Presented at the 81st annual meeting of the American Fisheries Society

August 1, 1951

Report No. 1294

Original: American Fisheries Society
cc: Fish Division
Education - Game
Institute for Fisheries Research
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The comparative mortality and growth of marked and unmarked lake trout fingerlings in the presence of predators[1]

[1] Contribution from the Michigan Institute for Fisheries Research

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Abstract

Two experiments were conducted between October 4, 1948 and October 25, 1949 at the State Fish Hatchery at Marquette, Michigan, to determine the effect of predation on fin-clipped lake trout (Cristivomer n. namaycush [Walbaum]) fingerlings. One experiment involved 4,000 unmarked fish and 4,000 clipped fish confined in the presence of adult brook trout, brown trout, rainbow trout and lake trout.

In a smaller experiment, another pond was divided by a fish-tight screen and bulkhead. In the lower half, weighted brush piles were added to provide cover. The upper half was left in the condition of no cover. Into each half of this pond 500 normal fish and 500 marked fish were released, along with various predator fish. The small experimental pond was covered with chicken-wire screen to prevent bird predation.

Observation of deaths caused by factors other than predation, plus the counts of survivors at several examinations revealed the numbers of fish lost to the predator fish between various dates. Chi-square analysis

of predation loss in the two experiments shows that the losses of marked fish among the predator-caused mortalities was not significantly greater than for normal (unmarked) fish. Statistical analysis shows no significant difference in the growth of marked and unmarked fingerling lake trout in the presence of predatory fish.

Clear-cut results concerning the effect of cover on mortality of marked and normal fish in the presence of predators was not obtained. Unobserved deaths of predator fish in both parts of the split pond invalidated efforts to keep the amount of predation equal at all times in the two experimental enclosures.

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THE COMPARATIVE MORTALITY AND GROWTH OF MARKED AND UNMARKED LAKE TROUT FINGERLINGS IN THE PRESENCE OF PREDATORS

By

David S. Shetter

In the period 1944-1948, over 450,000 fin-clipped lake trout fingerlings were planted in Lakes Michigan and Huron as part of a general study of this valuable food fish by the Great Lakes Lake Trout Committee (Hazzard, 1947). The effects of fin-clipping on growth and survival have been described by Shetter (1951). Dr. W. E. Ricker, formerly a member of the committee, suggested that it would be desirable also to learn what effect the removal of the fins has on the ability of the marked fish to escape predators. Studies on fingerling-size centrarchids in Indiana ponds in the presence of predator fish led to the conclusion by Ricker (1949) that the fin-clipping of young large-mouth black bass resulted in a survival of marked fish only 52 percent as great as unmarked specimens. If a similar effect was caused by removing fins from lake trout fingerlings, it would have an important bearing on the interpretation of the results of the large-scale releases of marked fingerlings in Lakes Michigan and Huron.

This paper describes the results of experiments with marked lake trout fingerlings held in shallow hatchery ponds together with predatory species. The experiments were conducted during the period from October 4, 1948 to October 25, 1949, at the State Fish Hatchery at Marquette, Michigan.

Experimental procedure

Two experiments were initiated. One large-scale experiment involved 4,000 unmarked and 4,000 marked fingerling lake trout placed in the same pond with large brook trout, brown trout, rainbow trout and lake trout as predators. Among the marked fish, 1,000 each were marked by the removal of the dorsal and adipose fins, the right pectoral fin, the left pectoral fin, and the right pelvic fin. The combination and the single fins were clipped in the large-scale planting experiments referred to above. The experimental fish were marked, weighed, counted and placed in the large circular display pool of the hatchery on October 6, 1948. To determine the initial average lengths of the experimental fish, 12.5 percent of each of the groups (taken at random) were measured individually. The predator fish, consisting of two each of adult brook trout, brown trout, rainbow trout, and lake trout, were measured and weighed and introduced on October 7 and 8, 1948.

The pool into which the experimental fingerlings and the predators were placed was approximately 30 feet in diameter and was operated with a water depth of 36 inches. It had vertical sides of stone blocks. The water came from one upright supply pipe capped by a fine-meshed screen several inches above the water level. The outlet was blocked by a fine-meshed screen; the water level was controlled by stop-logs set in a small concrete bulkhead.

A smaller experiment was initiated at the same time in one of the rectangular raceways to run concurrently with the large-scale experiment

in the circular pool. This raceway was divided into two separate experimental ponds by placing a fish-tight stop-screen on sheet-piling, approximately in the middle of the raceway. The upper half (34.5 feet by 8.5 feet) was left in the normal, more or less exposed, condition characteristic of most hatchery ponds where the only cover available is under overhanging grass and sod. The lower half (30 feet by 8.5 feet) had cover added by placing in it four small brush piles located at irregular intervals. Broken paving blocks were loaded on water-logged tamarack and cedar branches to form the shelters. Depth of water in the split pond ranged from 15 inches at the edges to 22 inches in the middle.

