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The effect of fin removal on fingerling lake trout (Cristivomer namaycush)[1]

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[1] Contribution from the Michigan Institute for Fisheries Research

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Abstract

Four different lots of fish marked by fin removal were held at the State fish hatchery, Marquette, Michigan to ascertain the amount of fin regeneration, comparative survival and comparative growth which would follow this treatment over varying periods of time.

It was determined that the following percentages of the marked fish surviving should be recognizable (regeneration 0-50 percent of the fin area) in the future:

1944 mark--dorsal and adipose fins clipped--90.4 percent

1945 mark--right pectoral fin clipped --96.5 percent

1946 mark--left pectoral fin clipped --89.8 percent

1947 mark--right pelvic fin clipped --64.1 percent

Observations of fin regeneration suggested further that the calculated numbers of marked fish surviving in the mortality--growth experiments conducted at the same time should be adjusted upward, as it was demonstrated that from 0.2 to 20.8 percent of the survivors of the regeneration experiments had fully regenerated fins when examined at various times during the course of the experiments.

The difference in mortality which occurred among marked and normal lake trout fingerlings in experiments performed under identical conditions and initiated with equal numbers of fish was concluded to be of insignificant proportions for the 1944, 1945, and 1947 markings. However, on the basis of chi-square tests for the departure of normal:marked fish from the originally established ratio, removal of the left pectoral fin appears to have resulted in a 16.1 percent increase in instantaneous mortality among fish of the 1946 experimental group.

Comparison of the growth of normal and marked lake trout fingerlings held in the same ponds indicates that removal of the dorsal and adipose fins (1944), right pectoral fin (1945), or right pelvic fin (1947) had no effect on the growth of marked fish; the differences had no statistical significance. However, the left pectoral mark used in 1946 appears to have slowed growth of the fish so marked by a small (8.6 mm.), but statistically significant amount.

Introduction

When the Great Lakes Lake Trout Committee set up a research program in April, 1944, one phase of the investigation called for marking at least ten

percent of all hatchery-reared lake trout fingerlings released in Lake Michigan during 1944, 1945, and 1946. Since approximately one million fingerling lake trout were planted annually in Lake Michigan, this decision entailed the marking of 100,000 or more fish each year. The only feasible method of marking such large numbers of fish was by the removal of fins in various combinations.

To measure the effect of fin removal on the experimental fish released in Lake Michigan, several groups of fin-clipped fish from the 1944, 1945, 1946, and 1947 [2] markings were held along with companion groups of

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[2] The 1944, 1945 and 1946 plantings were made in Lake Michigan; the 1947 planting, in Lake Huron.

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unmarked fish of the same stocks for controls. Observations of fin regeneration and of growth and survival were recorded for these fish over periods ranging from 2 to 4 1/2 years.

All marking was done in September of each year at the U. S. Fish and Wildlife Service Fisheries Station at Charlevoix, Michigan, and fish for the controlled experiments were assembled there at the same time. The experimental fish were then shipped by tank truck to the State fish hatchery at Marquette, Michigan and held there in ponds.

Design of Experiment

Each year as the fish for release in Lake Michigan (or Huron) were marked, they were held in several hatchery troughs. Each experimental lot of fish was then selected by scapping up equal numbers of fish from each

trough to make up the desired total; furthermore, the head, middle and lower portions of each trough were sampled equally to compensate for possible differences in size of fish at different levels in the troughs.

For the mortality-growth experiments in 1944, 2,007 marked and 2,000 unmarked fish were used; but by March, 1945, it was obvious that these numbers were too large for the pond facilities at Marquette and both lots were reduced to 1,005. For the 1945, 1946, and 1947 fish, each experimental lot was 1,000 fish.

For the experiments on regeneration of fins in 1944, 1,003 marked fish were used, and this lot was reduced to 500 in March, 1945 (the original number was too great for the available pond space considering the experiments to be held in the future); for 1945, 1946 and 1947 the lots were each 500 fish.

On fish in the several experimental lots, length measurements (mm.) were taken as follows: from the 1944 experiment, at the time the experiment was initiated, 20 percent of the regeneration group and 25 percent of the mortality-growth group were measured; for subsequent checks on the 1944 fish, and for all other lots, all fish were measured.

After marking in September, each lot of fish was transferred to the Marquette (Michigan) Hatchery. Here they were held over winter in covered troughs in a heated building and moved to outside ponds in late March or April. The mortality-growth experiment and the regeneration experiment were conducted in separate ponds. During the spring of 1945, considerable predation by birds was noted on the experimental ponds, and all experimental ponds were covered by chicken wire thereafter.

Examinations of the experimental fish were conducted semi-annually each year in March and October through 1949; counts and measurements on certain groups were obtained also in May of 1948 and 1949. At each examination, all experimental fish were sorted, counted, measured individually and weighed in groups. Daily mortality records for the various experimental groups were kept by the staff of the Marquette Hatchery. At the marking and at all subsequent examinations when the experimental fish were measured, they were anesthetized with ether, using 1/4 ounce of ether per quart of water, strengthened as necessary from time to time.

Observations on Fin Regeneration

Observations on the extent of regeneration of marked fins were conducted over the following periods:

Fins removed	Duration of experiment
Dorsal and adipose	September, 1944 - March, 1946
Right pectoral	September, 1945 - March, 1947
Left pectoral	September, 1946 - March, 1948
Right pelvic	September, 1947 - October, 1949.

For the purpose of determining the efficiency of the mark, a number of marked fish were held separately each year and examined at intervals to determine the extent of regeneration. These fish were examined individually at the time of measurement and graded visually as having no regeneration, 1/4 regeneration, 1/2 regeneration, 3/4 regeneration, or full regeneration (the latter were either fins completely missed or only partly removed in the clipping operation). Grading was done with frequent reference to normal fins of unmarked lake trout, and the estimated grade applied regardless of what portion of the fin was regenerated. Almost all of the regeneration grading

was done by the author. The regeneration controls were held for at least 18 months, by which time the process of regeneration appears to have reached a level of negligible increase. When the percentage of recognizable specimens remained more or less constant in two consecutive examinations that group of regeneration control fish was planted out in order to utilize pond space for new experiments. The general growth history of fish in the various regeneration experiments is given in Table 1.

