Therefore, there is a possibility that crawfish can be added to a rice field after the toxic effect of the herbicide has decreased. Further studies should be conducted to determine the effects on crawfish reproduction before this recommendation is made. Granular potassium azide was again less toxic to bluegill sunfish than to crawfish. The 24 and 48-hour TL_ms were 6.0 ppm and 2.5 ppm, respectively.

Two formulations of sodium azide were also tested. The granular formulation was slightly less toxic to crawfish than the technical formulation. When the mud was added to the containers of both formulations, the toxicities were the same. These toxicities closely agreed with that for the technical sodium azide without mud. Crawfish that were exposed to sub-lethal concentrations of sodium azide exhibited some irritation. Most of the crawfish held in concentrations of sodium azide from 0.4 ppm to 1 ppm would exhibit autotomy. This type of reaction to irritants has been noted on occasion by other workers (LaCaze, 1966).

Sodium azide was more toxic to bluegill sunfish than potassium azide. The 24 and 48-hour TL_ms for the technical formulation of sodium azide were 1.5 ppm and 1.3 ppm, respectively. The granular formulation of sodium azide was less toxic to bluegill sunfish than the technical formulation for 24 hours (1.8 ppm) but was more toxic at the end of 48 hours (0.8 ppm).

On the basis of the foregoing data, it is apparent that the use of potassium azide is preferable to sodium azide for weed control in rice fields where crawfish production is desired.

ACKNOWLEDGMENTS

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EVALUATION OF ROTENONE SAMPLING WITH SCUBA GEAR

JAMES P. HENLEY
Department of Fish and Wildlife Resources
Frankfort, Kentucky

ABSTRACT

Eleven rotenone studies were evaluated with SCUBA gear between 1961-1964 to determine the numbers and weights of fish that do not float to the surface and are not recovered. It was determined that 74% of the number and 95% of the weight of all fishes present in the sample area were recovered on the surface within a 52-hour period. Fingerling fishes represented 91% of the unrecovered population by numbers; intermediates, 6%; and harvestable-size fish, 3%. The species of fish which were lost in the greatest numbers were threadfin shad,

brook silverside, gizzard shad, black bass and white crappie, respectively. The highest percentage of recovery occurred during the month of September with the low recorded in August. Species composition and size distribution affected the recovery of fish more than other factors.

INTRODUCTION

Rotenone is generally considered less selective and more reliable than any other means of fish population sampling in large reservoirs, but our knowledge of the completeness of recovery of the killed fishes (the ratio of non-recovered fish to recovered fish) in a given sample is limited. The purpose of this study was to determine the species composition, numbers and weights of fishes that sank and remained on the bottom after rotenone treatment and were thus unavailable for sampling at the surface.

Various methods and procedures have been used in the past in an attempt to determine the proportion of a fish population that sink to the bottom and are lost (Ball, 1948; Carlander and Lewis, 1948; Krumholz, 1950; Fredin, 1950; Jenkins, 1951; Hall, 1956; Huish, 1957). With the development of SCUBA (self-contained underwater breathing apparatus) in recent years, biologists now have the opportunity to observe the effects of rotenone on fish in their natural environment. Rupp and DeRoche, 1965, while eradicating the fishes in three lakes in Maine, estimated that over 50% of the total numbers and standing crop sank in deep water and were lost. They also found that certain species of fish tended to sink and remain on the bottom more readily than others, and that a greater percentage of young-of-the-year fishes are lost than large fish of the same species.

DESCRIPTION AND METHODS

Lake Cumberland is a 50,200-acre impoundment created in 1950-1951 by the construction of Wolf Creek Dam on the Cumberland River. The lake is approximately 100 miles long, has a shoreline of more than 1,000 miles and an average depth of 92 feet at summer pool elevation (723 feet msl). Cumberland is a multipurpose reservoir with an annual drawdown of approximately 40 feet.

The lake is relatively infertile by most standards with an average of 1,649 fish and a standing crop of 136 pounds per acre recorded during 42 population studies conducted during 1960-1964. Lake Cumberland was chosen because of the uniformly clear water which was necessary to insure that the SCUBA divers could see and record the fish that sank to the bottom. Diving was curtailed in 1962 because of excessive turbidity in the thermocline and below due to severe flooding in the winter months.

The qualitative data were obtained from 11 studies and the quantitative data were obtained from 10 studies. Three population studies were conducted in June, three in July, two in August and three in September.

The rotenone studies were conducted in coves of approximately 1 to 1.5 surface acres, and the maximum depth was 30 feet. The open end of the coves was blocked with a 300′ x 30′ x 1″ square mesh net.