Into each part of this pond 500 unmarked lake trout fingerlings were placed, along with 500 marked fish; of the latter, 125 each were given the dorsal-adipose mark, the right pectoral mark, the left pectoral mark, and the right pelvic mark. Marking, counting and sorting took place on October 4, 1948. All fish were measured individually to determine the average sizes of the various groups.

For predator fish, one brown trout and one yellow pike-perch were placed in each half of the experimental pond on October 5, 1948. The predators were changed at a later date for various reasons. To prevent bird predation the entire pond was covered completely with chicken-wire screen (mesh size approximately 1 inch by 1 1/2 inches).

The experiment in the split pond was set up in an attempt to determine if there was any significant difference in the comparative mortalities of marked and normal fish exposed to predators in the presence or absence of escape cover.

All experimental fish were fed a diet of 50 percent pork melts and 50 percent horse hearts. The mixture was finely ground. During the first 6 months, the circular pool was fed 14 pounds of the above mixture weekly,

while the split pond received 6 pounds weekly. During the last 6 months, the two ponds each received 10 pounds of the diet weekly.

Results, Circular pond experiment

It was not practicable to cover this pond to eliminate the possible factor of bird predation on the experimental fish. Thus this pond was probably subjected to predation by birds and mammals (such as mink, otter, and weasel) as well as by the large trout which were introduced. To a certain degree the vertical sides and the greater depth of water probably somewhat limited predation by birds and mammals.

This pond was inspected and the surviving fish were measured on March 8, 1949, May 24, 1949, and on October 25, 1949. The numbers of fish present on those dates are shown in Table 1.

Daily inspection of the pond was carried on by the hatchery staff. All dead fish found were recorded as to the mark borne, or whether they were unmarked fish. It is possible that some fish died and were unobserved between daily inspections or were picked up by scavengers other than the large introduced trout.

Obviously the fish which died from causes other than predation should be eliminated from calculations. Thus to arrive at predator-caused mortality between any two dates, the survivors plus the known mortalities picked up are substracted from the numbers present at the prior date to determine the numbers of fish lost through predation in any time period.

The observed mortalities for the circular pond experiment are given in Table 2. By combination of the data in Tables 1 and 2, the numbers of fish of the various groups lost through predation may be calculated, and these calculations are given in Table 3.

Table 1.--Numbers of experimental lake trout fingerlings present in circular-pond experiment on October 6, 1949, and numbers of survivors at subsequent examinations

Date	Normal fish	Marked fish			
		Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip
October 6, 1948	4,000	1,000	1,000	1,000	1,000
March 8, 1949	665	149	171	176	145
May 24, 1949	378	82	102	94	79
October 25, 1949	91	11	21	23	16

Table 2.---Observed mortalities and calculations on losses to predator fish in circular-pond experiment, October 6, 1948 to October 25, 1949.

Date or item	Normal fish	Marked fish			
		Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip
October, 1948	27	5	11	5	4
November, 1948	3	3	2	7	2
December, 1948	1	1	2	12	2
January, 1949	1	..	2	4	2
February, 1949	..	..	..	..	..
March, 1949					
Before March 8	4	2	..	2	..
After March 8	11	2	2	5	2
April, 1949	..	..	..	..	..
May, 1949	2	..	..	1	1
June-October, 1949	..	..	..	..	..
Observed mortality	49	13	19	36	13
Alive at end	91	11	21	23	16
Known fate	140	24	40	59	29
Lost to predators or by other unknown means.	3,860	976	960	941	971

Table 3.--Numbers of lake trout fingerlings lost to predator fish between indicated dates, circular-pond experiment.

Chi-square values for comparison of normal and marked fish are given under "Marked fish." Under "Normal fish" the chi-square value given is based on a comparison between all normal fish and all marked fish.

Date	Item	Normal fish	Marked fish			
			Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip
October 6, 1948	Number alive	4,000	1,000	1,000	1,000	1,000
March 8, 1949	Number alive	665	149	172	176	145
	Lost to predators	3,299	840	812	794	845
	Chi-square	0.29	1.56	0.17	0.94	2.47
May 24, 1949	Number alive	398	82	102	94	79
	Lost to predators	276	69	67	75	63
	Chi-square	0.06	0.13	0.26	0.18	0.14
October 25, 1949	Number alive	91	11	21	23	16
	Lost tp predators	285	71	81	72	63
	Chi-square	1.79	3.92	0.40	0.02	0.37
October, 1948 to October, 1949	Number alive	91	11	21	23	16
	Lost to predators	3,860	976	960	941	971
	Chi-square	2.12	4.95	0.03	0.00+	1.43

If a significantly larger number of marked than unmarked fish were lost to predators, then fin removal should be considered as a factor in analysis of recoveries from plantings of fin-clipped fingerling lake trout. Chi-square analysis was applied to the data in Table 3 to determine if the differences in numbers of fish lost to predators between marked and normal fish were of significant proportions. Adjusted chi-square values were calculated by the use of the formula given in Snedecor (1948, p. 197), utilizing the four-fold test of independence.

