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The Use of Antimycin as a Selective Fish Toxicant in Alkaline Waters of Nebraska

by

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Introduction

Antimycin and rotenone are currently the two fish toxicants registered for use in the United States. Unlike rotenone, there is a wide range of susceptibility to antimycin among various fish species, a characteristic that has been used frequently by fishery managers to selectively thin overpopulations of certain forage and rough fish populations. However, the toxicity of antimycin reportedly diminishes rapidly as the pH of the water to be treated increases above a value of approximately 8.4. For this reason, successful application of antimycin in fish population control has been largely limited to soft, relatively acid waters.

Selective control measures are of particular value in cases where reinvasion of undesirable species cannot be prevented. In Nebraska there are approximately 65 small lakes, ranging in size from four to 53 acres, in the Platte River Valley that are presently managed for public sport fishing. Most of these lakes are subject to periodic flooding from the adjacent Platte River. Most Platte Valley lakes are also subject to heavy fishing pressure, ranging from 50 to 500 angling trips per acre. Fish population controls aimed at total eradication using rotenone often prove futile owing to reinvasion during periods of flooding. Furthermore, the lengthly recovery period required to reestablish sport fishing following total reclamations is often unacceptable in the management of high use areas. Because Nebraska's waters are characteristically alkaline in nature, the use of antimycin to selectively correct population imbalances has met with only limited success. However, in the absence of a more suitable chemical for selective population control, antimycin has seen increased use in Nebraska in recent years. This report is a review of Nebraska's experience with the use of antimycin in alkaline waters.

Procedures

Careful volumetric measurements were made of each lake to be treated. When contour maps were available surface areas of portions to be treated were determined using a compensating polar planimeter. When contour maps were not available, volume information was taken from the lake using averages of direct measurements of depth, shoreline length and width of the treated areas.

Immediately prior to treatment, lakeside measurements of water quality parameters that were felt to be of potential importance were made. These parameters included pH, methyl orange, phenolphthalein and total alkalinity, and total hardness. Dissolved oxygen and temperature profiles were taken to determine the location of any sharp thermal gradients and whether oxygen depletion had developed in the hypolimnion. Initially, all water chemistry determinations were made using a Hach Model AL-36-WR field test kit. Later, with aquisition of improved field test equipment, alkalinity titrations were performed according to procedures outlined in Standard Methods for the Examination of Water and Waste Water (Amer. Public Health Assoc., 1965) and pH values were determined using either a Beckman Model G or Lamotte Model HA meter.

Initially, bioassays were conducted prior to all antimycin renovations, using bioassay kits supplied by Ayerst Laboratories. Bioassay procedures closely followed those recommended by Ayerst with the exception that plastic bags supplied for use as bioassay chambers were filled with 40 gallons, rather than the recommended 20 gallons of water. All bioassays were conducted utilizing control test bags in which no chemical was added. Fish were collected using either A.C. electro-fishing equipment or bottom trawl. From 220 to 280 grams of test fish were added per bag. Test periods varied from 18 to 48 hours in duration. The use of bioassays was discontinued when it became apparent that the sealed bag technique was yielding misleading results.

Live cages containing target species were placed at various depths during three lake renovations to determine roughly the extent of kill induced and depth of chemical penetration. The cages measured 5' x 2.5'x 2.5' and were constructed of 1/4 inch mesh galvanized hardware cloth.

The chemical used was "Fintrol Concentrate" a liquid formulation of antimycin marketed by Ayerst Laboratories. In most cases the chemical was applied using venturi type boat bailors. Sprayer equipment was used to reach very shallow areas. The chemical was diluted with water by a factor of approximately 100 to 1 at the time of application.

Most renovations consisted of the "donut" variety, involving the treatment of the shoreline only. Treatments were usually conducted during the spring or early summer when such target species as bluegill, white perch, gizzard shad and carp had moved to the shallows to spawn. Treatments generally extended to depths of 5 to 10 feet. In cases where severe oxygen depletion was observed below the thermocline, treatment was often extended to the depth contour corresponding with the development of oxygen depletion. Floats were used to define areas to be treated in shoreline renovations.

