ANTIMYCIN—A FISHERIES MANAGEMENT TOOL FOR OKLAHOMA?

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A description and brief history of the development of antimycin A as a fish toxicant is presented, together with methods of application, effects of physico-chemical factors on its action, and its toxicity for fishes, other vertebrates and invertebrates. Antimycin A has been demonstrated to be an effective tool in control of excess sunfishes and in channel catfish culture operations. The usefulness and cost of rotenone and antimycin A treatments are compared.

The long standing problem of deteriorating sport fishing in impoundments was the initiating factor of this review. Lambou et al (1) predicted that by 1974 there will be 440,473 acres of farm ponds, 28,803 acres of lakes (10-500 acres), and 696,934 acres of reservoirs (over 500 acres) in Oklahoma. There are now approximately 100,000 acres of streams in the state. The maintenance and management of the sport fishery of Oklahoma is and will continue to be a tremendous task.

New and better ways of managing fishing waters are constantly being developed. The practice of reclaiming streams, rivers, ponds, lakes, and reservoirs is a common method, and over the past 40 years this practice has grown rapidly according to Lennon *et al* (2). Application of fish toxicants and drainage of ponds are two of the oldest methods of controlling pondfish populations and reclaiming fishing waters. Problems associated with these practices are the limitations set by meager financial resources and the ensuing delay in resumption of fishing in a rehabilitated pond, lake, or stream.

Fish toxicants still have a potential value in fisheries management, although much remains to be learned. For years remedial stockings with fingerling and intermediate largemouth bass for the purpose of controlling excessive numbers of bluegill were tried, but managers found this procedure unsatisfactory (2). The stocking of predators as a population control measure in small impoundments has been attempted many times, but often anglers fished heavily for the predators while leaving the sunfishes virtually untouched. Largemouth bass have been a desirable species for small impoundments, but angling pressure has often led to elimination of this species and rapid overpopulation of the impoundment by sunfishes. Lennon *et al* (2) stated that, in view of the difficulties involved, chemical toxicants presently offered the most efficacious, economical, and widely applicable means of manipulating fish populations. They also stated that chemical toxicants were the only practical means for controlling fish in streams. As long as man must manipulate his environment and if we cannot bring about a change in fishing habits, perhaps fish toxicants are necessary for economical, long-range maintenance of good fisheries.

A large number of toxicants have been used. Lennon *et al* (2) list forty that have been used to kill fish. However, only a few of these, including antimycin A and rotenone, are presently registered as fish toxicants. Lennon and Berger (3) reported, in 1970, that over fifty known applications of antimycin A to control fish had been made in the field. The number must have increased considerably by now; four trials have been made in Oklahoma. Use of antimycin A in ponds near Purcell, Stillwater, and Claremore, Oklahoma demonstrated its potential in state fisheries management.

The purpose of this paper is to explore further the potential value of antimycin A in Oklahoma fisheries management and to compare its usefulness with that of rotenone.

ANTIMYCIN A AS A FISH TOXICANT

Description

It is interesting that two important fish toxicants, rotenone and antimycin A, are products of living organisms. Rotenone can be extracted from the roots of many species of beans (4). Antimycin A is an antibiotic produced in cultures of a species of *Streptomyces,* a genus of mold-like bacteria. The following is a summary description of the nature of antimycin A and its toxic properties:

Chemical formula	$C_{28}H_{40}N_2O_9$
Trade names	Fintrol-5; Fintrol-15; Fintrol Concentrate
Formulation	Controlled-release coating on sand grains; water-soluble liquid
Primary use	Registered fish toxicant in United States and Canada
Secondary use	Fungicide; miticide
Mode of action	Irreversible inhibitor of cellular respiration
Toxicity for fish	Extremely toxic to freshwater and marine fishes
Toxicity for birds	Highly toxic to quail
Toxicity for mammals	Low toxicity for mouse, rat, rabbit, guinea pig, dog, and lamb
Safety hazard	Conjunctivitis; protect eyes with safety glasses
Persistence in environment	Non-persistent

Development and registration

Originally antimycin A was used to combat certain fungi damaging to crops (5). The value of antimycin A as a fish toxicant was discovered in 1963, and in 1964 it was patented as a fish toxicant (2). The first formulation of Fintrol, a product consisting of antimycin A coated on sand grains, was registered in the United States and Canada in 1966.

