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FISH TOXIFICATION: BIOLOGICAL SANITY OR INSANITY?

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ABSTRACT

In opposition to massive fish poisoning projects in Wisconsin, environmental organizations and the academic community have sought relief through the courts. Strongest opposition has been directed against the Wisconsin Department of Natural Resources in its antimycin-rotenone program for the Rock River watershed, which includes 5% of the total area of the state. Pre- and post-treatment surveys of several waters have shown a sharp decrease in the number of species of fish. An analysis of antimycin field tests held in 1965 and 1967 showed, even as late as 1972, a decrease in the number of fish species and an apparent reduction in the number of individuals for many species. Attention is called to the fact that ecological changes have not been investigated, nor is it clear why certain fish populations have remained depressed. Concern is voiced for the unique gene pools in forage fishes and for the rare and endangered fishes which are eliminated through mass poisoning projects. In Wisconsin no attempts have been made to protect known rare and endangered fishes. Also, the effects of antimycin on aquatic insects, clams, and other organisms are just beginning to become evident. Initial data show that clams are particularly sensitive, and that some species may have been eradicated. Mass poisioning of waters appears to work contrary to those biological and ecological principles which support the concept that great species diversity leads to stability of the environment. I am concerned that a reduction in species diversity will lead to instability, accompanied by new, often unforeseen, problems. Careful use of fish toxicants and renewed emphasis on standard fish management procedures are recommended. A policy statement on the use of fish toxicants for fish management is included.

In recent years opposition has grown in Wisconsin against the accelerated and massive fish poisoning programs undertaken by the Wisconsin Department of Natural Resources (DNR). So heated has this opposition become that on 18 November 1971, Wisconsin's Governor Patrick Lucey appointed a study committee on the use of toxicants for fish management. The committee's report, completed in February 1972, is included as an appendix to this paper. These recommendations were sent with the Governor's approval to the DNR for adoption. To date no official confirmation has been received by the study committee as to the status of the statement within DNR.

Position papers regarding fish poisoning programs have been prepared by both parties. The stance of DNR was represented by Threinen (1972) and Schneberger (1973). I wrote in opposition (Becker 1972a, 1973) and repeat here the findings and opinions that support my point of view.

In 1971 the State of Wisconsin initiated a rotenone-antimycin project in the Rock River basin, a 2,594-square-mile watershed in southeastern Wisconsin between Madison and Milwaukee. "The drainage area includes all or parts of ten counties, five percent of the state area. A total of 2,802 miles of streams are considered for treatment in this proposal as well as 100,400 acres (157 square miles) of marshes and 39,940 acres (62.4 square miles) of lakes and ponds." (U.S. Bureau of Sport Fisheries and Wildlife and DNR 1972).

Completion is planned by September 1977. It is estimated that chemicals and airplane rentals may cost $1.2 million and labor $2.4 million. Expenses for equipment, fish barriers, restocking, and pre- and post-treatment studies may bring the total cost to near $5 million.

It has been stated publicly by fish managers that deterioration may set in soon after treatment and that the program may have to be repeated within 5 to 7 years to maintain the quality of fishing desired.

The opposition, coming primarily from environmental organizations and the academic community, carried the matter to Wisconsin courts in 1971 and 1973, naming DNR the defendant. The plaintiffs claimed that the fish poisoning program would have the following effects, among others:

1. Members of all species of fish will be killed—not only game and pan fish and others whose presence in the stream is known and which can presumably be replaced after the poison has dissipated, but also other native species whose presence in the stream is now unsuspected, and which perhaps cannot be replaced.
2. Members of other, perhaps numerous, species of native animal life other than fish will be killed, including certain insects, molluscs, and other invertebrates, and certain amphibians and other vertebrates, to an extent impossible to ascertain because of the lack of accurate information about the species present and their abundance.
3. Some rare and endangered species of fish may be destroyed.
4. Certain native species of fish and other forms of animal life may be completely and permanently eliminated from the Rock River system.
5. Species diversity in the Rock River system may be permanently reduced.
6. Later production of valuable game and pan fish may be permanently diminished or impaired.
7. Later return of the ecosystem to a state of high biological and esthetic value may be permanently prevented.
8. Because of destabilization of the ecosystem, constant management and increased public expenditures may be required to keep the treated waters in a permanently productive and valuable condition.

The plantiffs held that DNR is in violation of its duty as trustee to maintain, manage, and protect the navigable waters of the state from pollution; and that poisoning the Rock River system violated the DNR's responsibilities under said trust, by the destruction of various forms of fish and animal life which will be irrevocably lost.

A hearing in August 1973 before a State of Wisconsin Circuit Judge failed. On 13 November 1973, the decision was appealed to the Supreme Court of the State of Wisconsin, where the case rests as of this writing.

EFFECTS OF TOXICANTS ON FISH DIVERSITY AND NUMBERS

Fishery inventories were made on the Tomorrow River, in central Wisconsin, 1 month before and 11 months after treatment. Total numbers of species and individuals captured were both lower in the post-treatment inventory (Table 1).

