VEGETATION CONVERSION IN PONDFISH CULTURE

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Abstract: A technique of vegetation conversion for the liberation of nutrients contained in filamentous algae and submerged rooted aquatic plants is presented as a practice which may prove useful in the management of warm-water hatchery ponds and possibly small farm ponds. An experiment in the production of bluegill fingerlings was conducted comparing three methods of fertilization with the vegetation converson technique. The rate of production in the conversion treatment compared favorably with that in two of the three fertilizer treatments and the cost of production was less than half that of the best fertilizer treatment. The density of phytoplankton as measured by the light penetration readings made during the growing season was best in the vegetation conversion treatment. Of the fifteen ponds receiving inorganic fertilizer, four of the ponds were dominated by the branched summer alga *Pithophora,* and four developed rooted aquatic vegetation. Only seven of the fifteen initially produced the type of vegetation which was desired. It was possible to convert the rooted vegetation by use of sodium arsenite and produce phytoplankton later in the season, but in the case of the *Pithophora* dominated ponds, conversion methods used were unsuccessful. In the unfertilized vegetation conversion treatment, all ponds developed rooted vegetation which was successfully converted to basic nutrients using sodium arsenite on one-fourth to one-eighth of the pond area. Phytoplankton blooms resulted from the sodium arsenite applications in all of the five ponds, with difficulty in liberating the nutrients tied up in the rooted vegetation being experienced in only one pond out of five.

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A new technique in the management of warm-water ponds has been tested at the Marion, Alabama, Fish Cultural Station and at other federal hatcheries in the southeast during the past four years (Blosz 1952). This management technique makes use of an idea which has been exploited by agriculturists for many years, that of using cover or green manure crops which are turned under and converted to basic components by bacterial action with the released nutrients stimulating the following crops. Applied to pondfish culture, rooted vegetation and filamentous algae, both generally considered by fish culturists to be undesirable forms of vegetation, are treated in such a way that this vegetation is killed and converted by bacterial action to basic nutrients, zooplankton or bottom organisms suitable for use as fish food. The liberated nutrients are available for use by phytoplankton which quite often becomes the dominant form of vegetation after the existing form is eliminated.

For want of a better term, the process described above when used in ponds is referred to as the technique of "Vegetation Conversion" as it differs basically from vegetation control methods used primarily for the purpose of ridding a pond of an objectional form of aquatic plant life that interferes with harvesting operations. While the idea of using aquatic plants as an organic fertilizer is not a new one (Meehean 1935; Swingle and Smith 1942; Hasler and Einsele 1948; and Topel

1949), there has been no widespread use of the vegetation conversion concept until its adoption by federal hatcheries in the southeast as a management practice in the propagation of largemouth black bass and bluegill fingerlings (Blosz 1952).

As most warm-water fish culturists will agree, the problem of aquatic vegetation control is a major one on a majority of the hatcheries engaged in propagating species of warm-water fishes and in many of the waters where they are stocked. Thus a method which control undesirable vegetation and converts existing plants into a more useful form is doubly valuable in warm-water pond management.

Fertilization using both organic and inorganic materials is a standard production practice at many warm-water hatcheries (Hogen 1946; Blosz 1952), and is also an essential part of the successful management of farm fish ponds (Swingle and Smith 1942; Swingle 1947). Addition of these nutrients is carried out for the purpose of stimulating the growth of an abundant crop of phytoplankton which many fishery workers consider necessary for high biological productivity in a pond or lake. While the use of fertilizers as recommended normally produces the desired result of a water bloom of phytoplankton, under hatchery conditions this is not always the case. Often rooted aquatic vegetation becomes dominant in a pond instead of the more desirable phytoplankton. In other instances filamentous algae such as *Pithophora oedogonia*, Wittr., *Cladophora sp.*, *Hydrodictyon reticulatum*, Lagerh, or *Oedogonium sp.* will become the dominant form of vegetation to the exclusion of plankton algae. Only in a very sterile or unproductive environment does some form of vegetation normally fail to develop.