Chi-square values calculated for a comparison between normal fish and each mark used, at the March 8, 1949 and May 24, 1949 examinations, ranged between 0.13 and 2.47. Values for all normal fish compared with all marked fish were 0.29 and 0.06, respectively. When these values were referred to a chart of chi-square (prepared by C. E. Bliss, Department of Pharmacology, Yale University), the percentage chance that the differences observed are significant ranged from 15 to 88.5, all below significant levels.

Chi-square calculations on the comparative losses between normal and marked fish between May 24 and October 25, 1949 were all non-significant, except for the dorsal-adipose group (chi-square = 3.92) where the value obtained was just barely over the 95 percent confidence level. For all normal fish compared with all marked fish for this same period, a non-significant value of 1.79 was obtained.

Over the course of the entire experiment, comparison of losses to predator fish among normal fish and the various groups of marked fish yielded non-significant values of chi-square for the right pectoral mark (0.03), left pectoral mark (0.00+), and the right pelvic mark (1.43). The significant value of chi-square computed for the dorsal-adipose mark (4.95) yields a percentage chance of 97.4 that this mark made these fish more vulnerable to predators. Over the period October 6 to October 25, 1949, comparison of losses to predators between normal fish and all marked fish yielded a non-significant value of chi-square (2.12) corresponding to an 85 percent confidence that the difference is significant.

Growth of the experimental fish in the circular-pond experiment

The average total lengths of the experimental fish used in the circular-pond experiment are given in Table 4, which lists the average total length, standard deviation, standard error and size range of the various groups of fish at the start and at the later examinations. The averages are based on measurements of all fish present except at the initial examination, when a 12.5 percent sample was utilized because of the large number of fish involved.

The growth data have been treated statistically to determine if significant differences in average length were present during the course of the experiment. This analysis will be found in Table 5.

The greatest difference in average lengths observed at any time was between normal fish and right pectoral-clipped fish at the start of the experiment in October, 1948 (2.31 mm.). This difference was significant (t = 4.44). The other groups of marked fish all had average sizes at the start slightly larger than the normal fish, but the statistical tests indicated the differences to be non-significant (t values ranged between 0.93 and 1.48). Grouping all marked fish together and comparing them with the normal fish at the initiation of the study, the marked fish were 0.11 mm. smaller than the normal fish; the statistical tests indicated that this rather minute difference was significant (t = 3.67).

At all other examinations there was no significant difference in average length between any single group of marked fish and normal fish, or between normal fish and all groups of marked fish combined (t values ranged between 0.04 and 1.55).

In general, the experimental fish grew from about 62 mm. in October, 1948 to approximately 154 mm. in October, 1949.

Table 4.--The average size and numbers (in parentheses) of experimental lake trout examined at the four inspections, circular-pond experiment.

Date examined	Item [1]	Experimental group: Normal fish	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip	All marked fish
October, 1948	Average total length	62.16(500)	62.90(125)	59.85(125)	62.66(125)	62.77(125)	62.05(500)
	Standard deviation	5.18	4.91	5.21	5.48	5.75	5.48
	Standard error	0.23	0.44	0.47	0.49	0.51	0.25
	Size range in mm.	44 - 73	50 - 73	47 - 74	46 - 73	39 - 73	39 - 74
March, 1949	Average total length	76.41(665)	75.65(149)	76.14(171)	76.23(176)	76.79(145)	76.20(641)
	Standard deviation	5.62	5.31	6.10	5.37	5.32	5.55
	Standard error	0.22	0.44	0.47	0.41	0.44	0.22
	Size range in mm.	52 - 90	58 - 88	62 - 92	61 - 90	65 - 91	58 - 92
May, 1949	Average total length	95.04(378)	94.01(82)	94.97(94)	94.01(102)	95.47(79)	94.59(357)
	Standard deviation	7.93	8.68	9.14	13.23	7.87	10.12
	Standard error	0.41	0.96	0.94	1.31	0.89	0.54
	Size range in mm.	69 - 115	75 - 115	76 - 118	78 - 111	81 - 108	75 - 118
October, 1949	Average total length	153.09(91)	154.45(11)	154.29(21)	154.52(23)	154.13(16)	154.35(71)
	Standard deviation	37.65	13.95	14.04	11.89	13.27	12.89
	Standard error	3.95	4.21	3.06	2.48	3.32	1.53
	Size range in mm.	129 - 186	125 - 171	134 - 183	134 - 179	128 - 178	125 - 183

[1] Formulae used throughout were:

$M = 2x/n$,

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

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

Table 5.--Statistical comparisons of average total lengths of normal lake trout fingerlings with marked lake trout fingerlings at four inspections, circular-pond experiment.

