# THE FATE OF FISH INTRODUCED AS PREDATORS ON INSECTS IN MISSOURI OXIDATION LAGOONS[1]

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ABTRACT. Five species of fish were stocked in several sewage oxidation lagoons in the vicinity of Columbia, Mo. These included bantam sunfish, bluegill, redear sunfish, golden shiner and black bullhead. Observations also were made in other lagoons stocked with goldfish and mosquitofish by municipal health department and other personnel.

Goldfish and golden shiners survived fairly well under conditions found in the oxidation lagoons. Mosquitofish (*Gambusia*) thrived under summer conditions but could not tolerate seriously cold weather. Clear ice on lagoons did not appear to be detrimental but when covered by snow caused anaerobic conditions, with concomitant mortality of fish and tadpoles.

Stocked fish made very little use of midge larvae as food. However, much further study is needed on fish stocking to determine their effectiveness in controlling insect populations in oxidation lagoons.

INTRODUCTION. The use of fish to control mosquito larvae is well-known. Gerberich (1946) reviewed the work that had been done on this subject up to the year 1942. Recent work on the use of fish in insect control includes that of Cook *et al.* (1964), Springer (1964), Bay *et al.* (1965), and Bay and Anderson (1966). *Gambusia* ranked high among the effective fish predators on mosquito larvae.

Most of the above work dealt with the use of fish as predators on aquatic insects in natural waters. With the exception of the work of Bay *et al.* (1965), little information is available on the use of fish as predators on insects in oxidation lagoons or in polluted water. Information on the biology and distribution of aquatic insects in Missouri oxidation lagoons has been reported by Fagan and Enns (1966), Roberts *et al.* (1967), Smith and Enns (1967; 1968), Kimerle and Enns (1968) and Smith (1969). Fisher (1962) reported on the rearing of golden shiners, *Notemigonus crysoleucas* (Mitchell), commercially in the Fayette, Missouri secondary and tertiary oxidation lagoons. These lagoons were described by Clare *et al.* (1960). Although these fishes survived adverse summer and winter conditions and showed good growth rates, they did not reproduce during the study period, 1959–1962.

In the investigation reported here, several oxidation lagoons were selected for study near Columbia, Missouri. Of prime interest, in addition to survival, was the question of effective predation by the fish on midge larvae as well as mosquitoes. Most of the fish used in stocking the lagoons were obtained through the cooperation of the Missouri Department of Conservation. Data on the fish stocking are found in Table 1. Additional observations were made of oxidation lagoons stocked with *Gambusia* by personnel of the Columbia Department of Health.

MATERIALS AND METHODS. Some of the fish used in stocking the lagoons were collected by the use of a one-fourth inch mesh drag seine about 15 feet long and 4 feet wide. A few *Gambusia* were collected from the lagoons by means of an

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TABLE 1.—The stocking of fish in oxidation lagoons near Columbia, Missouri, 1965.

| Species of Fish | Number of Adults Stocked | Date of Stocking | Lagoon Stocked | Size of Fish Stocked |
|---|---|---|---|---|
| Bantam sunfish, *Lepomis symmetricus* | 36 | May 25, 1965 | South Side Trailer Court | .... |
| Bluegill, *Lepomis machrochirus* | 275 | Aug. 4, 1965 | New Haven School No. 2 | ½" to 6" |
| Bluegill, *Lepomis machrochirus* | 5 | Nov. 6, 1965 | A&M Supply Co. North Cell | 5" |
| Redear sunfish, *Lepomis microlophus* | 6 | Nov. 6, 1965 | A&M Supply Co. South Cell | 6" |
| Redear sunfish, *Lepomis microlophus* | 200 | Dec. 10, 1965 | A&M Supply Co. South Cell | 2" to 3" |
| Golden shiner, *Notemigonus crysoleucas* | 50 | Nov. 6, 1965 | A&M Supply Co. North Cell | .... |
| Black bullhead, *Ictalurus melas* | 135 | May 13, 1965 | Midway Heights Elementary School | 2⅜" to 4⅛" |

aquatic dip net with a 40-inch handle. Routine tests for dissolved oxygen, pH, and temperature were made during each observation following procedures outlined in *Standard Methods for the Examination of Water and Wastewater,* Eleventh Edition, 1960. These data are on file in the Department of Entomology, University of Missouri–Columbia where they may be consulted. Copies are available on request.

RESULTS AND DISCUSSION. The Mosquitofish—*Gambusia affinis* (Baird & Girard). This active little fish reproduced quite rapidly and tolerated adverse summer conditions. Since cold weather will kill it in regions of severely cold winters, it is necessary to restock the waters each year.

During the summer of 1964, a health officer of Columbia, Missouri placed adult *Gambusia* in some of the municipal oxidation lagoons. Numerous schools of these fishes were observed during inspection trips along the shore of West Lagoons in the fall of 1964. On January 28, 1965, only two *Gambusia* were recovered from the West Lagoon, South Cell. Subsequent cold weather eventually eliminated the fish for none were seen in later inspections and no report was received of any survivors. Some of the Columbia oxidation lagoons were restocked during the early summer of 1965. On August 2, 1965, ten *Gambusia* were recovered from aquatic beetle traps in the North Cell of West Lagoon.