When the available basic nutrients become bound up by undesirable forms of aquatic vegetation, they are either temporarily or permanently removed from the food chain and do not materially contribute to the available supply of fish food as they normally would were they in the form of plankton algae. Also the rooted plants produced crowd the water making harvesting operations difficult (Meehean 1935). When a form of vegetation other than phytoplankton becomes dominant, additional applications of either organic or inorganic fertilizers usually serve only to increase the quantity of undesirable vegetation growing in a pond if nothing else is done to the existing plant growth. Even in the case of some forms of filamentous algae, which are the dominant vegetative species only temporarily, nutrients are diverted away from plankton algae long enough so that rooted submerged aquatics can begin to grow. These plants in turn eventually dominate the pond where, had the nutrients originally gone into phytoplankton, growth of the rooted plants would have been inhibited by the shading effect of the plankton.

The development of a form of vegetation other than phytoplankton in a hatchery pond gives a major setback to fish food production because of the relatively short period of time available normally for the production of a crop of fish. Since the production season for both bass and bluegill fingerlings is usually from two to four months duration, any appreciable delay in setting up the desirable food chain results in reduced fish production.

NUTRIENT LIBERATION

Maciolek (1954) in reviewing the artificial fertilization of lakes and ponds states that there are two approaches that can be made to artificial enrichment. One, of course, is the addition of fertilizing materials. The other is the liberation of nutrients present, a method which he states has been considered theoretically but not practically. In the conversion process where aquatic vegetation other than plankton algae is treated with chemicals so that decay and nutrient liberation occur with the resultant phytoplankton development, this method of enrichment is placed on a practical basis. Not only are the soluble nutrients which were taken by the undesirable vegetation from the pond water liberated, but in the case of some forms of rooted vegetation, nutrients located in the pond bottom to a depth of several inches might be ultimately made available for use by phytoplankton.

Natural waters often support a large quantity of filamentous algae or submerged rooted vegetation. Rickett (1922, 1924) found that the dry weight of rooted submerged aquatic plants from two Wisconsin lakes varied from about 1,600 to 1,800 pounds per acre. Meehean analyzed the aquatic vegetation in ponds on the Natchitoches, Louisiana, Station and found that the amount on one acre was equivalent to from 172 to 2,080 pounds of cottonseed meal. In unfertilized hatchery ponds on the Marion, Alabama, Fish Cultural Station, samples of vegetation taken indicated a standing crop of from 870 to more than 2,000 pounds per acre on a dry weight basis. Observation of hatchery ponds in fertile locations indicate that they may support a much greater weight than this. Where the nutrients contained in this vegetation are liberated, the effect on desirable plant development is highly favorable.

In practice the procedure of vegetation conversion is not simple. It involves the use of either fertilization with inorganic fertilizers which stimulates the growth of filamentous algae which in turn shades out the undesirable vegetation (Smith and Swingle 1942; Surber 1948; Patriarche and Ball 1949), or the use of some chemical agent or dye which will cause the death of all or a part of the unwanted vegation present. Since time normally does not permit the slower acting and seasonal fertilization technique to be effective in hatchery ponds, use of chemicals or dyes must be resorted to. Surber (1949) reviewed methods of controlling undesirable forms of vegetation with some of the advantages and disadvantages of each along with their limitations. With some modifications these chemicals are being used on hatchery ponds at present to control vegetation along with several new agents which are currently being tested for their practicability. Of primary concern to the fish-culturist is a method which will not have a deleterious effect on the crop of fish which must be in the pond either at the time of or shortly after the chemical treatment has been applied.

Several workers have reported greatly increased phytoplankton production as a result of killing off higher aquatic plant growth (Swingle and Smith 1942; Surber 1949; Topel 1949; Blosz 1952). Not only is the quantity of phytoplankton increased, but productivity of the ponds in pounds of fish per acre usually increases also. In the past four years on the Marion Station, successful vegetation conversion was accomplished in six of the ten highest producing bluegill ponds observed during this period.