Date examined	Item [1]	Comparison of normal fish with: Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip	All marked fish
October, 1948	Difference between average total length	0.74	2.31	0.50	0.61	0.11
	Standard error of difference	0.50	0.52	0.54	0.56	0.03
	t value	1.48	4.44	0.93	1.09	3.67
	Percentage chance	86	99+	63	72	99+
March, 1949	Difference between average total length	0.76	0.27	0.18	0.38	0.21
	Standard error of difference	0.49	0.52	0.46	0.49	0.31
	t value	1.55	0.52	0.39	0.78	0.68
	Percentage chance	88	39	32	56	50
May, 1949	Difference between average total length	1.03	0.04	1.03	0.43	0.45
	Standard error of difference	1.04	1.03	1.38	0.98	0.68
	t value	0.99	0.04	0.75	0.44	0.66
	Percentage chance	68	3	55	34	49
October, 1949	Difference between average total length	1.36	1.20	1.13	1.04	1.26
	Standard error of difference	5.77	5.00	4.66	5.16	4.24
	t value	0.24	0.24	0.24	0.20	0.30
	Percentage chance	19	19	19	16	23

[1] Formulae used throughout were:

$$\text{Standard error of mean difference} = \sqrt{(SE_1)^2 + (SE_2)^2}$$

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

The analysis of the average lengths of the survivors indicates that the marked fish in this experiment suffered no disadvantage as far as growth was concerned when compared with normal fish. The differences in average length between marked and unmarked survivors after the start of the experiment can be demonstrated to be non-significant.

Growth of the predator fish

The size of the predators at the start and at the various examination dates are given in Table 6. One brook trout died on November 4, 1948 and was not replaced. To assure that a reasonable number of survivors would be alive in October, 1949, the predators were reduced to one each of brook, brown, rainbow and lake trout after the March, 1949, examination. One brook trout and one brown trout died and were replaced after the March, 1949, check.

The growth noted by measuring and weighing the large fish at each examination was not consistent, and there appears to have been some weight loss among the brook and brown trout, between October, 1948, and March, 1949, caused apparently by shedding of gonadal products. Also one rainbow trout appeared to lose in length as a result of injuries to his tail incurred in attempted spawning activities. The greatest gains noted were among the predator lake trout.

Results, split-pond experiment

The same general procedure was used in this experiment as in the study in the circular-pond, except that five instead of three inspections were made during the 12 months. The additional inspections were undertaken one week after the start and 2 1/2 months later in mid-January. Table 7 lists the numbers of experimental fish in the split pond at the

Table 6.--Growth history of the predator fish in the circular-pond experiment.

(Lengths are given in millimeters, weights, in pounds)

Date checked	Brook trout[1] L - W	Brook trout[2] L - W	Brown trout L - W	Brown trout[3] L - W	Rainbow trout L - W	Rainbow trout L - W	Lake trout L - W	Lake trout L - W
October, 1948	355-1.30	335-1.20	520-4.30	516-4.60	460-2.90	538-4.40	490-2.50	470-2.10
March, 1949		350-1.10	520-3.75	516-3.50	500-3.00	529-4.00	520-2.50	520-2.80
May, 1949		384-1.83		514-3.97		541-4.25		541-3.88
October, 1949		397-1.88		470-3.00		579-4.75		578-3.50

[1] Died November 4, 1948, at 356 millimeters, 1.25 pounds.

[2] Died March 24, 1949, at 350 millimeters, 1.10 pounds; replaced April 5, 1949 by brook trout of 368 millimeters, 1.50 pounds.

[3] Died May 24, 1949, at 514 millimeters, 3.97 pounds; replaced same day with brown trout of 397 millimeters, 1.75 pounds.

Table 7.—Numbers of experimental lake trout fingerlings present in the split-pond experiment on October 4, 1949, and numbers of survivors at subsequent examinations.

Date	In pond with no cover					In pond with cover				
	Normal fish	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip	Normal fish	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip
October 4, 1948	500	125	125	125	125	500	125	125	125	125
October 11, 1948	473	105	122	116	116	474	121	117	122	115
January 17, 1949	223	46	56	51	56	319	78	89	83	89
March 9, 1949	168	35	48	39	42	259	59	70	65	66
May 24, 1949	72	6	20	14	21	200	43	52	43	49
October 25, 1949	10	0	2	1	2	79	15	18	23	22

start, and the numbers of survivors found at subsequent inspections. The observed mortalities picked up from the split pond are recorded in Table 8, along with the calculated numbers of fish lost through predation.