In most cases involving gizzard shad, a species highly sensitive to antimycin, two treatment concentrations were used; the shoreline receiving a relatively high concentration and the lake's center receiving only what was considered to be a sufficient concentration to be toxic to gizzard shad.

Numbers and pounds of fish removed were usually determined by counts of randomly selected shoreline units. Wind action tended to clear the lake centers of dead fish, and for this reason fish kill estimates were determined from shoreline counts only.

Results

Fish mortality evaluations as well as physical and chemical characteristics of 14 lakes, ponds and impoundments of Nebraska that were treated with antimycin are presented in Table 1.

Only pH and carbonate (phenolphthalein) alkalinity appeared to be potentially useful indices for determining chemical concentration requirements. In general, the concentration of antimycin required to achieve adequate thinning of target species was much higher when measurable quantities of carbonate alkalinity were present and when pH values approached 9.0. In two cases (Table 1), when carbonate alkalinity measurements ranged near 50 ppm and pH exceeded 9.0, treatment concentrations of 7.5 and 8.0 ppb antimycin produced insignificant fish mortalities (Berger, et al., 1967; Rupp, unpublished data and personnel communication, 1974).

Waters without measurable carbonate and with pH values of 8.7 or less required relatively low treatment concentrations. In such waters, from 1.0 to 3.5 ppb antimycin achieved adequate control of bluegill, although somewhat higher concentrations were required to achieve adequate carp removal (Table 1).

Fish kills resulting from what were considered to be satisfactory renovations ranged from about 30 pounds per acre of bluegill to 500 pounds per acre of primarily carp and gizzard shad, without significant losses of largemouth bass. Several unsuccessful reclamations resulted in no significant mortality. One treatment unintentionally resulted in the complete removal of all species with the exception of catfish and bullhead (Table 1). Excessive alkalinity or the inability to accurately predetermine required treatment concentrations appeared to be the sources of all unsuccessful reclamation attempts.

Bioassays using Ayerst Laboratory bioassay kits generally yielded misleading information concerning required treatment concentrations (Table 2). With the exception of control groups, amoung which mortality was minimal, at least some mortality always occurred at all concentrations tested. Often, complete mortality was induced by all chemical concentrations. In general, treatment concentrations indicated by bioassay results proved to be less than half those actually necessary to produce the desired removal of target species.

Results of live cage tests conducted during three renovations are presented in Table 3. Fish placed in five feet of water sustained complete mortality in all three renovations. Some mortality occurred in most live cages set at depths of 7 and 10 feet, although mortality was never complete. Two groups of fish held in these live cages in untreated water incurred no mortality and were in good condition after 24 hours, indicating that confinement probably did not contribute substantially to the mortality observed in cages set during renovations. Evidently, the liquid concentrate formulation of antimycin used in these renovations achieved limited penetration to depths of seven and 10 feet.

Thermoclines had developed, beginning at depths of from 10 to 12 feet in all three lakes in which live cage tests were conducted. All live cages were set above the thermocline, therefore providing no information concerning the ability of the Fintrol Concentrate formulation to penetrate thermal gradients.

Discussion

Four factors, alkalinity, pH, water temperature and light intensity, have been reported to affect the toxicity of antimycin in water.

Antimycin is susceptible to alkaline degradation. The degradation rate is rapid in water and field observations have been documented indicating that degradation is sharply accelerated in the presence of carbonate (phenolphthalein) alkalinity (Walker et al, 1964). There is currently little evidence to suggest that the quantity of bicarbonate (methyl orange) alkalinity significantly affects the degradation rate of antimycin (Lee et al, 1971; Marking, 1973).

The toxicity of antimycin in water has also been shown to decline with increasing pH (Figure 1). The change of toxicity is especially critical between pH values of 8.5 and 9.5 (Lee et al, 1971; Marking, 1973).

