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Education - Game
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COMPLETION OF CONTROL EXPERIMENTS ON LAKE TROUT FIN-CLIPPING OPERATIONS WITH A SUMMARY OF THE RESULTS TO DATE

By David S. Shetter

ABSTRACT

From four different lots of marked fish held for at least 18 months for observations on fin regeneration, it was determined that the following percentages of the marked fish would likely be recognizable (regeneration 0-50 percent of 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 on fin regeneration also suggested that the numbers of marked fish surviving in mortality-growth experiments under observation at the same time should be adjusted upward, as it can be demonstrated that from 0.2 percent to 20.8 percent of the survivors of the regeneration experiments had fully regenerated fins at the various examinations.

The comparative mortality between equal numbers of normal and marked lake trout fingerlings held under identical conditions was tentatively concluded to be of insignificant proportions for the 1944, 1945 and 1947 marks. However, on the basis of chi-square tests for departure of normal:marked fish from a 1:1 ratio removal of the left pectoral fin appears to have resulted in a 16.1 percent increase in instantaneous mortality among the 1946 group.

Comparison of the growth between marked and unmarked lake trout fingerlings held in the same ponds suggests that normal fish and marked fish grew at the same rate in both length and weight, and that it was not likely that marking influenced growth.

Field studies on the effects of fish predation on comparative mortality between normal and marked fish were completed during 1949, but the data still remain to be treated statistically. One clear-cut result of the experiment indicates that mortality among either marked or normal fish is considerably less where underwater cover is available.

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INTRODUCTION

When the large-scale marking experiments involving the planting of fin-clipped fingerling lake trout were initiated in 1944 on Lake Michigan waters, coincident control experiments also were begun to determine possible regeneration of fins and the comparative mortality and growth between normal lake trout fingerlings and fingerlings bearing the various marks used. A random sample of the fish marked in 1944, 1945, and 1946 for Lake Michigan, and in 1947 for Lake Huron was saved for observations on fin regeneration, mortality and growth. The experimental fish were marked at the U. S. Fish and Wildlife Station at Charlevoix, Michigan in September of each year and then transferred by tank truck to the State Fish Hatchery of the Michigan Department of Conservation at Marquette, Michigan. Since it appears that these experiments have served their purpose, they were terminated in October, 1949. This report will summarize the results of the experiments.

General Experimental Plan

Each year as the fish were marked, a sample of fin clipped fish were taken from each trough of marked fish by scapping up the requisite number

to make up 1,000 marked fish[1] for the mortality-growth experiments (i.e. - if there were 20 troughs of fish 50 were drawn from each trough). Samples were taken from the head, middle and lower ends of the troughs in an attempt to obtain a random sample for determination of average length. A similar procedure was used to draw the unmarked stock for the experiment.

For observations on regeneration of fins, 500 marked fish each year[2] were drawn from the stock of clipped fish, following the procedure outlined above.

After 1944, total lengths of all experimental fish were measured individually in millimeters, and weights obtained by groups in pounds. In 1944, 20 percent of the regeneration group and 25 percent of the mortality-growth experiment were measured when these experiments were set up.

After marking in September, each lot of fish was transferred to Marquette where they were held in covered troughs in a heated building and were placed in outside ponds in late March or April, the mortality-growth experiment and the regeneration experiment being segregated in separate ponds.

Examinations of the experimental fish were conducted semi-annually each year in March and October through 1949, and counts and measurements on certain groups also were obtained 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 a 1/4 ounce of ether per quart of water.

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[1] Except in 1944, when 2,007 marked and 2,000 unmarked fish were used. In March, 1945 it was obvious this number was too large for the pond facilities at Marquette and the experiment was reduced to 1,005 in each group.

[2] Except in 1944, when 1,003 were used, and later 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.