In addition to reestablishment of fish from untreated tributaries, baitfishes from a bait dealer had access to this section of the river. The DNR, in addition to stocking brown and rainbow trout, reported that it returned specimens of the following species to the river system: sculpin, common shiner, blacknose dace, Johnny darter, fantail darter, banded darter, blackside darter, and logperch (J. F. Zimmerman,

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Species[a]
Brown trout
Rainbow trout
Northern pike
White sucker
Creek chub
Hornyhead chub
Blacknose dace
Longnose dace
Southern redbelly
Common shiner
Spotfin shiner
Bigmouth shiner
Sand shiner
Emerald shiner
Blacknose shiner
Brassy minnow
Bluntnose minnow
Fathead minnow
Stoneroller
Yellow perch
Johnny darter
Mottled sculpin
Brook stickleback
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TABLE 1. *Species and numbers of fish collected in Tomorrow River before and after the stream was treated with antimycin in October 1971. (Each collection was made in about 6 seine-hours by ichthyology classes near Amherst–Sect. 28 and 29, T23N, R10E, Portage County, Wis.)*

Species[a]	Pre-treatment (1 September 1971)	Post-treatment[b] (30 August 1972)
Brown trout	2	52
Rainbow trout	–	61
Northern pike	1	–
White sucker	63	46
Creek chub	36	–
Hornyhead chub	47	1
Blacknose dace	2	–
Longnose dace	65	–
Southern redbelly dace	9	–
Common shiner	488	146
Spotfin shiner	1	–
Bigmouth shiner	22	6
Sand shiner	–	2
Emerald shiner	30	6
Blacknose shiner	1	–
Brassy minnow	61	–
Bluntnose minnow	27	3
Fathead minnow	16	–
Stoneroller	–	3
Yellow perch	22	–
Johnny darter	100	4
Mottled sculpin	8	–
Brook stickleback	1	2
Total number of fish	1,002	332
Total number of species	20	12

[a]Specimens are housed in the Museum of Natural History, Univ. of Wisconsin–Stevens Point, except for 48 brown trout and 55 rainbow trout caught during the post-treatment survey, which were returned to the stream.

[b]Fishes taken from the holdings of Rhode's Bait Farm at Amherst, about 1/4 mile above the collection site, 6 Nov. 1972, were as follows (reported by Dan Sexton): common shiner, brassy minnow, hornyhead chub, fathead minnow, blacknose dace, white sucker, brook stickleback, and Johnny darter. The holding ponds drain into the Tomorrow River.

interdepartmental memorandum, DNR, 2 February 1972).

Similar data for a downstream site in Waupaca County also showed that total numbers of species and individuals captured dropped in the post-treatment inventory (Table 2).

TABLE 2. *Species and numbers of fish collected in Waupaca River before and after the stream was treated with antimycin in October 1971. (Each collection was made in about 6 seine-hours by ichthyology classes at River Road–Sect. 15, T 22 N, R 11 E, Waupaca County, Wis.)*

Species[a]	Pre-treatment (1 September 1971)	Post-treatment (30 August 1972)
Brown trout	–	19
Brook trout	3	–
Central mudminnow	–	3
White sucker	134	19
Northern hog sucker	13	–
Golden shiner	1	–
Creek chub	31	180
Blacknose dace	31	31
Longnose dace	67	7
Finescale dace	–	1
Common shiner	158	26
Emerald shiner	3	12
Spottail shiner	–	1
Brassy minnow	1	–
Bluntnose minnow	2	1
Fathead minnow	1	2
Stoneroller	6	–
Smallmouth bass	–	4
Yellow perch	2	–
Johnny darter	33	–
Rainbow darter	3	–
Banded darter	15	–
Fantail darter	1	–
Mottled sculpin	48	–
Brook stickleback	–	6
Total number of fish	553	312
Total number of species	19	14

[a]Specimens are housed in the Museum of Natural History, Univ. of Wisconsin–Stevens Point, except for 14 brown trout and 3 smallmouth bass, which were returned to the stream.

In August 1971 more than 230 miles of the East Branch of the Rock River and tributaries in southcentral Wisconsin were treated with antimycin and rotenone. The objective was the total elimination of carp. The dosage of 15 parts per billion (ppb) of antimycin would eliminate, according to prescription, all species of fish except members of the catfish, gar, and bowfin families. Pre-treatment studies were completed in the summer of 1971 by DNR biologists. Ten months after the treatment the number of fish species had decreased sharply in all areas studied (Tables 3-5). Wherever numerical data were available in the pre-treatment survey, a strong decrease was noted in numbers of each species as well, except in Limestone Creek.

