ISSUE TWENTY
AUGUST-1957

THE CANADIAN FISH CULTURIST

Published at Ottawa by
The Department of Fisheries of Canada

CONTENTS

	Page
Comparative Survival and Growth of Tagged and Untagged Brook Trout—M. W. SMITH......................	1
Survival and Growth of Wild and Hatchery Rainbow Trout (*Salmo gairdnerii*) in Corbett Lake, B.C.—S. B. SMITH..	7
Increase in Levels of Lactic Acid in the Blood of Cutthroat and Steelhead Trout Following Handling and Live Transportation—EDGAR C. BLACK and ISADORE BARRETT...	13
Introduction of the Hybrid Between the Eastern Brook Trout and Lake Trout into the Great Lakes—JOHN BUDD....	25
Management, Fishing Results and Growth of Speckled Trout (*Salvelinus fontinalis*) in Baldwin Pond, Stanstead County, Que.—RICHARD L. SÉGUIN.....................	29
Lea's Hydrostatic Tag on Brook Trout and Atlantic Salmon Smolts—M. W. SMITH............................	39

The Canadian Fish Culturist is published under the authority of the Minister by the Department of Fisheries of Canada as a means of providing a forum for free expression of opinion on Canadian fish culture. In the areas of fact and opinion alike, the responsibility for statements made in articles or letters rests entirely with the writers. Publication of any particular material does not necessarily imply that the Department shares the views expressed. In issuing The Canadian Fish Culturist the Department of Fisheries is acting only as an instrument for assisting in the circulation of information and opinion among people in the fish culture field. Those who may wish to discuss articles which have been published in The Canadian Fish Culturist are encouraged to do so and space will be made available.

Correspondence should be addressed to the DIRECTOR, INFORMATION AND EDUCATIONAL SERVICE, DEPARTMENT OF FISHERIES, OTTAWA, CANADA.

Published under Authority
of
HON. J. ANGUS MACLEAN, M.P.,
Minister of Fisheries

Comparative Survival and Growth of Tagged and Untagged Brook Trout

by

M. W. Smith

Fisheries Research Board of Canada, Biological Station, St. Andrews, N.B.

Jaw-tags have been used in a study of the movements and populations of the eastern brook trout (*Salvelinus fontinalis*) in Prince Edward Island streams (Smith, 1951; Smith and Saunders, 1956). However, possible effects of these tags upon the well-being of the trout have not been assessed. To obtain information of this sort, tagged and untagged brook trout were held in two Prince Edward Island ponds, one (Simpson's) of 2.3 and the other (Stevenson's) of 3.0 acres in area.

Procedure

On September 23-24, 1954, equal numbers (367) of tagged and untagged trout, age 1, were planted in Stevenson's Pond. The survival and growth of these trout were determined 248 days later on May 30, 1955, by draining the pond. On June 3-4, 1955, 333 tagged and 330 untagged trout, age 1, were also planted in Simpson's Pond. Assessment of survival and growth was made 108 days later on September 20-22, 1955. The ponds were drained prior to the planting, and any trout removed.

The ponds have been formed on small spring-fed streams and are readily drained to the original stream bed. The trout were efficiently recaptured on draining by trapping at the dams as the water was lowered (the majority of the fish were accounted for in this way) and by liming the stream to drive down any remaining individuals. Self-cleaning screens at the dams, and barriers at the heads of the ponds prevented escapement of the trout.

The tags employed were of the strap variety, 3.5 x 0.3 cm. in dimensions (number 2, Salt Lake Stamp Company). The tags were serially numbered. They were applied in a circular form around the mandible of the fish (Fig. 1). The ends of the tags overlapped and were pressed together, but not clinched. Rupp (Anon. 1952) and Horrocks (Anon. 1956) have devised pliers for applying this strap jaw-tag. To distinguish the trout in the event that tags were lost, the tagged individuals had the adipose and right ventral, and the untagged, the adipose and left ventral, fins removed. The fork length of each trout was measured on planting and on recovery. Except in June, 1955, at Simpson's Pond, when they were weighed in groups of ten, the weight of each trout was determined to the nearest quarter-of-an-ounce. The mean weights have been converted to grams in Table II.

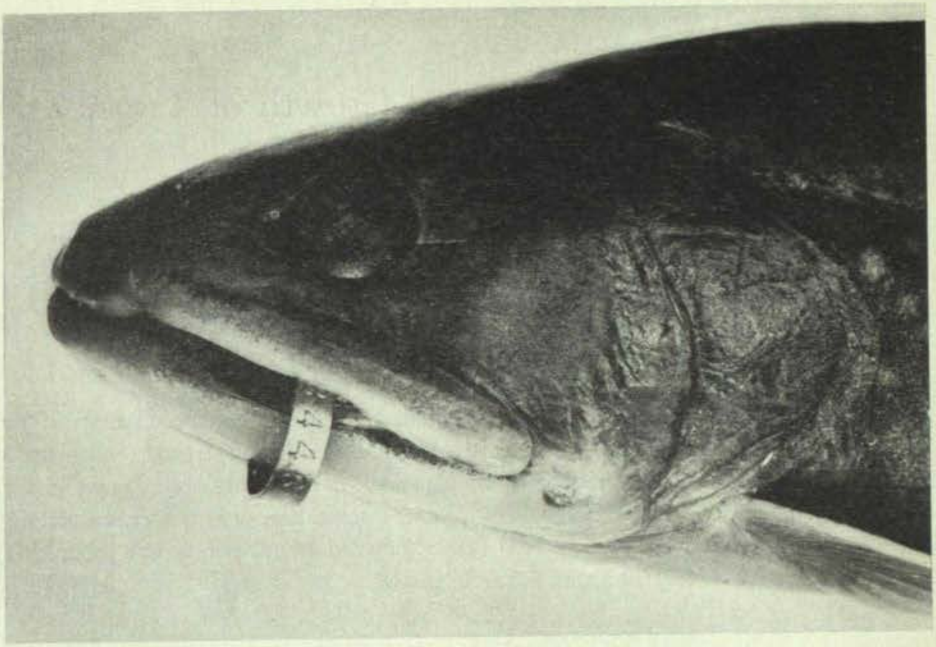


Figure 1.—Head of 24-centimetre brook trout showing attachment of circular jaw-tag.

Survival

The numbers of tagged and untagged trout that were planted and the numbers recovered on draining the ponds are given in Table I. Differences in the percentage recovery between the tagged and untagged trout were small. A somewhat better recovery of tagged trout was found when the fish were held over winter in Stevenson's Pond. The reverse situation was experienced for the summer period in Simpson's Pond.

In tagging, the trout may suffer ill-effects not only from carrying the tag, but also from the necessary handling in capture and application of the tag. In our tests the untagged trout were marked by fin-clipping. They were handled about as much as those that were tagged. The carrying of the tag was the principal difference experienced by the two groups. It may be concluded from the data that the carrying of the tag did not affect the survival of the trout adversely.

Growth

The length and weight of the tagged and untagged trout when planted and on recapture are given in Table II. In both Stevenson's and Simpson's ponds the untagged trout gained more in length and weight, but this gain was the greater in the former pond. (The difference in mean length on recovery between the tagged and untagged trout from Stevenson's Pond is significant at the 1 per cent level.) The apparent effect of the tag upon growth was most adverse when the trout were held longer and over a winter period.

In either pond both groups of trout were subjected to the same environmental conditions and had a common food supply. Almost the only difference in treatment of the two groups was the tagging. With other factors comparable, growth may be considered almost entirely as a function of feeding. Our results suggest that the jaw-tagging interfered to a moderate degree with the ability of the trout to feed and resulted in the differences in growth between the tagged and untagged fish. Rounsefell and Everhart (1953) point out that the jaw-tag "has been criticized on the grounds that there is evidence that fish so tagged do not feed properly".

The relative heaviness of the trout, as expressed by the condition factor K and determined from the relationship, weight $\times$ 100 = K (length)^3, was calculated from the mean length and weight of the trout (Table III). The untagged trout on recovery from Stevenson's Pond had the higher condition factor. The result is in keeping with that reported by Schuck (1942) upon the effects of jaw-tagging brown trout in Crystal Creek, New York. He found that tagged wild brown trout were significantly lighter for their length than untagged individuals after being at large for one and two years. However, the results from Simpson's Pond, in which the trout were held only over a summer period, are not in agreement. Actually the untagged trout were lighter in weight for their length. The differences in results suggest that the longer the tags are carried, more adverse are the effects.

It is pertinent to note that the tagged trout recovered from Stevenson's and Simpson's ponds exhibited no pathological condition arising from the tags.

Loss of Tags

It was possible to determine whether tags were lost since the tagged trout also had the adipose and right ventral fins removed. It was found that the loss of tags from trout held over winter in Stevenson's Pond was considerable. Twenty-eight per cent of the trout that had been tagged and were recaptured (195) lost the tags during the 248 days in the pond. In contrast, no tags had been lost by the tagged trout (233) recovered from Simpson's Pond after being held a 108-day summer period. The time interval at large may have been a factor in the differences in loss of tags. The trout were held in Stevenson's Pond about twice the length of time that those were retained in Simpson's.

The size of fish may also have been an important factor in the loss of tags. When recaptured in Stevenson's and Simpson's ponds the mean lengths of the tagged trout were 26.2 and 21.4 cm., respectively. At Stevenson's Pond the recaptured tagged trout still retaining the tags was 26.0 cm., while those that had lost them averaged 26.5 cm. The difference in mean length was small, but suggested that the larger individuals were more prone to lose tags. The tags were not clinched when applied. The ends of the tags may spring apart as the fish become larger and make loss of the tags easier.

Some evidence was previously obtained from trout held in rearing ponds at the Saint John, N.B., fish hatchery of the federal Department of Fisheries, that the tag employed in our studies at Stevenson's and Simpson's ponds was too small for fish approximately 30 cm. in length. Of 98 trout tagged on July 16, 1947, at a mean length of 21.7 cm., 17 per cent lost the tags by December 3 of the same year. However, 83 per cent of the tags were lost by the following April. At that time the trout still retaining the tags averaged 29.9 cm. in length. The tags that held firm were becoming embedded in the mandible. Shetter (1936) found that there was a heavy loss of tags which were not sufficiently large to accommodate increase in size of the mandible.

It was indicated by observations at Stevenson's Pond that fin-clipping should be combined with tagging to evaluate properly the effects of the tags on survival and growth. Although certain of the trout that had lost tags could be identified from wound scars which resulted from applying the tags, it was noted that such wounds apparently may heal thoroughly. Previously tagged trout could be easily overlooked.

Summary

Jaw-tags on brook trout had no demonstrable effect upon survival in cool waters and when held for periods of less than one year. However, growth was retarded, presumably through interference with feeding. Growth was more retarded in ponds when the trout were held for 248 days over a winter period, than when retained 108 days in the summer season. A growth correction factor is indicated for tagged trout, but the correction will vary in magnitude with length of time and conditions under which the trout are held. Trout which have lost tags are not always recognizable from wounds caused by tagging. Fin-clipping provides identification of such fish.

Acknowledgments

The assistance in the field of J. W. Saunders, C. R. Hayes, and Cyril Williams is gratefully acknowledged. This paper is published with permission of the Fisheries Research Board of Canada.

Table I

Survival of tagged and untagged trout in ponds

I. Stevenson's Pond

——	Planted Sept. 23-24, 1954	Recovered May 30, 1955
Number tagged	367	195 (53.1%)
Number untagged	367	186 (50.7%)

II. Simpson's Pond

——	Planted June 3-4, 1955	Recovered Sept. 20-22, 1955
Number tagged	333	233 (70.3%)
Number untagged	330	244 (73.9%)

Table II

Mean length and weight, with standard deviation, of tagged and untagged trout in ponds. Length in centimetres and weight in grams. Number of trout in samples in brackets.

I. Stevenson's Pond

—	When planted Sept. 23-24, 1954		When recovered May 30, 1955	
	Tagged	Untagged	Tagged	Untagged
Mean length	22.6±1.72 (200)	22.5±1.95 (200)	26.2±1.87 (191)	26.7±1.75 (188)
Mean weight	139±35.7 (200)	136±39.1 (200)	203±51.9 (190)	221±47.3 (185)
Gain in length	—	—	3.6	4.2
Gain in weight	—	—	64	85

II. Simpson's Pond

—	When planted June 3-4, 1955		When recovered Sept. 20-22,1955	
	Tagged	Untagged	Tagged	Untagged
Mean length	17.1±1.88 (333)	16.8±2.45 (330)	21.4±1.89 (230)	21.6±2.58 (240)
Mean weight	62 (333)	60 (330)	122±36.0 (178)	122±46.2 (182)
Gain in length	—	—	4.3	4.6
Gain in weight	—	—	60	62

Table III

Relative heaviness, expressed by the condition factor K, of tagged and untagged trout.

—	When planted	When recovered
I. Stevenson's Pond		
Tagged	1.20	1.13
Untagged	1.20	1.17
II. Simpson's Pond		
Tagged	1.25	1.24
Untagged	1.26	1.21

Literature Cited

ANONYMOUS. 1952. *Pliers for tagging fish with flat fingerling strap tags.* Progressive Fish-Culturist, 14(1): 32.

1956. *Improved pliers for applying ring tags.* Progressive Fish-Culturist, 18(2) : 91.

ROUNSEFELL, GEORGE A., and W. HARRY EVERHART. 1953. Fishery Science. Its methods and applications. John Wiley and Sons, New York, 444pp.

SCHUCK, HOWARD A. 1942. *The effect of jaw-tagging upon the condition of trout.* Copeia, 1942, pp. 33-39.

SHETTER, DAVID S. 1936. *The jaw-tag method of marking fish.* Papers of the Michigan Academy of Science, Arts, and Letters, 21, pp. 651-653, 1935.

SMITH, M. W. 1951. *The speckled trout fishery of Prince Edward Island.* Canadian Fish Culturist, No. 11, pp. 1-6.

SMITH, M. W. and J. W. SAUNDERS. 1956. *Efficiency of year-round operation of trout counting fences on a small stream.* Canadian Fish Culturist, No. 18, pp. 6-19.

Survival and Growth of Wild and Hatchery Rainbow Trout *(Salmo gairdnerii)* in Corbett Lake, British Columbia

by

S. B. Smith

British Columbia Game Commission, Vancouver, B.C.

Many workers have shown that success of planting hatchery trout in streams is limited by a variety of conditions. It has also been clearly demonstrated that catches by anglers of planted fish may be expected to decrease rapidly in proportion to the lapse of time following release of the fish. At the same time, survival rate of hatchery trout through the winter months generally is very low. At least one of the causes of mortality following planting of hatchery trout in streams has been shown by Miller (1952) to stem from exhaustion of hatchery trout as they attempt to maintain themselves in a stream already populated by wild trout. Since Schuck (1948) and Miller (1952) have provided comprehensive literature reviews with their published works, it would appear to be unnecessary further to summarize the results of previous investigations on this problem. Data appear to be lacking on the survival of hatchery fish in lakes in which wild populations of the species to be planted already are established. Commonly it has been observed, for Centrarchidae at least, that where adequate natural spawning exists, little can be done by additional plantings from hatcheries to supplement natural production of wild stocks. Most of the lakes in British Columbia, which receive artificial plantings of hatchery trout, lack adequate spawning facilities or spawning streams are intermittent or marginal in nature. Generally these lakes are stocked with fry, unless they also contain predator or competitor species, in which case it has been the practice to plant larger fingerlings or yearling trout.

Some of the larger plantings of fingerling and yearling trout are made in lakes which also have good spawning streams and which support sizeable spawning runs of trout each year. The question arises as to whether it is economically feasible to supplement this natural production with hatchery plantings. Creel census records and marking experiments (Smith, 1955b) indicated a yield to anglers of planted yearling trout in at least one artificially stocked lake to be 30 per cent or greater in the first year following planting of hatchery fish. Additional data are required before it can be determined whether this rate can be equalled or exceeded in all artifically planted lakes in the face of completely unrestricted natural reproduction. It therefore becomes important that an understanding be gained of the factors affecting hatchery trout following release from an obviously artificial and protective environment, particularly if they are to be subjected to conditions under which they must compete with wild fish of their own species. The following summarizes data obtained from experimental plantings of wild and hatchery trout in a small lake in southern British Columbia.

Parent Stock and Rearing Methods

Fish for the experimental plantings were obtained from wild stock at the B.C. Game Commission trout egg-station at Beaver Lake, near Kelowna, B.C. in 1952. Some of these fish were released as fry into natural ponds at Kelowna, while others of the same stock were reared at the B.C. Game Commission trout hatchery at Summerland, B.C. In May, 1953, about 3,000 yearling trout were removed from the Kelowna ponds and transferred to Summerland, where 1,500 were marked by removal of the right pelvic fin. At the same time, 1,500 yearlings of the same stock which had been reared at Summerland were marked by removal of the left pelvic fin. The two groups of fish were then transferred to the same holding pond and retained together for about 10 days, when they were released into Corbett Lake, near Merritt, B.C. At time of release, Kelowna fish averaged 7.2 cm. fork length, while the Summerland fish were 10.1 cm. fork length. In 1954 the experiment was replicated with 4,000 yearling fish from each group, reared from eggs taken at Beaver Lake in 1953. Kelowna fish in this case were 6.1 cm. fork length, while Summerland fish were 6.8 cm. long.

The following comparison of survival and growth of wild and hatchery trout illustrates probably the simplest situation which is practical to simulate. Wild trout in this case were subjected to an artificial environment only for two short periods, first, from the time the eggs were taken from wild parents in a natural spawning run, and second, for a period of about 10 days after the yearling fish had been transferred to the Summerland trout hatchery for marking and subsequent release. On the other hand, the hatchery trout were subjected to the protection of an artificial environment from the time eggs were taken until the fish were released in Corbett Lake.

Since the two groups of trout had similar parental backgrounds, it was to be expected that any possible differences in their reactions to a new environment should result from their histories between hatching and yearling age. It was further expected that results of the experiment should indicate whether the protective environment of the hatchery preserved undesirable qualities in the stock, thus postponing high mortalities from egg to yearling stage commonly observed in wild populations only until some date subsequent to release from the artificial environment.

Survival

Gillnet catches in 1953, 1954 and 1955 and anglers' catches in 1954 and 1955 provided specimens upon which all subsequent comparisons were based. Both of these sampling methods have disadvantages. First, where a considerable variation exists in the lengths of fish being sampled, the nets used in catching them may be selective as to size (Ricker, 1942). Secondly, it has been shown (Larkin and Smith, 1954) that intensive angling tends on the average to select faster growing individuals from any given age class during any particular period of the fishing season. Further, it has been found (Hiyama and Kusaka, 1952) that size of hooks used and skills of individual anglers also are selective as to size of fish caught.

Table I shows the occurrence of wild fish (Kelowna ponds) and hatchery-reared fish (Summerland hatchery) in 14 catches from 1953-55. Trout caught in 1953 had been resident in Corbett Lake for approximately 6 months and were classed as yearling plus (I+). Those caught in 1954 were of the same age-group and were II+ when captured, while the fish which were captured in 1955 were II+ trout of the 1954 yearling stock. Many more samples, both in 1954 and 1955 were available from anglers' catches, but could not be included either because they were not complete records of all fish from individual catches or because scale samples from some of the 1954 and 1955 catches were not taken at the same time, and the ages of the fish were not known.

Table I

Occurrence of wild and hatchery trout in gillnet and anglers' catches in Corbett Lake, B.C.

Sampling method	Year captured and age	Occurrence of trout in samples		
		Summerland hatchery	Kelowna ponds	X^2 values
Gillnet	1953	7	9	6.256
Angling	I+	11	2	($P<0.02$)
Gillnet	1954	4	3	
Gillnet	II+	2	13	
Angling	—	8	5	
Angling	—	3	2	27.456
Angling	—	0	8	($P<0.01$)
Angling	—	7	1	
Angling	—	3	2	
Angling	—	0	6	
Total from 1953 stocking		45	51	
Angling	1955	6	11	
Gillnet	II+	17	9	9.958
Gillnet	—	9	7	($P<0.05$)
Gillnet	—	0	6	
Total from 1954 stocking		32	33	

When *total catches* of wild and hatchery trout were compared (1953 stocking, I+ in 1953 and II+ in 1954; 1954 stocking, II+ in 1955) there was no significant difference in their numerical strength. Survival rate, as shown by total availability to capture, was therefore presumed to be equal in wild and hatchery fish for both stockings. However, from the X^2 values listed in Table I it is apparent that there was a significant departure from homogeneity in individual catches of the two groups of trout.

Objections probably could be raised for any method of sampling fish from a natural environment, and in this case was complicated by non-random occurrence of the two groups in the samples. Data presented here on total gillnet and angling catches both from 1953 and 1954 stockings offer a clear enough illustration of the total survival of the two groups of trout. Regardless of the degree to which various factors of sampling may have biased estimates of survival, the available evidence plainly lacks any significant indication of unequal survival of the two groups.

Growth Rates

Any attempts to describe and compare growth rates of the two lots of trout in Corbett Lake are complicated by the factors of selective sampling mentioned previously. However, since there were no significant numerical differences in the total catches, it was assumed that each lot of trout not only existed in equal strength, but also that each was equally available to capture by angling or by gillnetting. Growth rates of the respective age-groups therefore were compared directly, both for the 1953 and 1954 stockings.

Growth rates were calculated by use of the formula:

$$k = \frac{\text{Log}_e L_2 - \text{Log}_e L_1}{N}$$

where L_1 and L_2 represent calculated length (Smith, 1955a) at formation of first and second annulus respectively and N is equal to one year. Table II summarizes pertinent growth data for the two lots of trout, both from the 1953 and 1954 stockings.

Table II

Growth of wild and hatchery trout in Corbett Lake, B.C.