Vegetation conversion differs basically from conventional pond vegetation control methods in the purpose for which treatments are applied and the technique used. In the case of bluegill fingerling culture, normally the rooted vegetation is tolerated until several weeks prior to the time of harvesting the fish crop and the pond then cleared of vegetation. Most of the liberated nutrients are probably lost when the pond is drained. In the case of vegetation conversion, treatments are applied early enough to allow the converted plant material to be used in the fish food chain with the initial treatment being applied before or about the time the brood fish are stocked. In clearing a pond for draining, quite often only the deeper waters are treated. In the vegetation conversion process the chemical treatment is applied to shallow water areas and when a phytoplankton bloom subsequent develops, the vegetation growing in the deeper waters is shaded out gradually and the slow decay releases nutrients over a period of from two to eight weeks. This slow decay reduces the danger of oxygen depletion and fish loss by spreading out the oxygen demand of the conversion process over a longer period of time.

AN EXPERIMENT WITH VEGETATION CONVERSION

In 1951 in a fertilization experiment with bluegill *(Lepomis macrochirus Raf.)* fingerling production, the vegetation conversion technique was compared with treatments involving moderately heavy inorganic fertilization in hatchery ponds of the Marion Station. Four treatments were used as follows:

Treatment 1. Vegetation Conversion. No fertilizer applied, with any submerged aquatics developing to be used as a green manure crop by killing out plots of vegetation with sodium arsenite as soon as adequate growth had occurred. Four of the five ponds used for this treatment had previous records of fertilization. This was applied only during the year 1950 and consisted of from four to seventeen 100-pound per acre applications of 8-8-0.

Treatment 2. A control treatment where three weekly applications of inorganic fertilizer consisting of 100 pounds per acre of an 8-8-0 was added followed by similar amounts at two-week intervals as was needed to maintain a good bloom of phytoplankton.

Treatment 3. Heavy Spring Fertilization. Beginning April 1, seven weekly applications of 100 pounds per acre of 8-8-0 were applied, followed by additional fertilization at the same rate at three-week intervals until the pond was drained.

Treatment 4. Use of light inorganic fertilization plus weed control. Fertilization consisted of three 100-pound applications of 8-8-0 per acre applied at 3-week intervals with later applications at the same rate being applied each fourth week. Any rooted vegetation developing was to be killed out using sodium arsenite.

The treatments were replicated five times in as representative a group of ponds as was available on a random basis except for the unfertilized ponds. Since the water supply system at Marion consists of crossdrains between ponds with water for the lowest ponds flowing through higher ponds from the artesian well supply, the ponds which were not fertilized were selected because they had an independent water supply and were not contaminated by fertilized water.

The fertilized ponds in the experiment were fertilized according to schedule, and thus were liberally supplied with nitrogen and phosphorus according to most hatchery production standards. The nitrogen was supplied by ammonium nitrate containing 33.5 percent nitrogen, and the phosphorus by superphosphate containing 20 percent P_2O_5. Data on the fertilizers applied are summarized in Table 1.

The ponds in the study were observed at least once each week throughout the production period. At the time they were checked, notes were made on the amount and form of vegetation present, the amount of phytoplankton in the water as indicated by the degree of turbidity, and any other characteristics which might affect the production process. In measuring the turbidity caused by phytoplankton, a Secchi Disc was attached to a graduated yardstick, and the reading in inches

Table 1. Data on fertilization.

