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THE IMPACT OF ARTIFICIAL REDUCTION OF LIGHT ON A EUTROPHIC FARM POND

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A novel technique for reducing growth of aquatic macrophytes and decreasing primary productivity in an eutrophic farm pond was evaluated by the addition of commercial blue and brown aniline dyes to pond water isolated from the surrounding pond in experimental boxes. Blue-dyed water completely eliminated all aquatic macrophytes, while brown-dyed water eliminated only *Potamogeton* sp. Primary productivity was reduced, and phytoplankton populations similar to those observed in spring and fall pulses in lakes were present in the dyed water during the summer. Intense thermal stratification, anaerobiosis, and chemical changes were recorded in the enclosed waters after dye addition.

† † †

INTRODUCTION

Accelerated production of plant populations in aquatic ecosystems—one of the consequences of eutrophication—is a problem faced by biologists and engineers wherever lakes and people occur together. Increased production rates, either directly or indirectly, reduce water quality and decrease recreational opportunities in lakes where these increases are occurring.

In the Great Plains region, many small reservoirs have been built and more are being planned. Most often these reservoirs are constructed for flood control with additional benefits for recreation. The reservoirs are located in agricultural settings where intensive crop culture occurs on the fertile soils of their watersheds. The reservoirs depend upon surface runoff as their source of water; such runoff is rich in the nutrients required for the growth of plants. Under these conditions, growth of algae and rooted macrophytes is greater than desired.

Methods for controlling excessive aquatic vegetation vary from harvesting the plants—with problems of disposal of the organic material—to the use of chemical herbicides. Biological controls have been attempted with limited success. Physical controls, such as reservoir drawdown and replacement of substrate, in many cases is inefficient and expensive and may create other problems in fish and wildlife management. In some areas where circumstances allow, advanced treatment of influents to lakes for the removal of nitrogen and phosphorus is being used in an effort to control eutrophication. All of these controls have serious disadvantages—such as high initial operation and maintenance costs or undesirable effects on the environment—which make their application to the solution of eutrophication problems in Midwestern reservoirs impractical.

In 1944-1945, George Eicher, a biologist with the Arizona Game and Fish Commission, recognizing the need for some method to control nuisance growths of aquatic plants in hatchery ponds, dyed two ponds with a black aniline dye (Eicher, 1947). His idea of decreasing available light to reduce aquatic plant growth was largely successful; however, he lacked information as to the other biological, chemical, and physical effects of this treatment on the pond water.

Algal and macrophyte photosynthesis is well known to be a function of both light intensity and day length (Ryther, 1956; Chapman and Burrows, 1970; Edwards, 1969; Peltier and Welch, 1970). A reduction of either intensity or duration, regardless of how achieved, should result in lower total production in lakes. This relationship is the basis for the experiments to be described.

Our objective in these experiments was to determine whether the addition of specific colored solutions to a eutrophic pond which supported large populations of both algae and rooted plants could affect a significant decrease in the standing crops of these plants and exert some control on their abundance. Ideally, the added material should persist for at least 4-5 months in the lake (over the growing season), should be aesthetically pleasing, and should have no adverse effects on other components of the environment. Theoretically, it should be possible to add the material in the spring before submerged macrophytes begin their growth and inhibit light penetration during the remainder of the growing season. Furthermore, it should also be possible to add only the amount of dye necessary to achieve a reduction in standing crop but not totally eliminate it. If effective, this method would seem to be a relatively inexpensive and simple way to exert control over excessive plant populations and would be particularly appropriate for small reservoirs in the Great Plains where nutrient removal from inflowing waters is impractical.

It seems prudent for us at this point to inject a note of warning concerning the use of aniline dyes by those who might contemplate using them in research projects similar to ours or who might apply the results we have obtained to their

specific situation. The toxicities of aniline dyes and their degradation products are not well known for most organisms other than man. For humans, the toxicities are thoroughly known; aniline dyes are hazardous chemicals. Our research was designed to determine if the *concept* of eutrophication control by the alteration of the light environment is a feasible alternative to other methods of control. We used aniline dyes because of their availability and convenience. They most likely would not be the chemicals of choice, nor do we advocate their use in eutrophication control. Broad, detailed, long-term studies must be conducted on potential harmful effects of aniline dyes on organisms other than man if dissemination of these chemicals into the aquatic environment is anticipated.

METHODS

Teton Pond, a farm pond draining 59.5 hectares of fertilized cropland north and west of Dunbar in southeastern Nebraska, was selected for the experimental work. The pond met certain characteristics necessary for testing the dye method of treatment. It was generally clear (Secchi disc to 3 m), shallow (mean depth 1.6 m, with the deepest point varying from 2 3/4 to 3 1/2 m), and small (surface area of .96 hectares). A contour map of the pond is shown in Fig. 1. A large population of *Potamogeton foliosus* and *Potamogeton pusillus* grew to the surface of the pond from the shore to the 2 m contour, with lesser growth to the 2 1/2 m contour. An algal mat of *Spirogyra, Mougeotia,* and *Cladophora* occurred concurrently with the *Potamogeton.* As a result, an extremely dense canopy of vegetation covered two-thirds of the pond during the summer months.

In order to secure base-line data for the experiment, aquatic macrophytes, plankton, and water samples were taken every two weeks in the summer (May through September) in 1970, and plankton and water samples taken once per month in the fall, winter, and spring of 1970-1971. *In situ* carbon-14 primary productivity tests were conducted monthly during the summer of 1970 to estimate productivity of the phytoplankton.

