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New York Fish and Game Journal

EXCELSIOR

CONSERVATION DEPARTMENT

January, 1955

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NEW YORK FISH AND GAME JOURNAL

VOLUME 2 | JANUARY, 1955 | NUMBER 1

SURVIVALS OF PLANTED ATLANTIC SALMON IN LAKE GEORGE [1]

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ABSTRACT

As part of a study of methods for increasing salmon in New York lakes, experimental plantings of Atlantic salmon were made. Yearlings, planted in streams tributary to Lake George, included 3,000 marked individuals in 1948 and 6,000 in 1950. In order to check relative survivals with reference to each planting stream, three different fins (adipose, right ventral, and left ventral) were clipped from lots of fish planted in three different streams each year. Upon sampling, age determination by the scale method was used to prevent confusion in interpretation of clip marks. Survival was evaluated on the basis of 131 individuals netted during the spawning season of 1952. Salmon released after handling were tagged, thus preventing errors in counting at recapture. Analysis of recoveries of marked salmon according to planting stream indicated some recoveries from each of the six streams. Although Lake George was known to have had a small population of landlocked salmon prior to the planting experiments, analysis of ratios of marked to unmarked salmon recovered indicated that planted Atlantic salmon accounted for virtually the entire population. Also, clip marks were recognizable at recapture without major sources of error. These fish are of high angling value and are indistinguishable from landlocked salmon. They yield eggs of excellent quality for fish cultural purposes.

Although there is an increasing tendency toward classifying landlocked and sea-run salmon as the same species, *Salmo salar,* racial differences may be expected to have an effect upon the adaptability of salmon to fresh-water lakes. In the study of methods for increasing salmon in New York lakes, in progress since 1944, it was considered desirable, in addition to work on stock from lake sources (so-called landlocked salmon), to test Atlantic salmon from sea-run sources. Lake George was used as a study area and fin-clipping provided a positive means of recognizing survivors (Figure 1). The experimental fish comprised yearling Atlantic salmon, reared at the Cambridge Fish Hatchery from eggs obtained from South Esk, New Brunswick. A total

[1] Atlantic salmon eggs were available through cooperation of the Department of Fisheries of Canada. Assistance by personnel of the Adirondack Fish Management District of the New York State Conservation Department and especially of Martin Pfeiffer, Aquatic Biologist, included fin-clipping and sampling of the salmon population. Personnel of the Glens Falls District, Bureau of Law Enforcement, assisted in planting the salmon.

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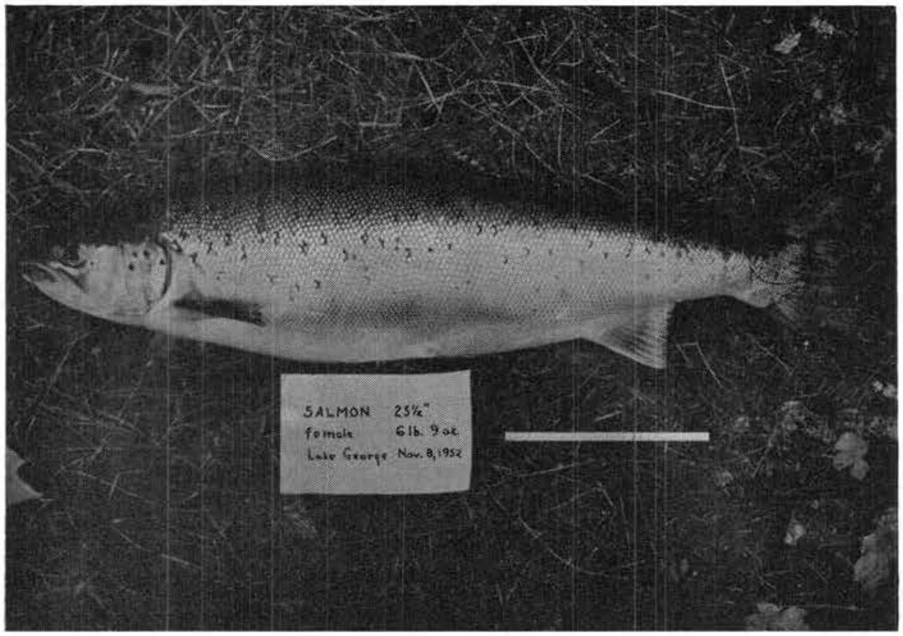

Figure 1. A marked, Atlantic salmon showing typical left ventral fin-clip scar.

of 9,000 were marked and planted in tributaries of this lake (3,000 in 1948 and 6,000 in 1950) along with unmarked salmon from the same stock. Survival was evaluated on the basis of a sample of 131 salmon taken by gill netting during the fall of 1952 for the combined purpose of spawn-taking and survival study. Information on the relative success of stocking and natural reproduction was also obtained. By means of three different clip marks and age determination from scales, a check on survival as related to each planting stream yielded conclusions applicable toward improvement of planting methods.

CONDITIONS IN LAKE GEORGE WITH RELATION TO SALMON

Lake George is an oligotrophic type of lake with a maximum depth of 187 feet and a computed area of 28,416 acres. Its fish fauna comprises at least 23 species of which lake trout, smallmouth bass, salmon, rainbow trout, yellow perch, northern pike, rock bass, red-bellied sunfish, common sunfish, and common bullhead are of angling importance. Brown trout and brook trout are occasionally taken. An unusual forage fish situation exists due to the large number of ciscoes. These fish *(Leucichthys artedi greeleyi* Koelz) are small, seldom exceeding 7 inches in total length.

Landlocked salmon were successfully introduced into Lake George

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many years ago, prior to 1900, but failed to reach a high level of abundance although the persistence of a few salmon over long periods when stocking was not done indicates that there was some natural reproduction.

CONDITIONS IN TRIBUTARIES WITH RELATION TO SALMON

Six tributaries of Lake George were used in the survival experiments: West Brook; High Point Brook; Huddle Brook; Indian Brook; Northwest Bay Brook; and Hague Brook. All are upland brooks of relatively rapid descent with considerable rubble and boulders. All contain trout in at least some areas. Adult salmon ascend at least two, Hague Brook and Northwest Bay Brook, in some years during the fall but evidence of successful reproduction in them has not been discovered. Planted salmon have been observed in all these streams at various times subsequent to planting. Further details are given for the several streams individually.

West Brook is the coldest of the streams, seldom having exceeded 58° F. on days when the others showed readings of above 70° F. It is mostly spring fed and shows relatively slight fluctuation in flow. Most of the area planted with salmon is accessible to rainbow trout and suckers ascending from Lake George. Brown trout and brook trout are present in considerable numbers, together with sculpins and black-nosed dace.

High Point Brook is fed by springs and surface drainage and fluctuates rather widely in volume. Rainbow trout, brook trout, and black-nosed dace are present. A waterfall near its mouth is probably impassable to fish ascending from Lake George.

Huddle Brook (Figure 2) is fed by Trout Lake and springs. It shows relatively slight fluctuation in volume. In addition to some brown trout and rainbow trout there are a few brook trout. Horned dace, black-nosed dace, and suckers are numerous. Due to the lake at its source, Huddle Brook contains more species of fish than the other brooks, having occasional chain pickerel, rock bass, sunfish, and others.

Indian Brook is fed by springs and a large amount of runoff water, giving a high degree of fluctuation in volume. Impassable falls near the mouth stop ascent of fish from Lake George. Brook trout, black-nosed dace, horned dace, and common suckers are present.

Northwest Bay Brook is fed by springs, pond outlets, and a large amount of runoff water and fluctuates very widely in volume. It has an impassable falls near the mouth. The stream has a larger amount

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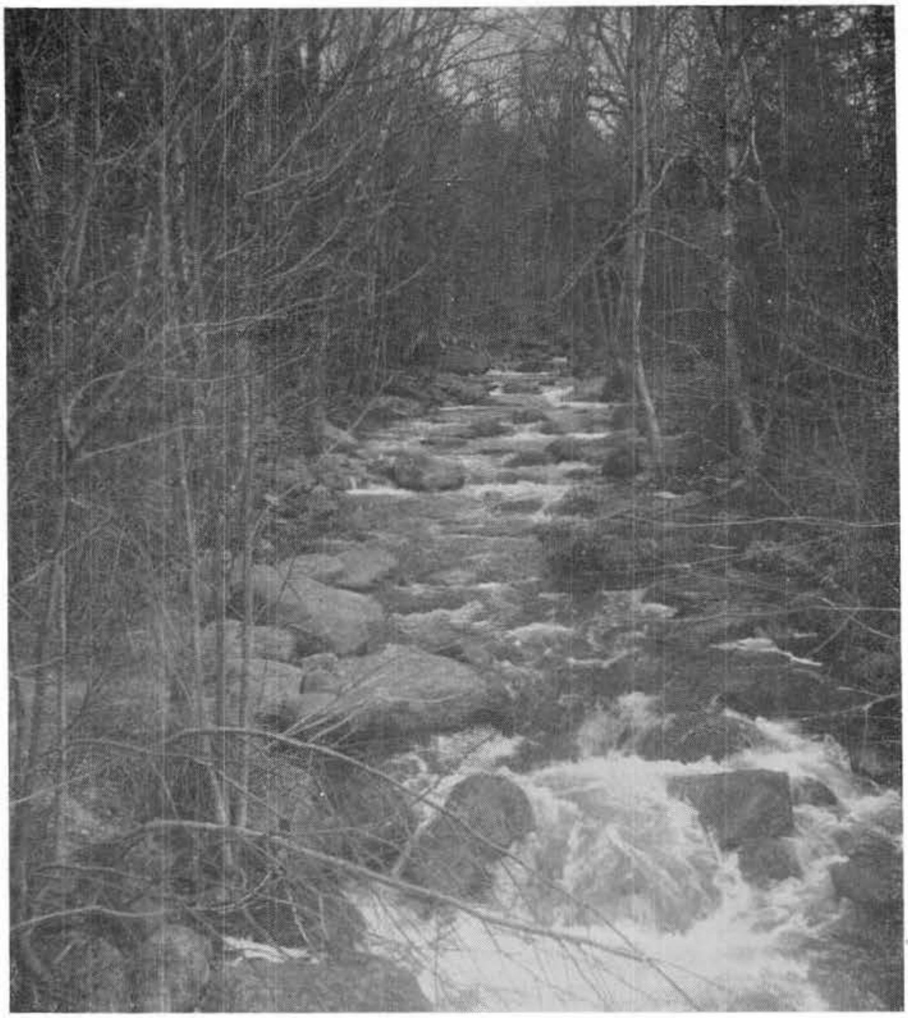

Figure 2. Huddle Brook (May 6, 1953) showing rapid, boulder section at spring high water. This was fairly typical of other Lake George tributaries selected for salmon planting.

of sluggish deep water than the other streams. Brook trout, brown trout, black-nosed dace, horned dace, and suckers are present. Adult salmon have been observed in the lower part of this stream during several years.

Hague Brook is fed by springs and surface runoff. It fluctuates moderately in volume. A waterfall above its mouth is a barrier to upstream migration, but the area below this is subject to migration of fish from Lake George including rainbow trout and common suckers. In 1951 considerable numbers of salmon were taken in the lower part

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of this stream during the fall run. The stream supports many rainbow trout and some brown trout, as well as black-nosed dace.

METHODS

The methods employed in the study may be outlined briefly.

Planting

Efforts were made to standardize the conditions and technique of planting as closely as possible. Urethane was used to quiet the fish during clipping with toenail snips and losses after marking were small. Stocking was timed to coincide with the seasonal rise of stream temperatures to approximately 50° F. Water pails were used to carry the salmon and a stocking rate of 1,000 per mile was approximated. This would be one fish to each 5.28 feet, but in actual practice stocking was done by releasing several fish at intervals roughly approximating this density. The sizes of salmon varied rather widely, some

Table 1. Yearling Atlantic Salmon Planted in Tributary Streams of Lake George in 1948 and 1950

Year	Stream	Salmon planted					
			Marked			Unmarked	
		Total	Number	Average length in inches	Clipped fin	Number	Average length in inches
1948	West Brook....	1,500	1,000	3.90	right ventral	500	3.90
	Northwest Bay Brook........	1,500	1,000	3.90	left ventral	500	3.90
	Hague Brook...	1,500	1,000	3.90	adipose	500	3.90
1950	Indian Brook...	3,137	2,000	2.75	adipose	1,137	3.00
	Huddle Brook..	4,393	2,000	2.75	left ventral	2,030	3.00
						363	3.25
	High Point Brook	4,384	2,000	2.75	right ventral	2,384	2.50
	West Brook....	2,415	....	......	....	1,431	3.00
						984	2.75
	Northwest Bay Brook........	2,414	....	......	....	1,430	3.00
						984	2.75
	Hague Brook...	2,910	....	......	....	2,910	3.00

individuals as small as 2 inches or as large as 6 inches being represented. Oxygen was used during transportation and the fish arrived in excellent condition. Tank temperatures on arrival were kept close to 50° F., ranging up to 55° F. Except for several observations of immediate predation by trout, there were no observed losses after plant-

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ing. The numbers of salmon planted were determined by actual count for marked fish and from weights for unmarked fish. Average lengths are given from a table used for converting trout weights to lengths (Deuel *et al.*, 1952).

In 1948, plantings of both marked and unmarked salmon were made on May 5 in West Brook, Northwest Bay Brook, and Hague Brook at water temperatures of 51°, 53°, and 55° F., respectively. Temperatures during transportation ranged from 48° to 54° F.

In 1950, plantings of both marked and unmarked salmon were made on April 27 in Indian Brook and on April 28 in Huddle Brook and High Point Brook. Also, additional lots of unmarked salmon were planted on April 27 in West Brook and Northwest Bay Brook and on April 26 in Hague Brook.

The number and size of the fish used in each case, as well as the fins clipped for marking, are given in Table 1.

SAMPLING

The netting of salmon in shallow water areas of Lake George was carried on during the fall of 1952 for the combined purposes of studying survival and of obtaining spawn. Gill nets having mesh sizes of 4, 4½, 5, and 6 inches were set at a number of locations where salmon were seen or were considered likely to be present, 400 to 800 feet of net being used at each site. This operation began November 7 and was continued until November 26. It was also resumed briefly on December 8 and 9. Trap nets were tried briefly but took relatively few salmon. The total catch was 132 salmon, but one escaped during measurement so 131 were used for analysis.

Both adult and immature salmon were taken in the gill nets and trap nets. Tagging of immature, spent, and stripped salmon was done for the combined purposes of preventing duplication of data on individual fish, of studying migration and yield, and of obtaining other useful information. Clip type tags were used on the dorsal fin.

AGE DETERMINATION

Scale samples were studied with a binocular microscope for age determination. Although salmon scales are generally considered relatively easy to read, a large percentage of the Lake George scale samples gave some difficulty in the interpretation of age. This was in part due to a high degree of variation in growth rate before planting, the more advanced hatchery fish showing a recognizable annulus in late spring and the more retarded ones not showing such an annulus.

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Another variable factor was the different rate of growth in various streams. Interpretations of age are not considered infallible, but misinterpretation by more than 1 year is considered unlikely. Errors would tend to compensate, i.e., as many fish probably being read as a year too old as were read as a year too young.

OBSERVATIONS

The observations and deductions to be derived from the data obtained fall under several topics.

Age Composition and Size

In interpreting ages, it should be kept in mind that annual growth is virtually complete by November. Thus age in growing seasons, for fall-caught specimens, is almost a full year more than age in winters. (For example, a fish designated as II+ is virtually 3 growing seasons old.) The distribution of age groups (in terms of winters) in the sample of 131 salmon, as well as the range of total lengths (to end of tail tip) and weights recorded for each group, are given in Table 2.

Table 2. Range of Total Length and Weight According to Age Groups for 131 Salmon Recovered

Age group	Number	Total length (inches)			Weight (pounds)		
		Minimum	Maximum	Average	Minimum	Maximum	Average
II	17	14.00	23.63	20.38	0.5	5.00	3.45
III	60	18.25	27.25	22.12	2.0	10.00	4.04
IV	26	18.38	27.38	23.60	2.0	8.88	4.91
V	27	19.00	30.25	23.78	2.5	9.00	5.09
VI	0	.....	.....	.....	...	....	....
VII	1	xxx	xxx	30.00	xx	xx	9.00

Planting had not been done for a large number of years prior to 1948 (represented by age group V) so the single specimen for age group VII was evidently a landlocked salmon from natural reproduction.

Separate averages for males and females showed no consistent differences throughout the age groups for length or weight. Weights were somewhat affected by stripping of a number of females.

Age group II+ contained two fish in the 14- to 14½-inch range. The nets used were of too large mesh to sample this size of fish well.

Growth Types

The size attained by Atlantic salmon in a given period of years is known to be greatly affected by age at migration from stream to ocean as well as by early or late attainment of sexual maturity. Vibert

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(1950) has recently given a terminology based on time of descent of smolts.

Interpretations of the types in the Lake George sample are based both upon scale reading and upon observations of migration obtained through use of a horizontal screen trap weir on Huddle Brook during 1953. Because, so far, it has not been possible to be certain of the growth type for all specimens, percentages are not given.

Smolt migration begins at 1 year (formula 1, Vibert). There were appreciable numbers (usually at least 10 per cent) of smolts in the lots of salmon planted. Moreover, many salmon migrate before they have completely attained the silvery coloration of typical smolts.

Type 1, however, passes gradually into the late yearling migrant (formula 1+, Vibert). This is a frequent type in Lake George. At its extreme, this type may show a very large amount of stream growth before migration and can easily be read as a year too old.

The early 2-year-old type (formula 2, Vibert) is very frequent in Lake George. Migration in late fall, winter, or early spring would account for this type. This problem is being investigated by means of the trap on Huddle Brook previously mentioned. Early spring migration is known to occur.

The late 2-year-old type (formula 2+, Vibert) is frequent in Lake George.

Early 3-year-old migrants (formula 3, Vibert) are not uncommon in Lake George.

Late 3-year-old migrants (formula 3+) were not found by Vibert. Several Lake George fish seemed to be of this type.

According to their first year of maturity, Lake George salmon include some males maturing at the end of one growing season in the lake (comparable to grilse), many of both sexes maturing at the end of two growing seasons in the lake, and some fish maturing at the end of three growing seasons in the lake.

There is considerable evidence that some Lake George salmon survive several breeding seasons. The usual type shows annual spawning marks but several individuals appear to have skipped a year after initial maturity before breeding again.

Maximum longevity has not been determined. The oldest Atlantic salmon from the 1948 planting were several encountered by anglers in 1953 (then VI plus).

The growth history of many Lake George salmon shows a period of accelerated growth late in life. There is an abundant food supply for large salmon. Many stomachs examined contained only ciscoes. The food of small salmon was not studied.

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EVALUATION OF SURVIVAL BY STREAMS

The recoveries of marked salmon from the plantings made are given in Table 3. Those from the 1948 stocking are represented by age group V and those from 1950 by age group III.

TABLE 3. RECOVERY OF MARKED SALMON PLANTED IN TRIBUTARY STREAMS OF LAKE GEORGE IN 1948 AND 1950

Year	Stream	Number planted	Recovered	
			Number	Per cent
1948	West Brook	1,000	2	0.20
	Northwest Bay Brook	1,000	6	0.60
	Hague Brook	1,000	8	0.80
	Total	3,000	16	0.53
1950	Indian Brook	2,000	20	1.00
	Huddle Brook	2,000	6	0.30
	High Point Brook	2,000	4	0.30
	Total	6,000	30	0.50

The fact that the returns obtained for the six streams varied from 0.2 to 1.0 per cent yields useful conclusions as a basis for planning further stocking. It should be pointed out that the above figures do not warrant close quantitive conclusions as to the relative survival from each stream but a considerable amount of field observation in these streams also helps in evaluating survival and has been taken into account in revising stocking recommendations upward or downward.

EVALUATION OF CLIPPING METHOD AND OF NATURAL REPRODUCTION

A significantly higher return of unmarked salmon than would be expected from known planting ratios of marked to unmarked fish might indicate: contribution to the stock from natural reproduction; regeneration of clip marks to the extent of confusion of marked with unmarked fish; or differential survival in favor of unmarked fish. By using planting ratios of marked to unmarked fish in relation to recoveries of marked and unmarked fish of the same year of planting it was possible to determine whether or not the numbers of unmarked fish were above the expected figures.

In the 1948 experiment the planting ratios of marked to unmarked salmon were equal in the three streams used, there being 1,000 marked and 500 unmarked salmon planted in each. Hence, the ratio would remain the same despite mingling in the lake. Under these conditions a 2:1 ratio of marked to unmarked fish would be expected

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if the clip marks were permanent, if there were no differential mortality between marked and unmarked fish, and if there were no unmarked fish contributed from natural reproduction. The actual recovery ratio of 16 marked to 11 unmarked gave a test for chi-square of 0.67. This is not statistically significant. Therefore, while the variation was in the direction of unmarked fish in a ratio higher than planted, there is a strong probability that this could have been due to chance.

In the 1950 experiment the planting ratios of marked to unmarked salmon were not equal in the three streams used for the first time and the sizes of unmarked salmon were not closely standardized. Moreover, unmarked salmon only were planted in the three streams which had also been used in 1948. The aggregate total of 6,000 marked salmon (2,000 in each of three streams) and 13,653 unmarked salmon (unequally distributed in six streams) gives a computed ratio of 1 marked to 2.28 unmarked. The actual recovery of 30 marked and 30 unmarked was in strong contrast, being a ratio of 1:1. Testing for chi-square gives a value of 10.78. This is statistically significant and the variation was strongly toward a higher recovery of marked fish than unmarked fish.

As use of the average ratio of 1 marked to 2.28 unmarked is questionable, due to the different planting ratios in different streams and to the planting of unmarked fish in three streams, expected returns were calculated separately for each brook in which both types were used (Table 4).

TABLE 4. EXPECTED RECOVERY OF UNMARKED SALMON PLANTED IN THREE TRIBUTARY STREAMS OF LAKE GEORGE IN 1950

Stream	Planted			Recovered	
	Marked	Unmarked	Ratio	Marked	Unmarked*
Indian Brook	2,000	1,137	1:0.57	20	11.4
Huddle Brook	2,000	2,393	1:1.20	6	7.2
High Point Brook	2,000	2,384	1:1.20	4	4.8

*Calculated according to planting ratios.

These calculations total 23 unmarked fish, or 0.4 per cent of the number planted in these streams. There were 7,739 unmarked fish planted in other streams where marking was not done in 1950. Using the percentage derived from the streams where both types were planted, a calculation of the expected recovery of these would approximate 31 fish. These calculations would give 23 plus 31, or 54,

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as the expected number of unmarked salmon in the sample. The actual recovery of only 30 unmarked salmon was still far below the expected number of 54 derived by this method. Chi-square is 5.37 which is statistically significant.

Both of these methods of calculation indicate a significantly higher return of marked salmon than unmarked salmon in 1950. It should be mentioned that, in that year, the clipped lots were more even in size distribution than the unclipped. If there had been a difference in survival against the smallest fish this would have decreased the recovery ratio of unmarked fish. Small fish would be expected also to have given more late migrating types which, at age group III, would have been too small to be sampled by the gill nets used.

To sum up conclusions from analysis of returns: there is no statistical evidence that the unmarked salmon recovered included significant additions from natural reproduction or from loss of clip marks. Observational data indicated as much as 50 per cent fin regeneration in a few instances but no fins approaching complete regeneration.

Maturity of Planted Salmon

During the 1951 and 1952 spawning seasons eggs were taken and fertilized from the Lake George population of salmon. The quality of these eggs was very good and the fish reared from them showed no obvious differences as compared to landlocked salmon.

Angling Value

Planted Atlantic salmon in Lake George are usually called landlocked salmon by anglers, there being no apparent differences in appearance or behavior. The 1948 planting came into the angling catch for the first time in the spring of 1950 under the 20-inch limit then in effect. At the present 15-inch limit, legal size is frequently reached before the end of the third year. Salmon are taken on a wide variety of lures from the start of the season April 1 until its close September 10. Interest in angling for salmon and angling success have steadily risen since 1950.

CONCLUSIONS

Landlocked salmon were present in small numbers in Lake George prior to the planting of Atlantic salmon in 1948 and one specimen from natural reproduction, age group VII, is represented in the sample.

Salmon from natural reproduction were a minor factor in the population as sampled in 1952, virtually the entire sample being accounted for by survivors of the planted yearling Atlantic salmon.

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All six of the tributaries in which marked fish were planted (three in 1948 and three in 1950) gave some returns, ranging from 0.2 to 1.0 per cent of the number planted.

Clip marks showed some regeneration but appeared to be recognizable and there was no statistical evidence of clipped fish being identified as unclipped.

Planted Atlantic salmon matured normally and produced normal progeny from eggs obtained by stripping.

Planted Atlantic salmon are of high angling value in Lake George and are considered as landlocked salmon by anglers.

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THE BIOLOGY AND MANAGEMENT OF THE FISHER IN NEW YORK [1]

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ABSTRACT

The fisher has increased notably in the Adirondack Mountain region in recent years. During the 1940's, the species extended its range from the mountainous country to outlying areas. The present population is estimated at 3,000 to 4,000 individuals, or, according to trappers, about four times that of 20 years ago.

Fishers apparently move in rough circuits, encompassing an area of about 10 square miles. The males range more widely than do the females. The species is as active by day as at night.

Average measurements (in millimeters) of 27 males were: total length, 940; tail, 350; hind foot, 118. Corresponding data for 42 females were 808, 306, and 100, respectively. Average weight was 3,707 grams for males and 2,057 grams for females. The largest male weighed 12 pounds, 1 ounce; the largest female, 6 pounds, 15 ounces.

Analysis of 60 stomach and intestinal tracts of late fall and early winter specimens indicated deer (chiefly carrion), red squirrel, red-backed mouse, shrews, varying hare, and porcupine to be the principal mammalian foods. Grouse and bluejay were the only indentifiable bird remains. Fruits of swamp holly, fern tips, and mosses were eaten. Beechnuts occurred in 10 stomachs.

Uterine horns were syringed for blastocysts. These, numbering from one to four, were recovered from seven females. The blastocyst is spherical, amber yellow to pale yellowish white, and has a diameter of 1 millimeter.

Endoparasites identified include *Capillaria mustelorum, Physaloptera* sp., *Arthrocephalus lotoris, Molineus patens, Dracunculus insignis, Uncinaria stenocephala,* and *Mesocestoides variabilis.*

It is suggested that fishers might be live-trapped and released in suitable habitats of the Catskill Mountains, where the species does not presently occur.

It is essential that field and laboratory studies be made on a species before sound management practices can be instigated. Little specific information on the life history of the fisher (*Martes pennanti pennanti*) is available. de Vos (1952) summarized the existing data and added the results of his own studies in Ontario. With the renewal, in 1949, of

[1] We acknowledge the help of Dr. W. C. Senning and of District Game Protector Ray Burmaster and his staff of game protectors, New York State Conservation Department, as well as a host of trappers too numerous to mention individually. Endoparasites were determined by Allen McIntosh and Aaron Goldberg, Animal Disease and Parasite Branch of the U. S. Department of Agriculture. Dr. E. W. Price collaborated in the determinations. Specimens are deposited in the U. S. National Museum Helminth Collection and the Department of Conservation, Cornell University. Dr. T. W. McCameron, Institute of Parasitology, MacDonald College, Quebec, determined some nematodes.

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open seasons for trapping fisher in New York, efforts were made to secure carcasses from Adirondack trappers. Requests were made to all those who reported trapping fishers in the seasons of 1949 to 1953 to ship carcasses to the laboratory at Cornell and met with excellent response.

PRESENT STATUS OF THE FISHER IN NEW YORK

Those concerned with the perpetuation of vanishing species have voiced some alarm about the fisher, a species supposedly declining in numbers throughout its range. Seton (1929), Anderson (1934), and Rand (1944) have all indicated the status of the fisher in Canada during recent years. There are reports of a decline in the United States (Grinnell *et al,* 1937; Allen, 1942). The former eastern range of the fisher was coextensive with the coniferous forests. At one time it occurred as far south as mountainous Tennessee. Its prized pelt has resulted in relentless hunting and trapping, so that presently the wilder sections of green timber constitute its stronghold. For Pennsylvania, Poole (1932) recorded fisher tracks on the mountain top above Strausstown, Berks County, in February, 1931, and added an additional record from Holtwood, Lancaster County, in 1921, but probably it does not occur in the state at the present time. The fisher still occurs in some numbers in northern Maine and a few undoubtedly occur in the White Mountains of New Hampshire and northern Vermont. George W. Davis wrote us (September 19, 1947): "A few weeks ago John V. Raser, Jr. of Londonderry [Windham County], Vermont killed a fisher in his hen house."

De Kay (1842) stated that the fisher "was formerly very abundant in this State [New York], but is now confined to the thinly settled northern districts. Twenty years ago, they were numerous [about 1820] in the western part of the State, where they are now scarcely ever seen."

Fishers appear to be more numerous in the Adirondacks at the present time than for many years. If the species is cyclic in nature, there is no supporting evidence from New York. The marked increase in the past few years is apparently not a mark of cyclic or irruptive population change. In March of 1932 and 1937, Hamilton traveled the Adirondack area on a fur survey and saw little sign of fishers. Trappers and fur buyers in this region, who were well acquainted with the fisher, remarked on its scarcity. To be sure, numbers were present and the species persisted in areas removed from settlements. A steady increase was noted through the 1940's and has continued. The fisher

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has also greatly extended its range. This increase undoubtedly has been due to a number of factors.

A closed season from 1936 to 1948 undoubtedly contributed. During the 1920's and early 1930's, fishers were often tracked to their dens, there to be trapped or removed following den destruction. As pelts of small individuals, females or young of the year, were more valuable than the larger, coarsely-furred males, hunters would select small tracks to follow whenever there was a choice. Thus, there may have been a preponderance of females removed from the population. That this may have been true is suggested by reports of trappers or fisher hunters who were active during the period.

Lumbering and fires in the Adirondacks were characteristic of the latter part of the last century and the first quarter of the present one. Since about 1930, however, their intensity has diminished, and it is probable that the overall fisher habitat has improved. There are probably intangibles which fostered the increase of the fisher population, but of these forces we have no knowledge. Certainly the increased population is a positive and notable one.

Regarding the present status of the species in the Adirondacks, 83 replies were received to a questionnaire sent to those who reported trapping fishers in 1950 and 1951. Of these, 78 indicated an increase in recent years, one indicated no increase since the season was opened in 1949, and four made no comment. Typical remarks are listed.

"Much more plentiful now than 20 years ago, actually numerous in some areas." "Have spent my life in this area [DeGrasse, St. Lawrence County], and the first fisher track I ever saw was in 1943. Now we have more fisher than red fox. Have never seen any animal make a better come-back." "There are at least ten times as many fisher as there were ten years ago [Hopkinton, St. Lawrence County]." "The fisher has greatly increased in the past few years." "There is no doubt the fisher has increased rapidly in the past few years around Number Four [Lewis County]." About Tupper Lake, a trapper wrote "They have spread all over, even near villages." At Colton, St. Lawrence County, a beaver trapper first saw tracks of the fisher in the area in 35 years of hunting and trapping. "They have spread farther south than most folks realize. I know of fisher in the extreme southern part of Oneida County." "Great increase in past few years not only in section I hunt and trap [Tupper Lake, Franklin County], but in all this part of the Adirondacks." "Very much so in Lewis County." "Not a few are being killed by cars [Lowville, Lewis County]." "More numerous than in years." "Increased a lot in this

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area [Malone, Franklin County]." "The increase has been tremendous [Raquette Lake, Hamilton County]." "A great comeback in this region [Paul Smiths, Franklin County]." "More than tripled in past five years [Lewis County]." "More plentiful than red fox [Northville, Fulton County]." "Ten times the number than 20 years ago [Big Brook]." "The fisher is four times its numbers in the past four or five years."

Ives Turner, an accomplished trapper who knows the fisher as few others do, noted an increase in Essex, Franklin, Herkimer, Hamilton, and St. Lawrence Counties. He feels "spread" is not a strong enough term. Turner wrote the authors (February 26, 1951): "In many places where I ran mink lines year after year in the twenties, without ever seeing a fisher track, I have seen 20 or more [tracks] in a day's travel which were definitely made by several different fisher. In the twenties, they could be found in the mountains, now they are in every area that I've been through. Comparable to the beaver increase." In March, 1937, Hamilton made a fur survey of the Adirondacks and did not see a single fisher track. He was advised by residents well acquainted with the animal that it was scarce.

On March 13, 1952, the authors visited the Jerseyfield Lake area in Herkimer County and found fishers abundant. Tracks of four different individuals were noted along a 3-mile stretch of logging road. This was in an area of hard maple, yellow birch, and hemlock. In February, 1949, Oliver Signs saw 32 trails (tracks in snow) of fisher over a distance of a mile and a half in an area about 10 miles west of Piseco. These trails presumably were made by several fishers.