The differences in the effectiveness of fish survey methods (i.e. electrofishing by Priegel and Brynildson vs. seining by the other collectors) in highly silted waters was indicated by collections with the two gears in pre-treatment inventories of the West Branch of Rock River (Table 6). Although only 300 yards were sampled by seine compared with 1 mile by shocker, the seine took five more species and larger numbers of individuals. The data of Table 6 thus support the reliability of the comparisons made in Tables 3-5. Also, it is apparent that species diversity was great before

TABLE 3. *Species and numbers of fish collected in Limestone Creek (Washington County, Wis., near county trunk highway W) before and after the stream was treated with antimycin in August 1971.*

Species	Pre-treatment 1971[a]	Pre-treatment 21 July 1971[b]	Post-treatment (12 June 1972)[c]
Carp	–	x	–
Stoneroller	3	–	–
Redfin shiner	–	x	–
Common shiner	2	x	–
Southern redbelly dace	1	–	–
Fathead minnow	–	x	–
Bluntnose minnow	3	x	–
Creek chub	5	–	–
Fantail darter	–	x	–
Iowa darter	–	x	–
Least darter	–	x	–
White sucker	3	–	–
Brook stickleback	–	x	–
Central mudminnow	1	–	1
Yellow bullhead	1	–	–
Black bullhead	–	x	20
Green sunfish	–	x	–
Tadpole madtom	–	–	1
Northern pike	–	–	2
Pumpkinseed	–	–	2
Total number of fish	19	–	26
Total number of species	8	11	5

[a]Priegel and Brynildson (1971). Collections were made with electrofishing gear in 1.5 miles of stream.
[b]Collections made with minnow seines by Clifford Germain and Don Samuelson. Pre-treatment data for the basin of the West Branch of the Rock River, on file, Wisconsin Department of Natural Resources, Madison.
[c]Collections made with minnow seines in 300 yards of stream by George Becker, Don Samuelson, Ralph Albrecht, and David Becker. Post-treatment data for the upper Rock River basin, on file, Museum of Natural History, University of Wisconsin–Stevens Point.

TABLE 4. *Species of fish collected in the East Branch Rock River (upstream from Allenton, Washington County, Wis.) before and after the stream was treated with antimycin in August 1971. (x=species collected)*

Species	Pre-treatment[a] (21 July 1971)	Post-treatment[b] (12 June 1972)
Minnows		
Carp	x	–
Golden shiner	x	–
Emerald shiner	x	–
Redfin shiner	x	–
Common shiner	x	–
Creek chub	x	–
Bluntnose minnow	x	–
Fathead minnow	x	1
Southern redbelly dace	x	–
Darters and forage species		
Blackstripe topminnow	x	–
Iowa darter	x	–
Johnny darter	x	–
Blackside darter	x	–
White sucker	x	–
Central mudminnow	x	1
Brook stickleback	x	1
Game and pan fish		
Northern pike	x	2
Yellow perch	x	–
Rock bass	x	–
Green sunfish	x	–
Pumpkinseed	x	–
Bluegill	x	–
Longear sunfish	x	–
Largemouth bass	x	–
White crappie	x	–
Black bullhead	x	4
Tadpole madtom	–	4
Total number of fish	–	13
Total number of species	26	6

[a]Collections made with minnow seines along 300 yards of stream by Clifford Germain and Don Samuelson.
[b]Collections made by Becker et al. (see footnote c, Table 3).

TABLE 5. *Species and numbers of fish collected in East Branch Rock River (county trunk highway D to Bridge Road, Washington County, Wis.) before and after the stream was treated with antimycin in August 1971.*

Species	Pre-treatment[a] (1971)	Post-treatment[b] (12 June 1972)
Stoneroller	17	–
Carp	145	–
Common shiner	2	–
Redfin shiner	15	–
Bluntnose minnow	26	–
Creek chub	1	–
White sucker	38	–
Stonecat	1	–
Rock bass	20	–
Green sunfish	80	–
Bluegill	2	–
Pumpkinseed	10	3
Fantail darter	2	–
Johnny darter	3	–
Blackside darter	1	–
Yellow perch	–	1
Central mudminnow	1	2
Northern pike	22	7
Blackstripe topminnow	46	1
Black bullhead	85	7
Yellow bullhead	5	–
Channel catfish	–	3
Total number of fish	522	24
Total number of species	20	7

[a]Collections made with electrofishing gear in 1.5 miles of stream (Priegel and Brynildson 1971).
[b]Collections made with minnow seines in 400 yards of stream by Becker et al. (see footnote c, Table 3).

TABLE 6. *Species and numbers of fish collected with different gears in West Branch Rock River (Fond du Lac County, Wis., near Highway 151) before the stream was treated with antimycin. (VA=very abundant)*

Species	Gear and date: Electro-fishing (1971)[a]	Minnow seine (12 June 1972)[b]
Central mudminnow	4	3
Northern pike	27	3
Stoneroller	–	1
Carp	VA	7
Common shiner	–	5
Redfin shiner	–	8
Redbelly dace	88	3
Bluntnose minnow	6	15
Fathead minnow	5	14
Creek chub	1	–
White sucker	VA	60[c]
Black bullhead	9	55
Yellow bullhead	–	6
Green sunfish	8	10
Yellow perch	–	1
Rainbow darter	11	10
Fantail darter	1	3
Johnny darter	8	20
Blackside darter	–	1
Total number of fish	>168	225
Total number of species	13	18

[a]Collections made with electrofishing gear in 1.0 mile of stream (Priegel and Brynildson 1971).
[b]Collections made with minnow seines in 300 yards of stream by Becker et al. (see footnote c, of Table 3).
[c]Fifty-seven white suckers were young of the year.

treatment, and similar to that reported by Greene (1935).