Three to five samples of macrophytes were removed from the pond each sampling date to determine standing crop. Random sample points were selected from a table of random numbers corresponding to a predetermined grid system superimposed on the pond. A half-square meter, metal quadrat was sunk over the sampling point, and all vegetable matter in the quadrat from the surface to the bottom, including roots, was removed and placed in an opaque polyethylene bag. The bag was iced and returned to the laboratory for analysis (Vollenwieder, 1969).

Water samples for chemical and biological analyses were taken from the surface—1m, 2m and 3m levels—with a Van Dorn water sampler, and composited. A four-liter sample was removed from the composite for chemical analysis, and
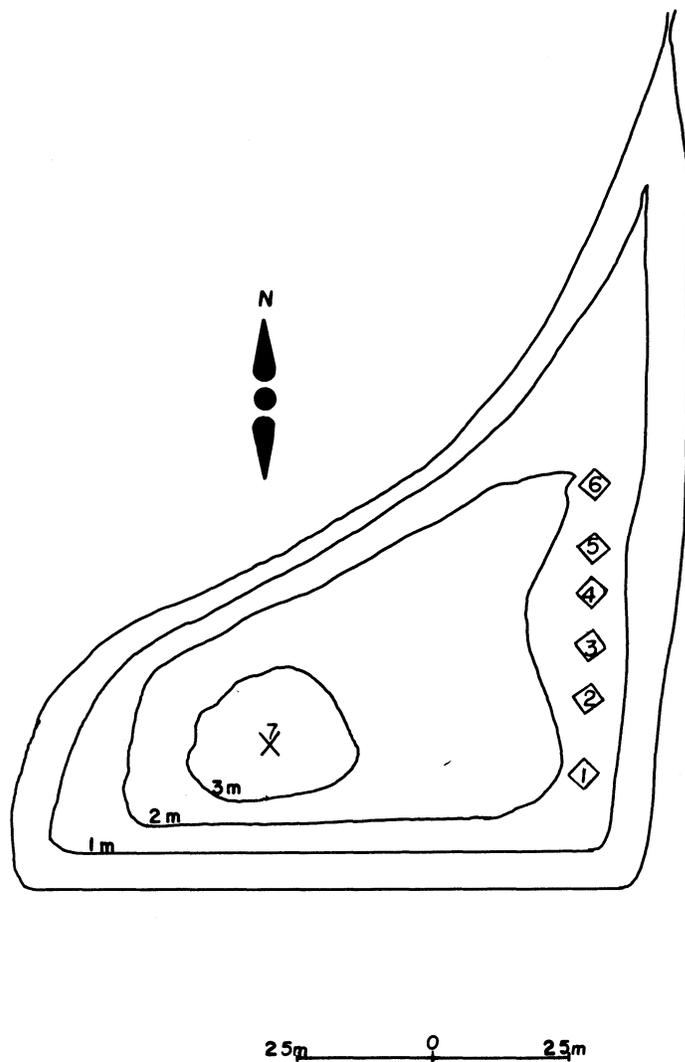

Figure 1. Contour map of Teton Pond showing locations of experimental boxes (1-6) and pond sampling point (7).

the remainder poured through a 35 micron mesh plankton net for identification of the algae present. Temperature and dissolved oxygen were measured in the field with a thermister/dissolved oxygen meter. Chlorophyll extractions were performed according to the method described by Richards with Thompson (1952), and concentrations calculated using the formula described in a UNESCO (1966) publication. Composited algal samples were preserved on a membrane filter (McNabb, 1960) for counting and volumetric measurements. *In situ* carbon-14 tests were run by the methods described by Goldman et al. (1966), exposed to fuming HC1 (Wetzel, 1965), and counted in a thin-window, gas-flow, Geiger-Mueller counter. Other measured water chemistry parameters were determined according to Standard Methods (APHA, 1965).

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In April, 1971 an experimental box, 3m x 3m x 2m, constructed of wood and wrapped with translucent polyethylene, was inserted in the pond to test the feasibility of the structure for the dye experiment. After determining that this method of isolation and structural design was adequate for the test, five more experimental boxes were constructed so that the lowermost portion could be sunk into the bottom mud and effectively seal water inside the boxes. Appropriate water and biological samples were taken in each box to determine the macrophyte and algal standing crops. A one-half meter grid system similar to that used for the pond was designed to sample the macrophytes rooted in the boxes.

Sandolan dark brown and Alizanine blue, commercial dyes purchased from the Sandoz Chemical Company (Hanover, New Jersey 07936), were selected for experimental use. Of the variety of colors of dyes received as samples, blue and brown dyes were chosen for the experiment for aesthetic reasons only. Desired limits of Secchi disc visibility, using various concentrations of the dyes in tap water, were determined in the laboratory in a 55 gallon (608.2 liters) aquarium; these concentrations were then calculated for the experimental boxes. Box No. 1, the first box inserted into the pond, was selected as the control enclosure with no dye added. Alizanine blue dye was added to boxes No. 2, No. 4, and No. 6 to bring the Secchi disc depth immediately after addition to 31 cm, 15 cm, and 10 cm, respectively. Boxes No. 3 and No. 5 were brought to Secchi disc visibility limits of 61 cm and 31 cm, respectively, with Sandolan dark brown.