Gilderhus (1972) documented that, when continuous toxicant concentrations were maintained, exposure times necessary to administer lethal doses of antimycin to fish were much longer in cold than in warm water (Figure 2). However, antimycin degrades much more rapidly in warmer waters (Derse and Strong, 1963), which is a factor that apparently complicates the role of water temperature in the toxicity of antimycin, particularly, as in lake renovations, when continuous antimycin concentrations cannot be maintained owing to degradation of the chemical. Thus, while antimycin is taken up by fish at a faster rate in warmer water, high temperatures also accelerate degradation. The net result is that antimycin, though reported to be somewhat more toxic in warmer waters, has been used economically on waters encompassing a wide range of temperatures (Burress, 1968; Walker et al, 1964).

Apparently, light intensity can dramatically influence the degradation rate of antimycin. Lee et al (1971) reported laboratory results indicating

that the half life of antimycin in aqueous solution in both sunlight and open shade was less than 20 minutes (Figure 3).

Results of antimycin treatments of Nebraska waters (Table 1) appear to indicate that carbonate (phenolphthalein) alkalinity measurements can provide valuable information for predicting the toxicity of antimycin in alkaline waters. As a rule, the presence of small quantities of carbonate alkalinity (roughly 1-10 ppm) indicated that treatment concentrations of 7.0 to 10.0 ppb antimycin were required to achieve the desired removal of most target species. In the absence of carbonate alkalinity, treatment concentrations ranging from 1.0 to 4.5 ppb produced satisfactory results. Evidently, antimycin cannot be used economically for reclamations of lakes containing relatively high concentrations of carbonate alkalinity. Degadation of antimycin in such waters may be too rapid to permit adequate exposure of fish to the chemical. On several occasions in Nebraska, lake reclamation plans calling for the use of antimycin have been postponed or abandoned when high carbonate values were measured.

Measurements of pH did not appear to be as useful in determining antimycin concentration requirements as were carbonate alkalinity readings. Evidently, when pH exceeds a value of roughly 9.0 it may be infeasible to attempt the use of antimycin, at least for relatively "hard" waters. However, most Nebraska lakes treated with antimycin ranged in pH from 8.4 to 8.7 (Table 1). There was no apparent correlation of pH with the concentration of antimycin required over this pH range. Some field measurements of pH presented in Table 1 are probably not entirely accurate, however. Many measurements of pH were made using colorimetric field kits. Later, when pH meters became available, the colorimetric method was found to yield values of approximately 0.2 pH units in excess of those obtained

using calibrated meters. The colorimetric measurements presented in Table 1 have been adjusted to account for this discrepancy. In view of the relatively narrow range of pH encountered in most Nebraska waters, rather sensitive field measurement techniques will have to be used in order to determine if pH measurements can be useful in predicting the concentration requirements of antimycin in fish population control procedures.

There was a noticable affect of water temperature upon the time required for fish populations to react to antimycin. When water temperatures approached 80° F fish would often appear in distress within 4 hours or less of the time the chemical was applied. Bluegill mortality was usually complete in less than 24 hours, although mortality of such species as carp, buffalo and crappie would often continue for a much greater length of time. When water temperatures ranged from 52° to 67° F, however, significant numbers of distressed fish often would not appear for 16 to 24 hours following treatment and bluegill mortality continued for 48 hours or more. Lee et al (1971) hypothesized that colder water temperatures lengthen exposure times required to induce mortality by reducing the metabolic rate of the fish.

Although water temperature appeared to have an important influence on exposure time, the affect of temperature upon toxicant concentration requirements was less apparent. All Nebraska experience with antimycin has been with relatively warm water, ranging from 51° to 90° F (Table 1). There was often a considerable delay between treatment and the onset of mortality for colder waters, ranging in temperature from 51° to 60°. However, there appeared to be little if any, affect of temperature on the ultimate toxicity of the antimycin.