Antimycin field trials were instituted in Wisconsin during the mid-1960's (Gilderhus et al. 1969). My colleagues and I operated electrofishing gear in two streams in September 1972 to determine recovery of species diversity and numbers. The number of species in Sidie Hollow Creek (west-central Wisconsin) dropped from 11 to 7. The post-treatment collections included one new species, the bluegill (Table 7), which, along with trout, was stocked in the stream and its new impoundment, Sidie Hollow Lake. Even many years after treatment, the creek appeared sterile for a stream of its size and character. From Westfield Creek of central Wisconsin, we captured one species more than was recorded in 1967, before treatment (Table 8). Of the 16 species taken in 1972, the presence of brown trout, yellow bullhead, rock bass, green sunfish, black crappie, and yellow perch—all game and pan fish—may be the result of stocking after treatment. The remaining species were generally relatively scarce.

All the above studies, including those of the earliest antimycin treatments, indicate a general reduction in species diversity, and an overall reduction in the number of

TABLE 7. *Species and abundance of fish collected in Sidie Hollow Creek (Vernon County, Wis.) before and after the stream was treated with antimycin on 13 August 1965. (A=Abundant; C=common; S=scarce)*

Species	Pre-treatment (July-August 1965)[a]	Post-treatment (2 September 1972)[b]
Rainbow trout	S	–
Brown trout	S	3
Stoneroller	C	16
Blacknose dace	A	5
Longnose dace	C	–
Creek chub	C	3
White sucker	C	6
Northern hog sucker	S	–
Brook stickleback	C	56
Bluegill	–	2
Johnny darter	C	–
Mottled sculpin	S	–
Total number of fish	–	91
Total number of species	11	7

[a]Gilderhus et al. (1969). (Collections made before purported 100% kill of all species.)
[b]Collected by George Becker, Tom Joy, and Dan Sexton by electrofishing in 200 yards of stream, beginning 1/4 mile above Sidie Hollow Lake (Sect. 3, T 12 N, R 5 W).

individuals for many species. Species which seem to be sharply reduced in numbers or eliminated after applications of 15 ppb (10 ppb in Westfield Creek) of antimycin are as follows (Table 1-5, 7, 8):

Lampreys
- American brook lamprey

Trouts
- All species

Suckers
- White sucker
- Northern hog sucker

Minnows
- Carp
- Hornyhead chub
- Blacknose dace
- Longnose dace
- Emerald shiner
- Brassy minnow
- Common shiner
- Stoneroller
- Northern redbelly dace
- Southern redbelly dace
- Fathead minnow

Pike
- Northern pike

Topminnow
- Blackstripe topminnow

Darters
- Johnny darter
- Rainbow darter
- Banded darter
- Fantail darter
- Iowa darter
- Least darter
- Blackside darter

Sunfishes
- Rock bass
- Green sunfish
- Pumpkinseed

Sculpin
- Mottled sculpin

Ecological changes which resulted from the treatment have not been investigated. That something is operating to depress populations of species that find their way back into the treated system appears evident. Statistically all the above studies fail because replicate pre- and post-treatment studies are not available. In a particular stretch of water in a single run, not all species are captured nor are the species composition and abundance identical in all seasons. To get valid pre- and post-treatment data, one should conduct a number of surveys at a particular station, using a variety of collecting

TABLE 8. *Species and abundance of fish collected in Westfield Creek (Marquette County, Wis.) before and after the stream was treated with antimycin on 29 June 1967. (A=abundant; C=common; S=scarce)*

Species	Pre-treatment (June 1967)[a]	Post-treatment (2 September 1972)[b]
American brook lamprey	C	4
Rainbow trout	S	–
Brown trout	–	6
Carp	A	–
Bluntnose minnow	A	66
Fathead minnow	C	–
Blacknose dace	A	–
Creek chub	C	20
White sucker	A	15
Yellow bullhead	–	2
Tadpole madtom	–	5
Brook stickleback	S	–
Rock bass	–	1
Green sunfish	–	4
Pumpkinseed	S	39
Bluegill	C	13
Largemouth bass	C	5
Black crappie	–	2
Fantail darter	C	–
Johnny darter	C	4
Yellow perch	–	2
Mottled sculpin	C	2[c]
Total number of fish	–	190
Total number of species	15	16

[a]Gilderhus et al. (1969). (Collections made before purported 100% kill except for American brook lamprey [50%]).
[b]Collected by George Becker, Tom Joy, and Dan Sexton by electrofishing in 400 yards of stream from a point 80 yards below town road bridge to 320 yards above it (Sect. 9 and 10, T 1 N, R 8 E).
[c]Taken from tributary spring.