As in the circular-pond experiment, combination of data on survival and observed mortalities makes possible the calculation of predation-caused mortalities between any two dates. Table 9 presents the calculations for the split pond, along with chi-square values which compare the losses of normal fish to losses of marked fish among the predation-caused deaths between any two dates.

Chi-square values were calculated in the manner described on a previous page. In Table 9, the two significant values of chi-square found are underlined. Both occurred in comparisons between dorsal-adipose fish and normal fish. Removal of the dorsal and adipose fins apparently made fingerling lake trout significantly more vulnerable to predator fish between October 5 and October 11, 1948 (chi-square = 16.05) in the pond with no cover. In the same pond and for comparisons of the same two groups of fish, a significantly greater loss of dorsal-adipose fish occurred between March 9 and May 24, 1949 (chi-square = 7.63). However, all other chi-square values calculated for the other fin combinations and periods involving the pond without cover are small and non-significant (or in one instance the value is significant and in an opposite direction).

In the pond with cover, losses of marked fish, when compared with losses of normal fish to the introduced predators, were no more than were to be expected by chance selection. Only in one instance (right pelvic mark, between October 11, 1948 and January 17, 1949) was there a significant value found for chi-square (4.76), and that involved better survival of marked fish. For all other comparisons, chi-square values were non-significant, ranging from 0.00+ to 3.63.

All comparisons for the entire period of the experiment yielded non-significant chi-square values.

Table 8.—Observed mortalities and calculations on losses to predator fish in split-pond experiment, October 4, 1948, to October 25, 1949.

Date or item	In pond with no cover					In pond with cover				
	Normal fish	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip	Normal fish	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip
October, 1948										
Before October 11	8	2	2	2	..	1	1	0	..	1
After October 11	3	2	1	3	..	10	..	2	..	1
November, 1948	..	..	1	..	..	..	..	1	..	..
December, 1948	1	..	1	..	..	..	..	..	1	..
January, 1949										
Before January 17	6	6	1	4	1	13	4	1	4	4
After January 17	..	..	..	..	..	..	..	..	..	..
February, 1949	..	..	..	..	..	..	..	..	..	..
March, 1949										
Before March 9	3	..	..	2	2	4	..	..	3	..
After March 9	8	1	..	..	..	4	2	1	..	..
April to October, 1949	..	..	..	..	..	..	..	..	..	..
Observed deaths	29	11	6	11	3	32	7	3	8	6
Known survivors	10	0	2	1	2	79	15	18	23	22
Known fate	39	11	8	12	5	111	22	23	31	28
Loss by predation	461	114	117	113	120	389	103	102	94	97

Table 9.--Numbers of lake trout fingerlings lost to predator fish between indicated dates, split-pond experiment.

Chi-square values for comparison between marked and normal fish are given under the marks listed. Under "Normal fish" the chi-square values given are for comparison between all marked and all normal fish.

Date and item	Pond without cover					Pond with cover				
	Normal fish	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip	Normal fish	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip
October 4, 1948										
Alive	500	125	125	125	125	500	125	125	125	125
October 11, 1948										
Alive	471	105	122	116	116	474	121	117	122	115
Lost	21	18	0	8	9	25	4	8	3	10
Chi-square	3.14	16.05	4.17	0.62	1.27	0.02	0.39	0.16	1.04	1.17
January 17, 1949										
Alive	223	46	56	51	56	319	78	89	83	89
Lost	238	51	63	57	59	132	38	24	34	20
Chi-square	0.03	0.00+	0.02	0.01	0.00+	1.44	0.38	2.53	0.01	4.76
March 9, 1949										
Alive	168	35	48	39	42	259	59	79	65	66
Lost	52	11	8	10	12	56	19	19	15	23
Chi-square	0.62	0.02	1.77	0.08	0.00+	2.07	1.35	0.37	0.00+	2.38
May 24, 1949										
Alive	72	6	20	14	21	200	43	52	43	49
Lost	88	28	28	25	21	55	14	17	22	17
Chi-square	1.62	7.63	0.06	0.72	0.16	1.93	0.10	0.15	3.63	0.32
October 25, 1949										
Alive	10	0	2	1	2	79	15	18	23	22
Lost	62	6	18	13	19	121	28	34	20	27
Chi-square	0.58	0.12	0.01	0.06	0.02	0.01	0.15	0.24	2.30	0.28
October 4, 1948 to October 25, 1949										
Alive	10	0	2	1	2	79	15	18	23	22
Lost	461	114	117	113	120	389	103	102	94	97
Chi-square	1.06	1.36	0.00+	0.24	0.00+	0.08	0.93	0.13	0.33	0.08

The effect of cover

To test the effect of cover, chi-square analysis was employed on the losses to predators in the pond with cover and without cover for marked fish only and also of all fish combined. This was done for each examination and also for the final results. The data on this point are summarized in Table 10.