This brief summary of trapper records indicates the increase, but by no means tells the whole story. Here is a mustelid normally inhabiting the green timber and restricted at one time (only a decade ago) to the coniferous parts of the higher Adirondacks. Yet, since then, it has spread until fishers have been taken within 3 miles of Utica, and a few have been trapped on the garbage dumps of small towns only a few miles north of Oneida Lake. The reason for the expanding range and the increase in numbers of this species is hard to fathom. Complete protection for a few years is not the answer. Neither do periodic abundance and scarcity induced by cyclic behavior explain the marked increase in the fisher. In the face of decline in other parts of North America, the fisher has increased measurably in New York State (Figure 1). The record from Saratoga County is that of an animal shot in a hen house at Ballston Spa. Additional records secured

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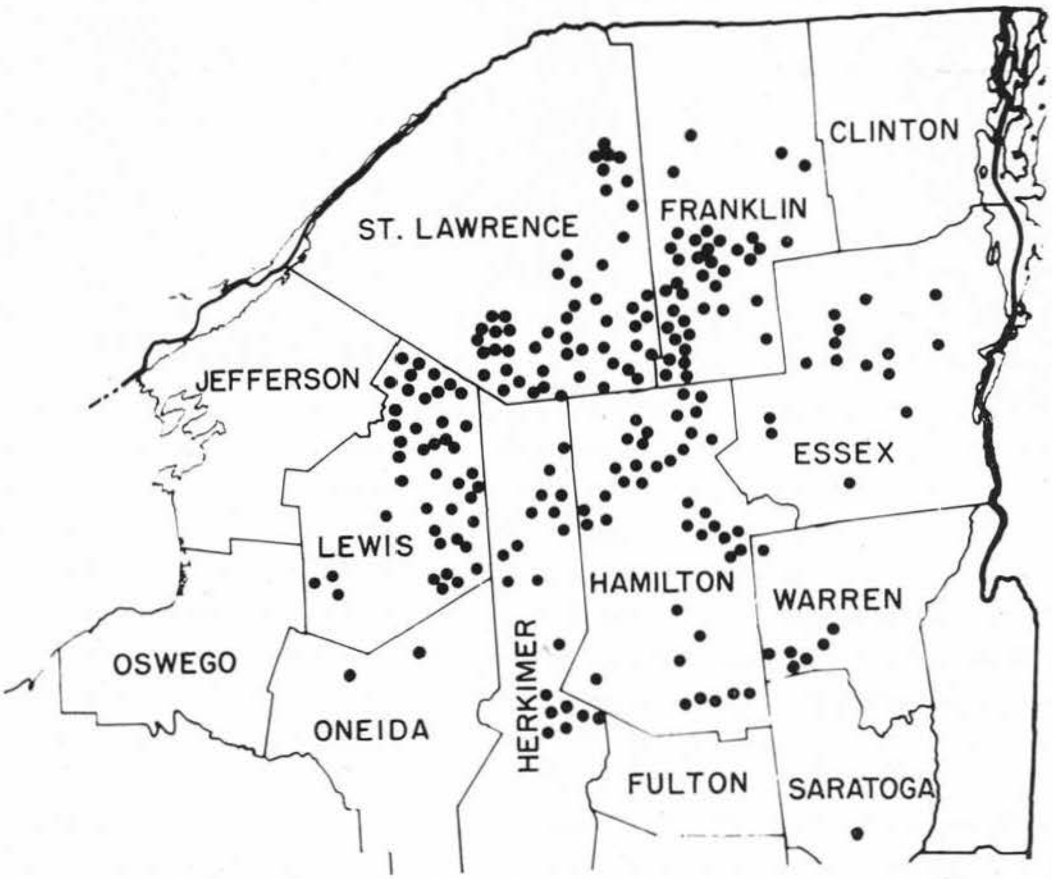

Figure 1. Distribution of the fisher in New York based on trappers' reported take for 1950 and 1951. Each spot represents one animal (of 246 reported, 32 not included because of insufficient data).

in 1952 and 1953 include several from northern Oneida County. Trappers report the animal numerous in northern Fulton County.

It is lamentable and scarcely understandable that so valuable a furbearer as the fisher would be without protection until 1936. Prior to that time the animal could be taken at any time and in any manner. That it was not exterminated in this State may be attributed to the fact that few persons attempted to hunt or trap it when its pelt was unprime.

The take of fishers in New York, as reported by trappers prior to the period when a season was established, is not accurate. While the figures may give trends or some indication of fluctuating numbers for a species, they are notoriously inaccurate individually (Hamilton, 1935). The number of animals taken is influenced by a variety of factors such as actual abundance or scarcity, fur prices, seasonal weather, and a number of intangibles. From 1918, the first year for which records are available on the species, to 1935, the annual reported take was as follows:

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Year	Number	Year	Number
1918	396	1927	156
1919	353	1928	66
1920	132	1929	110
1921	186	1930	158
1922	563	1931	181
1923	112	1932	105
1924	144	1933	31
1925	61	1934	308
1926	146 [2]	1935	275

In 1949, the Conservation Department declared an open season on fisher. After closed seasons for 13 years, the increase of the species indicated that the population had made such a pronounced recovery that an open season would result in harvesting surplus animals. This first open season extended from October 25 to November 25 in eight Adirondack counties, trappers being limited to three fishers each. The regulation required pelts to be tagged by game protectors within 5 days after the close of the season and before disposal or removal from the county in which trapped. The tags were to remain on the pelts until they were tanned. In 1951 the season was extended to January 1, 1952, and in 1953 until January 5, 1954. The regulations in 1952 did not contain instructions for tagging pelts so figures for this season are not available. In 1949, 113 were tagged; in 1950, 52; in 1951, 194; in 1952, no record; in 1953, 172. In the years 1950, 1951 and 1953, the total catch of 264 trappers was 418 fishers, or an average of 1.6 per trapper. Many of those who reported taking the legal limit of three stated that they trapped more, a few taking six animals. Some were taken by mink trappers, although the majority were taken in sets designed for bobcats.

The value of fisher pelts is reflected in prices paid to the trapper over a 40-year period. Our earliest records are from the books of Brightman Brothers of Rochester, New York. In 1916, 18 pelts averaged $16.40. In 1921, 37 pelts commanded an average of $65.50 per skin. In 1924, eight pelts averaged $38.00 each to the trapper. The late 1920's witnessed an increasing demand for fisher pelts, and some dealers paid $150 for a good silky pelt. The Brightmans paid $288 for five pelts in 1928 and $214 for four pelts in 1929, the average price per pelt being $57.60 and $53.50, respectively. In the early

[2] For 1926 the Conservation Department tabulated the reported game take for only 31 counties (half of the total), more or less evenly distributed throughout the State, and doubled the results. For these counties 73 fishers were recorded.

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1930's, a good fisher pelt averaged about \$20. With the opening of the season in 1949, long furs were not in demand and prices received by the trapper would not induce a special effort to trap these animals. The highest price reported in 1951 for a female was \$40, and that for a male, \$35. Average prices received by trappers in that year were \$27.50 for females (based on 15 skins) and \$19.50 for males (29 skins).

Data obtained from tagging records do not indicate the actual take, since many fishers are shot illegally by deer hunters while some which are legally trapped are not tagged. Fur buyers often purchase fisher pelts which are presented as silver foxes, shot by deer hunters who do not know the identity of the animal.

Tagging pelts of the rarer fur-bearers is a desirable practice, since only in this manner can data be secured on the probable take by trappers. It is likewise an aid in providing a source of research material, secured through the game protector and trapper.

In estimating the present population of the fisher in the Adirondacks, one is dependent on the observations of experienced trappers who have spent many years in the big woods trapping and observing fur-bearers. Estimates range from one animal to 4 square miles to concentrations of four animals to a square mile over extensive areas, based on the number taken in a known area. They do not include the probable number remaining in a region after trapping operations have ceased. Certain areas have higher concentrations than others and it is probable that populations in some parts of the range vary from year to year. There is surprising unanimity of opinion among experienced trappers that fisher populations throughout much of the Adirondack forest average about one animal per square mile. Considering clearings and burns, there are approximately 6,000 square miles of suitable fisher habitat in the Adirondacks, and this area appears to be occupied, in varying degree, by the species. We judge the present population at between 3,000 and 4,000 individuals.

MEASUREMENTS, WEIGHTS, AND SEX RATIOS

Measurements and weights of New York specimens of the fisher are scarce, as indeed they are for the species in general. The data recorded from 69 Adirondack fishers trapped from 1949 to 1953 exceed in this respect previous records for the fisher in the United States. In the main, measurements were made of the skinned carcasses. Practically all of the specimens examined were essentially fresh. The few

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TABLE 1. WEIGHTS AND MEASUREMENTS OF 27 MALE FISHERS TAKEN IN THE ADIRONDACK REGION OF NEW YORK (1949-53)

Estimated live weight in grams	Measurements in millimeters			
	Body length	Total length	Tail	Hind foot
2560	562	906	344	. . .
2856	563	. . .	. . .	. . .
2856	570	927	357	121
2968	547	887	340	. . .
2968	579	916	337	. . .
3080	558	882	324	116
3080	604	961	357	. . .
3220	551	892	341	120
3220	572	911	339	. . .
. . . .	580	926	346	106
3360	519	847	328	97
3411	611	969	358	. . .
3416	582	946	364	. . .
3640	579	916	337	124
3640	584	921	337	125
3640	608	. . .	. . .	. . .
3640	627	998	371	. . .
3780	620	998	378	. . .
3920	595	946	351	117
4060	662	. . .	. . .	121
4200	634	992	358	121
4200	589	960	371	120
4480	700	1073	373	. . .
4760	594	952	358	121
4928	618	973	355	123
5040	602	923	321	. . .
5460	601	948	347	114
Average 3707	593	940	350	118

dried specimens were thoroughly soaked to permit stretching, and allowance was made in weighing these carcasses. The unskinned weight was estimated after weighing the carcass. Since a number of the animals were weighed before and after skinning, this adjustment may be considered reasonably accurate. In six specimens (three males and three females) the skinned weight of the fresh carcass averaged 80 per cent of the unskinned weight. The phalanges are often removed with the pelt. Half of the specimens had only a single hind foot intact. The data are given in Tables 1, 2, and 3.

All specimens appeared to have been in good health, as evidenced by the presence of fat and lack of any apparent pathological condition. The disposition of fat on the fisher is generally similar to that in the genus *Mustela*. It is restricted in the fisher to certain portions of the body and not overlaid on the back as in the skunk and often the otter. Males invariably carry more fat in proportion to their size than

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TABLE 2. WEIGHTS AND MEASUREMENTS OF 42 FEMALE FISHERS TAKEN IN THE ADIRONDACK REGION OF NEW YORK (1949-53)

Estimated live weights in grams	Measurements in millimeters			
	Body length	Total length	Tail	Hind foot
1260	499	804	305	87
1316	450	703	253	...
1402	477	783	306	...
1510	473	784	311	100
1568	491	789	298	...
1680	489	782	293	...
1680	492	782	290	...
1686	484	808	324	...
1820	506	812	306	109
1828	465	771	306	...
1832	495	791	296	104
1848	574	883	309	89
1904	493	794	301	90
1960	477	786	309	106
1960	485	806	321	107
1962	...	...	...	107
1962	502	818	316	...
1964	517	826	309	...
1968	501	817	316	...
1970	491	764	273	104
1986	517	826	309	...
2016	504	836	332	...
2040	499	803	304	97
2110	500	815	315	...
2110	501	741	240	98
2115	512	821	309	...
2122	531	827	296	...
2213	508	784	276	106
2240	481	804	323	90
2246	482	809	327	...
2246	501	803	302	106
2268	471	783	312	...
2270	515	829	314	...
2296	522	831	309	...
....	515	846	331	109
2520	517	824	307	106
2522	501	741	240	98
2576	522	848	326	101
2610	511	826	315	...
2800	495	826	331	...
2805	531	839	308	89
3136	582	946	364	107
Average 2057	502	808	306	100

the females. In the latter, noticeable fat is usually restricted to the inguinal region, a scanty omental layer, and a strip from the kidneys to the anus. In a female whose live weight was estimated at 2,240 grams, 71 grams of fat were removed from the carcass. A large male (estimated live weight 4,928 grams) had an inguinal fat blanket 15

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TABLE 3. AVERAGE AND EXTREME WEIGHTS AND MEASUREMENTS OF 69 FISHERS TAKEN IN THE ADIRONDACK REGION OF NEW YORK (1949-53)

Item	Male (27)	Female (42)
	Estimated live weight	
Average in grams	3,707	2,057
Range		
in grams	2,560–5,460	1,260–3,136
in pounds	5.64–12.04	2.78–6.91
	Body length	
Average in millimeters	593	502
Range		
in millimeters	519–700	450–582
in inches	20.43–27.56	17.72–22.91
	Total length	
Average in millimeters	940	808
Range		
in millimeters	847–1,073	703–946
in inches	33.35–42.24	27.68–37.24
	Length of tail	
Average in millimeters	350	306
Range		
in millimeters	321–378	240–364
in inches	12.64–14.88	9.45–14.33
	Length of hind foot	
Average in millimeters	118	100
Range		
in millimeters	97–125	87–109
in inches	3.82–4.92	3.43–4.29

millimeters thick. Fat from this region, the omentum, flanks, and shoulder totaled 236 grams.

A nearly balanced sex ratio was reported by de Vos (1952) who listed 245 males and 260 females taken by Ontario trappers during the period from 1932 to 1951. Of the sexed carcasses, 23 were males and 38 females, a ratio of 38:62. Of 69 Adirondack carcasses examined, 27 were males and 42 females, a ratio of 39:61. The pre-

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ponderance of females might be attributed to specific attempts to track the smaller animals, since their pelts are worth considerably more than those of the larger, coarser-furred males. Such a situation prevailed in the 1920's but is not the case at present. Males range farther and presumably are more active. Moreover, the majority of these fishers were taken in bobcat sets.

ACTIVITY AND MOVEMENTS

The fisher is active both day and night. It is often seen by trappers and deer hunters. Trappers frequently note fresh fisher tracks in newly made snowshoe trails. Its diurnal activity is reflected in the number shot by hunters. Nelson Jones, fur buyer of Remsen, New York, was offered six fisher pelts shot by hunters in the fall of 1951. Andrew Buff, Syracuse, could have purchased as many fishers that had been shot by hunters as were taken by trappers in the 1950-51 season. In addition to these records, other observations attest to the fisher's daytime activity. Franz Winters, Stratford, New York, reports that he has seen several fishers traveling during the day. Glenn Rowe, Ellenburg Depot, New York, saw three fishers while prospecting for fur sign in the fall of 1950.

A great traveller, the male may circle an area of 10 square miles, often an area of considerably greater size. Fishers visit the same area at rather regular intervals in the winter. According to de Vos (1952) the foraging movements of these animals are more or less circuital, but not restricted to a definite pattern. He believes their movements are apparently governed by the availability of food, topography, and cover. Some Adirondack trappers are of the opinion that the fisher travels much like the fox, while others believe that the line of travel is unpredictable, individuals not restricting themselves to a specific circuit. Bruce Racha, trapping in Hamilton County in November, 1950, followed three fisher which stayed more or less together for several days. They would travel some distance and then track up a small area (approximately 10 acres) so that it was impossible to determine where they had taken refuge. The next night all would leave this area and travel several miles, then settle down and hunt in a small area again. On the fourth night these fishers found a dead deer and remained about the carcass for several days. Ives Turner observed an instance where a fisher, identifiable by its tremendous tracks, traveled 6 or 7 miles in a few hours (Little Tupper Lake). Like many others who have followed fisher trails, Turner believes the fisher is a random traveller, not restricting its movements to a rather marked

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itinerary as does a mink or fox. Usually most areas in a given section will be visited in a month or so. One area may be well marked by fresh sign, yet the following day no indications of fishers will be observed.

John Battram who spent a great deal of time for many years tracking down fisher, informs us that they usually work an area not exceeding 10 miles in radius. In the mid-1920's, when a prime female pelt occasionally brought $150, he often camped on the trail of one individual for 3 days. He once tracked one 30 miles in a period of 2 days. Battram believes the fisher utilizes trees for dens in the warmer months, while, in the winter, rock ledges and holes (fox dens) are frequented.

During the warmer months, the animals are found at the higher elevations but with the advent of cold weather they often frequent the swamps at lower elevations.

FOOD AND FEEDING HABITS

The food of the fisher has not been carefully investigated. Carcasses are usually difficult to obtain, and droppings are not easily secured since the animal does not have regular places for depositing scats as do many other fur-bearers. Coues (1877), Seton (1929), and Grinnell *et al.* (1937) have given generalized accounts of the fisher diet. The most detailed study was that of de Vos (1952). In an examination of 59 stomach and intestinal tracts of Ontario fishers collected from November to April, he identified varying hare, porcupine, deer, red-backed mouse, shrews, red fox, raccoon, otter, beaver, red and flying squirrel, ruffed grouse, fish, insects, and mountain ash berries. In addition to these items, scats contained jumping mouse remains and the seeds of sarsaparilla.

In the present study the stomach and alimentary tracts of 65 fisher carcasses received from New York trappers over five trapping seasons (1949-53) were examined. All but one represented trapped animals, the exception being a dead individual found by a trapper. Almost without exception the stomach, and frequently the entire intestinal tract, contained trap debris (finely chewed material from the trap stake or spruce and hemlock needles ingested by the trapped animal). This debris may not all have been adventitious. Clarence La Parr, an Adirondack trapper of wide experience, believes that fishers occasionally chew on the ends of old tree stumps, based on evidence observed following winter tracks.

Contents of the stomach and alimentary tract were placed in a

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large food strainer and held under a stream of water which washed out the dirt and small debris into a pail. This material was later examined for small parasites and food items that might be overlooked. The residue from the strainer was placed in white enamel pans, covered with water, and the evident food material removed.

Sixty contained recognizable natural food remains. No attempt has been made to estimate the volume of the various food items. Usually a single item was recovered from each animal, although on occasion several different foods were present. The results are presented in Table 4.

Deer are of primary importance in the winter diet. Most fishers are trapped during the deer season when carcasses provide a ready source of food over a rather long period. To be sure, a large fisher is able to cope with a weakened doe or fawn, but other forms of live prey appear more abundant and certainly more easily secured. Trappers occasionally use a deer carcass for bait, particularly the paunch. Most deer eaten by fishers must be considered not as initial kills but rather as carrion or trap bait.

Of the red squirrel, its use by both the fisher and marten is proverbial and the present study bears out this conclusion. Occurring in 16.7 per cent of the specimens examined, it is evident that this species contributes materially to the diet.

Porcupine remains occurred in five of the animals. There is an abundant literature on the role of the fisher as predator of this big rodent.

Varying hare remains were found in eight stomachs. It is possible some of these may have represented trap bait, although the hare is a common prey species in the region studied. In an analysis of 59 fisher stomachs and intestinal tracts from Ontario, de Vos (1952) found this animal in 25 of the specimens. While trapping coyotes for the New York State Conservation Department in the summer of 1951, Louis Wallace saw a hare run across a logging road, followed shortly by a fisher. The fisher follows the trail by scent. Several trappers have remarked on its keen sense of smell.

Small mammals appear to be one of the mainstays of this species during the fall and winter months. Red-backed mouse *(Clethrionomys)* remains were found in 10 stomachs, shrew (*Blarina*) in eight, and deer mouse (*Peromyscus*) in four. Other mammals, recorded once each, included the flying squirrel (*Glaucomys*), mink, and muskrat. Because trapping seasons for both mink and fisher coincide, it is possible the mink was taken from a trap. Nelson Jones of Remsen,

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TABLE 4. ANALYSES OF 60 STOMACHS AND INTESTINAL TRACTS OF FISHERS TAKEN IN THE ADIRONDACK REGION OF NEW YORK FROM OCTOBER TO JANUARY (1949-53)

Food item	Frequency of occurrence	
	Number	Per cent
Mammals		
Deer	11	18.3
Red squirrel	10	16.7
Red-backed mouse (*Clethrionomys*)	10	16.7
Varying hare	8	13.3
Shrew (*Blarina*)	8	13.3
Porcupine	5	8.3
Deer mouse (*Peromyscus*)	4	6.7
Flying squirrel	1	1.7
Mink	1	1.7
Muskrat	1	1.7
Sub-total	48	80.0
Birds		
Bluejay	3	5.0
Grouse	3	5.0
Undetermined	1	1.7
Sub-total	7	11.7
Fish	1	1.7
Insects	2	3.3
Fruit		
Beechnuts	10	16.7
Swamp holly (*Ilex verticillata*)	3	5.0
Black cherry (*Prunus serotina*)	1	1.7
Sub-total	14	23.4
Mosses and ferns		
Moss (*Mnium*)	2	3.3
Fern (*Asplenium*)	3	5.0
Sub-total	5	8.3

New York, writes: "He [fisher] stole a mink out of one of my traps." Presumably the fisher is able and apt at taking a mink upon occasion. The muskrat season had not opened when the fisher with muskrat remains was trapped.

The bird remains included three bluejays, three grouse, and an undetermined small bird.

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Most carnivores accept fruits when such are abundant. To recover swamp holly (*Ilex verticillata*) in three fisher is yet a surprise. The intestine of one individual contained a half cup of seeds and fruit, while the other two provided sufficient material (a tablespoon or more in quantity) to demonstrate that the fisher had fed voluntarily on these berries. One individual contained the pulp and eight stones of black cherry fruit *(Prunus serotina)*.

The occurrence of fern frond tips *(Asplenium)* in some quantity in the hind gut precludes any possibility of ingestion while the fisher was in the trap. Two animals contained sizeable quantities of the moss, *Mnium*.

Coues (1877) stated that the fisher is sometimes forced, by failure of other sources of supply, to a vegetarian diet, when it feeds freely on beechnuts. Merriam (1884) argued that a good beechnut year is almost invariably followed (in the Adirondacks) by an abundance of small game—grouse, squirrels, chipmunks, and mice alike fattening upon the mast. He remarked that beechnut years are apt to be followed by mild winters, while it is during the deep snows of the severest winters, when there are few or no beechnuts and a consequent scarcity of small game prevails, that the fisher is likely to be pinched for food.

There is no evidence to support the thesis proposed by Merriam. Good beechnut crops are not a biennial affair, nor is any vertebrate dependent, even in small measure, upon a seasonal fare of this mast. Beechnuts are not an emergency food. In some instances, their husks and meat filled the gut. Judging by the quantity, two individuals had eaten more than a hundred beechnuts. These nuts may be considered a primary seasonal food of the fisher when they are available.

In brief, the diet of the fisher is similar to that of many other carnivores. If flesh is not available, fruits and insects suffice. As with the fox, seasonal food appears to be determined by availability.

FISHER VS. PORCUPINE

A voluminous, although for the most part popular, literature has developed on the role of the fisher as a predator of the porcupine. Since the time of Richardson (1829), many writers have listed the fisher as an implacable foe of the porcupine. That it is not wholly immune to the quills is attested by the accounts of several trappers who indicate they have taken these animals in an emaciated condition, the head and forepart of the body riddled with quills. It is probable, however, that the majority are in some manner immune to the action

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of these quills, for, of the 69 carcasses handled in this study, none of those containing quills appeared to be affected in any manner. One large male contained more than 20 quills, distributed over the breast, throat, upper neck muscles, and postorbital regions. Occasionally the quills become imbedded in the gums or lips. In one animal a quill had penetrated halfway through the trachea just above the bronchi. None had caused suppuration. Trappers often find quills, usually soft and partially surrounded by connective tissue, lying in the fascia between the hide and body muscles.

How the porcupine is overcome by the fisher entails no end of stories, many of problematic accuracy. The few eyewitness accounts we have gathered are presented below.

Arthur Scheffler of Orono, Maine, writes: "On June 24, 1951 while walking in the woods [20 miles west of Princeton, Maine], I heard a thrashing. Just over a knoll I saw a fisher circling a porcupine. The porky kept turning, trying to keep its tail toward the fisher. The porcupine apparently became confused, for it could not keep up with the circling of the fisher. The fisher finally came head on to the porky and turned it over. With the porcupine on its back, the fisher had an easy kill. I could not be sure how the fisher turned the porcupine over, whether with its muzzle or paw, for I was about one hundred feet away."

Glenn Rowe of Ellenburg Depot, New York, prospecting for fur in southern Essex County in the fall of 1950, reconstructed a porcupine kill by a fisher. The fisher, apparently, had backed the porcupine against a log, then approached under the log and grabbed it by the throat. The log was full of quills, and beside it were the remains of the porky on its back with cut throat, the viscera and one hind leg eaten. Wellington Benson of Harrisville, New York, provided this note: "A fellow and I saw a fisher kill a porcupine. The fisher chased this quill pig up a tree, out on a limb, then swung under the porky and opened him up. The fisher dropped about four feet with the pig's entrails and started to eat them while the porky went up the tree. We shot them both." Schoonmaker (1938) recorded two instances in which Adirondack porcupines were hamstrung by fisher and the belly opened.

A notable decline in porcupine populations in some areas of the Adirondacks has been concurrent with the fisher increase. In March, 1937, Hamilton, in making a fur survey of extensive areas of St. Lawrence, Franklin, Hamilton, and northern Herkimer Counties did

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not see a fisher track but encountered abundant evidence of porcupines. In March, 1952, the authors traveled the same area and saw but a single porcupine track, while fisher sign was abundant.

Ives Turner writes: "The half dozen or so fisher that I saw in the twenties all had quills. The ones we caught this fall [1952] and three or four others I have seen recently did not have quills. Neither did I see a single sign of a hedgehog where we trapped this fall. The same condition prevailed there [Whitney Estate, Hamilton County] four years ago. Several fisher and no hedgehogs. In my territory the hedgehog appears to be on the way out." In northern Herkimer County and western Lewis County, few porcupine have been seen since the fisher increase in those parts. Gordon La Parr writes that "15 or 20 years ago it was practically impossible to keep the porkys from ruining our camp [Webb, Herkimer County], now with the great increase of the fisher in that area it is seldom we see a porky [1951]." The fisher appears to be less common on the eastern border of the Adirondacks. From Elizabethtown to Lake George porcupines are reasonably common, particularly in the area bordering Route 9, although their numbers have decreased about Keene with a corresponding increase of the fisher.

To our knowledge, the fisher does not presently occur in the Catskill Mountain area. Porcupines are extremely abundant, however. Two hunters shot 43 in 1 week (May, 1950), and another killed 35 in a 10-day period about the same time. These animals were all shot along a 4-mile stretch of highway near Westkill, Greene County, New York. A few miles north of Edgewood, Earl Van Valkenberg killed more than 50 porcupines about his home in 1951-52. William Dilger and E. M. Reilly, Jr. killed 34 about their camp on the summit of Slide Mountain, Ulster County, on June 8-10, 1954. Since no Adirondack populations approach these numbers, it seems probable that the increase of the fisher has had a part in the reduction of the once populous and destructive porcupine.

FISHER VS. RACCOON

In the Adirondacks, the fisher and raccoon occur in the same habitat, although the fisher appears more at home in the dense green timber (spruce and balsam) than does the raccoon. Coues' report (1877) of a fisher attack on a raccoon precipitated other accounts, some perhaps with foundation. Five trappers who took fishers in the 1950 and 1951 seasons indicate that this animal habitually preys on the raccoon. Harry Cook (Paul Smiths, New York) writes: "I once saw

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a fisher attacking a good sized 'coon and certainly would have killed it had I not frightened him off." Frank Webb of New York Mills observed (March 5, 1952) where a fisher had attacked and killed a raccoon in a stump. A number of trappers have related instances of raccoon kills which they attributed to the fisher, but specific information from these men is lacking. In parts of St. Lawrence and Hamilton Counties, the raccoon has decreased over the period of fisher increase although Ives Turner took 10 large raccoons in mink sets in the Saranac Lake region in the 1950 season. Trapped raccoons are frequently killed and partially eaten by fishers.

FISHER VS. DEER

The high incidence of deer eaten by fishers can, we believe, be attributed primarily to feeding upon carcasses which they come upon during their travels. Large numbers of deer are killed but not recovered by hunters, and traps set about these kills are effective in taking fishers. Natural winter deer mortality likewise provides a staple for the fisher. Our correspondents indicate that a large male fisher can and will overcome a small deer upon occasion. Quoting Manly Hardy, Seton (1929) recorded a specific instance of a kill by a fisher. We believe that such instances are uncommon and that few deer, including fawns, are attacked by fishers.

REPRODUCTION

It has long been known that the fisher mates shortly after the birth of the young and has a prolonged gestation. This lengthy uterine stay is accomplished by a complete cessation of growth sometime during the period between fertilization of the egg and parturition. Embryonic development proceeds in a fashion similar to that among the majority of mammals until the formation of the blastocyst. At this time, cell division ceases and the blastocyst remains free in the uterine horn. How long this situation prevails is unknown. Our meager data indicate that resumption of embryonic development does not start until January, and possibly not until 2 months before birth.

Hall (1942) has summarized the available information on this subject. In 15 cases, females observed on fur farms had a mean gestation of 352 days, the minimum being 338 days and the maximum 358 days.

In an effort to determine whether New York females examined had bred, the uterine horns were syringed for recovery of blastocysts. This was accomplished by inserting the needle at the junction of the

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uterine tube with the distal end of the vagina. After cutting off the Fallopian tube at its junction with the uterine horn, a stream of water was directed into the horn, the water flushing into a dish any blastocysts that were present. Removal of the Fallopian tube was necessary, since its small diameter militated against adequate flushing. The macroscopic blastocyst could readily be observed in the dish. Flushing was repeated several times for each horn, although the blastocysts were invariably recovered on the first flushing.

The blastocyst is spherical, amber yellow to pale yellowish white, and has a diameter of 1 millimeter. Counts were made from each horn of the uterus. The blastocysts remain in good condition a remarkably long time after death. In some specimens, syringed 2 months after being trapped, blastocysts were recovered, although somewhat shrivelled.

The following records of blastocysts, all of similar size, were obtained.

Estimated weight of female	Date of capture	Number of blastocysts
5 lb., 4 oz.	November 10, 1953	3 (2 R, 1 L)
4 lb., 2 oz.	November 15, 1953	3 (2 R, 1 L)
4 lb., 12 oz.	November 23, 1951	3 (1 R, 2 L)
4 lb., 4 oz.	November 25, 1953	3 (1 R, 2 L)
4 lb., 9 oz.	December 1953	1 (0 R, 1 L)
4 lb., 6 oz.	December 1950	2 (1 R, 1 L)
6 lb., 5 oz.	December 26, 1953	4 (2 R, 2 L)

None of the females presumed to be young of the year (7 to 8 months old) contained blastocysts. Captive females may breed successfully when a year old (Hall, 1942). It is believed that some of those examined in the present study and which contained blastocysts were only a year old when bred.

Mrs. Amy Garland of Malone, New York, has provided the following data with respect to the northern Adirondacks (letter April 6, 1952): "A winter afternoon in February, 1924, John Battram and my husband arrived home from one of their trapping excursions with two baby fisher, a male and female. They had found them in a hole in a tree high above ground . . . they were like baby rats, making grunting-like noises." This appears to be an exceptionally early birth date for the fisher, and it is possible Mrs. Garland's memory may have tricked her on the time of capture. On another occasion, Battram took

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three young fishers from a cavity in a hard maple about 20 to 30 feet from the ground in mid-March. After the female had been captured, he heard mouse-like sounds and recovered the kits. Their eyes had not opened.

According to Hall (1942) the average number of young in 21 captive litters was 2.70. Blastocyst counts and two wild litters from New York averaged 2.66.

PARASITES

Incidence of internal parasites appears to be much lower in the fisher than in other mustelids (mink, skunk, weasel) examined. Contrasted with the more abundant mustelids, relatively few fisher carcasses have been explored for parasites. Chitwood (1932) recorded the nematode *Uncinaria stenocephala,* while Morgan (1943) found *Soboliphyme baturini* in the intestine of a fisher, and de Vos (1952) recovered *Physaloptera* and *Ascaris devosi* and the cestode *Mesocestoides variabilis,* a common tapeworm of skunks.

Routine examination for endoparasites was made of 65 carcasses, most of which were reasonably fresh or had been frozen after the pelt had been removed. The heart, lungs, liver, gall bladder, and bile duct were examined, and the stomach and intestinal tract were subjected to a thorough search for helminths. Kidneys were cut to expose the calyx. The wrists, ankles, and limbs were carefully examined for guinea worms.

Nematodes were the most frequently encountered parasites. *Capillaria mustelorum* is a small threadlike nematode rather common in the fisher. Twenty-three stomach and intestinal tracts produced this parasite. From 12 to 30 individuals were recovered in an animal. Due to the small size, it is possible that both the incidence of occurrence and the number per specimen were considerably greater than indicated. *Physaloptera* sp., probably *P. maxillaris,* was found in seven animals. All were of small size, none exceeding 30 millimeters in length. Twenty-four individuals were removed from the stomach lining of one fisher. *Arthrocephalus lotoris,* taken from the stomach and fore intestine, occurred in seven animals. *Molineus patens,* a common nematode of several species of mustelids, was found in three fishers. The guinea worm, *Dracunculus insignis,* occurred in eight (13.3 per cent) of the animals examined. These nematodes were imbedded beneath the fascia of the wrist or ankle, often lying well within and between the insertion of the superficial digital flexor and the plexor carpi radialis muscles, or beneath the transverse ligament and the muscle insertions

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of the ankle. They varied in size, the smallest being 114 millimeters while the largest was 206 millimeters in length. Part of this parasite is normally exposed and is often observed by trappers while skinning fisher and mink. A single *Uncinaria stenocephala* was recovered from the small intestine of a fisher.