A 5% emulsifiable rotenone product (Noxfish) was used as the fish toxicant at a concentration of 0.6 to 1.0 ppm. The required amount of rotenone was pre-mixed with 20 gallons of water and pumped to all depths through a weighted perforated plastic hose. This facilitated an excellent distribution of rotenone into and beneath the thermocline. All fish that surfaced within three days were recovered and were processed following the guidelines suggested by Surber, 1959.

After completing the surface recovery of fish on the third day, three to six non-stratified random transect lines were established by stretching a weighted rope across the long axis of the cove. The combined area of the transects to the total study area varied from

8 to 12 per cent. A SCUBA diver followed the transect line across the bottom and recorded the species and length of fish that were within sight. The width of each transect depended largely on the clarity of the water and the maximum distance a diver could cover satisfactorily was 6 feet on either side of the rope. The diver was equipped with a wax pencil and a piece of white formica calibrated in inches for recording the fish and inch groups. The weights of the fish recovered from the bottom were derived from those of fish picked up from the surface on the first day of the study.

The darters were not included in this study because they do not possess an air-bladder and did not float readily, therefore, could not be compared with the other species.

Expansion of the total number and weights of fishes observed in the transects to the entire area of the cove bottom was done using the expression:

$$N = \frac{(A \, . \, n)}{a}$$

where N = estimated number (or weight) of fish on the cove bottom
A = the cove area in square feet
n = the number of fish observed in the transects
a = the transect area in square feet.

RESULTS

Recovery Rate

The total number of fish recovered from the surface in 11 fish population studies was 17,740 fish and the weight was 1,867.5 pounds. The estimated number and weight of fish that sank to the bottom and did not float to the surface by the morning of the third day (52 hours) was 6,113 fish and the weight was 98.1 pounds. Thus, an estimated 25.6% of the total numbers and 5% of the weight sank, remained on the bottom and were never recovered in the surface sample.

The recovery of fish in relation to each day of the study is presented in Table 1. These data were obtained from the total numbers

TABLE 1. THE TOTAL NUMBERS AND WEIGHTS OF FISH RECOVERED DURING EACH DAY, THE TOTAL ESTIMATED LOSS AND THE PERCENT OF NUMBERS AND WEIGHTS RECOVERED.

	Recovery		Percent	
Days	Numbers*	Weight**	Numbers	Weight
First day	9,432	1,196.2	39.5	60.8
Second day	6,509	469.2	27.3	23.9
Third day	1,799	202.1	7.6	10.3
Total	17,740	1,867.5	74.4	95.0
Estimated loss	6,113	98.1	25.6	5.0
Grand Total	23,853	1,965.6	100.0	100.0

* Based on 11 studies 1961-1964.
** Based on 10 studies 1962-1964.

and weights of fish that were recovered from the surface during each day of the studies. The estimated loss was determined as described above.

The greatest percentage of fish were recovered on the first day within four to six hours after the application of rotenone. An average of 39.5% of the total number and 60.8% of the total weight was taken during this period. The reason for the higher percentage of weight recovered on the first day is because the majority of the larger fish came to the surface soon after the application of rotenone and were recovered.

On the second day, an additional 27.3% of the total number and 23.9% of the weight floated to the surface. The total two-day (28-30 hours) recovery was 66.8% of the total numbers and 84.7% of the total weight. The recovery for the third day was 7.6% of the total numbers and 10.3% of the weight.

These data show that approximately 60% of the total fish population and 40% of the standing crop will normally sink to the bottom during the first day of a rotenone study. The factors affecting the recovery of fish that sink to the bottom will be discussed later.

Size Distribution

Ninety-one per cent of the fishes that remained on the bottom were young-of-the-year fish three inches or less in length. Six per cent of the fish were intermediate-size fish and 3% were harvestable-size. Fifty-two percent of the weight of the fishes recovered on the surface of the coves was made up of fingerling-size fish, 16% by intermediate-size fish and 32% by harvestable-size fish. The largest individual fish observed within the transects was a 17-inch carp that weighed 2.14 pounds and was the only carp recorded in the transects. Bluegill and longear sunfish, five to six inches in length, and gizzard shad, eight to ten inches in length, were other relatively large specimens recorded in the transects. No game fishes of harvestable size were recorded, although several intermediate-size black bass and white crappies were observed.

Seasonal Influence

A comparison of the mean number of fish that surfaced and those that sank to the bottom and were not recovered are presented by months in Figure 1. Effort was made to keep the total study areas as nearly equal in size as possible so these data could be directly compared.