After addition of the dyes, a change in the chlorophyll extraction technique was required. Preliminary evaluation of various techniques in the laboratory indicated that the dyes would adsorb to the membrane filters, rendering the resulting extract unsuitable for pigment analysis. However, it was found that comparable pore-sized glass filters could be rinsed free of dye with distilled water. To determine what effect a substitution of glass filters for membrane filters would have on the results, 113 comparisons of undyed membrane filters and glass fiber filters with dye added to the samples were made using both brown and blue dyes. The resulting correlation coefficient of r = .97 between the final pigment concentrations of the membrane and glass filters was determined to be satisfactory for continuation of the pigment analysis.

Appropriate physical, chemical, and biological samples as previously described were taken from each box. *In situ* carbon -14 tests were performed in each box to estimate phytoplankton primary productivity. In addition, water samples from the open pond were incubated at various depths in the boxes, and samples from the boxes were placed in the pond to determine the effect of reduced light on phytoplankton productivity and viability.

RESULTS

Temperature patterns and the intensity of thermal

stratification illustrated in Fig. 2 varied with each experimental box after dye treatment, from basically having the same thermal profile as the pond (box No. 1, control) to a maximum surface-to-bottom temperature differential of 6 1/2°C in boxes No. 2 and No. 4. Boxes with blue water exhibited greater temperature gradients than those with brown water. Dissolved oxygen concentrations in the boxes fluctuated independently of those in the pond and ranged from oxygen supersaturation conditions before dye treatment to anaerobic conditions after dye treatment. Fig. 3 illustrates the dissolved oxygen concentrations recorded for each experimental box. With time, water clarity as measured with a Secchi disc in experimental boxes No. 2, No. 4 and No. 6 stabilized at approximately 30 cm after dye addition, regardless of the initial dye concentrations added to the boxes. Secchi disc visibility in the brown-water boxes (No. 3 and No. 5) stabilized at about 45 cm. Table I summarizes the ranges of chemical parameters recorded for the pond and for the experimental boxes after dye addition. The boxes with blue water exhibited up to a 6-fold increase in ortho and total phosphate concentrations, while in each case nitrate-nitrogen was essentially eliminated from the water with a corresponding increase in ammonia-nitrogen, presumably due to the anaerobic conditions present in each of the blue-water boxes. The boxes with brown water showed some ortho-phosphate increases and nitrate elimination, but not to the extent as in the blue-water boxes.

Table I:

Ranges of Chemical Parameters Measured in the Experimental Boxes and Teton Pond

Sample Point	pH	PO$_4$ (mg/1)	Total P (mg/1)	NH$_3$-N (mg/1)	NO$_3$-N (mg/1)	TDS (mg/1)
Pond (1970-1971)	7.9-9.6	.02-.23	.09- .36	.25- .81	Trace-.60	137-245
Box 1 (control)	8.2-9.8	.02-.16	.12- .29	.15- .84	.10-.38	137-228
Box 2* (blue)	8.0-9.2	.31-.81	.51-1.01	1.40-2.29	Trace-.25	148-230
Box 3* (brown)	8.3-9.2	.08-.20	.13- .50	.52-1.10	Trace-.10	149-197
Box 4* (blue)	8.0-9.2	.15-.72	.23- .81	.89-2.50	Trace-.08	177-236
Box 5* (brown)	9.3-9.4	.08-.25	.10- .36	.15- .44	Trace-.10	160-188
Box 6* (blue)	7.8-9.5	.12-.68	.28- .69	.52-1.58	Trace-.10	152-218

