ing tagging, each bass was handled four times and made two short trips in a hatchery truck before being restocked in Indian Camp Lake.

The tied spaghetti tag appears to offer a number of advantages compared with the jaw tags. The spaghetti tag is highly visible to the fisherman and will continue visible after almost unlimited growth of the bass, while it appears that the jaw tag may be overgrown and become unobservable after a couple of seasons growth.

The spaghetti tag apparently did not interfere with growth while evidence indicates that just the opposite may be true of the jaw tag.

In marking and recovery experiments the fish for tagging and the recoveries often come from fish taken in gill and trammel nets. The use of Peterson disk tags in work of this nature may make the fish more susceptible to recapture, while, because of its location on the body and its construction, the spaghetti tag would minimize this effect. In the course of largemouth bass netting and recovery experiments on an impounded power reservoir in North Carolina the spaghetti tag was used. All bass were taken with experimental gill nets and trammel nets. In two instances of tagged bass being recovered in gill nets there was no indication that the tags had any effect on the recapture.

When the use of spaghetti tags was first considered it was thought possible that the white tags trailing over the back of the fish would attract other bass and they would strike at the material. The water in Indian Camp Lake is comparatively clear and schools of tagged and untagged bass were observed swimming together on several occasions. Apparently no attention was paid to the tags on some of the individuals. There was no indication on the recovered spaghetti tagged fish that the tags had been attacked by other fish.

Tied tags of hollow, white vinylite tubing appear to have a minimum effect on survival and growth of largemouth bass, and have several advantages in use as demonstrated.

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ALGAE CONTROL IN WARMWATER HATCHERY PONDS [1]

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ABSTRACT

Control of *Hydrodictyon reticulatum* Lagerh. and *Pithophora oedogonia* Wittr. in warmwater hatchery ponds using copper sulfate, sodium arsenite and abietylamine acetate is discussed. Some of the disadvantages of these chemicals as algicides for hatchery use are presented. A method of controlling the above species of vegetation in hatchery ponds using abietylamine acetate is described and recommended for use where either copper sulfate or sodium arsenite has not given satisfactory results.

INTRODUCTION

Increased use of organic and inorganic fertilizer in the culture of fingerling largemouth black bass and bluegills has rendered more acute the problem of controlling or eliminating undesirable forms of plant growth in recent years. Surber (1943) and O'Donnell (1943) describe objectional algal growths occurring in hatchery ponds. More recently Lawrence (1954) has described the increase in occurrence of the branched alga *Pithophora* sp. in farm ponds located in the southeast.

1 Prepared for presentation to the Southern Division of the American Fisheries Society held in conjunction with the conference of the Southeastern Association of Game and Fish Commissioners at Little Rock, Arkansas, October 8-10, 1956.

Occurrence of *Pithophora* has not been restricted solely to farm ponds but has made its appearance in warmwater hatchery ponds also. *Pithophora oedogonia* Wittr. was first identified at the Marion, Alabama fish cultural station in 1951. Net algae, *Hydrodictyon reticulatum* Lagerh., appeared in the spring of 1953. Both forms readily established themselves in the hatchery pond system and have plagued fish cultural operations since then. The following experiences were recorded in attempting to control 62 heavy and 68 light *Pithophora* infestations, along with 75 different infestations of *Hydrodictyon.*

Existing recommendations for the control of algal growths were tried on both *Hydrodictyon* and *Pithophora* in the Marion ponds with indifferent success. O'Donnel (op. cit.) controlled *Hydrodictyon* with repeated doses of copper sulfate at a rate of 0.33 p.p.m. applied as a solution treatment to a pond for several successive days. He also recommended addition of enough concentrated copper sulfate solution to the water supply of a pond for a 40-minute period to give a 0.33 p.p.m. concentration with treatment being repeated daily until the ponds were clear of algae.

Rose (1954) reports that in lake water having a methyl orange alkalinity of 224 p.p.m. Daphnia were unable to withstand a 0.5 p.p.m. concentration of copper sulfate for a period of 20 hours *in vitro.* One week old walleye fry were killed by a concentration of copper sulfate greater than 1 p.p.m.

