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CONTRIBUTIONS TO THE NATURAL HISTORY OF SOME GAME FISHES OF MICHIGAN, PARTICULARLY THE BROOK TROUT, *Salvelinus f. fontinalis* (MITCHILL), AS DETERMINED BY TAGGING EXPERIMENTS.

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INTRODUCTION

Even in the days of Izaac Walton fishermen speculated on where and when the salmon moved, and Walton (1653) mentions that some anglers more curious than the others tied ribbons around the tails of salmon they had caught so that they might be later identified. As time progressed, interest in the habits and life histories of many commercially important species of fish was stimulated, and it became necessary to know with some exactness where and at what time movements of the species occurred. Fisheries biologists developed means of marking which were better adapted to the work at hand than those first originated, and the results of their experiments became more exact. This development of the technique of marking has been relatively rapid, as it has taken place within the last 60 years. Marking experiments are now recognized as instruments of research for use in solving other problems than those of migration and growth (as will be pointed out later in this paper). It was therefore natural that the progressive Michigan Department of Conservation has sponsored research with and on the tagging method in its efforts to solve biological problems connected with the sport fisheries of the state.

During the six years from 1928 to 1933 inclusive, Dr. Jan Metzelaar and later the staff of the Institute for Fisheries Research tagged various species of fish for the Michigan Department of Conservation. Of more than 20,000 fish tagged, recoveries from anglers were obtained on only 2.1 per cent. These recoveries needed to be analyzed, and it was hoped that the comparatively small percentage of returns from the early experiments might be increased in future tagging studies by different methods of marking the fish and by other methods of recovery. To these ends the author was assigned the study of the biology of Michigan game fishes by the tagging method. The accumulated mass of letters and notes were analyzed by the author to find what information concerning migration of game fishes in Michigan waters was available from the first experiments. The results of this analysis are presented on pp. 43 to 68.

In 1934 the writer began tagging experiments both in hatcheries and in natural waters. The hatchery experiments were designed to further test the effectiveness of the jaw-tag method of marking trout (p 22), while field experiments were carried on using the jaw-tag method of marking, particularly on the North Branch of the Au Sable River, to learn more facts concerning the life history of the brook trout. Smaller marking experiments have been conducted at Wintergreen Lake on the Kellogg Bird Sanctuary (p. 73), and in the tributaries of the Pine River in Osceola and Wexford counties (p. 69). The work on the North Branch of the Au Sable River and at Wintergreen Lake may be considered to be still in progress, as returns from marked fish will undoubtedly be made during the coming trout and bass seasons of 1937.

The results of these several studies, together with conclusions are herewith presented.

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When one looks back over this assemblage of names, and thinks of the conditions under which he worked with each person, the value of an interested friend, be he scientist or sportsman, is more readily realized.

METHODS AND MATERIALS

There have been two sources of fish for tagging experiments conducted in Michigan waters. In the earlier experiments (pp.43 to 48), rainbow trout, walleye, northern pike, suckers and perch were obtained from natural waters; some of the brook trout tagged were also wild fish. Brown trout, most of the brook trout tagged, and most of the small-mouthed mass tagged were of hatchery stock. In the experiments on the North Branch of the Au Sable River conducted by the author, all but 500 of the 4300 trout tagged were wild fish; this particular lot of 500 were brook trout from the stock of the State Hatchery at Paris, Michigan.

Wild fish were captured for marking purposes with seines of different mesh size and different length. In the North Branch, a relatively wide and shallow trout stream, the most successful net was found to be one of 40 to 60 feet in length and 6 feet deep with a $\frac{1}{4}$ inch mesh (bar measurement). The pools or sections to be seined were selected by cruising the stream carefully to locate comparatively heavy concentrations of trout in water that was not too full of snags. With the exception of a few quiet water pools, most of the seining had to be downstream and across the current.

Captured fish were placed immediately in a washtub half full of water, or were measured and tagged directly from the seine. Measurements were taken on a specially constructed board on which rulers had been inset (Fig.4). Total lengths only were recorded during 1934 and 1935, but since May, 1936, standard and total lengths, and also the length to the point where the caudal fin forks. All measurements were made to the nearest eighth of an inch.

Careful notes, made both at the time of tagging and at subsequent recovery cover the following items: date, exact locality, lengths, species, tag number. During the summer of 1936, scale samples have been taken from all fish tagged and recovered. Field data were recorded on C.B.A. Tabulating pads ($8\frac{1}{2}$ x 11 inches). These pads fit conveniently into a steel notebook cover of similar dimensions, and the pads are well-spaced and divided for serial tabulation of data.

Laboratory procedure consists of recording each recovery on a separate card (Fig.2) which provides a space for all information relating to the tagging and the recovery of the fish bearing any particular tag number. This was found to be the most convenient method by which to file information on recovered fish, and facilitated the compilation of all data.

The jaw-tag method of marking (Shetter, 1936) was employed in the experiment on the North Branch of the Au Sable, and on the tributaries on the Pine River. A variation of jaw-tag method was used in the experiments at Wintergreen Lake; most of the centrarchids in this lake were tagged by ringing the maxillary instead of the mandible with the strap tag.