In the 1944 experiment, in which the dorsal and adipose fins were clipped, 13 months elapsed between marking (September, 1944) and the first examination to classify extent of regeneration (October, 1945), when 254 of the 255 survivors were checked (Table 2). Although this experiment was started with 1,003 marked fish, the number was reduced to 500 specimens selected at random in March, 1945, when overcrowding in the pond became apparent.

As the 1944 mark involved two fins, there were 25 possible combinations of regeneration observable. Table 2 lists the results of the examinations on the dorsal-adipose mark, and it will be seen that 17 combinations were observed. In the table, the 9 most easily recognized combinations are starred; the 231 fish so designated constituted 90.9 percent of the total number examined in October, 1945.

The same group was examined and graded again in March, 1946, when 251 fish were present. Of this number 227, or 90.4 percent of the total survivors, had 1/2 or less regeneration. Since there had been little change in the amount of regeneration observed on these two examinations, this control experiment was discontinued. It is felt that marked fish with no greater regeneration than is represented in these groups will be identifiable in the futureby anglers, commercial fishermen, and fishery investigators.

Table 1.--Summary of growth in length and weight of fingerling lake trout in regeneration experiments. Average lengths are given in millimeters, average weights in grams. Numbers in parentheses indicate numbers of survivors at each examination.

	1944		1945		1946		1947	
Date of examination	Average length	Average weight	Average length	Average weight	Average length	Average weight	Average length	Average weight
September, 1944	73.5	3.2(1,003)						
March, 1945[*]	93.7	4.8(500)						
September, 1945	...	...	82.5	4.7(499)				
October, 1945	167.4	39.6(255)	...	...				
March, 1946	188.5	53.1(251)	107.5	9.1(492)				
September, 1946			...	...	82.2	4.1(500)		
October, 1946			175.2	39.0(328)	...	...		
March, 1947			191.7	50.3(294)	107.6	8.6(488)		
September, 1947					...	...	74.3	2.9(500)
October, 1947					165.7	29.5(259)	...	...
March, 1948					192.3	57.7(175)	98.4	6.8(483)
October, 1948							182.4	51.7(405)
March, 1949							200.5	58.1(390)
October, 1949							246.9	121.1(234)

[*] Concerning the number of fish in this lot, see text.

Four hundred ninety-nine (499) right pectoral-clipped lake trout fingerlings from the fall marking were set aside for observation in September, 1945. This group and all subsequent regeneration groups were examined at an earlier date in their growth history than were the 1944 fish. The data on regeneration among the marked fish for the 1945 experiment are given in Table 3, which shows the percentage of the surviving fish in each of the five arbitrary classes of regeneration. The percentages of surviving fish with the observed amounts of fin regeneration for the 1946 and 1947 marks will be found listed in Tables 4 and 5.

Statistical Significance of Regeneration Experiments

On the basis of the observations on regeneration among the various fin marks listed above it is obvious that some adjustments should be made in future calculations involving the numbers of recognizable marked fish available from any marking. Table 6 summarizes the end results noted for the four different marks after it appeared that the amount of regeneration had ceased to increase. In the last column of the table will be found the upper and lower limits of the observed percentages of survivers having 1/2 or less regeneration, following the method of Snedecor, (1948, Table 1.1, p. 4), who lists the possible limits for observed percentages from samples of various sizes. The theory behind Snedecor's table is that the limits given will take in 95 percent of all sample ratios observed; or, stated in another way, that there is only 1 chance in 20 that another observed sample would lie outside the limits entered in the last column of Table 4.

The data in Table 6 indicate that between 86 and 93 percent of the 1944 dorsal-adipose-marked survivors are recognizable and between 94 and 98 percent of the 1945 right pectoral-marked lake trout fingerlings surviving have 1/2 or less regeneration. The survivors bearing the 1946 mark

Table 2.--Summary of observations on fin regeneration among dorsal-adipose clipped lake trout fingerlings held at Marquette Hatchery. Initiated September, 1944 with 1,003 marked fish with average length of 73.5 millimeters, average weight of 3.2 grams. (See also Table 6)

Regeneration of fin		October 5, 1945		March 13, 1946	
Dorsal	Adipose	Number of fish with combination	Percentage of total present with combination	Number of fish with combination	Percentage of total present with combination
None	None*	121	47.6	129	51.4
	1/4*	21	8.2	16	6.4
	1/2*	2	0.8	1	0.4
	3/4	3	1.2	...	0.0
	Full	2	0.8	3	1.2
1/4	None*	38	14.9	40	15.8
	1/4*	24	9.4	18	7.2
	1/2*	4	1.7	1	0.4
	3/4	2	0.8	...	0.0
	Full	...	0.0	1	0.4
1/2	None*	5	1.9	12	4.8
	1/4*	10	3.9	7	2.8
	1/2*	6	2.4	3	1.2
	3/4	...	0.0	2	0.8
	Full	...	0.0	...	0.0
3/4	None	3	1.2	3	1.2
	1/4	3	1.2	3	1.2
	1/2	1	0.4	...	0.0
	3/4	...	0.0	...	0.0
	Full	...	0.0	...	0.0
Full	None	4	1.7	4	1.6
	1/4	...	0.0	1	0.4
	1/2	...	0.0	...	0.0
	3/4	...	0.0	...	0.0
	Full	5	1.9	7	2.8
Totals	...	254 #	100.0	251	100.0

One fish escaped, not graded or measured.

NOTE: The 9 most easily recognized combinations are starred.

Table 3.--Summary of observations on right pectoral clip regeneration experiment. Initiated September, 1945, with 499 marked fish, average length 82.5 millimeters, average weight 4.7 grams.