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Pre-treatment (... ıne 1967)[a]	Post-treatment (2 September 1972)[b]
C	4
S	–
–	6
A	–
A	66
C	–
A	–
C	20
A	15
–	2
–	5
S	–
–	1
–	4
S	39
C	13
C	5
–	2
C	–
C	4
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–	190
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A contrasting viewpoint was expressed by Schneberger (1973):

> In reality, about the only non-target animals that might be affected might be a very limited number of little-known and poorly-identified species of fish that probably make little or no contribution to the well-being of the environment. In addition, these seem to exist in the shallow water tributaries which would not be treated, thereby leaving seed stock for future repopulation.

Whether this paragraph fits into our 1973 conceptions of the diversity and stability of the environment is for the reader to decide. One wonders why the fish which will be destroyed are "little-known" and why they need be "poorly-identified." In the absence of such information, the claim that they "probably make little or no contribution to the well-being of the environment" is difficult to support. In the statement that "these seem to exist in the shallow water tributaries which would not be treated, thereby leaving seed stock for future repopulation," the word "seem" appears to disregard responsibility and dismiss ecological principles.

EFFECTS OF TOXICANTS ON RARE AND ENDANGERED SPECIES OF FISH

Rare and endangered species present a special problem (Becker 1972b). Frequently they are so depleted in numbers that they may not be captured in a pre-treatment survey, resulting in a loss of that population through ignorance. When in 1971 the DNR treated the Crystal River in the Tomorrow-Waupaca Basin, a single specimen of a greater redhorse was discovered among the thousands of fish killed in Carey Pond of the lower Crystal River. I alerted the DNR that this rare fish was in the watershed and that care should be exercised in making certain that the population was not destroyed. At the same time, I called attention to the possibly damaging effects of drawdown on the only known population of the western sand darter (Becker 1965) in the Great Lakes drainage. No corrective action was taken by DNR, but in its "Endangered animals in Wisconsin" (Hine 1973) the greater redhorse was given "endangered" status. However, the unique population of the western sand darter in the Great Lakes drainage is given no special Wisconsin recognition because, according to DNR, it is fairly common in parts of the Mississippi drainage of the state.

In 1971, before the treatment of the East Branch of the Rock River, attention was called to a population of longear sunfish, one of four known populations in Wisconsin. Nevertheless, this population was destroyed by the treatment. The longear sunfish was later given "changing status," which includes those species "that may or may not be holding their own at the present time" (Hine 1973). In the same category is the redfin shiner, a population of which was eliminated in the August 1973 treatment of the West Branch of Rock River (see Table 6).

In Wisconsin no attempt has been made to date in any antimycin treatment to salvage known rare species. The prevailing attitude which has developed in official circles with respect to the species of fish, rare or otherwise, was stated by Threinen (1972):

> We fully recognize that in some places we may hurt populations of unique fishes such as the many species of darters. However, even they are commonly given a chance to repopulate their habitat because stream treatment covers only those portions of the waterways where competitive species are giving problems. On the Tomorrow River, for example, treatment began at a point above the Nelsonville millpond and left many miles of trout water above. We are sensitive to the needs of rare species, but at the same time recognize that in some places the greater public good will have to prevail.

A number of points made by Threinen are debatable. The fact is that populations of unique gene pools are removed through total-kill fish removal programs. After treatment, these are not necessarily replenished by upstream small-water populations of fishes. In fact, large-water main stem fishes may be completely removed. Some redhorses, darters, and minnows are found commonly only in large-water areas—all of which may be scheduled for treatment. If no provision is made for preserving the stocks, the species may be permanently removed from such waters.

The dismissal of rare species because "the greater public good will have to prevail" is a judgment value subject to challenge. Fish management appears to be setting itself up as superior judge for present and future generations. That rare species may be sacrificed for "the greater public good" is unacceptable to many ecologists, philosophers, theologians, and others. I find such an attitude difficult to comprehend, in that it is being espoused by the very agency entrusted with the protection of natural resources.

EFFECTS OF TOXICANTS ON ORGANISMS OTHER THAN FISH

The effects of antimycin on benthic macroinvertebrates in the natural stream environment are just beginning to be understood. Gerald Jacobi, of the University of Wisconsin–Stevens Point, collected both pre- and post-treatment samples from the Tomorrow-Waupaca River (results unpublished) and Johnson (1972) tabulated pre- and post-treatment inventories of macroinvertebrates from the East Branch of the Rock River, Dodge County, Wisconsin.

Jacobi and Degan (1972) reported that some macroinvertebrate taxa exhibited a delayed mortality varying from 1 to 4 weeks after treatment. Degan (1973) found that most invertebrate taxa were sharply reduced; chironomids and simuliids recovered quickly but at the end of the 7-month sampling period a caddisfly and a cranefly were still depressed in numbers.

Bruce Markert (Institute of Paper Chemistry, Appleton, Wisconsin, personal communication) reported that the population of macrobenthos in the West Branch of Rock River was "virtually wiped out from the chemical treatment, except for beetles, midges, and flatworms; but my last harvest has shown that the population is on its way back. . . ."