For both sets of comparisons there were significantly fewer mortalities in the pond with cover up to January 17. Between January 17 and March 9, there were significantly fewer mortalities due to predation in the pond without cover. Between March 9 and May 24, the pond with cover had significantly fewer deaths as a result of predation, but between May 24 and October 25 the situation was reversed again. If all mortalities (either among marked fish, or all fish combined) are compared from the two enclosures, there were significantly fewer mortalities as a result of predation in the pond with cover.

History of predators in the split pond

It is necessary to consider the course of predation in this experiment closely. To satisfy experimental conditions, both ponds should have been subjected to the same amount of predation if all conditions except the factor of cover were to be equal. Despite our efforts the amount of predation was not always equal in the two ponds (Table 11). Between October 5 and October 11, 1949, a rock bass was present in the pond with cover. This fish had escaped observation at the initiation of the experiment. Also in the pond with cover the predatory lake trout apparently was removed by some unknown agent and at some unknown date between October 11 and January 17. In this same pond the brook trout predator died in late March and was not replaced for 11 days.

Table 10.--Comparative losses to predation of (a) all marked fish, and (b) all fish in pond with cover and pond with no cover, with chi-square values for periods between the indicated dates.

Date and item	Marked fish			All fish		
	No cover	Cover	Chi-square	No cover	Cover	Chi-square
October 4, 1948						
Alive	500	500	....	1,000	1,000	....
October 11, 1948						
Alive	459	485	....	930	949	....
Lost to predators	35	25	1.55	56	50	0.32
January 17, 1949						
Alive	209	339	....	432	658	....
Lost to predators	230	116	67.01	468	248	113.42
March 9, 1949						
Alive	164	260	....	332	519	....
Lost to predators	41	76	0.37	93	132	0.31
May 24, 1949						
Alive	61	187	....	133	387	....
Lost to predators	102	70	50.07	190	125	98.35
October 25, 1949						
Alive	5	78	....	15	157	....
Lost to predators	56	109	21.73	118	230	37.05
October, 1948 to October, 1949						
Alive	5	78	....	15	157	....
Lost to predators	464	396	67.45	925	785	126.89

Table 11.--Growth history of predator fish in the split-pond experiment

Lengths (L) are given in millimeters, weights (W) are given in pounds.

The numbers of predator-days are given in parentheses.

Date	Predators in pond without cover				Predators in pond with cover				
	Brown trout[1] L - W	Yellow pike-perch[1] L - W	Lake trout[2] L - W	Brook trout L - W	Brown trout[1] L - W	Yellow pike-perch[1] L - W	Lake trout[2] L - W	Brook trout L - W	Rock bass[1] L - W
October 5, 1948	345-0.75 (6)	549-3.20 (6)	310- (3)		259-0.50 (6)	510-2.25 (6)	315- (3)		187-0.41 (6)
October 11, 1948	345-0.75	549-3.20	310- (98)	310- (98)	259-0.50	510-2.25	315- (?)	318- (98)	187-0.41
January 17, 1949			330-0.62 (51)	315-0.75 (51)			346-0.84[4] (51)	328-0.91 (51)	
March 9, 1949			336-0.61 (76)	321-0.72 (76)			354-0.84 (76)	330-0.91[5] (65)	
May 24, 1949			340-0.67 (?)	335-0.77 (154)			372-1.03 (154)	383-156 (154)	
October 25, 1949	(6)	(6)	[3] (228+?)	362-1.31 (379)	(6)	(6)	433-1.56 (2[illegible]1)	406-1.81 (368)	(6)

[1] These fish removed October 11, 1948.

[2] These fish put in October 8, 1948

[3] This fish disappeared sometime between May 24, 1949 and October 25, 1949.

[4] This fish disappeared sometime between October 11, 1948 and January 17, 1949, and another of the indicated size put in on January 17, 1949.

[5] This fish died April 24, 1949 at a size of 339 millimeters, 1.12 pounds. It was was replaced on April 5, 1949 with a brook trout of 368 millimeters, 1.32 pounds.

All predators were present in the pond with no cover between October 5, 1948 and May 24, 1949. Sometime between the latter date and October 25, 1949, the predatory lake trout was removed, as there was no evidence of this fish when the experimental pond was finally drained.