Date of examination	Number surviving	Average total length (millimeters)	Range in total lengths	Number (and percent of total surviving) with indicated amount of regeneration				
				0	1/4	1/2	3/4	full
March 1946	492	107.5	84-130	474 (96.4)	12 (2.4)	3 (0.6)	2 (0.4)	1 (0.2)
October 1946	328	175.2	105-218	257 (78.4)	47 (14.3)	11 (3.4)	6 (1.8)	7 (2.1)
March 1947	294	191.7	145-234	233 (79.2)	40 (13.6)	11 (3.7)	7 (2.3)	3 (1.2)

Table 4.--Summary of observations on the 1946 (left pectoral clip) regeneration experiment. Initiated September, 1946 with 500 marked fish, average length 82.2 millimeters, average weight 4.1 grams.

Date of examination	Number surviving	Average total length (millimeters)	Range in total lengths	Number (and percent of total surviving) with indicated amount of regeneration				
				0	1/4	1/2	3/4	full
March 1947	488	107.6	87-134	339 (69.4)	118 (24.1)	19 (3.8)	8 (1.6)	4 (1.1)
October 1947	259	165.7	122-210	106 (40.9)	87 (33.8)	40 (15.4)	15 (5.7)	11 (4.2)
March 1948	175	192.3	148-284	76 (43.5)	53 (30.3)	28 (16.0)	9 (5.1)	9 (5.1)

Table 5.--Summary of observations on 1947 (right pelvic clip) regeneration experiment. Initiated September, 1947, with 500 marked fish, average length 74.3 millimeters, average weight 2.9 grams.

Date of examination	Number surviving	Average total length (millimeters)	Range in total lengths	Number (and percent of total surviving) with indicated amount of regeneration				
				0	1/4	1/2	3/4	full
March 1948	483	98.4	83-117	52 (10.8)	211 (43.7)	149 (30.9)	64 (13.2)	7 (1.4)
October 1948	405	182.4	138-232	35 (8.6)	117 (28.9)	111 (27.4)	77 (19.0)	65 (16.1)
March 1949	390	200.5	135-254	42 (10.8)	94 (24.1)	98 (25.1)	75 (19.2)	81 (20.8)
October 1949	234	246.9	175-305	11 (4.7)	78 (33.3)	61 (26.1)	45 (19.2)	39 (16.7)

Table 6.--Summary of pertinent statistics on percentage of regeneration of 1944, 1945, 1946, and 1947 fin marks used on lake trout fingerlings.

Year of marking	Fins removed	Number of survivors at last check	Percentage of survivors showing 1/2 regeneration or less	95 percent confidence range for percentage of survivors showing 1/2 regeneration or less (from Snedecor) [*]
1944	Dorsal and adipose	251	90.4	86-93
1945	Right pectoral	294	96.5	94-98
1946	Left pectoral	175	89.8	84-94
1947	Right pelvic	234	64.1	58-70

[*] There is one chance in twenty that another sample would lie outside the indicated percentages.

(left pectoral fin clipped) may be said to contain between 84 and 94 percent with 1/2 or less regeneration. It would appear then that the fin-clip combinations used on the Lake Michigan plantings were applied with reasonable efficiency, as approximately 90 percent or more of the survivors were noted to be carrying marks that could be recognized with ease.

Such was not the situation for the right pelvic mark applied to the 1947 plantings of lake trout fingerlings in Lake Huron. In this experiment only 64.1 percent of the survivors were adjudged to be in those classes with 1/2 or less regeneration (95 percent confidence limits, 58-70 percent, from Snedecor (1948), in the manner previously described). There appear to be two reasons for the comparative inefficiency in the application of this mark which are as follows: (a) the time schedule for the 1947 marking and planting operation was such that too few technicians had to mark too many fish in too short a time; (b) the size, shape and visibility of the pelvic fins on lake trout fingerlings of the lengths handled made it difficult to determine whether or not a clean operation was performed.

Slater (1949), studying fin regeneration in king salmon fingerlings, was able to demonstrate slight statistical correlation between quality of pelvic marks and length of fish. He felt that the correlation noted was not due to the greater regenerative capacity of small fish, but was a result of difficulty in seeing and removing small, transparent fins in a clean manner.

Armstrong (1949), working with marked lake trout fingerlings, has reported that for the dorsal-adipose marking approximately 95 percent of 487 survivors of 500 marked fish at the end of 10 months of observation had 1/2 or less regeneration, which is in general agreement with the results noted here.

The observed results noted for the regeneration experiments have an important bearing on the interpretation of the data obtained from the experiments concerned with comparative mortality. For example, it was found, that various percentages of marked fish in the regeneration experiments were missed entirely in the clipping operation, or their fins regenerated completely. Since a sincere effort was made to draw both experimental groups at random from the stock of marked fish, it seems reasonable to assume that the percentage of completely regenerated fins should be the same among the marked fish of the mortality-growth control experiments as was found in the regeneration control group for the same year and mark.

To illustrate with an example from the data, consider the regeneration group and the mortality-growth experiment fish from 1944 at the March, 1946 examination. There were 251 regeneration control fish alive, of which 7 or 2.8 percent bore fully regenerated dorsal and adipose fins (or these fins were missed in the clipping operation). This observation suggests that of the 660 mortality-growth experiment fish surviving, the 296 fish classed as marked represent only 97.2 percent of the marked fish alive and present, and that actually there were 305 marked fish among the 660 counted($\frac{296}{0.972}$). Thus the corrected figures for this particular examination would be 355 unmarked fish, 305 marked fish.

For the dates of examinations where the percentages of total regeneration could be applied to the companion mortality-growth experiments, the mortality data have been corrected by the observed percentages of regeneration for those dates. However, the regeneration experiments were not held as long as the mortality experiments, and after the regeneration experiments were discarded, the last percentage of regeneration observed was applied to any further observations on survival, inasmuch as it was the best measure available.

