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Effects of Fluridone and Terbutryn on Phytoplankton and Water Quality in Isolated Columns of Water

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ABSTRACT

Algicidal properties of fluridone and terbutryn were evaluated in 20-m^3 isolated columns of water in two Alabama Piedmont ponds. Two applications of fluridone at the highest recommended rate (125 μg/l) made 25 days apart were not effective in consistently reducing phytoplankton densities and chlorophyll-*a*. Terbutryn treatment rates of 6 and 12 μg/l in 1985 and 12 and 24 μg/l in 1986 were also evaluated. Chlorophyll-*a* concentrations were significantly reduced in the low rate (6 μg/l) terbutryn treatment when compared to the high rate (12 μg/l) in 1985 and in the high rate (24 μg/l) treatment when compared to the control in 1986. Significant water quality changes in 1986 included reduced DO and turbidity and increased Secchi disk visibility in both the low and high rate terbutryn treatments when compared to the control. Neither fluridone nor terbutryn were effective in selectively eliminating blue-green algae.

Key words: Algae control, algicide, blue-green algae, Cyanobacteria, Igran 80W®, limnocorrals, Sonar®.

INTRODUCTION

Aquaculturists, unlike their agrarian counterparts, have relatively few registered chemicals that exhibit target plant specificity (Schnick et al. 1986). This is particularly true in the case of algicides. Although many algicides are extremely phytotoxic, most are indiscriminate, killing whatever plant species are present at the time of application. Chemical elimination of pond phytoplankton can cause prolonged low dissolved oxygen levels, resulting in reduced fish growth (Tucker and Boyd 1978) or fish mortality.

Some algal groups are considered more beneficial than others. Grazing experiments have shown small green algae (Chlorophyta), flagellates, and diatoms (Chrysophyta) are more easily filtered, ingested, and assimilated by zooplankton and fish than are blue-green algae (Cyanobacteria), many of which have undigestible gelatinous sheaths (Porter 1977). Lower fish feeding efficiencies (Burke and Bayne 1986) and growth rates (Bayne et al. 1991) have been reported from blue-green algae dominated production ponds. Several species of blue-green algae may cause off-flavor in pond-reared fish (Brown and Boyd 1982; Armstrong et al. 1986). Losses associated with off-flavor in 1985 alone, cost the catfish industry an estimated $8.3 million (Sindelar et al. 1987).

Fluridone (1-methyl-3-phenyl-5-[3-(trifluoromethyl)-phenyl]-4- (1H)-pyridinone), marketed as Sonar® (Elanco Products Co., Indianapolis, Indiana), is an aquatic herbicide that has been registered for use in food-fish waters (Schnick et al. 1986). Fluridone can control a wide variety of aquatic plant species, but can also be partially selective by varying the time of application and rate (Schmitz 1986). Additionally, different macrophytes naturally vary in their tolerance to fluridone (Schmitz 1986). The increased susceptibility of certain macrophytes to the effects of fluridone sparked interest in whether fluridone could be used to selectively reduce or eliminate blue-green algae while allowing the more desirable green algae and diatoms to flourish.

Research examining the effects of fluridone on phytoplankton has been contradictory. In three pond experiments, phytoplankton densities have been found to be unaffected by fluridone treatment (Leva and Lembi 1978; Parka et al. 1978; Arnold 1979). However, Parka et al. (1978) and Arnold (1979) reported reductions in blue-green algae densities relative to pretreatment numbers within two weeks after application. Likewise Kamarianos et al. (1989) reported the elimination of blue-green algae in addition to a seven fold decrease in phytoplankton den-

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sities in a single 0.06 ha pond following fluridone treatment. More convincing results demonstrating an algicidal potential for fluridone was reported by Millie et al. (1990). They found algal biomass, chlorophyll-*a*, and total carotenoid contents significantly decreased in axenic cultures of *Oscillatoria agardhii* Gomont when exposed to increasing fluridone concentrations.

Terbutryn (2-(tert-butylamino)-4-(ethylamino)-6-(methylthio)-s-triazine), marketed as Igran 80W® (Ciba-Geigy Corp., Greensboro, North Carolina), is a substituted triazine herbicide used in winter wheat, barley, and sorghum, and for nonselective weed control. Terbutryn, as a 1% active ingredient granular formulation called Clarosan, was cleared for use in Great Britain through the Pesticides Safety Precautions Scheme for use in or near water (British Agrochemicals Association 1976). Terbutryn is not registered for aquatic use in the United States.

Terbutryn research in aquatic systems has focussed on the efficacy of this herbicide on periphyton (Goldsborough and Robinson 1983; Gurney and Robinson 1989), filamentous algae (Marks 1974; Robson et al. 1976; Tackett 1983), and higher aquatic plants (Riemer and Trout 1980). An exception was research by El-Dib et al. (1989) who examined the effects of three triazine herbicides, including terbutryn, on the growth of *Scenedesmus* sp. However none of the above research quantitatively examined the effects of terbutryn on phytoplankton under field conditions although Riemer and Trout (1980) noted that terbutryn-treated ponds did not appear to have dense plankton populations. Recent reported use of terbutryn by commercial catfish farmers to "thin" phytoplankton blooms in western Alabama production ponds (Steve Brown, personal communication) prompted our interest in this compound.

The objectives of this study were to evaluate the effects of fluridone and terbutryn on phytoplankton abundance and community structure and to measure any effects of herbicide treatment on selected water quality variables.

MATERIALS AND METHODS

Two ponds located at the Auburn University Fisheries Research Unit, Lee County, Alabama, were used in this study. Pond S1 (9.1 ha) was managed for commercial catfish (*Ictalurus punctatus* Rafinesque) production. Pond S3 (3.8 ha) was managed for sportfishing and was stocked with largemouth bass (*Micropterus salmoides* Lacepedae), bluegill (*Lepomis macrochirus* Rafinesque), redear sunfish (*L. microlophus* Gunther), and channel catfish.

Column dimensions, construction and placement

The isolation columns used in this study were purchased from Curry Industries, Ltd., Winnipeg, Manitoba, Canada.[3] The columns were open-ended cylinders the tops of which consisted of clear, polyvinyl chloride sheeting, 71 cm in length. The remainder of each column was made from an opaque polyethylene fiber. A 10.2-cm-diameter corrugated PVC tube filled with styrofoam "peanuts" served as a floatation collar. Weighted polyethylene tubing (3.8 cm diameter) was sewn to the bottom of each column and served as a lead line. Each column had a diameter of 3.10 m and a height of 3.05 m.