Source of Fish*	Year of capture	Mean fork length (cm.)			Instantaneous growth rate (k) from I to II	Number of fish in sample
		Age I (at release)	Age II	Age II+ (at capture)		
Summerland.......	1954	10.1	24.9	34.1	0.90	22
Kelowna..........	1954	7.2	17.2	28.9	0.87	11
Summerland.......	1955	6.8	14.4	25.0	0.74	34
Kelowna..........	1955	6.1	15.5	26.6	0.95	21

* *Summerland = hatchery reared trout; Kelowna = wild trout.*

The data summarized in Table II suggest that growth rates of wild and hatchery trout in Corbett Lake were very nearly identical for the first (1953) planting of 1,500 fish from each lot. In addition, the few III-year fish from the 1953 planting (5 hatchery and 6 wild trout) which were captured in 1955 exhibited remarkably uniform size. Trout of this age-group from Kelowna ponds averaged 41.0 cm. in length with a range in length of only 3.6 cm., while Summerland fish averaged 40.6 cm. with a range in length of 5.1 cm. Data from the second (1954) planting of 4,000 fish of each group indicated that when the two lots of trout were released at more nearly the same size, the wild-reared trout had a significantly higher growth rate ($P < .05$) for the first year in the lake. Although the two lots of trout in the 1954 planting did not differ significantly in mean length at any age, the wild fish were 0.7 cm. smaller than the hatchery fish at time of release and were 1.1 cm. larger at the end of their second year. Unfortunately, data are not available for comparisons of growth between ages II and III of the wild and hatchery fish of the 1954 plantings, since Corbett Lake "winter-killed" during the winter of 1955-56.

Discussion

It would appear from data in Table II describing mean lengths at release and subsequent rates of growth of wild and hatchery fish, that wild-reared fish, which possibly are better able to compete, grow faster under natural conditions than hatchery fish from the same parental stock. Whether wild fish in this case were better adjusted to a natural environment prior to release or whether a proportion of "weaklings" were preserved by hatchery rearing (where mortality from egg to yearling was less than 15 per cent in each of the two years) it is not possible to state. From the results of sampling, which showed a rather sharp dissociation of each group of trout (lack of homogeneity in occurrence in samples) it is likely that the two groups of trout were differently conditioned in one way or another in their early life.

Although detailed costs for each operation are not given here, cost *per yearling trout* was about 40 per cent higher for Kelowna pond fish than for trout raised in Summerland hatchery. Cost *per pound* of Kelowna fish was about 3.5 times greater than cost per pound of Summerland hatchery fish. Since the key factor in trout production is the ultimate yield of fish to anglers, probably the most effective basis for comparing efficiency of the two operations would be on the basis of cost *per fish* produced. This becomes evident from equal survival (availability to anglers) of individuals of the two groups of trout following stocking.

Aside from practical considerations of comparative costs of rearing and survival and growth after release of wild and hatchery trout, the results of sampling point out the importance of behaviour of individuals of the two groups. Corbett Lake is a relatively small body of water (50 acres) and typical of many lakes of the interior of British Columbia in which yearling trout are planted each year. It was selected for the experiment chiefly to minimize sampling problems. At the same time, the two groups of trout in both years were held together and fed the same food at Summerland hatchery for at least ten days before being released, to preclude the possibility of bias from temperature and diet acclimation. Nevertheless, it is evident that members of each group either aggregate in such a way that they are susceptible to capture as schools, or tend to exclude interchange of members between schools. The results of this experiment suggest that where survival, growth and behaviour of wild fish of any species are being assessed, either by comparison with hatchery-raised fish or by handling of wild stocks, an awareness of possible conditioning of young fish during early life or at time of handling is of considerable importance.

During the past few years considerable work has been done in evaluation of fish cultural practices, both in methods of rearing game fish in hatcheries and in assessment of planting requirements for angling waters. Dr. R. B. Miller's series of experiments with hatchery trout in Alberta streams has clearly shown that hatchery trout have a very low survival when forced to compete with wild trout in streams. Dr. Miller's experiments suggest that planting of hatchery trout in streams can be justified only in special circumstances, such as stocking a stream barren of fish life or planting catchable trout for the immediate demand of heavy angling pressure. The present experiment would appear to indicate that conditions limiting survival of trout in lakes likely are not as stringent, and that hatchery trout are as well able to utilize the resources of a natural lake environment as are wild trout of the same size and age. It is therefore apparent that where a heavy demand exists for angling in lakes, the presence of wild trout does not preclude the possibility of supplementing stocks by hatchery plantings.

Literature Cited

HIYAMAN, YOSHIO and TAKAYA KUSAKA, 1952. *Size selection in fishing caused by size of hook and skill of angler.* Japanese J. Ichthyology, 2: (3): 134-137.

LARKIN, P. A. and S. B. SMITH, 1954. *Some effects of the introduction of the redside shiner on the Kamloops trout* in Paul Lake, British Columbia. Trans. Amer. Fish. Soc., for 1953, 83: 161-175.

MILLER, RICHARD B., 1952. *Survival of hatchery-reared cutthroat trout in an Alberta stream.* Trans. Amer. Fish. Soc. for 1951, 81: 35-42.

RICKER, W. E., 1942. *The rate of growth of bluegill sunfish in lakes of northern Indiana.* Investigations of Indiana Lakes and Streams, 2: 161-214.

SCHUCK, HOWARD A., 1948. *Survival of hatchery trout in streams and possible methods of improving the quality of hatchery trout.* Prog. Fish-Cult., 10: 3-14.

SMITH, S. B., 1955a. *The relation between scale diameter and body length of Kamloops trout, Salmo gairdnerii kamloops.* J. Fish. Res. Bd. Canada, 12: (5): 742-753.

1955b. *Creel census records for Paul Lake, 1955.* Unpubl. Rept., B.C. Game Commission, 11 pp.

Increase in Levels of Lactic Acid in the Blood of Cutthroat and Steelhead Trout Following Handling and Live Transportation

by

Edgar C. Black and Isadore Barrett

The Department of Physiology, the University of British Columbia, the British Columbia Game Commission, and the Institute of Fisheries of the University of British Columbia, all at Vancouver, Canada.

There are many causes of death of fishes such as adverse temperature changes, lack of oxygen, and metallic poisoning. In addition to these causes, the view was put forward by Black (1956) that the increased production of lactic acid and other changes following vigorous muscular activity may be the cause of death in the so-called delayed planting mortality in salmonoids reported by Horton (1956), Miller (1951) and Wales (1954). Black's contention rests on the observation that lactic acid increased in the blood of Kamloops (*Salmo gairdnerii*) and lake trout (*Salvelinus namaycush*) following live transportation, and on the earlier observations of von Buddenbrock (1938), Huntsman (1938) and Secondat and Diaz (1942) that death in fishes followed vigorous muscular activity.

In a recent paper, Miller (1955) showed that death of yellowstone cutthroat, *Salmo clarki lewisi* (Girard), occurred when the fish were transported and planted in a stream containing resident cutthroat trout. However, mortalities were no greater than 13 to 16 per cent when fish were transported and planted in a section of the stream free from trout. Miller noted that death was possibly due to exhaustion but no biochemical tests were performed. It would appear then that death may be due to muscular exercise resulting from activity induced during handling, transportation, and subsequent activity in the new environment.

Nielson *et al* (1957) have recently demonstrated that there is no significant difference in the survival of hatchery raised rainbow trout (*Salmo gairdnerii*) and resident wild brown trout (*Salmo trutta*). However, if improper diet for the hatchery fish is used, losses subsequent to planting may be considerable (Wales, 1944.)

Nielson (1957) has not found any losses of rainbow trout which could be attributed to handling, marking and transportation. These studies extended over a period of 6½ years at Convict Creek Station, California. Delayed planting mortality following transportation may occur only under special circumstances and by the use of special care in feeding (Wales, 1944) and by controlling the temperature (Horton, 1956) the incidence of mortality may be reduced.

In the present study, hatchery raised coastal cutthroat trout, *Salmo clarki clarki* Richardson, and steelhead trout, *Salmo gairdnerii*, were used. The effects of handling, such as the capture and transferring of fish from an outside pond to an inside hatchery trough were examined. The influence of holding the fish in the hatchery for one to two days before transportation was investigated. Finally, the effect of an immediate sham transportation run in a tank truck from the outside and a subsequent return to inside hatchery trough was examined. Cutthroat trout were selected for the reason that the related subspecies, the yellowstone cutthroat trout, reared in hatchery may suffer 100 per cent mortality after planting (Miller, 1951). As steelhead trout were available, they were used for comparison with the cutthroat trout.

Evidence has been obtained in the present paper that significant activity does result from handling of fish as well as from transportation. However, no unequivocal evidence has been obtained that the increase in the blood level of lactic acid during transportation is the cause of delayed planting mortality.

Methods

Yearling and two-year-old cutthroat and yearling steelhead trout were used. All fish had been reared at the Smith's Falls Trout Hatchery, which is operated by the British Columbia Game Commission at Cultus Lake, B.C. Weights of the fish used are given in the tables. The blood changes resulting from handling and the sham transportation run were studied at Smith's Falls. Certain transportation hauls were made from the Smith's Falls Hatchery to the experimental laboratory of the Institute of Fisheries of the University of British Columbia, a distance of 70 miles = 112 kilometres. The tank truck used for the transportation experiments was the same one described in the previous study (Black, 1956a). Certain details of the methods of handling and storage will be given later.

The method of taking blood samples by cardiac puncture while the fish respired in water has been already described (Black, 1955), as were the procedures for the determination of hemoglobin and lactic acid. When blood samples were taken at Smith's Falls Hatchery, the hemoglobin determinations and the precipitation of the protein were carried out at Smith's Falls. The tungstic acid filtrates were analyzed at the Institute of Fisheries on the following day. Mortalities in control groups were also recorded for the fish reported in Tables VI and VII.

Results

I. Alterations in blood level of lactic acid in salmonoids following vigorous muscular activity.

Immediate increase in the blood lactic acid level of yearling and two-year old Kamloops trout following 15 minutes of vigorous exercise is shown in Table I. For example in yearling Kamloops trout the lactic acid increased from the unexercised level of 15.7 mg. % to 99.8 mg. %. During the recovery period the blood level continued to increase up to 170 mg. % at the end of two hours. Ultimately, the lactic acid returned to near-resting level, and after 24 hours of recovery was 16 mg. %. Full description of changes are given in the paper by Black (1957).

Similar changes were noted for the two-year old Kamloops trout. However, in all cases the blood level of lactic acid was somewhat lower than in yearlings.

The blood level of cutthroat trout following 15 minutes vigorous exercise was 85.7 mg. % for yearlings and 72.9 mg. % for two year olds, while the value for yearling steelhead was 113.0 mg. %. These values are not greatly different from those for the respective age groups of Kamloops trout.

It was not possible to obtain values for the unexercised condition in cutthroat and steelhead trout. As an approximation, the values for 24 hours recovery from a transportation run from the Smith's Falls Hatchery at Cultus Lake to the Institute of Fisheries at Vancouver are given. It will be noted that these values are low compared with the values for the 24 hour recovery period after vigorous exercise. As will be discussed in Section IV, the fish brought to the Institute of Fisheries were probably never in a resting condition, so that these low values may mean that the lactic acid precursor had not been resynthesized to any large extent.

Table I

Weights and blood levels of hemoglobin and lactic acid in trout following various conditions.

Standard error of the average is given after the average.

Species and Condition	Year	No. of fish	Average weight g.	Average hemoglobin g.	Average blood lactic acid mg.%
Kamloops trout, yearling					
Unexercised	1953/54(*a*)	41	57±2.0	11.0±2.0	15.7±1.09
Exercised	1953/54(*a*)	35	57±3.2	10.7±0.23	99.8±0.95
Recovered 2 hrs. after exercise	1953/54(*b*)	10	82±6.0	11.0±0.60	170±9
Recovered 24 hrs. after exercise	1953/54(*b*)	11	70±2	11.2±0.3	16.0±2.2
Kamloops trout, 2 year old					
Unexercised	1954 (*a*)	11	125±17.8	10.1±0.43	8.0±0.95
Exercised	1954 (*a*)	11	134±12.3	11.2±0.30	82.2±10.0
Recovered 2 hrs. after exercise	1955 (*b*)	6	167±34.5	14.8±0.57	117±10.8
Recovered 24 hrs. after exercise	1955 (*b*)	9	151±10.4	15.3±0.41	11.1±1.35
Steelhead trout, yearling					
Rested 24 hrs. after transportation	1956	5	54.2±1.7	12.7±0.49	4.0±1.0
Exercised	1956	9	44.3±1.4	13.0±0.47	113±30.5
Cutthroat trout, 2 year old					
Rested 24 hrs. after transportation	1956	5	90.2±3.44	15.0±0.49	1.02±0.38
Exercised	1956	7	117.7±12.2	11.1±0.4	72.9±2.3
Cutthroat trout, yearling					
Exercised	1956	10	37.6±1.9	10.6±0.2	85.7±4.3

(*a*) Black 1955.
(*b*) Black 1957a.

These values in Table I will be used as a basis for comparison in interpreting the lactic acid values reported in Tables II–VII inclusive.

II. Effect of handling fish on the blood level of lactic acid.

In the previous paper (Black, 1956a) on the effects of transportation, no effort was made to determine the importance of the handling procedures themselves on inducing muscular exercise and hence in raising the blood level of lactic acid. As is well known by those who constantly work with live fish, nearly every change in the external environment may startle fish or otherwise increase their activity. The following steps in capturing and transferring the fish may all cause an increase in muscular activity: (1) Hatchery attendants appearing at the pond; (2) removing the pond cover; (3) lowering the water level to facilitate capture; (4) capturing the fish by means of a dip net; (5) transferring the captured fish to a pail; (6) carrying the pail to hatchery trough (in this case the distance was 60 yds. = 54.9 metres); (7) liberating the fish into the trough, and (8) subsequent holding in the hatchery trough. In an actual transportation run, some of the last few steps probably wculd be left out.

A. CUTTHROAT TROUT.—The relation of the above handling procedure to the blood level of lactic acid in two-year old cutthroat trout is shown in Table II, Column 5. These values may be compared with those for completely rested fish given in Table I. However, it is important to point out that these resting values are unexpectedly low, as compared with two-year old Kamloops trout. After 15 minutes vigorous exercise the blood lactic acid level was 72.9 mg.% (Table I).

In 7 cases out of 9 in Table II, the lactic acid values are increased significantly. In 5 of 9 readings, the values are higher than 20 mg.%. However, only in one case was the level above the 50% average for fully exercised cutthroat trout.

Table II

Weights and blood levels of hemoglobin and lactic acid of cutthroat trout at various times following the transferring of two year old cutthroat trout from outside ponds to a trough inside the hatchery at Smith's Falls, B.C. (Temperature 46° F. = 7.8° C.)

Experiment Number	Time elapsed after transfer complete	Weight	Hemoglobin	Lactic acid
	Minutes	Grams	Grams per 100 cc.	Milligrams per 100 cc. of whole blood
2	1	98	10.7	21.7
4	7	157	15.1	7.7
6	14	172	11.1	22.2
10	37	210	14.3	5.8
14	63	205	9.1	56.5
18	91	136	10.4	14.9
22	119	132	10.2	24.4
26	104	85	11.2	22.4
36	214	121	13.8	14.5

No control fish were held to determine the possible mortality from the handling, capturing, transfer, and confinement in the hatchery troughs.

It is concluded that handling procedures, including confinement, result in muscular activity as judged by significant increases in the blood level of lactic acid.

B. STEELHEAD TROUT.—The relation of handling procedures on the blood level of lactic acid in yearling steelhead trout is shown in Table III, column 5. In 8 of the 9 readings, there was a significant increase in lactic acid above the average for condition of recovered fish (Table I). In 6 of the 9 cases, the values were 30 mg.% or higher (Table III). That is, the values were 10 mg.% or higher than the two-year old cutthroat (Table II). In 2 cases out of 9, there were increases in lactic acid above the 50% level for steelhead exercised vigorously for 15 minutes (Table I). The differences may be due to size, for Black (1955) found that the blood levels in two-year old Kamloops trout were lower than yearlings. The differences noted could also be due to species differences in behaviour, muscle glycogen levels and circulation.

No control fish were held to determine the possible mortality from the handling, capture, transfer and confinement.

It is concluded that handling results in increased muscular activity as shown by the very significant increase in lactic acid of the blood in yearling steelhead trout.

III. *Effect of immediate transportation on the blood level of lactic acid.*

Fish were taken from outside ponds at the Smith's Falls Hatchery and then placed in the tank truck and transported on a sham run for two hours. The sham run was identical to a routine liberation, except that the fish were returned to the hatchery. On return, the fish were placed in troughs inside the hatchery.

Table III

Weights and blood levels of hemoglobin and lactic acid of yearling steelhead trout at various times following the transferring of the trout from outside ponds to a trough inside the hatchery at Smith's Falls, B.C. (Temperature 46°F. = 7.8°C.)

Experiment Number	Time elapsed after transfer completed	Weight	Hemoglobin	Lactic acid
	Minutes	Grams	Grams per 100 cc.	Milligrams per 100 cc. of whole blood
1	2	47	14.6	36.5
3	16	47	11.1	21.1
5	24	50	12.7	30.6
7	41	40	11.8	34.1
13	72	42	11.9	44.4
17	101	42	12.6	23.7
21	126	54	9.9	53.5
25	154	48	8.8	8.7
35	224	42	10.9	35.4

A. CUTTHROAT. In this experiment, yearling cutthroat were used since the supplies of two-year old cutthroat were exhausted. In 13 of the 17 readings, the blood level of lactic acid following the sham transportation run was 28 mg.% or higher (Table IV). In 7 cases out of 17, the concentration of lactic acid was greater than a half load for yearling cutthroat trout following 15 minutes of exercise (Table I). In 2 cases out of 17 the lactic acid was near a full load, namely nearly 83 mg.%. In one case, where the sample was taken 2½ hours after the run was completed, the lactic acid level was 106 mg.%. The blood levels of lactic acid were substantially higher and persisted for a longer time than those noted for either the year-and-one-half-old lake trout or two-year-old Kamloops trout (Black, 1956a).

If the results for the handling alone (Table II) are subtracted from those for the handling plus the transportation run (Table IV), it is clear that there is a significant increase that must be attributed to the transportation factor alone. A strict comparison, however, is not warranted, since the two groups differed in age. The younger group which showed the higher values was used for the sham run. Moreover, the time course of the appearance and subsequent disappearance of blood lactic acid following activity does not warrant comparison between Tables II and IV.

No control fish were held to determine the possible mortality from capturing, sham transportation and subsequent holding.

It is concluded that live transportation of yearling cutthroat resulted in considerable muscular activity as judged by the very significant quantities of lactic acid which appeared in the blood.

Table IV

Weights and blood levels of hemoglobin and lactic acid of yearling cutthroat trout, at various times following sham transportation for two hours. Smith's Falls, B.C. (Initial temperature 51.8°F. = 11.0°C., final temperature 55.4°F. = 13.0°C.)

Experiment Number	Time elapsed after run completed	Weight	Hemoglobin	Lactic acid
	Minutes	Grams	Grams per 100 cc.	Milligrams per 100 cc. of whole blood
12	10	33	10.4	31.7
14	16	47	8.9	83.3
16	23	29	8.6	52.4
18	35	31	9.9	42.5
20	47	58	9.6	68.1
22	52	37	9.0	34.0
24	60	45	10.9	27.6
26	83	51	10.6	10.2
28	90	42	—	88.0
30	98	35	10.3	40.0
32	105	36	—	32.8
34	114	33	9.0	68.7
36	120	49	10.3	60.7
38	133	37	—	15.6
40	140	52	10.7	12.8
42	147	35	9.4	106.0
44	155	46	11.8	19.9

B. STEELHEAD. In 12 cases out of 17, the blood lactic acid in yearling steelhead following two hours of live transportation was 28.7 mg.% or greater (Table V). In 9 cases there was greater than a half load of lactic acid found in steelhead trout vigorously exercised for 15 minutes (Table I). In two cases, the lactic acid levels were 111.5 and 115.0 mg.%. While the blood levels of lactic acid begin to fall at the end of 2 hours after transportation, the highest value recorded was for the sample drawn 129 minutes after the trip was completed.

In considering the effect of handling on the blood level of lactic acid in steelhead (Section IIB and Table III) it would appear that approximately one third of the lactic acid following transportation might be attributed to handling alone. Evidently transportation alone is associated with a significant increase in blood lactic acid.

The lactic acid levels observed in the yearling steelhead were greater and persisted for a longer period than those recorded for lake trout and Kamloops trout (Black, 1956a).

No control fish were held to determine the possible mortality from capturing, sham transportation and subsequent holding.

From the above observations, it is concluded that sham transportation of yearling steelhead resulted in significant muscular activity, as judged by the quantities of lactic acid which appeared in the blood.

Table V

Weights and blood levels of hemoglobin and lactic acid of yearling steelhead trout at various times following sham transportation for two hours. Smith's Falls, B.C. (Initial temperature 51.8°F. = 11.0°C; final temperature 55.4°F. = 13.0°C.)

Experiment Number	Time elapsed after run completed	Weight	Hemoglobin	Lactic acid
	Minutes	Grams	Grams per 100 cc.	Milligrams per 100 cc. of whole blood
11	7	43	10.9	16.1
13	13	42	11.5	40.1
15	19	45	10.4	65.0
17	31	43	10.6	56.9
19	43	35	—	35.7
21	49	43	11.3	35.2
23	56	35	11.5	70.6
25	78	51	10.8	13.0
27	87	41	12.2	39.1
29	95	45	9.1	111.5
31	102	36	10.8	28.7
33	110	42	8.9	71.3
35	117	40	9.4	11.9
37	129	45	9.9	115.0
39	137	46	11.0	17.5
41	143	34	11.5	11.1
43	151	47	12.0	40.7

IV. Influence of holding trout 1 to 2 days after initial capture on the blood levels of lactic acid following transportation in tank truck.