Antimycin is available in sand based formulations which are designed to achieve uniform dispersion of chemical to depths of 5 to 15 feet. However, the live cage results of the present study indicated that the liquid Concentrate

formulation achieved excellent penetration to depths of five feet and probably achieved limited penetration to depths of seven and 10 feet. Selection of the proper treatment concentrations, rather than depth penetration, appears to have been the primary determinant of the outcome of the renovations reported here. It appears, therefore, the Concentrate formulation is adequate for most partial renovations, unless depth penetrations of 10 feet or more are considered desirable.

It remains unclear why the sealed bag bioassay results consistently underestimated required treatment concentrations. It appears possible, however, that confinement of the test specimens resulted in slight changes in water quality which may have affected the toxicity of antimycin, owing to the buildup of carbon dioxide or metabolites. Unfortunately, no measurements of pH or carbonate alkalinity were made to determine if measurable fluxuations in water quality had occurred within the bags.

A more effective means of determining toxicant needs, which proved feasible for renovations of relatively large bodies of water, consisted of spot treatments of selected areas of shoreline. Test areas consisted of either small bays or 100 to 120 yard reaches of shoreline. Live cages containing both target and nontarget species (i.e. bluegill and largemouth bass) were placed in the middle of each test area, at a depth where target species were expected to be most abundant. The survival in live cages was monitored from 24 to 48 hours following treatments. Mortality among both caged and uncaged fish in each treatment area was used to estimate toxicant requirements for that particular body of water. This procedure appeared to provide a better accounting for the extent of dispersion to be expected when the shoreline only was to be treated. Spot testing also eliminates the necessity of isolating the test water from the lake water to be treated, as is the case with the sealed plastic bag

procedure. Spot treatments generally are not, however, feasible bioassay techniques for small bodies of water of roughly less than 50 acres, and improvements in the area of field bioassay techniques for antimycin are badly needed.

Conclusions

1. Careful measurements of pH, carbonate (phenolphthalein) alkalinity, temperature and other pertinent water quality criteria should be made immediately prior to all reclamations employing antimycin. With sufficient documented information of this kind from renovations of alkaline waters, it may become possible to determine with more certainty those water quality characteristics which are of critical importance in determining concentration requirements.

2. From limited information available from antimycin treatments of alkaline waters of Nebraska, carbonate alkalinity and perhaps pH appear to be valuable criteria in determining toxicant concentration needs. It appears that the presence of Carbonate alkalinity may indicate that higher toxicant concentrations than usual may be required, and that when carbonate readings are relatively high and pH exceeds roughly 9.0, the use of antimycin may prove infeasible. One should become aware of any seasonal fluxuations of pH and alkalinity and schedule renovations so that they will coincide with any seasonally favorable conditions of water quality.

3. Although no clear evidence appears to exist indicating that sunlight causes excessive degradation of antimycin under field conditions, laboratory studies have shown that antimycin is light sensitive. Until information to the contrary becomes available, antimycin probably should not be applied during periods of intense sunlight.

4. Field bioassays employing sealed plastic bags for bioassay chambers evidently provide underestimates of required treatment concentrations. Spot

renovations of selected shoreline areas can provide more reliable results than the sealed bag approach, but are not usually feasible for renovations of small bodies of water.

5. The Fintrol Liquid Concentrate formulation appears to achieve sufficient depth penetration for most shoreline or "donut" type renovations. When depth penetrations of approximately 10 feet or more are considered desirable or when dispersion across a thermal gradient is necessary, the sand based formulations should probably be used.