The "strap" type of tag, as manufactured by the Salt Lake Stamp Company of Salt Lake City, Utah, has been used in all Michigan tagging experiments in natural waters. These tags are made in several different sizes, but the ones most frequently used have been the "fingerling" size and the No. 3 size strap tags (Fig.1). The fingerling size tags are made from monel metal, while the No. 3 tags are made from Duralumin, both of which are very light and both resist the corrosive action of water.

After hatchery experiments during 1932 and 1933 had demonstrated that attachment of the tags to the gill cover was unsatisfactory (pp.22 to31) marking trout by means of ringing the mandible with the strap tags was adopted for use in the field. The attachment of the tag to the jaw of the fish is a relatively simple operation. A small slit is made with a scalpel under and inside the mandible. The short end of the tag is then inserted through the aperture and clamped through the lock-hole on the opposite end of the tag. This projecting short piece is pinched down firmly with jeweler's pliers, locking the tag. To allow for growth of the jaw, the resulting elongate oval is spread to an approximately circular shape by pressure exerted on both ends of the oval by means of the pliers. The tag as it is carried by the fish is shown in Fig. 10. The procedure may at first be somewhat slow for one not experienced in the technique of marking fish on the lower jaw, but with a little practice it soon becomes quite rapid. From 75 to 100 fish can be marked in one hour when one man measures and tags fish while another records the data.

In the course of the research attempts were made to develop a mark which might be both permanent and easy to apply to the jaw of fish. After considerable experimentation, a tag not unlike the nose rings placed on hogs was tried. Pliers for use in applying the tags were machined by the University of Michigan Instrument shop, and in 1936, The Salt Lake Stamp Company kindly furnished 300 unnumbered tags of the experimental specifications.

These experimental marks were of the same dimensions and materials as the regular No. 3 strap tag furnished by them, but had no lock-hole or lock-piece, and were bent at a different angle. Their holding ability is derived solely from friction and the inherent spring of the metal. This tag has, as yet, been used only experimentally; it was employed at the State Hatchery at Paris, Michigan, and has demonstrated that it will remain attached to brown trout over a six-months period (pp. 28 to 31). The experimental mark might have given better results had the edges been milled or tumbled more smoothly. Since this tag requires almost the same effort to apply it to the jaw of the fish as does the regular strap tag, it presents no great advantages over the strap tag as it is now used in the jaw-tag method of marking.

EARLY HISTORY OF FISH MARKING

Steinmann (1931) infers that the marking of fish so that they might be recognized on subsequent recovery may have its roots in Oriental antiquity. He quotes from an ancient volume on fish by G. T. Wilhelm ("Unterhalten aus dem Tierreich, Fische, No. 1, Augsburg, 1799") as follows: "In another place the author writes: Oriental princes mark certain noteworthy fishes with a silver or golden neck-band and then liberate them. By these bands they may be recognized on later recovery." Mr. Wilhelm also marked salmon by "providing them with a copper ring" on liberation. Of twelve salmon so marked he was able to recover eleven.

"The Compleat Angler", by Isaac Walton (1653), carries the earliest known reference to fish marking. Walton mentions that certain fish were marked by tying ribbon around their tails (p. 139). In these earlier days it is quite probable that the marking of fish was carried on more as a form of amusement by the more wealthy salmon fishermen of the British Isles. Calderwood (1902) lists the experimental work done on the Scottish salmon (Salmo salar) previous to 1902 as follows:

1823 - Grilse kelt marked with brass wire by McKenzie of Andross. Recovery effected a year later, grew from 3½ to 7 lb.

1824 - McKenzie marked another grilse with brass wire around the tail. This was also out a year and doubled its weight.

1829 - Fraser clipped the adipose fins of salmon. One was recovered.

1830 - Fraser marked a salmon by wiring its tail. He recovered one six months later.

1834 - Shaw at Drumlamig, marked 524 sea trout by clipping their fins. 68 were recaptured in 1835.

1835 - Shaw marked 60 sea trout with copper wire on the dorsal fin. He also marked 60 trout with copper wire around the maxillary bone. 5 of the latter marking were recovered in 1836.

1845 - 1854 - The Duke of Athol turned in 6 authentic reports of marking and subsequent recovery.

1851 - 1864 - The Experimental Committee of the Tweed Commissioners marked a large number of salmon.

1859 - The Duke of Athol marked salmon in the River Tay. He used a numbered copper disc 1 inch in diameter, or a gutta-percha ticket fastened by copper wire around the tail, 5 were recovered, but there was no record as to the number tagged.

1870 - 1872 - The Tweed Experimental Committee again conducted an experiment in which 1295 salmonids were marked. 31 of these were recovered, but no conclusions were offered.