In the section following which discusses comparative survival, the observed data will be corrected in the manner just described.

Comparative Survival of Normal and Fin-clipped Lake Trout Fingerlings

For each mark used an equal number of marked and normal fish of approximately the same average size were set aside to be confined together to determine any differences in survival between marked fish and normal fish. This group also permitted a comparison to be made of the average growth of marked and normal fish. The two components differed only in that one-half were marked, one-half were unmarked. The experimental groups for the various years were kept together for the duration of the experiments, and all factors causing mortalities should, in theory at least, have operated equally on marked and normal fish.

If marking had no effect on the survival of marked fish, then marked fish in the various experiments should survive in numbers approximately equal to their normal counterparts; or in other words, if marking is not a factor in mortality, the survivors of both groups should occur in the same ratio of normal fish:marked fish that was established at the initiation of the experiments.

The problem consists of determining whether the data on the comparative survival depart significantly from the ratio originally established. Wherever they do, marking can be said to be a cause of additional mortality. However, since it has been demonstrated in the previous section that various percentages of the surviving marked fish completely regenerate their marks and are not recognizable as marked fish, the comparative survival data logically should be adjusted to take this fact into account. The changes that occur

when correction for complete regeneration is made are shown in Table 7, which lists both observed and corrected data for the experiments on the four different marks. The corrected data may then be tested for significance by applying the chi-square test as outlined by Snedecor (1948, p. 26).

$$\text{Chi-square} = X^2 = \frac{(a - r\,b)^2}{r\,(a + b)}$$

Where: a = observed number of normal fish

b = observed number of marked fish

r = expected ratio of normal fish to marked fish

The chi-squares so obtained, unadjusted for bias due to small numbers, are not deemed to be significant unless they exceed 3.841, according to Snedecor (1948, p. 22). The detection of significant values suggests that marking has led to increased mortality among the marked fish, assuming that unmarked fish did not experience the greater rate of mortality.

It appeared desirable to learn what changes might occur between examinations, rather than to follow only the cumulative effect of marking through the entire course of the experiments. In following this procedure, the expected ration of normal fish:marked fish for any date of examination was that observed on the previous examination. Actually each examination constituted a new experiment with the survival ratio of the previous examination as the basis for determining the expected ration of normal fish:marked fish.

An example from Table 7 is the March, 1948 check on the dorsal-adipose-marked fish of 1944. Through the use of the formula given for chi-square we find:

$$X^2 = \frac{\left[309 - \frac{317}{281} \times 270\right]^2}{\frac{317}{281}\,(309 + 270)} = \frac{(4.4130)^2}{653.1699} = 0.03$$

Table 7.--Numbers of normal (N) and marked (M) lake trout fingerlings surviving at various dates from the mortality-growth control experiments of 1944, 1945, 1946 and 1947, and the calculated distribution of survivors when corrected by known amounts of total fin regeneration.

Item	1944: dorsal-adipose mark				1945: right pectoral mark				1946: left pectoral mark				1947: right pelvic mark			
	Observed		Calculated ✱✱		Observed		Calculated		Observed		Calculated		Observed		Calculated	
	N	M ✱	N	M	N	M	N	M	N	M	N	M	N	M	N	M
Number in September in year	2,000-2,007		2,000-2,007		1,000-1,000		1,000-1,000		1,000-1,000		1,000-1,000		1,000-1,000		1,000-1,000	
Alive, March, 1945 ✱	1,398-1,447		1,398-1,447 (0.68)													
October, 1945	407-336 (1.9)		400-343 (4.37)													
March, 1946	364-296 (2.8)		355-305 (0.004)		949-978 (0.2)		941-986 (1.05)									
October, 1946	325-273 (2.8)		317-281 (0.15)		900-860 (2.1)		882-878 (1.15)									
March, 1947	317-262 (2.8)		309-270 (0.03)		885-837 (1.2)		870-852 (0.11)		935-945 (1.1)		924-956 (0.54)					
October, 1947	278-228 (2.8)		271-235 (0.01)		615-599 (1.2)		608-606 (0.09)		475-396 (4.2)		458-413 (4.11)					
March, 1948	254-218 (2.8)		248-224 (0.20)		492-472 (1.2)		486-478 (0.04)		349-289 (5.1)		333-305 (0.04)		953-965 (1.4)		939-979 (0.83)	
May, 1948	...		...		429-378 (1.2)		424-383 (1.46)		...		...		...		...	
October, 1948	239-200 (2.8)		233-206 (0.05)						267-196 (5.1)		257-206 (2.04)		877-794 (16.1)		725-946 (19.57)	
March, 1949	235-198 (2.8)		229-204 (0.01)						240-171 (5.1)		231-180 (0.08)		837-810 (20.8)		... ✱✱	
May, 1949	228-189 (2.8)		223-194 (0.06)						...		...		...		...	
October, 1949	...		...						212-150 (5.1)		204-158 (0.004)		621-564 (16.7)		508-677 (0.13)	

✱ Fin regeneration not checked in March, 1945. Observed numbers reduced to 1,005 in each category.

✱✱ Under "Observed, M" in parentheses is given known precentage of total fin regeneration. See last columns, Tables 2,3,4, and 5

✱✱ In parentheses under "Calculated" are given chi-square values for corrected distribution.

✱✱ Here an obvious and unexplanable discrepancy occurs. There is a suggestion either that not all experimental fish were collected in October, 1948, or that there were some unexplainable additions after that date.

The expected ratio of normal fish:marked fish for the October, 1947 examination of this same group of fish would be 309/270, and so on. The resulting chi-square values indicate whether or not the observed ratio of normal fish:marked fish have departed significantly from the expected ratio of normal fish:marked fish. In this instance chi-square was not significant.

The cumulative effect of the marking operation may be determined by utilizing the ratio of normal fish:marked fish originally established and applying it to the observed data of the last examination to determine chi-square values.