*Gambusia* showed good growth and reproduced well in Pine Grove Trailer Village Lagoon during the summer of 1965. This lagoon was stocked with 15 adult *Gambusia* in the early summer of 1965. On July 22, 1965, four fish about 1/16 inch in length were observed swimming along the shore. On August 3rd, numerous *Gambusia* from 2 to 3 inches in length were observed along the north shore. On August 9, many of these fishes, about ½ inch in length, were observed along the southwest shore. Numerous specimens, from ⅛ inch to 2 inches in length, were found along the lagoon shores on August 18th.

On October 12, 1965, a number of *Gambusia* were collected from this lagoon and were preserved for subsequent stomach examination. Eight stomachs were examined but none contained midge or mosquito larvae. Examination of 8 stomachs from *Gambusia* collected from West Lagoon, North Cell on December 9, 1965 revealed that 3 stomachs contained midge larvae. Although *Gambusia* are quite ef-

fective in controlling mosquito larvae, a study by Bay and Anderson (1966) indicated that they were not very effective in reducing midge larvae in some California ponds.

The Bluegill, *Lepomis macrochirus* Rafinesque. Cook *et al.* (1964) ranked the bluegill as the number one fish predator on the larval and pupal stages of chironomid midges in a study conducted in Clear Lake, Lake County, California.

On August 4, 1965, 275 bluegills were obtained from Little Dixie Lake near Millersburg, Mo. and placed in the sewage lagoon of New Haven School No. 2 located south of Columbia. About 90 of these fish were ½ inch in length; the remainder varied from 2 to 6 inches in length. Observations were made in this lagoon at various times during 1965 and 1966. Although no fish were observed along the shore, they probably were present in the deeper sections of the lagoon. At times, as much as ½ of the surface of the lagoon was covered by a growth of duckweed, *Lemna* sp.; however, the rest of the lagoon was free of this plant. Dissolved oxygen recordings obtained on two occasions in August 1965 were quite high. However, with the beginning of the school year, a considerable amount of sewage was received by the lagoon. This continued until the next vacation period during the following June. School lagoons in general receive considerable sewage loadings during the sessions from September to the following June. During the summer vacation, little if any sewage enters these lagoons. Therefore, algal growth, photosynthesis, and dissolved oxygen concentrations of such lagoons vary considerably during the year.

The Redear sunfish, *Lepomis microlophus* (Günther). Since the redear or "shellcrackers" feed to some extent on the bottom, it was thought that they might be used as predators on midge larvae. On November 6, 1965, six redear sunfish were placed into the A&M Supply Co. Lagoon, South Cell. On December 10, 1965, 200 redear sunfish from 2 to 3 inches in length were obtained and also placed into the South Cell of A&M Supply Co. Lagoons.

During late January 1966 both lagoons were covered with ice about 5" thick, but the ice was free of snow and was transparent. The waters underneath were green with dense algal growth and the dissolved oxygen readings were high, *e.g.* the north cell had 16.5 ppm while the south cell had 15.7 ppm. Both lagoons became snow-covered during early February and analysis of water samples revealed that the dissolved oxygen content had diminished to 4.7 ppm with 14 ppm $CO_2$ in the north cell and only 0.5 ppm DO and 19 ppm $CO_2$ in the south cell. Considerable mortality occurred involving green sunfish, bluegills, golden shiners, redear sunfish, and tadpoles. Most of this mortality, however, was observed along the shoreline of the north cell. The dead creatures observed along the shoreline of the south cell included only one redear sunfish and 12 tadpoles. See discussion under golden shiner.

These lagoons were inspected again during early April and the north cell had regained its usual dark green color and high DO (18.3 ppm), but the south cell was dark grey in color and contained only 0.4 ppm DO and 7 ppm $CO_2$.

Although the fish population in question was not precisely sampled, the water quality data coupled with observations on mortality strongly suggest that the redear sunfish was not able to survive or reproduce in the sustained anaerobic conditions characteristic of the south cell lagoon.

The Bantam sunfish, *Lepomis symmetricus* Forbes. On May 25, 1965, 36 adult bantam sunfish were obtained from the Little Dixie Lake Fisheries Laboratory. The fish ranged in length from ½ to 2½ inches and were stocked in the sewage lagoon of the South Side Trailer Court located south of Columbia on Highway K. This species failed to establish itself and may have been eliminated by insecticidal sprays applied by the city health department during the summer.

The Golden shiner, *Notemigonus cry-*

*soleucas* (Mitchell). On November 6, 1965, 50 adult golden shiners were placed in the North Cell of the A&M Supply Co. lagoons. Heavy coverage of opaque ice over this cell and the South Cell in early February 1966 caused depletion of oxygen of the water and serious mortality among the stocked fish.