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Table 1. Physical and Chemical Characteristics of Some Nebraska Waters Treated With Antimycin and Renovation Results

Area (acres)	pH	Surface Temp. (^{o}F)	Alkalinity (ppm $CaCO_3$) M.O.	Alkalinity (ppm $CaCO_3$) Phen.	Hardness (ppm $CaCO_3$)	Treatment Concentration (ppb)	Fish Kill Results	Name
15.5	9.4	90	154	51	-	8.0	Insignificant Kill	Fremont #2[1]
9.7	8.7	66	171	10 (approx.)	274	7.0	Satisfactory	Interstate 306
50	8.5	67 - 51	170	10 (approx.)	170	2.0 and 3.5	Insignificant Kill	Rock Creek Lake[2]
50	8.5	67 - 51	170	10 (approx.)	170	6.0 and 7.0	Satisfactory	Rock Creek Lake[2]
25	8.7	74	205	10 (approx.)	-	3.0	Insignificant Kill	Pibel[1]
25	8.7	74	205	10 (approx.)	-	7.0	Satisfactory	Pibel[1]
490	9.1	62	262*	48*	204	7.5	Insignificant Kill	Whitewater Lake[3]
14.2	8.4 - 8.5	82	175	5	200	8.0	Satisfactory	East Hord
315	8.4 - 8.5	72	222	3	-	8.0 - 10.0	Inadequate Kill	Wagon Train
8.5	8.5	71.5	205	0	257	4.5 shore 1.3 center	Satisfactory	West Hord
6.0	8.4	77	222	0	188	4.0 shore 0.9 center	Satisfactory	Louisville #1
18.0	8.4	79	222	0	188	3.5 shore 0.7 center	Inadequate Kill	Louisville #2
1.0	8.5	79	188	0	274	2.0	Excessive (Total)	Bader #1
3.3	8.5	73	222	0	342	1.0	Satisfactory	Bader #6

*Measured 8 days following treatment.

1. Rupp, L. 1974. Unpublished data and personnel communication. Nebraska Game and Parks Commission

2. Madson, M. 1974. Unpublished data. Nebraska Game and Parks Commission

3. Berger, Bernard L., P.A. Gilderhus and R.E. Lennon. 1967. Attempted Reclaimation of Whitewater Lake Valentine National Wildlife Refuge, Nebraska. U.S. Department of the Interior Bureau of Sport Fisheries and Wildlife.

Table 2. Toxicant Concentrations Indicated by Sealed Bag Bioassay Procedures and Actual Treatment Concentrations Required

Lake Name	pH	Phen. Alkalinity	Concentration Indicated by Bioassay	Approximate Concentration Actually Required
Pibel *	8.7	10 ppm	3 ppb	7 ppb
Rock Creek Lake **	8.5	10 ppm	< 2 ppb (all fish dead or distressed in all treated bags)	7 ppb
West Hord	8.5	0	< 2 ppb (all fish dead in all treated bags)	4 ppb
Louisville #1	8.4	0	< 2 ppb (all fish dead in all treated bags)	4 ppb
Bader Lake #1	8.5	0	< 2 ppb (all fish dead in all treated bags)	1 ppb
Bader Lake #2	8.5	0	< 1 ppb (all fish dead in all treated bags)	1 ppb

Table 3. Depth Penetration of Fintrol Concentrate as Indicated by Live Cages Set During Three Shoreline Renovations

Live Cage Depth	Survival		
	West Hord* (4.5 ppb)	Louisville #1 (4.0 ppb)	Louisville #2 (3.5 ppb)
5'	1 black crappie, 4 bluegill. All dead after 48 hours.	6 bluegill, 1 white crappie. All dead after 18 hours.	10 bluegill, all dead after 24 hours.
7'	---	5 bluegill, 3 white crappie, 2 bluegill and 2 crappie dead after 20 hours.	4 white crappie, 6 bluegill. All bluegill escaped. 1 crappie dead, 3 alive after 24 hours.
10'	1 green sunfish x bluegill hybrid, 1 green sunfish, 6 bluegill. All alive but all distressed after 48 hours.	5 bluegill, 2 crappie. 1 bluegill, 2 crappie dead after 19 hours.	8 bluegill and 2 white crappie. All bluegill dead, both crappie alive after 48 hours.

*Control cages set at both depths previous day sustained no mortality.