Registration is important for a fish toxicant; environmental concern dictates that any poison be studied carefully before its use becomes widespread. Lennon *et al* (2) described the requirements which should be met by a fish toxicant. Incidentally, they also stated that more specific toxicants, such as TFM, Fintrol, and Squoxin, are needed, but that the research necessary to find and develop them is long and expensive. Lennon (6) reports that, as of 1967, only 18 of 95 chemical fisheries tools have been registered to any extent for use in aquatic circumstances. Since the early 1960's, the Food and Drug Administration (FDA) has urged registration of such chemicals; research is currently being carried out in order to register those which are essential and most widely used (6). All fisheries chemical tools and their use will come under careful scrutiny by the FDA.

The three formations of Fintrol, Fintrol-5, Fintrol-15, and Fintrol Concentrate (Ayerst Laboratories, New York, N.Y.) contain 1% antimycin A by weight, 5% antimycin A by weight, and 20% antimycin A by volume, respectively (5). Antimycin A is soluble in acetone or ethanol (7). The antimycin A of Fintrol-5 and Fintrol-15 has been formulated on Carbowax coated on fine sand to precise and uniform specifications. Fish are thus exposed readily to exact quantities of active ingredient with no influence from carriers.

Antimycin A has been used for partial reclamations and as a general or selective toxicant (2). It adds no color to the water, has no odor, and does not repel fish. The toxic action involves respiratory inhibition and appears to be irreversible in most fishes.

Methods of application

Antimycin A can be applied in many ways; methods will be dictated by particular situations, depth of water, water currents, and the formulation selected for use. Lennon, Berger, and Gilderhus (8) developed a powered spreader. Grass seed spreaders, hand-type spreaders, and release from a can into the propwash have also been used successfully. The 400-mesh sand and Carbowax formulation is designed to release the active ingredient evenly over a certain depth range as the sand sinks in the water. Lennon and Berger (3) constructed a helpful table (Table 1) on the proper concentration of antimycin A to use, depending on the species of fish to be eradicated and the existing physiochemical conditions.

Effects of physicochemical factors

Lee, Derse, and Morton (9) found pH to be the most important factor in the toxicity and degradation of antimycin A. Half-lives for antimycin A concentrations at pH 4.5 and pH 11.0 were 7 hr and 6 min, respectively. Antimycin A degrades within a few hours at pH 8.5 or higher (2). Since the pH of pondwater is usually at its maximum during afternoon hours, it is best to apply this toxicant early in the morning for maximum effectiveness (6).

Antimycin A was found to be effective in waters which were either fresh or marine, acid or alkaline, cold or warm, and flowing or static (2). Alkalinity and hardness were found to be of no significance in the toxicity and degradation of this substance (9). In soft, acid waters antimycin A was degraded to harmless components within 7 to 10 days; it could be deactivated quickly with potassium permanganate (2, 4). Turbidity proved to have no adverse effect on the action of the toxicant (9).

The thermocline can alter the effectiveness or desired results of toxicant applications. Sand base antimycin A formulations are designed to release the active ingredient within the first 5 feet (Fintrol-5) or first 15 feet (Fintrol-15). The thermocline would, therefore, not affect desired penetration of this toxicant.

S.B. Penick and Company (10) described the development of rotenone formulations which pentrate the thermocline (Pro-Noxfish and Noxfish), and also experiments with a rotenone formulation that will not penetrate the thermocline. The latter formulation is an emulsion which sinks slowly, but does not penetrate the thermocline. Since little or no life exists in the hypolimnion because of oxygen deficiency, it would be advantageous, costwise, to treat only that volume of water above the thermocline (10). Obviously, experiments which test the penetration of toxicants are important when cost is considered. If a thermocline exists the proper toxicant formulation should be selected to gain maximum effectiveness at the lowest possible cost.