Fragments of the cestode *Mesocestoides variabilis* were taken from the small intestines of four animals.

No ectoparasites were recovered, since the pelt had been removed from the carcass on receipt. Holland (1950) listed the flea, *Oropsylla arctomys,* while de Vos (1952) recovered a tick, presumably *Ixodes cookei,* from a fisher.

There was no evidence to indicate that the fishers examined had been affected in any manner by the parasites they harbored. All were in good condition. The only indication of distress observed by us among mustelids, occasioned by an internal parasite, occurred in a mink with large kidney worms *(Dioctophyme renale)*. This nematode was not present in the fishers examined.

MANAGEMENT OF THE FISHER

Management of a mammal, such as the fisher, must be limited, by and large, to administrative measures rather than to environmental manipulation. In considering the latter, only two possibilities seem available to state and federal agencies. Of these, perpetuation of extensive wild areas would seem to be essential to the well-being of the population, particularly during periods of severe trapping pressures. In addition, it may be possible to reestablish this fur-bearer, through a live-trapping and transfer program, in suitable parts of its range from which it has been extirpated.

Administrative management may apply directly to the fisher by defining open seasons, bag limits, and manner of taking. Indirect, and of equal importance, is the influence of open seasons, bounty payments, or the method of capture of other species. Such may influence the take of fishers, both legal and illegal.

For example, data obtained from trappers suggest strongly that few trap for fishers alone for profit, but rather do so in conjunction with bobcat, fox, or coyote trapping. For counties such as St. Lawrence, where bounties are paid on large predators, the intensity of bobcat and coyote trapping may be indicated by the following. In 1948, 29 trappers took 13 bobcats and 10 coyotes. In 1949, 72 bobcats were offered for bounty payment by 48 trappers. This same year 15 trappers received bounty payments on 20 coyotes. In 1950, 15 trappers

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took 13 bobcats and 5 coyotes. The same general pattern is prevalent throughout the fisher range in the Adirondack area. Thus, it is probable that the harvest of fishers is stimulated by the opportunity to take bobcats and coyotes.

Management presupposes an inventory of stock. With the fisher it is extremely difficult, if not impossible, to make an annual inventory of the population by direct observations, track counts, or other methods. An excellent method for ascertaining trends in abundance is to require trappers to have game protectors tag fisher pelts before they are offered for sale. This practice has been employed in New York for the rarer fur-bearers for many years. If maintained, it will continue to yield information of great value for the management of this species.

Most of those who trap fishers are agreed that the present season and bag limit are satisfactory. Many feel the pelts are not fully prime until mid-November.

Reestablishment of the fisher in the Catskills is another possibility that might be considered. There are wild areas of sufficient size and suitable habitat to support a substantial population in this region. The Hunter and Slide Mountain sections are examples. Fishers are easily trapped and could be taken in live-traps or padded steel traps. Stock obtained from parts of the Adirondacks where the species is abundant might be liberated as an experiment in one or two selected localities. Probably the best time for such trapping and transfer would be early fall to minimize the effect of low temperatures on the animals. Stocking would need to be carried on for only a few years. After that, success or failure would be evidenced by whether the species persisted or disappeared. If successful, natural spread might extend its range to other parts of the region or further liberations might be warranted.

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TOXICITY OF EMULSIFIABLE ROTENONE TO VARIOUS SPECIES OF FISH

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ABSTRACT

The toxicity of rotenone to six species of fish was studied under controlled laboratory conditions. Toxicity curves were constructed for comparing the effect of temperature, acid and alkaline waters, and variation between species. The data are restricted to 100 per cent mortality occurring within an exposure period of not more than 24 hours.

An additional variable was found to be associated with the size of the fish and correction was made by multiple regression whenever the effect was found to be significant by the use of the *t*-test.

Generally, decrease in temperature and increase in length were found to extend the time for death. No difference in effect was found between the two waters used. A wide variation was found among the six species tested in the exposure required for death at equivalent concentrations.

The use of rotenone for the removal of undesirable fish populations has increased greatly in recent years and is now recognized as an important tool in fishery management. The concentrations employed are believed to have been based mainly upon the work of Leonard (1939) which indicated that a 0.5 p.p.m. concentration of powdered derris root (5 per cent rotenone) was adequate to kill bluegill *(Lepomis macrochira)*, common sunfish *(Lepomis gibbosus)*, common sucker *(Catostomus c. commersonnii)*, golden shiner *(Notemigonus c. crysoleucas)*, common shiner *(Notropis cornutus frontalis)*, brook stickleback *(Eucalia inconstans)*, mudminnow *(Umbra limi)*, and goldfish *(Carassius auratus)*. A concentration of 0.25 p.p.m. was not toxic to these species.

Leonard made some comparison of the toxicity in different types of water and concluded that rotenone was more toxic in a naturally acid water than in alkaline water, especially so to the more resistant species such as goldfish. He also reported a rapid loss of toxicity in solution, a 1.0 p.p.m. concentration failing to kill sunfish and bluegills between 20 and 41 hours after preparation. He found that an affected fish was unable to recover even when transferred to pure water as soon as equilibrium was lost.

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Smith (1940) reported treatment of the acid waters of Bills Lake, New Brunswick, with 0.25 p.p.m. derris powder having a rotenone content of 5 per cent. This produced a complete kill of bass and white perch, but failed to eliminate all eels, lake chubs, and sticklebacks, as was evident when the lake was treated 4 months later with sufficient derris to provide a 1.0 p.p.m. concentration.

Yearling trout were reported killed in concentrations of 0.20 p.p.m. of both derris and cube powder (5 per cent rotenone content) at temperatures of 5° and 20° C. Lake chubs and a few suckers were killed by a 0.20 p.p.m. solution of derris powder containing 3 per cent rotenone, although some suckers survived the period of exposure which was approximately 24 hours. Increased temperature increased the toxic action of rotenone. Brook trout which had lost their equilibrium revived when placed in untreated water.

Greenbank (1941) reported that powdered derris root produced an apparently complete kill in the epilimnion of two lakes in Michigan at concentrations of 0.44 and 0.62 p.p.m., yet apparently failed to penetrate the thermocline in both instances. A concentration of 0.56 p.p.m., in a pond without a thermocline, was assumed to have given a complete kill during the same period, with the possible exception of mudminnows.

Brown and Ball (1943) reported that, in a surface application in May of a slurry of derris powder to give a concentration of 0.56 p.p.m. in a Michigan lake with a maximum temperature of 48° F., the toxic effect was restricted to the upper 10 feet. Samples were removed from the lake and checked in the laboratory. None was found to be toxic until the temperature was raised to at least 57° F. Samples collected daily over a period of 7 days were found to be lethal to fish within a 24-hour exposure time, although a subsequent sample failed to kill fish with an 8-day exposure. They reported the order of tolerance of the species tested, from least to most, to be: largemouth bass, bluegill, sunfish, blunt-nosed minnow. Temperatures between 69° and 70° F. gave the same order. Aeration delayed the time of death only slightly. The affected fish could not be revived.

A second poisoning was made in August, at a slightly higher concentration, with chemical added in the region between 18 and 25 feet. A thermocline was present between 15 and 21 feet. Cage experiments showed fish were killed to the 15-foot level in the first day and to the 22-foot level by the end of the second. Samples collected after the second day showed the time for death became pro-

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gressively greater as the depth increased from the surface to 25 feet. After 72 hours the water was non-toxic below 15 feet, even at a temperature of 72° F. Some of their experiments showed the fish to be unaffected at a temperature of 45° F. in spite of the higher concentrations in the surface water used. At a temperature of 50° F. sunfish survived 2½ hours longer than largemouth bass.

Krumholz (1948) stated that experience has shown that bullheads *(Ameiurus* sp.) and possibly other kinds of fish are more resistant to the effects of rotenone than centrarchids or trout. In support he referred to treatments to give concentrations of 1.0 and 1.5 p.p.m. in a pond in Indiana, which failed to produce a complete kill of bullheads. He suggested that the characteristics of the water may have caused rapid dissipation of rotenone, or that a non-uniform distribution may have occurred despite efforts to insure that the waters were mixed thoroughly.

Smith (1950) quoted from a manuscript of Anthony to the effect that semi-controlled laboratory determination of the toxicity of "Fish-Tox", using banded killifish *(Fundulus diaphanus)* as the principal test species, but also white suckers, golden shiners, lake chubs, eels, white perch, and sunfish, gave results which indicated that less than a 2.0 p.p.m. application would not assure a complete kill. These conclusions were alleged to conform with the results on Cassidy Lake, New Brunswick, where a 0.5 p.p.m. application, followed by a 1.0 p.p.m. treatment failed to produce a complete kill.

Clemens and Martin (1953) used concentrations ranging from 0.5 to 3.5 p.p.m. in terms of 5 per cent emulsifiable rotenone and vehicle (or carrier). Dissipation of the rotenone occurred progressively from the bottom to the surface. Thermoclines were not penetrated. They found that the toxicity of the water to their test species, usually shiners *(Notropis lutrensis)*, was lost in from 1 to 3 days in Oklahoma ponds with methyl orange alkalinities ranging from 60 to 284 p.p.m., while 3 to 6 days were required when the alkalinity was about 16 p.p.m. Turbidity increased by 1 or 2 days the time required for detoxification of waters of high alkalinity.

They recommended that toxicity should persist for 3 days, or possibly 7 to 10 days, if spawn is to be killed. A concentration of 1.0 p.p.m. was suggested for ponds having up to 60 p.p.m. alkalinity and, for ponds of greater alkalinity, 1.0 p.p.m. if turbid and 2.0 p.p.m. if clear.

Danneel (1933) reported that the action of rotenone destroys gill tissue and, once affected, the fish is unable to recover.

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Hamilton (1941) disagreed with that viewpoint and, while he accepted the possibility of gill destruction at extremely high concentrations, maintained that, at normal dosages, death is caused by constriction of the gill capillaries preventing passage of blood through the gills. Fish can and do recover.

Prevost, Lanquette, and Grenier (1948) explored the apparently aberrant behavior of rotenone in the laboratory and came to the conclusion that, especially at low concentration, rotenone is removed quite rapidly by the fish undergoing exposure. In small volumes of solution this may seriously affect the accurate determination of toxicity. This may be corrected by using larger volumes of solution. They recommended that a volume of 8 liters per fish be used when working with rotenone. It is evident from their data that the volume is dependent upon size, presumably weight, as the same percentage mortality was attained with 2-inch bullheads at 0.4 liters per fish as with 5-inch fish at 4.0 liters per fish. Calculated in terms of weight, suckers averaging 35 grams would have a ratio of 1 gram to 0.23 liters of solution when 8 litters are used. Trout, with an average weight of 11 grams, would have a ratio of 1 gram to 0.72 liters.

The preceding summary of the literature presents a rather confused picture of the necessary rate of application of rotenone. While it is clear that tolerance varies between species, there is little indication of how widely separated different species may be in resistance to this poison. There seems to be considerable divergence of opinion on the recovery of fishes after having been affected by the toxic agent. Much of the reported work has been done with powdered or wettable rotenone, rather than with the more recently developed emulsifiable rotenone.

The prolonged toxicity to fingerling trout, which has accompanied the use of emulsifiable rotenone in many waters in this State, led to a belief that the more complete and thorough dispersion by the emulsifying agent accounted in part for this persistence, which often lasted for months. This apparent increase in toxicity might permit a reduction in concentration without a significant change in effectiveness.

In opposition to this theory, in certain State waters a complete kill of all species was not being obtained, even when the toxicity to trout persisted for a long time. This could be associated either with an abnormally high individual resistance in some species, or with a greater variation between species than had been indicated by many of the previous recommendations on the effective concentration.

In 1953 and 1954, laboratory studies were conducted in an

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attempt to clarify the situation with respect to the toxicity of emulsifiable rotenone solutions, using species common to New York, some of which did not appear to have been used before. Studies reported here include brown trout *(Salmo trutta)*, smallmouth bass *(Micropterus dolomieu)*, rock bass *(Ambloplites rupestris)*, creek chub *(Semotilus a. atromaculatus)*, common sucker *(Catostomus c. commersonnii)*, and brown bullhead *(Ameiurus nebulosus)*.

GENERAL PROCEDURE

A preliminary dilution of emulsifiable rotenone was made by diluting 1 milliliter to 1,000 milliliters in a volumetric flask. The addition of a measured quantity of this emulsion to a 20-liter Pyrex jar containing 10 liters of water provided the concentration desired which was recorded in p.p.m. by volume of the rotenone and the vehicle. Preliminary dilutions were made up daily. The water was held at the desired temperature and thoroughly aerated before the addition of the rotenone.

The jars were immersed in a constant temperature tank, electrically controlled within 0.5° F. of the required experimental temperature. The temperature was continually recorded by a Negretti-Zambra immersion bulb recorder. If, for any reason, the temperature fluctuated beyond the limits set, the results of that experiment were discarded.

The solutions were stirred thoroughly after the addition of rotenone and the oxygen was then determined by the unmodified Winkler procedure (American Public Health Association, 1936). Carbon dioxide and alkalinity were determined by the procedures recommended in the same reference. The pH was determined electrometrically with a Leeds and Northrop pH meter.

Following removal of the samples (approximately 375 milliliters) for chemical determinations, from one to five fish were added to each jar. Controls were run in a similar fashion from time to time.

All fish used were acclimatized to water from the hatchery spring for a minimum of 1 week at the initial temperature at which the experiments were to be conducted. In the set of experiments involving comparison of the effect of temperatures from 55° to 70° F. in 5-degree steps, a period of at least 48 hours was given for acclimatization to each successively higher temperature. No food was given the fish for a period of at least 48 hours before use.

With the exception of the brown trout, which were hatchery stock, all species used were collected from natural bodies of water

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and were maintained for some time in the hatchery water supply before acclimatization to temperature. The fish used were generally small in order to avoid the necessity of using large quantities of solution.

Two waters were used during these studies. The Rome Fish Hatchery spring water, on the alkaline side of neutrality, ranged in pH from 7.40 to 8.10, in methyl orange alkalinity from 97 to 109 p.p.m., and in carbon dioxide content from 1.0 to 6.1 p.p.m. A complete chemical analysis of this water has been reported previously (Burdick *et al.,* 1954). The other water was collected from Woodhull Creek (near Rome) and was faintly acid, with a pH from 6.28 to 6.80, a methyl orange alkalinity from 6 to 20 p.p.m., and a carbon dioxide content from 3.0 to 6.0 p.p.m.

A complete chemical analysis of the Woodhull water as of April 7, 1953, follows. With the exception of pH, alkalinity, and acidity (as CO_2), the determinations were made by M. Lipschuetz, Senior Analytical Chemist with the Rochester Pollution Unit of the Conservation Department. Aside from pH, all figures are in parts per million.

pH at 12° C.	5.86	Calcium (as Ca)	3.8
Alkalinity (as $CaCO_3$)	6.0	Magnesium (as Mg)	0.09
Carbon dioxide (acidity as CO_2)	3.0	Sodium (as Na)	0.92
Ammonia (as NH_3)	0.05	Potassium (as K)	0.50
Organic nitrogen (as N)	0.20	Iron (as Fe)	0.096
Nitrate nitrogen (as NO_3)	0.37	Manganese (as Mn)	0.027
Total phosphorus (as P)	0.002	Total solids	28.8
Silica (as SiO_2)	4.7	Volatile solids	14.0
Chloride (as Cl)	0.71	Specific conductance (in reciprocal ohms)	0.0000225 at 20° C.
Sulphate (as SO_4)	5.5		

The Woodhull water had to be hauled to the laboratory in specially prepared milk cans from a distance of 20 miles. For this reason it was found impossible to maintain a flowing supply for acclimatization, so an attempt was made to acclimatize the fish to be used in the study in aerated standing water. Continued aeration caused a small change in the chemical analysis and the results showed no significant differences from those for fish used without such treatment. Acclimatization to this water was not continued.

The time of turn-over (loss of equilibrium) and time of death were noted for all fish, although calculations were based only on the time of death. Except for those concentrations where it was anticipated that death would be greatly delayed, the fish were under con-

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tinuous observation. Where they were not, the experiment was started so the death of most, if not all, could be observed.

One hundred per cent mortality within 24 hours was chosen as an arbitrary datum point beyond which it was not planned to conduct the experiments. Except for the 0.70 p.p.m. concentration on bullheads, in which two exceptionally large fish were still living at the end of 24 hours, all concentrations which failed to meet this criterion have been eliminated from the computations.

Lengths of all fish were recorded in millimeters.

STATISTICAL TREATMENT [1]

Time for death, expressed in minutes, was found to be logarithmically distributed and the logarithmic mean is used in place of the arithmetic mean. When the mean time is plotted against concentration on logarithmic paper, a curve is obtained that closely approximates a straight line over much of its extent, departing therefrom as the time for death approaches 24 hours. The regressions of these means have been computed by the method of least squares as described by Bliss (1952). The standard deviations of the means and the standard errors of the means have also been calculated.

Length was observed to have an apparent effect upon the time for death and, in order to correct for this additional variable and allow a better comparison of toxicity, multiple regressions for three variates have been computed by the procedure outlined by Snedecor (1940). The regressions of time on concentration are then presented in two-dimensional graphs in the planes of the mean lengths, thus facilitating comparison.

Plotting the actual concentrations against time on logarithmic paper enables direct reading of the intermediate points. Tabulation of the data is made in this manner, even though all calculations except those involving length must be made using logarithms. Since standard deviation and standard error produce unequal results as antilogarithms, these are represented as a range, the plus and minus deviations having been combined as the spread of the statistic.

COMPARISON OF TOXICITY IN ACID AND ALKALINE WATERS

Many of the ponds which have been reclaimed by rotenone in this State contain acid water and have a low methyl orange alkalinity.

[1] The authors wish to express appreciation for the advice and assistance rendered by Hubert Maguire, Principal Statistics Clerk, New York State Conservation Department, in certain phases of the statistical treatment.

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Leonard (1939) concluded that rotenone was more toxic in this type of water. His conclusions were based on relatively few fish and his data do not permit the construction of comparison curves for the toxicity.

Preliminary plans involved the study of various species, using the normally acid, low-alkalinity water from Woodhull Creek and the Rome Hatchery spring water which is commonly slightly alkaline with a methyl orange alkalinity about median for the waters of this State. After initiation of this phase of the study, results with the first three species (creek chub, brown trout, and smallmouth bass) indicated further consideration was unnecessary. The data for the creek chub are the most extensive.

Creek Chub

Five concentrations were used, ranging from 0.10 to 0.50 p.p.m. by volume of rotenone and vehicle. At the 0.10 p.p.m. concentration most of the fish survived the 24-hour exposure period so it is not included in the computations. Twenty fish were tested at 60° F. in each of the remaining concentrations in both creek and spring water. The data are presented in Table 1, including the means for the times for death and the spreads of the standard deviations and standard errors of the means. No mortality occurred in the controls in equal volumes of water over periods of 24 hours.

The regression equations for the data were computed by the method of least squares and for the acid water (Woodhull Creek) and the alkaline water (hatchery spring) were, respectively:

$$\log Y = 1.58338 - 1.03318 \log X$$
$$\log Y = 1.53541 - 1.11604 \log X$$

In these and similar equations log X represents the common logarithm of the concentration.

Corrected means were computed from these equations and are presented in Table 1. Figure 1 presents the experimental means and their regression lines graphically.[2]

From Table 1, the variation in the average size of fish in the different groups can be observed. As a result of random selection, the range extended from 48.95 to 56.15 millimeters. Small fish appeared to be less resistant to rotenone than the larger fish within the

[2] In Figures 1, 2, and 3, solid circles indicate the logarithmic mean of time for death for fish in Woodhull Creek (acid) water; open circles, for hatchery spring (alkaline) water.

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TABLE 1. COMPARISON OF ROTENONE TOXICITY IN ACID AND ALKALINE WATERS FOR CREEK CHUBS, USING ANTILOGS OF THE LOGARITHMS OF THE COMPUTATIONS

Number of fish	pH of solution	Temperature (degrees Fahrenheit)	Concentration (in p.p.m.)	Average length of fish (in millimeters)	Range of lengths (in millimeters)	Volume of solution per fish (in liters)	Range of time for death (in minutes)	Mean time for death (in minutes)	Standard deviation of the mean (spread in minutes)	Standard error of the mean (spread in minutes)	Mean calculated from regression of time against concentration	Mean calculated for average length of 53.16 millimeters by multiple regression
Acid*												
20	6.50–6.65	60	0.2	54.25	40–75	2	108–560	218	137 –345	196 –241	202	198
20	6.28–6.65	60	0.3	55.25	40–83	2	60–174	117	87.5–157	110 –125	133	130
20	6.30–6.80	60	0.4	50.25	43–62	2	65–198	97.6	73.5–130	91.6–104	98.8	100
20	6.45–6.80	60	0.5	50.35	45–60	2	58–106	83.7	71.8– 97.5	80.9– 86.6	78.4	80.7
Alkaline*												
20	7.80–7.90	60	0.2	55.70	45–77	2	111–438	215	139 –333	191 –237	207	205
20	7.80–8.10	60	0.3	48.95	37–59	2	67–166	123	96.7–156	117 –130	132	131
20	7.81–7.90	60	0.4	54.35	40–77	2	62–145	94.6	75.1–119	89.8– 99.6	95.4	95.5
20	7.90–7.90	60	0.5	56.15	44–83	2	51– 90	77.1	66.1– 90.0	74.5– 79.8	74.4	74.2

*Source of acid water, Woodhull Creek; alkaline water, Rome Fish Hatchery spring.

size ranges used. This introduced an additional variable which, if uncontrolled or uncorrected, might confuse the comparison between the two waters.

Multiple regression has been used to make this correction. While there is some indication that the slope for the regression of time on length may be slightly curved, the data are inadequate for determining the curvature which may be involved, or whether a curvature is actually present. Only slight error appears to be involved if it is considered to be a straight line.

The equations for the acid and the alkaline waters are, respectively:

$$\log Y = 1.38669 - 0.98224 \log X_1 + 0.00421X_2$$
$$\log Y = 1.37921 - 1.11199 \log X_1 + 0.00294X_2$$

In this and other equations of this type, $\log X_1$ represents the common logarithm of the concentration, and X_2 is the length in millimeters.

Snedecor (1940) presented a method for using the *t*-test in determining the significance of the betas which control the values involved in the equations. The betas representing the regressions of time

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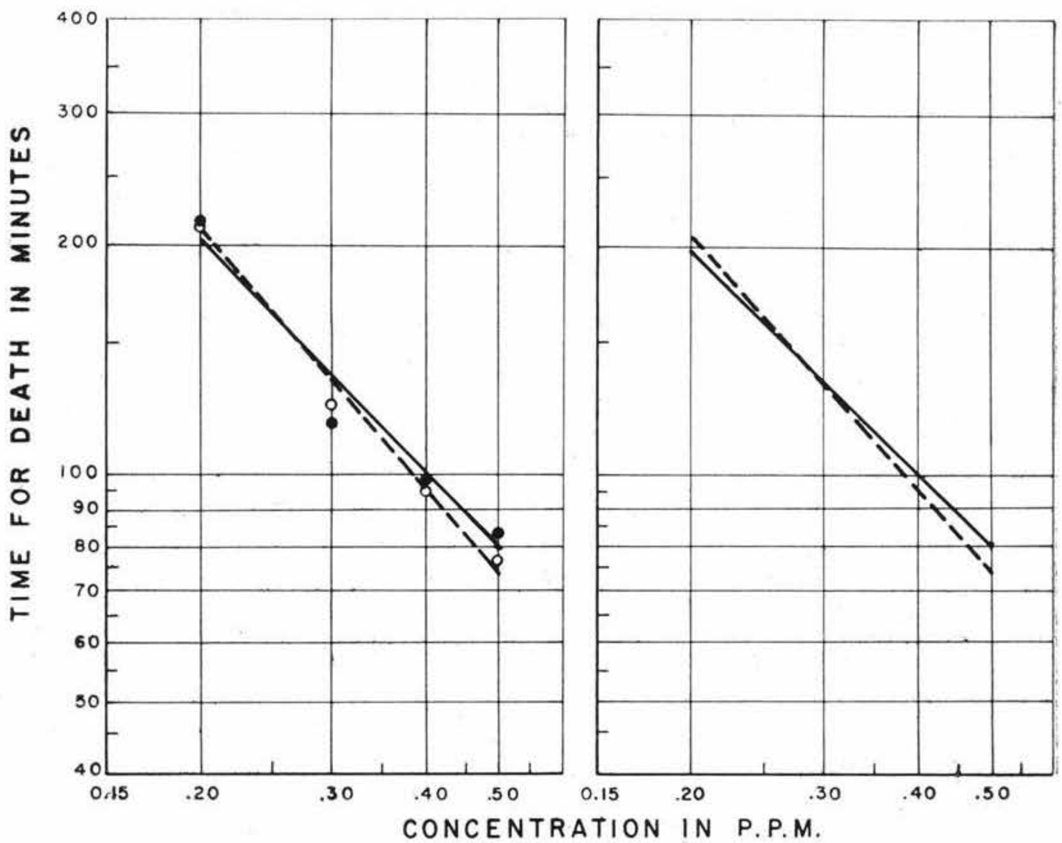

Figure 1. Toxicity curves for creek chubs in acid water (solid line) and alkaline water (broken line): plotted means and their regression (left); regression corrected to a mean length of 53.16 millimeters (right).

on length, independent of the concentrations, were both found to exceed the 5 per cent critical level with a value of 2.32 for the acid water and 2.077 for the alkaline water. The combined data exceeded the 1 per cent value at 3.046. The effect of length was confirmed and correction by the use of these equations was justified.

Calculation of the mean time for death for each concentration, at the average length of 53.16 millimeters, has been made using the pertinent equations. These corrected means are presented in Table 1. A two-dimensional graph of the concentration-time relationship in the plane of 53.16 millimeters can be found in Figure 1.

While the uncorrected regression lines of the means failed to show any significant difference in the toxicity of rotenone in the two waters, the possibility that variation caused by interaction of length might be hiding a real difference remained unresolved. When placed on the basis of equal length, the regression lines for the means computed from the multiple regression equations proved definitely that no significant differences were present.

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BROWN TROUT

Six concentrations, ranging from 0.01 to 0.20 p.p.m. by volume of emulsifiable rotenone and vehicle, were used in testing the effect of the two waters on the toxicity of rotenone to brown trout. The temperature was 63° F. For this study the pH of the acid water was 6.5 and that of the alkaline water was 7.8. The fish ranged from 35 to 68 millimeters in length with an average of 48.88 millimeters. The 0.01 p.p.m. concentration failed to kill all the fish within 24 hours so that level was eliminated. Five fish were used in each of the other concentrations in each water, the comparison thus comprising 25 fish in each water.

TABLE 2. COMPARISON OF ROTENONE TOXICITY IN ACID AND ALKALINE WATERS FOR BROWN TROUT, USING ANTILOGS OF THE LOGARITHMS OF THE COMPUTATIONS

Number of fish	pH of solution	Temperature (degrees Fahrenheit)	Concentration (in p.p.m.)	Average length of fish (in millimeters)	Range of lengths (in millimeters)	Volume of solution per fish (in liters)	Range of time for death (in minutes)	Mean time for death (in minutes)	Standard deviation of the mean (spread in minutes)	Standard error of the mean (spread in minutes)	Mean calculated from regression of time against concentration	Mean calculated for average length of 48.88 millimeters by multiple regression
Acid*												
5	6.50	63	0.02	47.0	37-51	2	98-260	140	95.6-205	118 -165	141	146
5	6.50	63	0.03	43.8	35-50	2	75-135	112	88.0-142	101 -125	113	119
5	6.50	63	0.05	45.8	38-54	2	70-113	94.2	78.7-113	87.2-102	86.3	91.5
5	6.50	63	0.10	44.8	41-49	2	48- 60	52.9	48.7- 57.3	51.0- 54.8	59.6	64.2
5	6.50	63	0.20	41.6	37-47	2	40- 50	43.3	39.7- 47.1	41.7- 44.9	41.1	45.1
Alkaline*												
5	7.85	63	0.02	55.0	42-63	2	155-252	202	163 -249	183 -222	182	165
5	7.85	63	0.03	57.6	46-68	2	106-198	141	102 -195	122 -163	142	130
5	7.85	63	0.05	50.2	43-62	2	63-138	88.0	63.3-122	75.9-120	103	97.1
5	7.85	63	0.10	56.8	45-67	2	54- 96	66.4	53.1- 83.0	60.0- 73.4	67.5	65.1
5	7.85	63	0.20	46.8	35-61	2	40- 52	47.5	42.2- 53.6	45.1- 50.1	44.0	43.7

*Source of acid water, Woodhull Creek; alkaline water, Rome Fish Hatchery spring.

The data were treated in the same manner as for the creek chubs and are given in Table 2. Calculations of the regression of time on

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concentration, based on the means of the times for death, gave the following equations:

for the acid water, $\log Y = 1.23996 - 0.53513 \log X$
for the alkaline water, $\log Y = 1.21359 - 0.61565 \log X$

Random selection produced a variation from 41.6 to 57.6 millimeters in the average length of the fish in the different concentrations. Without exception, the average length of the fish in the acid water was less than that for the corresponding concentrations in the alkaline water. Except for the 0.05 p.p.m. solution, the mean times for death were less for the smaller fish.

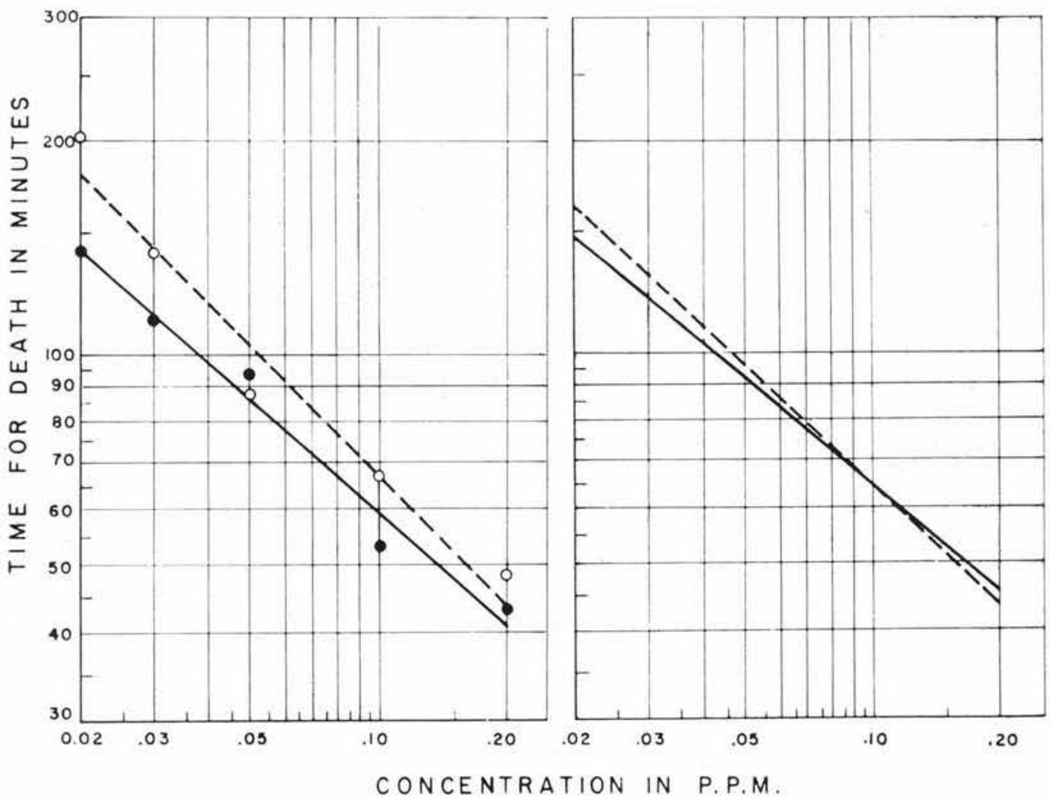

Figure 2. Toxicity curves for brown trout fingerlings in acid water (solid line) and alkaline water (broken line): plotted means and their regression (left); regression corrected to a mean length of 48.88 millimeters (right).

As can be seen in Figure 2, where the means and their regression lines are presented graphically, this might indicate increased toxicity of rotenone in acid water, which could reach statistical significance with the use of a larger number of fish. An equally satisfactory explanation of this divergence could be based on the effect of length, if it could be shown that greater length was associated with greater resistance as has been shown for the creek chubs.