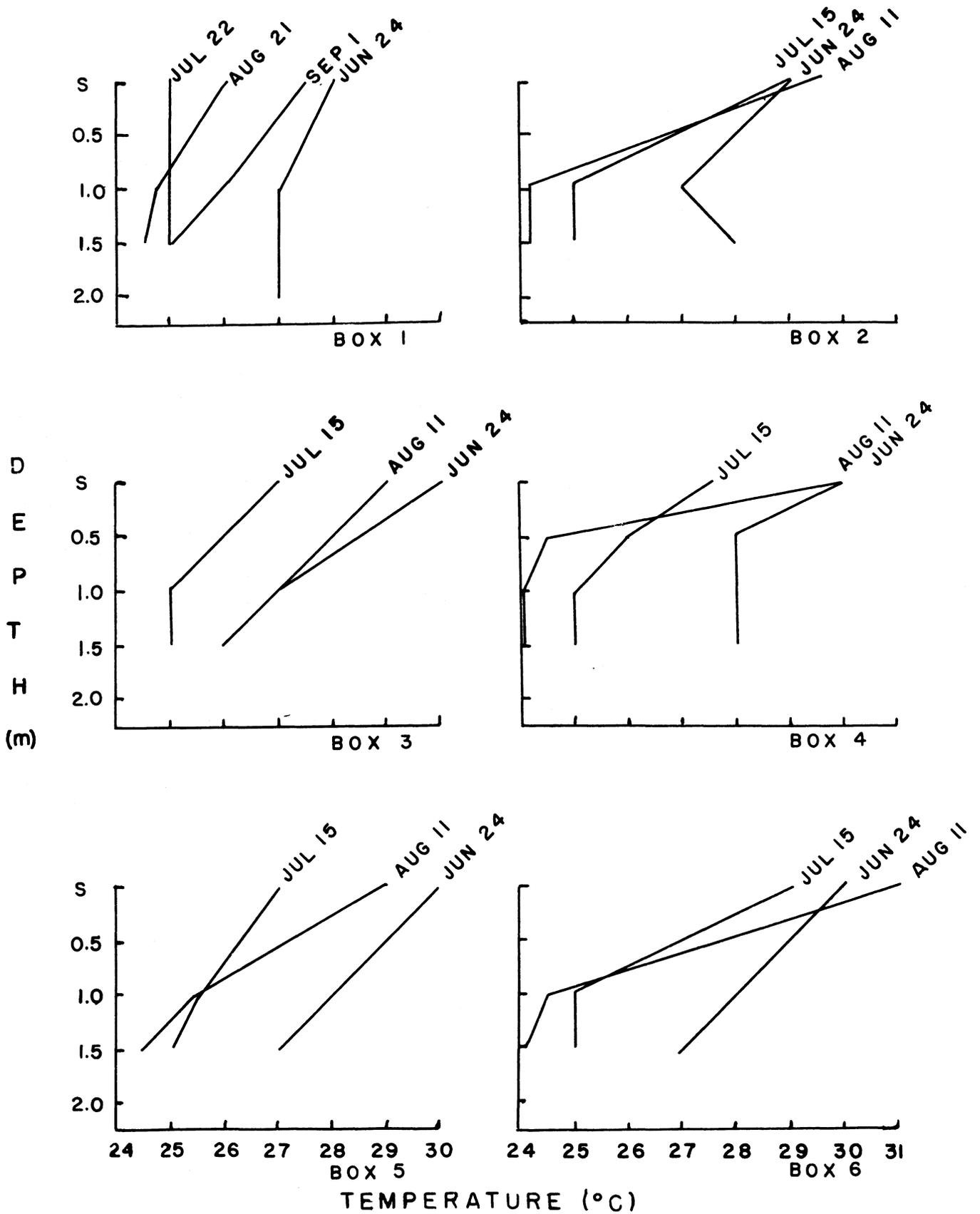*Parameters after dye addition

Figure 2. Temperature profiles for experimental boxes 1-6. Box 1 is the control, Box 2, 4 and 6 treated with blue dye, and Box 3 and 5 treated with brown dye.
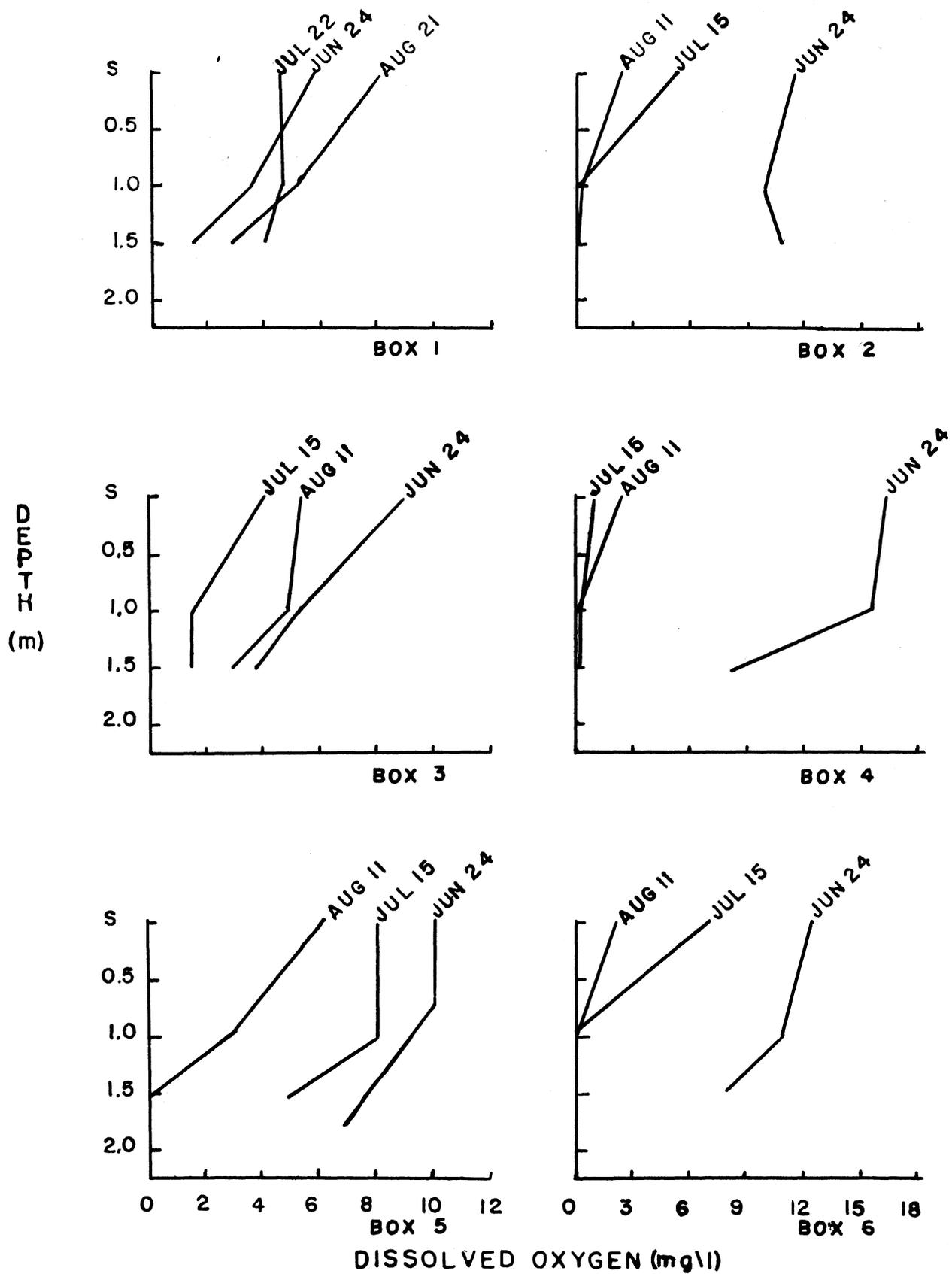
Figure 3. Dissolved oxygen profiles for experimental boxes 1-6.