Dorsal-adipose mark, 1944

The chi-square values obtained from the various sets of data have been used as criteria in evaluating the effect of the mark on the survival of marked fish. In the 1944 experiment, between September, 1944, and March, 1945, marking had no effect on survival (chi-square = 0.68), as more marked fish than normal specimens were alive. However, from March, 1945, to October, 1945, marking apparently was a significant factor in the survival of marked fish, as a chi-square value of 4.37 was noted. From October, 1945, through May, 1949, marking apparently was not a factor in survival, as chi-square values ranging between 0.00+ and 0.20 were obtained.

For the entire period of observation (September, 1944 to May, 1949), using the data at the last check, a chi-square value of 2.12 is obtained. In combination with the period-to-period calculations, which were all non-significant except for one, the data led to the conclusion that the dorsal-adipose mark has not lowered the survival of fish so marked.

Right pectoral mark, 1945

Reference to Table 7 will show that the chi-square values obtained for the corrected observations on comparative survival were consistently so small as to be insignificant through the entire course of the experiment. Chi-square values ranged between 0.04 and 1.46. The chi-square value calculated over the total period (September, 1945 to May, 1948) of the experiment was 2.08, which is non-significant. The right pectoral mark appears not to have affected the survival of the fish so marked.

Left pectoral mark, 1946

The removal of this fin, when compared with the clipping of the companion fin on the other side, yielded entirely different results. The chi-square value obtained for the March, 1947 observation (0.54) suggests that during the period (September 1946 to March, 1947) the mark had no effect on the survival of the marked fish.

A significant chi-square value was obtained for the October, 1947 observations (4.11), suggesting that the survival of marked fish was adversely affected by marking during the period March, 1947 to October, 1947. From October, 1947 to October, 1949, the chi-square values were not significant, indicating that after October, 1947, marking was not a factor in the survival of marked fish. Chi-square values ranged between 0.00+ and 2.04. However, over the course of the entire experiment (September, 1946 to October, 1949) a chi-square value of 5.85 was obtained. Since a lesser number of marked fish were present at the last check the significant value noted indicates that the left pectoral mark had an adverse effect on the survival of fish so marked.

Why the removal of the left pectoral fin should have a more deleterious effect on the survival of marked fish than the right pectoral fin is unexplainable at present.

Right pelvic mark, 1947

Chi-square values calculated on the corrected observations for this experiment were non-significant except for the October, 1948 examination, at which time a significant value in favor of marked fish was noted. Calculated numbers of marked fish present exceeded the calculated numbers of normal fish alive at all examinations. This suggests that removal of the right pelvic fin was not a factor in the mortality of fish marked in 1947.

Some rather glaring and unexplainable discrepancies occur in the data for this year's experiment in the October, 1948 and/or the March, 1949 observations. However, observed and calculated data in all other examinations followed the trends of the other experiments.

Discussion of Comparative Survival

Of the four marks tested, it is concluded that the dorsal and adipose mark, the right pectoral mark, and the right pelvic mark have not had any significant effect on the survival of the lake trout fingerlings to which these marks have been applied. The left pectoral mark, although not affecting survival of fish on which this fin was removed during the first 6 months after marking, apparently was the cause of significant mortalities over the entire period of the experiment. The increase in instantaneous mortality caused by this mark may be measured in a manner suggested by Ricker (1949). Using the tables in Ricker (1948, pp. 98-101), and assuming the corrected results of the last observation in October 1949 to be the best measure of survival, the corrected data indicate that 20.4 percent of the normal fish survived as compared with 15.8 percent of the marked fish. Corresponding instantaneous mortality rates, as determined from Ricker's table, are 1.589 and 1.845. The difference, 0.256,

divided by the value observed for the normal fish, 1.589 suggests that marking increased the instantaneous mortality 16.1 percent, or by about 1/6.[3] More recently,

[3] Instantaneous mortality is defined by Ricker (loc. cit.) as the number of fish which would die from a given cause during the year if recruitment were to exactly balance total mortality from day to day.

Radcliffe (1950) has shown rather conclusively that fin removal did not affect the "cruising speed" (as defined by Fry and Hart) of goldfish or coho salmon fry. Although none of the fin combinations he used were the same as those utilized in the lake trout experiments, the fact that he could find no statistical significance between the cruising rates of normal and marked fish in his experiment suggests the possibility that the same results might be obtained with the various fin combinations used on the lake trout. As Radcliffe points out, fin removal probably affects the fish's ability to swim steadily only slightly but it probably has noticeable effects on the equilibrium particularly in starting, stopping or turning, or in combination of these maneuvers.

Comparative Growth of Normal and Marked Fish

The data on comparative growth of marked and normal fish have not been treated statistically[4] in their entirety because of the voluminous amount of tabulation

[4] The formulas used in the statistical analyses were as follows:

$$M = \Sigma X/n$$

$$\text{Standard deviation} = \sqrt{\frac{\Sigma X^2 - \frac{(\Sigma X)^2}{n}}{n-1}}$$

$$\text{Standard error of mean} = \frac{\text{Standard deviation}}{\sqrt{n}}$$

$$\text{Standard error of the difference} = \sqrt{(S.E._1)^2 + (S.E._2)^2}$$

$$\text{"t"} = \frac{\text{Difference between means}}{\text{Standard error of the difference}}$$

involved, and also because the differences between average total lengths of marked and normal fish at all times were relatively small. However,

statistical analyses were made on each group of fish at the start of the various experiments and on the measurements of the survivors at the last examination. In all but one experiment (1944), the last measurement also was the one which revealed the greatest difference between the average sizes. In the 1944 experiment, the March, 1948, data were also examined statistically. The average sizes of marked and normal fish at the various times of examination will be found in Table 8. The results of the statistical examinations are listed in Table 9.