Trout were taken from the outside ponds and transferred by pails to inside troughs at the Smith's Falls Hatchery. The cutthroat trout were stored two days (40 hours), and the steelhead trout 1 day (16 hours) before transportation in the tank truck to the Institute of Fisheries at the University of British Columbia. The transportation run occupied 2 hours and 50 minutes. At the Institute of Fisheries the fish were transferred to 6 tanks measuring $19\frac{1}{2}$ x 17 x 14 inches = 49.5 x 43.2 x 35.5 cm. There are the following differences in experimental treatment from Section III:

(1) The fish were held for 16 hours (steelhead) or 40 hours (cutthroat) after capture from the ponds and before transportation.

(2) The fish were transported for 2 hours and 50 minutes.

(3) The fish were transferred to small tanks rather than standard hatchery troughs.

(4) The fish were placed in Vancouver city water that had been passed through a dechlorinator.

A. CUTTHROAT TROUT. The lactic acid levels of the blood of the two year-old cutthroat trout following holding for 40 hours and subsequent transportation in a tank truck for 2 hours and 50 minutes are low (Table VI). The values are actually lower than those in Table II where no transportation or holding were involved. Two explanations are offered for the low blood levels of lactic acid following the above experimental conditions: (1) It is possible that the fish were not active. (2) It is possible that the fish continued to swim vigorously and sufficiently to deplete most of the glycogen stores and that most of this presumed activity occurred at least 12 hours before the transportation run. Thus the lactic acid, if produced, would have disappeared.

The second explanation is the one which is considered the more likely. This opinion is based on the following evidence. When fish from the above sample were vigorously exercised for 15 minutes the day following transportation, the average value for 5 readings was 15.5 ± 7.8 mg.%. Indeed, only one value of 46.6 mg.% was higher than the average. The second piece of evidence is drawn from work on Kamloops trout which indicates that it may take more than a week to restore the initial glycogen level (based on lactic acid yields) after 15 minutes of vigorous activity (Black, 1956b).

Fontaine and Hatey (1953) in their study of the carbohydrate changes in adult migrating Atlantic salmon, *Salmo salar*, showed that the content of muscle glycogen is very variable and that there was no significant reduction of muscle glycogen during the ascent up river despite the fact that feeding had stopped on leaving salt water. These studies indicate that no final inference should be drawn about the content of muscle glycogen till direct analyses are made.

It is concluded from these experiments that the glycogen, once expended, may take days to be resynthesized to the initial level.

The 50 control cutthroat trout that were held for 40 hours, transported to the Institute of Fisheries and then held in the small tanks did not fare well. All were dead within a week. This death cannot be associated with high levels of lactic acid in the blood, for in samples taken on the first and second days, none of the 7 examined showed a lactic acid level higher than 12.6 mg.%, even though the cutthroat appeared to be constantly active in holding tanks as judged by efforts to escape and frequent bumping into sides of tank.

Table VI

Weights and blood levels of hemoglobin and lactic acid of two year old cutthroat trout removed from outside ponds and held for 40 hours in the hatchery before transporting, for 2 hours and 50 minutes, from Smith's Falls Hatchery to the Institute of Fisheries, University of British Columbia at Vancouver. (Initial temperature 46°F. = 7.8°C.; final temperature 53.5°F. = 11.9°C.)

Experiment Number	Time elapsed after run completed	Weight	Hemoglobin	Lactic acid
	Minutes	Grams	Grams per 100 cc.	Milligrams per 100 cc. of whole blood
1	10	98	14.8	17.5
3	18	267	14.2	4.3
5	32	104	11.1	6.5
7	36	228	11.0	6.7
9	41	112	10.8	12.2
11	50	120	8.1	15.1
13	58	53	14.0	3.5
15	67	104	12.9	14.6
17	76	67	13.3	3.9
19	81	107	15.2	4.2
21	87	126	14.1	0.8
23	97	113	12.1	2.4
25	103	104	12.0	8.2
27	113	90	14.8	5.8
29	122	119	12.8	4.4
31	130	100	13.4	3.5

B. STEELHEAD. The treatment for these yearling steelhead was precisely as above except that these were held in troughs at Smith's Falls only 16 hours prior to transport to the Institute of Fisheries. These were brought in in the same tank truck as the cutthroat and were held in three small tanks at the Institute of Fisheries.

Very significant quantities of lactic acid were found to be present in the blood right up to the end of 2 hours (see Table VII). All the steelhead controls also died within 10 days. Moreover, it appeared that the steelhead reacted violently to their small enclosure, but less frequently than the cutthroat. Here, then, death following transport appears to be associated with lactic acid in the blood, following handling and a day's rest at Smith's Falls, and transport from Smith's Falls to the Institute of Fisheries. There are still the differences to be explained between these data and those for the cutthroat trout. When a sample of these steelhead were exercised for 15 minutes, 48 hours after transportation, the average lactic acid was 46.7 ± 5.0 mg.%. However, the value obtained for steelhead at Smith's Falls which had *not* been subjected to transportation was 80.8 ± 6.0 mg.% (Table I). The steelhead then, either had not been so active or had resynthesized glycogen at a faster rate than the cutthroat.

Table VII

Weights and blood levels of hemoglobin and lactic acid of yearling steelhead trout removed from outside ponds and held for 40 hours in the hatchery before transporting, for 2 hours and 50 minutes, from Smith's Falls Hatchery to the Institute of Fisheries, University of British Columbia at Vancouver. (Initial temperature 46°F. = 7.8°C.; final temperature 53.5°F. = 11.9°C.)

Experiment Number	Time elapsed after run completed	Weight	Hemoglobin	Lactic acid
	Minutes	Grams	Grams per 100 cc.	Milligrams per 100 cc. of whole blood
2	15	57	9.9	31.9
4	21	53	9.1	59.0
6	34	65	8.5	60.7
8	39	57	8.0	42.7
10	44	59	10.3	21.0
12	53	56	8.1	35.4
14	60	56	10.1	48.2
16	70	56	8.5	51.2
18	79	72	11.1	54.2
20	85	53	11.4	71.4
22	90	63	8.3	37.8
24	101	58	10.0	51.3
26	105	64	10.2	88.0
28	120	59	11.8	11.0
30	125	53	10.3	59.2
32	133	54	14.7	9.5

These experiments show that increased lactic acid is associated with death in the steelhead trout. It is admitted, however, that death of the control fish may not have been due to transportation alone.

Secondly, it is concluded that, as was the case with the cutthroat, recovery from muscular fatigue may not only involve removal of the lactic acid from the blood, but a slow regeneration of the muscle glycogen.

Commonly it was the practice in some hatcheries to exercise fish by lowering the water for a few minutes each day for a few days previous to liberating them. It is thought that the basis for this practice should be systematically investigated by observing not only changes in the blood biochemistry but also in making observations on behaviour and survival.

Summary

Alterations in the blood levels of lactic acid were investigated in hatchery raised cutthroat and steelhead trout in the following conditions:

A. After transferring from outside ponds to troughs inside the hatchery 60 yards = 54.9 metres away.

B. Sham transportation run for two hours in tank truck.

C. Holding cutthroat for 40 hours, steelhead for 16 hours in hatchery troughs before transportation run of 2 hours 50 minutes.

The following results were noted:

(1) Significant increases in blood lactic acid occurred in both species as a result of minimal handling, i.e. in transporting the fish from outside ponds to inside hatchery troughs.

(2) Very significant increase in blood levels of lactic acid following sham transportation run for 2 hours in a tank truck. The levels were higher in both species than those observed for lake trout and Kamloops trout in 1955.

(3) Storage of cutthroat for 40 hours resulted in significant lowering of blood level of lactic acid (range 0.8 — 17.5 mg.%) following transportation run of 2 hours and 50 minutes.

Storage of steelhead trout for 16 hours before the same transportation run of 2 hours and 50 minutes resulted also in a lower blood level of lactic acid (range 9.5 — 88 mg.%).

Conclusions

A. It is concluded that even minimal handling caused significant increase in muscular activity both for cutthroat and steelhead trout.

B. Handling and live transportation for 2 hours caused a very significant degree of muscular activity.

C. It is concluded that previous history of activity may result in lowered blood levels of lactic acid following a second phase of activity. It is possible that this phenomenon may be due to a very slow rate of resynthesis of muscle glycogen. It is possible that if the muscle glycogen is depleted and takes a long time to be resynthesized, this may have some bearing in the conditioning of fish by exercise previous to liberation.

Acknowledgments

The authors gratefully acknowledge the assistance and encouragement provided by Frank Pells, Hatchery Supervisor in charge of the Smith's Falls Trout Hatchery; technical assistance provided by F. D. Forbes, A. Hanslip and K. Henze of the Department of Physiology. The facilities provided by the Provincial Game Commission, through Commissioner F. R. Butler and Robert McMynn, and the Institute of Fisheries of the University of British Columbia through the director, Dr. P. A. Larkin are acknowledged. The National Research Council of Canada provided a grant-in-aid to the senior author for the support of the technical assistance provided by Messrs. Forbes and Hanslip, and other expenses. The Research Committee of the University of British Columbia provided a special water dechlorinator used during this study.

Literature Cited

BLACK, EDGAR C. 1955. *Blood levels of hemoglobin and lactic acid in some freshwater fishes following exercise.* J. Fish. Res. Bd. Canada, *12*: 917-929.

BLACK, EDGAR C. 1956a. *Appearance of lactic acid in the blood of Kamloops and lake trout following live transportation.* Can. Fish Culturist, No. 18, 20-27.

BLACK, EDGAR C. 1956b. *Unpublished data.*

BLACK, EDGAR C. 1957. *Alterations in the blood level of lactic acid in certain salmonoid fishes following muscular activity. I. Kamloops trout Salmo gairdnerii.* J. Fish. Res. Bd. Canada, 14: 117-134.

BUDDENBROCK, W. VON. 1938. *Beobachtungen ueber das Sterben gefangener Seefische und ueber den Milchsaueregehalt des Fischblutes.* Con. Perm. Inter. pour l'explor. de la mer. Rapports et Proc. Verbaux, 101, IV, (2), 3-7.

FONTAINE, M. and J. HATEY. 1953. *Contribution à l'étude du metabolisme glucidique du saumon (Salmo salar L.) à diverses étapes de son développement et de ses migrations.* Physiologia Comparata et Oecologia, III, 37-52.

HORTON, HOWARD F. 1956. *An evaluation of some physical and mechanical factors important in reducing delayed mortality of hatchery-reared rainbow trout.* Prog. Fish. Culturist, *18*: 3-14.

HUNTSMAN, A. G. 1938. *Overexertion as cause of death of captured fish.* Science, 87: No. 2269, 577-578.

MILLER, R. B. 1951. *Survival of hatchery-reared cutthroat trout in an Alberta stream.* Trans. Am. Fish. Soc. *81*: 35-42.

MILLER, R. B. 1955. *Trout management research in Alberta.* Trans. 20th N. Am. Wildlife Conference. 242-252.

NIELSON, REED S. 1957. *Personal communication.*

NIELSON, REED S., NORMAN REIMERS and HARRY D. KENNEDY. 1957. *A six-year study of the survival and vitality of hatchery-reared rainbow trout of catchable size in Convict Creek, California.* California Fish & Game *43*: No. 1, 5-42.

SECONDAT, MARCEL and DIEGO DIAZ. 1942. *Recherches sur la lactacidimie chez le poisson d'eau douce.* Compt. Rend. Séances de l'Académie des Sciences, *215*, 71-73.

WALES, J. H. 1944. *Fresh ocean fish as a trout diet.* California Fish & Game 30: No. 1, p. 43-48.

WALES, J. H. 1954. *Relative survival of hatchery and wild trout.* Prog. Fish. Culturist, *16*: 125-127.

Introduction of the Hybrid Between the Eastern Brook Trout and Lake Trout into the Great Lakes

by

John Budd

Research Division, Ontario Department of Lands and Forests.

In May, 1954, the Ontario Department of Lands and Forests stocked 7,135 marked yearling hybrids between the eastern brook trout *Salvelinus fontinalis* (Mitchill) and the common lake trout *Salvelinus namaycush* (Walbaum) in South Bay in northern Lake Huron. An experimental fishery is being carried on in South Bay by the Department's Research Division. It was hoped that this fishery would afford a chance to examine a sample of the hybrids as they became large enough to be taken in the gear being used.

Stenton (1950, 1952) has described the cross made between the two species at Banff, and the subsequent introduction into some of the Jasper Park lakes. Introductions have also been made in a number of inland lakes in Ontario and in several of the northern states (Scott, 1956) but so far as is known, no other introductions have been made in the Great Lakes or their tributary waters. Careful documentation of all new introductions into these international waters is highly desirable.

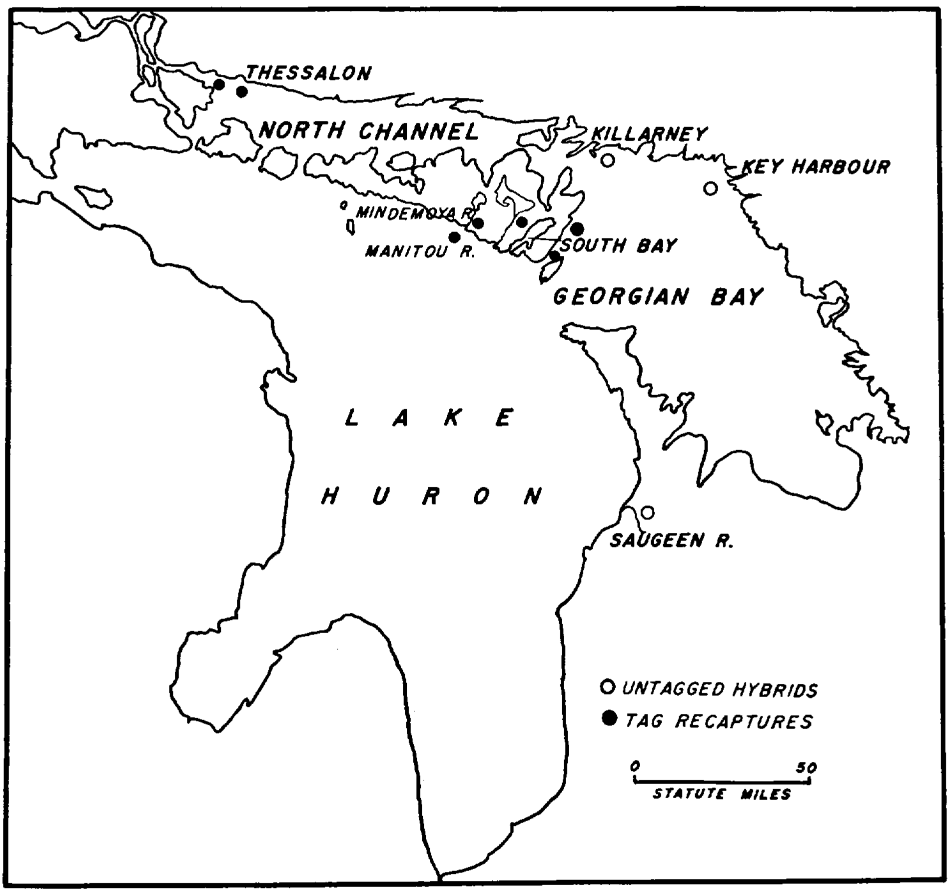
The parent stocks were wild female lake trout taken during lake trout spawning operations on the Montreal River, a stream flowing into the east shore of Lake Superior about eighty miles north of Sault Ste. Marie, Ont., and hatchery reared male brook trout. The cross was made at the Tarentorus hatchery near Sault Ste. Marie in early October, 1952. The eggs hatched during the winter of 1952-53 and the fry were reared according to standard hatchery procedure. In August, 1953, the fingerlings were transferred to a trout rearing station at Chatsworth, Ont., where they were held until the introduction was made. The fish were marked by removal of the right pectoral fin and planted in South Bay on May 19 and 20, 1954. The planting was done from a slowly moving boat, the fish being scattered in the shallow water over gravel and rubble bottom areas at the rate of about 2,000 fish per mile of shoreline. A small sample was measured and preserved for future comparison. This sample averaged 3.8 inches in fork length, and is considered to be representative of the entire lot.

Recaptures

No hybrids were captured during rather extensive netting with small-mesh gillnets in the summer and fall of 1954. The first hybrids were taken in the first lift of pound nets on May 13, 1955, almost exactly one year after the original stocking. Except for some specimens preserved for study purposes, the fish were measured to the nearest half inch, tagged with streamer type plastic tags and released at the site of capture. Growth for the first year in the lake had been rapid. The 77 fish measured in May averaged 13.9 inches in fork length with a range of from 11.5 to 17.0 inches. Native lake trout of the same age in South Bay (Fry 1953) were found to average only 10.0 inches in fork length.

The total number of hybrids tagged during May, June and early July was 229. Recaptures in South Bay through November, 1955, numbered 99 individual fish or 43.2 per cent of those tagged. Seventy-one were recaptured once, 17 twice, seven three times, three four times and one five times. This is a rather high recapture rate when compared with other species in South Bay and recapture rates reported by other investigators. The recapture pattern for fish taken in pound nets suggests that they do much moving. One fish was recaptured five times in three widely separated nets over a twenty-day period. As the surface water warmed the hybrids moved into deeper water. In general, however, they did not go as deep as the lake trout and were taken in depths of from eight to 12 fathoms or in the region of the thermocline. In late October and early November ripe male hybrids were taken on shoals where lake trout were known to have spawned in past years. No mature females were taken, which is not unusual since in many species of fish the males mature a year before the females.

The recapture of tagged hybrids from outside South Bay presents a very interesting and rather unexpected picture. It should again be noted that the female parents were



from a river spawning race of trout. River spawning is rather uncommon in lake trout and only six such runs are known to occur in the Great Lakes. These are all in the eastern half of Canadian Lake Superior waters, and at present are being rapidly depleted by the sea lamprey.

Seven tags were returned from outside South Bay and several reports of untagged hybrids were received but not verified. It is of interest that in one instance, when a hybrid was taken alive in a pound net by a commercial fisherman, there was some discussion as to whether the fish was a lake trout or a brook trout. The solid circles on the map denote the location of capture of tagged hybrids.

Two of the tagged recaptures were taken in streams, one from the Manitou River, the other from the Mindemoya River. These are both small rivers that flow into Lake Huron on the south shore of Manitoulin Island, five and 15 miles west of the entrance to South Bay. The fish from Mindemoya River was taken about two miles up from the mouth, while the one from the Manitou River was taken about 10 miles upstream near where the river begins as the outflow from Lake Manitou. A third hybrid was taken off the mouth of the Mindemoya River by a commercial fisherman.

Two other tags were returned from pound nets fished in Owen Channel on the east shore of Manitoulin Island about 15 miles east of the South Bay entrance. One of these fish was released alive on June 29 and recaptured again in South Bay on October 24, 1955.

Two additional tagged hybrids were taken in the west end of the North Channel near Thessalon. These fish had travelled a distance of about 100 miles from South Bay, one in 20 days, the other in 116 days.

In addition to the recapture of the tagged hybrids, reports of the untagged hybrids have been received from the Saugeen River, from the area east of Killarney, and the Key Harbour area in the north-east corner of Georgian Bay. These locations are designated on the map by open circles.

Limited observations suggest that smelt and alewives form major items in the diet of the hybrids. In Lake Huron and Georgian Bay there is a large, and at present, unutilized population of both smelt and alewives that could serve as an ideal source of food for any predatory fish that can withstand the current level of lamprey predation. It is hoped that the hybrids may prove to have an advantage in this respect because of their more rapid growth rate and the earlier age at which they attain maturity. It is expected that both males and females will be mature in the fall of 1956, and possible spawning activity at that time will be of major interest.

Summary

Marked yearling hybrids between eastern brook trout and common lake trout were planted in South Bay in northern Lake Huron in the spring of 1954. Growth was rapid and after one year in the lake the hybrids averaged 13.9 inches in fork length. A number of the fish were tagged and subsequent recapture data recorded. Seven tags were returned from distances up to 100 miles. Two of the tagged fish had entered streams while the other five were taken by commercial gear. Ripe male hybrids were taken in South Bay during late October and early November.

Literature Cited

FRY, F. E. J. 1953. *The 1944 year class of lake trout in South Bay, Lake Huron.* Trans. Am. Fish. Soc. Vol. 82 (1952): 178-192.

SCOTT, W. B. 1956. *Wendigo the hybrid trout.* Royal Ontario Museum, Division of Zoology and Palaeontology.

STENTON, J. E. 1950. *Artificial hybridization of eastern brook trout and lake trout.* Canadian Fish Culturist, No. 6, Mar. 1950: 20-22.

1952. *Additional information on eastern brook trout x lake trout hybrids.* Canadian Fish Culturist, Issue 13, Dec. 1952: 15-21.

Management, Fishing Results and Growth of Speckled Trout (*Salvelinus fontinalis*) in Baldwin Pond, Stanstead County, Que.

by

Richard L. Séguin

Fisheries Biologist, Department of Fish and Game, University of Montreal, Montreal, Que.

At one time Baldwin Pond (Fig. 1) had the environment favourable to speckled trout. Unfortunately, its sport value was decreased by a single factor: the introduction of unwanted species of fishes with consequent serious reduction in the number of trout. To restore the lake to its former suitability for speckled trout for angling, it was necessary to take appropriate management measures.

Management

In the fall of 1953, a complete poisoning of Baldwin Pond took place to destroy undesirable species, making it possible to recondition the lake for speckled trout angling.

Plantings, made from the Eastern Townships Fish Hatchery, were as follows:

Spring 1954:	20,000 yearlings (7-9 inches)	Not marked
Fall 1954:	5,000 fingerlings (5-6 inches)	Left pectoral fin removed
Spring 1955:	2,500 yearlings (6-7 inches)	Right pectoral fin removed

Three distinctly marked plantings of speckled trout were available for study when the first day's angling was allowed in the lake on May 23, 1955.