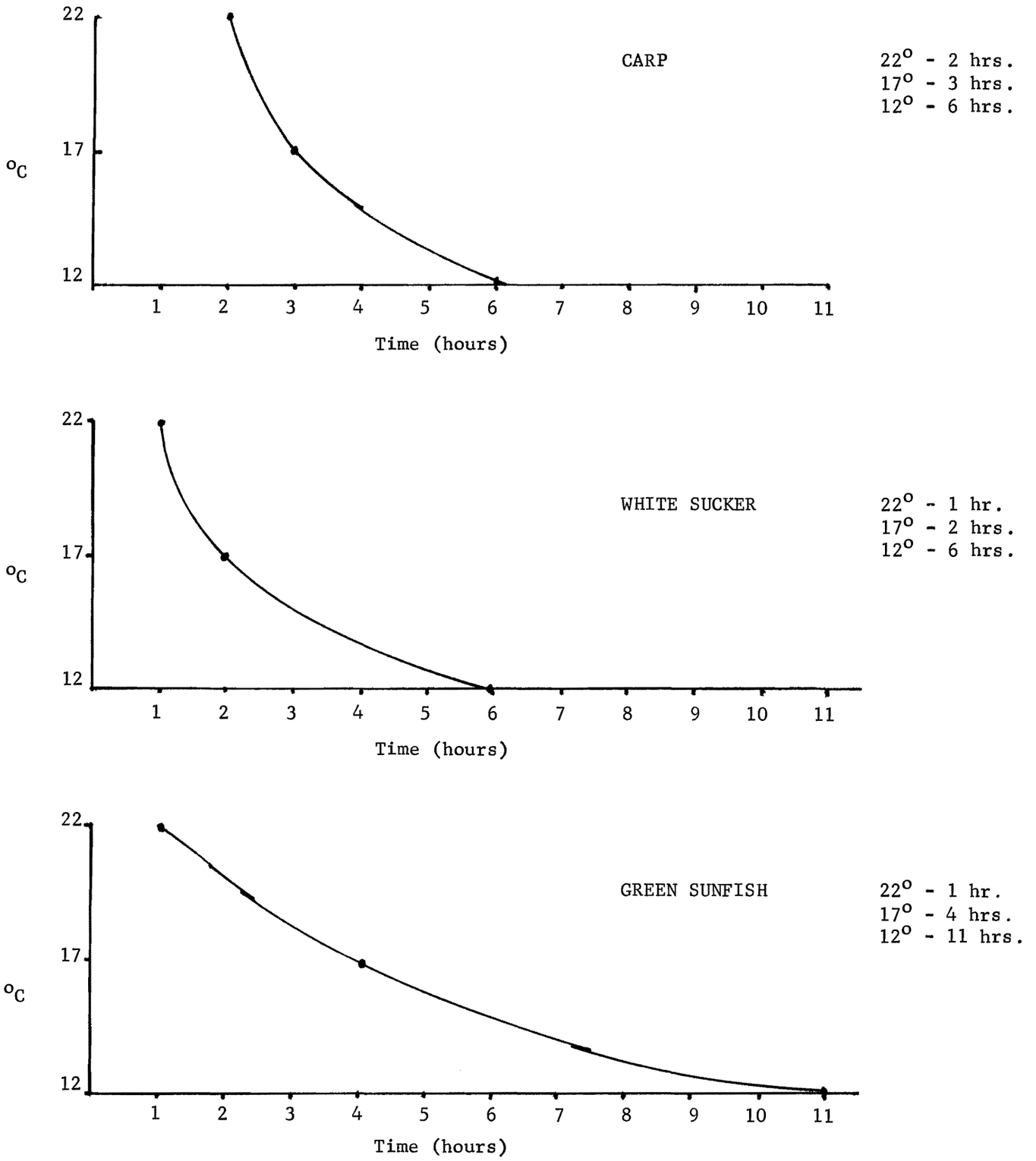

Figure 2.--The influence of temperature upon effective contact time to eliminate selected species of fish with 5 ppb antimycin (Gilderhus, 1972).