Mathiak (1972), who studied the mussels of the East Branch of Rock River, found that peak mortality occurred 16 to 19 days after treatment. One species, *Alasmidonta calceolus*, was eliminated from the study area by the 27th day after treatment, and others were substantially reduced in numbers.

Mathiak (1973) also studied the effects of the 1973 fish-poisoning program on the mussels of the Rock River from Horicon to Waupuun and Kekoskee. He collected 1,681 dead or dying shells, among which were 10 of the rare paper pond shell, *Anodonta imbecillis*—"one of the rarest mussels in Wisconsin." Mathiak stated:

> It is doubtful if the clam population will ever recover from this drastic mortality. An electrical barrier at Hustisford will prevent glochidia bearing fish from moving upstream. Most of the fish used in restocking will come from lakes already treated with fish toxicants and are not likely to provide glochidia. . . . The decimation of fish species further decreases the chances of reproduction in the widely scattered individual clams surviving the 1973 treatment. Fish control projects using antimycin thus are a real threat to clams many of which are already in a precarious condition due to siltation and pollution.

Antonioni (1973) exposed two species of clams native to the Rock River to each of five dosage levels of antimycin at three temperatures. For both species, mortality increased significantly as temperature increased for antimycin concentrations of 12 or 15 ppb, but not for 5 or 10 ppb. There was an overall significant increase in mortality as temperature increased. Addition of fluorescein dye did not significantly increase mortality. Antonioni concluded that antimycin is harmful to clams at fish-killing concentrations. when tested under laboratory conditions in which pH and water quality are held constant.

Unexpected harmful results from the 1973 chemical treatment of the Rock River occurred when more than 8,000 local ducks on Horicon Marsh and Lake Sinissippi died in August and September, of a form of botulism known as western duck sickness. The bacteria in the exposed mud flats responded to high air temperatures and suitable moisture levels.

DISCUSSION

McAllister (1970) wrote that, among the many man-made environmental changes which are occurring with unprecedented magnitude and rapidity, are "pollution . . . spraying of biocides."

A similar observation was made by Johnson (1973), who called attention to the problems which may follow pesticide pollution: "Non-target organisms, such as predators that control pests, fish, birds or other wildlife may be destroyed. . . . Pests may develop that are resistant to common pesticides. . . . Former non-pests may become pests if their natural predators are eliminated by pesticides." The article clearly summarized the effects of pesticide pollution. What the author failed to recognize was that fish poisoning is a form of pesticide pollution. The fact is that thousands of dead fish and associated organisms do not distinguish between euphemisms—they are dead in both cases.

Our knowledge of what happens to the aquatic ecosystem is sketchy at best. We still do not know all of the short- and long-range effects of antimycin, and in all likelihood we will never have all the answers. This in itself suggests caution in any treatment. We have no assurance that all is well and that we can use antimycin with less damage than we use DDT.

The opposition to the DNR policy maintains that there are priorities other than good fishing. Conservationists and environmentalists both say: "We have only one environment." As important as it is to supply game and pan fish for fishermen, is it not more important to protect what remains of our damaged aquatic environments?

I visualize a future when hunting and fishing will be for a landed elite—as we see it in Europe. The great masses will have to derive their enjoyment from knowing that the greater redhorses, the gravel chubs, and the gilt darters were recognized and saved from them way back in 1974, when agencies stopped dosing them with antimycin and using rotenone for a chaser.

A wise man sensed this program of imbalance—a program which tends to make the nonfishermen second-class citizens (and this means most Americans). He observed:

> Artificialized management has, in effect, bought fishing at the expense of another and perhaps higher recreation; it has paid dividends to one citizen out of capital stock belonging to all.

In many universities an ecological law is preached: "Allah is diversity of the environment and stability is his prophet." How can biologists wittingly reduce species diversity when they have learned about prior cases with disastrous consequences? Tell me, Who has given fish managers special license over the life and death of thousands of miles of our ecosystem? How can they justify their drip tanks, back-pack sprayers, and helicopters in reducing millions of fish and invertebrates—the big and the small, the common and the rare—to something less? Do not the laws of ecology apply to them as well as to the rest of us?

Leopold (1953) must have sensed this dilemma long ago when he wrote:

> One of the penalties of an ecological education is that one lives alone in a world of wounds. Much of the damage inflicted on land is quite invisible to laymen. An ecologist must either harden his shell and make believe that the consequences of sciences are none of this business, or he must be the doctor who sees the marks of death in a

community that believes itself well and does not want to be told otherwise.

> The outstanding scientific discovery of the twentieth century is not television, or radio, but rather the complexity of the land organism. . . . The last word in ignorance is the man who says of an animal or plant: 'What good is it?'

And there is still another consideration. Antimycin-killed fish are not recommended for human consumption. This means that thousands of tons of high-protein food must be buried. In a protein-hungry world in which starvation is a reality, can we afford to discard humanitarian concerns?