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Calculation of the multiple regression for three variables gave the following equations:

for the acid water, $\log Y = 1.00108 - 0.51120 \log X_1 + 0.00604X_2$
for the alkaline water, $\log Y = 0.95639 - 0.57615 \log X_1 + 0.00575X_2$

Applying the *t*-test for the significance of the betas for the regressions of time on length, independent of the concentrations, to the groups of 25 fish in each of the waters, the alkaline water at 2.916 exceeded the 1 per cent value for *t*, while the acid water at 1.517 fell between the 20 and 10 per cent critical values for *t*, failing to reach the level for significance. Combination of the two groups produced a value for *t* of 4.39, far exceeding the 1 per cent level for significance. This behavior would seem to indicate that there is an actual relationship between length and time in spite of the failure of the acid water data to reach significance with 25 fish.

Plotting the regression of time on concentration at the mean length of 48.88 millimeters gave (Figure 2) intersecting lines similar to those obtained for the creek chubs. This indicates the divergence to be associated with length rather than with variation in toxicity due to the type of water. The two lines are so nearly similar that it is concluded that there is no significant difference between the toxicities.

SMALLMOUTH BASS

This species was tested in concentrations ranging from 0.15 to 0.50 p.p.m. of rotenone and vehicle by volume, at a temperature of 60° F. The acid water had a pH of 6.72 and the alkaline water one of 7.80. The fish varied in length between 35 and 58 millimeters, with an average of 47.75 millimeters. The sets of five fish used in the individual concentrations averaged from 42.4 to 50.8 millimeters in length.

The data for the 0.40 p.p.m. solution in acid water were extremely aberrant, not only in the average time for death which might have been due to an error in the measurement of the rotenone, but in a standard deviation and a standard error which were 3 to 4 times larger than were found at any other concentration. Since this was among the higher concentrations where variability is usually reduced, the most reasonable supposition is that some abnormal fish must have been included. As additional fish were not available to repeat the experiment, this concentration has been rejected and, to maintain an equivalent comparison, the corresponding concentration in alkaline water has been eliminated.

The data were handled in the same way as those for the creek

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TABLE 3. COMPARISON OF ROTENONE TOXICITY IN ACID AND ALKALINE WATERS FOR SMALLMOUTH BASS, USING ANTILOGS OF THE LOGARITHMS OF THE COMPUTATIONS

Number of fish	pH of solution	Temperature (degrees Fahrenheit)	Concentration (in p.p.m.)	Average length of fish (in millimeters)	Range of lengths (in millimeters)	Volume of solution per fish (in liters)	Range of time for death (in minutes)	Mean time for death (in minutes)	Standard deviation of the mean (spread in minutes)	Standard error of the mean (spread in minutes)	Mean calculated from regression of time against concentration	Mean calculated for average length of 47.75 millimeters by multiple regression
						Acid*						
5	6.72	60	0.15	50.8	41-58	2	332- 977	608	380 -974	493 -761	678	635
5	6.72	60	0.20	49.0	43-53	2	295- 690	451	303 -674	378 -540	417	398
5	6.72	60	0.30	49.6	45-56	2	172- 357	236	177 -315	208 -269	210§	225§
5	6.72	60	0.50	48.2	44-55	2	66- 93	81.4	70.0- 94.7	76.1- 87.1	88.7	90.2
						Alkaline*						
5	7.80	60	0.15	42.4	38-48	2	317-1127	444	204 -966	314 -628	536	623
5	7.80	60	0.20	47.2	35-58	2	320- 645	386	288 -516	339 -439	451	373
5	7.80	60	0.27	46.8	39-54	2	195- 290	235	199 -278	218 -253	202§	198§
5	7.80	60	0.50	48.0	44-54	2	60- 68	65.3	62.1- 68.7	63.9- 66.8	72.8	74.7

*Source of acid water, Woodhull Creek; alkaline water, Rome Fish Hatchery spring.
§Calculated for a concentration of 0.285 p.p.m., the mean for the two waters involved.

chubs and are presented in Table 3. The following equations were obtained for the regressions of the means:

for the acid water $\log Y = 1.43915 - 1.68987 \log X$
for the alkaline water, $\log Y = 1.36300 - 1.65824 \log X$

As can be seen from the table, the fish in the alkaline water had an average length less than those in the acid water and the mean times for death were also less. The plotted lines for the regressions of the means in Figure 3 would indicate the alkaline water to have been slightly more toxic. This reverses the condition shown by the uncorrected data for brown trout, and appears to follow closely the variation in size of the fish.

The multiple regression equations for the concentration-length-time relationship gave the following:

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for the acid water $\log Y = 0.61473 - 1.61987 \log X_1 + 0.01752X_2$
for the alkaline water, $\log Y = 0.62818 - 1.78308 \log X_1 + 0.01432X_2$

Plotting the regression lines for time against concentration in the plane of the mean length (Figure 3) produced a much closer coincidence of the lines than was found with the uncorrected data. This would indicate an absence of significant difference in the reaction of this species to the effect of rotenone in the two waters.

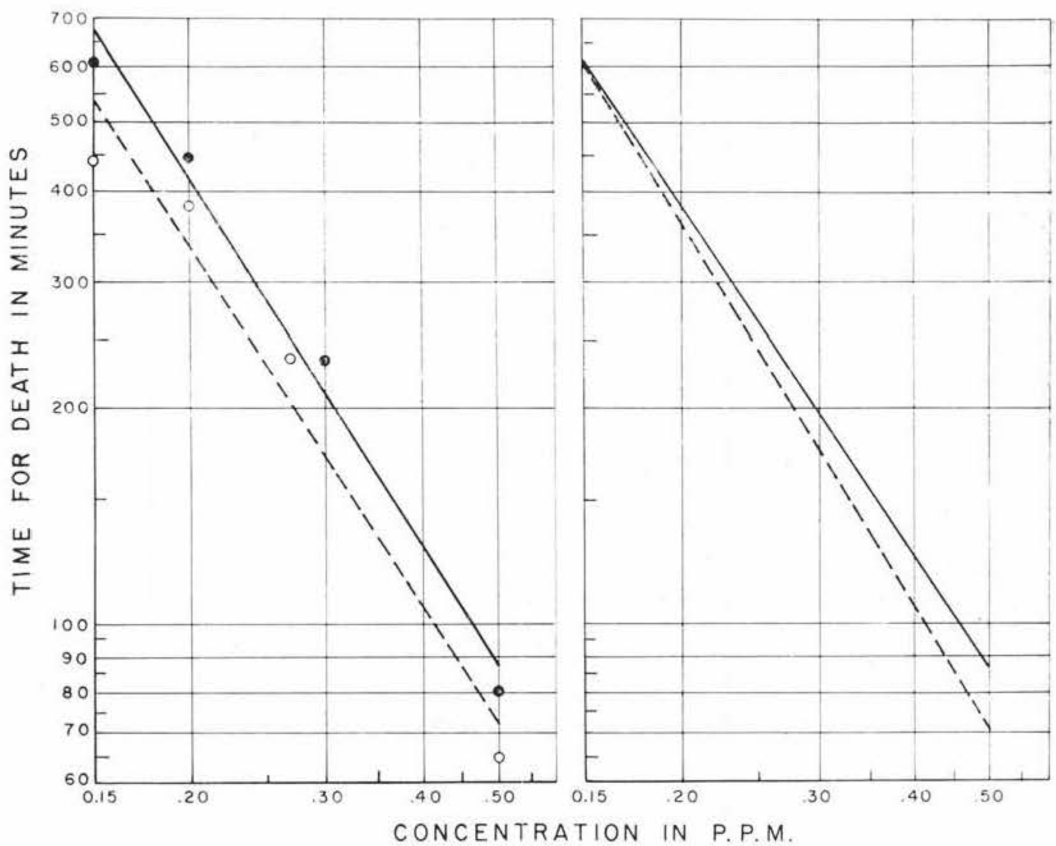

Figure 3. Toxicity curves for smallmouth bass fingerlings in acid water (solid line) and alkaline water (broken line): plotted means and their regression (left); regression corrected to a mean length of 47.75 millimeters (right).

The regression equations show evidence of a positive relationship between the length of the fish and the elapsed time to death, the time increasing with greater size. Justification for the use of these equations for the correction of the mean in Table 3 and the use of the corrected means to compare toxicity in the two waters is found by application of the *t*-test to the betas for the regressions of time on length, independent of the concentration. A value of 2.724 was obtained for the acid water data and 2.133 for the alkaline water, in spite of the use of only 20

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fish in each experiment. Both these values exceed the 5 per cent level for t. The beta for the combined data gave a value for t of 3.899, far exceeding the 1 per cent level for significance.

Even without the confirmation afforded by application of the principle of multiple regression to separate the effect of length upon the time, it would have been necessary to conclude either that there was no significant difference in the toxicity of the two waters, or that there was a difference in effect for the different species. As the divergence over the range of concentration was generally too small to be significant in relation to the standard error of the means, the first hypothesis would appear the more logical. The shifting of the regression lines when corrected for the effect of length makes them nearly coincide and seems to be adequate support for the contention that the difference in pH does not affect the toxicity of rotenone solutions significantly. It was decided that there was no reason to extend this phase of the study to other species.

EFFECT OF TEMPERATURE ON THE TIME FOR DEATH

A separate lot of brown trout was used in evaluating the effect of temperature on the time for death. Since these fish were already acclimatized to the hatchery water supply, they were held only 1 week at the initial temperature of 55° F. Increases in temperature were made in steps of 5 degrees with the fish acclimatized to each increase for a minimum of 48 hours before use.

At the experimental temperatures of 55°, 60°, 65°, and 70° F. fluctuation was held to plus or minus 0.5 degree. The procedure corresponded with that previously described, except that 10 fish were used in 15 liters of solution. The fish were small, from 32 to 61 millimeters in length. Random selection of the 10 fish used in the individual concentration-temperature combinations resulted in a variation of the average length from 40.5 to 50.1 millimeters.

The logarithmic mean of the times for death was computed for each combination and is presented with other data in Table 4. The equations for the regression of time on concentration for each temperature were computed by the method of least squares and are as follows:

$$55^\circ \text{ F.: } \log Y = 1.66325 - 0.48820 \log X$$
$$60^\circ \text{ F.: } \log Y = 1.24806 - 0.50656 \log X$$
$$65^\circ \text{ F.: } \log Y = 1.08112 - 0.55601 \log X$$
$$70^\circ \text{ F.: } \log Y = 0.95072 - 0.58986 \log X$$

Log X is the common logarithm of concentration. Corrected means

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TABLE 4. COMPARISON OF THE EFFECT OF TEMPERATURE ON THE TOXICITY OF ROTENONE TO BROWN TROUT

Number of fish	Concentration (in p.p.m.)	Average length of fish (in millimeters)	Range of lengths (in millimeters)	Volume of solution per fish (in liters)	Range of time for death (in minutes)	Mean time for death (in minutes)	Standard deviation of the mean (spread in minutes)	Standard error of the mean (spread in minutes)	Mean calculated from regression of time against concentration	Mean calculated for average length of 44.03 millimeters by multiple regression
					Temperature 55° F.					
10	0.050	44.8	35–52	1.5	173–842	360	228 –570	312 –417	*	*
10	0.100	46.2	38–56	1.5	78–294	139	90.2–216	122 –164	142	143
10	0.200	41.9	36–50	1.5	72–157	103	78.8–134	94.5–112	101	99.9
10	0.400	40.5	35–49	1.5	54– 88	73.2	62.4– 85.8	69.6– 77.0	72.0	69.7
10	0.800	42.9	34–49	1.5	41– 65	50.5	43.3– 59.0	48.1– 53.1	51.4	48.6
					Temperature 60° F.					
10	0.025	42.5	35–54	1.5	124–353	189	140 –249	170 –205	*	*
10	0.050	47.4	38–55	1.5	55–155	86.7	61.0–123	77.5– 96.9	80.8	83.4
10	0.100	50.1	38–59	1.5	42– 68	51.7	43.5– 61.5	48.9– 54.6	56.8	59.3
10	0.200	47.3	37–55	1.5	32– 48	39.1	34.6– 44.2	37.6– 40.7	40.1	41.3
10	0.400	45.0	36–57	1.5	24– 50	29.5	23.8– 36.6	27.6– 31.6	28.2	28.7
					Temperature 65° F.					
10	0.025	42.2	32–50	1.5	65–187	98.2	70.6–136	88.5–109	93.7	92.3
10	0.050	44.4	34–57	1.5	44–100	65.7	49.5– 87.1	60.1– 71.8	63.8	62.7
10	0.100	41.6	33–61	1.5	31– 60	38.3	31.0– 47.2	35.8– 40.9	43.4	42.6
10	0.200	44.0	33–59	1.5	22– 39	28.8	24.4– 33.8	27.3– 30.3	29.5	28.9
10	0.400	42.0	35–52	1.5	17– 29	21.6	18.2– 25.7	20.5– 23.3	20.1	19.7
					Temperature 70° F.					
10	0.025	47.9	39–54	1.5	63–111	79.1	65.1– 96.1	74.4– 84.4	78.7	79.9
10	0.050	41.6	33–49	1.5	46– 86	55.3	46.4– 65.8	52.3– 58.4	52.3	52.5
10	0.100	43.3	34–56	1.5	24– 44	31.8	26.7– 39.2	30.5– 34.4	34.7	34.5
10	0.200	40.9	35–50	1.5	18– 25	22.0	19.4– 24.8	21.1– 22.8	23.1	22.7
10	0.400	43.4	35–60	1.5	14– 18	16.3	15.0– 17.7	15.8– 16.7	15.3	14.9

*Means deviate from straight line; not used in computing regression statistics.

have been calculated from these equations and appear in the next to the last column of the table. The relationships of the regression lines to the experimental means are shown graphically in Figure 4.

The same criticism may be applied to these data as was applied to the comparison of toxicity in the two types of water. If time for death is affected by length, variation of average length among the means

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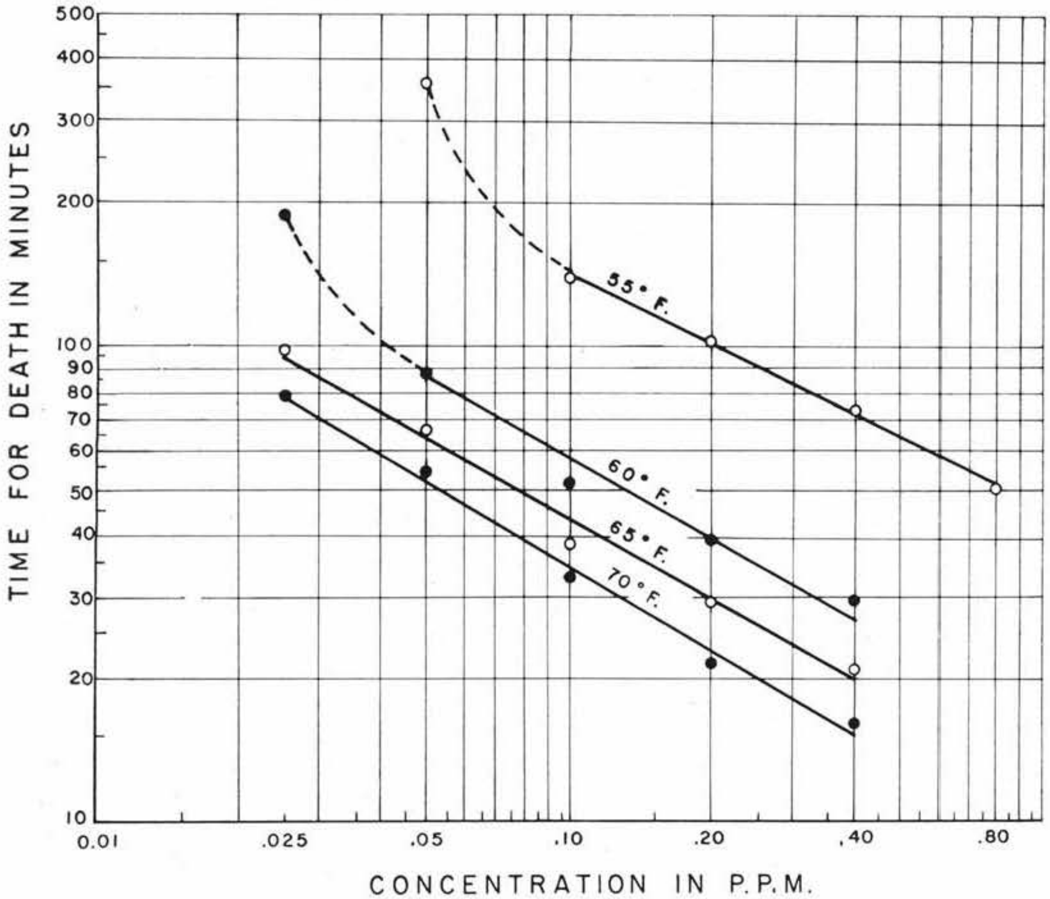

Figure 4. Comparison of the toxicity of rotenone to brown trout fingerlings at different temperatures. The solid lines represent the regression of the plotted means and the broken lines represent extensions to points obviously departing from the straight line. Solid circles and open circles are used merely to differentiate between the sets of data.

could have resulted in error in the means and skewing of their regression lines.

Multiple regressions were calculated for each temperature and the following equations were obtained:

$$55^\circ \text{ F.: } \log Y = 2.00900 - 0.51999 \log X_1 - 0.00847X_2$$
$$60^\circ \text{ F.: } \log Y = 1.48598 - 0.52448 \log X_1 - 0.00539X_2$$
$$65^\circ \text{ F.: } \log Y = 1.35871 - 0.55774 \log X_1 - 0.00652X_2$$
$$70^\circ \text{ F.: } \log Y = 1.14085 - 0.60505 \log X_1 - 0.00472X_2$$

Log X_1 is the common logarithm of the concentration, and X_2 is the length in millimeters.

These multiple regressions showed the smaller fish to have been more resistant to rotenone than the larger fish at every temperature. This was a reversal of the reaction of this species in the comparison of

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the two waters, as well as of its reaction in the comparison of the toxicity of rotenone to different species a discussion of which appears later.

The *t*-test was again applied in determining the significance of the betas. Those representing the regressions of time on length were all found to be significant. The two groups of 40 fish at the 55° and 60° F. temperatures gave *t*-values of 2.384 and 2.461, respectively. These fall between the 5 and 1 per cent critical values for *t*. The groups of 50 fish at the 65° and 70° F. temperatures had values for *t* exceeding the 1 per cent level for significance, being, respectively, 3.53 and 3.212. This seems to support the conclusion that the greater resistance of the smaller fish in this lot was actual and not a matter of chance.

Corrected means have been calculated from the equations, at the mean length for X_2 of 44.03 millimeters. These appear in the last

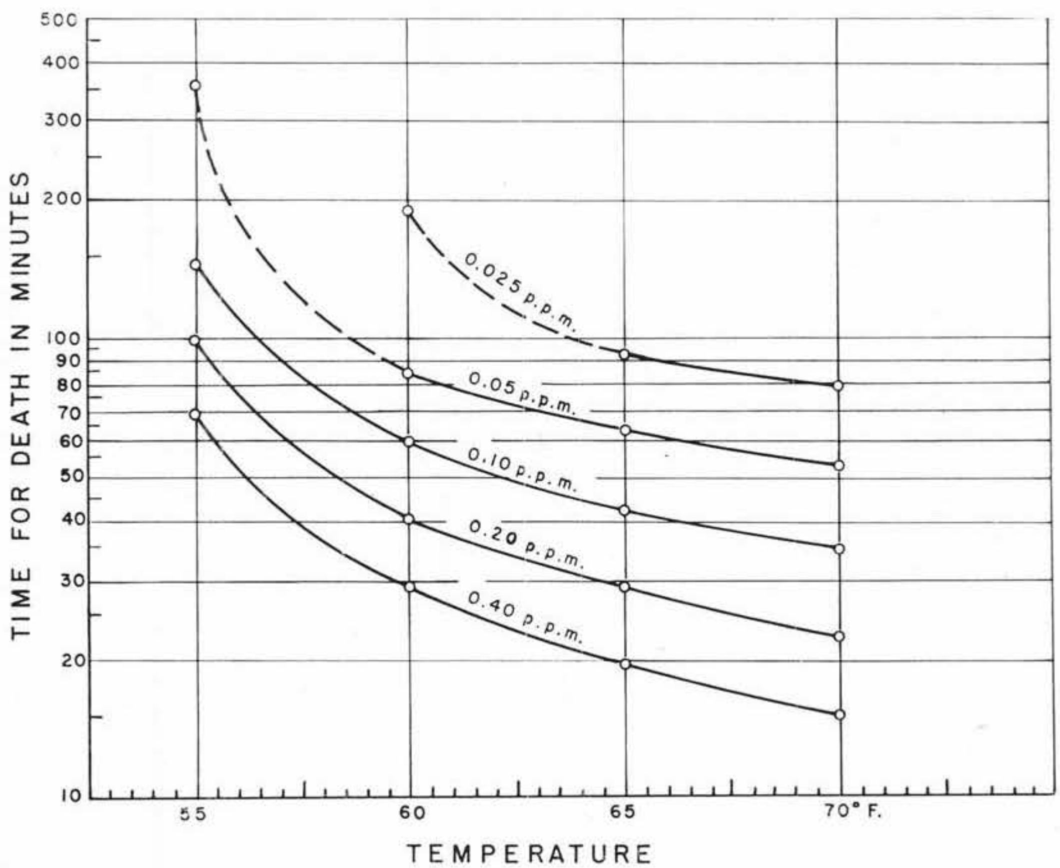

Figure 5. Effect of temperature on the mean time for death of brown trout fingerlings at various concentrations of rotenone after correction to a mean length of 44.03 millimeters. The broken lines represent extensions to points not corrected.

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column of Table 4. The lines for the regressions of time on concentration at the mean length for all data are presented graphically in Figure 4.

The regression lines in Figure 4 are not uniformly separated, the divergence increasing with decreasing temperature, becoming pronounced between 55° and 60° F. This indicates that the regression of time on temperature at any concentration will be a curve. Using the mean times for death, corrected by multiple regression to a common length, the data for equal concentration at the different temperatures have been plotted on semilogarithmic paper in Figure 5, the logarithmic scale representing time, and the arithmetic scale, temperature. The means not used in calculation of the regressions because of departure from a straight line appear as obtained, uncorrected. The lines thus plotted are curves, although in the higher temperature range they may be fitted with reasonable accuracy by straight lines. It can be concluded that toxicity decreases slowly and nearly proportionally at those temperatures for which the curves approximate straight lines, but that it decreases more rapidly and disproportionally at those temperatures which depart from the straight-line relationship. At the particular concentrations tested, except for the lower concentrations, departure from the line occurred between temperatures of 55° and 60° F.

COMPARISON OF THE TOXICITY OF ROTENONE TO DIFFERENT SPECIES

The relative order of susceptibility of the six species used in this comparison and the magnitude of the specific variation may be shown, at least within the straight-line portion of the toxicity curves, by a graph covering their reaction to rotenone at a common temperature. Two such graphs are presented. One shows the means for the time for death at various concentrations and the regression of these means as calculated by the method of least squares. The other represents the regression after correction for the effect of variation of length by means of the multiple regression equations. This correction was applied only when the beta for the regression of time on length, independent of the concentration, was found significant after application of the t-test. The experimental data have been treated in the same manner as in the preceding sections.

The different species are considered individually to permit tabulation of the data.

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CREEK CHUB

No significant difference in toxicity was shown by the comparison of equivalent concentrations in the acid and alkaline waters. Therefore, the data have been combined to give 40 fish in each of the four concentrations used in the computations. Table 5 summarizes this combination. The means and their regression have been plotted in Figure 6. The equation for the regression is:

$$\log Y = 1.55939 - 1.07461 \log X$$

in which log X is the common logarithm of the concentration.

The multiple regression equation, in which $\log X_1$ represents the common logarithm of the concentration, and X_2 is the length in millimeters, is:

$$\log Y = 1.37979 - 1.08883 \log X_1 + 0.00325 X_2$$

TABLE 5. SUMMARY OF EXPERIMENTAL DATA FOR DIFFERENT ROTENONE CONCENTRATIONS AT 60°F. FOR CREEK CHUBS

Item	Concentration (in p.p.m.)				
	0.10*	0.20	0.30	0.40	0.50
Number of fish	5	40	40	40	40
Range in pH	7.95	6.50-7.90	6.28-8.10	6.30-7.90	6.45-7.90
Average length of fish (in millimeters)	...	54.98	52.10	52.30	53.25
Range of lengths (in millimeters)	...	40-77	37-83	40-77	44-83
Volume of solution per fish (in liters)	...	2	2	2	2
Range of time for death (in minutes)	...	108-560	60-174	62-198	51-106
Mean time for death (in minutes)	...	216	120	96.1	80.3
Standard deviation of the mean (spread in minutes)	...	139-337	92.7-157	74.4-124	67.1-94.0
Standard error of the mean (spread in minutes)	...	202-232	115-125	92.3-100	78.4-82.4
Mean calculated from regression equation	...	204	132	97.0	76.4
Mean calculated for average length by multiple regression	...	201	132	96.8	76.9

*Computations not made because only one fish died in 24 hours.

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The beta for the regression of time on length gave a value for t of 3.046, well above the 1 per cent level for significance. The corrected regression line for the effect of concentration on the time at the mean length of the fish appears in Figure 7.

SMALLMOUTH BASS

The tabulation of the data for this species which appear in Table 6 also represents a combination of the data from the comparison of

TABLE 6. SUMMARY OF EXPERIMENTAL DATA FOR DIFFERENT ROTENONE CONCENTRATIONS AT 60°F. FOR SMALLMOUTH BASS

Item	Concentration (in p.p.m.)			
	0.15	0.20	0.285*	0.50
Number of fish	10	10	10	10
Range in pH	6.72-7.80	6.72-7.80	6.72-7.80	6.72-7.80
Average length of fish (in millimeters)	46.6	48.1	48.2	48.1
Range of lengths (in millimeters)	38-58	35-58	39-56	44-55
Volume of solution per fish (in liters)	2	2	2	2
Range of time for death (in minutes)	317-1127	295-690	172-357	60-93
Mean time for death (in minutes)	520	417	236	72.9
Standard deviation of the mean (spread in minutes)	319-847	298-585	188-294	62.7-84.8
Standard error of the mean (spread in minutes)	445-606	375-464	219-253	69.5-76.5
Mean calculated from regression equation	603	373	206	80.5
Mean calculated for average length by multiple regression	614	376	207	78.6

*Mean of the concentrations (0.27 and 0.30 p.p.m.) for the two waters involved.

the two waters. This combination is permissible since no significant variation in toxicity was found between the two waters. The regression of the means produced the equation:

$$\log Y = 1.40220 - 1.67243 \log X$$

These means and their regression are presented in Figure 6.

Computation of the three-factor multiple regression resulted in the equation:

$$\log Y = 0.61330 - 1.70759 \log X_1 + 0.01608 X_2$$

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The beta for the regression of time on length tests well over the 1 per cent level with a t value of 3.899. The line for the regression of time on concentration at the mean length of all fish appears in Figure 7.

COMMON SUCKER

Ten fish in each of the five concentrations provided the experimental data for this species as given in Table 7. There was no

TABLE 7. SUMMARY OF EXPERIMENTAL DATA FOR DIFFERENT ROTENONE CONCENTRATIONS AT 60°F. FOR COMMON SUCKERS

Item	Concentration (in p.p.m.)				
	0.3	0.4	0.5	1.0	2.0
Number of fish	10	10	10	10	10
Range in pH	7.90-8.05	7.70-7.70	7.83-8.05	8.00-8.00	7.85-8.00
Average length of fish (in millimeters)	59.7	60.9	59.4	60.4	61.7
Range of lengths (in millimeters)	46-75	45-82	48-72	46-70	45-73
Volume of solution per fish (in liters)	2	2	2*	2	2
Range of time for death (in minutes)	137-1130	132-726	160-484	81-357	52-220
Mean time for death (in minutes)	602	403	338	199	98.5
Standard deviation of the mean (spread in minutes)	314-1151	238-682	216-520	129-310	64.4-151
Standard error of the mean (spread in minutes)	490-737	341-476	293-387	173-229	86.1-113
Mean calculated from regression equation	560	432	353	188	100
Mean calculated for average length by multiple regression	569	436	354	187	98.2

*One set of five fish in 10 liters per fish.

variation in procedure, except that five fish at the 0.05 p.p.m. concentration were tested individually in 10 liters of solution per fish as a check of the adequacy of the volume. Since the range of the time for death was not shortened, it was concluded that a volume of 2 liters per

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fish was sufficient for the size being tested. The equation for the regression of the means, uncorrected for length, is:

$$\log Y = 2.44120 - 0.90962 \log X$$

The regression line for this equation and the means from which it was derived are presented graphically in Figure 6.

The effect of variation in length was checked by the use of multiple regression, the equation being:

$$\log Y = 1.83088 - 0.92613 \log X_1 + 0.00728 X_2$$

The beta for the regression of time on length gave a value for t of

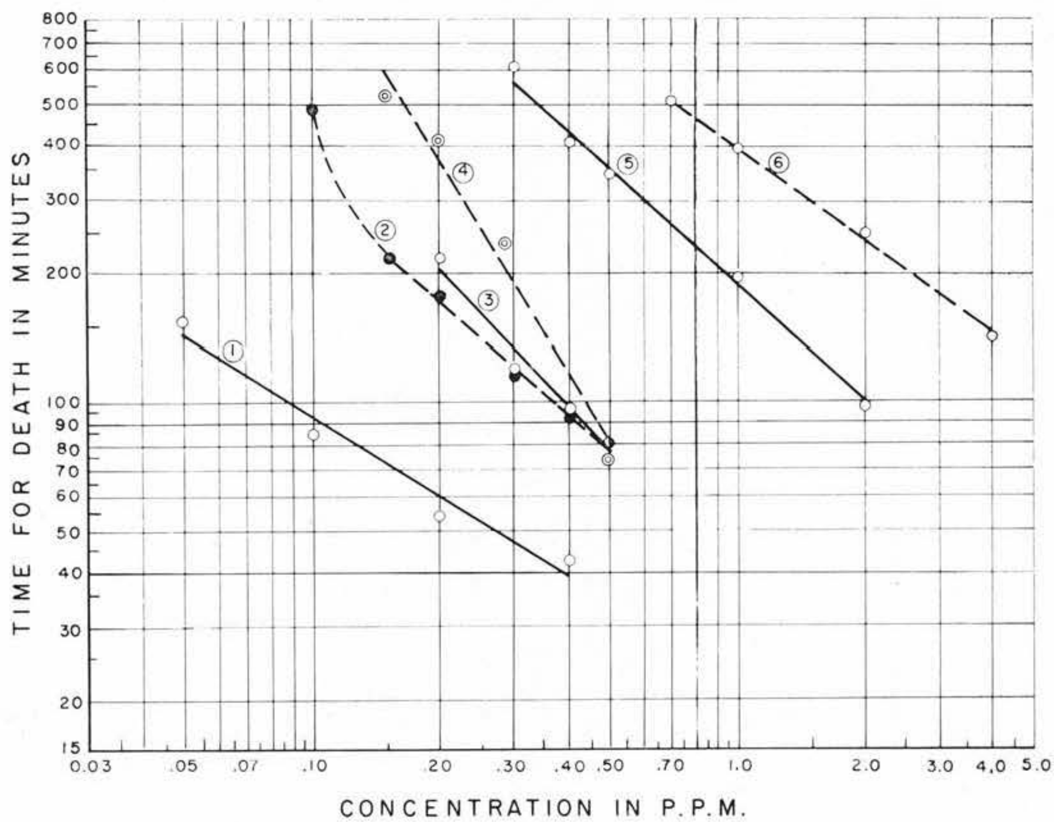

Figure 6. Toxicity curves based on plotted means and their regression: (1) brown trout; (2) rock bass; (3) creek chub; (4) smallmouth bass; (5) common sucker; (6) brown bullhead.

2.06, slightly over the 5 per cent level for significance. The regression of time on concentration at the mean length for the fish is plotted in Figure 7.

BROWN BULLHEAD

Fifteen fish were used in each of the four concentrations from which the toxicity curve for this species was constructed. The ex-

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perimental data and the results of some of the computations are presented in Table 8. Two lower concentrations were tried, a 0.10 p.p.m. solution that failed to produce loss of equilibrium within 24 hours, and a 0.50 p.p.m. solution that produced only one death among five fish in

TABLE 8. SUMMARY OF EXPERIMENTAL DATA FOR DIFFERENT ROTENONE CONCENTRATIONS AT 60°F. FOR BROWN BULLHEADS

Item	Concentration (in p.p.m.)*				
	0.5§	0.7	1.0	2.0	4.0
Number of fish	5	15	15	15	15
Range in pH	7.72	7.82-7.82	7.80-7.82	7.72-7.80	7.70-7.80
Average length of fish (in millimeters)	...	52.07	45.13	43.87	45.33
Range of lengths (in millimeters)	...	42-92	41-52	38-48	40-50
Volume of solution per fish (in liters)	...	2	2	2	2
Range of time for death (in minutes)	...	240-1440†	172-1206	164-592	85-197
Mean time for death (in minutes)	...	504	397	253	142
Standard deviation of the mean (spread in minutes)	...	273-929	214-738	164-392	114-177
Standard error of the mean (spread in minutes)	...	430-590	338-466	226-283	134-150
Mean calculated from regression equation	...	514	397	241	146
Mean calculated for average length by multiple regression	...	481	383	258	158

*A concentration of 0.10 p.p.m. produced no turnover in 24 hours.
§Computations not made because only one fish died in 24 hours.
†Represents time for fish that actually died; two specimens were still alive at end of test.