Use of more than a 0.25 p.p.m. concentration of copper sulfate as a solution treatment in ponds at Marion noticeably affected the density of zooplankton in bass rearing ponds and apparently reduced the food supply of the small fish being cultured. Analysis of typical water supplies used at Marion are shown in Table I. Often the repeated use of a concentration of 0.25 p.p.m. copper sulphate was inadequate to check the growth of *Hydrodictyon* in bass rearing ponds supplied by such water especially in the late spring when the net alga was growing rapidly.

TABLE I

ANALYSIS OF TYPICAL MARION WATER SUPPLIES

Source	*p.p.m.* CO_2	*p.p.m.* $-HCO_3$	*p.p.m.* $-CO_3$	*Total Hardness*[1]	*Calcium*[1]	*Magnesium*[1]	*Total Alkalinity*[1]
Well 2	17.6	118.9	....	66.0	58.0	8.0	196.2
Well 8	25.9	90.9	....	68.0	35.0	33.0	149.0
Well 9	2.97	131.2	....	107.8	73.4	34.4	215.0
Reservoir ...	19.8	76.3	....	58.0	38.0	20.0	125.9

1 Expressed as $CaCO_3$ equivalent.

Surber (op. cit.) successfully killed scums of *Hydrodictyon, Oedogonium,* and *Cladophora* in the hatchery ponds at Leetown, West Virginia with concentrations of up to 5 p.p.m. of sodium arsenite. Use of two 4.0 p.p.m. treatments of sodium arsenite applied at 1-2 week intervals was required at Marion to give any appreciable kill of *Hydrodictyon.* A single 8.0 p.p.m. treatment gave about the same effect as the two 4 p.p.m. ones. About six weeks were required for the arsenic to kill the majority of vegetation present. Normally for bass rearing ponds, it is desirable to harvest the fish crop in from two to four weeks after stocking, so the arsenic treatment was too slow even though it was successful. The possible influence of 8 p.p.m. arsenic to the standing crop of fish food is another objection to the use of arsenic for algae control where increased amounts must be used to obtain a kill.

Because of the presence of interferring agents such as iron and possibly other elements in the Marion water supply, increased quantities of sodium arsenite have been required to effectively control susceptible species of vegetation. Rooted weeds such as *Najas flexilis* and *Potamogeton* sp. which were killed by a 2.5-5.0 p.p.m. concentration at Leetown and other locations required an 8.0 p.p.m. concentration for a kill at Marion. *Pithophora* was not controlled by normal sodium arsenite concentrations and a complete kill was not obtained even when a concentration of 16 p.p.m. was used. In one pond an 8 p.p.m. treatment was applied weekly for five consecutive weeks resulting in only a 50 per cent reduction of *Pithophora.*

Application of a solution of one part sodium arsenite to seven parts water sprayed over the dewatered pond bottom gave better results than any other arsenic treatment tried. The amount of sodium arsenite needed for an 8 p.p.m. concentration with the pond full of water was used, applied with a power sprayer as uniformly as possible over the pond bottom. *Pithophora* did not become dominant in one pond for three months following such a treatment and a good growth of phytoplankton persisted during this time. Low bluegill production was obtained from the pond following the treatment however, which may have been caused by the effect of arsenic on the food organisms.

Where enough copper sulfate was applied to *Pithophora*-infested bluegill ponds to control the alga, poor bluegill production usually was obtained. Although conclusive evidence was not available to verify this supposition, there appeared to be an inverse relationship between the amount of copper sulfate used in a pond and the yield of bluegill fingerlings obtained.

Since copper sulfate is directly toxic to many forms of plankton at comparatively low concentrations, use of enough to kill *Pithophora* conceivably could eliminate some desirable vegetation and small food organisms as well. Rose (op. cit.), studying the effect of adding 13.3 pounds of copper sulfate per acre to a natural lake during a period extending from July 17 to October 15, found that the number and volume of bottom organisms declined slightly at a time when they normally should have increased.