After installation of the experimental boxes and before the addition of the dye solution, one-time random macrophyte samples were taken to estimate the standing crop in each box. After dye addition, further samples were taken to measure the effect of the dyed water on standing crops of macrophytes. As shown in Table II, aquatic macrophytes were completely eliminated from the blue-water boxes No. 2, No. 4, and No. 6 for the duration of the experiment. No living macrophytes were found in any of these boxes over the next 2 months. Toxicity tests in the laboratory determined that the dye was not toxic to the plants because they maintained their vigor in the presence of the dye if adequate illumination was also provided. It is therefore presumed that reduced light penetration effectively eliminated macrophytes from the experimental boxes. The anaerobic conditions in these boxes probably resulted from the decomposition of the aquatic plants at the bottom of the boxes and the absence of normal wind-induced circulation and aeration which the boxes effectively eliminated, resulting in the rapid death and subsequent decomposition of the plants in the boxes. Somewhat different results were obtained from boxes No. 3 and No. 5 which contained brown water. Before dye addition, *Chara* and *Potamogeton* were sampled in each box. Three weeks after addition of the brown dye, there was a three-fold increase in the standing crop of macrophytes in box No. 5 which consisted exclusively of *Chara*. Although no macrophytes were taken in the random samples in box No. 3, *Chara* was observed growing in the bottom muds, while *Potamogeton* appeared to be eliminated. Unfortunately, the experiment was terminated by the destruction of the boxes during a severe thunderstorm before additional data could be obtained; however, it was evident *Chara* survived and apparently flourished under the light conditions produced by the brown water.

The results of the carbon-14 primary productivity tests are given in Table III. Calculated values for the experimental boxes with blue water were extremely low compared with productivity in the pond. Production rates in the brown water were also reduced markedly, but not always to the same extent as those in the blue water. In order to determine whether the dyes themselves had an inhibitory effect on carbon assimilation or whether their effect was simply due to physical reduction of light, reciprocal exchanges of water samples were made between the pond and the experimental boxes. Samples of pond water were placed at appropriate depths in the boxes and samples of box water were placed at appropriate depths in the pond. As expected, calculated productivities of pond samples placed in the experimental boxes were reduced from 64-94% of those measured in the pond. These samples were, of course, enclosed in bottles, and the algae in them never came in direct contact with the dyes. The results indicate clearly that light reduction was the factor most responsible for the decreased production. Further attesting to this conclusion is the fact that pond samples incubated in the pond in mid-summer characteristically showed the highest production rates at the one-half meter

depth. This suggests that the well-known surface inhibition phenomenon is occurring and is resulting from light intensities which are too high for optimal photosynthesis and which physiologically damage the algal cells. When pond samples were placed in the experimental boxes, the highest production rates usually occurred in the surface bottles, and surface inhibition was no longer present. Clearly, the reduction in available light must be responsible (Table III). In all cases where samples from the experimental boxes were placed in Teton Pond, rates of production greater than those in the boxes were measured.

Table II:

Standing Crop Estimates of Macrophytes

Sample	Date	Number of samples	Grams dry weight per m^2	estimated standing crop in kg dry weight
Before dye treatment				
Teton Pond	17 Jul 1970	5	86	823
	27 Jul 1970	5	237	2262
	6 Aug 1970	5	78	746
	24 Aug 1970	5	101	955
	8 Sep 1970	5	31	300
	22 Sep 1970	3	41	387
	19 Oct 1970	⁻3	52	501
Teton Pond	2 Jul 1971	3	16	154
Box 2	2 Jul 1971	1	83	788
Box 4	2 Jul 1971	1	28	264
Box 6	2 Jul 1971	1	151	1442
Box 3	15 Jul 1971	1	2	15
Box 5	15 Jul 1971	1	46	447
After dye treatment				
Teton Pond	16 Jul 1971	3	34	326
Box 2 (blue)	16 Jul 1971	1	0	0
Box 4 (blue)	16 Jul 1971	1	0	0
Box 6 (blue)	16 Jul 1971	1	0	0
Teton Pond	11 Aug 1971	3	81	776
Box 1 (control)	11 Aug 1971	1	37	356
Box 2 (blue)	11 Aug 1971	1	0	0
Box 3 (brown)	11 Aug 1971	1	0	0
Box 4 (blue)	11 Aug 1971	1	0	0
Box 5 (brown)	11 Aug 1971	1	141	1350
Box 6 (blue)	11 Aug 1971	1	0	0

While at this point it is difficult to know whether the dyestuffs would have a direct inhibitory effect on the algae if mixed directly with them, it is obvious that when the algae are placed in more favorable light conditions (Teton Pond), they respond by fixing carbon at much increased rates.