In parts of Europe and Asia the carp and its allies are a delicacy. And smoked carp at nearly $1 per pound in Wisconsin supermarkets is not exactly trash fish. Or perhaps it is the most expensive garbage known to man.

So committed have some departments of fish and game become to the use of fish poisons that now such programs "restore, reclaim, renew, and rehabilitate." They can do no wrong! Some agencies are convinced that the only effective management tools are rotenone and antimycin. They have locked themselves and the public into a panacea trap from which neither can escape.

I do not propose to review alternatives here. They are tough and expensive, but ecologically sound. They are spelled out in our management manuals; they are recognized in the State of Wisconsin Policy Statement on the Use of Toxicants in the Management of Aquatic Resources (Appendix).

Yes, even fish toxicants have useful applications (Becker 1973):

> Where used in confined and limited areas—such as hatchery ponds, artificial ponds, small lakes with stunted run-away populations of perch, and spawning concentrations of problem fishes—it can be a valuable management tool. However, when the "hatchery syndrome" (expansion of the hatchery pond concept to include natural waters) is promoted, when poisoning programs are prescribed for massive stream and reservoir systems, when natural diversity is destroyed simply to provide "good fishing and hunting," when programs are advanced without understanding impact on the many intricate and fragile life systems, when the very survival of man and the organisms upon which he depends are threatened, when the valuable products of poisoning are wasted and rendered useless—then it seems there must be a serious reordering of priorities.

William Ruckelshaus, former director of the Environmental Protection Agency, said, "Maintaining the life systems of our earth is our most sacred task."

We are not the only generation—it is to be hoped that others will follow. We have a responsibility to them. We must leave intact as much as we can.

There is no second chance.

There is no other alternative.

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APPENDIX

POLICY STATEMENT ON THE USE OF TOXICANTS IN MANAGEMENT OF AQUATIC RESOURCES[1]

Introduction:

The primary goal in the management of all our living resources must be to protect and enhance the integrity of ecosystems. A diversity of aquatic habitats and natural communities must be preserved to provide for education, research, and esthetic enjoyment. It should be recognized that other generations will follow ours, and that we have a responsibility to maintain a suitable number of untampered ecosystems in representative habitats throughout the State, and to place them "in trust" for the future.

Therefore, the manipulation of an ecosystem must only be undertaken after a comprehensive management plan has been formulated. Management projects should be highly coordinated and include the participation of all appropriate agencies to promote the most comprehensive and effective effort for resolving the total problem and managing the system.

Policy:

The following pertain to the management of aquatic ecosystems by the Department of Natural Resources or other agencies:

1. When management is planned, pre-operational surveys of sufficient scope and duration must be conducted at carefully selected stations to yield baseline data on kinds of abundance of aquatic flora, aquatic invertebrates, fish, amphibians, reptiles, waterfowl, and mammals. Post-operational surveys must be conducted at the selected stations for at least one year to measure any significant variations from baseline data on flora and fauna.
2. Pest populations which disturb natural systems should be managed by applying combinations of available techniques and alternatives such as:
   a. Harvesting by mechanical devices and utilization of the crop whenever possible.
   b. Assessment and correction of those conditions in the drainage basin which have contributed to the environmental deterioration of the aquatic habitat.
   c. Habitat manipulation and improvement.
   d. Biological control.
   e. Use of toxicants.
3. A toxicant should be used only as a last resort in any integrated management program

[1] Prepared by the Wisconsin Governor's Study Committee on the Use of Toxicants for Fish Management: Robert S. Cook, chairman, George Becker, Alfred M. Beeton, Philip N. Cook, Phillip H. Derse, Arthur Hasler, Robert E. Lennon, Paul Sager, and William Selbig. February 1972.

(see addendum). In situations where chemical treatment is necessary, the following conditions should be met:

a. Only EPA and FDA registered aquatic toxicants will be used. Utilization of such approved aquatic toxicants must be considered provisional. Toxicants, whether natural or artificial, may have deleterious side-effects with results more injurious than the benefits gained. Therefore, constant vigilance and evaluation in the use and effects of all approved toxicants must be emphasized.
b. All toxicants and associated chemicals used, e.g., dyes, solvents, carriers, shall degrade rapidly into biologically harmless products.
c. The toxicants and their formulations shall be as specific to the target species as technologically feasible. Solvents, dyes, and other chemicals used with a toxicant shall be restricted to concentration levels which do not increase the required toxicity of the formulation.
d. The procedure of toxicant application shall be as specific as technologically possible, e.g., adherence to current Federal guidelines.
e. Every reasonable effort must be made to protect and preserve all non-target species of plants and animals because species are an irreplaceable resource.