Fishing Results

Two biologists of the Quebec Biological Bureau, Raymond Desrochers and the author, went to the lake on May 23 and 24 to investigate fishing results and methods, and to gather pertinent data on the behaviour of the planted trout. The actual creel census, and the organization of the many factors which made it possible, was a co-operative undertaking of the technicians of the Eastern Townships Fish Hatchery, directed by Louis-Roch Séguin; the local fish and game warden, Seth Blake and members of the Stanstead County Fish and Game Club. Mr. Blake undertook, during the entire season, to gather daily fishing data on the number of anglers, the number of fish caught, and the number of fishing hours per angler.

Control was made easier by the fact that access to the lake is usually confined to one place. Fishing from the banks was not allowed, and fishing hours were defined as between 5:00 a.m. and just after sunset. The creel limit was ten fish per angler per day. Statistics were facilitated by the fact that boats were rented by the hour and those bringing their own boats were registered and charged a small fee.

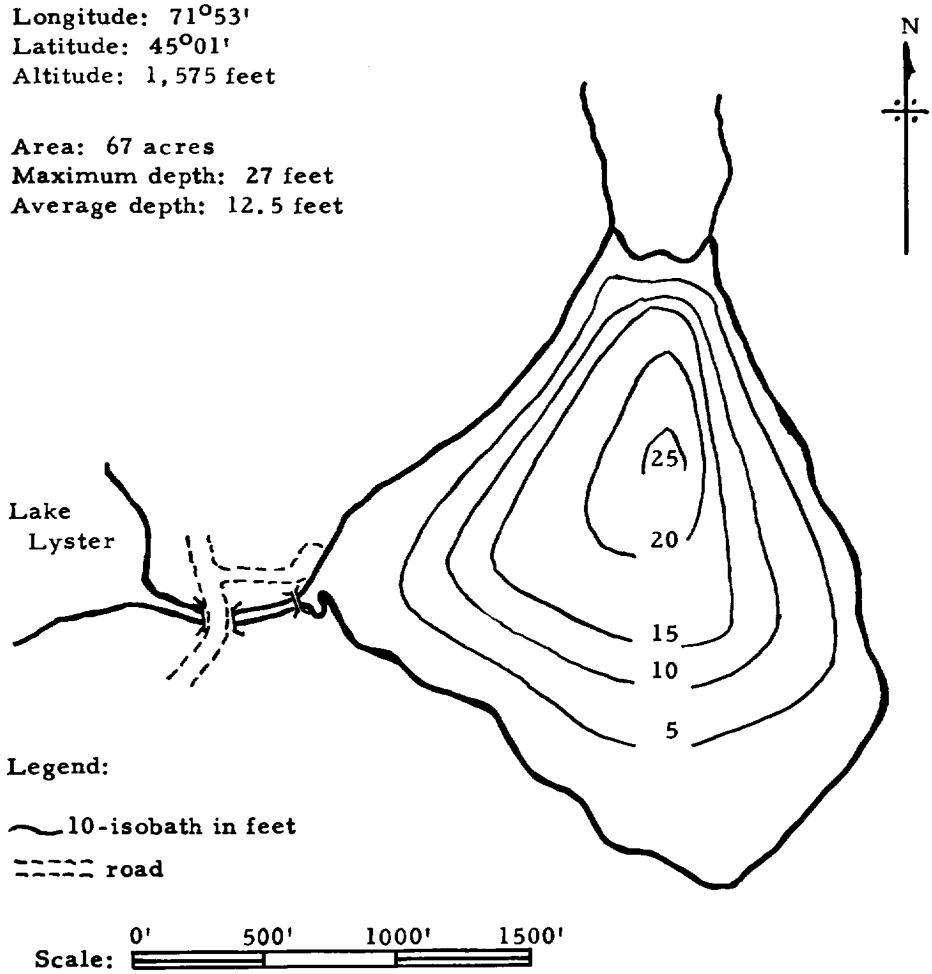
BALDWIN POND

County: Stanstead
Township: Barnston

Range: XI
Lot: 16

Longitude: 71°53'
Latitude: 45°01'
Altitude: 1,575 feet

Area: 67 acres
Maximum depth: 27 feet
Average depth: 12.5 feet



Soundings: Calibrated metal sounding line with lead by Louis-Roch Seguin, August 4, 1949.

Figure 1.—Description and location of Baldwin Pond.

There was a good season's fishing with 5,407 speckled trout reported. Distribution was as follows:

May 23	2,759 (384 anglers)	June	818
May 24	351	July	515
End May	500	August	253
	——	September	211
Total for May	3,610		

These figures show a great number of speckled trout taken during the season but tell nothing about the yield per hour per angler. As there are some gaps in the data as to the number of anglers and hours of fishing, particularly for July, we have omitted these doubtful periods from our compilation. In Table I we have a study of fishing yield.

Table I

Yield per angler in Baldwin Pond during 1955 season.

Date	No. of anglers	Trout caught	Fishing hours	Trout per angler	Trout per hour
May 23	374	2,670	1,212	7.18	2.20
May 24	86	351	299	4.08	1.17
End May	193	413	464	2.14	0.89
Total: May	653	3,434	1,975	5.26	1.74
Total: June	366	744	952	2.03	0.78
July 2, 3, 4	36	93	111	2.58	0.83
Total August	144	234	360	1.62	0.65
Total September	104	186	254	1.79	0.73
Total: Season	1,303	4,691	3,652	3.60	1.28

The results of fishing in a lake during the first open season after it has been rehabilitated are highly significant. A yield of 1.28 trout per hour per angler through an entire season is very good fishing.

Comparison is made with results in other Canadian and American lakes in Table II.

In the light of these figures we can place Baldwin Pond in the category of excellent speckled trout fishing water. By continuing to gather angling results during future fishing seasons, biologists will be in a better position to know what trend to follow in future management work to give the anglers of Baldwin Pond continued good returns.

Table II

Comparative yields of various Canadian and U.S. speckled trout lakes.

Trout per hour	Lakes and Places	Creel census duration	Authors
0.2–1.9	Crecy Lake, N.B.	1943–1953	Smith, M. W. 1955
0.3–1.2	Banff National Park (3 lakes), Alta.	1951	Cuerrier and Ward, 1952b
0.2–0.8	Nova Scotia (4 lakes)	1945–1947	Smith, M. W. 1952
0.87	Michigan (trout waters)	1928–1947	Fukano, K. G. 1948
0.8–1.2	Cape Breton Highland National Park (2 lakes)	1951	Cuerrier and Ward, 1952a
0.2–3.3	Jasper National Park (11 lakes), Alta.	1951	Cuerrier and Ward, 1952b
1.1	Charlotte County, N.B. (8 lakes)	1941–1947	Smith, M. W. 1952
1.2	Gull Lake, California	1940–1941	Curtis, B. 1951
1.28	Baldwin Pond, Quebec	1955	Present document
1.7	Castle Lake, Calif.	1947–1949	Curtis, B. 1951
1.4–2.5	Montague Pond, P.E.I.	1943–1953	Smith, M. W. 1954
3.1–4.0	Fundy National Park, N.S. (3 lakes)	1951	Cuerrier and Ward, 1952a

Fishing Methods

On the opening day, May 23, anglers were asked about their method of fishing. As Table III shows, the majority of anglers went in for just one type of fishing. However, a few tried two or even three methods. In these latter cases it was hard to find out just what device captured the fish, so we have refrained from detailing them. Still fishing was the most popular and had excellent results. However, although more trout were taken this way, spinning proved more efficient, although it was less used because of the more expensive equipment needed. On May 23, still fishers caught 2.04 speckled trout per hour while spinners took 2.95 speckled trout. The best spinning device proved to be the Mepps Spinner. We believe some fly fishermen became discouraged and tried another method. These were probably the less expert at the exacting sport of fly fishing, because those ten who adhered to fly fishing achieved the same fishing efficiency as those who confined themselves to the easier method of still fishing. Only twelve fishermen finished the day with empty creels.

Table III

Fishing methods used at Baldwin Pond May 23, 1955.

Fishing method	No. of anglers	Trout taken	Trout per hour
Still fishing (worms)	240	1,667	2.04
Spinning	51	417	2.95
Spinning and still fishing	45	374	
Fly	10	96	2.04
Fly and spinning	3	24	
Still fishing, spinning, fly	4	40	

Growth of Speckled Trout

In addition to registering the fishing results on May 23 and 24, the three different plantings of speckled trout were measured and weighed in order to study their growth in Baldwin Pond. As only legal-length (7 inch) fish were reported, it was necessary to await the opening of the 1955 season to get the results of the fall planting of 1954. However, there were a few clipped-fin specimens reported from the fall planting of 1954 and the spring planting of 1955.

Table IV shows the minimum, average and maximum size per group. A glance at age groups, say yearlings, from the same hatchery but planted at different seasons shows that those planted as fingerlings in the fall and which consequently spent the winter and early spring in Baldwin Pond had better growth than those of the same age which wintered at the hatchery and were planted at the beginning of spring preceding the fishing. True, there are not many of these latter; but it does seem for these two days that the difference is remarkable.

Table IV

Length and weight of speckled trout taken May 23 and 24, 1955 for different plantings.

Group	Age	Date	Number	Length in mm.			Weight in oz.		
				Min.	Ave.	Max.	Min.	Ave.	Max.
Not marked	II	May 23	2,673	155	245.5	310	1.00	4.75	9.00
		May 24	317	180	239.7	285	1.75	4.32	7.00
Left pectoral fin off*	I	May 23	52	165	206.7	240	1.25	2.88	5.00
		May 24	17	170	204.7	244	1.50	2.73	6.00
Right pectoral fin off**	I	May 23	4	175	194.5	221	1.75	2.37	3.00
		May 24	4	182	193.0	200	1.75	2.18	2.50

* Planted in fall 1954 as fingerlings.
** Planted in spring 1955 as yearlings.

Speckled trout hatchery-reared a year and planted in Baldwin Pond reached, in length and weight, a year later, the following measurements: the 2,673 speckled trout of the same age measured from 155 and 310 mm. (6 to 12 inches) and weighed from 1 to 9 oz. (28 to 255 grams). Average length was 245.5 mm. (9.7 inches) and average weight 4.75 oz. (135 grams).

For a population of speckled trout of the same age, say two years, it is highly interesting to know at that time of the year, in this case May 23, the trout's conditioning factor and relate this to the conditioning factors of other speckled trout in comparable circumstances. To this end we use the formula set up by Klak (1941), English system:

$$CF = \frac{W \times 100.000}{L^3}$$

where CF stands for coefficient of condition in the English system,

W stands for weight in pounds

L stands for total length in inches

100,000 is a multiplier used to establish the decimal point at the right of two significant figures.

Taking the average length and weights found in Baldwin Pond, we find CF to be 32.5, with minimum 24.9 and maximum 38.1. Table V compares these results with those obtained by Greene (1952) from speckled trout of the same age in Stillwater Pond, Putnam County, New York.

Table V

Conditioning factor of speckled trout in Baldwin and Stillwater Ponds.

Pond	Group	Number	Age	Area (acres)	Maximum depth (feet)	Conditioning factor
Stillwater.......	Hatchery.....	189	II	55	30	ave. C(TL.) 40.3
	Wild.........	149	II	—	—	ave. C(TL.) 31.5
Baldwin.........	Hatchery.....	2,673	II	67	27	ave. C(TL.) 32.5

Table VI distributes the 2,673 speckled trout by length and weight groups, so we can plot a growth curve (Fig. 2). Since it is illegal to take speckled trout less than 7 inches long, it is understandable that the number of captures of shorter fish is not representative of the population. Hence, in plotting the curve for this population we have omitted groups less than 175 mm. in average length.

Total length is related to weight according to the formula:

$$W = cL^n$$

where

W is weight in grams,

L is total length in millimeters,

c and n are constants to be determined, being characteristics of the lake and the fish.

These constants can be calculated according to the following formulae, which are solutions of the initial equation resolved by the method of least squares:

$$\mathit{Log\ c} = \frac{\Sigma \text{Log W. } \Sigma(\text{Log L})^2 - \Sigma \text{Log L. } \Sigma(\text{Log L. Log W})}{\text{N. } \Sigma(\text{Log L})^2 - (\Sigma \text{Log L})^2}$$

$$\text{and } n = \frac{\Sigma \text{Log W} - (\text{N. Log c})}{\Sigma \text{Log L}}$$

Here N represents the number of length-classes utilized in the calculations.

The length-weight relationship for Baldwin Pond can now be concretely expressed by:

$$W = 2.995 \times 10^{-5} L^{2.781}$$

Table VI

Length-weight relationship of speckled trout in Baldwin Pond.

Total length in mm. by classes of 10 mm.	Number of fish	Weight in grams
151–160	1	28.35
161–170	2	31.89
171–180	4	53.15
181–190	11	55.08
191–200	21	68.32
201–210	38	87.82
211–220	133	94.34
221–230	288	109.45
231–240	554	119.06
241–250	644	129.72
251–260	505	148.40
261–270	271	165.36
271–280	132	184.15
281–290	40	200.57
291–300	24	218.51
301–310	5	241.67
	2,673	

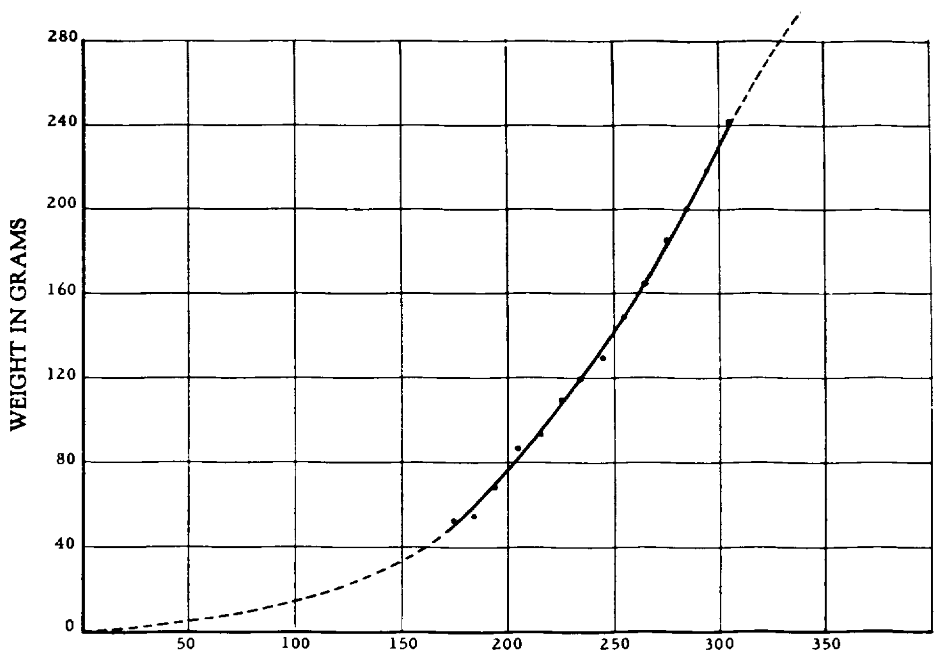


Figure 2.—Length-weight relationship of speckled trout two years old in Baldwin Pond. (Points are based on lengths and weights, Table VI.)

Operation and installation for weighing and measuring fish for creel census at Baldwin Pond in spring of 1956. Richard L. Séguin, author, (left), his brother, also a biologist, Louis-Roch Séguin (right) and a local fisherman.

Summary

Baldwin Pond appears well managed to date. After the poisoning of the unwanted species of fish during fall 1953, the lake was ready to receive the speckled trout plantings of 1954 and 1955. The 1955 fishing season gave the first pertinent data necessary for the management of the lake. Successive creel censuses were the best tool to check management.

The opening day, May 23, was very successful; 384 anglers caught 2,759 speckled trout. To prevent rapid depletion of the fish from the lake, in co-operation with the organized anglers, a limit was set of ten fish per angler per day. The 5,407 speckled trout caught and reported from May 23 to the end of September prove that the plantings of hatchery stock gave good results.

The yield of 1.28 trout per hour per angler for all the season proves the value of the lake as a speckled trout producer. The anglers made an outstanding contribution during this study of the lake.

Still fishing, the preferred method of the majority, proved very efficacious. On May 23, 2.04 trout per hour were taken by this method. Spinning and fly fishing which were less in vogue were also effective. These more active methods need a little more equipment and are not, perhaps, for the inexperienced angler. To make a complete analysis of the fishing methods it would be necessary to study the baits and lures used by anglers.

As Baldwin Pond seemed overpopulated at the opening of the season, it is understandable that the conditioning factor may be a little low. It did not prove practicable to learn the factor at the end of the fishing season, but it is a reasonable hypothesis, which later studies may confirm, that the conditioning factor improves in Baldwin Pond as overpopulation is reduced by fishing. By continuing the census year after year, it would be easier to approach the answer. Other data will help to compare growth curve. The constant $n = 2.781$ characteristic of the fish is a little lower than the optimum $n = 3$, but it is still very good.

Acknowledgments

This study has been carried out as part of the freshwater management programme of the Quebec Biological Bureau, directed by Dr. Gustave Prévost. This work has been greatly aided by Louis-Roch Séguin, biologist and director of the Eastern Townships Fish Hatchery. It is a pleasure to acknowledge the co-operation of all anglers of Baldwin Pond during the creel census. Thanks are due also to Paul Bouchard, Larry Wilson and other associates in the Quebec Biological Bureau for helpful suggestions in the preparation of this manuscript.

Literature Cited

CUERRIER, J.-P. and J. C. WARD. 1952a. *Game fish creel census. Analysis of creel census cards received from Eastern National Parks during the 1951 angling season.* Canadian Wildlife Service, National Parks Branch. Dept. of Resources and Development. Ottawa, Canada. 14 pages.

1952b. *Game fish creel census. Analysis of creel census cards received from Mountain National Parks during the 1951 angling season.* Canadian Wildlife Service, National Parks Branch, Dept. of Resources and Development. Ottawa, Canada. 31 pages.

CURTIS, BRIAN. 1951. *Yield of hatchery trout in California lakes.* California Fish and Game, 37 (2): 197-219.

FUKANO, K. G. 1948. *General creel census of fishing, 1947.* Michigan Conservation, 17 (12): 8, 9, 15.

GREENE, WILLARD C. 1952. *Results from stocking brook trout of wild and hatchery strains at Stillwater Pond.* Trans. Am. Fish. Soc., 81 (1951): 42-52.

KLAK, GEORGE E. 1941. *The condition of brook trout and rainbow trout from four eastern streams.* Trans. Am. Fish Soc., Vol 70 (1940): 283-289.

SMITH, M. W. 1952. *Limnology and trout angling in Charlotte County lakes, New Brunswick.* Jour. Fish. Res. Bd. Canada, 8 (6): 383-452.

1954. *Annual crops of speckled trout from a Prince Edward Island pond.* Progress Reports of the Atlantic Coast Stations, Fish. Res. Bd. Canada, No. 58: 21-23.

1955. *Fertilization and predator control to improve trout angling in natural lakes.* Jour. Fish. Res. Bd. Canada, 12 (2): 210-237.

Lea's Hydrostatic Tag on Brook Trout and Atlantic Salmon Smolts

by

M. W. Smith

Fisheries Research Board of Canada, Biological Station, St. Andrews, N.B.

Einar Lea first demonstrated the hydrostatic tag at a meeting of the International Council for the Exploration of the Sea in 1948. Since that time this tag has been used by a number of investigators on several species of fish. Dannevig (1953) obtained better returns with hydrostatic than either disk or strap tags in his studies of Norwegian cod. However, of more interest to us is the use of the hydrostatic tag on salmonoids. Went (1951, 1953) and Went and Vickers (1953) employed Lea's tag to advantage in tracing the movements of adult Atlantic salmon along the Irish coasts. Vibert (1953) tagged salmon smolts in southern France. A few of these smolts were later recaptured by mackerel fishermen well to sea in the Atlantic. Jensen (1955) recovered as high as 44.8 per cent of rainbow trout tagged and liberated in Roskild Fjord, Denmark.

In 1950 the hydrostatic tag was used on brook trout and smolts of the Atlantic salmon at Ellerslie Brook, Prince Edward Island. Since jaw tags had been and were currently being employed on brook trout at Ellerslie, a comparison of results from two types of tagging was possible. This article presents the results.

Lea's Hydrostatic Tag

The hydrostatic tag is illustrated in Figure 1. It has been previously described (Anon., 1953; Rounsefeld and Everhart, 1953; Went, 1951). Briefly, the tag consists of a small celluloid cylinder, plugged at both ends, and containing written instructions to the finder. It is attached by a bridle of stainless steel to a wire pin which pierces the flesh of the fish, usually just anterior to the dorsal fin (Fig. 2). Nylon line has been used for attachment in some instances (Collyer, 1954; Dannevig, 1953; Jensen, 1955). The specific gravity of Lea's tag is somewhat less than that of water.

The tags used at Ellerslie Brook were obtained from Mr. Lea. They were three centimetres long and four millimetres in diameter and coloured yellow with blue-tipped ends. Printed on the tag were the words "Canada", "Reward", and "cut ends, message inside", and a serial number.

Tagging

Tagging was done in connection with a study of the movements and populations in Ellerslie Brook of the brook trout primarily and the Atlantic salmon secondarily (Smith, 1951). Fish are captured in a two-way fish trap (trap A) as they move between salt water and Ellerslie Brook. A second similar trap (trap B), situated 650 yards upstream, captures fish as they move between the lower and upper sections of the brook. The traps have been described previously and their efficiency evaluated (Smith and Saunders, 1956).

Figure 1.—Lea's hydrostatic tag.

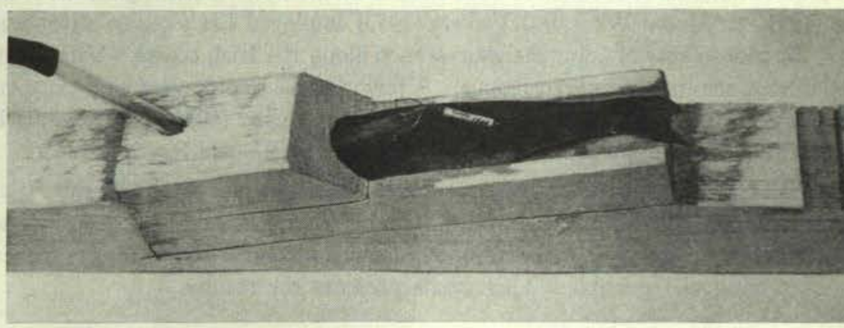


Figure 2.—Wooden "boot" in which trout were held during tagging.