24 hours although all fish lost equilibrium. When removed to fresh water after this exposure, these fish recovered and remained normal.

The regression of the means is represented by the equation:

$$\log Y = 2.59800 - 0.72106 \log X$$

The regression line for this equation and the means of the data from which it was derived appear in Figure 6.

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The multiple regression equation, with length as the additional variable, is:

$$\log Y = 2.04362 - 0.63871 \log X_1 + 0.01159X_2$$

The t test of the beta for the regression of time on length produced a value of 4.05, which greatly exceeds the 1 per cent level for significance. The regression of time on concentration at the mean length, as derived from this equation, is shown in Figure 7.

ROCK BASS

Ten fish in each of six concentrations were used in constructing the toxicity curve for this species. The mean for the lowest concentration was not used in computing the regression since it departed significantly from the straight line formed by the other means. The

TABLE 9. SUMMARY OF EXPERIMENTAL DATA FOR DIFFERENT ROTENONE CONCENTRATIONS AT 60°F. FOR ROCK BASS

Item	Concentration (in p.p.m.)					
	0.10	0.15	0.20	0.30	0.40	0.50
Number of fish........	10	10	10	10	10	10
Range in pH..........	7.70-7.70	7.70-7.82	7.70-7.70	7.70.7.82	7.82-7.82	7.70-7.82
Average length of fish (in millimeters)......	41.1	41.5	42.3	40.6	40.3	40.8
Range of lengths (in millimeters)......	35-48	35-48	35-52	35-47	34-46	37-45
Volume of solution per fish (in liters).......	2	2	2	2	2	2
Range of time for death (in minutes).........	241-814	129-315	124-295	96.0-179	77.0-115	58.0-102
Mean time for death (in minutes)........	496*	217	176	123	92.0	80.5
Standard deviation of the mean (spread in minutes)............	326-756	156-301	135-229	99.6-152	79.0-107	66.7-97.1
Standard error of the mean (spread in minutes)...............	434-567	195-241	162-191	115-131	87.7-96.6	75.8-85.4
Mean calculated from regression equation...	*	220	172	122	95.4	78.9

*Mean deviates from straight line; not used in calculating the regression.

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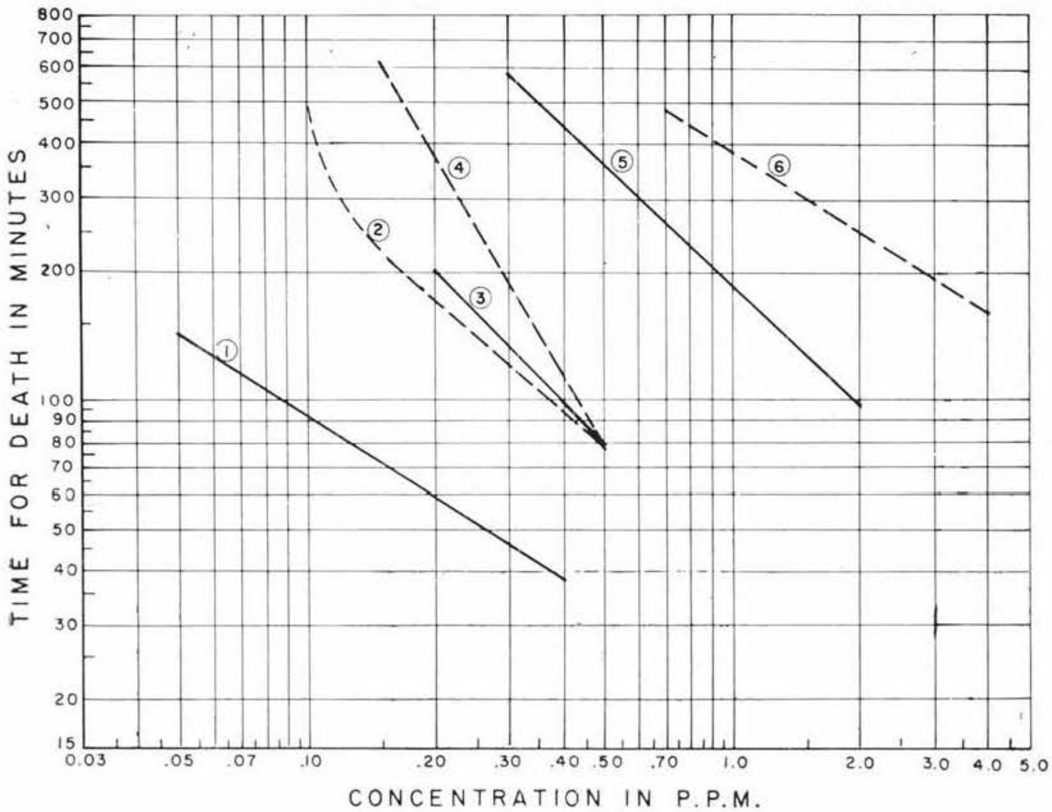

Figure 7. Toxicity curves based on the regression corrected to the mean length for each species: (1) brown trout; (2) rock bass; (3) creek chub; (4) smallmouth bass; (5) common sucker; (6) brown bullhead.

data are summarized in Table 9. The following equation was calculated for the regression of the means:

$$\log Y = 1.64133 - 0.85011 \log X$$

Multiple regression for the concentration-length-time relationship gave the equation:

$$\log Y = 1.64737 - 0.85051 \log X_1 - 0.00015 X_2$$

The slope for X_2 is very small and it is not surprising that the *t*-test of the beta for the regression of time on length, independent of concentration, fails to reach significance. The value of t is only 0.04. No correction was made for length in these data, the line for the regression of the means appearing in both Figures 6 and 7.

Brown Trout

Five concentrations, ranging from 0.03 to 0.40 p.p.m. of rotenone and vehicle by volume, were used for this species. An initial separation of the fish into small, medium, and large sizes was carried out to

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assure a fairly uniform distribution of lengths, as well as to permit comparison of the toxicity of rotenone within the different size ranges. The lengths ranged from 58 to 131 millimeters. The data for the combined groups at each concentration appear in Table 10. Several fish in the medium and large size groups were still alive after a 24-hour exposure to the 0.03 p.p.m. concentration, so this concentration was eliminated from further experimentation. The major variation in procedure involved the use of 10 liters of solution per fish, to make certain that the rotenone content remained adequate and fairly uniform. The regression of the means, uncorrected for length, gave the following equation, which is plotted in Figure 6:

$$\log Y = 1.32925 - 0.63444 \log X$$

The effect of length was evaluated by multiple regression. This

TABLE 10. SUMMARY OF EXPERIMENTAL DATA FOR DIFFERENT ROTENONE CONCENTRATIONS AT 60°F. FOR BROWN TROUT

Item	Concentration (in p.p.m.)				
	0.03*	0.05	0.10	0.20	0.40
Number of fish	45	45	45	45	45
Range in pH	7.40-7.65	7.41-7.80	7.45-7.75	7.50-7.70	7.40-7.75
Average length of fish (in millimeters)	....	87.56	85.31	85.98	87.33
Range of lengths (in millimeters)	....	58-131	64-128	64-127	61-120
Volume of solution per fish (in liters)	....	10	10	10	10
Range of time for death (in minutes)	....	83-264	62-119	40-68	31-56
Mean time for death (in minutes)	....	156	84.8	53.9	41.8
Standard deviation of the mean (spread in minutes)	....	122-199	72.3-99.4	47.6-61.2	36.2-48.4
Standard error of the mean (spread in minutes)	....	150-161	82.8-86.8	52.9-54.9	40.9-42.8
Mean calculated from regression equation	....	143	92.0	59.3	38.2
Mean calculated for average length by multiple regression	....	143	92.0	59.3	38.2

*Computations not made because one fish in the medium size range and four in the large size range were still alive at the end of 24 hours.

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resulted in the equation for the combined data of:

$$\log Y = 1.29861 - 0.63443 \log X_1 + 0.00036X_2$$

The slope for the effect of length is small and the betas for the three size groupings fail to reach significance, presumably due to too small a number of fish to validate the small slopes. The *t*-test for the combined size groups resulted in a value of 2.350 which lies between the 5 and 1 per cent levels of significance.

While the effect of length was small, it did shift the position of the regression line slightly and is plotted in Figure 7. Length produced a variation in time of only 9 minutes in the range from 58 to 131 millimeters at the 0.05 p.p.m. concentration, while the range was only 2.4 minutes at the 0.40 p.p.m. level.

Figure 7 can be used to demonstrate the resistance of the six species to the effect of rotenone. In order, from the least to the most tolerant, are: brown trout, rock bass, creek chub, smallmouth bass, common sucker, and brown bullhead. An estimate of the magnitude of the variation in tolerance can be obtained from the graph by comparison of the concentrations which would produce equivalent time for death. While such estimates may be valid only at the mean length for which the curves are constructed, the multiple regression equations may be used to extend the interpretation with relatively small error within the lengths covered by the data.

EFFECT OF SIZE ON THE TIME FOR DEATH

In toxicity studies size, or weight, has often been reported to affect the time for death. The effect is sometimes direct, as when the quantity absorbed must reach a definite ratio to the body weight, at other times, inverse.

During these studies there seemed to be a general tendency for the smaller fish to die upon shorter exposure than was necessary with the larger fish. In progressively decreasing concentration, the larger fish were found to be the first to exceed the 24-hour limit of exposure. The multiple regressions, with two exceptions, have confirmed a positive slope for the effect of length.

Of the exceptions, a small negative slope was found for the rock bass. However, the data fail to approach significance and it appears that an extremely large number of fish would be necessary to validate the small negative slope so that it could reach significance within the variability of the data. With the value of *t* shown in the preceding

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section it is assumed that the slope might as readily have been positive as negative.

Interpretation of the change to a negative slope for a single lot of brown trout, when two groups from a previous lot had both been positive, is difficult. It is further complicated by the fact that each of these tested significant to highly significant by the *t*-test. Such a relationship by chance does not seem probable. It might represent the measurement of a variable associated with length which may differ under certain conditions.

The metabolic rate may vary among fish of different ages or sizes. In that case the negative slope could be associated with inadequate acclimatization. The lot in which the larger fish died first was taken from outside pools at temperatures somewhat above freezing and was acclimatized for only 1 week at the much higher temperature of 55° F. A sudden rise in temperature reportedly results in an abnormal increase in metabolic rate which gradually returns to the norm for that temperature. If the reduction in the increased metabolic rate was more rapid in the smaller fish, and thus was not as complete in the larger fish, it could readily account for the negative slope in this lot.

Determination of the cause of this reversal of slope cannot be achieved with any certainty without additional experimental work. The variation is not believed to invalidate any of the data or the corrections made by means of the multiple regression equations, since they represent a variation which may occur under certain conditions rather than indicate abnormal or erratic variation within the lot.

The data were inadequate for determining whether the regression of time on length is a straight line or has a slight curvature. Separation of the data from the experiments involving the larger number of specimens to permit computation of separate portions of the slope, indicates that it may be a curve, decreasing in curvature with increasing size. Segregation into ranges leaves the number of fish in each group inadequate for the reduction of variation caused by any abnormal individual reactions which might have been present. As none of the betas for the regressions in the segregated data tested significant, the existence of curvature cannot be held to have been established.

If the slope is curved, fitting with a straight line will result in only partial correction. If transformed to the mean, the data will be under-corrected, with the error increasing at the extremes, particularly for the smallest sizes.

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EFFECT OF CONCENTRATION ON THE POSSIBILITY OF RECOVERY

At some of the lower concentrations, creek chubs, bullheads, smallmouth bass, and brown trout failed to die in 24 hours. In every case, including some instances in which loss of equilibrium had persisted for nearly 18 hours, complete recovery occurred after removal to clean water. At some of the higher concentrations fish failed to recover, even when removed very soon after the loss of equilibrium. There seems no basis for believing either that affected fish will recover if removed immediately to clean water, or that, once affected, they will be unable to recover. The ability to recover from an exposure to rotenone after equilibrium has been lost seems to depend upon the concentration to which the fish has been exposed. If exposure is in an area of sufficiently low concentration the fish will be able to recover, but, if subjected to a higher concentration, enough of the toxic material may be absorbed so that death will occur even though the fish may be removed immediately. While not all gills were examined, mechanical injury and loss of filaments were not apparent in the fish that were examined. It is believed that in areas of low concentration, resulting from the inadequate distribution of rotenone under field conditions, the survival of some fish is possible even though they may suffer loss of equilibrium for an extended period of time.

CONCLUSIONS

There was found to be no significant difference in the toxicity of rotenone in a faintly acid, low-alkalinity water, when compared to a water which was slightly alkaline with a much higher methyl orange alkalinity.

Increased temperature increases the toxicity of rotenone. The slope for the regression of time on temperature is a curve which approximates a straight line for brown trout at concentrations from 0.05 to 0.40 p.p.m. for temperatures between 60° and 70° F., but which increases in curvature rapidly between 55° and 60° F.

Toxicity curves indicate that the species studied fall in the following order of increasing resistance to rotenone: brown trout, rock bass, creek chub, smallmouth bass, common sucker, and brown bullhead. The separation of these curves in time is sufficient to indicate that a dosage of 0.50 p.p.m. is inadequate if a complete kill is required on a fish population which includes suckers or bullheads.

While the effect of size, calculated in terms of length, was generally significant in the evaluation of the time for death, the data were

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inadequate for the determination of the curvature, or lack of curvature, in the slope.

At low levels of concentration it was found that affected fish recovered permanently when removed to clean water, even though removal was delayed up to 18 hours. In the case of some of the higher concentrations, no recovery was possible in spite of almost immediate removal.

Variation of the oxygen content between 8.8 and 11.4 p.p.m. seemed to have no significant effect on the toxicity of rotenone solutions measured in terms of the time for death.

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WOOD DUCK PRODUCTION AND USE OF NEST BOXES ON SOME SMALL MARSHES IN NEW YORK [1]

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ABSTRACT

A study of wood duck nesting and brood production was conducted on 38 farm marshes of central and western New York. Data collected on 135 nest boxes indicate that type of box and amount of light at the nest are the principal factors that may influence a wood duck in choice of a nesting site. Information available indicates that a density of 1.5 nest boxes per acre is suitable for a box-erection program.

Twelve other species of mammals, birds, and insects used the nesting boxes for nests, roosts, or dens.

Raccoon predation was of some consequence, 20 per cent of 30 nests being destroyed by this species. Only 13 per cent of the boxes had raccoon-proof entrance holes. The two most practical methods of raccoon-proofing boxes are a 4 x 3-inch entrance hole with sheet metal facing, and a 4 x 4-inch wooden tunnel-like entrance guard. Nest predation by other species was not encountered.

The nesting period of the wood duck in central and western New York is from late April to late July. The peak hatching period in 1953 was the first three weeks of June. The average of 12 clutches was 12.7 eggs, of which 88 per cent hatched, producing 11.2 ducklings per nest.

Duckling production on the marshes was analyzed in relation to quantity and kind of vegetative cover. There was a statistically significant direct relationship between the percentage of cover and the number of ducks produced per acre. Aging and counting of ducklings showed that a high initial mortality occurred, after which the mortality rate leveled off. Causes of this mortality were not determined. Analysis of production according to cover type showed the most clearcut difference to be between open marshes and those with vegetative cover. Survival and production of ducklings were definitely lower on open marshes.

With the development of a small marsh program well under way in New York, an evaluation of its effectiveness was desirable. This paper is a report on a study conducted in the spring and summer of 1953 on some of the farm marshes in the central and western parts of the State. The purpose of the study was to evaluate wood duck nest boxes already erected and to estimate production of wood ducks on these marshes.

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project W-61-R.
The author wishes to acknowledge help received from Dr. Oliver H. Hewitt of Cornell University during the field work and in preparation of the manuscript. Assistant game research investigators of the Conservation Department in the counties visited were extremely helpful during the field study, as were fellow students engaged in similar work.

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PROCEDURE

Field work was carried on from the first week of April until mid-August. The greater part of the data was collected on 38 farm marshes constructed as part of the small marsh program of the New York State Conservation Department. Supplementary observations were made on six natural marshes, six beaver ponds, and one enclosed small marsh on a game farm. The marshes were located by county as shown in Table 1.

TABLE 1. TYPE AND LOCATION OF MARSHES STUDIED

County	Farm marsh	Natural marsh	Beaver pond	Game farm marsh
Erie	2	1	. .	. .
Genesee	5	1	. .	1
Livingston	. .	1	. .	. .
Niagara	1	. .	. .	. .
Ontario	4	. .	. .	. .
Schuyler	2	. .	. .	. .
Seneca	. .	1	. .	. .
Tioga	14	1	. .	. .
Tompkins	1	1	6	. .
Wayne	9	. .	. .	. .
Total	38	6	6	1

The farm marshes ranged in size from 1.1 acres to 19.0 acres, with a mean of 5.1 acres. There was great variation in vegetation on and surrounding the marshes, from heavy mature woods through brush to herbaceous cover. Some marshes were entirely devoid of cover on the water surface. Surroundings of the marshes varied also, from mature woods to open fields.

Initial field work consisted of erecting nest boxes on Tioga County marshes to supplement those already present. Contacts were made with the assistant game research investigators in the various counties to ascertain the location of farm marshes with wood duck nest boxes. Inspection of these boxes then began. Objectives were: (1) to determine quantitative use of the nest boxes by wood duck and other species of animals; (2) to gather nesting data, particularly clutch sizes and hatching success; (3) to determine amount of predation upon the wood duck and its nests, and to measure the protection against predation afforded by the nest boxes; (4) to investigate preference of wood ducks for certain types of nest box.

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Inspection of marshes and nest boxes was for the most part on a weekly basis. Marshes in the more distant western counties (Ithaca being the base of operations) were visited about every two or three weeks. Equipment consisted of fisherman's waders, lineman's pole climbers, and a pocket flashlight and mirror for inspecting boxes. A light car-top boat was used to reach boxes in the deeper marshes.

As broods began to hatch they were counted and kept under observation on subsequent weekly visits. Data on survival of ducklings and duck production per marsh were objectives of the latter part of the field work. This terminated in mid-August when most broods were nearly full grown. Marshes were also cover-typed in order to judge the effects of cover on production of ducks.

FINDINGS AND DISCUSSION

The study resulted in data both on the use by wood ducks of nest boxes of various types and in various situations, and on the productivity of wood ducks on small marshes of different sizes and vegetative composition.

Nest Box Preference

Choice of nest boxes may be influenced by a number of factors. The information gathered is presented for the ones that appeared to be most important.

Type of Box Two basic types of wood duck nest box were observed in this study. One type was made from an old nail keg by sawing a hole in the side near the top for an entrance, putting on a roof, and nailing a board down the back as a means of attaching it to a tree or post. The second type was made of rough boards, 10 or 12 inches square on the inside and about 2 feet deep.

Bellrose (1953) reported that board-type boxes were used twice as much as the keg-type in the same area. In the present study, however, there was not the opportunity to test the preference of the wood duck for one type over the other. Because the boxes were put up by different people in different areas, there was not an interspersion of box types throughout all of the study areas. Therefore, a measure of wood duck preference could not be obtained in each marsh.

On the areas studied there was a total of 135 boxes. Thirty of these (22 per cent) were used for nesting by wood ducks, of which 20 were board-type and 10 were keg-type. In proportion to numbers of each kind under observation (77 board-type and 58 keg-type) a use of 26 per cent for board-type and 17 per cent for keg-type is

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indicated. This difference is not statistically significant. The small sample size and the lack of comparison between box types in the same area may be the reason. It is felt that there is a tendency for wood ducks to avoid keg-type boxes if there are alternative nesting sites.

AMOUNT OF LIGHT AT NEST Type of box and amount of light reaching the incubating duck were closely related. Keg-type boxes were generally much lighter inside than board-type. This was due to the usually larger opening and the bulging sides of the keg-type box. Keg boxes were also not as deep as board boxes.

Bellrose (1953) and other workers believe that ducks will not use a box that admits too much light. Boxes in this study were rated as "bright" or "dim". Of 53 bright boxes 8 (15 per cent) were occupied, while 22 (27 per cent) of 82 dim boxes were occupied. A chi-square test indicated no significant difference between the two groups. However, a real difference may exist, masked for the same reasons given regarding type of box. Whether or not light intensity at the nest influences to any great extent a duck's choice of a nesting site is open to question. Availability of nesting sites undoubtedly has much to do with choice.

EXPOSURE OF BOX Observations on the direction faced by nesting boxes produced the information in Table 2. Differences in use

TABLE 2. PROPORTION OF NEST BOXES OCCUPIED BY WOOD DUCKS ACCORDING TO EXPOSURE

Item	Exposure (direction faced)							
	North	North-east	East	South-east	South	South-west	West	North-west
Boxes erected	16	10	24	10	19	23	9	18
Boxes occupied								
Number	3	2	6	2	4	6	1	6
Per cent	19	20	25	20	21	26	11	33

between variously faced boxes are not statistically significant. It appears that the exposure of a nest box makes no difference on a purely directional basis (Schreiner and Hendrickson, 1951). Rather, nest boxes should be placed and faced in a manner so they will be fairly exposed to view. McLaughlin and Grice (1952) reported that new boxes, which were more noticeable, were used more than weathered boxes. Bellrose (1953) found that ducks avoided boxes that were shielded by a dense canopy of branches.

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Another consideration in placing boxes is exposure to weather. It was felt that cold winds and/or rain killed 7 of 11 embryos in a clutch observed in this study. This particular nest box faced the northwest on an exposed, windy hilltop. It is recommended that boxes be faced so that nests will be spared the most rigorous weather.

HEIGHT OF BOX Schreiner and Hendrickson (1951) found that height of the box made little difference in degree of use. Bellrose (1953) reported that boxes erected low over land had little use and recommended nest box erection heights of from 10 to 25 feet.

Measurements of height were taken on 129 of the boxes observed in this study and these ranged from 1.5 to 14.5 feet above the surface. Ninety-five boxes were from 0 to 8 feet high, 19 of which (20 per cent) were occupied. Thirty-four boxes were between 8 and 15 feet high, 11 of which (32 per cent) were occupied. This difference is not statistically significant. Boxes should be placed as high as practicable under prevailing conditions. They should be placed at least out of reach of the casual human molester.

WATER OR LAND SITES Most of the boxes observed (123 of 135) were erected over water, and 29 of the 30 occupied boxes fell in this category.

It is well known, however, that wood ducks will nest a long distance from water. Survival of the ducklings is an important consideration in the overland journey from nest to water. Leopold (1951) observed 15 broods leave nest boxes and make their way down a 130-foot bluff to the Mississippi River. Of a total of 189 ducklings, 128 (67 per cent) reached the river. If this 33 per cent mortality is common in the wild, a noteworthy management practice would be the placement of nest boxes directly over the water areas where the ducks will be reared.

LITTER The principal litter materials supplied in the boxes were sawdust and wood shavings. Other materials, placed in the boxes by man or animals, were straw, bark and punky wood, cattail down, twigs, dried ferns, old squirrel nests, and old deer mouse nests. Of these materials, sawdust, wood shavings, straw, cattail down, and an old squirrel nest were used as nesting litter. The small numbers involved preclude any conclusion that the other materials were avoided. Rather, it appears that the wood duck will accept anything as litter, but there must be some material present or the box will not be used (Bellrose, 1953). Wood ducks are not known to carry in their own nesting material.

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NUMBER OF BOXES PER ACRE

It is well known that the wood duck exhibits none of the breeding territoriality of other ducks that limits the number of pairs per area. In fact, there is much evidence to show that the wood duck is quite sociable in its breeding behavior (Miller, 1952; Bellrose, 1953). The management problem is to decide how many boxes per acre should be erected in order to get optimum use. Some of the marshes with occupied boxes are listed in Table 3. From these data a formula for the

TABLE 3. COMPARISON OF NEST BOX FREQUENCY AND DEGREE OF USE BY WOOD DUCKS IN CERTAIN MARSHES *

Marsh	Size in acres	Nest boxes present		Nest boxes occupied		
		Number	Number per acre	Number	Number per acre	Per cent of total
De May	10.4	3	0.29	1	0.10	33
De Marse	7.6	2	0.26	1	0.13	50
De Neef	13.5	3	0.22	2	0.15	67
Wiktorski	5.0	2	0.40	1	0.20	50
Israel	4.0	2	0.50	1	0.25	50
Ketchum	4.0	3	0.75	1	0.25	33
Cotton N	3.7	4	1.08	1	0.27	25
Gernatt	10.6	12	1.13	3	0.28	25
Williams	3.2	2	0.63	1	0.31	50
Hulbert	1.5	3	2.00	1	0.67	33
Grove	2.7	3	1.11	2	0.74	67
Sutherland	2.4	4	1.67	2	0.83	50
Ford E	2.2	4	1.82	2	0.91	50
White Game Farm	3.0	17	5.67	3	1.00	18

*Arranged in order of number of occupied boxes per acre.

number of boxes per acre would not be justified. By noting a few of the situations, however, some trends may be perceived.

The White Game Farm had an unusually high number of boxes per acre, and, although rate of use was good (1.00 per acre), there was a much greater rate of unoccupied boxes per acre (4.67).

Four other marshes that had high rates of boxes occupied per acre (0.67 to 0.91) were Hulbert, Grove, Sutherland, and Ford E. These marshes also had a fair proportion of their boxes occupied (33 to 67 per cent) and may be considered to represent a condition somewhere near optimum, as far as boxes used per acre is concerned. Their box density rates were from 1.11 to 2.00 per acre. Considering this, a tentative density rate of 1.5 boxes per acre may be more or less arbitrarily selected. This figure should be used as a rough guide only,

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due to the meager evidence upon which it is based. Other factors will vary the decision of the game manager, among them being the suitability of the marsh for duck rearing and the number of boxes available.

Areas of successful wood duck nesting will show an increase in the breeding population until the carrying capacity is reached. This is caused by juveniles which follow adults back to the breeding grounds in succeeding seasons. The initial density of boxes may be low, but additional ones should be added as the population increases (Bellrose, 1953).

USE OF BOXES

Table 4 shows the number and species of animals that used the nest boxes. In a number of instances, there was joint or subsequent

TABLE 4. FREQUENCY OF USE OF NEST BOXES BY VARIOUS SPECIES *

Species	Number of boxes used	Use
Birds		
Grackle	3	nest
Screech owl	5	nest
	5	roost
Sparrow hawk	2	nest
Starling	11	nest
Tree swallow	15	nest
Wood duck	30	nest
	1	dump nest (1 egg)
Unidentified	1	nest
Mammals		
Deer mouse	3	nest
Flying squirrel	1	nest
Gray squirrel	4	nest
Red squirrel	1	nest
Raccoon	3	den
Other		
Honey bee	1	nest
Wasps§	22	nest

*44 boxes were not used at all; also, some boxes were used by more than one species.
§Included *Vespa*, *Polistes*, and Sphecidae.

use of the same box by different species. A Wayne County box contained a brood of wood ducks in June and a litter of gray squirrels in May and in July.

Personal communication with F. C. Bellrose of Illinois and David Grice of Massachusetts indicates that wasps are not important in preventing wood ducks from using nest boxes.

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No active competition for nest boxes was observed between wood ducks and starlings, grackles, or tree swallows. The latter three species generally seemed to nest in boxes that were placed in open situations. Starlings, and possibly grackles, may make a nest box unusable by filling it with straw and trash.

PREDATION ON NESTS

The opossum is not considered to be a serious threat to wood duck nests. Bellrose (1953) in a survey of wood duck nest boxes in Illinois reported a 7-year average of 1.8 per cent of the predation recorded attributable to opossums. No evidence of opossum predation was found in the present study.

The fox squirrel, a very serious nest predator in Illinois, is found only in the extreme southwest corner of New York State. No work was conducted in that area and fox squirrel-wood duck relationships are undetermined in this State.

The gray squirrel appears to be entirely innocent of any predatory habits concerning wood ducks and their eggs. No evidence to the contrary was found in this investigation.

The status of the red squirrel with regard to wood duck nests is unknown. Nothing was found in the literature concerning this animal. The extensive literature on the red squirrel covered by James N. Layne in his doctoral work at Cornell University yielded no instances of predation upon wood duck nests by this species. No instances of red squirrel damage to wood duck nests were found in this study.

Instances of mink and weasel predation upon nesting wood ducks were not found in the literature and no evidence of such was encountered in this investigation.

Although Bellrose (1953) mentioned red-headed woodpeckers, flickers, and starlings as possible egg destroyers, no sign of such damage was found.

Raccoon predation accounted for the destruction of 6 of 30 (20 per cent) wood duck nests observed in this study. Of 123 boxes that were closely inspected for raccoon sign, 38 (30 per cent) had been visited at least once during the nesting season. Other workers have reported higher rates of predation: McLaughlin and Grice (1952), 41 per cent; Miller (1952), 32 per cent in 1949; Bellrose (1953), 7-year average of 37 per cent. Protection against raccoon predation must, therefore, be an important consideration in a nesting box program.

One approach to the problem has been to keep raccoons from climbing up to the nest boxes. Boxes have been erected on angle iron,

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reinforcing rod, and metal pipe. Sheet metal has been used to sheath posts supporting boxes or to fashion cone-shaped shields around posts or trees. Some of these methods are effective, but cost and maintenance problems may make them prohibitive for any large-scale program.

Another method has been to keep raccoons from actually entering the nest box. The Illinois Natural History Survey has found that a 4 x 3-inch entrance hole will keep out most raccoons without excluding wood ducks. The hole should be faced with sheet metal cut to this size to prevent chewing away of the edges. The Massachusetts Division of Fisheries and Game has experimented with entrance guards. First tried were lengths of stove pipe 4 inches in diameter. These were placed at the entrance hole to form a tunnel-like guard. It was found that they inhibited use of the boxes by nesting ducks. A square, wooden, tunnel-like guard of 4 inches inside dimension was next tried. Wood ducks used these boxes readily and even seemed to prefer this type over others. The guard will keep out raccoons effectively.

Stullken and Kirkpatrick (1953) experimented with minimum hole sizes through which various animals could pass. For the raccoon, they found that the pelvis prevents the animal from passing through a hole which the rest of its body is able to enter. Although one of their captive raccoons could not pass through a 4 x 3-inch entrance hole in a wood duck nest box, it was able to reach food inside the box 19 inches below the hole. This is a point in favor of having tunnel-like entrance guards.

Of the 135 boxes observed in this study only 18 (13 per cent) had the optimum hole size (4 x 3 inches). The great majority of the remainder had larger holes which could easily admit a raccoon. Closer attention must be paid to protection against raccoons in future erection of boxes.

HATCHING SUCCESS AND CLUTCH SIZE

Hatching of clutches in nest boxes began the week of May 17 when one brood hatched. The most intense period of hatching was the first three weeks of June when 10 clutches were hatched, compared with a total of 16 clutches on which fairly good hatching information had been obtained for the whole season. Hatching dropped off after this period, and the last box was emptied about July 7. Observations on broods hatched in non-artificial situations indicated that clutches observed in boxes were a good measure of the general pattern of hatching.

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In 12 nests, egg counts ranged from 9 to 17, with a mean of 12.7. Hatching success was from 25 to 100 per cent. The average number of ducklings to leave the nest was 11.2, an 88 per cent overall hatching success. These figures compare well with the findings of Leopold (1951), Schreiner and Hendrickson (1951), and McLaughlin and Grice (1952).

DUCK PRODUCTION ANALYSIS ACCORDING TO PERCENTAGE OF COVER ON MARSH

For the remainder of this paper the data apply to the 32 most intensively studied farm marshes. As broods hatched from boxes or otherwise appeared on these marshes, observations and records were made on number and age of ducklings. Southwick's (1953) age classification was used. Quiet observation of a marsh with 7 x 35 binoculars was always attempted first in order to tally and age the ducks undisturbed.

Each marsh was inspected and the percentage of vegetation on the water surface was estimated. In Table 5 the marshes are arranged in increasing order of cover amount. The following summary statements may be made:

1. Using the total area (163.2 acres) as a basis for production rates: 132 ducklings represented 0.81 per acre.
2. Using only the combined areas on which ducks were produced (13 marshes totaling 84.4 acres): 132 ducklings represented 1.56 per acre.
3. Using the total of 36 broods still present in mid-August as a basis for the average final size: 132 ducklings represented 3.7 per brood which, for an estimated average initial brood size of 11.2, represented a survival of 33 per cent.