In each experiment (fluridone and terbutryn), the columns were placed in the pond(s) where sufficient water depth (2.7 m) was present to fill each column to about 90% of capacity. The volume of water contained within a single column was estimated to be about 20.4 m^3. A SCUBA diver inspected the lead lines to ensure they were embedded in the sediment. After placement, columns remained undisturbed for at least 2 weeks prior to treatment. Further details of column construction were described by Struve and Bayne (In press).

Fluridone 1984

In June, 1984 four columns were placed in Ponds S1 and S3 (Table 1). On 4 August, each column was fertilized with a liquid fertilizer (10-34-0) at a rate of 9.4 l/ha. On 10 August, fluridone was applied to two randomly selected columns in Ponds S1 and S3. The other two columns in each pond served as controls. The treatment rate was 3.5 l/ha (125 μg/l active ingredient) and was the manufacturer's maximum recommended rate for ponds having water in excess of 1.52 m deep. A second identical application of fluridone was made 25 days later on 4 September. Total length of the fluridone study was 39 days.

To monitor for potential water exchange between columns and the pond, a NaCl slurry was applied to each column. Each enclosure received 396 g of NaCl to create an estimated chloride concentration of about 12 mg/l, which was two orders of magnitude lower than values reported to cause growth inhibition to tested genera of algae (US EPA. 1988). Conductivity measurements were made twice a week using an Industrial Instruments Inc. Conductivity Bridge Model RC 16B2. All values were corrected for temperature and reported at 25° C.

Composite water samples for phytoplankton and chemical analyses were obtained with a 1.5-m column sampler (Boyd 1979). Total ammonia nitrogen (TAN) and nitrite (NO_2^--N) were determined by the phenate and azo dye methods, respectively (Boyd 1979). The cadmium reduction column method (APHA et al. 1980) was used for nitrate (NO_3^--N) analysis. Total phosphorus and soluble orthophosphate (SOP) were both analyzed by the stannous chloride method (Boyd 1979). Chemical oxygen demand (COD) was measured with a Hach COD Reactor Model 16500. Water samples for the analyses outlined above were

TABLE 1. YEAR, POND(S), TREATMENT, RATE(S), NUMBER OF APPLICATIONS, AND TOTAL NUMBER OF COLUMNS USED ON THE AUBURN UNIVERSITY FISHERIES RESEARCH UNIT FOR THE FLURIDONE AND TERBUTRYN EXPERIMENTS, 1984-1986.

Year	Pond(s)	Treatment	Rate(s) (μg/l)	No. of Applcations	Total No. of Columns Used
1984	S1, S3	Fluridone	125	2	8[1]
1985	S3	Terbutryn	6, 12	1	9
1986	S3	Terbutryn	12, 24	1	9

[1]The eight columns were divided evenly between Ponds S1 and S3.

[3]Use of manufacturer or trade names does not imply endorsement by Auburn University.

collected just prior to the initial fluridone application on 10 August and subsequently on 24 August and 6 September.

Turbidity was measured with a Hach Laboratory Turbidimeter Model 1860. Dissolved oxygen (DO) and temperature profiles were measured *in situ* at 1-m increments with a Yellow Springs Instrument (YSI) Company Model 51B polarographic dissolved oxygen meter and thermistor. A Secchi disk was used to measure visibility (Lind 1979). Phytoplankton samples were preserved with a merthiolate solution (APHA et al. 1980). Samples known to contain extremely low numbers of phytoplankters were concentrated by allowing the organisms to settle for at least 24 h before siphoning the supernatant. Phytoplankton were identified to genus using standard taxonomic keys and counted with the aid of an inverted microscope (Lind 1979). Chlorophyll-*a* was determined as outlined by Boyd (1979). Algal biomass could then be estimated by multiplying the chlorophyll-*a* content by a factor of 67 (APHA et al. 1980). All of the above samples were collected twice weekly.

Fish trapped inside the columns during column placement remained until the end of the experiment. At that time, all columns were treated with a 2% rotenone solution. Fish were identified, counted, and weighed to determine whether fish communities were similar among columns within each pond.

Within a pond, means for the entire experiment were subjected to an analysis of variance (ANOVA) to determine if differences existed between fluridone-treated and control columns. Column means from each pond were analyzed independently because of differences in pond management. Differences were declared significant based on an alpha value of 0.05.

Terbutryn 1985

In 1985 nine isolation columns were placed in Pond S3 in about 2.7 m of water. On 2 August each column was treated with a 2% rotenone solution and fish were removed. On the same date 300 g of NaCl were applied as a slurry to each column to monitor for potential column leakage. Each column then was fertilized with a liquid fertilizer (10-34-0) at a rate of 10.8 l/ha.

The isolation columns were randomly assigned to three treatments: control, 6, and 12 μg/l terbutryn. Column treatment occurred on 29 August. This study was conducted over a 106-day period from 2 August to 15 November 1985.

Samples for phytoplankton and water quality analysis were collected pre- and post-treatment. The procedures followed for the 1985 terbutryn study were identical to those cited for the 1984 fluridone study except where noted.

Composite water samples for total alkalinity, COD, NO_2^--N, and TAN analysis were collected just prior to terbutryn treatment on 29 August and afterwards on 5 September and 15 November. Secchi disk visibility, phytoplankton, and chlorophyll samples were collected on two dates prior to column treatment on 29 August. Following terbutryn treatment, these samples were collected about every two days until 5 September; thereafter, samples were collected about once a week. The trichromatic method was used to measure chlorophyll as outlined by Weber (1973) and values were corrected for pheophytin. DO and temperature measurements were made at the surface and at 1 m and followed the sampling schedule previously outlined for phytoplankton and chlorophyll.

Each column was checked for potential leakage by measuring conductivities on 2, 4, 12, 29 August and 3 September. Since conductivity values in all columns remained stable on these dates, conductivity sampling was discontinued after 3 September.