During the first week of confinement, no advantage can be demonstrated for cover (chi-square values insignificant; marked fish, 1.55; all fish, 0.32). At the January and May examinations, where chi-square values suggested that cover was a favorable factor, it was found that one predator fish had been missing from the pond with cover in the period immediately preceding the examination for an unknown length of time. Failure to maintain an equal number of predators in both ponds at all times very likely influenced the observed results.

For the course of the entire experiment, however, it can be shown that the pond with cover was subjected to a slightly greater number of predator-days (670 observed predator-days as against 619 for the pond without cover).

The measurements on the predators at the various inspections indicated that growth was more regular and of a more positive nature than was observed in the circular-pond experiment.

Growth of the experimental lake trout, split pond

The average total lengths (in millimeters) along with the standard deviation and the standard error are given in Table 12 for each group of experimental fish in the two parts of the split pond. The survivors were measured on four different dates after the start of the experiment. The "t" test was employed to determine if the differences in average length between marked fish and normal fish were significant. The results of the statistical analyses are contained in Table 13.

Table 12.--The average size and numbers (in parentheses) of experimental lake trout fingerlings examined at various dates, split-pond experiment. Size range is given in millimeters

Item	Pond without cover					Pond with cover				
	Normal fish	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip	Normal fish	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip
October, 1948										
Mean	59.86(500)	59.40(125)	61.30(125)	61.03(125)	61.05(125)	61.41(500)	63.17(125)	63.19(125)	62.66(125)	64.03(125)
σ	5.39	5.97	5.04	5.62	5.40	4.94	4.76	4.38	5.48	4.93
S.E.	0.24	0.53	0.45	0.50	0.48	0.22	0.43	0.39	0.25	0.44
Size range	45-72	47-72	44-73	46-74	44-72	50-72	50-75	52-73	50-73	52-77
January, 1949										
Mean	70.52(223)	70.35(46)	72.00(56)	71.41(51)	71.45(56)	74.84(319)	76.12(78)	75.96(89)	76.69(83)	76.89(89)
σ	5.05	6.13	3.69	6.43	3.34	5.19	5.22	4.49	4.40	5.60
S.E.	0.34	0.90	0.49	0.90	0.45	0.29	0.19	0.48	0.48	0.59
Size range	54-81	55-79	62-81	58-81	58-81	62-86	64-93	65-87	63-84	65-94
March, 1949										
Mean	73.15(168)	73.86(35)	74.65(48)	75.13(39)	74.83(42)	77.49(259)	78.61(59)	78.63(70)	79.71(65)	79.32(66)
σ	3.47	3.75	3.91	5.68	3.64	5.15	5.31	4.85	4.32	5.83
S.E.	0.27	0.64	0.56	0.91	0.56	0.32	0.69	0.58	0.54	0.72
Size range	57-84	67-88	65-82	62-87	61-84	65-91	67-94	67-91	68-88	66-97
May, 1949										
Mean	82.88(72)	80.00(6)	83.70(20)	80.71(14)	85.48(21)	91.01(200)	93.91(43)	92.42(52)	92.60(43)	94.53(49)
σ	5.45	7.62	5.61	5.24	6.09	7.88	6.77	5.97	6.01	7.36
S.E.	0.64	3.11	1.25	1.40	1.33	0.56	1.03	0.83	0.92	1.05
Size range	68-98	66-87	72-93	72-93	72-98	75-110	84-110	80-103	80-104	76-111
October, 1949										
Mean	118.90(10)	...	126.00(2)	121.00(1)	127.00(2)	139.47(79)	149.07(15)	141.56(18)	141.22(23)	143.82(22)
σ	13.52	...	2.00	0.00	15.56	12.79	11.68	12.43	11.09	11.97
S.E.	4.28	...	1.41	0.00	11.00	1.44	3.02	2.93	2.31	2.55
Size range	98-140	...	125-127	121	116-138	110-168	133-168	111-173	111-157	111-164

Table 13.--Statistical comparison of average total lengths of normal and marked lake trout fingerlings at various inspections, split-pond experiment. (See footnotes in Table 5 for formulas and procedures.)