PREVIOUS REPORTS ON DELRAD

Lawrence (op. cit.) has described the use of dehydroabietylamine acetate or Delrad as it is now being called by its manufacturers, in the control of *Pithophora* in farm ponds. He found that a concentration of 0.5 p.p.m. or less was toxic to *Pithophora* when water temperatures were above 70° F. It was applied either as a spray, in floats or by dragging a sack of the chemical over the pond using a boat powered by an outboard motor. He stated that a concentration of 0.7 p.p.m. was toxic to bluegills, goldfish, and largemouth black bass fingerlings. It was not harmful to phytoplankton when applied in the recommended amounts.

Johnson (1955) used Delrad 70 (a paste formulation containing 70 per cent abietylamine acetate) to control *Ulothrix zonatum* in circular rearing pools containing eastern brook trout. The material was distributed by means of an applicator attached to the water supply at a rate which provided a concentration in the pool of about 0.5 p.p.m. for 4-6 hours. No damage was sustained by the brook trout from this treatment when applied at weekly or longer intervals.

Makenthum (1955) reports that Delrad had been found to be toxic to small muskellunge at concentrations greater than 0.5 p.p.m. by Leon Johnston, Fisheries Biologist at the Spooner Wisconsin Hatchery. In order to avoid damage to fishes, ponds on this hatchery were treated for filamentous algae control prior to stocking.

OBSERVATION ON ALGAE CONTROL WITH DELRAD AT MARION

Work has been carried on with both the liquid and paste forms of Delrad at Marion since the summer of 1953. Toxicity studies using largemouth black bass and bluegill fingerlings as test animals indicated that mortality began among one-inch black bass fingerlings at a 0.4 p.p.m. concentration of dehydroabietylamine acetate in well water (Well No. 2, Table I), while no appreciable mortality was obtained at a concentration of 0.5 p.p.m. in spring water having a total alkalinity of about 35 p.p.m. Bluegills appeared able to tolerate slightly more of the chemical, with one lot withstanding an 0.8 p.p.m. concentration for 118 hours with only a 7 per cent mortality. These data, although variable, do not differ greatly from the level of 0.7 p.p.m. active Delrad which Lawrence (op. cit.) established as the toxic concentration to warmwater fishes.

Acquarium tests along with observations on the toxicity of Delrad under pond conditions suggest that the chemical increases in toxicity as the size of the fish decreases. Hatchery ponds containing adult and yearling blugills have been treated with as much as 1.5 p.p.m. active Delrad without mortality. Under

other conditions a 1.0 p.p.m. concentration killed 1-inch blugills. Largemouth bass adults and large fingerlings withstood a 2.0 p.p.m. treatment applied as a spray without mortality. In several ponds fingerling fish were killed or visibly distressed by Delrad applications although larger fish did not seem to be affected.

The method of application of Delrad in shallow rectangular hatchery ponds appears to have an important effect upon the toxicity of the chemical. Of the methods of application described by Lawrence, the float and spray methods have been extensively tested in ponds at Marion which were being used for bass and bluegill fingerling production.

Using the float method of application, a heavy mortality of ¾ inch bass fry occurred following a 0.4 p.p.m. treatment applied to a 1.7 acre pond for the control of *H. reticulatum*. Three floats were used located on a line extending diagonally across the pond. A stiff breeze was blowing and it is assumed that a lethal concentration of Delrad built up on the lee side of the pond from which the small bass could not escape. One-inch bluegills were killed in substantial numbers in two other ponds from a float application of 1.0 p.p.m. active Delrad under somewhat similar conditions. However, use of a spray application of 0.8 p.p.m. Delrad in a pond containing one-inch bluegill fingerlings did not cause any observed mortality.

Float applications of Delrad apparently are highly lethal to bluegill, green sunfish and fathead minnow fry when used in small shallow ponds at concentrations of 0.4 p.p.m. active ingredient or more. Pond 15 on the Marion Station was given weekly applications of a 0.4 p.p.m. active concentration of Delrad 70 beginning May 1, 1956. Within three weeks the treatment had eliminated practically all of the bluegill, green sunfish and fathead fry which were present when treatment was begun. One very light spawn of fry was noted during a nine-week period while Delrad was being used at the above rate each week. Following the cessation of Delrad applications, heavy reproduction of bluegills and green sunfish took place within three weeks.