Table III:

Primary Productivity Estimates with Depth,
Teton Pond and Experimental Boxes 2 through 6, 1971

Sample	Date	Surface (mgC/m³)	1/2 m (mgC/m³)	1 m (mgC/m³)	Calculated 4 hr Productivity (mgC/m²)
Teton Pond	15 July	15.4	37.4	30.0	77.1
Box 4 (blue)	15 July	9.4	10.6	4.2	8.7
Teton Pond in Box 4	15 July	11.5	3.4	1.0	4.8
Teton Pond	30 July	52.4	127.5	102.3	102.5
Box 2 (blue)	30 July	0	0	0	0
Box 2 in Teton Pond	30 July	0.9	5.7	13.3	6.5
Teton Pond in Box 2	30 July	4.9	14.2	0	8.4
Box 3 (brn)	30 July	445.9	392.0	68.4	324.6
Box 3 in Teton Pond	30 July	556.8	556.9	728.1	599.7
Teton Pond in Box 3	30 July	8.0	12.2	0	8.2
Teton Pond	1 Sept	48.9	119.0	47.0	83.5
Box 5 (brn)	1 Sept	3.4	4.0	2.0	3.4
Box 5 in Teton Pond	1 Sept	5.5	7.0	6.3	6.4
Teton Pond in Box 5	1 Sept	39.6	27.2	2.8	24.2
Box 6 (blue)	1 Sept	2.3	1.7	1.1	1.7
Box 6 in Teton Pond	1 Sept	3.2	2.1	2.4	2.4
Teton Pond in Box 6	1 Sept	96.8	11.4	1.3	30.3

Chlorophyll "a" concentrations did not correlate well with either calculated algal volumes or algal counts in either the pond or the experimental boxes. Instead, total chlorophyll (chlorophyll "a" + chlorophyll "b" + chlorophyll "c") correlated significantly (r = .53) with macrophyte biomass. This seemed to indicate the presence of extracellular chlorophylls in the pond and box waters.

During the period 24 April — 2 July 1971 in Teton Pond, diatoms comprised a majority of the algal volume, with green and blue-green algae present in smaller but equal amounts. The period 15 July — 1 September, the summer bloom period, consisted of approximately equal amounts of diatoms and blue-green algae. Green algae were present but in insignificant numbers or volume. The control experimental box, box No. 1, contained populations similar to the pond for the spring period, but during the summer period the diatom fraction was larger in the box than in the pond. The experimental boxes, prior to dye treatment, contained comparable

algal volumes as Teton Pond and the control box. After dye treatment, however, significant changes in algal populations occurred. Contrasting with the mixture of blue-greens and diatoms recorded for Teton Pond in the summer, diatoms and greens—mainly *Navicula, Nitzschia, Stephanodiscus, Diploneis, Synedra, Ankistrodesmus* and *Mougeotia*—dominated the algal populations. These populations were similar to the spring and fall algal pulses observed in Teton Pond which consisted of *Navicula, Dinobryon, Stephanodiscus, Synedra, Diploneis, Oocystis* and *Sphaerocystis*. Figures 4, 5, and 6 compare the volumes of algae present in the pond and in each of the experimental boxes before and after dye treatment. A comparison of algal numbers graphed in similar fashion yields comparable results. In both brown- and blue-water boxes, blue-green algae were reduced or completely eliminated from the algal populations during the summer bloom period (except in box No. 4), while blue-green algae were the dominant algal type observed in Teton Pond. The five most abundant genera for Teton Pond and each experimental box are listed both prior to and after dye treatment in Table 4. Green algae, practically nonexistent in Teton Pond during the summer bloom period, contributed 20% to 40% of the total algal volume observed in the experimental boxes. Diatom auxospores formed mats at the surface of the water in the blue-water boxes, and resembled in appearance the blue-green algae mats characteristic of highly eutrophic lakes.
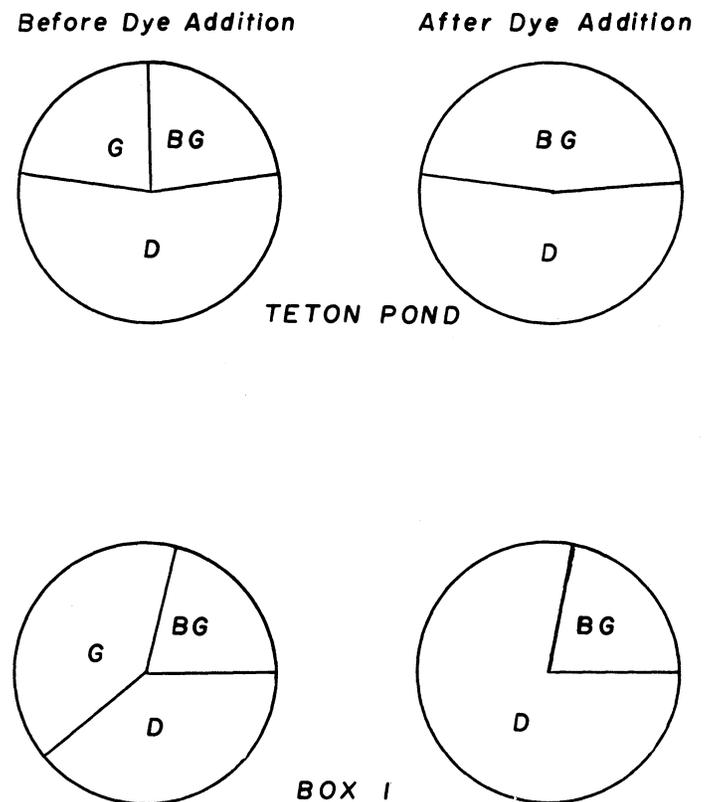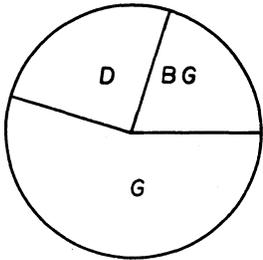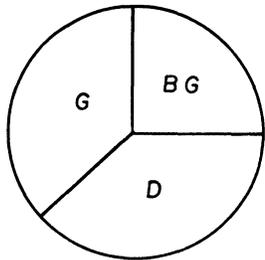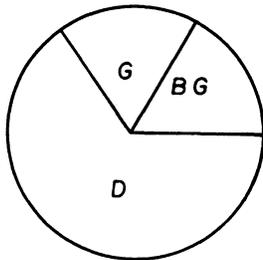