   Lists of unique, rare and edangered species of higher and lower plants and invertebrate and vertebrate animals in the State of Wisconsin must be prepared and updated periodically. These lists must be consulted and compared with an extensive and carefully conducted pre-treatment census. Project personnel must consult with specialists (outside the agency, if necessary) on the unique, rare or endangered species for the purpose of determining procedures which would ensure that these populations do not become eliminated. Pre-treatment bio-assays of toxicants should include as many non-target species as possible to allow an accurate prediction of mortalities. All efforts must be made to remove adequate populations of threatened non-target species prior to treatment and to restock them in the same areas to strengthen the stability of the biotic community. Also, this will ensure the preservation of unique genetic variations of non-target species.
f. Efforts should be increased for learning how to utilize surpluses of native and exotic aquatic species to augment food and fiber resources for societal needs.

4. The bureau of Environmental Impact in the DNR should develop a mechanism for external professional review of all management plans that involve chemical treatment. Adequate funds for this function should be made available if necessary.
5. Provisions must be made for a public review as will be provided by the enactment of Assembly Bill 875, *The Wisconsin Environmental Policy Act*, on the adequacy and suitability of each management plan after the agency has complied with the appropriate above conditions; or if the Wisconsin Environmental Policy Act (WEPA) is not enacted, provisions must be made for a public review as is outlined in the Federal Environmental Policy Act of 1970.

Recommendations:

1. Projects now pending should be subject to the above policy. The principles which this committee has adopted are applicable to these waters as well as to any waters slated for treatment under a long term fish management program.
2. Aquatic pesticide application by any agency, local county, state, or otherwise, shall conform to the provisions of the above policy.
3. We urge full consideration of the report of the Ad Hoc Committee to the Research Advisory Council, Wisconsin Department of Natural Resources, entitled, "Fish Toxicants and the Environment," April 1971.
4. A diversity of untampered aquatic habitats and natural communities throughout the State should be selected, set aside, and placed "in trust" for the future. This is the first priority and should receive immediate cooperative action from the Department of Natural Resources and the Scientific Areas Preservation Council.
5. A complete evaluation of the success and failure of past toxicant application programs is necessary. The DNR paper, "Summary of Lakes Treated with Toxicants (1941-68)," for example, is a possible starting point.
6. The Department should re-evaluate its definitions of "rough fish" and "trash fish." Serious consideration should be given to the proper use (in public speaking and in print) of these terms. The public is confused and being misled into thinking that the only good fish is the one which ends up in a fisherman's creel. All species in a natural ecosystem play a role, albeit not fully understood today by the biologist or fish manager.
7. Research:
   a. Detailed ecological case studies of selected lakes and streams–with and without chemical treatment history.
   b. Scientific documentation of short and long term detrimental effects to non-target species. This would include sublethal effects such as sterilization and decreased ability to survive stress.

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c. Detailed investigation of the harmful effects of toxicant degradation products such as blastmycic acid in the case of antimycin A. The possibility that degradation products may be nontoxic to fish but toxic to other fauna and aquatic flora must be investigated.
d. Study of the chemistry of the toxicants and their degradation products in natural waters; role in metal complexation, pathways for biomagnification, deviations from laboratory determined hydrolysis mechanisms and kinetics, etc.
e. Investigation of harmful ecological effects resulting from major fluctuations in population levels of ubiquitous species after chemical treatment.
f. A search for controllable segments of the life cycle of pest species.
g. Studies to determine the significance of water turbidity and its causes.
h. Encourage Statewide coordination of research on chemicals used in managing aquatic ecosystems. Research now being conducted by the Department of Natural Resources, the University of Wisconsin, Federal laboratories, etc., should be included.
i. Alternative methods of control other than chemical, e.g., use of predator species, interspecies competition, attractants, repellants.

8. We recommend that the Governor, after one year, request this same committee to review the above policy, evaluate the effectiveness of our recommendations, and to suggest corrections and improvements.

ADDENDUM TO THE POLICY STATEMENT

Some examples of pest problems that have involved the use of toxicants are as follows:

1. Exotic, transplanted, and native fishes.
2. The sea lamprey in the Great Lakes.
3. Viruses, bacteria, and parasites that cause serious fish diseases, and possibly public health problems; portions of streams and water-supply systems to fish hatcheries or municipalities have to be "sterilized" at times to eliminate disease organisms or their vectors.
4. Leeches in fish-production facilities and public swimming areas.
5. Snails that serve as hosts for "swimmer's itch" and human diseases.
6. Mosquito larvae contributing to nuisance or disease problems.
7. Insects preying on young fish in bait-fish and game-fish production facilities.
8. Crayfish in fish-production facilities.
9. Salamanders, especially the tiger salamander, in fish-production facilities.
10. Tadpoles and frogs, especially the bullfrog, in fish-production facilities.
11. Muskrats causing damage to water-control structures.
12. Slime-molds in paper production facilities.
13. Algae causing:
    a. Fishy tastes and odors in domestic water supplies
    b. Sickness or death in fish, wildlife, domestic animals and man
    c. Blooms in water-treatment and irrigation systems
    d. Slimes in water supplies
    e. Corrosion of concrete and steel pipes and conduits
    f. Oxygen depletion in ponds and lakes (summer-kill)
    g. Blooms in waters used for recreation, swimming, fishing and by municipalities and industries, etc.
    h. Off-color in water
14. Submergent and emergent aquatic plants.