppm oxygen evolved per hour)			
9/16	0.36 a	0.14 b	0.02 b
9/18	0.38 a	0.12 b	0.02 b
9/20	0.94 a	0.05 b	0.02 b

[1] Values designated by different letters were determined significantly different at the 0.05 level of probability by Duncan's New Multiple Range Test (horizontal comparisons only).

TABLE 6. TOTAL HEAT CONTENTS (AT 2 P.M.) IN CALORIES PER IN^2 OF WATER SURFACE IN CONTROL POOLS AND IN POOLS COVERED WITH ONE OF TWO SPECIES OF DUCKWEED. EACH VALUE IS THE AVERAGE OF DATA FROM FOUR REPLICATES

Treatment	Total heat content (calories/in^2)[1]				
	8/29	8/31	9/5	9/13	9/20
Control	256 a	240 a	168 a	237 a	219 a
Wolffia columbiana	240 b	225 b	170 b	232 b	213 b
Spirodela polyrhiza	231 c	220 c	164 a	220 c	210 b

[1] Values designated by different letters were determined significantly different at the 0.05 level of probability by Duncan's New Multiple Range Test (vertical comparisons only).

control pools. Both S. *polyrhiza* and W. *columbiana* have stomata *(7)*, but they expose a minimum leaf area to air for evapotranspiration. Larger floating plants such as *Eichhornia crassipes* and *Salvinia molesta* normally had much higher rates of evapotranspiration *(11)* than smaller duckweeds, Table 5.

Concentrations of dissolved oxygen increased during daylight and decreased during night in control and W. *columbiana* pools, Figure 4. This pattern is normal in aquatic habitats. Concentrations of dissolved oxygen throughout the 24-hour period were greater at all depths in control pools than in pools with W. *columbiana*. Concentrations of dissolved oxygen did not increase appreciably during daylight in pools with S. *polyrhiza*. Dissolved oxygen concentrations in these pools increased slightly at night probably because of continuous mixing of surface with deeper waters as Surface water cooled, Figure 4. Pools covered with S. *polyrhiza* had less dissolved oxygen than pools with W. *columbiana*. Representative data for average dissolved oxygen contents (2:00 p.m.) for pools of different treatments are summarized. Table 7. Control pools always had highest concentrations of dissolved oxygen and pools covered by S. *polyrhiza* had lowest concentrations. Shading by duckweeds restricted development of phytoplankton communities and reduced gross photosynthesis, Table 5. Although there was no significant difference in gross photosynthesis between pools covered with W. *columbiana* and those covered with S. *polyrhiza*, values were numerically higher in pools covered with W. *columbiana*. Pools with W. *columbiana* also had higher concentrations of dissolved oxygen in the afternoon, Table 7. W. *columbiana* did not form as tightly closed cover as S. *polyrhiza* and permitted more gas exchange with the atmosphere. Furthermore, there was an obvious increase in dissolved oxygen in pools with W. *columbiana* during daylight hours

Table 7. Dissolved Oxygen Concentrations in Water Column (at 2 p.m.) in Control Pools and in Pools Covered with One of Two Species of Duckweed. Each Value Is the Average Data from Four Replicates

Treatment	Average dissolved oxygen concentrations for water column (ppm)[1]					
	8/30	9/5	9/13	9/17	9/20	9/23
Control	7.8 a	9.1 a	10.5 a	10.9 a	14.2 a	14.3 a
Wolffia columbiana	5.4 b	4.2 b	5.8 b	7.2 b	7.1 b	8.5 b
Spirodela polyrhiza	3.6 b	4.9 b	3.3 b	3.3 c	2.8 c	3.7 c

[1] Values designated by different letters were determined significantly different at the 0.05 level of probability by Duncan's New Multiple Range Test (vertical comparisons only).

but not in pools covered with S. *polyrhiza*. These observations suggest that more photosynthesis occurred in pools with *W. columbiana* than in pools with S. *polyrhiza*.

There were no significant differences between treatments with respect to concentrations of phosphate, nitrate, and ammonia and levels of total alkalinity, Table 8. Dense phytoplankton in control pools removed all free carbon dioxide while pools covered with duckweeds had high concentrations of carbon dioxide, Table 8. Lower pH in pools with duckweeds resulted from higher concentrations of carbon dioxide. Chemical oxygen demand, Table 8, was greatest in pools of control and *W. columbiana* treatments since these pools had greatest densities of phytoplankton, Table 5. Furthermore, in pools containing *W. columbiana,* decaying fronds were present in water samples and contributed to the chemical oxygen demand. The higher total solids content of control pools resulted from their greater density of phytoplankton. Tannins and lignins from duckweeds imparted a brown stain to water. Accumulation of tannins and lignins was greatest in pools covered by S. *polyrhiza,* Table 8.