Fish were held in a wooden "boot" while the hydrostatic tag was attached (Fig. 2). A continuous flow of water was supplied through a hole at the head of the "boot". The forward end of the "boot" was tilted downward to insure that the head of the fish was entirely submerged. Three "boots" with holes of different diameters were used. It was necessary to have the hole sufficiently large so as not to interfere with movements of the opercula in respiration, yet small enough to retain the fish well. The fish remained quiet during the entire tagging operation.

The following operations were involved in the tagging. The flesh of the fish, just anterior to the dorsal fin, was pierced with a number 18 hypodermic needle. A right-angle bend was made at one end of the pin. The straight end of the pin was threaded through one loop of the bridle and then through the hypodermic needle. The needle was withdrawn, the pin cut to the desired length and the other loop of the bridle slipped over the pin. Finally the straight end of the pin was bent, using two needle-nosed pliers, one to hold the pin rigidly, the other to bend it.

From June 14 to July 4, 1950, hydrostatic tags were placed on 100 brook trout as they moved into Ellerslie Brook through trap A. These trout had an average fork length of 18.4 ± 0.62 cm. Similarly, in the period November 16 to 20, 1950, 77 trout were tagged as they went downstream through trap B, and 23 others when they were taken going to salt water through trap A. The mean fork length of these two groups of trout were 16.0 ± 1.60 and 16.3 ± 2.87 cm. respectively.

During April and May, 1951, hydrostatic tags were also applied to 493 salmon smolts as they ran to sea through trap A. These salmon had an average fork length of 13.6 ± 0.57 cm.

From June 1 to July 27, 1950, 152 trout were jaw-tagged when they moved into the brook through trap A. During the month of November, 1950, jaw tags were also applied to 312 trout as they ran downstream through trap B and 261 as they went to salt water through trap A. This tagging was a continuation of a programme already under way at Ellerslie Brook whereby all trout moving through the traps, up- or downstream, were tagged. The jaw tag was of the strap variety, applied in a circular form around the mandible of the trout (Smith, 1957).

Recapture of Tagged Trout

Records of recapture of tagged trout were obtained in a number of ways: (1) from the traps, (2) by an annual creel census maintained on the brook and estuary, (3) during population studies in the brook, and (4) by capture in commercial smelt nets in the estuary.

Table I

Recaptures of trout bearing hydrostatic tags.

Manner of recapture	Number recaptured and time at large		
	<1 week	2-4 weeks	<4 weeks
I—Of 100 trout tagged in A trap going upstream			
Angled	9	4	2
In traps	1	0	1
During population studies	0	1	1
In gill-nets	0	0	1
II—Of 77 trout tagged in B trap going downstream			
Angled	0	0	4
In traps	24	4	7
In gill-nets	6	0	0
III—Of 23 trout tagged in A trap going to salt water			
In traps	0	2	1
In gill-nets	2	0	0

Table II

Comparison of number of recaptures of trout bearing hydrostatic and jaw tags

Place tagged	Number tagged	Recaptures		Number of recaptures after 100 days at large
		Number	Percentage	
I—With hydrostatic tags				
A trap up	100	20	20	1
B trap down	77	45	58	5
A trap down	23	5	22	1
Totals	200	70	35	7
II—With jaw tags				
A trap up	152	93	61	36
B trap down	312	214	69	111
A trap down	261	179	69	94
Totals	725	486	67	241

Hydrostatic tags.

Data on the recapture of trout bearing hydrostatic tags are summarized in Tables I and II. Seven tagged trout were recaptured twice. The first time was in trap A as they ran to salt water. However, only the final recapture is recorded in the tables.

There were 20 recaptures from the 100 trout tagged as they entered the brook. The majority (13) of these recaptures was made by anglers within a month of the tagging dates. The longest period that any of this group of trout was at liberty between tagging and recapture was 150 days.

Forty-five (58 per cent) of the 77 trout tagged in trap B as they moved downstream were recaptured. These trout were tagged in November when there is a general movement from the brook to salt water. Accordingly, it is not surprising that the greater number of recoveries were made at the mouth of the stream in trap A within a few days. Six individuals were subsequently taken in gill-nets in the estuary within a period of a week. Five from this group of 77 trout were at liberty 132 to 151 days between tagging and last recapture.

Five recaptures were made from the 23 trout tagged in trap A when running to salt water. Two individuals were captured within a week in gill-nets. The other three were taken in trap A as they re-entered the brook, one after being in salt water for 220 days.

In summary, 35 per cent of the trout bearing hydrostatic tags were recaptured. However, the majority of these trout were at liberty for the short period of less than one month. Recovery of tagged trout after having run to salt water was poor. Out of 200 trout with hydrostatic tags, only seven upon recapture had been at large for more than 100 days.

Jaw tags.

As shown in Table II, 67 per cent of the trout that were jaw-tagged as they moved up- and downstream through the traps were recaptured. There was little difference in the percentage recovery between those tagged going upstream and those that were running downstream and into salt water. In contrast to the returns with hydrostatic tags, a large proportion (50 per cent) of the jaw-tagged trout were at liberty over 100 days before recapture.

Recapture of Tagged Salmon

There are no records that any of the 497 smolts bearing hydrostatic tags were recaptured. Twenty adult salmon entered Ellerslie Brook during the fall of 1953 and 17 in 1954. None of these fish showed any evidence of having been tagged. It is possible that tags could have been shed without leaving recognizable scars. However, careful examination of each salmon failed to reveal any. No capture of salmon with hydrostatic tags has been reported from the commercial salmon fisheries of the Gulf of St. Lawrence area.

Two hydrostatic tags that had become free from the fish were found. One was picked up on the shore of Lennox Island in Malpeque Bay at a point about two miles from the mouth of Ellerslie Brook. The other was found on the beach at Percé, Quebec, a distance (shortest) of about 150 miles from Ellerslie. Since the tag is hydrostatic it would act in the manner of a drift bottle after being freed from the fish.

Summary

It was observed that the bridle of the hydrostatic tag became fouled with aquatic vegetation, especially filamentous algae, in Ellerslie Brook and estuary. In the brook, the trout, including tagged individuals, sought hiding places when disturbed. In so doing it seems probable that snagging of the bridle would frequently occur. It was further observed that the hydrostatic tag and its bridle tended to ride to one or the other side of the fish. As a result, the flesh of the fish was abraded by the end of the bridle where twisted around the pin and by the sharp free end of the pin itself. These conditions would militate against the survival of the fish and the retention of the tag.

The brightly-coloured hydrostatic tags were surprisingly conspicuous in the clear water of Ellerslie Brook. The bright colours were intentionally used to aid in recovery of the tags, yet their conspicuousness might attract undesirable attention. In this regard it was noted that trout struck at the hydrostatic tags carried by other individuals.

The fortuitous recovery of two unattached hydrostatic tags that had been placed on salmon smolts has been noted. Five additional unattached tags were found in Ellerslie Brook. These had been put on trout. However, the loss of these tags did not necessarily indicate death of the fish as shown by the capture of seven previously tagged trout with scars at the point of attachment of the tags. It is pertinent to note that jaw tags were shed by trout without apparent injury to the fish. Of 1,625 trout that had been jaw-tagged and subsequently recaptured in trap A during 1950, 70 (4.3 per cent) had lost the tag. (In applying both the hydrostatic and jaw tags the adipose fins were removed, which aided in spotting the previously tagged fish.)

Although tried on only a few salmon smolts, it was found that the tendency of the hydrostatic tag and its bridle to slip sideways was largely prevented by placing two small celluloid disks on the pin or either side of the fish and inside the attachment of the bridle. The disks added some encumbrance to the tag. Attachment with nylon line may have lessened the difficulty. Jensen (1955) experienced more recaptures of rainbow trout when nylon was used to attach hydrostatic tags. On the other hand, Collyer (1954) found that attachment with nylon gave no better results than when wire was employed in tagging the yellowtail (*Seriola dorsalis*).

The hydrostatic proved inferior to the jaw tag when used on trout at Ellerslie Brook. Fouling and snagging of the tag, more to be experienced in the confined quarters of Ellerslie Brook and estuary than in open waters, were important factors conditioning the results.

Acknowledgment

The assistance of J. W. Saunders, C. R. Hayes and Cyril Williams is gratefully acknowledged. This paper is published with permission of The Fisheries Research Board of Canada.

Literature Cited

ANONYMOUS. 1953. *A guide to fish marks used by members of the International Council for the Exploration of the Sea.* J. Conseil., 19(2): 241-289.

COLLYER, R. D. 1954. *Tagging experiments on the yellowtail, Seriola dorsalis* (Gill). California Fish and Game, 40(3): 295-312.

DANNEVIG, GUNNAR. 1953. *Tagging experiments on cod, Lofoten 1947-1952: Some preliminary results.* J. Conseil., 19(2): 195-203.

JENSEN, I. BOHUS. 1955. *Transplantation experiments with rainbow trout in brackish water.* Salmon and Trout Mag., No. 144, pp. 157-161.

SMITH, M. W. 1951. *The speckled trout fishery of Prince Edward Island.* Canadian Fish Culturist, No. 11, pp. 1-6.

1957. *Comparative survival and growth of tagged and untagged brook trout.* Canadian Fish Culturist No. 20, pp. 1-6.

SMITH, M. W. and J. W. SAUNDERS. 1956. *Efficiency of year-round operation of trout counting fences on a small stream.* Ibid., No. 18, pp. 6-9.

VIBERT, R. 1953. *Voyages maritimes des saumons et retour à la Riviere natale.* Bull. francaise Pisciculture, No. 170, pp. 5-23.

WENT, A. E. J. 1951. *Movements of salmon around Ireland. I. From Achill, Co. Mayo (1948 to 1950).* Proc. Roy. Irish Acad., 54 (section B): 169-201.

WENT, A. E. J. 1953. *Movements of salmon around Ireland. III. From Carnlough, Co. Antrim (1950 and 1951).* Ibid., 55 (section B): 209-223.

WENT, A. E. J. and K. U. VICKERS. 1953. *Movements of salmon around Ireland. V. From North Country Antrim (1951 and 1952).* Ibid., 56 (section B): 13-28.

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1957.

ISSUE TWENTY-ONE
DECEMBER - - 1957

THE CANADIAN FISH CULTURIST

Published at Ottawa by
The Department of Fisheries of Canada

CONTENTS

Page

The Importance of Size in the Change from Parr to Smolt in Atlantic Salmon—P. F. ELSON 1

Using Hatchery-Reared Atlantic Salmon to Best Advantage—P. F. ELSON 7

Number of Salmon Needed to Maintain Stocks—P. F. ELSON 19

The Role of Hatcheries in Securing Maritime Stocks of Atlantic Salmon—P. F. ELSON 25

The Canadian Fish Culturist is published under the authority of the Minister by the Department of Fisheries of Canada as a means of providing a forum for free expression of opinion on Canadian fish culture. In the areas of fact and opinion alike, the responsibility for statements made in articles or letters rests entirely with the writers. Publication of any particular material does not necessarily imply that the Department shares the views expressed. In issuing The Canadian Fish Culturist the Department of Fisheries is acting only as an instrument for assisting in the circulation of information and opinion among people in the fish culture field. Those who may wish to discuss articles which have been published in The Canadian Fish Culturist are encouraged to do so and space will be made available.

Correspondence should be addressed to the DIRECTOR, INFORMATION AND EDUCATIONAL SERVICE, DEPARTMENT OF FISHERIES, OTTAWA, CANADA.

Published under Authority
of
HON. J. ANGUS MACLEAN, M.P.,
Minister of Fisheries

The Importance of Size in the Change from Parr to Smolt in Atlantic Salmon

by

P. F. Elson

Fisheries Research Board of Canada, Biological Station, St. Andrews, N.B.

The factors associated with the metamorphosis of young Atlantic salmon from river-dwelling parr to seaward-migrating smolts have not been very well defined. Size has been regarded as an important factor by some investigators and relegated to a minor position by others. Pyefinch (1955) gives a useful review of literature on the subject of this change from parr to smolt. Svardson (1955) suggested a set of hypotheses involving "physiological age" of the individual fish in combination with environmental considerations. Most investigators have concentrated their attention on the young salmon near or during the immediate season of migration. Vibert (1950), however, offered evidence that age at migration had been set by the end of the first winter of river life.

Salmon production of the Miramichi River system, in New Brunswick, has been investigated by the Fisheries Research Board of Canada for the past seven years. Part of the program calls for knowledge of the numbers of smolts produced. Direct counts have not been attempted in the larger tributaries because log drives prevent weir operations during part of the run. Indirect estimates are consequently necessary. These rely upon a combination of seining and electrofishing done late in the summer. In the Miramichi system approximately one-third of the smolts migrate as two-year-olds and two-thirds as three-year-olds. Observations by Canadian investigators indicate that size, or physiological condition associated with size, of parr in their pre-smolt year seems to be a more important factor than age in the change from parr to smolt. As a working approximation an arbitrary dividing line between large parr, likely to become smolts next spring and small parr, not likely to, has been set at about 10 cm. or 4 in. total length, measured from tip of snout to tip of tail. From the facts assembled here it appears that there is justification for using this convenient rule of thumb.

Evidence from hatchery yearlings

In mid-June, 1945, hatchery-reared yearling Atlantic salmon of sea-run, and of lake, or landlocked, stocks were being planted in the Rawdon River, Grand (Schubenacadie) Lake system of Nova Scotia. It was observed that the larger fish of both stocks had a heavy, silvery coating of guanin on their scales, much more than is normal for river-dwelling parr of comparable size. Other smolt characteristics such as low condition factor and easily loosened scales were apparent to a minor degree. Enquiry to the Department of Fisheries revealed that all the fish "had been fed (chopped) plucks and fish through January to the time of examination (June 16), except that they were fed fish only during the second and fifth weeks of May. It is quite possible that the thyroid gland was included in the plucks which were fed......". Hoar (1939) has shown that the change from parr to smolt stage, which he terms a true metamorphosis, is associated with greatly increased activity of the thyroid gland. Robertson (1949) showed that in large (9 to 10 inches) two-year-old rainbow trout (*Salmo gairdneri*) the silvery smolt stage could be induced by intra-muscular injection of mammalian thyroid extract. Hoar (personal communication) has expressed his opinion that "certainly fresh thyroid gland in the food supply should tend to initiate a smolt transformation".

At the time of the observations above, approximately 300 fish from each stock were taken at random from the supplies in the hatchery's holding ponds. Each fish was classified according to the extent of its silvery colour as "parr", or "smolt". The fish were measured and mean lengths were calculated for each of the categories in both stocks. For both kinds of salmon there was a fairly clear-cut division into large, silvery "smolts" and into smaller "parr" without obvious silvery colour. These size groupings are shown in Figure 1. There was some overlapping of sizes between parr and smolts but there was no silvery coloration on fish of sea-run stock under about 11½ cm. or on lake stock under about 10½ cm. long.

Comparison between sea-run and lake salmon is shown in Table I.

Table I.

Lengths (cm.) of yearling salmon of sea-run stock and of lake stock, from the Schubenacadie Grand Lake Rearing Ponds, Nova Scotia. (Measured June 16, 1945.)

	Parr			Smolts		
	Number Specimens	Mean Length	Standard Deviation	Number Specimens	Mean Length	Standard Deviation
Sea-run	264	10.2	±1.0	65	14.2	±1.3
Lake	238	9.7	±1.4	52	13.8	±1.5

The difference in size of the two stocks seems largely attributable to the lake salmon growing more slowly than the Atlantic salmon. In keeping with this a slightly smaller proportion of lake salmon (18%) than of sea-run salmon (20%) showed the change from parr to smolt. Wilder (1947) also found relatively slow growth to be a characteristic of lake salmon.

The data show that both the sea-run and lake salmon stocks conformed to a general size characteristic in relation to the incidence of guanin deposition. The evidence does not show that the fish became smolts at a specific size of about 10 cm. Rather it shows that, for both stocks, only those fish which had already reached 10 cm. were subject to the change from parr to smolt.

This evidence of a size prerequisite for transformation of hatchery-reared fish should be useful to fish culturists in planning salmon-rearing programs for particular purposes. For example, in a stream where smolts are typically three years old, fingerlings planted in one summer would be expected to produce a smolt run three years

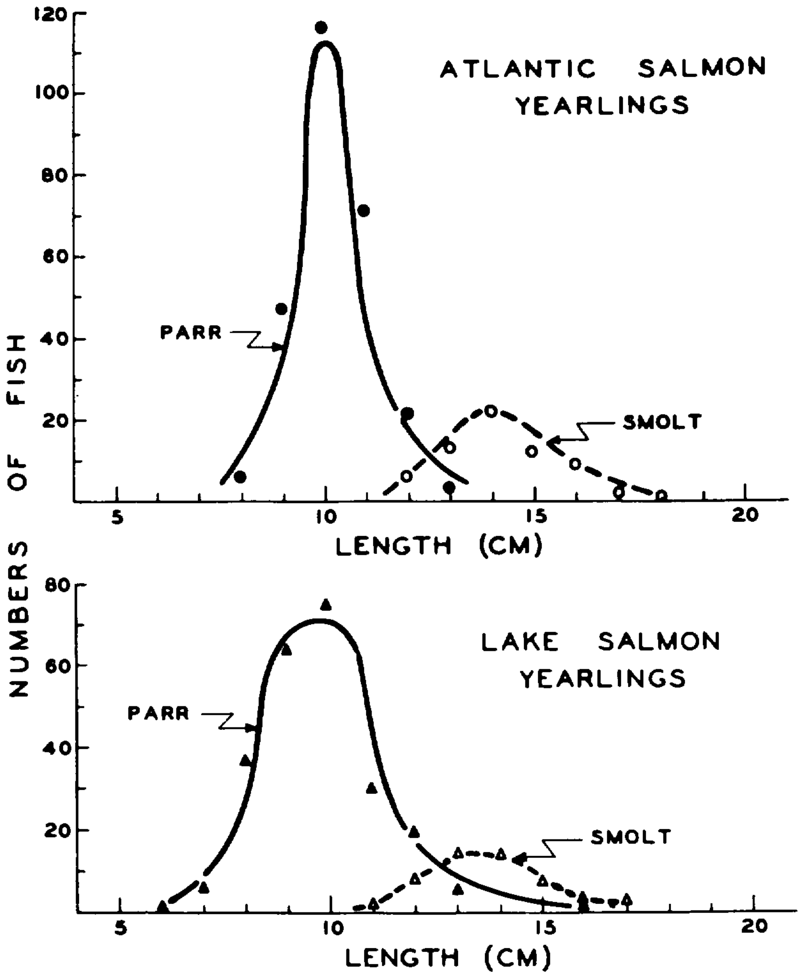


Figure 1.—Length-frequency distribution of hatchery-reared yearling salmon of Atlantic and lake stocks, classified as parr having no obvious silvery guanin deposit on the scales, and smolts having a heavy guanin deposit. Only fish over 11½ cm. (Atlantic) and over 10½ cm. (lake) showed this smolt characteristic. (Fish examined at Grand Lake Rearing Ponds, N.S., June 16, 1945)

later; planting small parr should yield a run only two years after planting, and planting large parr one year after. Liberating smolts directly from the hatchery is proving worth while for one Swedish river from which salmon have been excluded by a dam (Carlin, 1955). Programmes using hatchery-reared smolts might benefit by consideration of such a size prerequisite. This subject is now being examined through experimental plantings.

Evidence from Pollett River Smolts

During the course of experiments involving Atlantic salmon smolt production from the Pollett River, Petitcodiac River system, New Brunswick, scales from several thousand smolts were examined. For the most part age determinations only were made. Here, 90 to 95 per cent of the smolts run as two-year-olds, and almost all the rest as three-year-olds. Measurements of scale radii for the several years of river life were made on 250 typical samples from the 1950 smolt run. For the 14 three-year-old smolts measured, the calculated mean length and standard deviation at the end of the second winter was 10.7 ± 0.8 cm. For a representative group of 22 two-year-old smolts from the same migration, calculated mean length at the end of the second winter was 14.0 ± 1.7 cm. Examination of scales from Pollett parr collected monthly through most of a year indicated that usually about one-quarter of the growth for the year occurred during the laying down of the winter band, between about Mid-August and the following May. In consequence most fish which were about 11 cm. long by the time the winter band was completed were probably well under 10 cm. long in the preceding August: but those which were around 14 cm. long, or longer, in May must have been at least 11 or 12 cm. long in the preceding August. These Pollett young salmon conformed fairly well to the hypothesis that those which exceed a length of 10 cm. by late summer, become smolts in the following spring; while those which do not attain this size remain in the river for an additional year or more.

Evidence from Scotland—Thurso River

Allen (1944) made an extensive study of salmon smolts from the Thurso River system of northeastern Scotland. In his Table VII he gives the lengths at smolt stage and calculated lengths at the end of the immediately preceding winter for 1,317 two-year-smolts. These are expressed as mean lengths for fish captured during successive five-day periods. The general mean for all fish at the end of the preceding winter was 10.6 cm. Only two groups totalling 50 fish, or 4 per cent of the collection, had a mean length under 10 cm.; and it was 9.5 cm. at the end of the preceding winter. Unfortunately Allen does not give first- and second-winter lengths for the small percentage of three-year smolts he recorded. However, the fact that 96 per cent of his two-year smolts reached the 10 cm. length at this time, and the rest nearly attained it, gives support to the hypothesis that there was a size prerequisite for the change, which was of the same general order as that observed in Canada. Allen concluded that "there is no critical length at which migration takes place". But he concurred with earlier authors, that "parr must attain some physiological condition associated, at least as an index, with a minimum size before the smolt migration takes place". The hypothesis that this condition is associated with a length requirement of about 10 cm. during the latter part of the pre-smolt year of growth, is not at variance with the conclusions drawn by Allen.