Pond O was given weekly 0.4 p.p.m. applications of Delrad for a longer period. This pond contained bluegill and fathead fry when treatment was begun on May 1. Only a few of the fry survived to fingerling size although the survivors grew rapidly after reaching the fingerling stage. Only one light spawn of bluegills took place after treatment was begun. Delrad was added at weekly intervals for fourteen consecutive weeks. Fifty one days after the last Delrad was applied a medium spawn of bluegill fry was noted.

In two other ponds, use of two 0.4 p.p.m. float treatments of Delrad in the late spring for the control of *Hydrodictyon* appeared to delay normal bluegill spawning from two to four weeks.

In another pond treated with float applications of 0.7 p.p.m. active Delrad at weekly intervals for nine consecutive weeks, bluegill fry were not found until two weeks after treatment had ceased. This was four weeks after a normal spawn had been noted in three other ponds stocked from the same lot of brood fish as was the treated pond.

Use of the float method of applying Delrad did not appear to materially affect small bass at rates of 0.3-0.4 p.p.m. active Delrad if applied three days prior to stocking the pond with fry or after the fish had reached a length of one inch.

Generally ineffective results were obtained in controlling *Hydrodictyon* during late spring in bass ponds using the float method of applying Delrad paste at rates of from 0.3 to 0.5 p.p.m. active ingredient at weekly intervals. Although appreciable damage would be sustained by the alga following treatment, regrowth usually would be evident within three days necessitating treatment before the weekly interval in use had elapsed.

RECOMMENDATIONS FOR HATCHERY USE

The experience described above with Delrad paste and the float method of treatment led to adoption of the spray method of applying this algicide to hatchery ponds at Marion which contain bass or bluegill fingerlings. Delrad 50 solution is the source of abietylamine acetate used. A concentration of abietylamine acetate not to exceed 0.4 p.p.m. has been established as the maximum amount to be used in a pond containing small fish. Early in the

growing season a 0.3 p.p.m. treatment or a series of several treatments is preferable. This level has been generally effective for either *Pithophora* or *Hydrodictyon*. Since *Pithophora* is more resistant to the action of Delrad, several treatments normally are necessary, while one 0.3 p.p.m. treatment of net algae in a bass rearing pond in the spring has controlled the alga for a week to ten days. If the initial treatments do not achieve the desired effect, the concentration is increased to 0.4 p.p.m.

Where possible, the algicide is applied before the pond is stocked with small bass. Bluegill ponds are not treated when recently hatched fry are likely to be present in large numbers. Early treatment of *Pithophora* appears best as this species apparently becomes more resistant to Delrad as it increases in age.

Where an appreciable amount of surface scum is present, successful treatment usually involves several successive applications of Delrad applied to living growths of alga at 2-3 day intervals until all is killed. Often ponds will become green with phytoplankton where *Pithophora* is being treated by the time the surface mat has been killed. This phytoplankton bloom then shades the bottom and aids in inhibiting further growth of the *Pithophora* located on the bottom.

Where the spray method has been used during 1956 in bass culture and during 1953, 1954 and 1955 in bluegill production, no damage to the fish or the fish food supply has been noted except in isolated instances where a few small bluegills were killed. The possibility of oxygen depletion is present if the amount of algae killed at one time is large. The spray method of application allows the operator to control this hazard however and with experience, little damage will result even in poorly buffered water.

To treat a pond, the water volume should first be known. This information permits the maximum amount of Delrad which can be safely used to be determined. The required amount is then diluted with water to make a three per cent water solution of Delrad. If a scum is present this solution is uniformly applied as a fine mist to the portion of the scum which is to be killed. In small ponds a knapsack-type hand sprayer or a small power sprayer effectively distributes the solution. A little experience enables the operator to distribute the spray solution at a rate heavy enough to kill the form of alga being treated. Application of spray should be just heavy enough to kill the scum contacted. The solution should be applied in bands 15-25 feet in width if small fish are present so that they can escape from the area of high chemical concentration. Where the algal growth is submerged, best results have been obtained by applying the solution to all sections of the pond and then stirring the water thoroughly with an outboard motor.