Treatment	Pond	8-8-0 equivalent per acre pounds
2. Three initial weekly applications of 100 lbs. of 8-8-0 per acre followed by 100 lbs. per acre every 2 weeks as was needed to maintain a medium bloom of phytoplankton.	0	1,400
	5	1,700
	8	1,300
	15	1,400
	43	1,600
3. Heavy Spring Fertilization. Seven weekly applications of 8-8-0 at rate of 100 lbs. per acre with later applications of the same size every three weeks until the pond was drained.	1	1,300
	3	1,400
	11	1,500
	44	1,400
	49	1,200
4. Light Fertilization plus weed control. Three 100-pound-per-acre applications applied at three-week intervals with later applications used at four-week intervals. Vegetation developing to be converted with chemicals.	F	1,100
	7	800
	9	1,100
	12	1,200
	48	800

where the disc became invisible was recorded as a "visibility reading" for the pond. Zeller (1952) has also used this method to obtain comparative figures on plankton density in farm ponds. In the shallow hatchery ponds at Marion, light penetration to a depth greater than 36 inches makes it impossible to read the disc in many ponds as the maximum depth ranges from three to five and one-half feet. Since a pond this clear has little phytoplankton present anyway, readings of more than three feet were lumped together as a reading of plus 36 inches. The ponds were seined to observe the time of reproduction, rate of growth and relative abundance of small fish every three to four weeks.

The ponds were drained and the fish crop harvested during the period September 15 to December 15, 1951. Small fish were processed according to a standard procedure followed at the Marion Station where wire hardware cloth graders were used to separate the fish into inch-groups. After grading, three random samples were taken from each lot, weighed, and the number of fish in each determined. The average number of fish per pound in the three samples was then used to estimate the number of fish produced using this value applied to the total poundage of each size.

Undesirable vegetation was controlled by accepted methods currently recommended for that purpose (Blosz 1952) and included the use of sodium arsenite on rooted vegetation and copper sulphate crystals on the filamentous algae. These treatments were applied to all ponds in the test where it appeared that undesirable vegetation was developing to a point where it would dominate the pond for a considerable time.

Yields varied from pond to pond regardless of treatment. This variation has been mentioned by other workers and apparently is the rule rather than the exception. Some of the variation in results was caused by the physical influence of factors associated with the pond system (Table 3). Table 2 gives the average production of small bluegills which was obtained in this experiment.

Table 2. Average production of small bluegills.

Treatment	Replications	Fish per acre		Cost/ 1,000	Average visibility inches	Production in lbs. due to treatment[b]
		Number	Weight			
1. Vegetation conversion	5	88,184	191.5	$0.085	28.0	91.5
2. Regular fertilization	3[a]	88,303	235.6	0.340	29.7	135.6
3. Heavy spring fertilization	2[a]	121,966	312.5	0.195	30.0	212.5
4. Light fertilization with weed control	2[a]	65,702	107.8	0.360	28.2	7.8

[a] In Treatment 2 there were two ponds that were considered to be failures for causes other than the treatment, and in both Treatments 3 and 4 three additional ponds. Results from these ponds were not included in the above table.

[b] Untreated unfertilized ponds at Marion produce about 100 pounds of bluegills per acre. Values in this column are obtained by deducting this amount from the poundage produced.

Table 3. Cause of failures.

Treatment	Pond	Probable cause for failure
1		None.
2	0	Contaminated with largemouth bass fingerlings.
	8	Inadequate water coupled with oxygen deficiency caused by control measures used on dense growths of *Pithophora oedogonia.*
3	3	Defective brood fish.
	11	Contaminated with largemouth bass.
	44	Unexplained mortality of small fish.
4	9	Oxygen deficiency following treatment of filamentous algae with copper sulphate.
	12	Cause unknown but thought to be associated with control methods used on a dense growth of *Pithophora* which developed in the early summer.
	48	Defective brood fish.

While the highest production in both number and weight was obtained from Treatment 3, the vegetation conversion treatment gave about the same average production as the regular fertilization treatment at one-fourth the cost per thousand. Also, the production cost was less than half that of the highest producing treatment, heavy spring fertilization. The cost per thousand is the total cost of fertilizer and chemicals needed during the season for the management of a pond divided by the thousands of fish produced.

The highest poundage of small fish was obtained from heavy fertilization with the regular fertilization treatment being considerably less. The vegetation conversion treatment was the third highest producer with the light fertilization treatment being a poor fourth. It might be pointed out that several other factors influence the poundage of small bluegills obtained from a pond in addition to the amount of food produced there. These figures are the result of a complex interaction of all of the influences rather than a simple reflection of the food supply available for the bluegills.