In the 1944 dorsal-adipose-mark control experiment on growth (Table 8), which was held under observation for 4 years and 8 months, the unmarked control specimens grew in average total length from 74.6 to 451.4 millimeters; marked fish grew in average total length from 73.5 to 455.4 millimeters. The greatest difference noted in average size at any examination was in March, 1948, when the average length of the normal fish was 368.6 millimeters and that of the marked fish was 362.0, or 6.6 millimeters less. At all other examinations the differences in average total lengths ranged between 0.1 and 3.8 millimeters in favor of normal fish.

As shown in Table 9 statistical analyses of the length data for this experiment at the start in September, 1944, March, 1948 add May, 1949, resulted in "t" values of 1.556, 1.723, and 0.976 respectively. From unpublished tables furnished by Dr. E. L. Cooper it can be estimated that these values represent percentage chances that the average sizes of the marked and normal fish are different of 88, 91, and 67, reppectively. Since the 95 percent level of probability was not reached at any time it seems logical to conclude that the marked and normal fish did not differ significantly in average size at any time during the experiment. It is concluded that the application of the

Table 8.--Summary of average total length and number of survivors observed at the various examinations of the normal and marked lake trout fingerlings confined under identical conditions in 1944, 1945, 1946, and 1947. Total lengths are given in millimeters; numbers of survivors appear in parentheses.

	1944		1945		1946		1947	
Date of examination	Normal	Dorsal-adipose	Normal	Right pectoral	Normal	Left Pectoral	Normal	Right pelvic
September, 1944	74.6 (2,000)	73.5 (2,000)	...	...	...	...	...	...
March, 1945 ✓	93.4 (1,005)	93.6 (1,005)	...	...	...	...	...	...
September, 1945	...	...	82.0 (1,000)	81.5 (1,000)	...	...	...	...
October, 1945	164.9 (407)	162.4 (336)	...	...	...	...	...	...
March, 1946	185.5 (364)	184.1 (296)	106.4 (949)	105.6 (978)	...	...	...	...
September, 1946	...	...	...	...	80.6 (1,000)	81.9 (1,000)	...	...
October, 1946	261.0 (325)	256.2 (273)	169.5 (900)	169.2 (860)	...	...	...	...
March, 1947	274.9 (317)	272.1 (262)	185.6 (885)	185.2 (837)	103.5 (935)	104.3 (945)	...	...
September, 1947	...	...	...	...	...	...	73.1 (1,000)	73.8 (1,000)
October, 1947	339.8 (278)	335.6 (228)	245.2 (615)	245.3 (599)	162.4 (475)	161.4 (396)	...	...
March, 1948	368.6 (254)	362.0 (218)	276.8 (492)	278.0 (472)	192.1 (349)	191.9 (289)	97.5 (953)	97.8 (965)
May, 1948	...	...	295.4 (429)	298.2 (378)	...	...	...	...
October, 1948	422.0 (239)	422.2 (200)	...	...	258.9 (267)	256.6 (196)	173.8 (877)	174.8 (794)
March, 1949	438.7 (235)	437.8 (198)	...	...	284.6 (240)	286.2 (171)	194.3 (837)	195.2 (810)
May, 1949	451.4 (228)	455.4 (189)	...	...	...	...	...	...
October, 1949	...	...	...	...	343.9 (212)	335.3 (150)	234.9 (621)	236.5 (564)

✓ It was apparent at this date that this group was too large for the pond space available. The actual number of survivors was 1,398 normal, 1,447 marked. The experiment was reduced to 1,005 each and measurements taken on the latter number.

Table 9.--Statistical analysis of differences in average total length of marked and normal lake trout fingerlings at start and end of experiments. (The percentage chance that the means are different is given in parentheses under the "t" value.)

Year and mark	Date checked	Type of fish	Range in total length (millimeters)	Number of fish in sample	M (average length in millimeters)	Standard deviation	Standard error of M	Difference between M's	Standard error of difference	"t"
1944 dorsal and adipose	September, 1944	marked	45-105	500	73.5	11.25	0.50	1.1	0.71	1.556
		normal	47-101	500	74.6	11.16	0.50			(88)
	March, 1948	marked	205-472	218	362.0	42.02	2.85	6.6	3.83	1.723
		normal	282-480	254	368.6	40.87	2.56			(91)
	May, 1949	marked	313-563	189	455.4	41.73	3.03	4.0	4.10	0.976
		normal	321-601	228	451.4	41.61	2.76			(67)
1945 right pectoral	September, 1945	marked	55-110	1,000	81.5	9.03	0.29	0.5	0.38	1.316
		normal	54-105	1,000	82.0	8.01	0.25			(81)
	May, 1948	marked	231-391	378	298.2	31.75	1.63	2.8	2.20	1.273
		normal	163-376	429	295.4	30.73	1.48			(80)
1946 left pectoral	September, 1946	marked	63-104	1,000	81.9	6.78	0.21	1.3	0.29	4.482
		normal	61-108	1,000	80.6	6.20	0.20			(100)
	October, 1949	marked	218-446	150	335.3	46.06	3.76	8.6	4.43	1.941
		normal	238-449	212	343.9	33.87	2.33			(94)
1947 right pelvic	September, 1947	marked	56- 90	1,000	73.8	5.05	0.16	0.7	0.25	2.800
		normal	54- 91	1,000	73.1	5.86	0.19			(99)
	October, 1949	marked	164-304	564	236.5	27.40	1.15	1.6	1.59	1.006
		normal	160-303	621	234.9	27.32	1.10			(68)

dorsal-adipose mark had no effect on the growth of the lake trout fingerlings, at least over the four years and eight months of observation.

The right pectoral-mark control experiment of 1945 concerning comparative growth was conducted for a period of 2 years and 8 months. In this time, normal fish grew in average total length from 82.0 to 295.4 millimeters, while the average length of the marked lake trout fingerlings increased from 81.5 to 298.2 millimeters. The differences in average total length between normal and marked fish at any examination were very minutely in favor of the normal fish, ranging from 0.1 to 0.4 millimeter, except at the May, 1948, check when marked fish were 2.8 millimeters larger in average size.