Results of observations on fin regeneration

It might have been desirable to hold all experiments for longer periods of time, but the needs for pond space for trout production made it almost mandatory that the numbers of experimental ponds be kept at a minimum. Therefore when it appeared that there was nothing further to be learned from an experimental group, such fish were released in landlocked inland lakes of Michigan. The regeneration experiments on the various marks were observed over the following periods:

1944 - dorsal-adipose clip - September, 1944 - March, 1946

1945 - right pectoral clip - September, 1945 - March, 1947

1946 - left pectoral clip - September, 1946 - March, 1948

1947 - right pelvic clip - September, 1947 - October, 1949.

For the purpose of determining the efficiency of the mark, a number of marked fish were held each year separately 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 probably complete misses or faulty removal in the clipping operation). Grading was done with frequent reference to unmarked fish of the same size, 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 were planted out in order to utilize pond space for on-coming experiments. The general growth history of the various regeneration experiments is given in Table 1.

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

Date of examination	1944		1945		1946		1947	
	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 [1]	93.7	4.8(500)						
September, 1945	...	...	825	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)

[1] See footnote 2 on page 2.

1944 mark - dorsal and adipose fins clipped (Table 2)

In this experiment, 13 months elapsed between marking and the first examination to classify extent of regeneration (in October, 1945), when 254 of the 255 survivors were checked. Five hundred marked fish had been chosen at random in March of the same year because the pond was considered overcrowded.

As the 1944 mark involved two fins, there were 25 possible combinations of regeneration observable. Table 1 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 nine most easily recognized combinations are starred, and these 231 fish constitute 90.9 percent of the total examined in October, 1945. It is felt that marked fish with no greater regeneration than is represented in these groups will be identifiable in the future by anglers, commercial fishermen, and fisheries investigators.

This same group was examined and graded again in March, 1946, and 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.

1945 mark - right pectoral fin clipped (Table 3)

Four hundred ninety-nine (499) right pectoral-clipped lake trout fingerlings were set aside in September, 1945 from the fall marking for observation. 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 the regeneration among the control fish for 1945 are given in Table 3, which shows the percentage of the surviving fish in each of the five arbitrary classes.

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

Regeneration of		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 [1]	100.0	251	100.0

[1] One fish escaped, not graded or measured.

Table 3. Summary of observations on 1945 (right pectoral clip) regeneration experiment. Initiated September, 1945, with 499 marked fish of average size 82.5 millimeters, 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)

In March, 1946, 96.4 percent were classified as having no regeneration, and 0.6 percent as showing various amounts for 3/4 to full regeneration. By October, 1946, only 328 fish were present, and of this number 315, or 96.1 percent, were noted to have 1/2 or less regeneration. The proportion of survivors having no regeneration was reduced to 78.4 percent. At the March, 1947 inspection 294 survivors were present and the pattern of regeneration observed among these fish was very similar to that noted in October, 1946. The percentage of fish alive with 1/2 or less regeneration was 96.5 percent. This experiment was then discontinued.

1946 mark - left pectoral fin clipped (Table 4)

The control experiment on this mark also utilized 500 fish drawn from the September, 1946 marking operations. On inspection in March, 1947 there were 488 survivors classified as follows: No regeneration, 69.4 percent; 1/4 regeneration, 24.1 percent; 1/2 regeneration, 3.8 percent; 3/4 regeneration, 1.6 percent, and full regeneration, 1.1 percent. The easily recognizable classes (1/2 or less regeneration) contained 97.3 percent of the survivors.

By October, 1947, there were 259 survivors, of which 90.9 percent had 1/2 or less regeneration. In March of 1948, examination of the 175 survivors to that date were found to have 89.8 percent with 1/2 or less regeneration, and the experiment was concluded.

1947 mark - right pelvic fin clipped (Table 5)

From 500 fish with the above mark segregated in September, 1947, there were 483 survivors at the March, 1948 examination. The following percentages of regeneration were observed: No regeneration, 10.8 percent; 1/4 regeneration, 43.7 percent; 1/2 regeneration, 30.9 percent; 3/4 regeneration, 13.2 percent, and full regeneration, 1.4 percent.