Lawrence (op. cit.) recommended that fertilization be carried on while Delrad treatment was in progress in order to stimulate phytoplankton growth. The manufacturer of Delrad (Anon., 1955) advised against use of Delrad one week before or after fertilization as super phosphate decreases the algicidal activity of the chemical. Our experience indicates that fertilizer should not be used within 2-3 days of a Delrad treatment at least. Where only a partial kill is obtained, fertilization may aid in the recovery of unkilled algae.

No noticeable damage has been done to phytoplankton or zooplankton from using concentrations of 0.3-0.5 p.p.m. abietylamine acetate in either bass or bluegill ponds. No harmful effects were noted to phytoplankton following repeated use of 0.4-0.7 p.p.m. concentrations applied by floats. Where a scum of algae is being sprayed, small fish may be lost in insignificant numbers as they jump out of the water upon being contacted by the chemical and cannot return because their weight is not great enough to break the scum.

The principal disadvantages of Delrad as an algicide appear to be its toxicity to fishes and the high cost of repeated treatments. Where the margin of safety is less than 0.5 p.p.m., careful handling and application is essential if mortality of small fish is to be avoided. Cost of an algae control treatment using Delrad is intermediate between sodium arsenite and copper sulfate. At present the cost of a single treatment for one acre-foot of water is about $0.15 for copper sulfate (0.3 p.p.m.), $1.09 for Delrad 50 (0.3 p.p.m.) and $3.71 for sodium arsenite *

* Costs based on copper sulfate at $0.15 per pound, Delrad 50 at $0.675 per pound, and sodium arsenite solution at $0.70 per gallon.

(8 p.p.m.). More applications of copper sulfate and Delrad are usually needed as their effect often is of short duration. As many as 10-15 applications of Delrad have been required for *Pithophora* control in a pond doring one season.

CONCLUSIONS

Study of the experience gained in using abietylamine acetate (Delrad) for control of *Hydrodictyon* and *Pithophora* in warmwater hatchery ponds over a period of four years indicates that the chemical has possibilities as an algicide in warmwater hatchery ponds provided that its limitations are taken into consideration. It is highly toxic to fishes and recently hatched fry appear especially susceptible to its action. However, it is also toxic to objectional species of algae while being relatively non toxic to phyto and zooplankton. Concentrations should be determined accurately and amounts applied uniformly. Where either copper sulfate or sodium arsenite have proven unsatisfactory as algicides, use of abietylamine acetate is suggested in warmwater hatchery pond management.

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OBSERVATIONS ON THE INFLUENCE OF THE NEW JOHNSONVILLE STEAM PLANT ON FISH AND PLANKTON POPULATIONS

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As potential hydroelectric power sources are diminishing in Tennessee, the construction of steam plants for generation of electricity is increasing to satisfy expanding industrial power demands. The Tennessee Valley Authority has constructed five steam plants and more are being considered. The relationships of these plants to the fish populations of reservoirs or rivers should be understood by fishery biologists. Engineers who design these plants are also interested in their influence on the recreational uses of the water.

The present study was carried out at the New Johnsonville Steam Plant, 12 miles west of Waverly, Tennessee on Kentucky Lake from October, 1955 to August, 1956. The purposes were to determine: (1) seasonal fish concentrations, (2) seasonal food availability, and (3) the extent of influence of this plant beyond the immediate discharge harbor.

The New Johnsonville Steam Plant was completed in 1953 and has a total capacity of 750,000 kilowatts. The steam used to propel the turbines comes from distilled water and is reused after passing over condensers. Water required to cool the condensers is taken from Kentucky Lake through an inlet channel above the steam plant. This water is pumped at the rate of 633,000 gallons