Toxicity to fishes

The susceptibility of species to rotenone and antimycin A has been reported by Jenkins (11) and Gilderhus *et al* (7), respectively. The order of tolerance of various species to the two toxicants is quite different (Table 2). In studies by Walker, Lennon, and Berger (12), carp and other rough fish were killed by small concentrations of antimycin A after short exposures at cool or warm temperatures; longnose gar, bowfin, and black and yellow bullheads were relatively resistant to the quantities tested. It is reported that gizzard shad, trout, pike, carp, minnows, suckers, sticklebacks, white bass, sunfish, perch, freshwater drum, and sculpins are generally eliminated at 10 ppb of antimycin A, while gar, bow-

TABLE 2. *Susceptibility of fish (least tolerant to most tolerant species) to rotenone and antimycin A.*

Rotenone[a]	Antimycin A[b]
Gizzard shad	Certain minnows
Carp	White sucker
Largemouth bass	Gizzard shad
Redear	Yellow perch
Black crappie	Trout
Bluegill	Buffalo
White crappie	Carp
Green sunfish	Other centrarchids
Warmouth	Pumpkinseed
Black bullhead	Warmouth
	Crappie
	Smallmouth bass
	Largemouth bass
	Goldfish
	Gars
	Bowfin

[a] Data from Jenkins (11).

[b] Data from Gilderhus, Berger, and Lennon (7).

TABLE 1. *Guidelines for selecting concentrations(ppb) of antimycin A to control freshwater fish.*[a]

	pH below 7.5		pH 7.5-8.5		pH above 8.5	
	Water Above 60 F	Water Below 60 F	Water Above 60 F	Water Below 60 F	Water Above 60 F	Water Below 60 F
Sensitive Fish[b]						
Antimycin A in ppb	5.0	7.5	7.5	10.0	10.0	10.0
Fintrol-5 in ppm	0.5	0.75	0.75	1.0	1.0	1.0
Fintrol-5 in pounds per acre-foot	1.4	2.0	2.0	2.8	2.8	2.8
Resistant Fish[c]						
Antimycin A in ppb	15.0	20.0	20.0	25.0	25.0	25.0
Fintrol-5 in ppm	1.5	2.0	2.0	2.5	2.5	2.5
Fintrol-5 in pounds per acre-foot	4.1	5.5	5.5	6.9	6.9	6.9

[a] Data from Lennon and Berger (3).

[b] Species such as gizzard shad, trout, pike, carp, minnow, suckers, sticklebacks, white bass, sunfish, perch, freshwater drum, and sculpins.

[c] Gar, bowfin, goldfish.

fin, and goldfish, are eliminated at 25 ppb of antimycin A (3). Bullheads are even more resistant.

Toxicity to invertebrates and other vertebrates

Fish-killing concentrations of antimycin A are relatively harmless to most aquatic invertebrates and to higher vertebrates (2). In general Antimycin has a relatively low toxicity in mammals compared to its toxicity in fish when administered to the water, according to Herr, Greselin and Chappel (13). There may be moderate irritation if the compound is applied repeatedly, in high concentrations, to the skin or eyes of rabbits. Antimycin is easily degraded and the degradation products lack appreciable toxicity for either fish or mammals (13). Walker *et al* (12) observed that plankton, aquatic plants, bottom fauna, salamanders, tadpoles, and turtles were not harmed by piscicidal concentrations of antimycin A.

Callaham and Huish (14) reported some detrimental effects of antimycin A on benthic organisms and plankton populations. They noted that the numbers of zooplanktors in the groups Cladocera, Copepoda, Rototaria, and Nauplii larvae were severely reduced after application of 5 ppb antimycin A. Bottom organisms in the groups Tendipedidae, Ceratopogonidae, and Culicidae did not disappear. These workers believed that survival of benthic organisms at concentrations which severely reduced zooplankton may have been due to differential resistance or lack of contact with the toxicant. Recruitment was found to be limited 6 to 9 days after application of antimycin.