On February 14, 1966, following the melting of the snow, the lagoons were inspected and the waters were tested. The North Cell of A&M Supply Co. lagoon contained 4.7 ppm dissolved oxygen and 14 ppm dissolved carbon dioxide; the South Cell of the A&M Supply Co. lagoon contained 0.5 ppm dissolved oxygen and 19 ppm of carbon dioxide. Mortality among aquatic life was high. The following dead animals were noted:

1. A&M Supply Co. Lagoon-North Cell
2 green sunfish 3 inches in length
8 bluegill 1½ inches in length
1 bluegill 3 inches in length
5 golden shiners 3 inches in length
15 tadpoles

2. A&M Supply Co. Lagoon-South Cell
1 redear sunfish 2½ inches in length
12 tadpoles

Although no dead fish were observed along the shores of other lagoons stocked with fish, mortality probably occurred in them, the bodies sinking or having been eaten by predators.

The Black bullhead, *Ictalurus melas* (Rafinesque). Since black bullheads are bottom-feeders, they may be predacious on midge larvae. On May 13, 1966, 135 black bullheads ranging in length from 2⅞ to 4⅛ inches were released into the sewage lagoon of Midway Heights Elementary School located a few miles west of Columbia. Unfortunately, no data on fish survival were obtained for this lagoon.

The Goldfish, *Carassius auratus* (Linnaeus). Dr. James R. Whitley of the Missouri Department of Conservation (personal conversation with the senior author) reported that a small sewage lagoon at headquarters building, Little Dixie Lake, had been stocked with goldfish during 1963 and that they had survived and reproduced during the intervening period.

This lagoon was inspected on June 25, 1965. The water was quite clear. Some small goldfish about an inch in length, were noted swimming about in the water. Since little sewage is received by this lagoon, little organic matter was present on the bottom. Very few midge larvae were found in the bottom samples collected from this lagoon. It is not known whether predation by goldfish contributed to this rather small population of midge larvae.

No goldfish were stocked in the oxidation lagoons used in this study.

WINTER KILL OF FISH IN SOME OXIDATION LAGOONS. Waters of oxidation lagoons under a heavy layer of opaque ice and snow often become devoid of dissolved oxygen. Decomposition of organic matter, lack of effective photosynthesis, and respiration of aquatic organisms results in the rapid decline in dissolved oxygen, and an increase in carbon dioxide, hydrogen sulfide, and other gases of decomposition.

Adverse conditions developed in the Fayette, Missouri secondary and tertiary oxidation lagoons in March 1960 following low temperatures and heavy snowfall. This resulted in a serious kill of golden shiners which had been stocked in this lagoon during the previous spring (Fisher, 1962). However, later harvest operations indicated a survival of at least 32 large golden shiners.

Conditions in the other oxidation lagoon waters varied considerably in midwinter 1966. An inspection on January 25, 1966 showed that each was covered with clear ice about 5 inches in thickness. The water below the ice contained green plant growth. The dissolved oxygen readings of each of these lagoons was quite high: Pine Grove, 40 ppm; A&M Supply Co.-North Cell, 16.5 ppm; A&M Supply Co.-South Cell, 15.7 ppm; New Haven School 2, 17.7 ppm.

During the next 2 weeks, a heavy

cover of snow accumulated on these lagoons and adverse conditions developed in the water. Although no dead fish were observed along the shores of other lagoons stocked with fish, mortality probably occurred in them.

FURTHER NOTES ON FISH IN OXIDATION LAGOONS. Observations in the study lagoons were terminated in late August 1966. Unfortunately, the period of study did not permit further collection of fish from the lagoons for stomach analyses nor obtaining further information on the effect of the various species of fish upon insect populations, especially of midge larvae.

The harvest of fish from oxidation lagoons by means of drag seines is difficult due to the sticky black ooze that accumulates near the shore. Further, these seining operations undoubtedly cause disturbance of the bottom material and an increase in the turbidity of the water, thereby interfering with the natural operation of the lagoon. It is probable that the fish can be collected more efficiently from the lagoons by the use of some fish toxicant such as rotenone or preferably by the use of an electrical fish shocking device operated from a lightweight boat.

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## ABSTRACTS

Several years ago *Biological Abstracts* changed its policy of requesting that abstracts of papers should be prepared and submitted to them on special forms, which were sent to authors with the galley proof. Instead, abstracts are now taken directly from the journals. Several members of AMCA have pointed out that in order to facilitate this, and also for the benefit of readers who find it increasingly difficult to keep up with the expanding literature, the inclusion of an abstract at the beginning of each article is desirable.

Therefore, *Mosquito News* will adopt this practice as a policy, beginning with Volume 31, No. 1 (March 1971). Authors are requested to submit the abstract as a part of the manuscript, as many have already done. Those already on hand and approved for the December number will be included, and authors are requested to prepare and send in abstracts, if possible, for papers already submitted without them.

Abstracts of "Operational and Scientific Notes" are not required.