Terbutryn 1986

The nine isolation columns used in the 1985 terbutryn study were used in 1986. After the 1985 study had been terminated, water in all the columns was flushed out and replaced with surrounding pond water. On 12 September each column was fertilized with a liquid fertilizer (10-34-0) at a rate of 10.8 l/ha. In 1986 the columns were not treated with rotenone as these units had remained devoid of fish dating back to the initial rotenone application the previous summer. Also NaCl was not added to the columns in 1986 because the 1984 fluridone and 1985 terbutryn studies had shown no detectable column leakage.

In 1986 the isolation columns were randomly assigned to three treatments: control, 12, and 24 μg/l. Terbutryn application occurred on 16 September. This study was conducted over a 57-day period from 9 September to 4 November.

Water samples for COD, NO_2^--N, and TAN were collected pre- and post-treatment, on 9 September and 4 November. Phytoplankton, chlorophyll, and turbidity samples in addition to Secchi disk visibility, DO, and temperature measurements were collected on 16, 19, and 23 September and subsequently weekly. Water sample collections and analyses for 1986 were identical to those used in the 1985 terbutryn study.

Differences in overall treatment means for the 1985 and 1986 terbutryn studies were determined using contrasts with the ANOVA (Steel and Torrie 1980). Differences were declared significant based on an alpha value of 0.05.

RESULTS AND DISCUSSION

Fluridone 1984

Fluridone-treated columns in Pond S3 had significantly lower mean phytoplankton density and chlorophyll-*a* compared to control columns (Table 2). Lower mean turbidity and higher mean Secchi disk visibility measured in S3 treatment columns relative to the controls also indicated reduced phytoplankton populations. Similar trends in phytoplankton density, chlorophyll-*a*, turbidity, and Secchi disk visibility were found in S1 treatment columns although no significant differences were detected for any of these variables (Table 2).

The initial fluridone application to treatment columns in both ponds appeared to cause an immediate reduction

TABLE 2. MEAN VALUES FOR SELECTED CHEMICAL AND BIOLOGICAL VARIABLES FOR ISOLATION COLUMNS LOCATED IN PONDS ON THE AUBURN UNIVERSITY RESEARCH UNIT FOR THE FLURIDONE AND TERBUTRYN EXPERIMENTS, 1984 - 86. TREATMENTS WERE REPLICATED TWO AND THREE TIMES FOR THE FLURIDONE AND TERBUTRYN EXPERIMENTS, RESPECTIVELY .

	Fluridone						Terbutryn					
Variable	Pond S1 Control	1984 125 µg/l		Pond S3 Control	1984 125 µg/l		Pond Control	S3 6 µg/l	1985 12 µg/l	Pond Control	S3 12 µg/l	1986 24 µg/l
Chlorophyll-*a* (mg/m³)	107.8 A[1]	78.6 A		14.2 A	8.3 B		47.5 AB	32.1 A	52.2 B	174.2 A	121.4 AB	86.3 B
Phytoplankton (org./ml)	7,315 A	6,913 A		1,152 A	789 B		3,851 A	3,927 A	4,070 A	8,681 A	7,347 A	7,390 A
Turbidity (JTU's)	24.4 A	21.4 A		3.6 A	2.7 A		5.2 A	7.4 A	6.7 A	11.4 A	7.3 B	8.1 B
Secchi Disk (cm)	33 A	36 A		165 A	187 A		46 A	33 A	51 A	75 A	104 B	106 B
Dissolved Oxygen (mg/l)	4.7 A	4.7 A		6.4 A	6.4 A		6.3 A	7.1 A	5.3 A	9.9 A	5.8 B	4.6 B

[1]Means in a row for each experiment followed by the same letter were not significantly different (P > 0.05).

in phytoplankton densities and chlorophyll-*a* concentrations (Figures 1 and 2). However the second fluridone application on 4 September did not result in an immediate decline in either variable, although chlorophyll-*a* concentrations in S3 treatment columns remained substantially below control column values until near the end of the experiment (Figure 2).

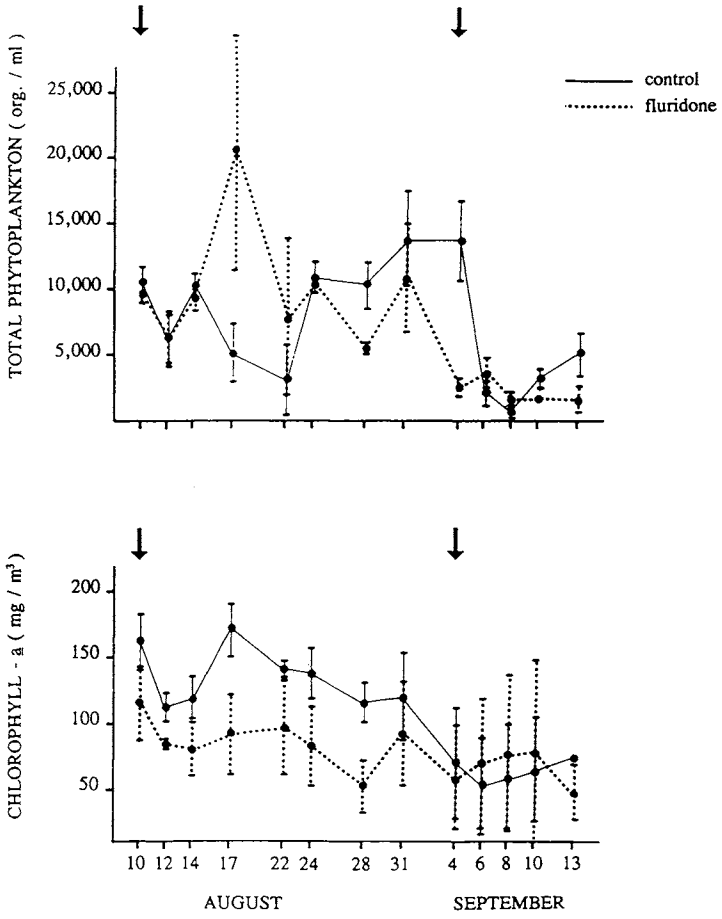

Figure 1. Phytoplankton densities (organisms/ml) and chlorophyll-*a* concentrations (mg/m³) for control and fluridone-treated columns located in Pond S1 on the Auburn University Fisheries Research Unit, 1984. The arrows indicate the timing of the two fluridone (125 µg/l) applications. Each data point represents the mean of two replicates ± one standard error.