Item	Pond without cover - comparison of normal fish with					Pond with cover - comparison of normal fish with				
	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip	All marked fish	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip	All marked fish
October, 1948										
Diff.	-0.46	+1.44	+1.17	+1.19	+0.84	+1.76	+1.78	+1.25	+2.62	+1.85
S.E.	0.58	0.51	0.55	0.54	0.35	0.48	0.45	0.33	0.49	0.31
t	0.79	2.82	2.13	2.20	2.40	3.67	3.96	3.79	5.35	5.97
%	57	99	97	97	98	100	100	100	100	100
January, 1949										
Diff.	-0.17	+1.48	+0.89	+0.93	+0.82	+1.28	+1.12	+1.85	+2.05	+1.58
S.E.	0.96	0.60	0.96	0.56	0.49	0.35	0.56	0.56	0.66	0.40
t	0.18	2.47	0.93	1.66	1.67	3.66	2.00	3.30	3.11	3.95
%	14	98	64	90	91	100	95	100	100	100
March, 1949										
Diff.	+0.71	+1.50	+1.98	+1.68	+1.49	+1.12	+1.14	+2.22	+1.83	+1.60
S.E.	0.69	0.62	0.95	0.62	0.43	0.76	0.66	0.63	0.79	0.45
t	1.03	2.42	2.08	2.71	3.47	1.47	1.73	3.52	2.32	3.56
%	70	98	96	99	100	86	92	100	98	100
May, 1949										
Diff.	-2.88	+0.82	-2.17	+2.60	+0.38	+2.90	+1.41	+1.59	+3.52	+2.35
S.E.	3.18	1.40	1.54	1.48	1.05	1.17	1.00	1.08	1.19	0.74
t	0.91	0.59	1.41	1.76	0.36	1.48	1.41	1.47	2.96	3.18
%	63	43	84	92	28	86	84	86	99	99
October, 1949										
Diff.	....	+7.10	+2.10	+8.10	+6.50	+9.60	+2.09	+1.75	+4.35	+4.07
S.E.	....	4.51	4.28	11.80	5.63	3.35	3.26	2.72	2.93	1.97
t	....	1.57	0.49	0.69	1.15	2.87	0.64	0.64	1.48	2.07
%	....	88	38	51	75	100	48	48	86	96

At the start of the experiment, marked lake trout fingerlings as a group were of slightly larger average size in both parts of the split pond than were the normal fish. Except for the dorsal-adipose-marked fingerlings in the pond without cover, the differences observed were statistically significant (t values ranged from 2.13 to 5.97).

In the pond with cover during the remainder of the year, marked fish as a group were always significantly larger than normal fish (t values ranged from 2.07 to 3.95).

After the experiment's beginning in the pond without cover, marked fish as a group were significantly larger only at the March, 1949, examination. At the January, May, and October, 1949, inspections, the differences between marked and normal fish were nonsignificant.

From the analysis of the results observed it is concluded that the removal of fins and later placement of marked fish among predator fish has had no retarding effect on the rate of growth of marked lake trout fingerlings.

At all times throughout the experiment both normal fish and marked fish in the pond with cover were of larger average size than their counterparts in the pond without cover. The "t" test indicated that these differences were significant (t for normal fish ranged between 4.6 and 14.1, t for marked fish varied between 4.6 and 23.2). The differences in average lengths between the experimental groups of fish confined in the two ponds increased during the course of the experiment. A possible explanation for the more rapid growth of the experimental fish confined in the pond with cover is that this pond was the lowermost of the two. In this position it may have received more food. An unknown amount of finely ground food placed in the pond without cover could be carried by the water current through the separating screen to the pond with cover.

Discussion

The results obtained, in both the large-scale experiment in the circular pond and the two small-scale tests in the split pond, yield the same conclusions: (1) that fin removal did not increase losses of marked fingerling lake trout to predatory fish to any greater degree than might be expected on a basis of chance selection, and (2) that the marking process did not cause any retardation of growth of the marked lake trout fingerlings so exposed.

It might be argued that the dorsal-adipose fish in the circular-pond experiment were adversely affected by the marking process and were significantly more vulnerable to predation. However, dorsal-adipose fish in the split-pond experiments were not found to be significantly more subject to predation than normal fish, according to the chi-square calculations for the entire year of observation. None of the chi-square calculations showed any consistent trend that indicated that marked fish were at a disadvantage as far as being more subject to predation than were normal fish. Chi-square values determined for the comparison of losses to predation of all marked fish and normal fish were non-significant in all three experiments over the entire year of observations.

Because predation was not maintained in equal amounts at all times in the ponds with cover and without cover, clear-cut results were not obtained concerning the effect of cover on the mortality of marked fingerling lake trout. However, total results suggest that cover very likely is a favorable factor in keeping mortality from predation at a lower level than in situations where no cover is present.

These experiments, although conducted under habitat conditions very unlike the natural haunts of fingerling lake trout, intimate strongly that the marked fish released in the Great Lakes have not suffered greater mortalities as a result of predation than have the unclipped lake trout fingerlings planted at the same time.

Acknowledgments

I wish to thank Russell Robertson, Hatchery Supervisor, and his staff at the State Fish Hatchery, Marquette, Michigan, for assistance received in handling the experimental fish, recording mortalities, and other aid as the need arose.

Dr. L. N. Allison, Fish Pathologist, Stanley Lievense, District Fisheries Supervisor, and R. F. Stinauer, Fisheries Technician, assisted me at various times with the sorting and recording. I am grateful for their help.

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