Figure 4. Comparative algal volumes recorded for Teton Pond and Box 1 (control) before and after dye treatment. G-Green Algae; D-Diatoms; BG-Blue-green Algae.
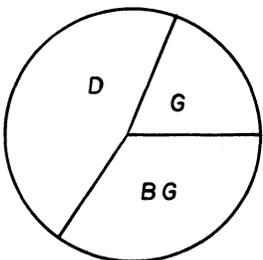
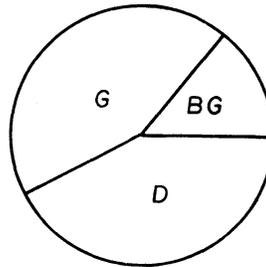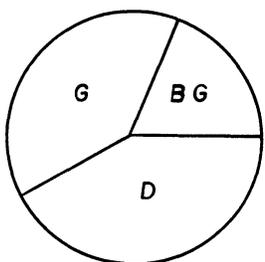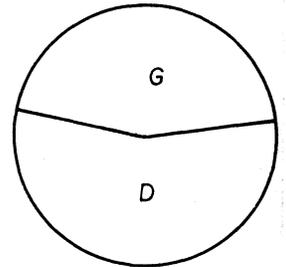Before Dye Addition   After Dye Addition

BOX 2

Before Dye Addition   After Dye Addition

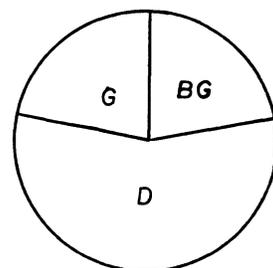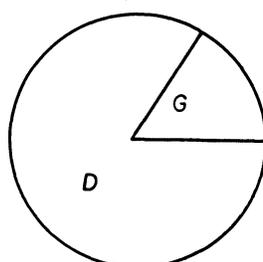BOX 4   BOX 3
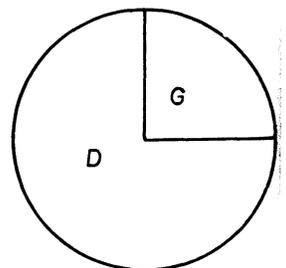
BOX 6   BOX 5

Figure 5. Comparative algal volumes recorded for blue dye treatment water, before and after dye treatment. G-Green Algae; D-Diatoms; BG-Blue-green Algae.

Figure 6. Comparative algal volumes recorded for brown dye treatment water, before and after dye treatment. G-Green Algae; D-Diatoms; BG-Blue-green Algae.

Table IV:

The Five Most Abundant Algal Genera in Teton Pond and Experimental Boxes

Sample	Before Treatment		After Treatment	
	Period	Genera	Period	Genera
Teton Pond	24 Apr − 2 July	*Aphanizomenon* *Chodatella* *Dinobryon* *Oocystis* *Synedra*	15 July − 1 Sep	*Aphanizomenon* *Microcystis* *Navicula* *Oscillatoria* *Radiococcus*
Box 1 (control)	24 Apr − 2 July	*Aphanizomenon* *Coelastrum* *Dinobryon* *Navicula* *Synedra*	15 July − 1 Sep	*Diploneis* *Microcystis* *Navicula* *Nitzschia* *Oscillatoria*
Box 2 (blue)	24 June − 2 July	*Aphanizomenon* *Asterococcus* *Navicula* *Oocystis* *Schroederia*	15 July − 1 Sep	*Coelastrum* *Gomphonema* *Microcystis* *Navicula* *Nitzschia*
Box 3 (brown)	24 June − 15 July	*Aphanizomenon* *Coelastrum* *Oocystis* *Sphaerocystis* *Stephanodiscus*	22 July − 1 Sep	*Ankistrodesmus* *Coelastrum* *Navicula* *Stephanodiscus* *Synedra*
Box 4 (blue)	24 June − 2 July	*Aphanizomenon* *Asterococcus* *Cosmarium* *Navicula* *Synedra*	15 July - 1 Sep	*Ankistrodesmus* *Dictyosphaerium* *Microcystis* *Navicula* *Synedra*
Box 5 (brown)	24 June − 15 July	*Aphanizomenon* *Dinobryon* *Navicula* *Oocystis* *Sphaerocystis*	22 July − 1 Sep	*Ankistrodesmus* *Diploneis* *Fragillaria* *Mougeotia* *Navicula*
Box 6 (blue)	24 June − 2 July	*Aphanizomenon* *Fragillaria* *Oocystis* *Sphaerocystis* *Stephanodiscus*	15 July − 1 Sep	*Asterococcus* *Diploneis* *Euglena* *Navicula* *Nitzschia*