In treatment columns of both ponds the dominant taxa exhibited little change between the first and second applications (Table 3). These data suggest the ineffectiveness of the second application can not be attributed to the presence of a different algal assemblage more resistent to the effects of fluridone that might have developed following the initial application. Phytoplankton communities in control and treatment columns in Sl exhibited low diversity (e.g., few taxa present) and were generally dominated by either the blue-green *Raphidiopsis* sp. or the green alga, *Actinastrum* sp. Phytoplankton biomass (based on chlorophyll-*a* estimate) in S1 was roughly an order of magnitude higher than was present in S3. Compared to S1, algal communities in S3 were more diverse. Treatment columns in S3 were dominated by the green alga, *Chlamydomonas* sp. on 8 of 14 dates. However in control columns *Chlamydomonas* sp. was dominant but once. Two greens, *Cosmarium* sp. and *Staurastrum* sp., along with *Raphidiopsis* sp., in descending order, were the dominant taxa most frequently identified from control column samples.

Analysis of phytoplankton community structure at the Division level also revealed fluridone was not effective in selectively eliminating blue-green algae from treatment columns in either pond. In S1 treatment columns the percentage of blue-greens declined toward the end of the experimental period, but this trend also occurred in the controls (Figure 3). Conversely in S3, both the fluridone and control columns experienced an increase in the percentage of blue-green algae over the duration of the experiment (Figure 3). In fact, on a percentage basis, treatment columns in both ponds had more blue-green algae relative to the controls on the majority of dates sampled (Figure 3). Thus we were unable to corroborate the findings of other researchers (Parka et al. 1978; Arnold 1979; Kamarianos et al. 1989) who have suggested a selective susceptibility of blue-green algae to the effects of fluridone.

There were no significant differences between treatment and control columns in either pond for the following

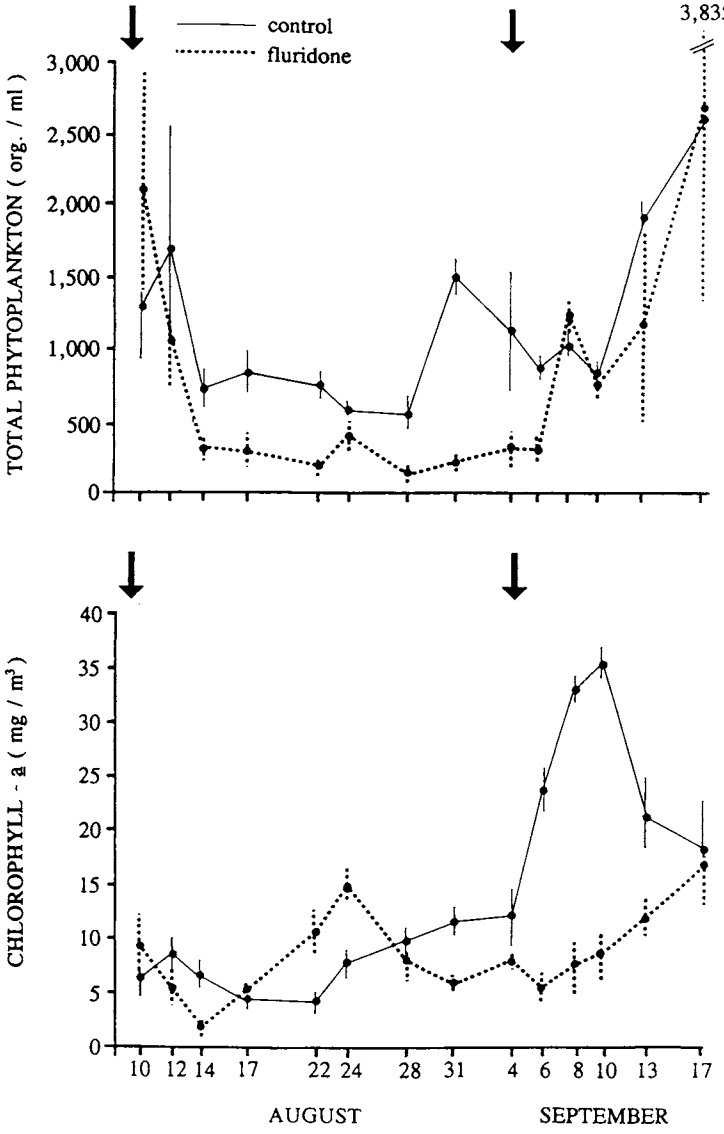

Figure 2. Phytoplankton densities (organisms/ml) and chlorophyll-*a* concentrations (mg/m³) for control and fluridone-treated columns located in Pond S3 on the Auburn University Fisheries Research Unit, 1984. The arrows indicate the timing of the two fluridone (125 μg/l) applications. Each data point represents the mean of two replicates ± one standard error.

water quality variables; DO, temperature, turbidity, Secchi disk visibility, TAN, NO_2^--N, NO_3^--N, TP, SOP, and COD, This is consistent with results from other studies (Leva and Lembi 1978; Parka et al. 1978; Arnold 1979) which have found water quality to be unaffected by fluridone treatment. Individual column conductivity values were consistently higher than their respective pond means, which indicated no detectable exchange of water between columns and the pond. Fish communities were found to be similar in numbers and composition among columns within each pond.

Terbutryn 1985

No significant differences in mean phytoplankton densities among the three treatments were detected in the 1985 terbutryn experiment (Table 2). However, mean chlorophyll-*a* was significantly reduced in the low rate (6 μg/l) when compared to the high rate (12 μg/l) treatment (Table 2 and Figure 4). El-Dib et al. (1989) reported that terbutryn at a rate of 5 μg/l significantly reduced chlorophyll-*a* in treated cultures of *Scenedesmus* sp. Higher terbutryn rates up to 50 μg/l did not result in any further significant reductions in algal biomass. Maximum uptake levels of terbutryn by *Scenedesmus* were associated with high growth rates attained in the presence of low herbicide concentrations. It appears that low terbutryn rates may be more effective than high(er) rates in reducing chlorophyll-*a* without adversely affecting DO (Figure 4).

Several researchers have documented reduced DO concentrations following terbutryn treatment (Goldsborough and Robinson 1983; Tackett 1983; Gurney and Robinson 1989). DO concentrations in the high rate terbutryn treatment were less than 2 mg/l for the week following terbutryn application and remained below those in both the control and low rate treatment throughout the month of September (Figure 4). The high rate (12 μg/l) was similar to the rate (10 μg/l) evaluated by Gurney and Robinson (1989) who also reported a dramatic decline in DO within 3 days following enclosure treatment. Overall no significant differences in mean DO were detected in our experiment, although the high rate treatment did have the lowest mean DO (Table 2).