Evidence from England—The Cheshire Dee

Jones (1949-Appendix, Table II) gives the calculated yearly lengths of 335 smolts taken from the River Dee, Cheshire, in 1938 and 1939. He had one-, two- and three-year smolts. Nearly 92 per cent of these fish satisfy the present hypothesis. Dee smolts which did not conform were those migrating at 1+ years. But even these had all made rapid growth during the first season—$7\frac{1}{2}$ to $9\frac{1}{2}$ cm. against $4\frac{1}{2}$ to 5 cm. Rapid spring growth in the season of descent brought them to about $12\frac{1}{2}$ cm. Since a large majority of the fish conform, the 10-cm. hypothesis should be useful in studying late summer parr populations in such a stream.

Evidence from France—River Adour

Vibert (1950) gives calculated mean lengths at the end of each year of river-life for 492 smolts and 1,022 virgin salmon, in his Table XIV. Nearly all the fish conformed in that they did not migrate if they had not reached the 10-cm. length, but migrated in the next spring, after reaching or exceeding an approximate 10-cm. length towards the end of a growing season. One three-year smolt reached a length of 11 cm. at the end of its second year, as did one of Jones' three-year smolts from the River Dee. Since the 10-cm. hypothesis is based on mean lengths in late summer rather than the length of individual fish at the end of a year's growth these do not constitute exceptions. Among Vibert's virgin salmon, a group of 11 which had been three-year smolts had a calculated mean length of 13.6 cm. at the end of their second year of river life but still spent one additional year in the river. The fact that 99 per cent of his fish conformed to the 10-cm. hypothesis indicates that it would be a useful working rule here also.

Discussion and Summary

Evidence is presented from both sides of the Atlantic to show that, as a general rule, parr which have reached or exceeded a certain size towards the end of one growing season are likely to become smolts at the next season of smolt descent. A similar size prerequisite also appears to hold for a slower-growing Canadian lake salmon stock. In fact, the concept of a size prerequisite appears to have more fundamental significance with respect to change from parr to smolt than either age or size at the actual time of transformation.

The hypothesis definitely does not specify that young Atlantic salmon become smolts as soon as they reach a length of 10 cm., but rather that they transform after reaching this length in the smolt-running season immediately following. Growth of parr is variable. Those which have nearly but not quite reached the 10-cm. length at the end of a summer will, if they grow fast, reach a much greater length, say 14 to 16 cm., at the end of the following summer, and make big smolts. Those which have just barely attained the required 10 cm. size at the right time will, if slow-growing, make little smolts, perhaps only about 12 cm. long. The 10-cm. hypothesis thus takes account of the extremely variable size-range of smolts from many types of rivers.

Some individuals destined to become older smolts may exceed this length, but seldom by more than two or three cm., at the end of their second last season of river growth. A few fish may not quite reach this size but still become smolts during the following spring if they grow fast and exceed the 10-cm. length during the smolt-running season. While not precise for individual fish, this 10-cm. hypothesis provides a useful and justifiable rule of thumb for gauging annual smolt production from streams.

Canadian investigators of Atlantic salmon at present classify young salmon as "small" parr, those which will probably spend one or more additional years in river growth, and "large" or "pre-smolt" parr, those which are likely to descend as smolts during the next seaward migration. The arbitrary division between the two groups of parr has been chosen at a total length of 10 cm. or 4 in. reached during the latter part of a year's growth.

Use of the hypothesis should contribute to effective planning of salmon-rearing programs for hatcheries, if special purposes can be served by planting larger fish.

Acknowledgments

The Grand Lake salmon were examined while assisting Dr. A. G. Huntsman in his investigations there; he kindly made time available for the observations on hatchery stocks. Mr. William Cameron, Superintendent of the Grand Lake Rearing Ponds, assisted in handling these yearling salmon. Mr. W. G. Carson of this Station made the scale measurements for Pollett smolts while reading some 2,000 smolt scale samples from this stream. I thank these gentlemen for their help.

Literature Cited

ALLEN, K. RADWAY. 1944. Studies on the biology of the early stages of the salmon (*Salmo salar*). 4. The smolt migration in the Thurso River in 1938. J. Anim. Ecol., Vol. 13, pp. 63-85.

CARLIN, BÖRJE. 1955. Tagging of salmon smolts in the River Lagan. Institute of Freshwater Research, Drottningholm. Report No. 36, Ann. Rept. for the year 1954 and short papers, pp. 57-74.

HOAR, WILLIAM S. 1939. The thyroid gland of the Atlantic salmon. J. Morph., Vol. 65, No. 2, pp. 257-295.

JONES, J. W. 1949. Studies of the scales of young salmon, *Salmo salar* L., in relation to growth, migration and spawning. Ministry of Agriculture and Fisheries, U.K. Fishery Investigations. Series I, Vol. V. No. 1, pp. 1-23.

PYEFINCH, K. A. 1955. A review of the Literature on the Biology of the Atlantic Salmon (*Salmo salar* Linn.). Scottish Home Department. Freshwater and Salmon Fisheries Research. No. 9, pp. 1-24.

ROBERTSON, P. H. 1949. Production of the silvery smolt stage in rainbow trout by intramuscular injection of mammalian thyroid extract and thyrotropic hormone. J. exp. Zool., Vol. 110, No. 3, pp. 337-355.

SVARDSON, GUNNAR. 1955. Salmon stock fluctuations in the Baltic Sea. Institute of Freshwater Research, Drottningholm. Report No. 36, Ann. Rept. for the year 1954 and short papers, pp. 226-262.

VIBERT, R. 1950. Recherches sur le saumon de l'Adour (*Salmo salar* Linné). (Ages, Croissance, Cycle génétique, Races) 1942-1948. With an English summary. Annales de la Station centrale d'Hydrobiologie appliqué, Tome 3, pp. 27-149.

WILDER, D. G. 1947. A comparative study of the Atlantic salmon, *Salmo salar* Linnaeus, and the lake salmon, *Salmo salar sebago* (Girard). Canadian J. Res. Section D. 25, pp. 175-189.

Using Hatchery-Reared Atlantic Salmon to Best Advantage

by

P. F. Elson

Fisheries Research Board of Canada, Biological Station, St. Andrews, N.B.

Good management of Atlantic salmon requires knowledge of how to get the best production of seaward-migrating smolts. This applies whether the stocking be through natural means or through the introduction of hatchery-reared stock. The Fisheries Research Board of Canada has, for a number of years, been investigating factors associated with the production of smolts from hatchery-reared stock. This is a preliminary survey of the results which can be found in condensed form at the end of the paper.

Much of the following discussion will refer to numbers which can be produced, must be planted and so on. To use total numbers from experiments would have no significance for other areas than the one in which studies were made. Hence, important figures have been converted to easily imagined units. For general use the average number per 100 square yards has been selected—an area 30 feet by 30 feet, or about the size of an average house. Sometimes it is more convenient to think in terms of the length and width of a stream. For this a unit of one mile of stream 10 yards wide (176 of the square units) has been selected. The 100 square yard unit will be meant unless otherwise stated.

1. PREDATION BY MERGANSERS SHOULD BE LIMITED

Several years ago White (1939) found that a stream stocked with native salmon gave more smolts when mergansers (*Mergus merganser americanus*) and kingfishers (*Megaceryle alcyon alcyon*) were kept away. A study has recently been completed on the effect of similar bird control in increasing the smolt yield from hatchery-reared fish. Experiments were done on a 10-mile stretch of the Pollett River, a tributary of the Peditcodiac system in southeastern New Brunswick. Table I shows the total number of two- and three-year-old smolts produced from seven different plantings of underyearling salmon. Two of the plantings were quite light; five were fairly heavy. However, as will be shown in Section 2, below, even the light plantings should have experienced a better survival rate than they did. If judged solely on a comparison of the results from the heavy plantings, there was an increase of about four times with birds kept away. If judged on the average "before and after" figures, by nearly seven times.

Table I also shows the estimated number of parr in the river, midway between planting and smolt descent. It is on these parr that the birds do most of their feeding.

Table I

Smolt production from known plantings of hatchery-reared underyearling salmon in the 10-mile experimental area (approximately 435,000 sq. yd.) of the Pollett River, N.B.

	Year of planting	Number of underyearlings planted (nearest 5,000)	Resulting parr 1 year after planting (nearest 5,000)	Resulting 2- and 3-year smolts (nearest 1,000)
With no bird control	1942	15,000	under 5,000	2,000
	1943	15,000	under 5,000	1,000
	1945	250,000	10,000	5,000
Average		over 15,000	5,000	3,000
With control of mergansers and kingfishers	1947	275,000	25,000	22,000
	1948	235,000	45,000	14,000
	1949	245,000	40,000	19,000
	1950	245,000	55,000	24,000
Average		250,000	40,000	20,000

Records were kept of all birds seen. The food recently eaten by many of those shot was studied. In Table II estimates are given of the number of fish which the birds could have eaten had there been no control. There are also estimates of the numbers that could have been eaten by those birds which escaped the patrols. Without control, enough mergansers visited the area to eat more parr than the river could support. But with control the remaining mergansers could take only about one quarter of the parr when there was a good parr crop. This is not enough to seriously affect the smolt-producing capabilities of the stream.

Table II

Estimated numbers of fish which visiting mergansers and kingfishers could eat annually while on the 10-mile experimental area of the Pollett River.

—	Mergansers		Kingfishers	
	All fish	Young salmon	All fish	Young salmon
Without Control	180,000	75,000	120,000	10,000
With control	20,000	10,000	10,000	1,000

Year-to-year records showed that when parr were more abundant, more mergansers came to the area. They came any time of the year that there was open water on the river (Fig. 1).

In general, the rate of production when mergansers had free reign was about one smolt per 100 square yards of stream. With bird control, production jumped to a rate of five to six smolts per 100 square yards.

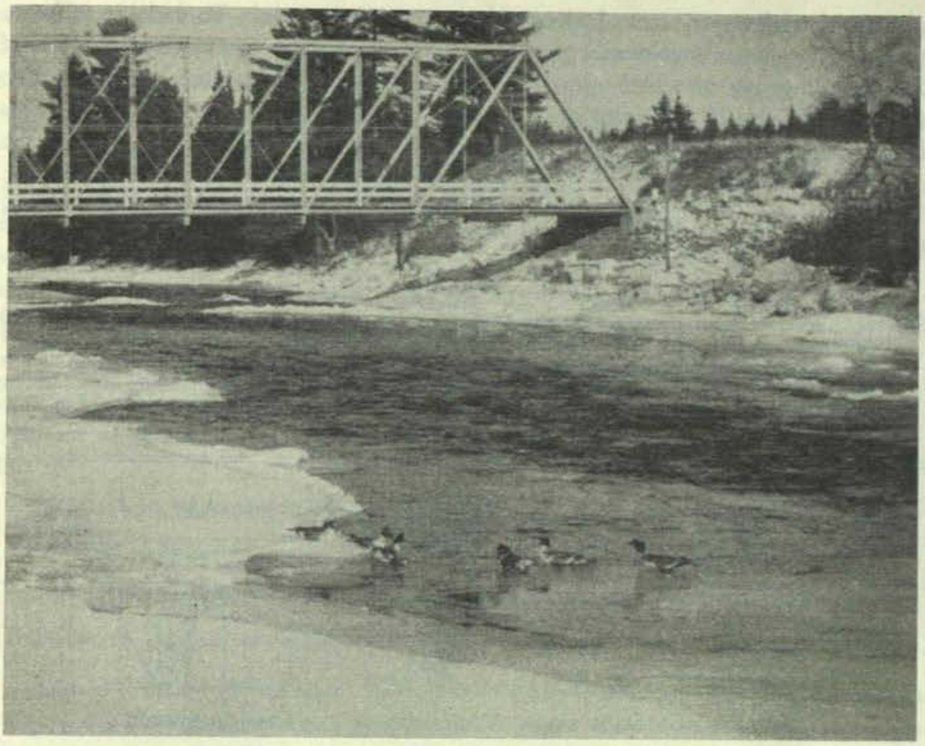


Figure 1.—Mergansers on a New Brunswick salmon stream in mid-winter.

Surveys have shown that mergansers are as abundant on many Maritime streams as they were on the Pollett. But they are furtive birds and their abundance can easily be underestimated. To get the best results from hatchery-reared stock, or native stock too, for that matter, mergansers should not be more abundant than about one bird for every 10 to 15 miles length and 10 yards width of stream.

Kingfishers, as shown in Table II, could not remove enough young salmon to seriously affect the smolt output unless the birds were to increase greatly in numbers. Their habits make them conspicuous along a stream. Because of this, in contrast to mergansers, it is very easy to overestimate their abundance and their importance to salmon. It is doubtful that the results of controlling kingfishers along most salmon streams would warrant the trouble and expense. However, if they were more abundant than two for every mile length and 10 yards width of stream, control might be worth while.

2. HOW MANY FISH SHOULD BE PLANTED?

To know how many fish to plant it is first necessary to know how many smolts an area can produce.

Smolt producing capacity of streams. The bird control studies mentioned above showed that the 10-mile stretch of the Pollett could produce smolts at a rate of about one per 100 square yards without bird control; but five with control. This was from planting fingerlings at rates of 55 to 60 per 100 square yards. To find out whether planting more fingerlings would give more smolts a planting was made at the rate of 213 fingerlings per unit area—about four times as many. Data are given in the two top rows of Table III. Smolts were produced at the rate of six per unit area. This is not sufficiently different from five smolts to be regarded as anything more than the difference between years with favourable or unfavourable conditions for survival. That is to say, the maximum capacity with bird control can be set at five to six smolts per 100 square yards.

Table III

Smolt production and survival rates from heavy, medium and light plantings of underyearlings and one small accidental spawning in a 10-mile stretch of the Pollett River, N.B. Total experimental area = 435,000 sq. yd. (a) Accidental spawning resulted when exceptionally high freshet brought a few adult salmon past a closed fishway into the experimental area. (b) "Best survival rate" from planting to parr was approximately 25%. (c) "Best survival rate" from parr to smolts averaged approximately 65%.

Number of underyearlings planted		One-year parr per 100 sq. yd.	Survival rate underyearlings to parr %	Two-year smolts		Survival rate parr to smolts %
total	per 100 sq. yd.			per 100 sq. yd.	total no.	
925,000	213	16	8	6	23,750	34
240,000	55	15	27(b)	5	22,852	35
65,000	15	4	27(b)	2	8,052	51(c)
accidental(a)	—	over 1	—	under 1	3,556	80(c)

Observations on young salmon in Miramichi streams (Elson, 1957a) indicate that the smolt producing capacity of these streams, both without and with bird control, is similar to that found for the Pollett. A relatively infertile stream in the Gaspé peninsula of Quebec, the Port Daniel River, also gives smolts at the approximate rate of one per 100 square yards; not enough mergansers visit this stream to warrant their control.

Survival rates from fingerlings to smolts. The plantings which gave maximum smolt production may have wasted quite a few fry. In fact, compared with results of the planting made at a rate of 55 fry, planting 213 fry did waste about three quarters of the fish. To discover the "best survival rate" when no such wastage was involved, a planting was made at about one quarter of the first rate (actually, 15 fry per 100 square yards). This and other measurements of "best survival rate" from sparse populations, which means no unnecessary wastage, are given in the last two lines of Table III. The best survival rates from fry to yearlings were a bit over 25 per cent. The best survival rates from sparse parr populations to smolts averaged 65 per cent. This gives over 16 per cent as the survival rate from fry to smolts. To play safe the general rate from late summer fingerlings to two-year smolts should be 15 per cent.

Although the smolt capacity of Miramichi streams is apparenly about the same as the Pollett, there is one important difference. Where nine out of 10 Pollett smolts are two years old, seven out of 10 Miramichi smolts are three-year-olds. This means Miramichi parr must go through an extra year in the river, during which there is some mortality. Here again the observations in the Miramichi area indicate that the survival rate over this extra year is of the same general order as the rate over the last year on the Pollett, i.e., about 65 per cent. So the survival rate for three-year smolts from late summer plantings of fry should be set at only 10 per cent.

It would be useful to know from which streams to expect three-year smolts and which streams two-year-olds. Smolt age appears to be clearly associated with water temperature. In general, warm streams, say over about 68°F. (20°C.) in summer give two-year smolts. Cool streams, say 60°F. to 65°F. give three-year smolts. In still colder, or in very infertile streams, smolt age may be increased to four, five or even eight years; but smolts this old are uncommon in the Maritimes.

Number to plant. The best number to plant is that which will give the full capacity of smolts, while giving the highest survival rate from the planted fish. Approximate figures for the largest numbers of fingerlings it would be worth while to plant are:

In fertile streams with mergansers less than one per 10 miles × 10 yd. of stream.

for two-year smolts	7,000 fingerlings per mile × 10 yd. wide
for three-year smolts	10,000 fingerlings per mile × 10 yd. wide

In barren streams, or fertile streams with mergansers more abundant.

for two-year smolts	2,500 fingerlings per mile × 10 yd. wide
for three-year smolts	3,500 fingerlings per mile × 10 yd. wide

These are the highest figures. In most years planting 1,000 or so less should give nearly all the smolts the stream could raise. But planting many more is almost certain to result in waste of all the excess either through predation or starvation.

3. AMOUNT OF DISPERSAL AT PLANTING.

There are two aspects to this: the amount of scattering at chosen planting sites; and the distance between planting sites.

Dispersal at planting sites. The best amount of dispersal at planting received study on a section of the Pollett 10 miles above the area used for the studies of smolt production already mentioned. Three different degrees of dispersal were tested at each of three similar planting sites located two miles apart. The fish planted in each area were distinctively marked by removal of certain fins. Three years was required to complete the planting schedule. The results were measured by counting the smolts from each planting as they passed through the smolt trap 15 miles downriver (Table IV).

The final results indicate that the different degrees of dispersal had no appreciable effect on the number of smolts produced. The difference in the various smolt runs (Table IV) proves on analysis to be largely the result of good and bad years. Further, the bad years were years when mergansers were relatively abundant. No bird control, other than removal of merganser broods, was employed for these dispersal experiments. The important conclusion from this study is that nothing would appear to be gained

Table IV

Smolts produced from plantings of 4,000 underyearling salmon given different amounts of dispersal at liberation.

Dispersal at planting, as nos. per 100 sq. yd.	Number of smolts produced			
	from 1948 plantings	from 1949 plantings	from 1950 plantings	from all 3 plantings
50	1,183	1,911	618	3,712
500	1,329	1,407	868	3,604
5,000	767	1 793	972	3,532
Total smolts from plantings of 1 year	3,279	5,111	2,458	10,848

by scattering underyearlings, at planting, more widely than at a rate of 5,000 per 100 square yards at each planting site. A similar study of dispersal rates for yearlings is just being started.

Distance between planting sites. The natural spreading of the young fish away from their points of liberation was followed in several of the planting experiments mentioned above. The general picture was that the surviving fish spread fairly uniformly over the stream for about one-half mile up- and one mile downstream in one to two months' time. A year after planting they were fairly well scattered over one mile up- and downstream. A few fish travelled several miles farther than this. But the intervening stream was clearly not being fully utilized. Such lack of utilization did apply to an area two miles below the lowest liberation site through all the years of extensive planting for bird control and smolt capacity studies.

It is therefore concluded that to get full utilization of a stream's resources planting sites should, ideally, not be over two miles apart. However, access for hatchery trucks will often make this impractical; in that event some, if not full use will be made of intervening areas, even if they be several miles long.

4. SIZE OF FISH TO PLANT.

Until recently most hatchery plantings of Atlantic salmon in Canada have liberated fingerlings around $1\frac{1}{2}$–2 inches long. By holding the fish a year they can be grown to 3–6 inches long. Rearing large fish is more costly than rearing underyearlings. When is the extra expense warranted?

A common reason for planting larger fish is the hope that they may be able to escape enemies better than small fish. Consider, however, streams where mergansers are the chief enemy. Mergansers usually take parr from about three inches upwards, but seldom take two-inch fish if larger are available. In such streams newly-planted parr may not be competent in avoiding their new enemies. But their brothers planted as much smaller fingerlings are well adjusted to life in streams by the time they reach this size. Newly-planted fish face not only predators, but also competition with native fish of their own kind. As shown by Miller (1953) for a related species (*Salmo* *clarki*) of the west coast this and the strain of adjustment to a new habitat may reduce survival to as low as 0 per cent–3 per cent, even for fish larger than any salmon parr.

The results of some small-scale experiments on yearlings planted in two streams of the Petitcodiac River system in New Brunswick are informative. Holmes Brook and Bennett Brook are each about five miles long and are from two to five yards wide. Both have small populations of native salmon (about two per 100 sq. yd.). In the Holmes Brook more than half the native salmon migrated as three-year smolts, the rest as two-year-olds. Practically all Bennett smolts were two-year-olds. Other fish present in both streams were eels, horned dace (*Semotilus atromaculatus*), Lake Northern chub (*Couesius plumbeus*), black-nosed dace (*Rhinichthys atratulus*) and brook trout (*Salvelinus fontinalis*) which are fished by local anglers. Occasional kingfishers visited the streams, but mergansers seldom if ever. Thus, the two brooks offered conditions similar to those on many Maritime salmon streams when mergansers are not abundant.

The hatchery yearlings, averaging about 10 cm. (4 in.) long, measured from tip of snout to end of tail, were divided into a number of small groups, some of which were of ordinary sea-run stock and some lake stock. Each lot was distinctively fin-clipped before planting. No differences in behaviour or survival value of the two stocks was noted. But considering the differently-marked groups as comprising different experiments adds to the value of the final result. All those surviving to smolt stage migrated the year after planting, as two-year-olds. This applied in both brooks. The results are given in Table V. They may be summed up, in the

Table V

Smolt production and survival rates from July plantings of hatchery-reared one-year-old Atlantic salmon parr in tributaries of the Petitcodiac River, N.B. (In 1945 both Atlantic and Lake salmon were planted in about equal numbers: in 1946 only Atlantic salmon.)