Concentrations lower than 5 ppb should not affect plankton and benthic populations so severely. Various authors have agreed that the effect probably varies with the time of year, type of water, and level of dosage. It would seem that a fall treatment should not have such adverse effects on an aquatic system. If the zooplankton population were drastically reduced during a fall treatment and that of the benthic organisms were not, it would appear that the largemouth bass fingerlings, by this time well over 30 mm, would have no problem finding food. Benthic organisms are the main food item of fingerling bass over 30 mm. The following spring should see adequate recruitment of the zooplanktors, and the new largemouth bass fry should have an adequate food supply.

Sunfish-largemouth bass management

Nationwide studies have revealed varying degrees of success with antimycin A treatments, depending on numerous geographical, environmental, and biological factors. Trials in Oklahoma have indicated apparent potential for antimycin A as a tool for elimination or thinning of excess and/or stunted sunfishes without complete eradication of pondfish populations. No largemouth bass or channel catfish were killed in four Oklahoma trials with antimycin A. Preliminary results indicated severe reduction of intermediate and young-of-the-year sunfishes, with no apparent harm to residual largemouth bass and channel catfish populations when concentrations from 0.8 to 2.3 ppb were applied. In at least one instance, largemouth bass reproduced successfully following treatment with antimycin A, with the young-of-the-year largemouth bass exhibiting above state average growth. In the same experiment, growth rates improved for all species one year after treatment; intermediate and young-of-the-year sunfishes represented a much smaller segment of the total pondfish population after treatment with antimycin A.

Burress and Luhning (15) studied the use of antimycin A for selective thinning of sunfish populations in ponds. Concentrations of antimycin A as low as 0.8 ppb were found to be more than adequate. A concentration of 0.8 ppb was used successfully in a Claremore, Oklahoma experiment. Burress (16) pointed out that multiple treatments might sometimes be necessary.

Most experiments with antimycin A have indicated that the toxicant treatment stimulated growth in residual populations and reduced inter-species competition. Some researchers have stocked largemouth bass in the summer, following antimycin A treatment, to allow them to feed upon sunfish spawn which resulted from the residual breeding population. The desirability of introducing largemouth bass depends on whether adequate largemouth bass stock remains after treatment and at what time of the year antimycin A is applied. Since the object is better control of the sunfishes, adequate largemouth bass stock should be present when a sunfish spawn occurs. One of the Claremore, Oklahoma experiments showed that an adequate stock of largemouth bass remained after a fall treatment with antimycin A. Many intermediate and young-of-the-year sunfish were removed by the treatment, and thus much of the forage for the largemouth bass was eliminated. Because the end of the growing season was near, the largemouth bass were presumed to be unharmed by loss of forage. Approximately one year later another survey confirmed the observations that the largemouth bass had reproduced successfully, almost no intermediate-size sunfish were present, an adequate young-of-the-year sunfish forage crop was available, and a number of very large sunfish were present. The antimycin A treatment had lessened intra- and inter-species competition and resulted in greater reproductive potential for the residual largemouth bass population.

Burress (17) reported that partial treatment, rather than whole treatment, of a pond or small lake might be a better, more efficient method of controlling sunfish with antimycin A. Smaller forage fish are generally more numerous in shallow confined waters than in deep waters, and upper areas of ponds and lakes generally contain a smaller volume of water. Even if partial treatment did not accomplish the desired results, it would be preferable to produce a light kill rather than overkill. Antimycin A will not completely mix if applied in the upper end of a lake and, even if complete mixing did occur, the concentration over the entire lake would be so low that it would serve as a built-in safety factor to avoid over-kill. Burress reported that partial treatments are also not likely to eliminate all of a size group that fingerling bass could prey upon, but such treatments adequately reduce the intermediate population of sunfish. If a pH rise occurred, target species would already have been affected by the above-normal concentration in the shallow end of the lake, before rapid antimycin A degradation occurred. Burress found that Fintrol Concentrate used at concentrations of 0.6 and 1.6 ppb antimycin A for partial treatments was a bargain; it cost $2.40 to treat a 2.8 acre pond and $21.20 to treat an 8.2 acre pond. Partial treatment could be used fairly effectively by inexperienced pond owners. Burress further reported that the method appeared to have possibilities for controlling certain year classes of crappie.