Figure 1 shows that there is definitely a higher population density in the coves in June and July than in August and September. Although there is a greater number of fish in the coves in June and July, the recovery of fish at the surface remained near the average, 73.4% in June and 75.2% in July. A low of 70.5% of the fishes was recovered in August and a high of 79.3% was recovered in September. The lowest recovery for any one study, 61.9%, occurred in August and the highest recovery, 89.3%, occurred in September. However, a low of 63.0% recovery was also reported for one cove in September.

The time of year and temperature of the water, providing it is 70° F. and above, appear to have less influence on the recovery of fish than was originally assumed. The mean water temperatures in the coves increased nearly 9 degrees from June through August, but a slight decrease in the fish recovery occurred in August.

Population Structure

The species which appeared with the greatest frequency in the studies and transects along with their recovery rate are presented in Figure 3. The sunfishes (bluegill and longear) were combined for tabulation of this data because of difficulty in separating these two species underwater in the transects.

The sunfishes were the most abundant fishes in the studies, but were relatively low in abundance in the transects. A total of 5,164 sunfish was recovered from the surface, but only 240 were found in the transects. Therefore, 95.5% of the sunfish were recovered on the surface. The gizzard shad and the threadfin shad were the second and third most abundant species recovered at the surface in the studies, respectively, even though the threadfin shad was the most abundant fish found on the lake bottom. Only 58.7% of the threadfin were recovered on the surface. Gizzard shad on the other hand ranked third in abundance in the transects, but 76.9% of these shad were recovered at the surface. The size difference between the two species was the major factor for this substantial difference in their per cent of recovery. The larger size gizzard shad floated to the surface more readily than did the one- to two-inch threadfin shad. The gizzard shad have increased from an average length of two to five inches in 1961 to an average length of six to eight inches in 1964. This is due to a lack of increment in the gizzard shad population because of the gizzard shad's apparent inability to reproduce successfully in the presence of a high population of threadfin shad.

The black bass and white crappie were the fourth and fifth most abundant species recovered in the studies. The basses were recovered at the relatively high percentage of 84.1 while 75.7 per cent of the white