In addition to DO, there were no significant differences among control, low, and high rate treatment columns for temperature, turbidity, Secchi disk visibility, total alkalinity, COD, NO_2^--N, and TAN. Individual column conductivity values were consistently higher than that of the pond water which indicated no detectable exchange of water between the columns and the pond proper.

Previous research has demonstrated particular algal groups are more sensitive than others to the effects of various triazine herbicides. Blue-green algae have been reported to be particularly susceptible to the effects of two closely related triazines, namely, atrazine (Herman et al. 1986) and simazine (Tucker and Boyd 1978; Tucker et al. 1983; Gurney and Robinson 1989). Gurney and Robinson (1989) reported a single 10 μg/l terbutryn application resulted in a shift in the periphyton assemblage from green algae towards diatoms. Our results revealed no discernable effect of terbutryn on algal community structure at the Division level (Figure 5). Control and treatment columns were dominated by green algae and an "others" category which was comprised mostly of euglenoids (Euglenophyta) and dinoflagellates (Pyrrhophyta). Yellow-green and blue-green algae were generally minor contributors to the phytoplankton community. Dominant phytoplankton taxa by treatment for each sampling date appear in Table 4. Despite differences in the dominant taxa among treatments for a given date, generally each taxon was dominant in two or more of the treatments over the course of the experiment. We found no evidence that any specific Divisions or taxa of phytoplankton were uniquely susceptible to the effects of terbutryn.

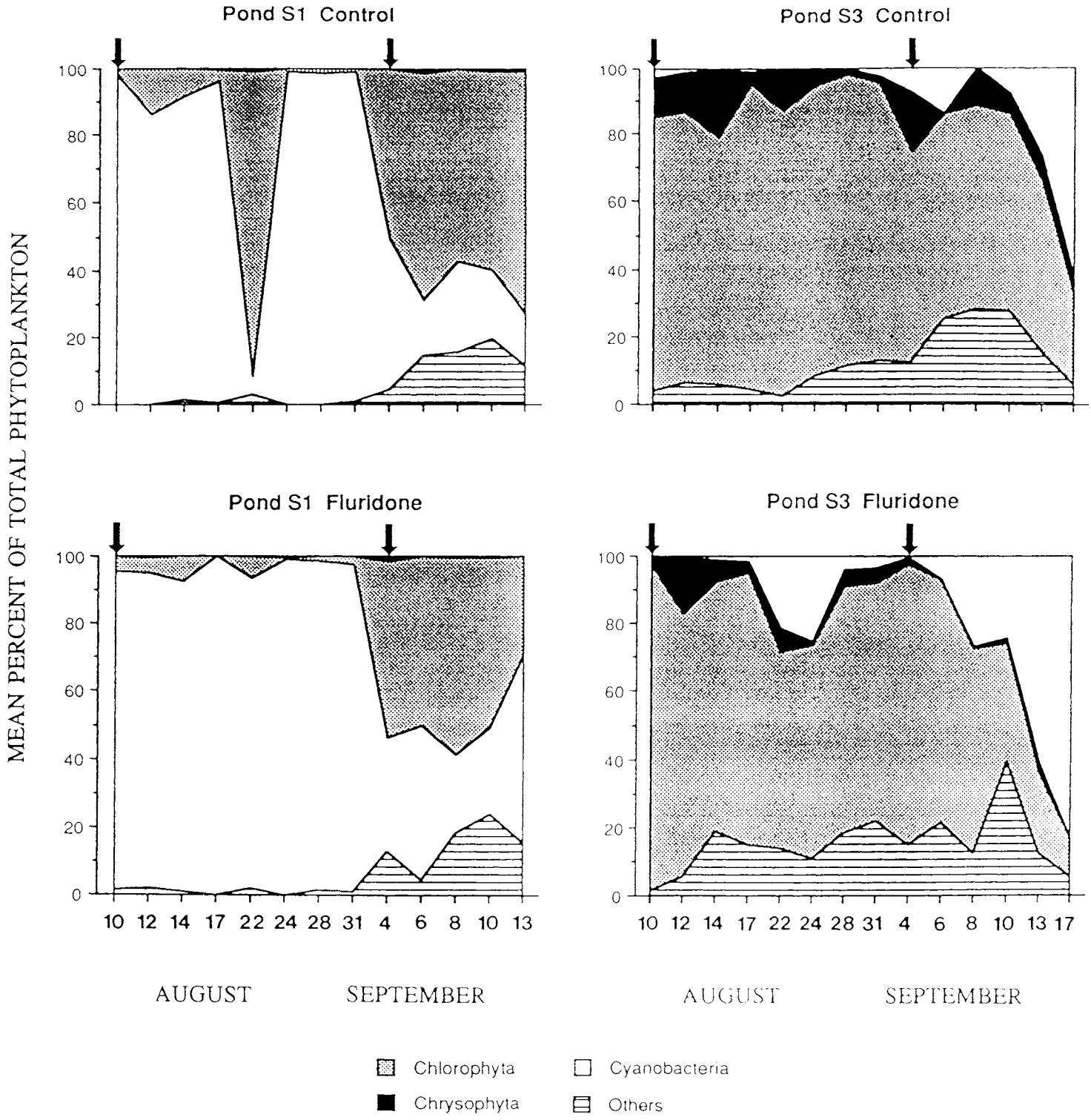

Figure 3. Mean percent composition of the four major phytoplankton groups for control and fluridone-treated columns located in Ponds S1 and S3 on the Auburn University Fisheries Research Unit, 1984. The arrows indicate the timing of the two fluridone (125 μg/l) applications. Treatments were replicated twice. The Others category includes the Divisions Euglenophyta and Pyrrhophyta.