The figures on duck production given under (1) cover all 32 marshes tabulated, but it can be seen that some produced no ducks. Reasons for low productivity are not always readily apparent. Poor cover was probably an outstanding reason for failure of ducks to nest on certain marshes. Tallying and aging of blue-winged teal, mallards, and black ducks were also carried on where these species were encountered. Only 2 of 11 (18 per cent) marshes with 15 per cent or less cover produced ducks to maturity, while 16 of 21 (76 per cent) marshes with 25 per cent or more of cover produced ducks. Using these data (not presented), a regression was drawn of total ducks produced per acre on percentage of vegetative cover. This indicated a

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TABLE 5. WOOD DUCK PRODUCTION ON 32 MARSHES ARRANGED IN ORDER OF INCREASING PERCENTAGE IN COVER

Marsh	Acres	Percentage in cover	Wood duck production: Number broods*	Number ducklings produced§	Per cent survival	Number ducklings per acre§
Signs	4.0	10	0	0	..	..
Hulbert	1.5	10	1(1)	0	0	..
Ford W	4.7	10	0	0	..	..
Spicer	7.0	10	0	0	..	..
Hazlett	2.0	10	0	0	..	..
Dudley W	6.0	10	0	0	..	..
Mulcahy	3.0	10	0	0	..	..
Ketchum	4.0	10	1(1)	0	0	..
Cotton N	3.7	15	2(2)	0	0	..
Atkinson	4.7	15	0	0	..	..
Wiktorski	5.0	15	1	6	54	1.20
Chase	7.0	25	0	0	..	..
Tull	2.2	50	2	8	36	3.64
Standish	4.4	50	0	0	..	..
Zorn	8.5	55	0	0	..	..
Canne	4.4	55	1	6	54	1.36
De Neef	13.5	55	5	19	33	1.41
De May	10.4	60	2	3	13	0.29
Dudley E	4.0	60	0	0	..	..
Owens	4.1	60	0	0	..	..
Grove	2.7	65	3(1)	6	27	2.22
Swanson	1.1	70	0	0	..	..
Williams	3.2	70	1(1)	0	0	..
De Marse	7.6	70	5	20	36	2.63
Pixley	3.5	70	0	0	..	..
Sutherland	2.4	75	2(2)	0	0	..
Schumacher	5.0	80	1	4	36	0.80
Cotton E	6.3	85	2	7	31	1.11
Ford E	2.2	85	1	1	9	0.45
Crocker	17.0	85	8	30	34	1.76
Cotton S	2.9	90	4	15	34	5.17
Brown	5.2	90	2	7	31	1.35
Total	163.2	XXX	44(8)	132	XXX	XXX

*Figures in parentheses indicate broods which appeared on certain marshes and later moved off.
§As of mid-August.

direct relationship between greater duck production and increasing amount of cover that is statistically valid.

In Table 5 are indicated the number of broods which appeared on certain marshes and later moved off. Reasons for this movement may have been lowered water level, lack of suitable cover, better rearing areas near by, or need for requirements of which nothing is known.

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Under (2), duck production figures are based upon the acreage of marshes that did produce ducks. In this way an approach is made to a knowledge of how many ducks per acre may be produced on a group of what may be called suitable duck rearing marshes.

DUCK PRODUCTION ANALYSIS ACCORDING TO VEGETATIVE TYPE AND SIZE OF MARSH

Marshes were cover-typed and assigned one of the following categories:

Open — less than 10 per cent of water area covered with vegetation of any type.

Herbaceous — at least 15 per cent of water area covered with cattail, rushes, sedges, grasses, or ferns.

Brush — at least 15 per cent of water area covered with low, woody vegetation such as willow, red-osier dogwood, alder, spiraea, aspen, high-bush blueberry, or swamp rose.

Brush-woods— at least 15 per cent of water area covered with an interspersed or consolidated mixture of the brush and woods species mentioned under those types individually.

Woods — at least 15 per cent of water area covered with trees 8 inches or more in diameter, hemlock, red maple, willow, elm, yellow birch, and aspen being the species most often present on flooded sites.

Using these vegetative types and the listed size classes, the 32 marshes were analyzed for brood and duck production as shown in Table 6. A weakness of this particular analysis is that the marshes were not evenly distributed with respect to the various type and size combinations. For those categories represented by only a few marshes, results may be unduly skewed. It must be emphasized that results obtained regarding the different vegetative types and size classes cannot be extrapolated in generalities. The small numbers involved prohibit this.

For each size class and for all classes combined, the number and total acreage of the marshes of each vegetative type are given. Also given are average numbers of ducklings produced per acre and of broods per acre. In addition to these four statistics, an index has

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TABLE 6. ANALYSIS OF DUCKLING PRODUCTION AND SURVIVAL ACCORDING TO SIZE OF MARSH AND VEGETATIVE TYPE

Type of marsh	Number	Acres	Average density per acre: Ducklings*	Average density per acre: Broods	Survival index§
			0.0–2.4 acres		
Open	2	3.5	0.00	0.29	XXX
Herbaceous	..	..	..	..	XXX
Brush	2	4.6	0.22	0.65	XXX
Brush-woods	2	3.3	2.42	0.61	XXX
Woods	..	..	..	..	XXX
Sub-total	6	11.4	0.79	0.53	1.49
			2.5–4.9 acres		
Open	5	20.4	0.00	0.05	XXX
Herbaceous	..	..	..	..	XXX
Brush	3	10.6	0.57	0.28	XXX
Brush-woods	5	18.6	1.13	0.32	XXX
Woods	1	3.7	0.00	0.54	XXX
Sub-total	14	53.3	0.51	0.22	2.32
			5.0–7.4 acres		
Open	2	13.0	0.00	0.00	XXX
Herbaceous	2	12.0	0.50	0.08	XXX
Brush	2	10.2	1.08	0.29	XXX
Brush-woods	..	..	..	..	XXX
Woods	1	6.3	1.11	0.32	XXX
Sub-total	7	41.5	0.57	0.14	4.07
			7.5–9.9 acres		
Open	..	..	..	..	XXX
Herbaceous	1	7.6	2.63	0.66	XXX
Brush	1	8.5	0.00	0.00	XXX
Brush-woods	..	..	..	..	XXX
Woods	..	..	..	..	XXX
Sub-total	2	16.1	1.24	0.31	4.00
			10.0 or more acres		
Open	..	..	..	..	XXX
Herbaceous	..	..	..	..	XXX
Brush	1	10.4	0.29	0.19	XXX
Brush-woods	..	..	..	..	XXX
Woods	2	30.5	1.61	0.43	XXX
Sub-total	3	40.9	1.27	0.37	3.43
			Combined acreage		
Open	9	36.9	0.00	0.06	0.00
Herbaceous	3	19.6	1.33	0.31	4.29
Brush	9	44.3	0.48	0.25	1.92
Brush-woods	7	21.9	1.32	0.36	3.67
Woods	4	40.5	1.39	0.42	3.31
Total	32	163.2	0.81	0.27	3.00

*As of mid-August.
§Derived by dividing the value for ducklings per acre by that for broods per acre.

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been derived by dividing the value for ducklings per acre by that for broods per acre for each vegetative type and each size class. This average number of ducklings per brood is used as a means of comparing various categories for their survival value, independent of their production value.

Vegetative Type Comparisons The low number of ducks produced per acre (caused mainly by poor survival) on marshes of brushy cover type is not necessarily an indication that such marshes are not suitable for wood ducks. The small number involved prohibits generalization on the results obtained. Factors involved in the low survival rate were: (1) three broods moved off two marshes; (2) there was very low survival on three marshes for reasons unknown.

Survival rate for the herbaceous vegetative type was somewhat higher than for the brush-woods and woods types. Again a generalization on the basis of only three marshes would most certainly be unsafe.

Size Group Comparisons Comparison of size groups is difficult because of the unbalanced distribution of the open-type marshes. Seven out of nine open marshes were less than 5 acres in area and may have unduly influenced results for the two size groups involved. The possibility that marshes of the smaller sizes do not give adequate protection to ducklings is open to question. Certainly the amount of protective cover on small marshes is much more critical than on large ones. Therefore, size alone must not be concluded to be the cause of the low survival indices in the marsh groups of less than 5 acres. These smaller marshes can produce ducks well if good cover and adequate food are available. This was demonstrated on some of the marshes observed.

Survival of Ducklings

Table 7 gives the average size of wood duck broods at different

Table 7. Average Size of Wood Duck Broods at Different Ages

Item	Age class*					
	1A	1B	2A	2B	3	Juvenile
Number of observations	14	17	12	9	14	5
Average number of ducklings per brood	6.6	6.1	4.5	4.7	4.0	3.8

*After Southwick (1953).

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ages. The observations included are only those that were thought to have represented complete tallies at the time they were made.

Considering 11.2 ducklings as an average initial brood size, it can be seen that there was a great deal of mortality in the 1A age class. The cause of this mortality is unknown. Of the approximately 40 broods which contributed to the survival figures, only eight (20 per cent) are known to have come from boxes which were directly over water. The other broods came from natural nests, some of them perhaps a long way from the marsh. A great deal of this initial mortality may have occurred on the overland trip to the water area. More nesting boxes at marsh sites may help to alleviate this situation.

CONCLUSIONS

There is a very real need for a wood duck nesting box program on New York State farm marshes. Many more nest boxes of suitable design are needed, particularly on areas where nesting sites are a limiting factor in duck production. Nest boxes at marsh sites may help to decrease mortality suffered by very young broods, possibly on overland trips from nest to marsh.

Nest predation by raccoons is of the most consequence. Boxes must be designed and built to insure protection for the nesting duck.

Among factors such as exposure, height, erection over land or water, type of litter, amount of light reaching the nest, and type of box, the latter two are paramount in influencing a duck's choice of a box for a nesting site.

Open marshes produced definitely fewer ducks than marshes with some kind of cover. Vegetation management on open marshes may be advisable in order to get some cover on them quickly. Long range vegetation management plans should be developed for all types of marshes in order to anticipate changes that may make them less suitable for duck production.

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AGE AND GROWTH OF A SMALL-STREAM POPULATION OF "STUNTED" SMALLMOUTH BLACK BASS, *MICROPTERUS DOLOMIEU DOLOMIEU* (LACÉPÈDE) [1]

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ABSTRACT

A study of smallmouth bass of Fall Creek, Tompkins County, New York, between the village of McLean and Beebe Lake was carried on during 1948 and 1949. A total of 966 specimens obtained by various methods was used for the study. The bass of Fall Creek were determined to be stunted although they were relatively plump ($K=2.35$). It was found that annuli were formed during the latter part of May and early June. The maximum annual increase in length occurred during the first year. The length-frequency distribution of the calculated fork lengths exhibited a large overlap in most age groups. A statistical test made on a sample of 213 specimens showed no significant difference in the growth rates between the sexes.

The present study was a subproject of a trout survival study (Webster, 1950) in Fall Creek, Tompkins County, New York. The latter was a cooperative investigation by Cornell University, the New York Conservation Department and the U. S. Fish and Wildlife Service. The data included in this paper were collected during 1948 and 1949.

[1] This paper is based on a manuscript submitted as partial fulfillment of a doctoral dissertation. The writer is indebted to various members of the New York State Conservation Department and to co-workers at Cornell University for cooperation in the collection of the material. Field operations were organized by Dr. Dwight A. Webster, Associate Professor of Fishery Biology, Cornell University, who also read the manuscript and offered certain critical suggestions for its improvement.

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Publications on growth of smallmouth black bass that inhabit small streams have been very few. Papers by Surber and Seaman (1949) and Tate (1949) are two recent studies which deal for the most part with stream inhabitants. Bennett (1938) and Doan (1940) worked mostly with lake specimens but did report some data for stream specimens. The various biological survey reports of the New York State Conservation Department (Bishop, 1936; Greeley, 1934, 1935, 1937, 1938, 1940; Greeley and Bishop, 1932, 1933; Greeley and Greene, 1931) give information on smallmouth bass collected from both lakes and streams but sufficient pertinent data are not available to enable one to make a critical comparison of growth. The purpose of this paper is to describe the growth of smallmouth bass in a stream which appears more suitable for trout through much of its length.

DESCRIPTION OF STUDY AREA

The study area comprised approximately 18 miles of Fall Creek, the principal tributary of Cayuga Lake. The village of McLean marks its upper end and Beebe Lake within the campus of Cornell University its lower end. Fall Creek has an altitude of 1,120 feet above sea level at McLean and flows in a southwesterly direction to the south end of Cayuga Lake. The upper 3 miles are characterized by a rubble bottom with numerous alternate pools and riffles. The stream then enters a broad valley and takes a meandering course for about 7 miles, throughout the greater part of which the bottom is made up of mud and clay. Pools are a prominent feature with only an occasional riffle. From the vicinity of Etna, where the latter section ends, the stream has a steep gradient to Beebe Lake. Large boulders and exposed bedrock are a common sight along this lower reach of the study area which is approximately 8 miles long. Fall Creek has an altitude of 800 feet at the point of its entrance into Beebe Lake which represents a drop of 320 feet from McLean.

MATERIALS AND METHODS

The measurements used in this study were obtained from 966 smallmouth black bass taken from Fall Creek during the years 1948 and 1949. The specimens were captured as follows: angling, 146; 10-foot seine, 52; 25-foot bag seine, 10; and electric shocker, 758. All specimens were removed permanently from the stream.

Calculations used in this paper were made on the basis of fork length to the nearest millimeter and all specimens were measured while in fresh condition. Weight was measured with a balance scale and

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recorded to the nearest gram. The standard, fork, and total length measurements were recorded for 195 specimens in order to compute conversion ratios. The 195 specimens ranged from 69 to 316 millimeters in fork length. A ratio of 1:0.862 was computed for conversion of fork length to standard length, and a ratio of 1:1.044 for conversion of fork length to total length.

A small patch of scales was removed from the left side of each specimen just posterior to the end of the extended pectoral fin. These scales were inspected with the aid of a binocular microscope and from each sample a few were selected. Impressions of these selected scales were made in cellulose acetate by a roller type press. The scale impressions were viewed with a microprojector at a magnification of 35X. The positions of the projected annuli were marked on slips of paper and used for age calculations.

RESULTS

The data afford a means of evaluating the rate of growth of the bass in Fall Creek and of comparing it with that in other waters.

AGE AND GROWTH

Table 1 includes 489 of the grand total of 966 specimens. The reduction was made because 577 of the 641 specimens electrically shocked in September, 1949, fell within a limited size group, namely, 51 to 100 millimeters. One hundred specimens were picked at random from the 577. Scales collected at various times of the year indicated that annuli were formed in May and early June.

The relationship of fork length to scale length was determined from measurements of the 489 bass mentioned above. The data were assembled by fork lengths into 5-millimeter groups and the means of the groups along with the means of the respective scale radii (X35) were used in computing the regression equation. This relationship for smallmouth bass from Fall Creek can be described by a second degree parabola with the following formula: $Y = 3.5008 + 0.3365X + 0.000543X^2$. By substitution of arbitrary values in the regression equation a curve was fitted to the frequency distribution as shown in Figure 1.

The average calculated fork lengths at the end of each year of life are given in Table 2 for all specimens which had at least one annulus. The greatest annual increment took place during the first year of life. Thereafter the growth rate decreased although apparently it was about the same during the third and fourth years.

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TABLE 1. MEAN LENGTHS OF THE ANTERIOR SCALE RADIUS (X35) AND MEAN FORK LENGTHS OF 489 SMALLMOUTH BASS FROM FALL CREEK

Fork length in millimeters	Number of specimens*	Mean anterior scale radius in millimeters (X35)	Mean fork length in millimeters
30— 39	2	10.5	38.5
40— 49	15	13.0	45.4
50— 59	10	15.5	53.8
60— 69	16	21.1	65.4
70— 79	30	24.2	73.8
80— 89	32	29.0	85.6
90— 99	40	32.2	94.2
100—109	35	36.9	104.4
110—119	27	43.1	114.5
120—129	42	47.8	125.1
130—139	38	52.7	134.3
140—149	40	57.6	144.4
150—159	33	61.3	154.3
160—169	30	66.3	163.9
170—179	12	69.5	174.8
180—189	15	75.7	185.1
190—199	11	83.6	194.5
200—209	11	88.4	204.4
210—219	11	94.0	214.5
220—229	13	97.6	224.8
230—239	7	107.7	233.3
240—249	4	102.5	243.0
250—259	8	117.4	253.2
260—269	3	125.3	264.7
270—279	2	125.0	272.5
280—289	1	144.0	280.0
340—349	1	160.0	343.0

*Includes all specimens from which scale impressions were made.

Table 3 is a frequency distribution of the calculated fork lengths given in Table 2, plus those for the 7-year-old specimen. A considerable amount of overlap occurred between the various age groups.

In comparison with those studied by Tate (1949), the bass in Fall Creek did not attain as great a length per year class as the same species in Iowa streams. However, because of the similarity in the growth increments (Table 4), much of the difference between the two results is probably not real. Rather, it may be attributed to Tate's treatment of his data as linear, whereas the data in the present paper are better described by a curvilinear regression. It is interesting to note that 5 years was the maximum limit of age in Fall Creek specimens with one exception, while 4 years was the maximum in Iowa streams with one exception. The exception in each case was a 7-year-old individual. If the samples used in this study were representative for

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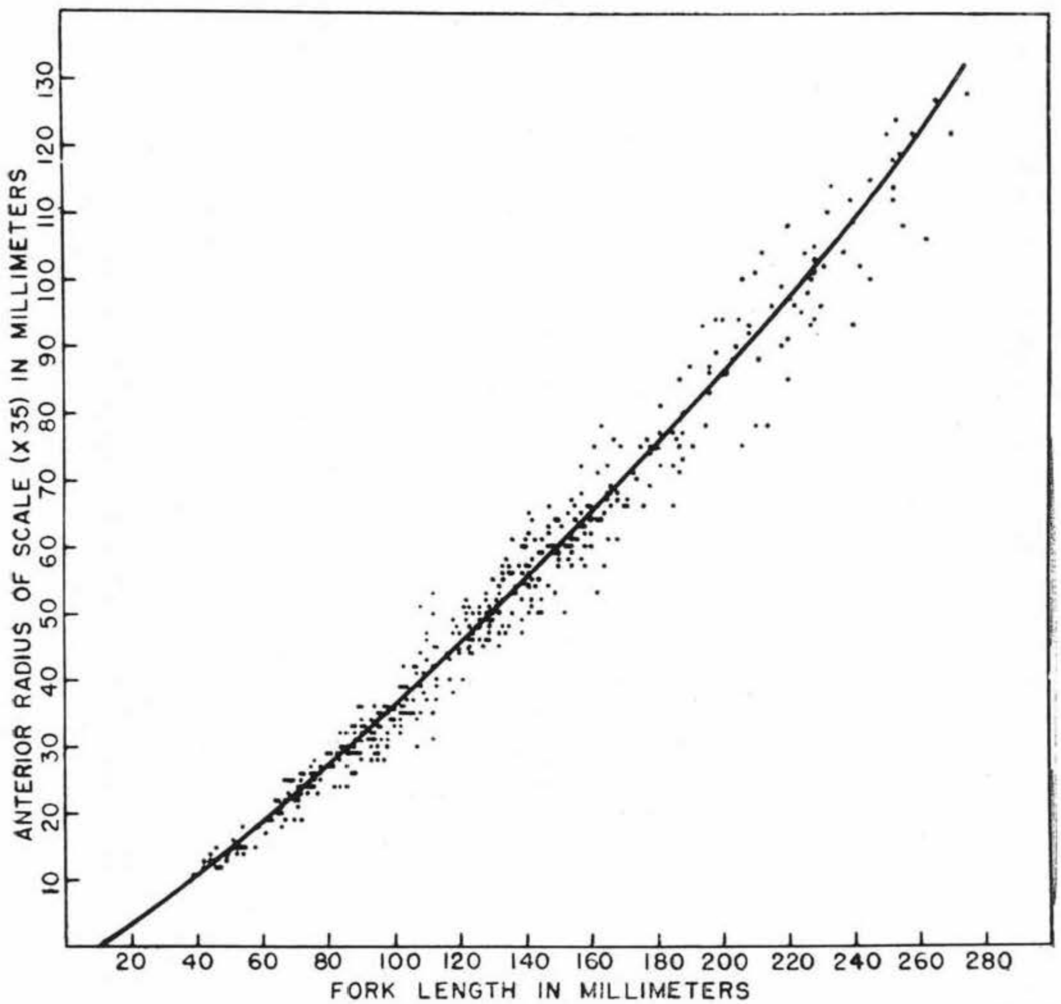

Figure 1. Relationship between scale length and fork length for 489 smallmouth black bass from Fall Creek, New York.

age groups in the population, then the bass in Fall Creek had almost a complete mortality early in life as compared, for example, with the same species in the St. Lawrence River (Stone, Pasko, and Roecker, 1954) where some individuals attain the age of 14 years.

In comparison with the bass studied by Surber and Seaman (1949) those of Fall Creek grew at approximately the same rate as recorded for the same species in the South Branch of the Potomac River and the Cacapon River in West Virginia, which were considered as poor to mediocre bass streams at the time of their study.

Greeley (1934) determined the percentage of legal-sized bass by age group for the specimens collected from various parts of the Raquette River watershed. Most of the specimens were from large rivers and lakes. Table 5 is a comparison of these data with similar records for Fall Creek.

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TABLE 2. AVERAGE CALCULATED FORK LENGTHS AND INCREMENTS IN LENGTH OF SMALLMOUTH BASS TAKEN FROM FALL CREEK IN AUGUST, 1948, AND JUNE TO OCTOBER, 1949*

Age group	Specimens: Number	Specimens: Per cent	Average length at capture in millimeters	Average calculated length, in millimeters, for previous years of life: 1	2	3	4	5
0	99	20.3	71	..	..	..	..	..
I	272	55.7	126	68	..	..	..	..
II	59	12.1	178	71	142	..	..	..
III	27	5.5	207	72	123	170	..	..
IV	17	3.5	231	69	124	171	215	..
V	14	2.9	238	69	117	152	191	224
Number of records	488	100.0	XXX	389	117	58	31	14
Average calculated length in millimeters				71	132	166	204	224
Average increment in millimeters				71	61	34	38	20
Average fork length in inches				2.8	5.2	6.5	8.0	8.8

*The one 7-year-old specimen omitted.

The percentages by age group for the 488 specimens included in Table 2 are erroneously high for age groups II, III, IV, and V. The other 477 specimens (mentioned at the beginning of this topic) would have to be added to the 0 and I age groups before a fair estimate of age composition could be made. The one 7-year-old specimen would also have to be added to obtain the total catch figure of 966.

Nevertheless, without this correction, age group V made up only 2.9 per cent of the sub-total of 488 specimens (Table 2) and only 50 per cent of this small proportion were of legal size (Table 5). The situation was worse for age groups II, III, and IV. Thus, it is apparent that Fall Creek was producing a stunted population.

The smallmouth bass of the upper Hudson River drainage (Greeley and Bishop, 1933) reach legal size (10 inches in total length) during their third year. Approximately 30 per cent of the 3-year-old and 50 per cent of the 4-year-old fish examined were of legal size. Bishop (1936) reported that the smallmouth bass of the Delaware River do not attain legal length in 2-plus years, that only seven of 20

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TABLE 3. FREQUENCY DISTRIBUTION OF CALCULATED FORK LENGTHS OF 390 SMALLMOUTH BASS FROM FALL CREEK

Fork length in millimeters	Age group						
	I	II	III	IV	V	VI	VII
41— 50	9	..	..	..	..	..	..
51— 60	68	..	..	..	..	..	..
61— 70	146	..	..	..	..	..	..
71— 80	90	..	..	..	..	..	..
81— 90	49	1	..	..	..	..	..
91—100	23	5	..	..	..	..	..
101—110	5	10	..	..	..	..	..
111—120	..	14	..	..	..	..	..
121—130	..	20	1	..	..	..	..
131—140	..	23	9	..	..	..	..
141—150	..	26	7	..	..	..	..
151—160	..	14	6	1	..	..	..
161—170	..	3	7	1	..	..	..
171—180	..	2	12	5	..	..	..
181—190	..	..	6	2	1	..	..
191—200	..	..	5	5	..	..	..
201—210	..	..	3	5	2	..	..
211—220	..	..	3	5	3	..	..
221—230	..	..	..	3	1	..	..
231—240	..	..	..	1	3	..	..
241—250	..	..	..	2	4	..	..
251—260	..	..	..	2	..	..	..
261—270	..	..	..	..	..	..	..
271—280	..	..	..	..	1	..	..
281—290	..	..	..	..	..	..	..
291—300	..	..	..	..	..	..	..
301—310	..	..	..	..	..	1	..
311—320	..	..	..	..	..	..	1
Total.	390	118	59	32	15	1	1

were legal at 3-plus years, and three of 15 at 4-plus. Further, Bishop stated that one was still below the legal length at 5-plus, and the largest had attained only 12$\frac{3}{16}$ inches in total length at 6-plus. In the report by Greeley (1935) Schoharie Creek was given as an example of a stream containing stunted bass. Some individuals failed to attain legal size as late as the sixth growing season. Many of the scale samples showed a conspicuous stunting during the third or fourth growing season. The scales of the Fall Creek specimens did not reveal that stunting occurred in any one growing season, but instead the relatively close spacing of the annuli indicated retardation throughout the life of the individual.

The frequencies of the observed lengths of the males and females in the September, 1949, sample were tabulated (Table 6) and, by statistical treatment of the data for age groups I and II, it was found

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TABLE 4. INCREMENTS OF GROWTH OF SMALLMOUTH BASS FROM THREE STREAMS IN IOWA AND ONE STREAM IN NEW YORK

State and locality	Number of specimens	Age group				
		I	II	III	IV	V
Iowa						
Lime Creek.....	11	76	45	49	18	..
Coffin Creek....	67	75	41	54	33	..
Prairie Creek*..	9	72	42	44	6	..
New York						
Fall Creek§.....	389	71	61	34	38	20

*One 7-year-old specimen omitted.
§One 7-year-old specimen omitted.

that no significant difference existed between sexes. The t values for age groups I and II were 1.577 and 0.899, respectively. The value of 1.577 gave odds of 1.6 to 1 against so great a deviation in either direction being due to chance, while that of 0.899 gave odds of 8 to 1.

TABLE 5. PERCENTAGE OF LEGAL-SIZED* SMALLMOUTH BASS BY AGE GROUP FOR SPECIMENS FROM THE RAQUETTE RIVER WATERSHED (1930-33) AND FALL CREEK (1948-49)

Locality	Age group				
	I	II	III	IV	V
Raquette River watershed.......	0.0	1.4	24.4	56.1	94.8
Fall Creek.........	0.0	0.02	11.1	35.3	50.0

*Minimum legal size was 10 inches total length.

Tate (1949) stated that the absence of fish over 4 years of age in three small streams in Iowa suggests the possibility of movement downstream to larger waters. There was certainly a lack of older fish, at least, in the study area of Fall Creek, but no tagging or marking of smallmouth bass has been done to determine if movement occurs. A reason for few older specimens in Fall Creek may be that smallmouth bass are of shorter life in small streams than in larger streams and lakes. Another possible solution to the problem could be the nearly complete elimination of the older bass by fishermen. Greeley (1940) stated that the scarcity of older, larger bass in some streams of the lower Hudson River system probably reflects the high intensity of angling.

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TABLE 6. LENGTH-FREQUENCY DISTRIBUTION BY AGE GROUP AND SEX FOR SEPTEMBER SPECIMENS

Fork length in millimeters	Age group and sex											
	0		I		II		III		IV		V	
	M	F	M	F	M	F	M	F	M	F	M	F
41—50	..	..	..	..	..	..	..	..	..	..	..	..
51—60	1	..	..	..	..	..	..	..	..	..	..	..
61—70	5	6	..	..	..	..	..	..	..	..	..	..
71—80	7	11	..	..	..	..	..	..	..	..	..	..
81—90	7	8	..	2	..	..	..	..	..	..	..	..
91—100	2	..	1	1	..	..	..	..	..	..	..	..
101—110	5	5	1	4	..	..	..	..	..	..	..	..
111—120	..	..	2	8	..	..	..	..	..	..	..	..
121—130	..	..	9	13	1	1	..	..	..	..	..	..
131—140	..	..	8	17	1	..	..	..	..	..	..	..
141—150	..	..	15	9	1	..	..	..	..	..	..	..
151—160	..	..	9	10	..	1	..	..	..	..	..	..
161—170	..	..	5	7	1	2	..	..	..	..	..	..
171—180	..	..	1	3	2	..	..	..	..	..	..	..
181—190	..	..	2	2	3	1	..	..	..	..	..	..
191—200	..	..	2	1	..	1	..	..	..	..	..	..
201—210	..	..	..	..	1	1	..	..	..	..	..	..
211—220	..	..	..	..	1	1	..	..	..	..	..	..
221—230	..	..	..	..	2	..	..	..	..	..	..	..
231—240	..	..	..	..	..	..	..	1	..	..	..	..
241—250	..	..	..	..	..	..	..	..	..	..	..	..
251—260	..	..	..	..	1	..	..	..	..	..	..	..
261—270	..	..	..	..	..	..	..	..	..	1	..	1
271—280	..	..	..	..	..	..	..	..	..	..	..	..
Mean length*	82	81	145	138	191	178	..	231	..	267	..	270
Number of specimens........	27	30	55	77	13	8	0	1	0	1	0	1

*Mean length rounded to the nearest millimeter.

LENGTH-WEIGHT RELATIONSHIP AND CONDITION

The relationship between standard length in millimeters and weight in grams of specimens from Fall Creek is given in Table 7. The methods of computation described by Beckman (1948) were employed and the following equation was derived:

$$\log W = 4.28802 + 2.85425 \log L$$

From interpretation of the length-weight relationship one may say that the bass in Fall Creek weighed relatively less per unit of length than the same species in Iowa streams as given by Tate (1949).

No attempt was made to smooth out fluctuations in coefficients of condition as suggested by Beckman (1948). The discrepancies can be attributed to the small number of fish in some groups and to the fact

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TABLE 7. LENGTH-WEIGHT RELATIONSHIP AND COEFFICIENT OF CONDITION (K) FOR 488 SMALLMOUTH BASS TAKEN FROM FALL CREEK FROM AUGUST, 1948, TO OCTOBER, 1949

Fork length in millimeters	Number of specimens	Average standard length in millimeters*	Average weight in grams	K§	K†
30— 39	2	33.2	1.0	2.81	2.73
40— 49	15	39.1	1.7	2.85	2.84
50— 59	10	46.4	2.4	2.47	2.40
60— 69	16	56.4	5.0	2.86	2.79
70— 79	30	63.7	5.7	2.28	2.20
80— 89	32	73.8	9.3	2.38	2.31
90— 99	40	81.2	11.4	2.16	2.13
100—109	35	90.0	15.8	2.22	2.17
110—119	27	98.7	20.3	2.16	2.11
120—129	42	107.8	27.5	2.24	2.19
130—139	38	115.8	34.7	2.28	2.23
140—149	40	124.5	43.6	2.34	2.26
150—159	33	133.0	55.4	2.41	2.35
160—169	30	141.3	64.2	2.34	2.27
170—179	12	150.7	80.3	2.43	2.35
180—189	15	159.6	93.9	2.38	2.31
190—199	11	167.7	106.7	2.33	2.26
200—209	11	176.2	128.4	2.39	2.35
210—219	11	184.9	140.5	2.29	2.22
220—229	13	193.8	171.2	2.42	2.35
230—239	7	201.1	194.4	2.47	2.39
240—249	4	209.5	218.3	2.43	2.37
250—259	8	218.3	244.4	2.42	2.35
260—269	3	228.3	287.0	2.49	2.41
270—279	2	234.9	323.5	2.56	2.49
280—289	1	241.4	312.0	2.28	2.22
Average K.....				2.41	2.35

*Converted from fork length using ratio 1:0.862.
§Fork length converted to standard length by use of ratio 1:0.854 (after Tate, 1949).
†Fork length converted to standard length by use of ratio 1:0.862.

that no separation was made according to sex, season or year of capture, or method of capture. Tate (1949) cited K values (coefficient of condition) reported by various workers and concluded that the bass from Iowa streams (K=2.49) were heavier for their length than had been reported for the same species elsewhere. The K values computed in this study are somewhat higher than those obtained by some workers. Stroud (1948) reported average K values by age group that range from 2.08 to 2.35 with a grand average of 2.21. Bennett (1938) gave K values of 1.96 to 2.45 with an average of 2.20. In order to make a comparison of K values with those presented by Tate the same conversion ratio (1:0.854) was used for converting fork lengths to standard lengths. The values are tabulated in Table 7.

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The average K of 2.41 for Fall Creek bass is higher than the values given by Stroud and Bennett but lower than that of 2.49 reported by Tate for bass from Iowa streams. An average K value of 2.35 resulted when the conversion ratio of 1:0.862 was used.