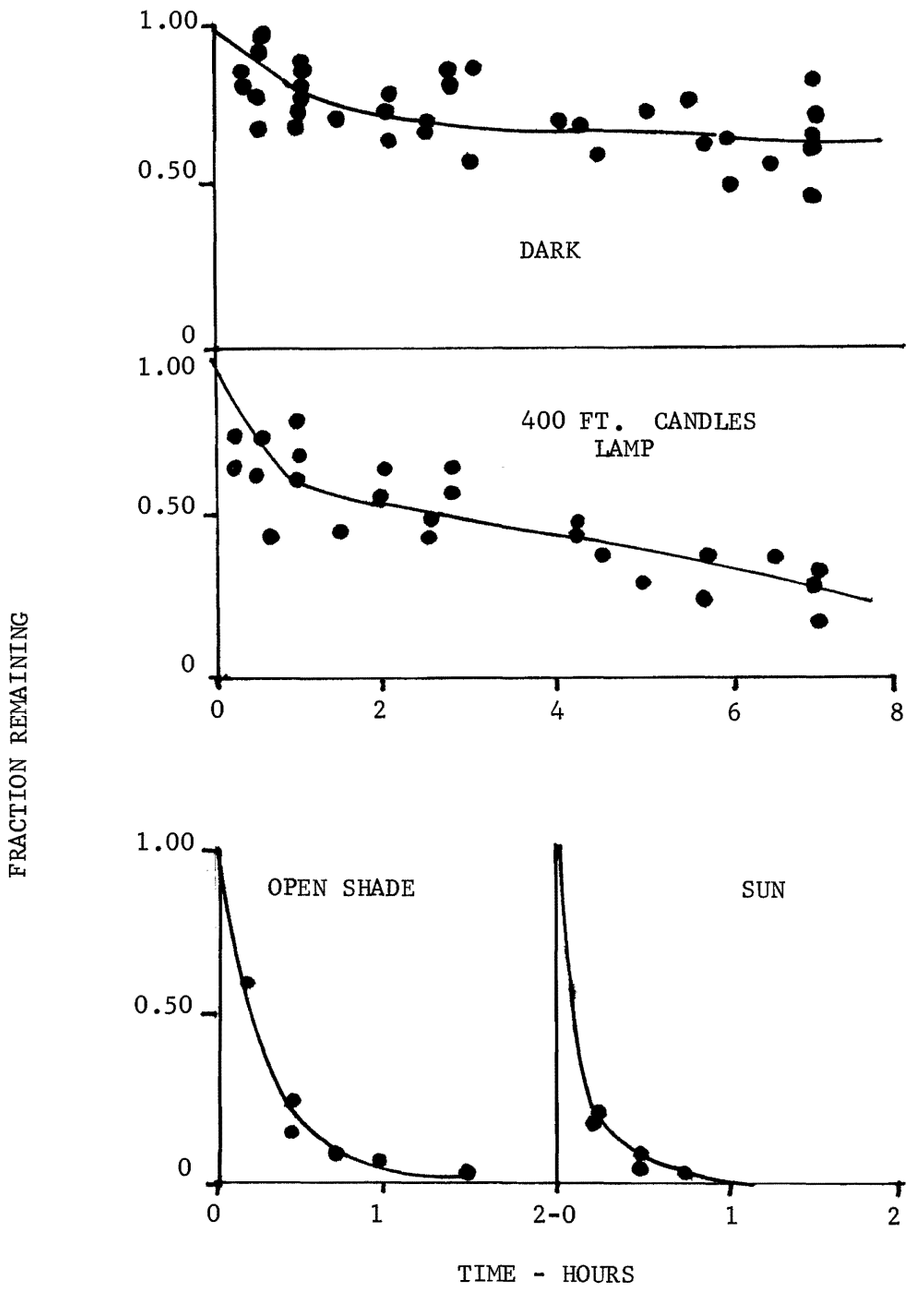

Figure 3.--Fraction antimycin remaining versus time at various light intensities at pH's 6.5-7.0. (From Lee et al., 1971)