Terbutryn 1986

A significant reduction in mean chlorophyll-*a* was detected in the high rate (24 μg/l) terbutryn treatment when compared to the control (Table 2). Mean chlorophyll-*a* for the low rate treatment (12 μg/l) fell midway between the control and high treatment mean values. Extreme variability in chlorophyll-*a* concentrations within the control and low rate treatments accounted for our inability to declare this difference significant (Figure 6). Mean phytoplankton

TABLE 3. DOMINANT TAXA FOR CONTROL AND TREATMENT COLUMNS IN PONDS S1 AND S3 FOR THE FLURIDONE EXPERIMENT, 1984. DOMINANT STATUS WAS ASSIGNED TO THE TAXON WHICH HAD THE HIGHEST MEAN DENSITY FOR EACH SAMPLE DATE. TREATMENTS WERE REPLICATED TWICE.

Date	Pond S1		Pond S3	
	Control	Fluridone (125 μg/l)	Control	Fluridone (125 μg/l)
Aug 10	*Raphidiopsis* sp.	*Raphidiopsis* sp.	*Chlamydomonas* sp.	*Cosmarium* sp.
Aug 12	*Raphidiopsis* sp.	*Raphidiopsis* sp.	*Cosmarium* sp.	*Cosmarium* sp.
Aug 14	*Raphidiopsis* sp.	*Raphidiopsis* sp.	*Cosmarium* sp.	*Chlamydomonas* sp.
Aug 17	*Raphidiopsis* sp.	*Raphidiopsis* sp.	*Cosmarium* sp.	*Cosmarium* sp.
Aug 22	*Actinastrum* sp.	*Raphidiopsis* sp.	*Cosmarium* sp.	*Chlamydomonas* sp.
Aug 24	*Raphidiopsis* sp.	*Raphidiopsis* sp.	*Cosmarium* sp.	*Chlamydomonas* sp.
Aug 28	*Raphidiopsis* sp.	*Raphidiopsis* sp.	*Cosmarium* sp.	*Chlamydomonas* sp.
Aug 31	*Raphidiopsis* sp.	*Raphidiopsis* sp.	*Cosmarium* sp.	*Chlamydomonas* sp.
Sept 4	*Actinastrum* sp.	*Raphidiopsis* sp.	*Staurastrum* sp.	*Chlamydomonas* sp.
Sept 6	*Actinastrum* sp.	*Raphidiopsis* sp.	*Staurastrum* sp.	*Chlamydomonas* sp.
Sept 8	*Actinastrum* sp.	*Actinastrum* sp.	*Cosmarium* sp.	*Chlamydomonas* sp.
Sept 10	*Schroederia* sp.	*Raphidiopsis* sp.	*Staurastrum* sp.	*Trachelomonas* sp.
Sept 13	*Actinastrum* sp.	*Raphidiopsis* sp.	*Raphidiopsis* sp.	*Raphidiopsis* sp.
Sept 17	———[1]	———	*Raphidiopsis* sp.	*Raphidiopsis* sp

[1]No samples were collected from Pond S1 columns on September 17.

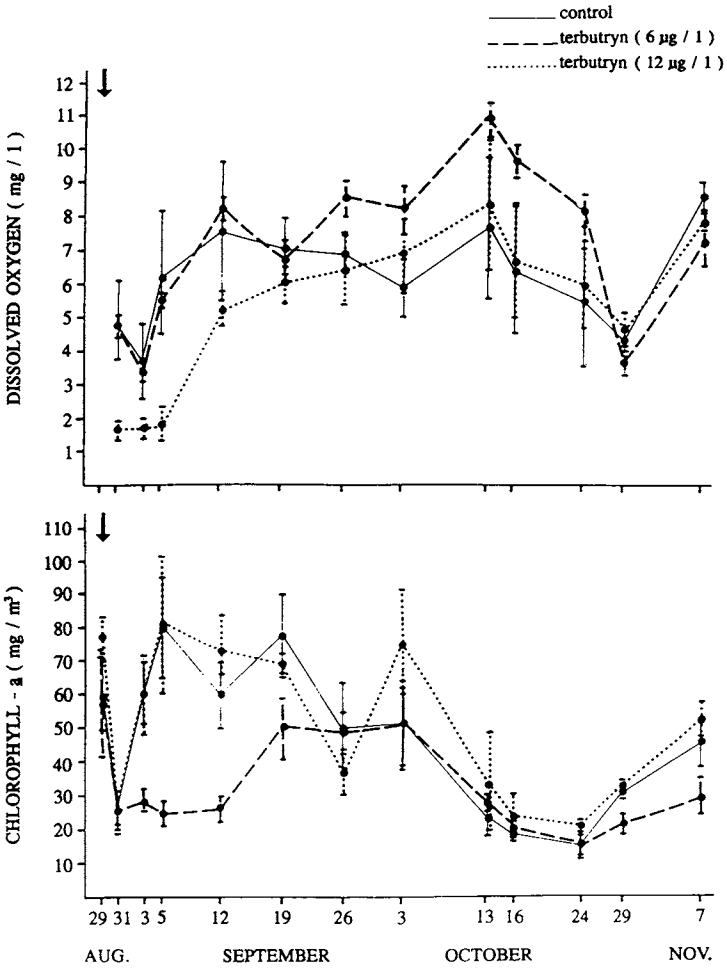

Figure 4. Dissolved oxygen (mg/l) and chlorophyll-*a* concentrations (mg/m³) for control, low (6 μg/l), and high (12 μg/l) rate terbutryn-treated columns located in Pond S3 on the Auburn University Fisheries Research Unit, 1985. The arrows indicate the timing of the terbutryn applications. Each data point represents the mean of three replicates ± one standard error.

density among the control, low, and high rate treatments were similar and no significant differences were detected. However chlorophyll-*a* provides a better (crude) estimate of algal biomass than does direct enumeration because of size differences among phytoplankton species (Boyd 1979; APHA et al. 1980; Wetzel and Likens 1991). Significantly higher mean Secchi disk visibility and significantly lower mean turbidity and DO detected in both the low and high rate treatments relative to the control also indicated a reduction in algal biomass within terbutryn-treated columns. No other significant differences in any water quality variables (e.g., COD, NO_2^--N, TAN) among the treatments were detected.

Figure 6 illustrates the dramatic decline in chlorophyll-*a* concentrations in the terbutryn treatments within the week following herbicide application. Accordingly, during this same period, DO dropped precipitously to below 1 mg/l in both the low and high treatments. Within a week, chlorophyll-*a* increased in both treatments and DO concentrations began to recover. However excluding the last sample date on 28 October, mean chlorophyll-*a* and DO concentrations in both low and high rate treatments usually remained substantially below control column values (Figure 6).