DISCUSSION

By reducing the intensity of available light in water through the use of dyes, not only was a decrease of algal photosynthesis and a change in the dominant algal genera achieved, but also elimination of aquatic macrophytes was accomplished. Primary productivity tests indicated a major reduction of algal photosynthesis in the experimental boxes. Not only was low productivity observed in most samples, but water samples taken from the pond and placed in the dyed water of the boxes showed substantial reduction in primary productivity. This result was in keeping with our original hypothesis: any reduction of light below the saturation intensity would influence productivity. The more heavily dyed, blue boxes reduced primary productivity to a greater extent than the brown-water boxes.

Average total chlorophylls and the average of chlorophyll "a" plus chlorophyll "b" decreased with increasing dye concentration for both blue- and brown-water boxes. Figure 7 suggests a very approximate upper and lower limit for the concentration of blue and brown dye required to achieve a maximum limitation of algal and macrophyte growth. Further experimentation with this technique for predicting chlorophyll concentration from dye concentration is warranted.

Our experimental results indicate that a dye method of treatment will alter summer algal populations from those containing largely blue-green algae to those characteristic of spring or fall algal pulses in lakes. Populations of rooted aquatic macrophytes can be either completely eliminated from a lake system, as was suggested by the results of the blue-dye treatment, or altered to a selected macrophyte type, as was observed in the brown-dye treatment.

Chara seemed to thrive in the reduced-light environment of the brown water, but is generally considered a clearwater alga (Macan, 1970; Smith, 1950). Our results suggest that *Chara* is able to grow under reduced light conditions as well. The massive elimination of *Potamogeton* and *Chara* in blue water suggests that these plants would not have even begun growing if the waters had been dyed prior to their emergence in the spring.

No attempt was made physically to mix the isolated water columns treated with dye. What effect continued mixing would have had is speculation; however, a further decrease in primary productivity could have resulted by forcing the more productive algae at the surface into the light-limiting depths of the experimental boxes. Anaerobiosis may not have occurred with adequate mixing, and aeration of the water would have altered the chemical composition we observed after dye treatment and elimination of macrophytes.

This research has demonstrated that the concept of controlling excessive plant production through the reduction of available light is valid and feasible. Research should be initiated: (1) to find the most suitable substance for coloring lake water; (2) to learn the most appropriate season for addition of the substance for control of aquatic weed and algal productivity; and (3) to investigate in more detail the over-all environmental effects.

It should be noted that recently a product (Aquashade, from Aquashade, Inc., Dobbs Ferry, New York) has come onto the commercial market. It employs the same principle of eutrophication control through light reduction that we demonstrated in this research. We do not know any specifics about its chemical composition or effectiveness, or whether it has any unanticipated environmental effects.
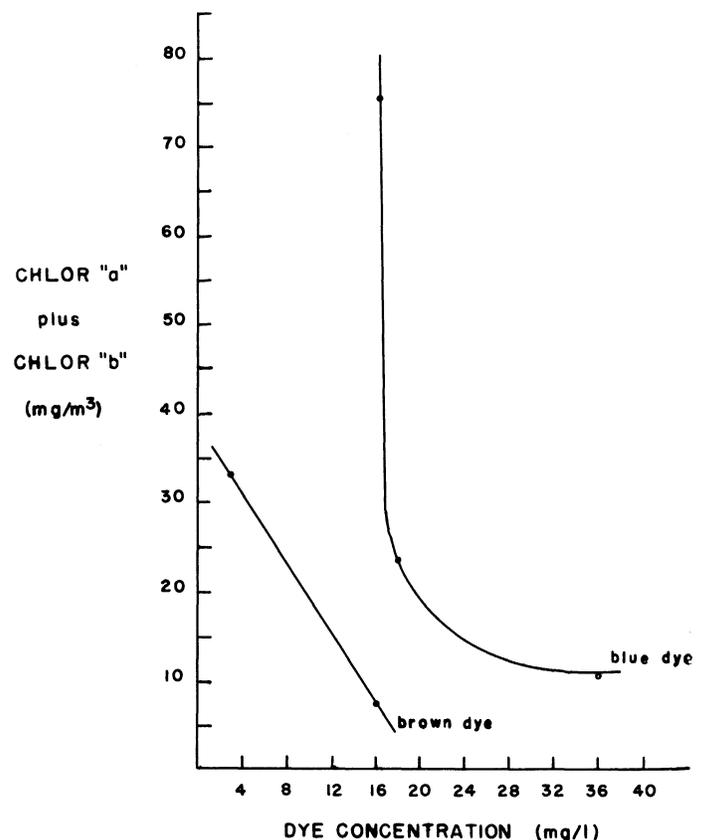

Figure 7. Average chlorophyll "a" plus chlorophyll "b" versus dye concentration.

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