Table 4. Summary of observations on the 1946 (left pectoral clip) regeneration experiment. Initiated September, 1946 with 500 marked fish of average size 82.2 millimeters, 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 of average size 74.3 millimeters, 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)

The percentage of the survivors among the readily recognizable classes (1/2 fin reformation or less) amounted to 85.4 percent.

In October, 1948, inspection of 405 right pelvic-marked survivors showed that the percentage of fish with 1/2 or less regeneration had diminished to 64.9 percent. In March, 1949, 390 survivors were present and of this number, only 60.0 percent were in the three most easily distinguished classes. Since these experimental fish had exhibited a noticeable decline in the percentage of easily recognizable fish they were held until the October, 1949 examinations. At that time there were 234 specimens surviving, of which 64.1 percent in the groups showed 1/2 regeneration or less.

Discussion of Regeneration Experiments

On the basis of the observations on fin regeneration among the various 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 survivors having 1/2 or less regeneration, according to Snedecor, (1948, Table 1.1, p.5)[3], who lists the possible limits for observed percentages from samples of various sizes. The theory behind the table is that the limits given will take in 99 percent of all sample ratios observed; or, stated in another way, there is only one chance in one hundred that an observed sample will lie outside the limits entered in the Table 4.

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[3] Snedecor, George W. Statistical Methods (4th edition), Iowa State College Press, Ames, Iowa. 1948. 485 pp.

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

Year and month of marking	Mark used	Number of survivors at last check	Percentage of survivors showing		Range in percent showing 1/2 regeneration (from Snedecor)
			1/2 regeneration or less	over 1/2 regeneration	
Sept. 1944	Dorsal-adipose	251	90.4	9.6	84-94
Sept. 1945	Right pectoral	294	96.5	3.5	91-98
Sept. 1946	Left pectoral	175	89.8	10.2	84-94
Sept. 1947	Right pelvic	234	64.1	35.9	52-68

The data in Table 6 would indicate that between 84 and 94 percent of the 1944 dorsal-adipose-marked survivors are recognizable and between 91 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 (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 (confidence limits 56-72 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)[4], 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 result of difficulty in seeing and removing small, transparent fins in a clean manner.

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[4] Slater, Daniel W. Re-formation of excised fins of king salmon fingerlings and its effects on recognition of marked adults. Transactions Am. Fish. Soc., Vol. 47 (1947) pp. 132-140. 1949.

Armstrong (1949), [5] working with marked lake trout fingerlings has reported that for the dorsal-adipose mark approximately 95 percent of 487 survivors of 500 marked fish at the end of 10 months 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 both experimental groups were drawn 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 year and mark.

To illustrate with an example from the data, consider the regeneration group and the mortality-growth experimental fish from 1944 at the March, 1946 examination. There were 251 regeneration control fish alive, of which 7 or 2.8 percent were fully regenerated or missed in the original operation. This observation suggests that of the 660 mortality-growth experiment fish present, 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 data for this particular examination would be 355 unmarked fish, 305 marked fish.

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[5] Armstrong, George C. Mortality, rate of growth, and fin regeneration of marked and unmarked lake trout fingerlings at the Provincial Fish Hatchery, Port Arthur, Ontario. Trans. Am. Fish. Soc., Vol. 47 (1947) pp. 129-131. 1949.

For the dates of examinations where the percentages of total regeneration could be applied to the companion mortality-growth experiments, the mortality data has 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 mortality, inasmuch as it was the best measure available. Had pond space been available it would have been desirable to have held all the regeneration experiments as long as the mortality-growth experiments, and to have checked them simultaneously.

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

Observations on comparative mortality between 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 served to compare the average growth between 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 mortality 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 1:1 ratio that was established at the initiation of the experiments.