CONCLUSIONS

Stunting in the Fall Creek population of smallmouth bass was clearly indicated by the data presented in this paper. Comparison of yearly increments revealed that the factors limiting growth must have been operative throughout the lives of the individuals.

Based on the numerous collections and observations of bottom fauna made by the author and a colleague, Robert M. Roecker, there apparently was no lack of food for the bass in Fall Creek. This conclusion is substantiated by the good condition or high relative plumpness of the specimens studied as demonstrated by the calculated coefficient of condition (K). Further study will be necessary to determine the nature of the factors responsible for the retardation of growth and it may be that these limiting factors are typical of small streams.

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EFFECTS OF RAPID DIRECT CURRENT PULSATIONS ON FISH [1]

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ABSTRACT

Comparing the effects of rapidly pulsating direct current, slowly pulsating direct current, and steady direct current in producing motion of fish toward the anode in a shocker circuit, it was found that about 20 per cent lower voltage is required by a current of 180 pulsations per second than by steady current. The threshold voltage was lowest when the long axis of the fish coincided with a line connecting the electrodes and highest when the fish was at 90 degrees to this position. The resulting motion was a minimum for the aligned position and a maximum for the 90-degree position. Rapidly pulsating current produced more erratic motion and had less power to hold fish at the anode than slowly pulsating current. It is pointed out that the electrical power required by rapidly pulsating current may be only about a tenth of that required by steady current.

During a study of the effects of direct current on fish (Haskell *et al.,* 1954), it was found that slowly pulsating direct current was more effective than steady current in producing motion of fish to the anode. An examination of the literature on the effects of direct current on human and animal nerves and muscles indicated a possibility that very high rates of pulsation might be combined with a slow on and off sequence to produce more pronounced effects than those produced by slow pulsation. In the present study the effect of direct current having 100 to 400 pulsations per second was investigated.

REACTIONS OF FISH TO PULSATING CURRENT

The effects of direct current on fish are: (1) to cause muscular contractions which promote or guide motion to the anode; (2) to anesthetize the fish and stop all motion. In comparing various rapid direct current pulsations, attention has been given to both effects as they apply to the objectives of the direct current method of collecting fish in streams. The fish used in the tests were fingerling brown trout produced by the State fish hatcheries at Caledonia and Rome. Except as mentioned, they were between 3 and 5 inches in length.

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-1-R. A large part of the experimental work in this study was performed in the laboratories of the Department of Physiology and Vital Economics of the School of Medicine and Dentistry at the University of Rochester. Thanks are due not only to the University but also to Drs. Wallace O. Fenn and E. B. Wright who provided technical advice throughout the study.

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Summation of Inadequate Stimuli

When muscle tissue in an aqueous solution is subjected to direct current and sufficient voltage is applied, the muscle will contract due to electric stimulation of the nerve endings. The electrical stimulation occurs during the current build-up following circuit closure and the more rapid the rate of voltage rise the greater is the effect.

For any particular experimental arrangement there is a definite voltage below which no muscle contraction is observed. In a whole muscle, as the voltage is increased above this threshold value, the contractions increase in magnitude in a step-like manner. When a certain voltage is reached, complete muscular contraction is obtained so that increasing the voltage above this maximal level does not change the effect. It has been found by Cooper and Eccles (1930) that, if direct current is rapidly pulsated with intervals between the "on" times of about 50 milliseconds, the muscular contractions increase above those obtained with single pulses of the same voltage. This is called summation of contractions. Even at sub-threshold voltages, where no responses would be obtained with single direct current shocks, muscular contraction can be obtained with pulsating currents. This effect is termed summation of inadequate stimuli.

Applying these principles to a fish, one must recognize that direct current produces an effect on a large number of muscles in the fish's body which receive varying amounts of shock depending on their location. This has the effect of making the threshold voltage less sharp than for a single muscle. Nonetheless, threshold voltage for tail flexure due to direct current may be measured and has been described in an earlier paper (Haskell *et al.*, 1954).

Threshold Voltages

In considering rapidly pulsating direct current is was hoped that summation effects could be obtained so that, when applied to the practical use of a shocker with a maximum voltage set for safety of the operators, wider electrode separations might be used without loss of effectiveness than would be possible with steady direct current. Figure 1 gives the results of a laboratory comparison of the threshold voltages for various rates of pulsation as compared with those for a single circuit closure followed by steady current.

A Grass stimulator was used capable of producing rectangular waves of various durations from 0.02 to 50 milliseconds. These waves could be applied either singly or at various frequencies from 0.5 to 500 per second. Longer waves were produced by means of a switch. The

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tests were made in a Lucite trough having a copper screen electrode mounted at each end. The trough was 5 inches square and 1 inch deep. The electrodes were 1 x 5 inches. The threshold voltages reported were electrode-to-electrode values.

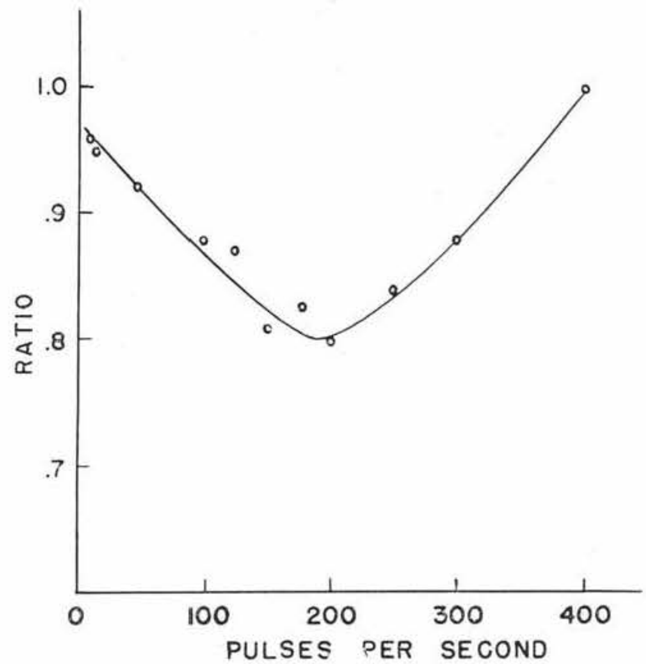

Figure 1. Variation in the ratio between the threshold voltages for pulsating and for steady direct current (in terms of the latter) at different rates of pulsation.

For purposes of the experiment the threshold voltage was defined as that which produced the first visible twitch in the fish. The data in Figure 1 represent tests made with a single fish, but they are typical of the results for a considerable number of repetitions with other specimens. Since destruction of the brain and spinal cord does not impair the effects, both were pithed in order to eliminate motions other than those caused by electric shock. Each test fish was placed in the trough with its long axis in the position which gave minimum threshold voltage. The threshold voltage for steady direct current was then determined. Next, the threshold voltage at a particular frequency of pulsation was determined. Following this, the threshold for steady current was redetermined and then the threshold for another frequency. Thus, each point in the plotted data results from two threshold determinations (first, for steady current, and second, for a particular rate of pulsation) and represents the ratio between them. The procedure of alternately measuring the threshold voltages for

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steady and for pulsating current eliminated from the data the effect of gradual tissue decay as the test continued.

From the data it appears that: (1) threshold voltages for pulsating direct current were in all cases lower than for steady current; (2) the optimum frequency was between 150 and 200 waves per second; (3) the reduction in threshold voltage by use of pulsating current of the optimum frequency was about 20 per cent (the mean of 12 such experiments).

ORIENTATION OF THE FISH IN AN ELECTRIC FIELD FOR OPTIMUM EFFECT

In an earlier study (Haskell *et al.*, 1954) threshold voltage determinations with direct current were made with the test fish at right angles to the lines of current-flow because the amount of tail flexure obtained at and above the threshold was greatest at this position and least when the fish's axis was parallel to the lines of current-flow.

The relationship between threshold voltage, amount of movement, and position in the electric field seems to depend on two factors. First, the voltage appearing on a fish is greatest when it is parallel to the lines of current-flow, i.e., when its long axis coincides with that connecting the electrodes. Therefore, the threshold voltage is a minimum for this position and a maximum for a position at right angles to the line connecting the electrodes. Second, the amount of motion produced by an impulse depends on so shocking a fish that the polarities of its two sides are opposite. Consequently, the greatest motion was produced when a fish was at right angles to the lines of current-flow.

At intermediate positions, the optimum combination of low threshold voltage and a considerable movement toward the anode was obtained. Thus, when the long axis of a fish was at an angle of 45 degrees to the line connecting the electrodes very satisfactory responses were obtained at low thresholds.

In Figure 2 data are given on the threshold voltage required to produce the first visible twitch in a fish for all positions with respect to the electrode axis. The 0-degree position represents a fish headed directly toward the anode, the 180-degree position a fish headed directly toward the cathode. The data were taken on successive trials with a single fish starting at 0 degrees. The gradual rise in the threshold throughout the test, seen by comparing the values for 0 and 360 degrees, was due to a slow decay of the tissue response as repeated shocks were given the same fish.

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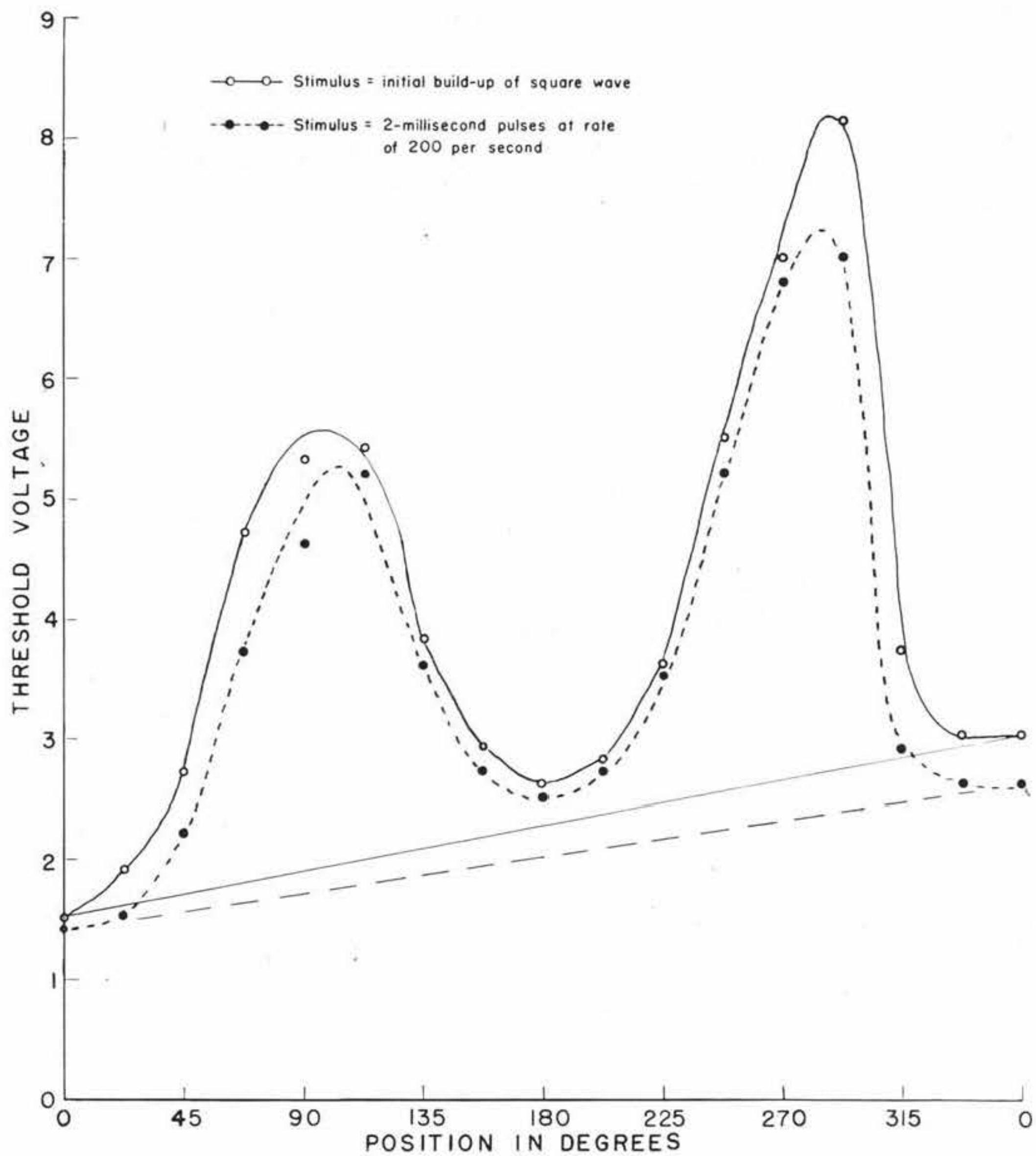

Figure 2. Variations in threshold voltage required for different positions of test fish with respect to axis of electrodes for two types of direct current stimulus. Zero degrees represents fish with head pointed toward positive pole.

DURATION OF WAVE OR PULSE

At the optimum rate of 150 to 200 pulsations per second, the question presents itself as to how short each may be made without reduction in the effect. Using 180 pulsations per second, the effect of changing the length of each was studied. At this rate the time from the start of one to the start of the next pulse is 5.6 milliseconds. Thus, a single pulse must be less than 5.6 milliseconds in length. Various

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lengths were tried (Figure 3) and it was concluded that one of 2 milliseconds' duration was optimal.

Movement Toward the Cathode

It was found during the study that the effect of direct current, either steady or pulsating, at very high voltages or field strengths was to produce motions which were sometimes toward the cathode, sometimes toward the anode. This effect was investigated but the findings are not included in this paper. Mention is made only to call attention to the existence of cathodal responses at high field strengths. It is believed such field strengths are exceptional in stream work, so that only anodal responses will be produced under ordinary circumstances.

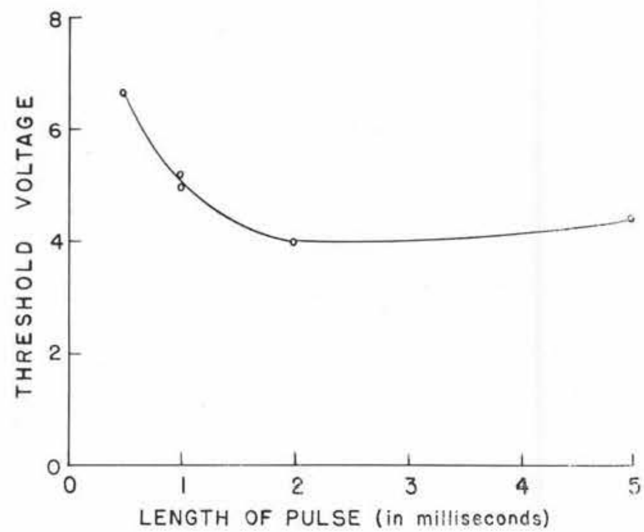

Figure 3. Relation of length of pulse to threshold voltage for direct current having a pulsation rate of 180 per second.

Anesthesia

Direct current produces a gradual anesthesia of fish, thereby stopping voluntary swimming motions and, as well, motions due to electric shock. A series of tests was performed to compare the anesthetic effect of steady current, slowly pulsating current, rapidly pulsating current, and rapidly pulsating current combined with a slow on and off sequence. The four types are illustrated in Figure 4.

Electrodes were placed 108 inches apart in a rectangular trough. Yearling brown trout averaging 6 inches in length were removed from water, held in the operator's hands, and allowed to slip from the hands into the trough about 8 inches from the cathode. Each trout was headed across the trough as it entered the water. The length of

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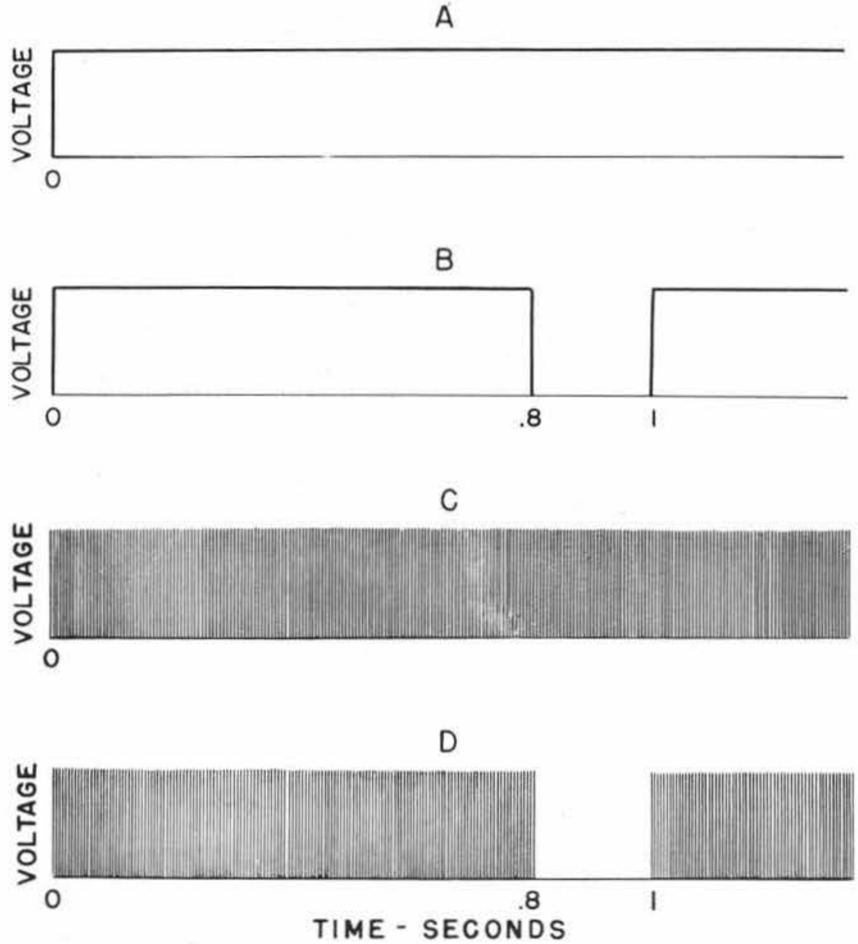

Figure 4. Types of direct current cycle studied: A, steady current (no cycle); B, slow cycle using continuous square wave at rate of 0.8 second on and 0.2 second off; C, rapid cycle using continuous pulsation of 180 per second; D, combined cycle using pulsation of 180 per second at a rate of 0.8 second on and 0.2 second off.

the fish's migration toward the anode before anesthesia developed was observed as a combined measure of: (1) the effectiveness of the shock in producing motion; (2) the rate at which anesthesia developed. Table 1 summarizes the results. The wave forms of the voltage used for the two types of rapidly pulsating current are illustrated in Figure 5 (B and C). No tests were made to compare these directly with the square wave used in the previous tests.

The migrations produced by rapidly pulsating direct current were somewhat erratic. The fish tended to dart in all directions. Migration toward the anode was produced because the motion in that direction was greater than in other directions. The ability of the current to hold the fish at the anode, in fact its ability to control motion, seemed considerably less than with slowly pulsating current.

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TABLE 1. EFFECT ON 6-INCH BROWN TROUT OF VARIOUS FORMS OF DIRECT CURRENT WITH RESPECT TO ANESTHESIA AND MIGRATION

Form of current*		Length of migration (in inches)	Remarks
Figure 4	Figure 5		
Peak voltage = 267			
A	..	86.0	Fish generally moved rapidly to anode; if stopped, never restarted
B	..	69.0	Fish generally moved rapidly to anode; if stopped, sometimes restarted
C	B	6.0	Immediate anesthesia
D	B	9.2	Immediate anesthesia
Peak voltage = 133			
A	..	75.0	Fish moved rapidly to anode; if stopped, anesthesia developed
B	..	100.0	Very little anesthesia, but strong holding power at anode
C	B	83.0	Migration erratic and slow
D	B	82.5	Motion erratic, sometimes continued after fish on side and apparently anesthetized
C	C	82.2	Migration to anode good but no holding ability, little anesthesia
D	C	100.0	Migration to anode good but no holding ability, little anesthesia; fish often returned to cathode

*Letter designations refer to types of cycle and wave depicted in Figures 4 and 5, and used either singly or in combination.

These considerations appear to nullify the effect of lower threshold voltage.

POWER REQUIRED FOR PULSATING DIRECT CURRENT

Considering the power required for the several forms of current depicted in Figures 4 and 5, if that for steady direct current is assumed to be 100, then for the same circuit with the slow cycle, i.e., 0.8 second on and 0.2 second off, the power required will be 80.

Assuming the same peak voltage for the rapid cycle (C in Figure 4), the power required will be 36 if a square wave (A in Figure 5) is used, or 12.5 if a quarter wave (B in Figure 5) is used.

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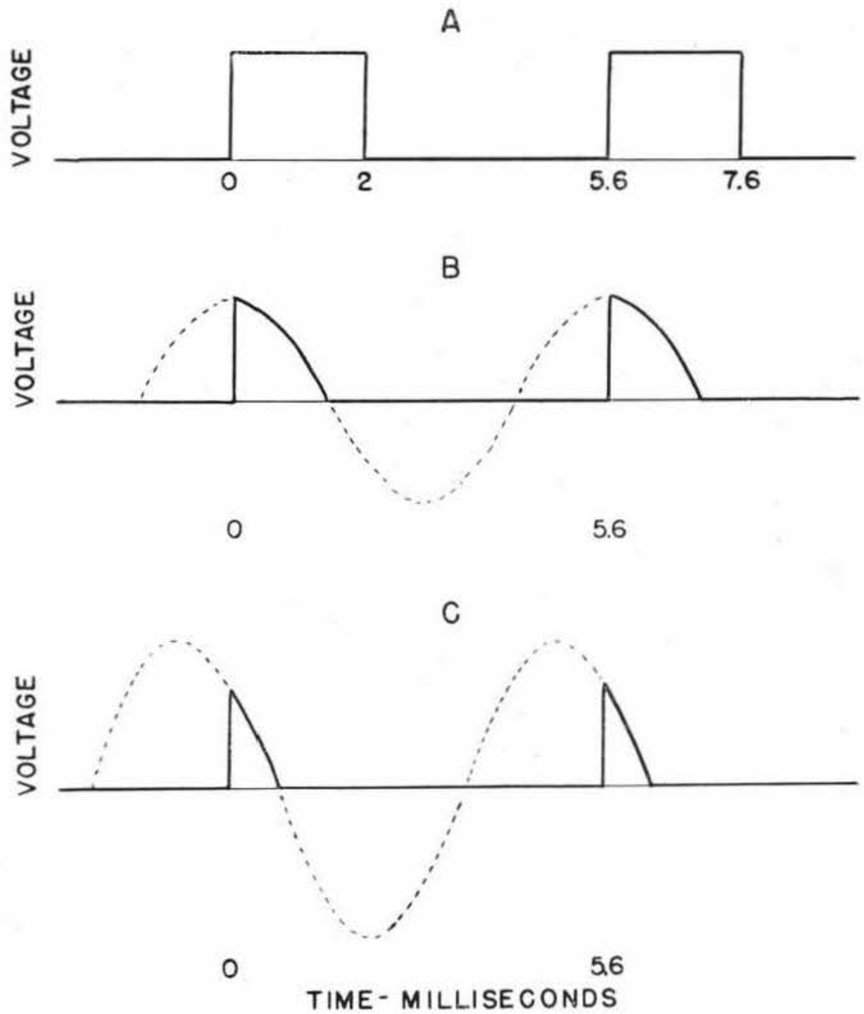

Figure 5. Types of wave or pulse studied in connection with rapid and combined cycles: A, square wave; B, quarter-cycle sine wave; C, eighth-cycle sine wave.

Using the combined cycle (D in Figure 4), the power required will be 28.8 if a square wave (A in Figure 5) is used, or 10.0 if a quarter wave (B in Figure 5) is used.

Thus, the total power required is enormously reduced by the use of pulsating current, so that, with properly proportioned and designed equipment for a specific job, a large reduction in equipment size and weight is possible.

EQUIPMENT FOR THE PRODUCTION OF PULSATING DIRECT CURRENT

The equipment used in the tests for producing pulsating direct current was, for the most part, suitable only for laboratory use. Other equipment suitable for stream use was tested. It will be described

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as indicative of the general type of apparatus which might be used, although it is probably not the most efficient that could be assembled.

For the production of steady current (A in Figure 4) a direct current generator was the sole equipment required.

For slowly pulsating current (B in Figure 4), the output of the direct current generator was fed into a contactor panel (Figure 6). The circuit used is shown in Figure 7.

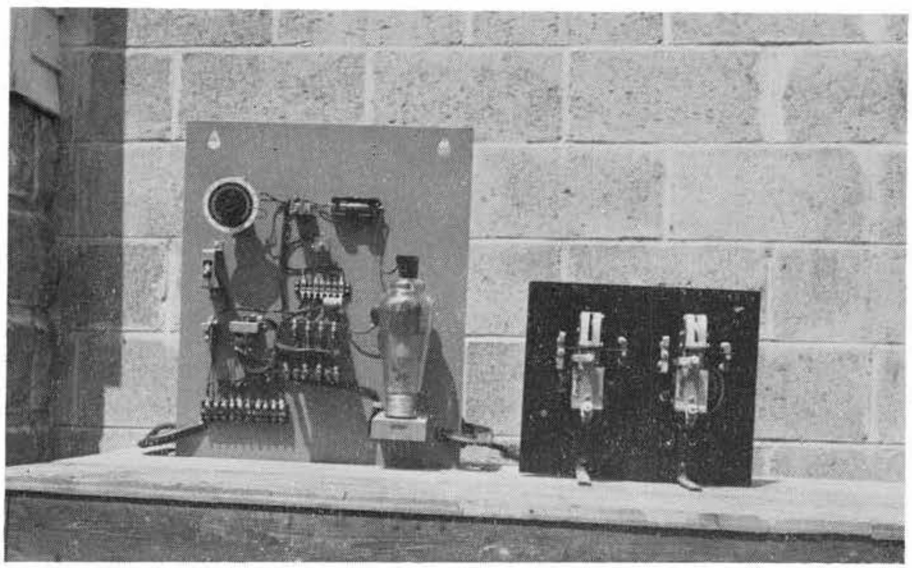

Figure 6. Equipment for producing pulsating current: (left) welding panel used to produce a rapid cycle; (right) contactor panel used to produce a slow cycle.

For the production of rapidly pulsating current (C in Figure 4), the output of a 180 cycle alternating current generator was fed into a welding control panel which could be regulated to produce either half-wave or quarter-wave power. The panel was a General Electric CR 7503 (modified) half-wave thyratron rectifier (Figure 6).

For the combined cycle (D in Figure 4), the output of the alternating current generator was fed into the welding panel, and its output into the contactor panel. It is believed that, for the combined cycle, a simpler method could be developed involving grid control of the thyratron tube for the slow pulsation, thus eliminating the contactor panel.

The 180 cycle alternating current generator used in this equipment is entirely suitable for alternating current shocking, thereby providing

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the possibility of a single generator for both alternating current and pulsating direct current use.

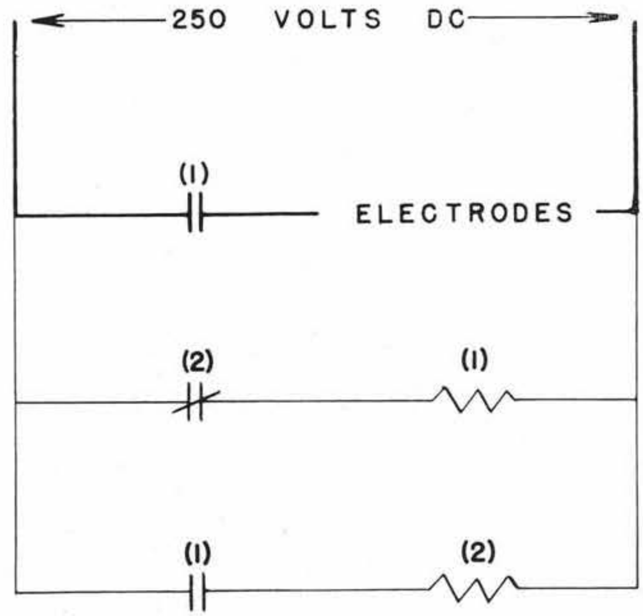

Figure 7. Schematic diagram of circuit used to produce 0.8 second on and 0.2 second off sequence by means of two General Electric contactors (CR 2820-1054) set for 0.8 second drop out (1) and 0.2 second drop out (2).

CONCLUSIONS

For direct current shocking, slow (one per second) pulsations are far more effective than steady current. Rapid (180 per second) pulsations produce movement toward the anode at about 20 per cent lower voltages than do slow pulsations. Rapid pulsations, however, produce quicker anesthesia and somewhat more unreliable migrations toward the anode. Rapidly pulsating direct current permits a reduction in the power required to about one-tenth of that required by steady current. The reduction in required power is so great that further study of this type of current seems warranted. Nevertheless, considering all factors, it is the opinion of the authors that slowly pulsating direct current is best for normal fish collections.

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A COMPARISON OF ALTERNATING AND DIRECT ELECTRIC CURRENTS IN FISHERY WORK [1]

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ABSTRACT

Alternating and direct current electric generators of equal rating (2,500 watts, 230 volts) were tested for maximum recovery of 640 marked brown trout in a 600-foot section of Cascadilla Creek, Ithaca, New York. In addition to type of electric current the experiment was designed to measure the effect of variations in fish size, water temperature, and stream type (pools and riffles). A recovery of about 80 per cent of the marked trout was realized with alternating current and one of about 40 per cent with direct current. Both temperature and fish size showed significant effects as judged by analysis of variance. Other considerations are involved in a choice of current for fish shocking, but it is evident that for quantitative work alternating current has a definite place where maximum recovery of fish is an important factor.

For the past several years opportunities have been presented at Cornell University for working with alternating and direct currents in studying stream fish populations. The work was concerned with both quantitative and qualitative aspects of this method of collecting fish. Casual observations suggested that, while direct current had undisputed merits for certain operations, alternating current was usually more suitable from the standpoint of maximum recovery of fish in relation to operating time. Data given by Pratt (1952) indicated higher recoveries with direct current, but the output of the direct current generator employed was several times that of the alternating current one.

In view of the absence of good comparative data bearing on the relative merits of the two types of current, an experiment was designed

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[1] Acknowledgment is made to the Homelite Corporation, Port Chester, New York, who kindly made the 230-volt, 2,500-watt direct current generator available for this and other tests. The brown trout were supplied by the U. S. Fish and Wildlife Service Hatchery, Cortland, New York. Douglas Robson, Biometrician, Cornell University, commented on the statistical procedure; C. W. Lyon, Fishery Technician, Cornell University, assisted with the field work; and Douglas Payne, Technician, Cornell University, took the accompanying photographs. David Haskell, New York State Fish Hatchery, Rome, New York, has read and offered suggestions on the manuscript.

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and executed to test some of the factors that were believed important in influencing the maximum recovery of fish. Discussions leading up to the design of the test as well as the field operations were part of laboratory exercises in an advanced course in fishery biology at Cornell University. While emphasis was definitely on teaching aspects, and minor inconsistencies and varying degrees of standardization and experience were inevitable, these in no way detract from the usefulness of the data forthcoming from the exercise.

DESIGN OF THE TEST

The experiments were based on the comparative recovery of fish from known populations released in enclosed areas. Other features incorporated into the design were different electric currents, water temperature, fish size, and stream type (pools and riffles). It was also attempted to hold stream flow and turbidity constant and generators of equal output were used.

A 600-foot section of Cascadilla Creek on the grounds of the Cornell Experimental Fish Hatchery was used. A long riffle and two pools of 2 to 3 feet in depth were contained in the area and stream width varied from 10 to 25 feet. During the tests the pools and riffles were segregated by barrier seines. Differences in water temperature were incorporated into the design by running identical tests on two separate days, one on April 14, 1953 (water temperature 46° F.) and another on May 19 (water temperature 61° to 63° F.). This variable was tested because previous observations indicated a marked decline in the "leading" power of direct current in warm water. Actually it would have been preferable to have had temperatures in the 70's for the second trial.

The stream flow was estimated at 26 cubic feet per second on both days, an increased flow being effected later in the season by discharging hatchery ponds into the stream above the test area. Turbidity was measured at 8.0 to 9.5 p.p.m. on April 14 and 3.7 p.p.m. on May 19. The attempt to equalize the turbidities on the two dates by roiling one of the hatchery ponds emptying into the stream was thus incompletely realized.

For test fish, brown trout *(Salmo trutta)* were graded into four size groups of 4, 5, 6, and 7 inches, respectively, although a few fish were under 4 inches or over 7 inches. For one trial with one current type, 20 fish were involved in each size group in the pools and another 20 in the riffles, yielding a total of 160 fish for any given trial or 640 trout for the entire experiment.

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The trout were distinctively marked by fin clipping (total of four marks) so that those involved in the alternating current and direct current tests on the two days would be identified. The trout for a particular trial were distributed immediately before the test took place. The test fish were used only once, with the one exception that it was necessary to fill out the required number in the 4-inch size class in the May test with a few fish carried over from the April test.