Abundance of phytoplankton as indicated by the light penetration measurements was greatest in the vegetation conversion treatment, where the measurements averaged 28.0 inches for 29 inspection dates as compared to 29.7, 30.0, and 28.2 inches, respectively, for fertilizer treatments, Numbers 2, 3, and 4.

The low production in three of the ponds in Treatment 4 was caused in part by management methods used and these were excluded from the production averages. Of the two ponds remaining, one was normal while the other was a low producer even though a good bloom of phytoplankton was maintained throughout the production season. Apparently the species of plankton algae present were not productive of bluegill food as seining in the later summer showed that the fingerling fish present were in an emaciated condition.

An unusual aspect of this experiment was the lack of failure in unfertilized ponds where rooted vegetation was killed by chemicals and converted into fish food. While none occurred in this treatment, eight of the fifteen ponds in the fertilizer treatments were failures. A study of the causes for failure in the eight ponds mentioned should be made to adequately evaluate the experiment. These causes are outlined in Table 3.

Only in the case of the three ponds where decay of filamentous algae was responsible for the failure of the pond to produce normally could the fertilizer treatments applied be even indirectly an influence on the cause for failure. However, in the case of *Pithophora* development, fertilization apparently greatly stimulates the growth of this weed during the summer months. Lawrence (1954) has described the spread and development of this form of alga in farm ponds in the Southeast in recent years, and there has been a similar increase in hatchery ponds which may be correlated in part at least with the increased use of fertilizers by hatcheries.

No *Pithophora* developed in the five unfertilized ponds apparently because submerged rooted vegetation was present and dominant before temperatures were favorable for growth of the branched summer alga. During the period that this type of alga has been under observation there have been no recorded instances where *Pithophora* was able to assume a dominant role in a pond where rooted vegetation was already dominant and flourishing. Occasionally, however, it will become dominant when rooted vegetation is killed out by chemical treatment.

It was necessary to control rooted submerged vegetation, mainly *Najas flexilis,* Willd. with sodium arsenite in six of fifteen fertilized ponds in the fertilized treatments. All five ponds in the vegetation conversion treatment developed moderate to heavy amounts of submerged rooted vegetation which was converted in the late spring without much difficulty by spraying a 1-1 sodium arsenite-water solution on sections of the ponds at a rate of eight parts arsenious oxide per million parts water (Surber 1931). The liquid sodium arsenite solution containing 40% sodium arsenite by weight was used in all cases. Data pertaining to the vegetation treatments are shown in Table 4.

Table 4. Data relating to the conversion method.

Treatment	Pond	Dominant vegetation	Agent	Control or conversion used: No. sq. ft. treated	No. applications
1	P	*Potamogeton sp.*	Sodium Arsenite[a]	40,000	2
	2	*Najas flexilis*	Sodium Arsenite	30,000	1
	4	*Najas flexilis*	Sodium Arsenite	10,000	2
	6	*Potamogeton sp.*	Sodium Arsenite	10,000	2
	50	*Najas flexilis*	Sodium Arsenite	52,000	4
2	8	*Pithophora*	Copper Sulphate[b]	11,000	6
	43	*Pithophora* &	Copper Sulphate[c]	32,000	7
		Najas flexilis	Sodium Arsenite[a]	23,000	2
3	1	*Najas flexilis*	Sodium Arsenite[a]	12,000	4
	11	*Pithophora* &	Copper Sulphate[b]	28,000	8
		Najas flexilis	Sodium Arsenite[a]	12,000	1
	44	*Najas flexilis*	Sodium Arsenite	44,000	3
4	F	*Najas flexilis*	Sodium Arsenite[a]	30,000	4
	7	*Potamogeton*	Sodium Arsenite	10,000	1
		diversifolius, Raf.	Sodium Arsenite		
	12	*Pithophora*	Copper Sulphate[d]	21,000	6

[a] 8 p.p.m. As_2O_3 in area treated.