The problem consists of determining whether the data on the comparative mortality departs significantly from a 1:1 ratio. Wherever it does, 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 marked fish surviving completely regenerate their marks and are not recognizable as marked fish, the comparative mortality data logically should be adjusted to take this fact into account. The changes that occur when this correction for complete regeneration are made are shown in Table 7, which lists the observed data and the 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). The unadjusted values so obtained are not deemed to be significant unless they exceed 3.841 according to Snedecor (1948, p.22). If significant values are found it suggests that marking has increased the mortality of the marked fish.

Dorsal-adipose mark, 1944

The chi-square values obtained from the various examinations have been used as criteria in evaluating the effect of the mark on the mortality of marked fish. In the 1944 experiment, between September, 1944 and March, 1945, marking had no effect on mortality, as more marked fish were alive than normal fish. However, from March, 1945 to March, 1946, marking apparently was a significant factor in the mortality of marked fish, as chi-square values of 4.373 and 3.794 were noted. From March, 1946 through May, 1949, apparently marking was not a factor in mortality, as chi-square values ranging between 1.220 and 2.167 were noted.

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 the 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[3]		Observed		Calculated		Observed		Calculated		Observed		Calculated	
	N	M[2]	N	M	N	M	N	M	N	M	N	M	N	M	N	M
Number in Sept. in year	2000-2007		2000-2007		1000-1000		1000-1000		1000-1000		1000-1000		1000-1000		1000-1000	
Alive in March 1945[1]	1398-1447		1398-1447													
October, 1945	407-	336 (1.9)	400-	343 (4.37)												
March, 1946	364-	296 (2.8)	355-	305 (3.79)	949-	978 (0.2)	941-	986 (1.05)								
October, 1946	325-	273 (2.8)	317-	281 (2.17)	900-	860 (2.1)	882-	878 (0.01)								
March, 1947	317-	262 (2.8)	309-	270 (2.63)	875-	837 (1.2)	865-	847 (0.19)	935-	945 (1.1)	924-	956 (0.55)				
October, 1947	278-	228 (2.8)	271-	235 (2.56)	615-	599 (1.2)	608-	606 (0.00)	475-	396 (4.2)	458-	413 (2.33)				
March, 1948	254-	218 (2.8)	248-	224 (1.22)	492	472 (1.2)	486-	478 (0.07)	349-	289 (5.1)	333-	305 (3.92)	953-	965 (1.4)	939-	979
May, 1948	...		...		429-	378 (1.2)	424-	383 (2.08)	...		...		...		...	
October, 1948	239-	200 (2.8)	233-	206 (1.66)					267-	196 (5.1)	257-	206 (5.62)	877-	794 (16.1)	725-	946
March, 1949	235-	198 (2.8)	229-	204 (1.44)					240-	171 (5.1)	231-	180 (6.32)	837-	810 (20.8)		*
May, 1949	228-	189 (2.8)	223-	194 (2.02)					...		...		...		...	
October, 1949	...		...						212-	150 (5.1)	204-	158 (5.88)	621-	564 (16.7)	508-	677

[1] Fin regeneration not checked in March, 1945.

[2] Under "observed, M" in parentheses is given known percentage of complete fin regeneration, see Tables 2, 3, 4, 5, last columns.

[3] In parentheses under "calculated" are given chi-square values for corrected distribution.

* Here an obvious and unexplainable discrepancy occurs. Observed data used for want of a better figure. There is a suggestion that not all experimental fish were gotten from the pond in October, 1948, or there were some unexplainable additions after that date.

Right pectoral mark, 1945

Reference to Table 7 will show that the chi-square values obtained for the corrected observations on comparative mortality were consistently so small as to be insignificant through the entire course of the experiment. Chi-square values ranged between 0.003 and 2.083. The right pectoral mark appears not to have affected the mortality of the fish so marked.

Left pectoral mark, 1946

The removal of this fin had entirely different results than the clipping of the companion fin on the other side. Chi-square values during the first year suggest that during this period the mark had no effect on the mortality of the marked fish (values of 0.55 and 2.33 for the corrected observations).