Date and place of planting.

Year	Brook	Miles above smolt trap	Number planted	Number of smolts	Survival rate %
1945	Holmes	1	26 (Atlantic)	12	23
		2¼	26 "		
		1	26 (Lake)	13	25
		2¼	26 "		
1945	Bennett	¼	24 (Atlantic)	1	4
		3	26 "	5	19
		5	26 "	4	15
		¼	31 (Lake)	4	13
		3	25 "	1	4
		5	26 "	3	12
1946	Bennett	¼	50 (Atlantic)	15	30
		2	150 "	22	15
		3	117 "	8	7
		4½	53 "	1	2
		5	50 "	1	2
	Total		682 1-year parr	90 2-year smolts	

Mean survival rate and its standard error .... 13 ± 3%

statement that it is unlikely that similar plantings of yearling parr would experience an average survival rate of less than 5 per cent or more than 20 per cent.

This is not materially better than the 15 per cent survival rate which can be obtained from underyearlings (see Section 2). But the yearlings yielded smolts one and two years earlier than underyearlings would have. On the basis of these data we must conclude that if the object of planting young salmon is merely *to obtain the greatest number of smolts*, then *proper numbers of underyearlings should be planted.* Whether a similar result would apply if such predacious fish as white perch, yellow perch, and fallfish (*Semotilus corporalis*) were abundant, as they are in some salmon streams, has not been investigated. Another conclusion is that *if the object is to obtain smolts as soon as possible, then larger parr should be planted.*

By properly selecting the fish it should be possible, in a three-year smolt stream to reinforce smolt runs occurring any time between planting and three-years later as desired. In order to become smolts, parr must, as a rule, reach a length of about 10 cm. (4 in.) some months before the spring period of smolt migration (Elson, 1957b). Thus, as happened in Holmes Brook, yearling fish which will reach this length in the year of planting will make two-year smolts the next spring, even though the normal smolt age for the stream is three years. Fish which will reach only eight or nine cm. in the year of planting should make smolts two seasons later.

Hatcheries rear some young salmon to smolt stage as yearlings. Will they migrate to sea immediately, if liberated? Hoar (1939) found that the change to smolt stage was associated with increased activity of the thyroid gland. But he also found that if smolts were forced to remain in fresh water after the normal migration period this gland tended to revert to the parr condition. The migratory urge may be lost. This is indicated by the behaviour of some of the yearling fish planted in Bennett Brook in July, 1946. Among the 420 fish liberated, 16 per cent appeared to be smolts, similar to the condition Elson (1957b) reported for other hatchery yearlings. None of these Bennett fish was taken in the smolt counting weir below, in the year of planting. Several were recognized living near their original planting sites, during the summer. Occasional post-smolts which failed to get to sea have been observed in other places. They appeared to be slowly reverting to characteristic parr appearance and behaviour. Hence it would appear advisable to liberate hatchery-reared smolts early in the spring —say in May—if advantage is to be taken of their migratory urge.

Occasions may occur when the expense of planting larger fish than normal underyearlings would be warranted. The recent decimation of Miramichi young salmon by spraying of DDT has been reported by Kerswill and Elson (1955). Plantings of assorted sizes of young salmon could properly reinforce the various year-classes. But these authors found that more large fish survived the spraying than small. It may be necessary that planted fish be subjected to spraying in order to preserve the forests. If so, it would seem advisable to plant them at the largest size reasonably possible. Spraying gives rise to one situation where *only* large fish could remedy some of the deficiencies.

5. TYPES OF BOTTOM FOR PLANTING.

In the experimental plantings described, most fingerlings were liberated in water less than one foot deep, usually in rapids. Studies of the distribution of native young salmon have shown that this is the kind of habitat they prefer. It would be incurring unnecessary risk to liberate such small fish, not yet adapted to the rigours of life in streams, in pools where larger trout or other fish could readily gobble them up. Equally hazardous are areas with large cobble and rocks where eels are abundant. In the Pollett plantings, eels from about a foot upwards in length, were found to take many fingerlings within a few hours of planting in such areas.

6. EELS AS A LIMITING FACTOR FOR SURVIVAL OF UNDERYEARLINGS.

Various observations made during earlier studies, as well as the Pollett experiments, have led to the belief that eels may sometimes limit survival between fry and parr stages. The dispersal experiments described in Section 2 were carried out above the 15-foot drop of Gordon Falls. The falls is a partial barrier to eels, there being one-third as many of the sizes that eat salmon above as compared to below. Up here over 45 per cent survival to smolt stage was reached in one case, the average for the nine plantings being 30 per cent (Table III). On the lower, main experimental area, with an abundant eel population, the comparable survival rate to smolt stage was only 15 per cent. Note that this concerns survival rates from sparse populations. The bird control experiment showed that mergansers act as a limiting factor *after* eels have done their damage. Hence control of the birds is of first importance.

Studies of eels in several New Brunswick streams indicate that they are abundant in streams flowing into the Bay of Fundy, e.g. the Pollett and several tributaries of the St John (Godfrey, 1956) but that in Gulf of St. Lawrence drainages, as represented by the Miramichi River, also Ellerslie Brook in P.E.I., eel populations in the salmon-growing reaches are relatively unimportant. Higher yields of salmon, because of better survival rates, might be expected from both hatchery and native stocks where eels are scarcer, providing predation on older parr and smolts, as by mergansers, is not the limiting factor. So far no practical way of controlling eels has been devised.

7. VALUE OF ADULTS DERIVED FROM HATCHERY STOCK.

Returns to the Pollett River of mature salmon derived from stocks collected in other rivers but planted as underyearlings in the Pollett have been almost negligible. These planted fish have contributed to distant commercial fisheries; but were not identified in any river where close inspection of the stock was maintained. At present a test is under way involving the returns from 800 marked smolts of Pollett stock, reared to the usual underyearling stage in a hatchery, then planted back in the Pollett.

Summary

This summary is given in the form of brief, if somewhat categorical statements, for convenient use of the practising salmon-culturist. The statements should certainly not be regarded as the "final word" on subjects which are still under investigation. But they do have more background of observed facts than has been generally available.

(1) *Control of mergansers.* Best production of smolts from plantings of hatchery-reared Atlantic salmon, or from native salmon should only be expected if mergansers do not exceed an abundance of one bird for every 10 to 15 miles and 10 yards width of stream. Control of kingfishers is of minor importance compared to control of mergansers; kingfishers may be tolerated up to, but not above, an abundance of two per mile × 10 yards width of stream.

(2) *Numbers to plant.* For streams on which mergansers will not greatly exceed the figure of one per 10 miles × 10 yards width, and which flow through geologically fertile areas the maximum number of smolts likely to be produced is around 1,000 per mile of stream 10 yards wide. To get this number of smolts about 7,000 underyearlings should be planted, per similar area, in streams with mostly two-year smolts and about 10,000 in streams with mostly three-year smolts.

For streams with no bird control or those in geologically infertile areas, e.g. flowing largely through granite country, these figures should be reduced to about 2,500 and 3,500 fish for a maximum expectancy of 400 smolts.

(3) *Amount of dispersal at planting.* When liberating underyearling salmon at planting sites, nothing is gained by scattering them more widely than at a rate of 5,000 fish in an area of 100 square yards. Given this start, as many will survive as if they had been dispersed more widely.

Planted underyearlings will move, in good numbers, about one mile up- and downstream from planting stations. So stations should ideally be about two miles apart. But some fish will disperse to as much as several miles away, so that partial use of intervening water will be made even if stations must be farther apart.

(4) *Size of fish to plant.* Where the object is simply to obtain smolts, underyearlings will give as good results as larger parr.

But by using appropriate sizes of parr, smolt runs can be produced earlier than with underyearlings. For example, in a typically three-year smolt stream:

(a) underyearlings will yield smolts three years after planting:

(b) parr which will reach a length of eight or nine cm. in the year of planting should produce smolts two years after:

(c) parr which will exceed a length of 10 cm. in the year of planting should produce smolts one year after:

(d) smolts planted from early spring until late in May might well migrate to sea shortly after being liberated but smolts planted in streams after June seem unlikely to descend in numbers until the following year.

Since underyearlings are very susceptible to DDT poisining and larger parr less so, the size of fish to be used for rehabilitating streams in DDT-sprayed areas should receive consideration.

(5) *Type of bottom for planting stations.* It would seem advisable, where feasible, to plant fish in natural habitats. For young salmon this means in shallow rapids with gravel to rubble bottom rather than in deep pools.

(6) *Eels a danger.* Eels feed voraciously on newly-planted underyearlings. Therefore, planting sites should if possible be located away from areas of eel concentrations. Areas of large boulders and rubble in moderately swift water and pools are places where eels tend to be abundant. Eels are abundant in Bay of Fundy salmon streams, but apparently not nearly so plentiful in Gulf of St. Lawrence salmon streams. No generally feasible means of controlling eels has so far been devised.

(7) *Return of adults.* The value of hatchery-reared stock, derived from other streams, for providing adult salmon to the stream planted, needs further measurement. Hatchery-reared stock do, however, contribute to sea fisheries, even far distant from the stream of planting.

Acknowledgments

Hatchery stock was supplied and delivered on the requested dates to designated points, by the Fish Culture Branch of the Department of Fisheries. Throughout much of the work I was able to call on Mr. H. C. White for advice and assistance in field problems. The unstinting efforts of the Pollett field crew, headed at first by H. W. Coates and later by P. R. Graves provided much of the data on which these studies are based. I wish to acknowledge my indebtedness to all who assisted in any way.

Literature Cited

ELSON, P. F. 1957a. Number of Salmon Needed to Maintain Stocks. Canadian Fish Culturist, No. 21, pp. 000-000.

ELSON, P. F. 1957b. The Importance of Size for the Change from Parr to Smolt in Atlantic Salmon. Canadian Fish Culturist, No. 21, pp. 000-000.

GODFREY, H. 1956. Catches of Fish in New Brunswick Streams by Direct Current Electrofishing. Canadian Fish Culturist, No. 19, pp. 1-8.

HOAR, WILLIAM S. 1939. The Thyroid Gland of the Atlantic Salmon. J. Morph. Vol. 65, No. 2, pp. 257-295.

MILLER, RICHARD B. 1953. Comparative Survival of Wild and Hatchery-reared Cutthroat Trout in a Stream. Trans. Am. Fish. Soc. Vol. 83, pp. 120-130.

WHITE, H. C. 1939. Bird control to Increase the Margaree River Salmon. Bull. Fish. Res. Bd. Canada, No. 58, 30 pp.

Number of Salmon Needed to Maintain Stocks

by

P. F. Elson

Fisheries Research Board of Canada, Biological Station, St. Andrews, N.B.

Most salmon streams obtain the greater part of their stock through natural spawning. How many fish must enter a river in order to keep up the stock? Such information can contribute materially to wise use of our Atlantic salmon resources. The number needed will depend not only upon the size of the river, but also upon how many young fish the river can raise by reason of its suitability for salmon, the abundance of predators and so on. Useful information on this problem is accumulating from research on the Pollett River, a branch of the Petitcodiac system, N.B., and on certain tributaries of the Miramichi River. This account is in the nature of an interim report pending accumulation of more complete data.

(a) HOW MANY SPAWNERS ARE NEEDED?

Experiments on planting hatchery underyearlings (Elson, 1957a) have shown how many young salmon one particular stream could support. The Pollett River could produce only five to six two-year smolts per 100 square yards of stream bottom. Such production could be obtained by planting underyearlings at the rate of about 35 per 100 square yards. This in turn should give about "10 large" parr, i.e. over 10 cm. or four inches total length measured from tip of snout to tip of tail (Elson, 1957b) which is the number required to assure the maximum production of smolts. Small salmon fingerlings, when first taken from a hatchery and liberated in a stream, do not live quite so successfully as native, wild salmon of the same size. But when they have lived in the stream for a year or more, they are probably equally valuable for producing smolts. So the question may be stated—How many adult salmon are needed to give large parr at a rate of about 10 per 100 square yards?

Studies are now being made of the numbers of underyearlings, parr and smolts produced by known numbers of adult salmon entering a 10-mile stretch of the Pollett River. The number of eggs brought into the stream is of more importance than the number of fish bringing them. Pollett salmon, most of which are grilse, weigh on the average, about $4\frac{3}{4}$ pounds. The number of eggs carried by female salmon tends to be in proportion to the weight of the fish. Pollett salmon carry 800 per pound of live weight. Hence it is useful to think in terms of the total weight of female salmon in the river, rather than their total numbers. In general, sex ratios and spawning habits of salmon are such that there tends to be a sufficient number of males for the females. The results which have accumulated from these Pollett observations to date are summarized in Table I.

Table I

Underyearling and pre-smolt parr produced from known quantities of adults entering a 10-mile section of the Pollett River (25 yd. wide) based on seining in the same 10 sample areas each year. (a) Five to 15 per cent of large parr in the Pollett River are two-year-olds. This, or the limits of accuracy for seining could cause the discrepancy in the survival of underyearlings to parr.

Total weight of adult females		Potential egg deposition @800 eggs/lb. of female		Underyearlings in 1st summer		Large parr in 2nd summer		
Year	Pounds	Total number	No. per 100 sq. yd.	No. per 100 sq. yd.	Survival from eggs	No. per 100 sq. yd.	Survival from under-yearlings eggs	
1953	210	168,000	38.6	2.2 (a)	6%	2.3 (a)	100%	6%
1954	390	312,000	71.7	5.9	8%	3.2	54%	4%
1955	310	248,000	57.0	4.0	7%	(in'57)	—	—

Using the results shown in this table, we can calculate that to get the 10 large parr needed in the Pollett for maximum smolt production will require, at the average survival rate of five per cent, potential egg deposition at a rate of about 200 per 100 square yards. This means about 44 pounds of female salmon (say 10 female grilse or four larger hen salmon) per mile of stream 10 yards wide. This is a general rate for the stream as a whole, not just for nursery areas or spawning beds.

In 1956 the average potential egg deposition in the same area was 252 eggs per 100 square yards. This last spawning will therefore provide a good test for the above hypothesis.

(b) DO MARITIME SALMON STREAMS RECEIVE ENOUGH STOCK?

There is strong public opinion that the Maritime salmon resource could be greatly increased by providing more very young stock, whether by legislating for greater spawning escapement, or by providing for greater distribution from hatcheries. The Miramichi is frequently referred to as a stream which should receive such benefits. For several years now, measurements have been made of the adult salmon runs into two Miramichi tributaries, and of the resulting populations of young salmon. The Northwest Miramichi has about 70 miles of effective salmon rearing water, which averages about 25 yards wide; the Dungarvon has 50 miles, and a similar width. Examination of adult salmon runs has shown the average size of the fish and the proportions of males and females. Records of the Fish Culture Branch of the Canadian Department of Fisheries show that, in general, as for Pollett fish, about 800 eggs are carried for every pound of female salmon. From this information it is possible to estimate the number of salmon eggs brought into these two streams—the potential egg deposition. The average annual figures are, for the Northwest Miramichi nearly 7½ million eggs and for the Dungarvon nearly 4½ million.

In Figure 1 potential egg deposition can be compared with resulting populations of young salmon as they advanced in age. All measurements are in terms of average numbers per 100 square yards of stream bottom. The values for young fish were determined by seining with electrofishing in several sample areas of each stream.

Tests have shown that the population figures for the sampling areas can be trusted to within about 20 per cent, ofter 10 per cent. Minor discrepancies in the figures given can be attributed to such error in counting the fish, but the general trends can be regarded as well established. For the Miramichi, nearly all small parr (10 cm. and under) are yearlings and over 90 per cent of the large parr (over 10 cm.), which will become smolts the following spring, are two-year-olds (Elson 1957b). For the diagram, parr have been allocated to years of egg deposition on the basis of size. Age analysis of samples, from studying scales, will doubtless result in minor corrections to the data.

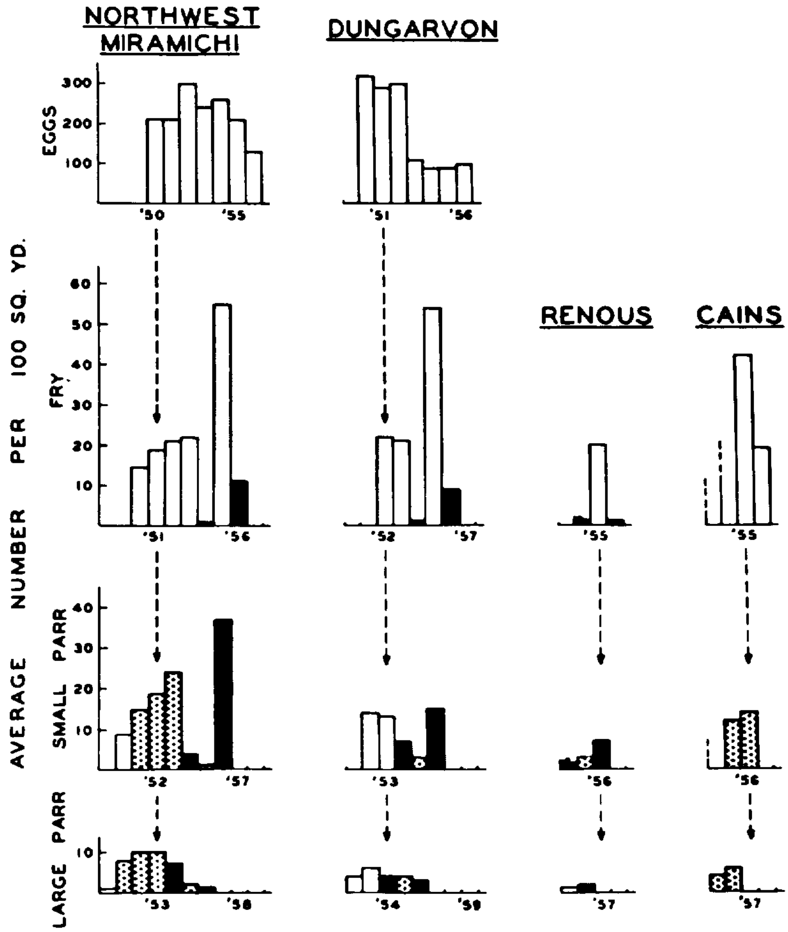


Figure 1.—Abundance of young salmon of various stages found in Miramichi streams by systematic population studies. Vertical arrows (↓) indicate survival between different stages of one year class. White columns (□) indicate abundance under natural condition. Dotted (⁝⁝) and black columns indicate abundance of groups affected by merganser control. Black columns (■) indicate abundance of groups subjected to DDT spraying as well as bird control.

Recall that in the Pollett River 10 large parr per 100 square yards were required to assure maximum smolt production. In the Northwest Miramichi similar numbers of large parr resulted from spawnings in 1949 and 1950 (Fig. 1). These two groups received full benefit of merganser control; earlier groups did not and later groups were reduced as a result of spraying the drainage basin with DDT against an epidemic of spruce budworm (Kerswill and Elson, 1955). However, the two groups do provide evidence that the Northwest was then receiving a good supply of young stock. On the Dungarvon, full production of large parr was not realized in the absence of merganser control. However, underyearlings were as abundant as on the Northwest. Under natural conditions, potential egg deposition at a rate of 300 per 100 square yards did not produce many more underyearlings (fry) in these two streams than did potential egg deposition at 200. (Compare Northwest and Dungarvon in 1952 and Northwest in 1950 and 1951, in Figure 1.) Such a condition carries the implication that a potential egg deposition of 200 eggs per 100 square yards did not limit the production of young salmon in these streams. The Renous and Cains Rivers carried just as good stocks of underyearlings. (Fig. 1). This evidence indicates that the Miramichi has recently been receiving all the young stock that it can rear to more advanced stages.

How does the potential egg deposition in these streams compare with the calculated requirement of 200 eggs per 100 square yards made for the Pollett? The average for the Northwest has been about 235 and the Dungarvon 200; the weights of female salmon received by these Miramichi tributaries are respectively 52 pounds and 44 pounds per mile of stream 10 yards wide in comparison with the 44 pounds calculated to be required for the Pollett. There is some possibility that the Miramichi may not actually require as many eggs per 100 square yards as the Pollett in order to have the 20 underyearlings apparently necessary to give highest production of smolts. For one thing, eels have been found to prey on both salmon eggs and alevins still in the redds, as well as on older stages. But eels are only from one-tenth to one-twentieth as abundant in the Miramichi as in the Pollett. The average *natural* survival rate from eggs to fry found for the Miramichi (8 percent) was just as good as that found on the Pollett (7 per cent) with *very light* spawning. A very light spawning should give a maximum survival rate, since no excess over actual requirements is involved. In the Miramichi area, the lighter spawnings observed *did* give the best survival rates so some excess over actual requirements may well have occurred in the heavier spawnings.

During the period of these observations the Miramichi has received some plantings of underyearlings salmon each year. The Northwest Miramichi, has been planted with underyearlings at an average rate of 25 per 100 square yards for the whole stream. All plantings were actually placed in the lower 25 miles, which are accessible for hatchery distribution. Young salmon were most abundant in the upper 40 miles. On the Dungarvon, plantings provided underyearlings at an overall rate of six per 100 square yards; but all were liberated in the lower five miles of the stream because above this it is impractical to reach the river with hatchery products. Again, young salmon were relatively much more abundant in the upper part of the river. Thus the largest parts of these streams were not available to hatchery stocks (Elson 1957a). Most of the young stock must have come from natural spawning.

It does appear that several Miramichi streams have, in recent years, received sufficient young stock, mostly native, to produce many more smolts than they are now doing. In fact, natural spawning has been sufficient to give maximum smolt production, if judged by standards developed on the Pollett River. It is hard to see how such streams could, *under normal conditions*, use to advantage more brood stock or hatchery products than they have recently been getting.