Channel catfish culture

Many experiments have demonstrated that antimycin A benefits channel catfish populations. Hogan (18) discovered that channel catfish fingerlings were from 42 to nearly 165 times more resistant than fingerlings of goldfish, fathead minnows, green sunfish, bluegill, largemouth bass, and carp were to the same antimycin A levels in 96 hr laboratory bioassays. Fingerling channel catfish which were exposed to 1,000 ppb of Fintrol-5 (10 ppb antimycin A) and cultured in vinyl wading pools for four months survived and gained weight at the same rates as did control fish.

Burress and Luhning (19) reported that green sunfish and golden shiners were effectively and economically controlled in channel catfish ponds on a Mississippi fish farm with 5.0 ppb and 7.5 ppb antimycin A treatments. A 10.0 ppb follow-up further reduced scale fishes with no apparent effect on yearling catfish. Untreated ponds yielded 27.4% fewer channel catfish than treated ponds and three times as many channel catfish that were too small for table use. This yield from treated ponds amounted to a net return of $2.48 for each dollar invested in the toxicant.

Large impoundments

Many Oklahoma reservoirs retain large populations of carp and gizzard shad. It is generally accepted that the reservoirs would benefit from fewer of these two species, although it must be realized that the gizzard shad is an important forage species. Partial kill of gizzard shad with rotenone has been attempted many times, with varying degrees of success. There has been little research on antimycin A treatment of reservoirs; whether antimycin A would be more or less effective than rotenone in partial removal of gizzard shad is unknown. Wisconsin has had some success with antimycin A in controlling carp in large impoundments (20).

Whether gizzard shad, carp, and other forage and rough species can be effectively and economically controlled in reservoirs remains to be seen, and whether antimycin A might assist in that control is also unknown at present. Jenkins (11) reported that partial fish removal projects in lakes where carp and gizzard shad were present presented many problems. He cautioned against certain game fish introductions following partial fish removal projects until means could be developed to eliminate the undesirable species completely. Since most Oklahoma reservoirs contain troublesome populations of carp and gizzard shad and results of partial fish removal projects with rotenone have generally been unpredictable, effective control of undesirable species in reservoirs remains a problem.

SPECIFIC ROLES OF ANTIMYCIN A AND ROTENONE

Both toxicants appear to be useful for a particular task. For total pond eradication projects rotenone is more economical; for selective species removal and partial treatment of ponds and small lakes, antimycin A generally gives more reliable and favorable results.

It would cost approximately $100 for antimycin A (Fintrol-5; 20 ppb antimycin A) and $23 for rotenone (5% rotenone; 2 ppm rotenone mixture) to treat a pond of 6 acre feet for total fish removal. If no catfish were present, it would cost approximately $36 for antimycin A (Fintrol-5; 7.5 ppb antimycin A) and $23 for rotenone (5% rotenone; 2 ppm rotenone mixture) to treat a pond of 6 acre feet for removal of scale fishes. Under normal situations it would cost about eight times more to use antimycin A than to use rotenone for a complete fish removal project (based on 1 ppm rotenone mixture and 20 ppb antimycin A requirement).

For selective treatment, rotenone is less predictable than antimycin A. Burress (17) stated that, although rotenone is effective in thinning forage fish populations, its use is circumscribed by weather and water conditions; at times undesirably large numbers of catchable-sized bass, crappies, sunfish, and channel catfish have been killed. When marginal applications of rotenone are used, it frequently is necessary to make from one to four applications to obtain the desired reduction in numbers of fish. Burress noted that, compared to rotenone, antimycin A has considerably greater selectivity among species and size groups of pond fishes, is less of a fish repellant, and has greater adaptability under a wide range of environmental conditions.

Antimycin A and rotenone can be used in combination. Howland (21) discovered that antimycin A and rotenone were not antagonistic. The antimycin A-rotenone combination was more toxic than either of the toxicants alone.

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