After October,1947, however chi-square calculations indicate that significantly greater numbers of marked fish died than normal fish (chi square ranges 3.92-6.33).

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 were not calculated on the corrected observations for this experiment inasmuch as when the percentages of complete regeneration were applied to the 1947 experiment on comparative mortality, calculated numbers of marked fish present exceeded the calculated numbers of normal fish alive at the same time. This suggests that removal of the right pelvic fin was not a factor in the mortality of marked fish in this year.

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.

Of the four marks tested, it may be tentatively concluded that the dorsal and adipose mark, the right pectoral mark, and the right pelvic mark have not had any effect on the mortality of the lake trout fingerlings on which these marks have been applied. The left pectoral mark, although not affecting mortality of fish on which this fin was removed during the first year after marking, apparently was the cause of significant mortalities after that time. The increase in instantaneous mortality caused by this mark may be measured in a manner suggested by Ricker (1949) and using the tables in Ricker (1948, pp. 98-101), assuming the corrected results of the last observation in October, 1949 to be the best measure of mortality. 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 about 1/6.

In an attempt to throw further light on the problem, the data for the four experiments were tested by another method outlined for chi-square tests by Snedecor (1948, p.206). This test should indicate whether the probability of death is independent of the year of marking. The data were treated as follows: the corrected observed results for each year's mark were grouped and tabulated at the end of 5, 13, 18 and 25 months, and chi-square calculated for each tabulation.

The results of these tabulations were inconclusive since at 5 and 18 months, chi-square values obtained were so small as to be insignificant,

whereas the chi-square values noted for the 13- and 25-month tabulations were so large as to indicate some dependence on the probability of survival and the mark used.

Observations on comparative growth of normal and marked fish

1944 - dorsal and adipose fins clipped

For the 1944 dorsal-adipose-mark control experiment on growth (Table 8), which was held under observation for 4 years and 8 months, the unmarked controls 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 normal fish were of an average length of 370.0 millimeters and the marked fish were of an average total length of 361.6, or 8.4 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.

1945 - right pectoral fin clipped

The right pectoral-mark control experiment of 1945 concerning comparative growth was observed for a period of 2 years and 8 months. In this time, normal fish grew from an average total length of 81.9 to 294.6 millimeters, while the marked lake trout fingerlings increased in average size from 81.5 to 298.1 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 millimeters, except at the May, 1948 check when marked fish were 3.5 millimeters larger in average size.

1946 - left pectoral fin clipped

The growth control experiment on the 1946 (left pectoral) mark was held for 3 years and 1 month. The unmarked fish grew from 80.6 to 343.9

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, number of survivors appear in parentheses.

Date of examination	1944		1945		1946		1947	
	Normal	Dorsal-adipose	Normal	Right pectoral	Normal	Left pectoral	Normal	Right pelvic
September, 1944	74.6 (2000)	73.5 (2007)	...	...	...	...	...	...
March, 1945 [1]	93.4 (1005)	93.6 (1005)	...	...	...	...	...	...
September, 1945	...	...	81.9 (1000)	81.5 (1000)	...	...	...	...
October, 1945	164.9 (407)	162.4 (336)	...	...	...	...	...	...
March, 1946	185.4 (364)	184.3 (296)	106.4 (949)	105.6 (978)	...	...	...	...
September, 1946	...	...	...	...	80.6 (1000)	81.9 (1000)	...	...
October, 1946	261.0 (325)	256.2 (273)	169.4 (900)	169.2 (860)	...	...	...	...
March, 1947	274.9 (317)	272.1 (262)	185.3 (875)	185.2 (837)	103.5 (935)	104.3 (945)	...	...
September, 1947	...	...	...	...	...	...	73.1 (1000)	73.8 (1000)
October, 1947	340.3 (278)	337.8 (228)	245.4 (615)	245.3 (599)	162.5 (475)	161.2 (396)	...	...
March, 1948	370.0 (254)	361.6 (218)	277.9 (492)	277.8 (472)	192.2 (349)	191.8 (289)	97.5 (953)	97.8 (965)
May, 1948	...	...	294.6 (429)	298.1 (378)	...	...	...	...
October, 1948	422.0 (239)	421.9 (200)	...	...	258.8 (267)	256.6 (196)	173.8 (877)	174.8 (794)
March, 1949	438.9 (235)	437.8 (198)	...	...	284.6 (240)	286.1 (171)	194.3 (837)	194.8 (810)
May, 1949	451.4 (228)	455.4 (189)	...	...	...	...	...	...
October, 1949	...	...	...	...	343.9 (212)	335.3 (150)	235.7 (621)	236.6 (564)