These findings reveal that surface coverage of ponds with duckweeds will greatly retard phytoplankton production and cause water quality problems. *Spirodela* was a more serious threat to the pool environments than was *Wolffia.*

TABLE 8. CHEMICAL ANALYSES OF WATER FROM 1-FT. DEPTH IN CONTROL POOLS AND POOLS COVERED BY ONE OF TWO SPECIES OF DUCKWEED. EACH VALUE IS THE AVERAGE OF DATA FROM FOUR REPLICATES

Determination	Treatment[1]		
	Control	*Wolffia columbiana*	*Spirodela polyrhiza*
Chemical oxygen demand (ppm)	48.4 a	40.6 a	20.1 b
Total solids (ppm)	127.9 a	107.6 a b	96.1 b
Tannins and lignins (ppm)	0.14 a	0.65 b	0.40 c
Total alkalinity (ppm as $CaCO_3$)	28.9 a	27.6 a	29.2 a
pH	9.5 a	7.1 b	7.0 b
Carbon dioxide (ppm)	0 a	15.9 b	50.5 c
Phosphate (ppm as P)	0.60 a	0.60 a	0.20 a
Nitrate (ppm as N)	0.08 a	0.10 a	0.05 a
Ammonia (ppm as N)	0.05 a	0.05 a	0.15 a

[1] Values designated by different letters were determined significantly different at the 0.05 level of probability by Duncan's New Multiple Range Test (horizontal comparisons only).

SUMMARY

Submersed aquatic weeds had low light requirements for photosynthesis. Maximum rates of photosynthesis for 13 species occurred within the light intensity range of 10,000 and 35,000 lux and none of these species required more than 9,000 lux for 50 percent of maximum photosynthesis. Even so, phytoplankton turbidity in most fertilized ponds was more than sufficient to reduce light penetration to the bottom and eliminate aquatic weeds through shading. In unfertilized ponds, shading by aquatic weeds reduced phytoplankton growth.

Surface coverage of experimental pools with duckweeds, *Spirodela polyrhiza* and *Wolffia columbiana,* restricted light penetration, reduced photosynthesis by phytoplankton, and caused serious deterioration in water quality. Surface coverage by *S. polyrhiza* caused more serious water quality problems than did coverage by *W. columbiana.*

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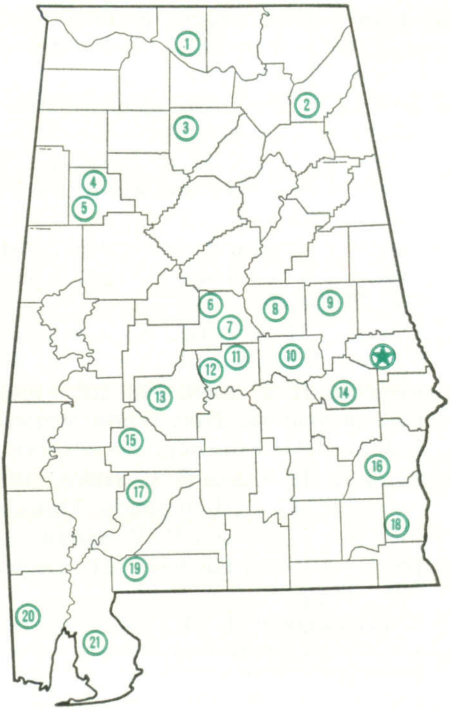

Research Unit Identification

★ Main Agricultural Experiment Station, Auburn.

1. Tennessee Valley Substation, Belle Mina.
2. Sand Mountain Substation, Crossville.
3. North Alabama Horticulture Substation, Cullman.
4. Upper Coastal Plain Substation, Winfield.
5. Forestry Unit, Fayette County.
6. Thorsby Foundation Seed Stocks Farm, Thorsby.
7. Chilton Area Horticulture Substation, Clanton.
8. Forestry Unit, Coosa County.
9. Piedmont Substation, Camp Hill.
10. Plant Breeding Unit, Tallassee.
11. Forestry Unit, Autauga County.
12. Prattville Experiment Field, Prattville.
13. Black Belt Substation, Marion Junction.
14. Tuskegee Experiment Field, Tuskegee.
15. Lower Coastal Plain Substation, Camden.
16. Forestry Unit, Barbour County.
17. Monroeville Experiment Field, Monroeville.
18. Wiregrass Substation, Headland.
19. Brewton Experiment Field, Brewton.
20. Ornamental Horticulture Field Station, Spring Hill.
21. Gulf Coast Substation, Fairhope.