Unlike 1985, slight changes in phytoplankton community structure at the Division level were discernable in 1986 (Figure 5). On a percentage basis, the low and high rate treatments in 1986 had more green and yellow-green algae and fewer euglenoids and dinoflagellates compared to the controls. At the generic level control and low rate treatment columns were dominated by euglenoid and dinoflagellate taxa on six of eight sample dates (Table 5). Taxa of green algae, primarily *Chlamydomonas* sp., were dominant more often from the high rate treatment than the control or low rate treatment columns. However, except for the green alga *Ankistrodesmus falcatus* (Corda) Ralfs which was never dominant in control columns, all treatments shared the same dominant taxa at some point over the course of the experiment.

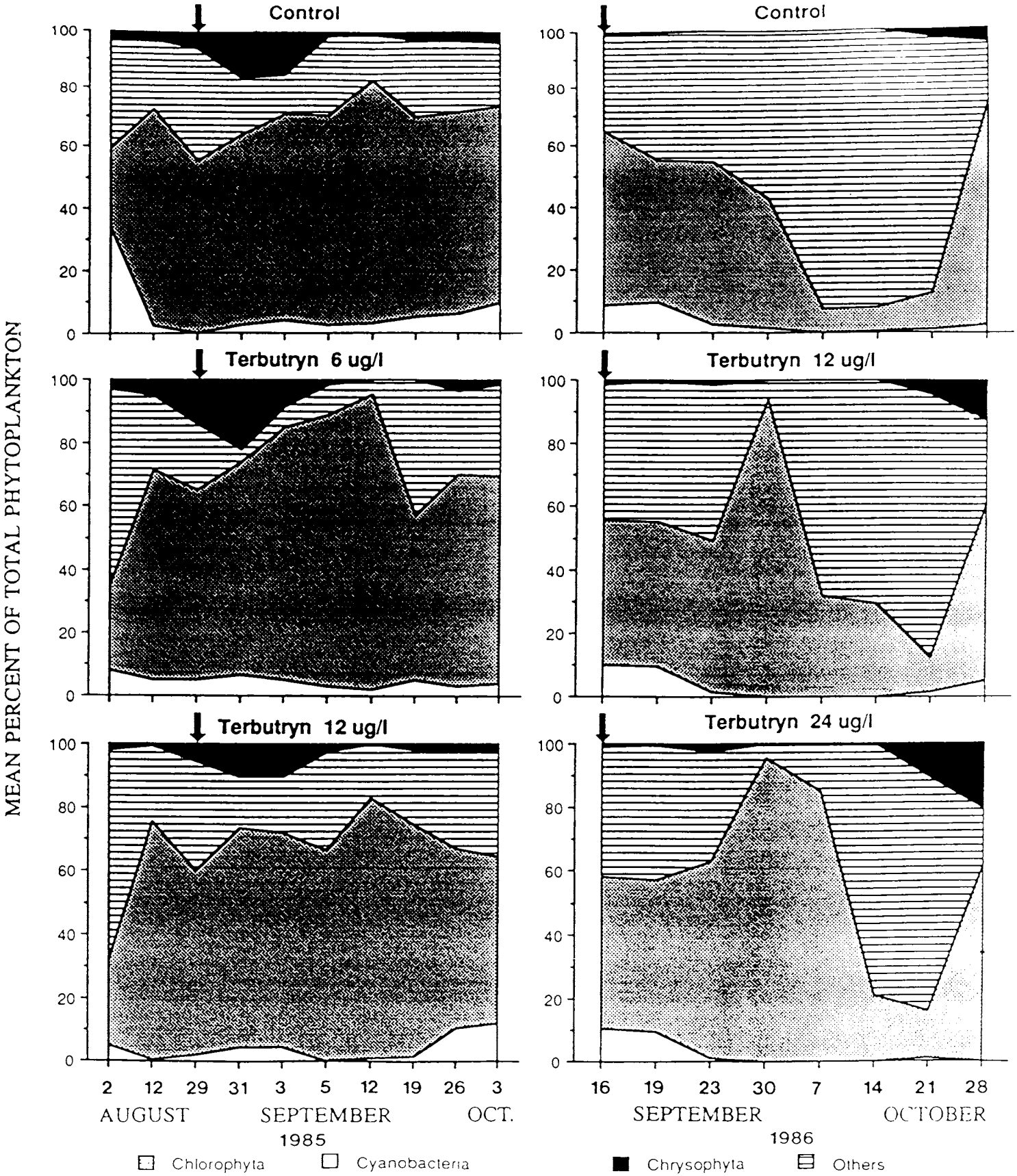

Figure 5. Mean percent composition of the four major phytoplankton groups for control and terbutryn-treated columns located in Pond S3 on the Auburn University Fisheries Research Unit, 1985-86. The arrows indicate the timing of the terbutryn applications. Treatments were replicated three times. The Others category includes the Divisions Euglenophyta and Pyrrhophyta.

TABLE 4. DOMINANT TAXA FOR CONTROL AND TREATMENT COLUMNS FOR THE TERBUTRYN EXPERIMENT, 1985. DOMINANT STATUS WAS ASSIGNED TO THE TAXON WHICH HAD THE HIGHEST MEAN DENSITY FOR EACH SAMPLE DATE. TREATMENTS WERE REPLICATED THRICE.

Date	Control	Terbutryn 6 μg/l	Terbutryn 12 μg/l
Aug 2	*Raphidiopsis* sp.	*Trachelomonas* sp.	*Trachelomonas* sp.
Aug 12	*Kirchneriella* sp.	Unidentified Euglenophyta	*Kirchneriella* sp.
Aug 29	*Ankistrodesmus* sp.	*Ankistrodesmus* sp.	*Peridinium* sp.
Aug 31	*Ankistrodesmus* sp.	*Cyclotella* sp.	*Ankistrodesmus* sp.
Sept 3	*Cyclotella* sp.	*Ankistrodesmus* sp.	Unidentified green flagellate
Sept 5	Unidentified green flagellate	Unidentified green flagellate	Unidentified green flagellate
Sept 12	*Chlamydomonas* sp.	*Chlamydomonas* sp.	*A. falcatus*
Sept 19	Unidentified green flagellate	Unidentified Euglenophyta	*Trachelomonas* sp.
Sept 26	*Scenedesmus* sp.	*Ankistrodesmus* sp.	*Trachelomonas* sp.
Oct 3	*Ankistrodesmus* sp.	*Ankistrodesmus* sp.	*Trachelomonas* sp.