[1] It was apparent at this date that this group was too large. 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.

Note: If chi-square can be used to test significance of differences in average growth then there is no significant difference between any group of marked fish and normal fish. See values for chi square: $X^2 = 0.03$ $X^2 = 0.04$ $X^2 = 0.19$ $X^2 = 0.0001$

millimeters in average total length while the marked counterparts were increasing in average size 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.

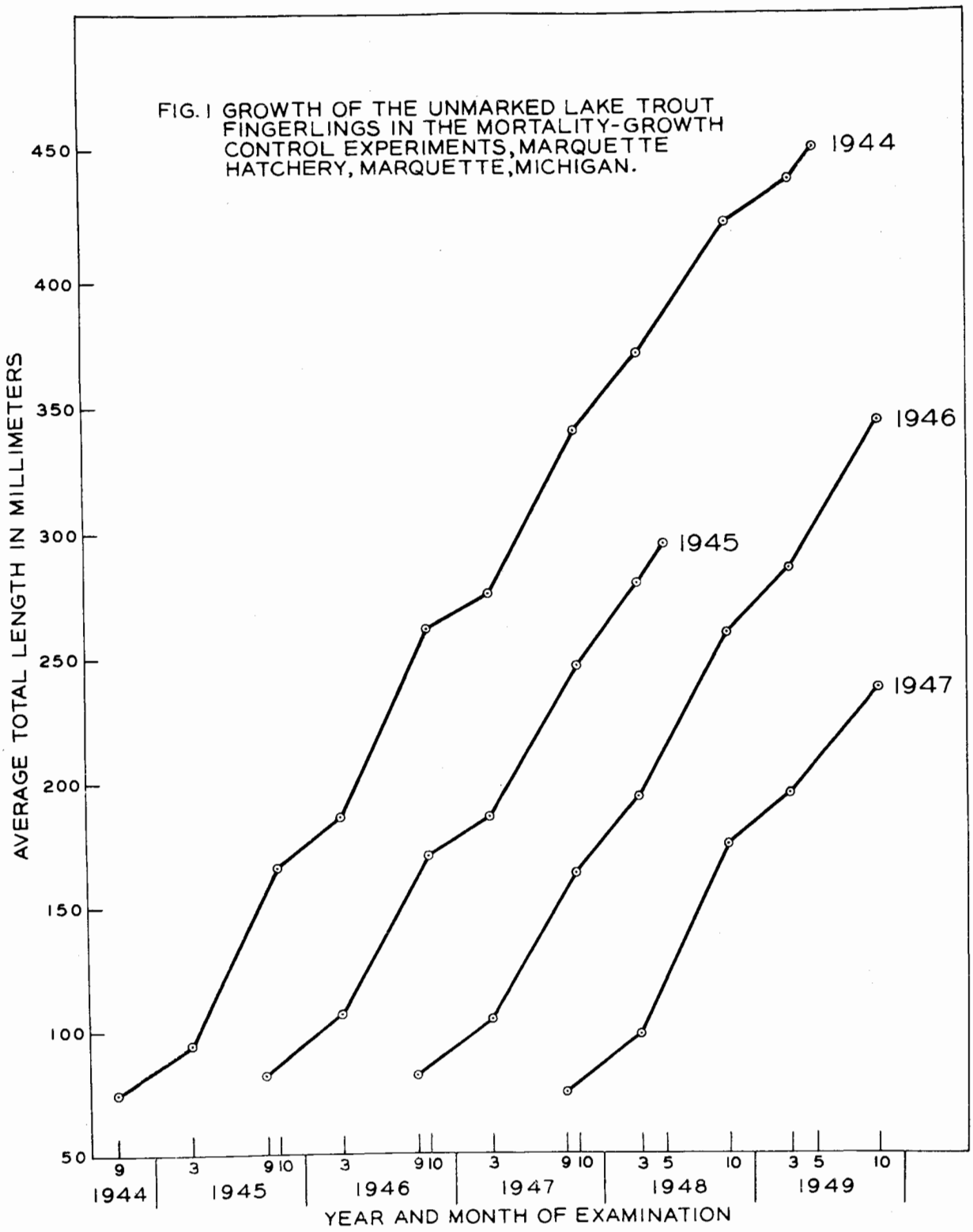
1947 - right pelvic fin clipped

Measurements on the 1947 growth control experiment (right pelvic fin removed) at four intervals over 2 years and 1 month indicate that normal fish increased from 73.1 to 235.7 millimeters in average size, while the marked fish grew from 73.8 to 236.6 millimeters in average size. At all times the marked fish in this experiment were from 0.3 to 1.0 millimeters larger in average size.

The data on comparative growth of marked and unmarked fish have not been treated statistically because of the voluminous amount of tabulation that would be involved and because the differences were so slight. Inspection of the material in Table 8 indicates that the greatest difference in average length between any group of fin-clipped and normal fish was 8.6 millimeters in favor of normal fish on one occasion. Numerous other instances will be noted where the average lengths of both marked and unmarked fish differed by 1.5 millimeters or less (doubtless within the range of error in measurement). In three of the four marks tested (1944, 1945, 1947), the marked fish were of slightly greater average length than the unmarked fish at the last examination. All these observations combined suggest that the average size of both marked and unmarked fish has not been significantly different, and provides evidence that the removal of the various fins or fin combinations has not affected the growth of marked fish in the various periods of observation.

The growth data for the unmarked fish listed in Table 8 are portrayed in graphical form in Figure 1. Since the marked fish differed only slightly