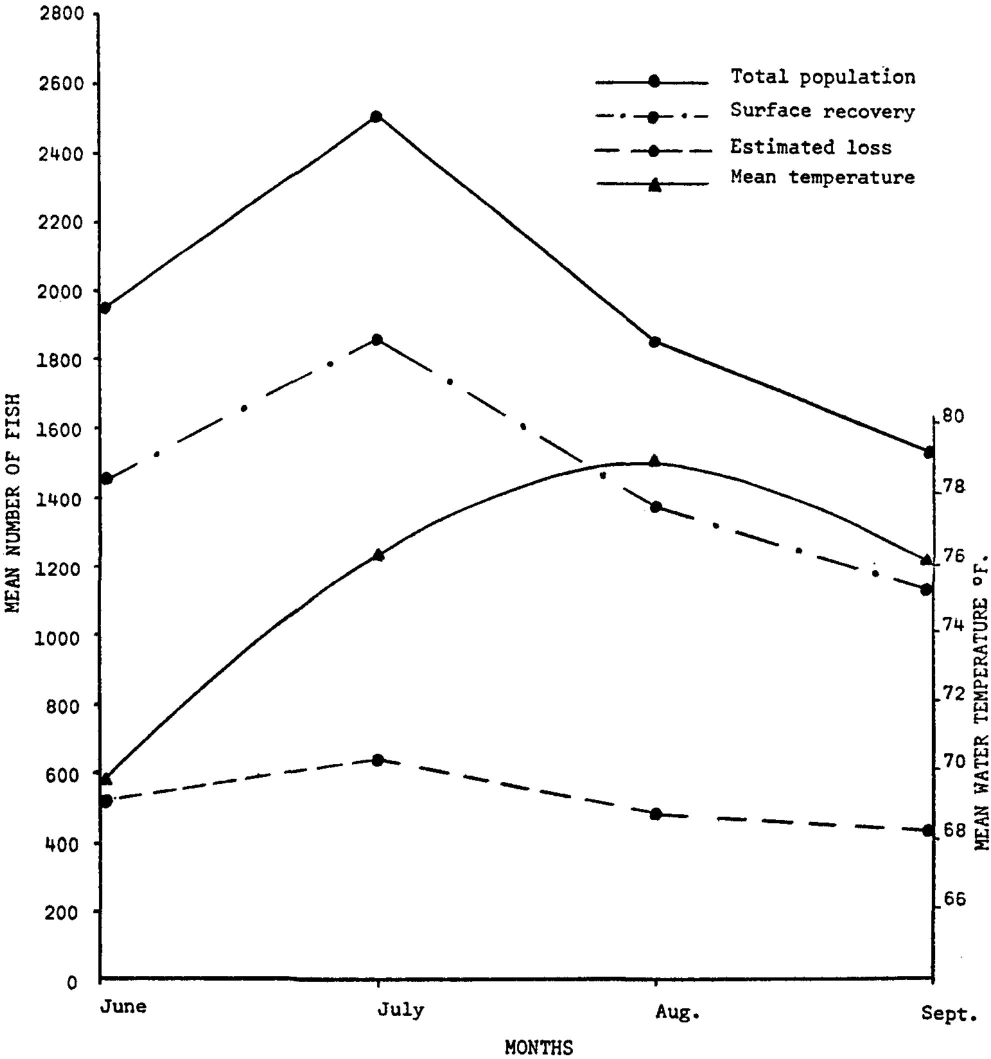

Figure 2. The mean number of fish, surface recovery, estimated loss and the mean water temperature of the coves for each month, June - September.

crappie were recovered. The recovery of both minnows and the brook silversides was relatively low. Only 39.3 per cent of the minnows and 1.4 per cent of the brook silversides were recovered. The small size of the individuals of these two groups of fishes definitely affected their recovery at the surface.

The white bass and the channel catfish represented only two per cent of the species of fish recorded on the lake bottom. On the surface, 65.9 per cent of the white bass and 76.5 per cent of the channel catfish were recovered.

It can be assumed that nearly all the individuals of the other species of fish not mentioned above and picked up during the studies floated to the surface by the morning of the third day. Most of these species were present in relatively small numbers, Appendix.

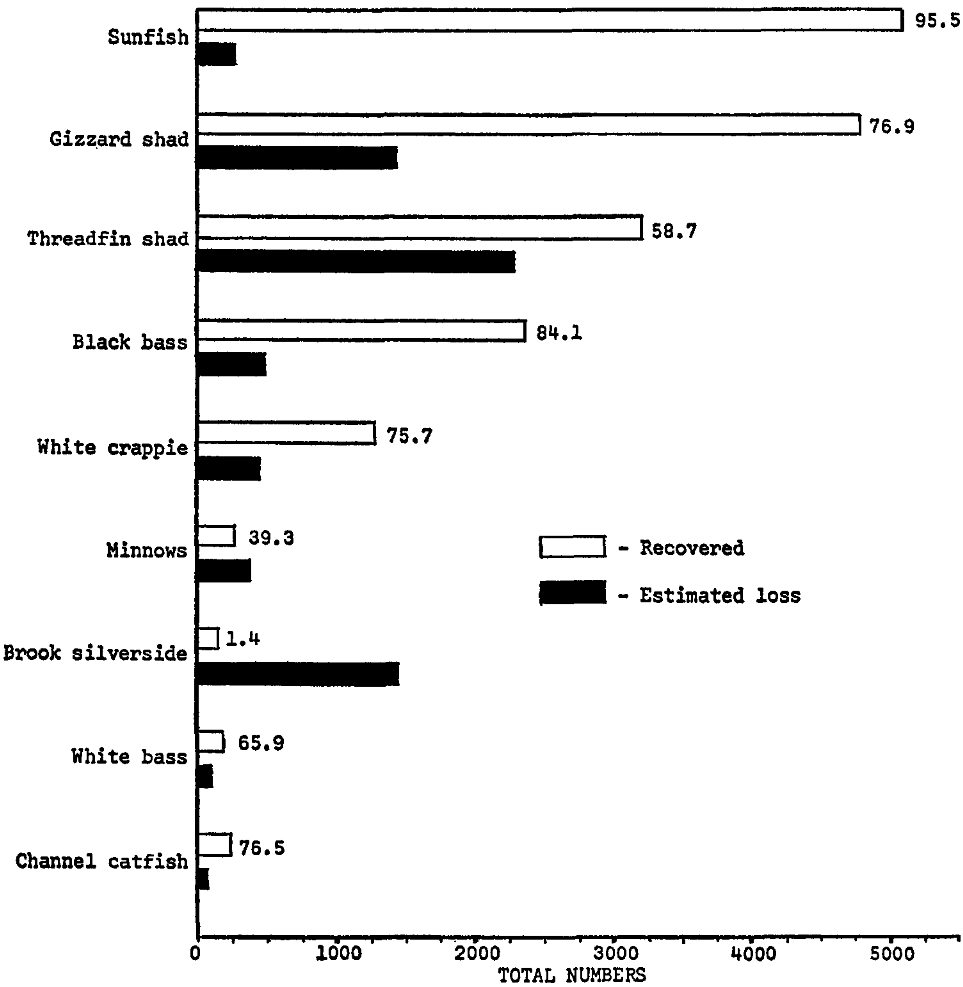

Figure 3. The total number of fish recovered at the surface for six species and three groups of fishes, their estimated loss and the per cent of recovery.