Statistical analyses of the September, 1945, length measurements on the control fish and again at the last examination of the survivors in May, 1948, indicate that the average lengths of the marked and normal lake trout fingerlings were so closely alike as to be regarded as drawn from the same stock. The "t" values were: September, 1945, 1.316; May, 1948, 1.375. The percentage chance that the means were different were 81 and 83 percent respectively, not very close to a 95 percent level of probability. It is concluded that the application of the right pectoral mark to the lake trout fingerlings had no effect on the growth of the fish to which this mark was applied.

The growth control experiment on the 1946 (left pectoral) mark lasted 3 years and 1 month. The unmarked fish grew from 80.6 to 343.9 millimeters in average total length while the marked counterparts were increasing in average length from 81.9 to only 335.3 millimeters. The differences in average size between normal and marked fish at any examinations of this group ranged between 0.3 and 8.6 millimeters.

At the initiation of this experiment it can be demonstrated that the marked fish were significantly larger than the normal fingerlings, although the difference between the average sizes was only 1.3 millimeters. The resulting "t" value found was 4.482--a virtual certainty that the means are different. The left-pectoral-marked fish held their advantage through the March, 1947 examination. Reference to Table 8 will show that the normal fish had a slightly larger average size at the examinations of October, 1947, March, 1948, and October, 1948, but that marked fish had a slight advantage in average size in March, 1949. At the last examination in October, 1949, normal fish had an average size of 343.9 millimeters as compared with an average size of 335.3 millimeters for the marked fish--a difference of 8.6 millimeters in favor of normal fish. Statistical examination of the length data on the last date gives a "t" value of 1.941 or a percentage chance of 94 that the two means are different. This suggests that the left pectoral mark has very likely reduced the growth of the lake trout fingerlings so marked by a small but significant amount.

Measurements on the 1947 growth control experiment (right pelvic fin removed) at four intervals over 2 years and 1 month indicate that the average length of normal fish increased from 73.1 to 234.9 millimeters while that of the marked fish grew from 73.8 to 236.5 millimeters. At all times the marked fish in this experiment were from 0.3 to 1.0 millimeters larger than the normal specimens in average size.

In this group of experimental fish, examination of the comparative data demonstrates that the marked fish were significantly larger in September, 1947, at the start, even though the difference between the means was only 0.7 millimeter ("t" of 2.800 yielding a percentage change of 99 that the means are different). At all examinations the average size of the marked fish was greater

than the average size of the normal fish. Statistical analysis of the length data from the October, 1949, check yields a "t" value of 1.006--a percentage chance of 68 that the means are different, nowhere near significance levels. It is concluded that the use of the right pelvic mark had no effect on the growth of the fish to which it was applied.

Discussion of Comparative Growth

In three of the four marks tested it should be noted that the "t" values decreased as the fish grew in size and the experiments progressed through time. This trend suggests that as the marked and normal fish from any experiment grew in size there was progressively less significance in the difference between their average sizes. It would appear likely in most instances that within 4 years after marking there would be no significant differences in average sizes between marked and normal fish surviving to that time.

In the one instance where the calculated "t" value was highest at the last examination (1945 mark-right pectoral clipped), the "t" values found suggested that there was no significant difference between the average sizes of marked and normal fish at any time.

The results of the observations on the control experiments lead to the conclusion that of the four marks applied the left pectoral mark used in 1946 is the only one which may have influenced growth unfavorably. The question arises as to why the clipping of the left pectoral fin should cause the results noted, and not the removal of the right pectoral fin. It might be argued that the results recorded are caused by "experimental error," and that were the experiment involving the left pectoral mark repeated a number of times the opposite conclusions might be reached regarding the effect of

Table 10.--Summary of comparison of growth in weight of normal and marked lake trout fingerlings for the four mortality-growth control experiments. Average weight in grams for the indicated numbers of survivors is given. Numbers of survivors are indicated in parentheses.

Date of examination	1944-dorsal-adipose mark		1945-right pectoral mark		1946-left pectoral mark		1947-right pelvic mark	
	Normal	Marked	Normal	Marked	Normal	Marked	Normal	Marked
September, 1944	3.4 (2000)	3.1 (2007)						
March, 1945 *	5.0 (1005)	5.1 (1005)						
September, 1945	...	...	4.8 (1000)	4.6 (1000)				
October, 1945	38.0 (407)	35.8 (336)	...	...				
March, 1946	48.5 (364)	52.5 (296)	not taken					
September, 1946	...	...	...	...	4.0 (1000)	4.0 (1000)		
October, 1946	139.3 (325)	136.1 (273)	38.1 (900)	37.6 (860)	...	...		
March, 1947	154.2 (317)	149.7 (262)	43.7 (885)	43.9 (837)	7.3 (935)	7.3 (945)		
September, 1947	...	...	...	...	...	...	2.9 (1000)	2.9 (1000)
October, 1947	326.6 (278)	322.1 (228)	121.6 (615)	121.1 (599)	33.7 (475)	32.3 (396)	...	...
March, 1948	425.5 (254)	402.8 (218)	171.0 (492)	172.8 (472)	54.4 (349)	54.4 (289)	6.7 (953)	6.4 (965)
May, 1948	...	...	217.7 (429)	220.9 (378)	...	...	...	...
October, 1948	626.0 (239)	639.6 (200)			141.5 (267)	142.4 (196)	43.5 (877)	42.6 (794)
March, 1949	721.2 (235)	725.8 (198)			191.0 (240)	192.3 (171)	54.0 (837)	55.3 (810)
May, 1949	816.5 (228)	830.1 (189)			...	...	...	...
October, 1949	...	...			329.3 (212)	319.3 (150)	100.2 (621)	101.6 (564)

* See footnote, Table 8.

marking on growth. However, it should be pointed out that the left pectoral mark apparently had a statistically significant effect on survival as well as a near-significant effect (if not significant) on growth. It would seem reasonable to assign the results to "experimental error" if the results had been found to be significant in only the mortality analysis or only the growth analysis. The fact that significance or near-significance was noted in the analysis of both growth and survival suggests, on the other hand, that more than chance is involved in the results noted for the experiments involving the left pectoral fin.