FIG. 1 GROWTH OF THE UNMARKED LAKE TROUT FINGERLINGS IN THE MORTALITY-GROWTH CONTROL EXPERIMENTS, MARQUETTE HATCHERY, MARQUETTE, MICHIGAN.



from the unmarked lake trout only the growth curve for the unmarked fish is 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 examinations.

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 9. 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. It is tentatively concluded that marking has no effect on growth in weight.

The effect of predation by fish on comparative mortality of normal and marked lake trout fingerlings

This study, suggested by Dr. W. E. Ricker, was initiated in October, 1948 and the field work carried to completion in October, 1949. One large-scale experiment involving 4,000 normal lake trout fingerlings and 4,000 marked lake trout fingerlings (1,000 each with the four marks previously used) held in the presence of adult brook, brown, rainbow and lake trout was set up. Two smaller experiments, involving the holding of 500 normal and 500 marked fish in the presence of adult brook and lake trout, one lot in an open pond, the other in a pond with underwater cover, also were conducted. The usual sorting data and length and weight measurements were obtained at intervals during 1949, as well as one week after the initiation of the small-scale experiments.

Table 9. 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. 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 [1]	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)	52.2 (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 (875)	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)

[1] See footnote 1 on Table 8.

Statistical analysis of the results of the tabulations have not yet been completed. However, it can be stated that the presence of underwater cover in the form of crossed tree limbs and boulders increased the survival of both normal and marked fish in the presence of predators very noticeably. The analysis of these experiments will be reported on as soon as they are completed.

All experimental fish remaining at the Marquette Hatchery were planted in Golden Lake, Iron County in November, 1949.

INSTITUTE FOR FISHERIES RESEARCH

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