APPENDIX

List of fishes collected from 11 population studies, Lake Cumberland 1961-1964.

LEPISOSTEIDAE	
Lepisosteus osseus (Linnaeus)	Longnose gar
CLUPEIDAE	
Dorosoma cepedianum (LeSueur)	Gizzard shad
Dorosoma petenense (Günther)	Threadfin shad
CYPRINIDAE	
Notropis atherinoides Rafinesque	Emerald shiner
Notropis glacturus (Cope)	Whitetail shiner
Notropis spilopterus (Cope)	Spotfin shiner
Pimephales notatus (Rafinesque)	Bluntnose
Cyprinus carpio Linnaeus	Carp
Carrassius auratus (Linnaeus)	Goldfish
CATOSTOMIDAE	
Ictiobus bubalus (Rafinesque)	Smallmouth buffalo
Moxostoma duquesnei (LeSueur)	Black redhorse
Moxostoma erythrurum (Rafinesque)	Golden redhorse
Carpiodes velifer (Rafinesque)	Highfin carpsucker
ICTALURIDAE	
Ictalurus punctatus (Rafinesque)	Channel catfish
Pylodictis olivaris (Rafinesque)	Flathead catfish
SERRANIDAE	
Roccus chrysops (Rafinesque)	White bass
CENTRARCHIDAE	
Chaenobryttus gulosus (Cuvier)	Warmouth
Lepomis cyanellus Rafinesque	Green sunfish
Lepomis macrochirus Rafinesque	Bluegill
Lepomis megalotis (Rafinesque)	Longear sunfish
Lepomis microlopus (Günther)	Redear sunfish
Micropterus dolomieui Lacépède	Smallmouth bass
Micropterus punctulatus (Rafinesque)	Kentucky bass
Micropterus salmoides (Lacépède)	Largemouth bass
Pomoxis annualris Rafinesque	White crappie
SCIAENIDAE	
Aplodinotus grunniens Rafinesque	Freshwater drum
ATHERINIDAE	
Labidesthes sicculus (Cope)	Brook silverside

DISCUSSION

The factors encountered in this study which had the greatest influence on the numbers of fish remaining on the bottom three days after the application of rotenone and, concurrently, caused the greatest number of fish to float to the surface were: (1) species composition of the fishes in the sample area, and (2) size structure of the population. There are other factors which effect the recovery rate of fish, such as, temperature, depth, bottom type and degree of cover on the bottom. However, these factors were not encountered in any magnitude during this study and, therefore, cannot be evaluated.

The percentage of fish that sink to the bottom on the first day seems to depend to some extent upon the techniques the investigator employs in applying the rotenone. I am not implying that a 100-per cent recovery can ever be achieved but it was found that fewer fish will sink to the bottom if the investigator applies the proper amounts of chemical in a manner that insures good distribution throughout the sample area. The higher the rotenone concentration used and the greater the speed at which it was applied, the faster fish died and the more that sink to the bottom. This resulted in a greater total loss or lower final per cent of recovery.

Some species of fish, and most small fishes, are more quickly affected by rotenone than other species and the larger fishes. Generally, it was found that fishes of rather large size and bulk, such as carp, buffalo, redhorse and drum, were recovered at a much higher rate than smaller fishes, such as threadfin shad, minnows, and brook silversides. The high recovery of sunfish, although most were small in size, may be attributed to their preference for the shallower waters of the coves and the shoreline habitat. Recovery from these areas is almost always greater than that from the open deeper waters.

In rotenone sampling in large reservoirs, one can expect a greater number of small fish than large fish to sink and remain on the bottom. Therefore, a relatively high recovery of the standing crop of the sample area can be expected.

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EXPERIMENTS ON THE USE OF A BIOFILTER TO REMOVE WASTES FROM FISH TANKS[1]

CHUNG LING CHU[2] AND GEORGE N. GREENE
Fisheries Laboratory
Agricultural Experiment Station
Auburn University
Auburn, Alabama

INTRODUCTION

High fish production in a pond can be obtained by feeding. Tiemeier (1962) obtained 1,622 pounds of channel catfish (*Ictalurus*

[1] This paper taken from a thesis presented to the Graduate Faculty of Auburn University in partial fulfillment of the requirements for the degree of Master of Science.

[2] Present address: Department of Food Science, University of Washington, Seattle, Washington 98105.