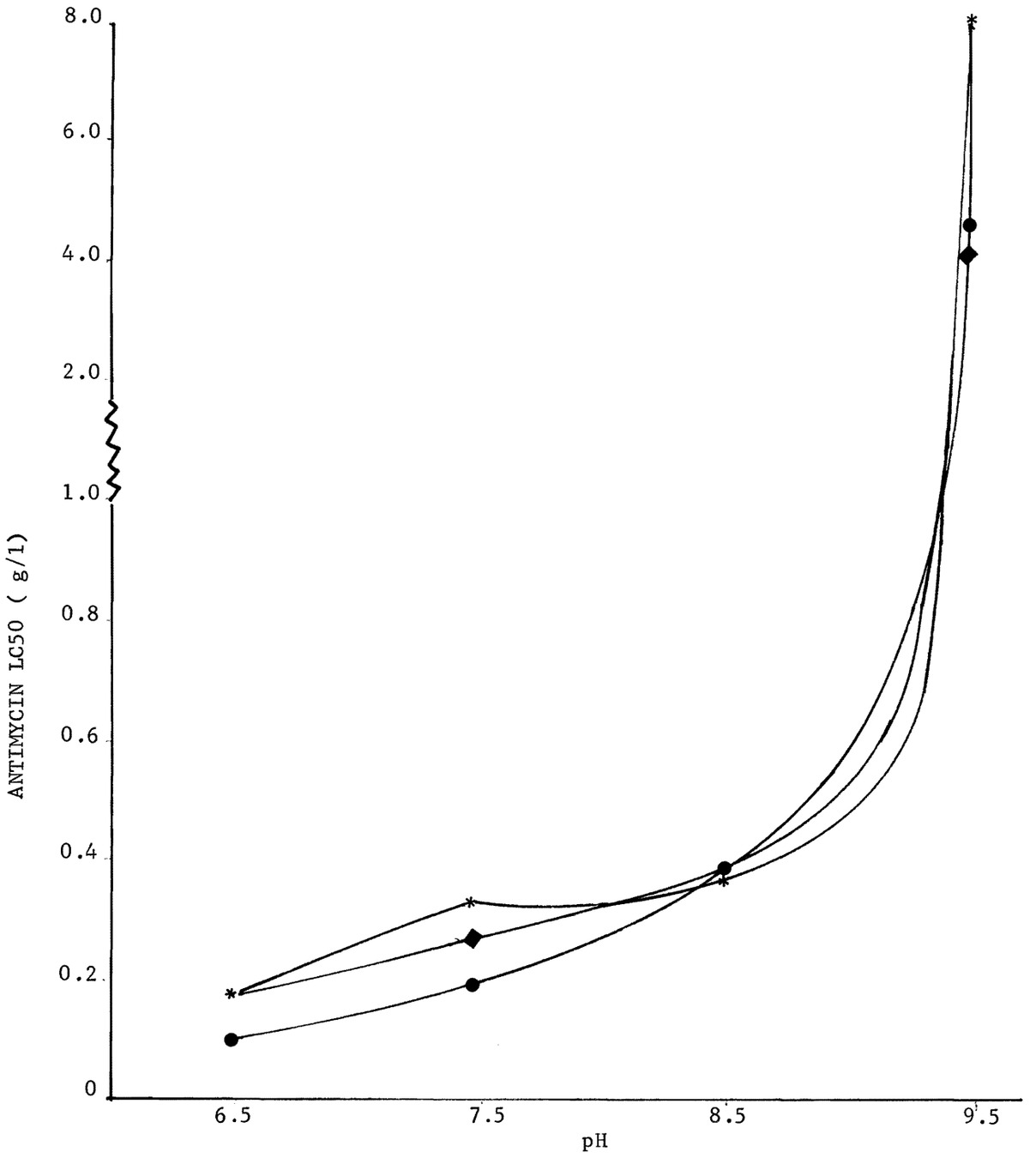

Figure 1.--Toxicity of antimycin to carp ◆, green sunfish * and bluegill ● in soft water at 12 C. (From Marking, 1972)