With the information at present available the best figure for the number of adult salmon required to maintain stocks can be set at "between 40 and 50 pounds of adult females per mile of stream 10 yards wide".

However, as shown in Figure 1, these young stocks are now seriously reduced as a result of spraying the adjacent forest with DDT. This chemical kills a high percentage of the young salmon. If spraying is to continue, natural spawning alone cannot provide a remedy, since the young fry are most susceptible of all to the spray. Carefully planned use of hatchery stocks seems to be the one way of getting better production under these circumstances.

Acknowledgments

Much of the data used has been collected through the untiring efforts of the Pollett field crew, consisting of P. R. Graves, H. P. Barchard, L. MacFarlane and A. G. Steeves, of Elgin, N.B. Others assisted this group in the Miramichi seining studies. Dr. C. J. Kerswill provided data on Miramichi salmon runs. To these and all others whose assistance facilitated the work I extend my thanks.

Literature Cited

ELSON, P. F. 1957a. Using Hatchery-reared Atlantic salmon to best advantage. Canadian Fish Culturist, Issue VI, PP. 00-00.

1957b. The importance of size for the change from parr to smolt in Atlantic salmon. Canadian Fish Culturist, Issue VI, pp. 00-00.

KERSWILL, C. J., and P. F. ELSON. 1955. Preliminary observations on effects of 1954 DDT spraying on Miramichi salmon stocks. Fish. Res. Bd. Canada, Atlantic Prog. Rep. No. 62 pp. 17-2

The Role of Hatcheries in Assuring Maritime Stocks of Atlantic Salmon

by

P. F. Elson

Fisheries Research Board of Canada, Biological Section, St. Andrews, N.B.

The abundance of Canadian Atlantic salmon as measured by records of catches has varied a good deal from time to time, even in "the good old days." Man has attempted to reinforce the stocks of these fish by artificial propagation of the young. Canada was one of the foremost countries in bringing such culture to a high stage of development. Our system for rearing young salmon and distributing them in suitable streams is one of the largest in the world.

Extensive distribution of hatchery-reared salmon in eastern Canada began about 1875. The early distributions were followed by large increases in the catches of salmon after the expected intervals, and in the proper districts (Wilmot, 1885). These increases were very welcome, following, as they did, right on the very lowest commercial salmon harvest on record, in 1881 (Fig. 1). Hatchery distributions continued to increase until they reached about 25,000,000 fingerlings yearly in the 1930's. Since then they have been reduced to around 10,000,000 to 15,000,000.

RELATION OF HATCHERY DISTRIBUTIONS TO CATCHES:

Have these widespread plantings had the notable effect on salmon harvests that was predicted in the 1885 report? If so, years of heavy planting should have been followed in due course by particularly good catches of salmon, and smaller plantings by smaller catches. For the Maritime Region (Cape Gaspé to the St. Croix River) most commercially caught salmon spend three years in rivers and two years at sea. The common interval from planting to harvest is therefore five years.

The sizes of hatchery distributions and corresponding catches in this region have been arranged diagrammatically in Figure 2. In the middle row vertical bars representing hatchery distributions between 1907 and 1947 have been arranged in descending order of magnitude. In the lower row bars representing commercial catches made *five years later* are arranged directly *under* their corresponding distribution bars. There is no clear resemblance between the patterns formed by the two different rows of bars. The conclusion seems to be that the contributions of hatchery plantings to the general salmon catches have not been large enough to show through the natural variations in these catches.

Hatchery distributions might be compared with commercial catches made *one year before* the distributions. Such catches represent, more or less, the availability of parent stock to the hatcheries. These catches are shown in the upper row directly

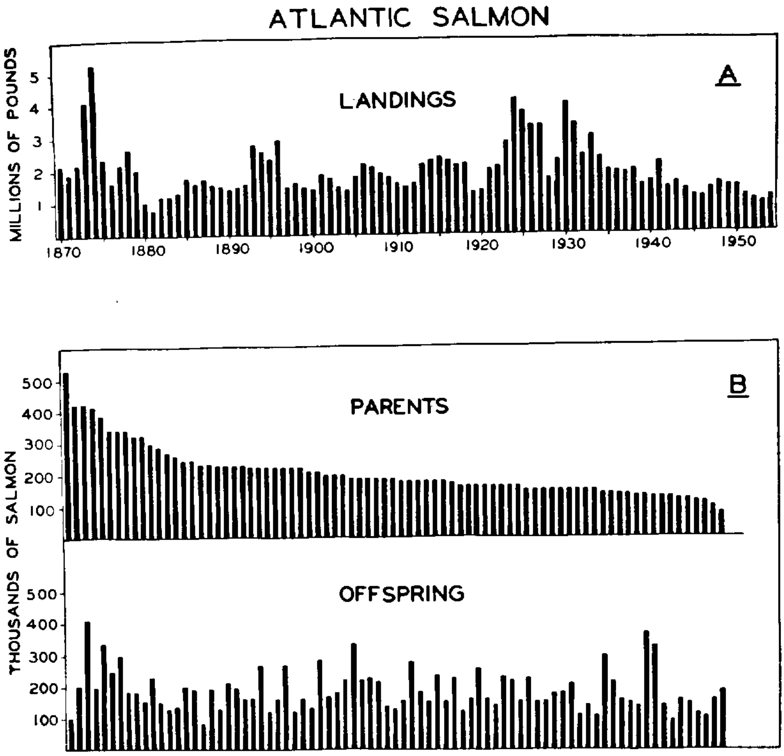


Figure 1.—Commercial landings of Atlantic salmon from the Gulf Area of the Maritime Region for 85 years. A. Annual landings in chronological order. B. Same catches plotted as numbers of 10-lb. salmon. Upper panel: numbers of parents in the first 79 years arranged in order of magnitude. Lower panel: numbers of offspring caught six years later, drawn directly below corresponding parent catch. There is no evidence of any relation between the size of catches from parents and the size of catches from their offspring. (Reproduced from Elson, 1955)

above their corresponding hatchery distribution. There is, in fact, a tendency for hatchery distributions to be larger in the years following abundant harvests of salmon. The relationship is obscured somewhat by a few particularly good catches; but the upper row of bars also tends to slope downward from left to right. It is quite logical that the hatcheries should be able to collect more eggs in years when mature salmon can be caught more readily. This is apparently what happened.

Both of the relations discussed above have been tested mathematically and the conclusions presented found to be valid.

As can be seen in Figure 1, there is no clear-cut relationship between the amount of parent salmon caught in one year and the amount of their offspring caught six years later (Elson, 1955). This can be interpreted as meaning that having a great many more salmon spawn in one year does not necessarily lead to an abundant catch of their offspring. Apparently naturally produced increases of young often do not show up in later catches. It should not be surprising, therefore, that artifically produced, smaller increases in young are not apparent either.

Thus the evaluation made in the 1880's of possible hatchery contributions has not been substantiated by later experience.

WHAT OUR HATCHERIES CAN CONTRIBUTE.

The fact that hatchery contributions cannot be identified by their effect on catches does not mean that they are not of value. In the last century practically nothing was known about the usual fate of planted fish. In the past quarter of a century considerable information on this subject has been collected. In those early years people

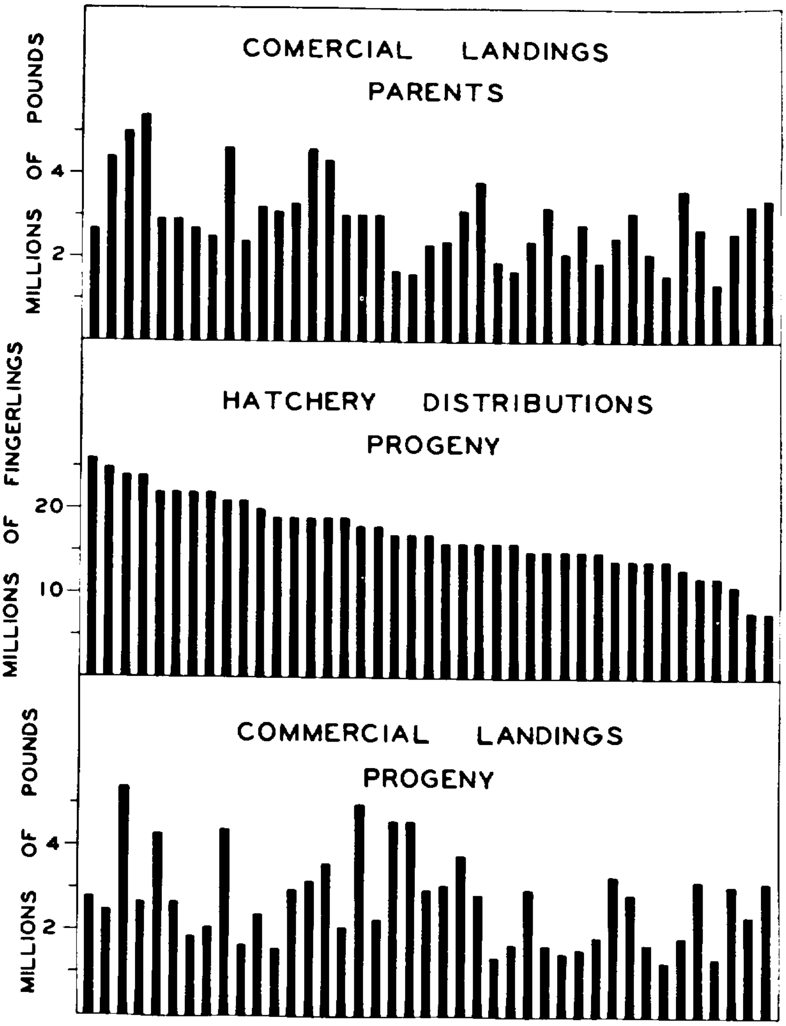


Figure 2.—Hatchery distributions of young Atlantic salmon arranged in order of magnitude (middle row) for comparison with commercial landings one year earlier (above) and five years later (below). There is a similarity of trend between earlier catches and distributions: this probably reflects availability of parent stock to hatcheries. There is no similarity between the trends for distribution and catches five years later when the planted fish should have made their biggest contribution to fishing: this indicates that hatchery contributions were not large enough to outweigh natural causes of fluctuation.

were pleased or worried over the status of salmon stocks according as recent catches had been good or bad (Perley, 1852) but there is no record of any attempt to estimate the total extent of Maritime salmon stocks. Now, as a result of researches made in the last 25 years, at least a rough estimate can be made. Thus it is now possible to place a better measurement upon the contribution which our hatcheries can make.

For this the first question to be asked is: How many mature salmon could be produced from 15,000,000 young salmon liberated each year by the hatcheries? It has been calculated on experimental evidence (Elson, 1957a) that with careful planning and management up to 15 per cent of hatchery-distributed underyearling salmon can be expected to survive to the smolt stage. Under adverse conditions the survival rate is liable to be only a fraction of this amount, perhaps around three per cent. Seaward-migrating smolts have been counted and marked in a number of instances, and their numbers compared to the numbers of returning adults. From these and similar studies it is found that, on the average, about eight per cent of the smolts (Table I)

Table I

Estimated survival rate of salmon marked as descending smolts based on reported returns to fisheries and counting fences in rivers; except Hayes (1953), which is based on estimates of total smolt production and total salmon associated with the river.

Place	Author	Survival rate
		%
LaHave, N.S.	Hayes, 1953	17
Margaree, N.S.	Huntsman, 1941	over 2
Miramichi, N.B.	Kerswill, 1957	5
Moser River (Mill Brook), N.S.	White, 1940	over 10
Moser River (main stream), N.S.	White, 1940	over 5
Moser River (Mill Brook), N.S.	White, 1941	10
Moser River (main stream), N.S.	White, 1941	9
Moser River (main stream), N.S	White, 1943	over 9
Apple River, N.S.	White and Huntsman, 1938	over 3

Mean survival rate and its standard error . . . . . 8 ± 1.5%

survive the rigours of life in the sea and return to fisheries and rivers as mature salmon. Considering these survival rates, the yearly contribution of hatchery fingerlings could conceivably add about 180,000 adult salmon to the stock available for fisheries and spawning. This amount is roughly equivalent, in numbers, to the total take by commercial fisheries in the Maritime region.

MAGNITUDE OF SALMON STOCKS IN THE MARITIME REGION

1. *Direct estimate from fisheries.*

In order to evaluate the hatchery contribution we should develop at least a general idea of the size of the total stock. Our impressions of abundance are usually obtained from the numbers of salmon caught in fisheries. But how is catch related to actual abundance? There have been a number of studies in which salmon caught in nets, at sea or along the coast, have been tagged and immediately released again. Subsequent recapture of some of these fish leads to our best available estimate of the total salmon stock. Table II gives the results from various areas. Applying the average value for recaptures (27 per cent) it appears that the combined commercial and sport fisheries of the Maritime region remove a little over one quarter of the salmon stocks available to the area. In recent years the commercial catch has amounted to around

Table II

Atlantic salmon tagged and liberated from commercial fisheries and recaptured in both commercial and sport fisheries.

Place of tagging	Number tagged	Total recaptures	Author
		%	
Petit Gaspé, P.Q.	100	38	Belding and Prefontaine, 1938
Sept Isles, P.Q.	80	9	
Rivière Nabissippi, P.Q.	43	28	
St. Augustin, P.Q.	63	6	
St. Paul P.Q.	150	29	
Port aux Basques, Nfld.	599	13	
Miramichi, N.B.	411	18	
Margaree, N.S.	758	13	Hayes, 1948
Margaree, N.S.	416	8	Hayes, 1949
LaHave, N.S.	192	28	Hayes 1953
Margaree, N.S.	100	25	Huntsman, 1939
Margaree, N.S.	161	26	
Margaree, N.S	267	25	
Saint John, N.B.	102	68	Huntsman, unpub.
Lorneville, N.B.	100	71	
Dipper Harbour, N.B.	102	31	
Total number tagged	3,644		

Mean rate of recapture and its standard error 27 ± 4.5%

150,000 salmon per season. The sport fishery in this region has been estimated to take 55,000 fish yearly, of which about one half are grilse (Kerswill, 1957). The grilse must be considered because they represent young stock which has survived to maturity just as much as larger salmon do. The total catch thus amounts to about 200,000 fish. If, as indicated in Table II, this is about one quarter of the available stock, there must be in the vicinity of 1,000,000 salmon available to the Maritime region. The rates of recapture listed indicate that it is unlikely that the total stock falls as low as 500,000 or exceeds 1,500,000 salmon in any one year.

2. *Stock size at various stages*

In order to appraise the usefulness of hatcheries, it is helpful to have estimates of the salmon stocks at various stages from eggs to adults. Estimates of this kind can be obtained from our data by using a slightly different chain of facts. The total catch by fisheries, say 2,000,000 pounds, is still used as the starting point. Also the proportion (27 per cent) that this forms of the total stocks as indicated by tagging results must be considered. Now let us assume that more fish are lost to seals, sharks, poachers and other causes of deaths in the sea and rivers, to the extent that only half of the total mature stock in the sea is left in the streams for spawning. As a matter of fact, Hayes' data for the Margaree (1949) shows not over 58 per cent of the counted, available fish for the system being thus available for spawning. (He counted fish removed by the commercial fishery, fish entering the river and fish removed by anglers.) Using the 50 per cent figure, we should have close to 4,000,000 pounds of salmon available for spawning in Maritime region rivers. In general, half of these would be females. Female salmon carry about 800 eggs per pound of body weight. The survival rate from eggs, brought into one particular river, to fingerlings the following summer has been established as about 5 per cent when there is no excessive spawning (Elson, 1957b). Using these figures, Maritime salmon streams, as a whole, are now receiving natural stocking at the rate of about 80,000,000 salmon fingerlings per year. Information now accumulating indicates that under favourable conditions, which include protection from excessive predation by mergansers, one-quarter or more of these fingerlings can survive to the smolt stage. These smolts, granting an 8 per cent survival rate over their sea life (Table I) would contribute a little over 1,500,000 salmon to the stock available for fisheries, spawning, etc. This second estimate is of the same general order as that obtained by a slightly different chain of thought, above.

The tagging studies referred to in Table II were made in areas of relatively important fisheries; and of course only salmon which had already entered the fisheries could be tagged. There are considerable numbers of salmon associated with small streams where fisheries are less intense. There are also many salmon which apparently do not reach fishery areas during open seasons; for example, the extensive autumn runs of the Miramichi system. To the extent that the tagging studies take no account of such fish the estimate of total stock given above is too low. However, plans for reasonable exploitation and conservation of the stocks based on low estimates are quite unlikely to damage our salmon resource.

Discussion

The potential value of the annual hatchery contribution might be evaluated on the basis of (1) 15,000,000 hatchery fingerlings added to the native stock of around 80,000,000 native fingerlings; or (2) 180,000 mature salmon added to the sea stock of about 1,000,000 fish; or (3) 50,000 salmon added to the 200,000 taken by fisheries. However assessed, the potential contribution seems to be of the general order of one-fifth to one-quarter of the present stock.

An addition of 500,000 pounds (commercially caught salmon average about 10 pounds weight) to Maritime region catches is a valuable contribution. But, spread over the entire region, it could scarcely be identified in catch statistics of a fishery which has fluctuated from under 1,000,000 to over 5,000,000 pounds per year during the last 80 years. This explains, at least in part, why the value of hatchery contributions does not show in such an analysis as is illustrated in Figure 2. However, an additional catch of 500,000 pounds divided among a few smaller fisheries could make a very evident contribution to these.

In the same way, an increase in general spawning stock of 75,000 to 100,000 salmon would scarcely be noticed by its effect. But this is enough salmon to completely stock a number of small rivers, or even one fairly large system. As an example, an annual run of 3,000 to 4,000 grilse and salmon combined appears to provide good angling and sufficient spawning stock in the 70-mile-long Northwest Miramichi River.

Thus Canada's hatchery system for Atlantic salmon can add a valuable amount to Atlantic salmon stocks. But even more important, it is a resource which can ensure against extinction of stocks if and when this should threaten.

The professional fish culturist, alone, is likely to have ready access to the background of facts which are necessary in order to make a sound decision about where and how hatchery stock can be used to best advantage. He must first get some clue as to why fish are scarce. Could it be simply that weather and water conditions were not right for getting the salmon into fishery areas? Or are young salmon really scarce in the nursery streams? If so, are they scarce, from the very youngest stages up, or only the older stages? What are the conditions that face the different stages of young in any particular stream? To be most effective, hatcheries must be able to add fish to replenish the stage at which native fish are scarce in the stream. Hatcheries are not designed to remedy shortages by supplying excessive stock in advance of depletion and regardless of the cause. These are the sort of problems that must be considered in order to get the most out of hatcheries for Atlantic salmon. Whenever well-considered answers can govern their procedures, hatcheries provide, over the years, a means of bolstering and restoring damaged fisheries; of revitalizing fisheries which have nearly or entirely disappeared; and even of creating new stocks for new fisheries. But if uninformed demands or other circumstances govern their procedures, our hatcheries can, at best, hope to add only about one quarter to the value of the general salmon harvest. No contribution of such magnitude could be positively identified in catch statistics.

Literature Cited

BELDING, D. L. and G. PREFONTAINE. 1938. Etudes sur le saumon de l'Atlantique. (*Salmo salar* L.).—1. Organisation et résultats généraux des recherches dans le golfe Saint-Laurent en 1937. Contributions de l'Institut de Zoologie de l'Université de Montréal, No. 2, pp. 1-50.

ELSON, P. F. 1955. Have Atlantic Salmon Been Overfished? Fish. Res. Bd. Canada, Atlantic Prog. Repts. No. 63, pp. 13-15.

1957a. Using Hatchery-Reared Atlantic Salmon to Best Advantage. Canadian Fish Culturist, No. VI, pp. 00-00.

1957b. Number of Salmon Needed to Maintain Stocks. Canadian Fish Culturist, No. VI, pp 000-000.

HAYES, F. R. 1948. Report of the Director of Fisheries. App. 1, Pt. II Margaree River. Ann. Rept. Dept. Trade and Industry, Nova Scotia, pp. 115-125.

1949. Report of the Director of Fisheries. App. 1, Pt. II, Margaree River. Ann. Rept. Dept. Trade and Industry, Nova Scotia, pp. 119-130.

1953. Artificial Freshets and Other Factors Controlling the Ascent and Population of Atlantic Salmon in the LaHave River, Nova Scotia. Bull. Fish. Res. Bd. Canada No. 99, 47 pp.

HUNTSMAN, A. G. 1939. Salmon for Angling in the Margaree River. Bull. Fish. Res. Bd. Canada, No. 57 75 pp.

1941. Cyclical Abundance and Birds versus Salmon. J. Fish. Res. Bd. Canada, 5 (3) pp. 227-235.
1954. Management of Saint John Salmon. (Typewritten MS.)

KERSWILL, C. J. 1957. Regulation of the Atlantic Salmon Fisheries. (Typewritten MS.)

PERLEY, M. H. 1852. The Sea and River Fisheries of New Brunswick. Report of Her Majesty's Emigration Officer at Saint John, New Brunswick, Fredericton, 294 pp.

WHITE, H. C. 1940. The Moser Salmon Run. Fish. Res. Bd. Canada, Ann. Rept. Atlantic salmon and trout investigations, App. 17, pp. 30-31 (Mimeo.).

1941. The Salmon Run. Fish. Res. Bd. Canada, Ann. Rept. Atlantic Salmon and Trout Investigations, App. 25, pp. 31-32 (Mimeo.).

1943. The Return from Marked Smolts at Moser River. Fish Res. Bd. Canada, Ann. Rept. Atlantic Salmon and Trout Investigations, App. 23, p. 35 (Mimeo.).

WHITE, H. C. and A. G. HUNTSMAN. 1938. Is Local Behaviour in Salmon Heritable? J. Fish. Res. Bd. Canada, 4 (1), pp. 1-18.

WILMOT, SAM. 1885. Report on Fish-Breeding in the Dominion of Canada, 1884. Canada Dept of Fisheries. First Ann. Rept. Supplement No. 2, pp. 1-71.

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1958