The growth data for the unmarked fish listed in Table 8 are portrayed in graphic form in Figure 1. Since the marked fish differed only slightly from the unmarked lake trout only the growth curves for the unmarked fish are given. It is of interest to note that the curves for the four different years are very similar in slope despite the varying numbers present at any one time or surviving to the last examination.

Armstrong (1949) compared the growth of the survivors from 500 dorsal-adipose-clipped lake trout fingerlings and 500 normal lake trout fingerlings held between August, 1947, and June, 1948, at the Provincial Fish Hatchery at Port Arthur, Ontario. He also found no difference between the growth of clipped and unclipped trout.

The data on average weight increases of normal and marked lake trout held for various periods of time are summarized in Table 10. Average weights were obtained by weighing marked and normal fish by groups in water and dividing the total weight by the number present. The inspection of this table suggests that there is little if any difference in the average weights of marked and normal fish held under identical conditions for the same length of time. In all years except 1946, marked fish grew at slightly faster rates than did normal fish, as judged by the average weights of the survivors at the

conclusion of the experiments. Statistical comparison of marked and normal fish was not possible because individual weights of fish were not obtained. It is tentatively concluded that marking has no effect on growth in weight.

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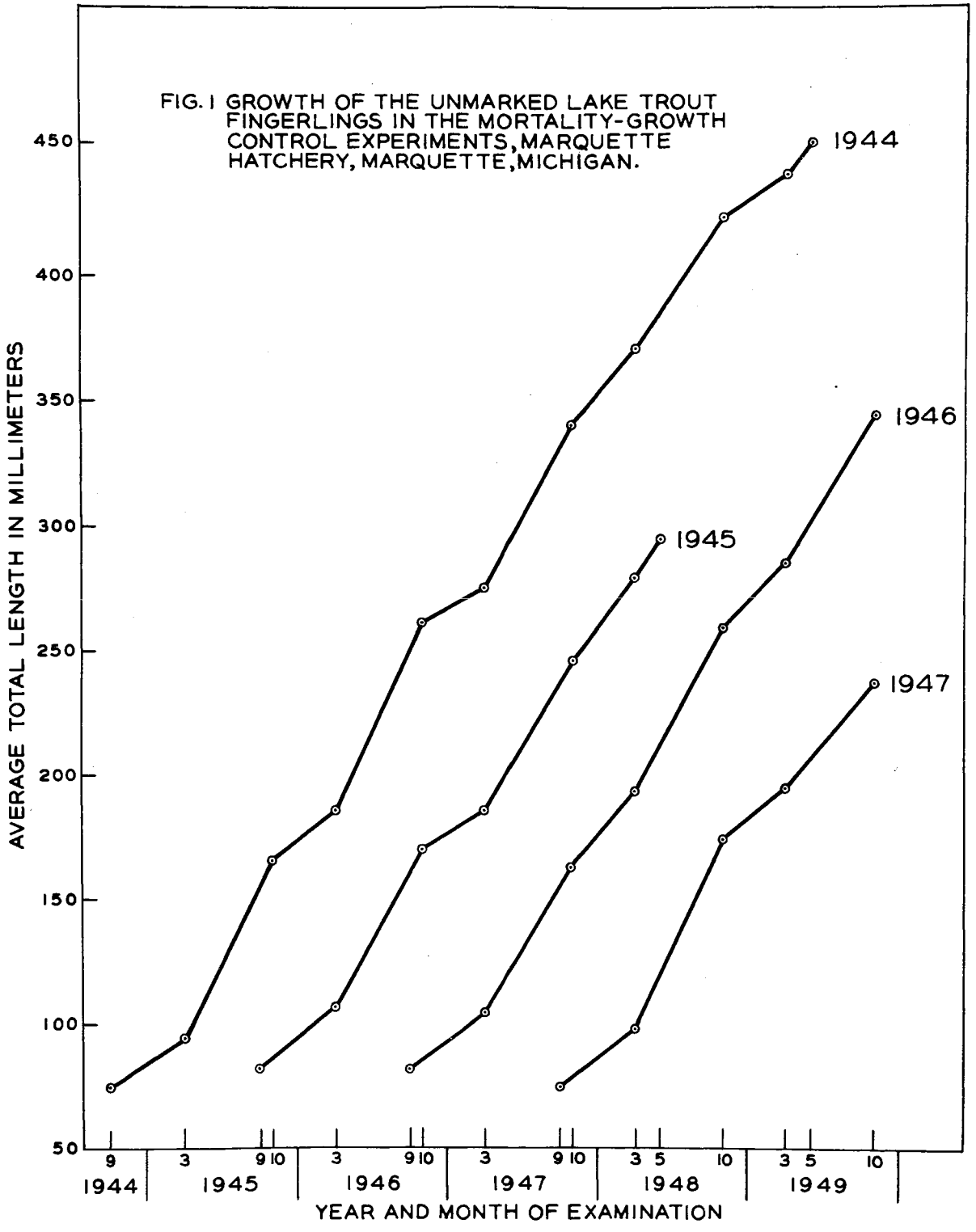
FIG. 1 GROWTH OF THE UNMARKED LAKE TROUT FINGERLINGS IN THE MORTALITY-GROWTH CONTROL EXPERIMENTS, MARQUETTE HATCHERY, MARQUETTE, MICHIGAN.
AVERAGE TOTAL LENGTH IN MILLIMETERS
450
400
350
300
250
200
150
100
50
1944
1945
1946
1947
9
3
9 10
3
9 10
3
9 10
3 5
10
3 5
10
1944
1945
1946
1947
1948
1949
YEAR AND MONTH OF EXAMINATION