[b] $CuSO_4$ crystals sprinkled over vegetation at a rate of 3 pounds per 1,000 square feet. Total amount not to exceed 0.75 parts $CuSO_4$ per million parts of water.

[c] One application of a 2.0 parts $CuSO_4$ per million parts water in water solution to entire pond was used.

[d] One application 0.75 p.p.m. copper sulphate in water solution over entire pond was used.

In more than half of the ponds where fertilizer was used, the dominant form of vegetation was either unwanted rooted submerged plants or summer type branched alga which was even more undesirable. In the fertilized ponds it was possible to control and at least partially eliminate the rooted vegetation by using sodium arsenite. A temporary plankton bloom was then obtained in two of four ponds handled in this way. In the other two instances difficulty was encountered in killing enough plants to allow another form to become dominant. Consequently, several applications of sodium arsenite were required during the growing season, increasing considerably the cost of the fish produced in those ponds.

In the other two fertilized ponds treated with sodium arsenite, *Najas flexilis* occurred along with *Pithophora.* Even though *Najas* was killed, the net result was an increase in the amount of *Pithophora* present, as the liberated nutrients were taken up by the alga.

Little success was experienced in converting or controlling *Pithophora* with copper sulphate crystals by sprinkling them over the floating mat of vegetation at a rate of 3 pounds per 1,000 square feet. Amounts ranging from 0.5 to 2.0 parts $CuSO_4$ per million parts pond water were relatively ineffective where six to eight applications were used. In one instance an entire pond was treated, once with a

0.75 p.p.m. copper sulphate application and in another with a 2.0 p.p.m. concentration. In none of the cases was *Pithophora* controlled or any substantial quantity converted to its basic components.

It is apparent from the results obtained in these fertilized ponds that weeds will usually develop in shallow hatchery ponds regardless of the amount of fertilizer added.

The five unfertilized ponds all developed moderately heavy growths of submerged rooted plants by late spring. Plots ranging in size from 1/8 to 1/4 of the pond area were sprayed with sodium arsenite solution mixed with equal parts of water at a rate to give 8 parts arsenious oxide per million parts water in the plot being treated. Surface water temperatures were about 85°F (± 5°) during the period the conversion treatments were being applied. Good kills resulted from the initial applications, but only one pond developed a heavy enough bloom of phytoplankton to shade out the remaining plants. The other four ponds were sprayed again using the same technique as followed previously with three of the four producing a good growth of plankton algae which shaded out the remainder of the rooted vegetation. The fifth pond was rather shallow and though the nutrients liberated by the decaying weeds caused phytoplankton to develop temporarily, the bloom soon faded as it never became dense enough to shade the bottom and cause the death of the rooted vegetation outside the treated areas. By the end of the growing season, however, most of the rooted vegetation in this pond had been converted and harvesting operations were not hampered even though all of the weeds had not been killed by shading.

CONCLUSIONS

Based on the findings of this experiment and related observations, the following conclusions are advanced:

1. In hatchery ponds, good production of bluegill fingerlings can be obtained very economically by conversion of existing rooted vegetation if an adequate amount of a desirable species is present.
2. Fertilization alone is not adequate on most fish hatcheries and in many farm ponds to control rooted or undesirable algal vegetation. Chemical weed control is essential for economic production of pondfish fingerlings where the dominant vegetative species is non-planktonic in form.
3. Where undesirable vegetation develops in spite of inorganic fertilization, this organic matter can be changed from an objectionable form to a desirable one in many cases by chemical treatment with the liberated nutrients entering the food chain to stimulate the growth of phytoplankton which is more productive of fish food and also clears the pond of vegetation which interferes with fish harvest.
4. Additional work on methods of nutrient liberation by the vegetation conversion technique is indicated. Successful methods for conversion of different forms and species of vegetation need to be developed. Fertilization methods designed to make use of this concept need to be worked out and the effect of the chemical used and of vegetation conversion on the ecology of the individual pond over a long period of time should be studied.

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