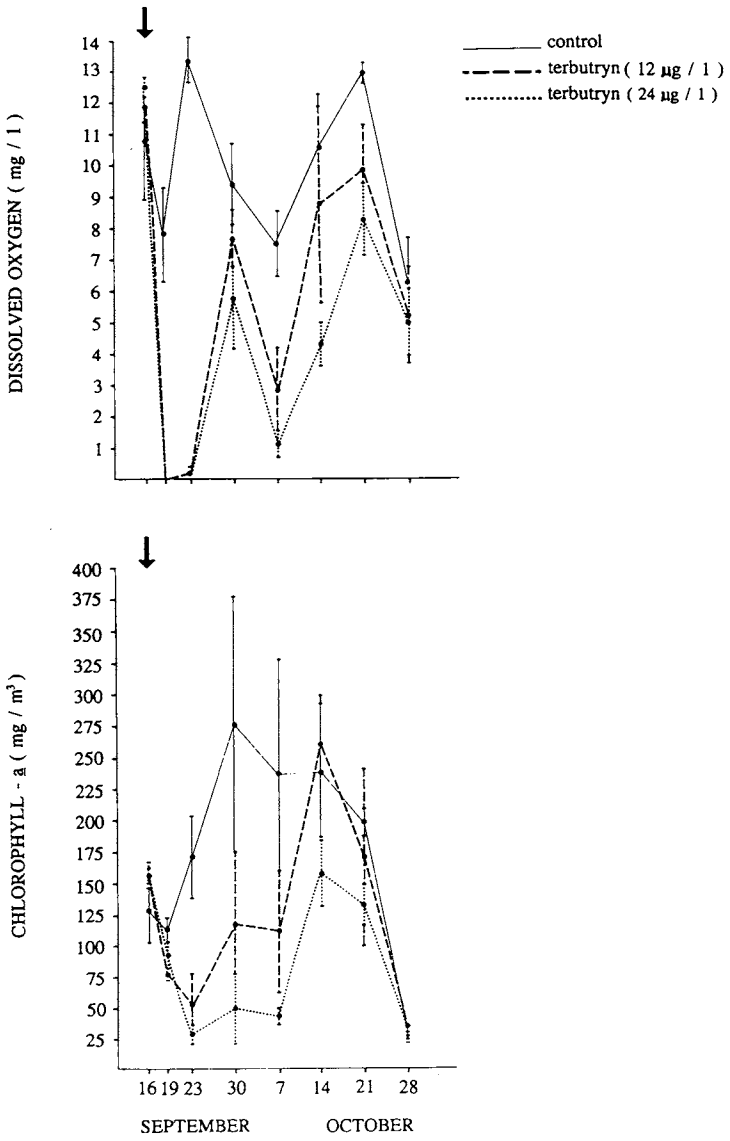

Figure 6. Dissolved oxygen (mg/l) and chlorophyll-*a* concentrations (mg/m³) for control, low (12 μg/l), and high (24 μg/l) rate terbutryn-treated columns located in Pond S3 on the Auburn University Fisheries Research Unit, 1986. The arrows indicate the timing of the terbutryn applications. Each data point represents the mean of three replicates ± one standard error.

CONCLUSION

Fluridone was not effective in consistently reducing phytoplankton densities or chlorophyll-*a* concentrations. Despite the significant reduction in both of the above variables in S3 treatment columns, the fact that DO, Secchi disk visibility, turbidity, and total phosphorus in S3 were unaffected by fluridone suggests the impact of this herbicide on phytoplankton was minimal. Fluridone did not selectively reduce or eliminate blue-green algae, nor did it otherwise affect phytoplankton community structure.

The effect of terbutryn on chlorophyll-*a* concentrations in 1985 and 1986 was variable. However in neither year were any of the three rates evaluated (6, 12, and 24 μg/l) effective in reducing phytoplankton densities. The occurrence of significantly lower DO concentrations from terbutryn-treated columns in 1986 generally confirm previous research that has documented dramatic declines in DO following treatment with a triazine compound (Tucker and Boyd 1978; Goldsborough and Robinson 1983; Tackett 1983; Tucker et al. 1983; Gurney and Robinson 1989). No discernable differences in the dominant phytoplankton taxa were evident as a result of terbutryn treatment in 1985 or 1986. However, in 1986, terbutryn-treated columns, on a percentage basis, contained more green and yellow-green algae and fewer euglenoids and dinoflagellates than the control. Blue-green algae were not affected by treatment in either year. In both the fluridone and terbutryn experiments, the high variability detected among replicates in addition to the inconsistent results obtained, were partially due to these experiments being conducted under field rather than under more controlled laboratory conditions. Neither fluridone or terbutryn, at the rates evaluated in this study, were effective in reducing phytoplankton densities, eliminating blue-green algae, or improving water quality.

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TABLE 5. DOMINANT TAXA FOR CONTROL AND TREATMENT COLUMNS FOR THE TERBUTRYN EXPERIMENT, 1986. DOMINANT STATUS WAS ASSIGNED TO THE TAXON WHICH HAD THE HIGHEST MEAN DENSITY FOR EACH SAMPLE DATE. TREATMENTS WERE REPLICATED THRICE.

Date	Control	Terbutryn 12 μg/l	Terbutryn 24 μg/l
Sept 16	*Chlamydomonas* sp.	*Trachelomonas* sp.	Unidentified Euglenophyta
Sept 19	*Trachelomonas* sp.	*Trachelomonas* sp.	*Chlamydomonas* sp.
Sept 23	*Trachelomonas* sp.	*Trachelomonas* sp.	*Chlamydomonas* sp.
Sept 30	Unidentified Euglenophyta	*Ankistrodesmus falcatus*	*Chlamydomonas* sp.
Oct 7	Unidentified Euglenophyta	Unidentified Euglenophyta	*A. falcatus*
Oct 14	Unidentified dinoflagellate	Unidentified Euglenophyta	Unidentified dinoflagellate
Oct 21	Unidentified dinoflagellate	Unidentified dinoflagellate	Unidentified Euglenophyta
Oct 28	*Chlamydomonas* sp.	*Chlamydomonas* sp.	*Trachelomonas* sp.

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