The two Homelite portable generators used, one producing alternating current (60-cycle) and one direct current, had identical ratings (2,500 watts, 230 volts). The alternating current circuit employed was the one commonly used in New York, consisting of grounding one terminal to six copper sheathed iron stakes driven into the stream bank at intervals of about 10 feet. The other terminal was connected to the lead wire and terminated in a moving electrode made of a 15-foot length of copper shielding cable buoyed by plastic floats. With this circuit the generator was moved once and two grounding areas were used, one at the head and another near the end of the 600-foot section (Figure 1).

In the direct current tests, two positively charged scap nets were fished simultaneously, using a trailing, floating negative of copper

Figure 1. Electrofishing with alternating current, one terminal grounded in the streambank and the other consisting of a floating electrode.

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sheeting approximately 14 x 24 inches (Figure 2). Each net was provided with a rocker-type switch and an irregular intermittent current was produced manually at the discretion of the net operators. There were no provisions for causing a regular current cycle such as was found by Haskell *et al.* (1954) to be most efficient in leading fish. A similar circuit, with a single dip net and a smaller power plant (1,000 watts, 110 volts) had given satisfactory results in many other situations in central New York.

Figure 2. Electrofishing with direct current, the negative terminal floating (center, beneath dip nets) and the positive terminal consisting of two charged dip net rims.

In operation, the trout were planted according to the schedule, the order of the trials being determined by lot. The electrodes were moved upstream starting at the lower barrier, the two pools being covered twice and the riffle section once. The trout recovered from pools and riffles were tallied separately. A 6-man crew was used with both types of current and approximately the same amount of actual shocking time (1 hour) was allotted to each run.

RESULTS AND DISCUSSION

The recoveries of trout in each of the several categories evaluated

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in this test are given in Table 1. From inspection alone the higher recovery of trout with alternating current is evident (251, or about 80 per cent, as compared with 121, or about 40 per cent, for direct current), and a clear superiority is indicated for it under the conditions of trial.

TABLE 1. RETURNS FROM TROUT STOCKED* PRIOR TO SHOCKING WITH ALTERNATE AND DIRECT CURRENTS IN CASCADILLA CREEK IN 1953

Temperature	Stream type	Direct current					Alternating current					Total
		Fish size (inches)				Sub-total	Fish size (inches)				Sub-total	
		4	5	6	7		4	5	6	7		
46° F.	Pools	10	13	12	12	47	13	20	18	20	71	118
	Riffles	6	11	8	10	35	12	20	16	16	64	99
	Sub-total	16	24	20	22	82	25	40	34	36	135	217
62° F.	Pools	4	6	5	3	18	9	11	20	17	57	75
	Riffles	6	5	4	6	21	12	14	16	17	59	80
	Sub-total	10	11	9	9	39	21	25	36	34	116	155
Total§		26	35	29	31	121	46	65	70	70	251	372

*20 fish of each size class stocked in each stream type for testing with each type of current.
§Total for each size class for both types of current; 4-inch = 72; 5-inch = 100; 6-inch = 99; 7-inch = 101.

Other deductions, not so well defined, are forthcoming after testing for significance by analysis of variance (Table 2). Recovery of the four sizes of trout differed significantly, although the difference is attributable only to 4-inch specimens in this experiment. (In other work in Cascadilla Creek using the same alternating current equipment and trout of similar size range, a graded recovery, commonly encountered in published works, was experienced.)

The warmer water temperature produced a lower recovery rate, most pronounced with direct current. The interaction (current x temperature), although just significant at the five per cent level, suggests that the differential recovery in 46° and 64° F. water is real. The experience has been that direct current gives a poor or completely unsatisfactory performance in waters of the Ithaca region when water temperatures are in the 70's. Conversely, alternating current has generally given as good or better results in warm water. The

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problem appears in part physiological, relating to the sensitivity of trout to shock in warmer water, and in part physical, since cold water is a poorer conductor of electric current. Furthermore, it is likely that under changing conditions of temperature (as well as volume and solutes) the proportion of electric current-flow in the water and in the stream bed will vary. Any one or several of these factors could be involved in greatly differing or erratic results experienced in the same stream at different times or even in different parts of the same stream. These elements are confounded in this experiment.

TABLE 2. ANALYSIS OF VARIANCE OF DATA IN TABLE 1

Source of variation	Degrees of freedom	Sums of squares	Mean square
Total	31	877.5	
Current	1	528.1	528.1**
Fish size	3	73.1	24.4**
Temperature	1	120.1	120.1**
Stream type	1	6.1	6.1
Interactions			
Temperature x current	1	18.1	18.1*
Fish size x current	3	34.7	11.6
Fish size x temperature	3	28.7	9.6
Stream type x current	1	0.5	0.5
Experimental error	17	67.5	3.97

*Significant at five per cent level.
**Significant at one per cent level.

An insight into the confounded portions of the problem is suggested by an experiment of Elson (1942). Here, brook trout were exposed to direct current stimulus at various temperatures and the distance they moved provided a measure of activity. The response was comparatively low in cold water but showed a rise with increased temperature until a maximum was reached at 50° F. Thereafter, the distance moved decreased as temperature continued to increase. Observations with direct current electrofishing are interpretable in terms of the positive part of such a response curve, for it means that fish on the fringe of an electric field would be less inclined to flee at lower water temperatures. Thus, they would be more likely to come in contact with sufficiently high voltages to induce a positive leading response to the electrode. However, similar field observations should also hold at high water temperatures and this does not seem to be the case.

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Although "stream type" did not produce significantly different recoveries in this experiment, it is conceivable that it would under other stream conditions or in more appropriately designed experiments. For example, the use of the barrier seines to isolate pools and riffles precluded the possibility of escape of the pool fish from a comparatively limited area. It was evident that these fish were readily driven from the deep to the shallow water at the barrier where they were immobilized with alternating current or picked up with the direct current charged dip nets.

Changes or improvements in the direct current circuit or gear used may give better results. The only alternative tried in connection with this experiment was a grounded negative using stakes driven into the stream banks as previously described. The supplementary tests consisted of attempts to recover 25 trout from an enclosed area of Cascadilla Creek presenting uniform stream conditions below a log dam. Three trips with a single dip net were made across the pool for each release of 25 trout. The results are given in Table 3.

TABLE 3. COMPARATIVE RECOVERY OF STOCKED BROWN TROUT* USING FLOATING AND GROUNDED NEGATIVES WITH DIRECT CURRENT IN CASCADILLA CREEK IN 1953

Trip	Floating negative		Grounded negative	
	Trial 1	Trial 2	Trial 1	Trial 2
1	13	16	12	19
2	7	2	6	3
3	2	2	5	1
Total	22	20	23	23
Time (minutes)	13	10	14	12

*25 fish stocked for each trial.

There was no clear-cut superiority of one circuit over the other insofar as these provisional tests went. In the headwaters of Cascadilla Creek, however, a floating ground was worthless, while a grounded negative gave excellent results. This observation has also been made on most of the smaller streams in the Ithaca region and even certain portions of the larger streams.

In the tests, maximum recovery of the known population released was considered of primary importance in evaluating the performance of the two currents. This will normally be the case in populations of low magnitude where errors of estimate based on small numbers of

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marked individuals will necessarily be high. Maximum sampling is perhaps not so important, or even desirable, in streams where the population in the area under study is numerically large. Obviously, many alternative conditions could arise in which other considerations might assume greater importance or in which the physical situations are such as to make the use of alternating current less desirable or impracticable. As examples may be cited operations involving a considerable proportion of large fish, operations involving sampling under a partial ice cover, or census work where the numbers of fish being shocked are so large as to make complete collection of fish impossible during the period of immobilization.

As now used, one of the principal disadvantages of direct current is that even with two dip nets there is considerable area in which the fish may move past the electrodes without coming into contact with sufficient voltage to be attracted to the dip net. Direct current is exceptionally well suited to the collection of fish which are congregated in comparatively small pools or along undercut banks where the tendency to drive or move out is reduced.

Fundamentally, direct current holds many attractive features for quantitative work and it is likely a matter of time before present methods of operation are greatly improved. Until that takes place, however, it appears that alternating current has a definite place in quantitative fishery studies.

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AN ALTERNATE-POLARITY ELECTRODE

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ABSTRACT

An alternate-polarity electrode with alternating current furnished by a 230-volt gasoline-driven generator has been developed for shocking fish in streams. This electrode was devised as a result of experimentation aimed at developing a more efficient and more effective movable electrode for fish collection work. The alternate-polarity electrode described consists of sections of braided shielding cable mounted on connected wooden dowels manipulated by means of a wooden handle at each end of the chain of dowels. Insulated wires which carry the current from the generator are connected to the braided shielding cable sections in such a manner that adjacent sections are of opposite polarity which produces an electric field in the water surrounding the electrode. Results obtained during the past three years with this particular type of electrode have been very satisfactory. Further experimentation with other types of electrodes based on the alternate-polarity system should produce an even more efficient apparatus.

During the course of fish population studies carried out with the aid of various types of electric shockers it has been apparent that improvement of the methods in common use would be desirable. In the quest for a more efficient apparatus for shocking fish an alternate-polarity electrode has been constructed which has proven successful under most of the conditions encountered to date in natural waters of the State. Probably the chief advantage of the alternate-polarity electrode over the grounded system has to do with the elimination of the soil as a part of the electrical circuit. The conductivity of the soil which has an important bearing on the success of a grounded system does not enter the picture in the case of the non-grounded system employed with the alternate-polarity electrode. Briefly, the latter system consists of the two lead wires, one from each side of the generator, alternately connected to a series of metal strips that form the electrode.

The electrode is made up of sections of copper shielding cable supported by ½-inch dowel stock. The dowel sections are 36 inches in length and connected end to end by web straps. A minimum of two sections is necessary but the maximum number is limited only by the output capacity of the electric generator and the length of the electrode that can be manipulated efficiently.

MATERIALS AND CONSTRUCTION

Two electrodes of different lengths have been constructed, one

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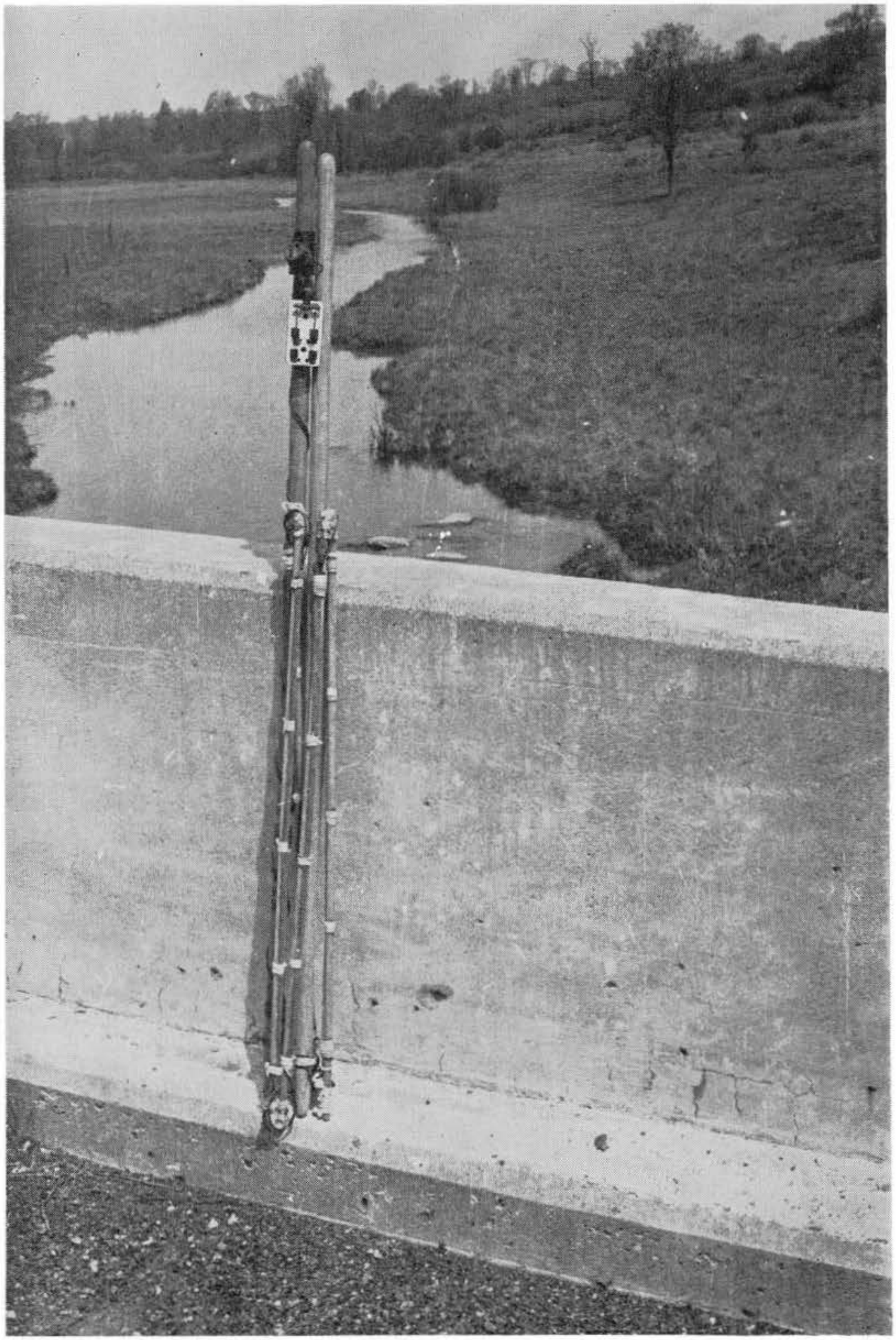

View of alternate-polarity electrode in folded position showing switch and connection for power source.

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of four sections for small streams and the other of eight sections for wider streams. A detailed description is given for the one composed of four sections.

The materials used consisted of:

2		Hardwood handles, 5′ x 1″
4		Smooth birch dowels, 36″ x ½″
1		Worm-drive, screw-type, adjustable hose clamp
1		Jumbo, female, rubber-covered cord connector
1		Double-throw knife switch, 2-wire
2	feet	Thick web strap, ⅝″ x ⅛″
10	feet	Heavy, braided, copper shielding cable, ½ inch wide
2		Large harness snaps
35	feet	Stranded, rubber-covered copper wire, #18
2	feet	Sash cord
		Rubber electrical tape
		Friction tape
		Medium-laid seine twine, #18

The procedure followed in constructing this electrode may be summarized briefly.

Attach the four dowels end to end by means of web strap riveted to them and whipped with seine twine making several ties to prevent unwinding. Two 4-inch lengths of web strap attached to opposite sides of two adjacent dowels make a satisfactory joint. Enough slack should be left between the dowel ends to permit their being folded together when not in use. Pass two pieces of the rubber covered wire, each 17 feet long, through four 30-inch sections of shielding cable. Each wire should be coded in some manner so that its identity can be determined when the necessary electrical connections are made. Lay the shielding cable sections alongside the dowels and slide each section so that it is equidistant from the ends of its respective dowel. This will place each end of the shielding cable sections about 3 inches from the dowel ends. When all are in position, the rubber-covered wires should be wrapped with friction tape at the points where they enter and leave each shielding cable section. This is to prevent wearing of the rubber insulation by the ends of the shielding cable. Attach the shielding cable sections to the dowels by whipping with seine twine at 8-inch intervals. It is important that enough slack wire be left between the shielding cable sections so that tension, when in use, will be on the web strap and not on the wires.

For purposes of explaining the procedure followed in making the

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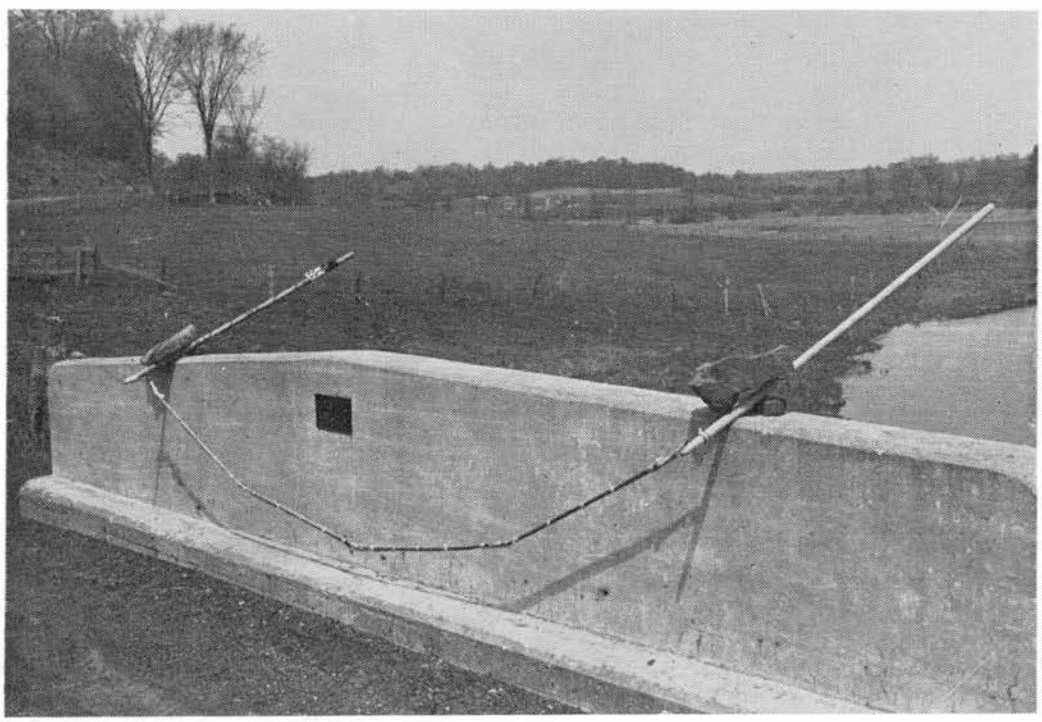
electrical connections consider the shielding cable sections as numbered 1 through 4 from one end. Also consider the two wires that pass through these sections as wire A and wire B. By means of short pieces (2-inch to 3-inch) of the rubber-covered wire make soldered connections from wire A to shielding cable sections 1 and 3, and from wire B to sections 2 and 4. Cover the soldered connections with rubber tape and friction tape and follow with seine twine whipping. The ends of the shielding cable should be securely taped (friction tape) and whipped to the dowels to prevent snagging. Insulate, with rubber tape, the free end of wire A that extends from shielding cable section 4. Securely attach, by whipping, a loop of sash cord approximately 2 inches long to each end of the chain of dowels. Approximately 6 feet of both wires A and B should extend from shielding cable section 1.



View of alternate-polarity electrode in extended position.

Securely attach a harness snap by whipping with seine twine approximately 4 inches from the lower end of each 5-foot handle. Hose clamps may be used instead of or in conjunction with the twine. Routing a groove in the handle to receive the strap end of the harness snap will prevent the snap from twisting and will make the attachment more secure. Bolt the knife switch about a foot from the upper end

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of the handle that is to receive the wires from the electrode and the generator. On this same handle mount the female cord connector a few inches above the knife switch. Friction tape can also be used in place of the hose clamp. Make an electrical connection between the cord connector and the center terminals of the knife switch. Insert the sash cord loops into the harness snaps and connect the free ends of wires A and B to the lower terminals of the knife switch. This will leave the two upper terminals free and when the switch handle is in this position the circuit will be broken. Two or three spiral turns of wires A and B should be made around the handle, between the knife switch and the lower end, to serve as a small reserve of wire if needed. These should be held in place with friction tape at two or three points, including one near the harness snap. Enough slack should be left in the wires between the handle and the electrode so that, when in use, all tension will be on the sash cord loop and not on the wires.

OPERATION

The four-section, alternate-polarity electrode has been found satisfactory in streams from 15 to 20 feet in width. It can be used in much wider streams depending on their physical character and the degree of efficiency desired. An eight-section electrode gives better coverage in larger streams but, due to its greater length, an additional center handle and an extra man are required for efficient operation. Experiments with this type of electrode also indicate that success may be expected in extremely soft water up to a resistivity of at least 85,000 ohms per centimeter cube.

Alternating current supplied by a portable, gasoline-motor-driven generator with a capacity of 230 volts has given very satisfactory results. In view of possible short circuits due to the bridging of adjacent sections of the electrode by scap nets or metallic objects encountered in the stream, a circuit breaker in the line is recommended. Safety precautions should be observed as in any similar work where electric current is introduced into water.

A distinct advantage of the non-grounded system over the grounded system has to do with the greater efficiency of the alternate-polarity electrode (Haskell, 1954). This is especially true in water 2 feet or more in depth. It has been observed that fry as small as one-half inch in length are immobilized even in deep water when they come within the effective range of such an electrode. On the other hand, there is reason to believe that use of this system may increase the

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possibility of mortality or injury to fish. Unless the death of the fish being collected is unimportant it certainly would not be advisable to permit their close proximity to the electrode. It has been found that an experienced crew of scap netters can hold mortality down to a minimum. The greatest chance of mortality has been found to exist in those streams where there is a large amount of submerged shelter in the form of undercut banks, vegetation, rocks, and logs, or where visibility is poor due to turbidity of the water. Observations seem to indicate that, in such situations, use of the grounded electrode system often tends to drive the fish out of hiding, at least temporarily, while a rapid approach with the alternate-polarity electrode may completely immobilize the fish while hidden from view.

Although this particular electrode has been in use for more than 3 years no changes or refinements have been made from the original form. However, it is felt that additional experimentation with the alternate-polarity system might develop a more workable and efficient electrode.

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HASKELL, DAVID C. 1954. Electrical fields as applied to the operation of electric fish shockers. New York Fish and Game Journ. 1(1):130-170.

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AN ELECTRIC TRAWL [1]

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ABSTRACT

Various problems encountered in attempting to develop an electric trawl for deep water are discussed. A method involving two pairs of electrodes operated by portable alternating current generators proved successful in collecting warm-water species.

As a part of a general study of the electric shock method of collecting fish, the possibilities of a method suitable for use in ponds with depths up to 20 feet were investigated. A scheme was devised which it is hoped will be the nucleus of a successful system. During the work, several unsuccessful methods were explored and these will be discussed, although it should be borne in mind that the conclusions reached are not as reliable as is customary in experimental data, due to the difficulty of accurately observing fish in deep water.

The first plans for a deep-water shocker involved slowly moving electrodes, one at the water surface and one at the bottom, connected to a direct current generator. The upper electrode was to be positive thus bringing the fish to the surface where they might be collected in a scap net. This method proved impractical, principally, it is believed, because the anodal swimming motions produced by direct current (Haskell *et al.,* 1954) require that the electrodes be in the frontal plane [2] of the fish. Thus, with electrodes vertically above one another, negligible motion will be induced in a fish in a normal horizontal position. No motion is induced unless the fish, by its own volition, assumes a position at an angle to the horizontal plane. Motion towards the surface proceeds rapidly once the fish has reached a somewhat vertical position. However, there is too little likelihood of an appreciable proportion of the fish assuming an angular position

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-1-R. The authors wish to acknowledge the assistance of the personnel of the Oneida Fish Hatchery in building and operating the trawl.

[2] The plane passing through both lateral lines of the fish.

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with respect to a horizontal plane for such an electrode arrangement to be practical.

Presuming, then, that the fish cannot be brought to the surface, a need for some underwater collecting device is indicated. In the experiments this took the form of a trawl, or bag net, drawn behind a boat.

Direct current was used first in an attempt to attract fish into the net from the front and sides. In order to produce an effective field, with an electrode separation of 10 or more feet, it was found that the electrodes would have to be very large, perhaps 8 or 10 feet square at a separation of 10 feet, to produce a uniformly effective field using 230 volts.

Extended experiments indicated that fish preferred to avoid any object of this size which approached them so that, as the electrodes moved along, the fish swam out of their path. Experiments during several weeks resulted in almost negligible collections in water where fish were abundant. During these experiments both alternating current and direct current were tried with similar results.

It was decided that a practical approach would be to use alternating current with inconspicuous electrodes placed ahead of the trawl so that the fish would not be scared by the trawl but could be collected by it after immobilization.

Two brass pipes, one half inch in outside diameter and 8 to 10 feet long, were found effective to stun 4-inch and larger fish when the pipes were parallel and not more than 6 feet apart. The effective field extends beyond the space between the pipes so that two such electrodes 6 feet apart will provide an effective field approximately 10 feet in width. The length of the pipes is important. If they are short the field spreads out around them in three dimensions, while as they are made longer the spreading from their ends becomes relatively unimportant and the major part of the field between them may be thought of as spreading in only two dimensions. The field, therefore, becomes slightly more nearly linear between the electrodes and results in a considerably greater field strength for shocking.

Using these principles, the electrode and trawl arrangement shown in Figure 1 was constructed and tests were made in Oneida Lake. The power supply was a 230-volt, 180-cycle alternating current generator. The trawl was drawn 5 minutes for each "run" and, at an estimated speed of about 1½ miles per hour, each run covered about 650 feet.

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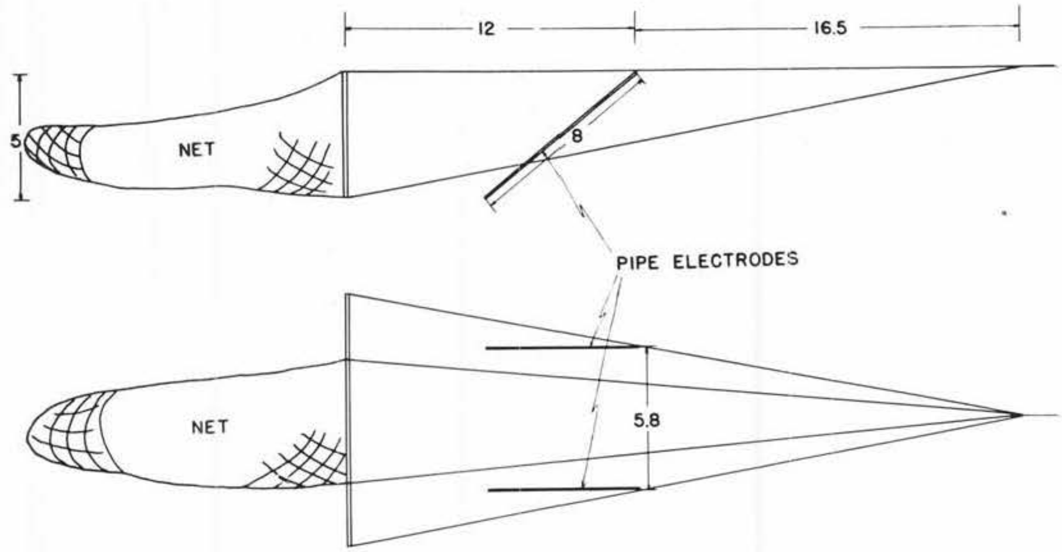

Figure 1. Design of trawl: side view (above); top view (below). Dimensions in feet.

In the first tests, it appeared that the catch included few game fish. It was suspected that the fish, after being stunned and collected in the trawl, recovered, and that the more active species were then able to swim out of the net. To avoid this, the frame forming the mouth of the net was rebuilt so that the top and bottom members were wood while the sides were metal (Figure 2). The metal sides were then connected to a generator and formed a second set of electrodes which prevented fish in the net from swimming out. Because any generator available for the experiment was of too limited capacity to operate this double set of electrodes, two generators were used. Undoubtedly one larger generator might have been used for both.

In operating the device, the generators, wire, rope, and net were loaded in a boat and taken to the location to be trawled. A second boat was brought alongside and the net and electrodes transferred to it. The first boat, propelled by an outboard motor, started away and the rope and wire were played out. Finally, the men in the second boat put the electrodes and net in the water, holding the net until it was entirely stretched out. In various runs the length of the pull rope was adjusted so that the bottom of the net dragged on the bottom of the lake. This required approximaely 65 feet at an 8-foot depth and 200 feet at a 20-foot depth. The collection of fresh-water mussels was used as an indicator that the net had fished bottom. At the end of the run the first boat stopped and the crew immediately started pulling in the net. When the leading electrodes approached the boat, the switch controlling the electric power to them was opened. As the

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pulling continued the mouth of the net came to the surface with the opening up. As it reached the surface the switch controlling the electrodes on the sides of the net was opened and the net frame was grasped by operators in both boats, the second boat having pulled alongside while the net was being hauled.

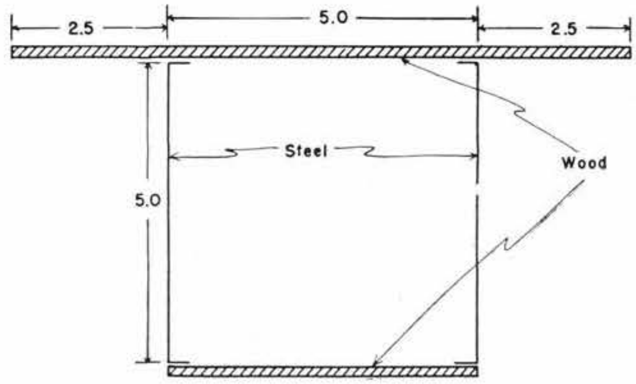

Figure 2. Design of net mouth showing location of metal sides used as electrodes. Dimensions in feet.

The resulting catches are summarized in Tables 1 and 2. Since knowledge of the location of fish populations in the area where the tests were made was meager, it is difficult to evaluate the catches.

TABLE 1. FISH CAUGHT DURING 5-MINUTE RUNS WITH ELECTRIC TRAWL IN ONEIDA LAKE ON SEPTEMBER 2, 1953

Electrodes used	Type of bottom	Depth (feet)	Fish caught*					
			Bull-head	Pike-perch	Yellow perch	Sun-fish	Great northern pike	Carp
None	Sandy, "grass"	8	3	1	0	0	0	1
Pipe only	Sandy, "grass"	8	15	1	0	0	0	1
Pipe and net frame	Sandy, "grass"	8	13	5	2	1	1	1

*Figures represent number of specimens.

Another series of tests made in mid-October resulted in much smaller catches. This may possibly have been due to fish movements resulting from wide seasonal temperature changes which occurred during the interim.

For comparison, the catch of one gill net set in 7 and 8 feet of water in the same area as the electric trawl was used is given in Table 3.[3]

[3] This information was supplied by James Galligan, Aquatic Biologist, New York State Conservation Department.

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Table 2. Fish Caught During 5-Minute Runs with Electric Trawl in Oneida Lake on September 8, 1953

Electrodes used	Type of bottom	Depth (feet)	Fish caught*							
			Bull-head	Pike-perch	Yellow perch	Rock bass	Small-mouth bass	Carp	Sucker	Ling
None	Sandy, "grass"	7	..	..	..	..	..	..	..	..
Pipe only	Sandy, "grass"	7	16.5	15.0	10.0	..	..	..	3.0	..
			16.0	..	9.0	..	..	..	..	..
			13.0	..	..	..	..	..	..	..
			12.5	..	..	..	..	..	..	..
			12.5	..	..	..	..	..	..	..
			11.5	..	..	..	..	..	..	..
			10.5	..	..	..	..	..	..	..
			8.5	..	..	..	..	..	..	..
Pipe and net frame	Sandy, "grass"	7	13.0	16.0	..	4.0	..	35.0	8.5	..
			13.0	14.0	..	4.0	..	29.0	..	..
			13.0	8.0	..	4.0	..	6.0	..	..
			13.0	6.5	..	..	..	..	..	..
	Sandy, "grass"	7	13.0	14.5	10.5	9.0	..	31.0	..	13.5
			12.5	14.0	8.5	9.0	..	26.0	..	..
			12.5	11.0	8.0	..	..	25.0	..	..
			12.0	..	..	..	..	..	..	..
			12.0	..	..	..	..	..	..	..
	Sandy, mud	15	..	..	..	..	..	..	..	..
	Sandy, mud	15	..	8.0	..	..	..	..	..	..
			..	8.0	..	..	..	..	..	..
	Sandy, mud	15	..	..	..	..	7.5	..	..	..
	Sandy, mud	20	..	14.0	10.0	..	..	..	..	..
			..	7.5	3.0	..	..	..	..	..

*Figures represent total length of each specimen in inches.

Table 3. Fish Caught with Gill Net in Oneida Lake During Night of September 22-23, 1953*

Species	Size of mesh§		
	1½	3	3½
Pike-perch	..	2	2
Yellow perch	2	11	3
Rock bass	1	..	..
Silver bass	2	..	..
Catfish	..	..	1
Carp	..	..	1

*Net set from 5:30 p.m. to 10:15 a.m., location corresponding to 7-foot depth of Table 2.

§Net was 300 feet long and consisted of 100 feet each of 1½-, 3-, and 3½-inch mesh.

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The entire trawl and electrode system used is subject to extensive improvements. For example, the bag net should probably be wider to encompass at least the same width as the effective electric field. The wires to the electrodes were run down the pull ropes. Undoubtedly wire can be secured which will serve the double function of pulling the trawl and carrying the current, thus reducing the complexity of the system and contributing to its inconspicuousness. Fortunately, although the author's study of electric shockers has been completed, another project in which it is hoped the electric trawl can be used has taken on its further development.

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