On the western side of the Atlantic, one early attempt at fish marking has been reported. As indicated by Kendall (1914), p. 90), the Forest and Stream Magazine for November, 1877, published an account of brook trout tagging which was begun in 1870 by the Oquossoc club on the Rangeley Lakes in Maine. Under the direction of G. S. Page, platinum wire was cut into one and one-half inch lengths and flattened at one end. Various numbers from ½ to 4 (indicating weight in pounds) were stamped hereon, together with the date ('70, '71, '72 etc.). The only one of these fish recovered was one tagged ½ - '71. Since this fish weighed 2¼ pounds when caught in June, 1873, it had gained approximately 1 3/4 pounds in 2 years. These tags were attached through the flesh just under the adipose fin. This represents the first known attempt at marking trout in the United States.

THE DEVELOPMENT OF TAGGING AS AN EXPERIMENTAL METHOD

The first systematic tagging experiments were conducted by Atkins (1876, 1885), shortly after the establishment of the U. S. Bureau of Fisheries in 1871. Atkins experimented with three methods of marking Atlantic salmon (Salmo salar) on the Penobscot River at Bucksport, Maine. He first tried branding, but abandoned this method after operating on one salmon. In the same year Atkins tagged salmon by fastening thin aluminum plates (1½ x 1/4 inches) to the caudal peduncle by means of rubber bands. Atkins gave no statement of the number marked in this manner, but none were recovered, and the experiment was not repeated.

Atkins had fair success by attaching platinum or aluminum tags to the posterior margin of the dorsal fin with platinum or aluminum wire. Platinum seemed to be the best material. A reward for return of tags with information concerning the recovery was also a part of his program. A summary of Atkin's results follows:

Year Tagged	Number Tagged	Number Recovered
1872	Not given	0
1873	391	29 (9 of these in 1875)
1875	357	"a considerable number in 1876" 3 in 1877
1880	252	12 in 1881, 5 in 1882

In 1885 Archer (1893) started marking Norwegian salmon with a numbered triangular platinum label (7 mm. on a side) by attaching this mark to the adipose fin with platinum wire (0.15 mm. in diameter). Oblong silver labels attached with silver wire were also tried. Later experiments in the Sands River, Scotland, wherein the silver labels were passed through the dorsal fin membrane and the ends of the label fastened together with silver wire, were deemed to be the most successful.

Fulton (1890, 1893), a Scottish fishery worker, entered the field of fish marking in 1889 when he marked ten different species of fish in Saint Andrews Bay and in the Firth of Forth by tying numbered brass labels around the caudal peduncle with aluminum wire or silk thread. Few recoveries were made, but returns were all from fish which had been marked using silk thread to attach the label.

Methods of marking later tested by Fulton were:

(a) the use of pigments;

(b) the fastening of small oblong tags to the opercle;

(c) the fastening of a small tag to the shank of the fish hook and inserting the hook in the flesh of the fish;

(d) herring were marked by punching a triangular hole in the fins with a special punch;

(e) an oval brass disc was fastened to the caudal peduncle with silk thread.

The last named method was considered the most successful of any that were tried.

Fulton also submerged leather, gutta-percha, india-rubber, lead, copper, zinc, and brass in sea water in an effort to determine the resistance of the several materials to corrosion. Brass was found to be superior to others.

These earlier methods of attaching the mark to the fish have been outmoded, and have seldom been used in more modern experiments. One of the better types of tags, developed in 1893 by C. G. J. Petersen (1894) of Denmark, consisted of two bone buttons joined by a silver wire which passed through the tissue of the fish just below the dorsal fin, so that a button lay on each side of the fish. Later vulcanized rubber was substituted for the bone. This type of tag has been widely used in European waters with good results, especially on the flatfish (Pleuronectidae).

This particular type of tag in its present form (Pearson, 1934) is made of red and white buttons of laminated celluloid, held together with nickel wire. One button carries a serial number, the other carries the address to which information concerning the recovery is to be forwarded. When these tags are used in marking salt-water fish there seems to be little infection of the flesh if the discs are not held too tightly against the sides of the fish. Losses are slight if these tags are not carried by the fish for too long a period. However, when the fish grow considerably in girth after the placement of the tag, the wires holding the buttons tend to move out from the flesh and be lost.

Several variations of the "button type" of tag have been attempted, but none has proved any more successful than the original model. The more important variations are listed by Graham (1929) as follows:

Lofting's mark for salmon consists of a firmly united disc and pin, with an accompanying disc to be placed over the head of the pin. Flaps on the head of the pin are then bent over to hold the second disc in place against a shoulder on the pin. Graham classed this as an unsatisfactory mark, at least when inserted through the operculum.

Heincke's ebonite plaice mark is shaped much like a collar button, having an enlarged head over which a rubber washer is fitted. The mark is attached by inserting the "collar button" through the flesh or fin, and then forcefully applying the washer to the head of the tag.

Hjort silver cod mark consists of two silver discs joined by a silver pin.

It is attached through the operculum. The Norway mark is almost the same, except that the connecting piece is silver wire instead of a stiff pin. Graham states that this type of tag is frequently lost, because of a break at the point where the wire was riveted to the tags. Loss by suppuration is rare, for the wounds are healthy and without serious enlargement.

Archer's salmon mark is a modification of the connected button principle. In this, two wires are used to connect two oblong plates, one of oxidized silver, the other of celluloid. The wires are passed through the dorsal musculature at the base of the dorsal fin, then through holes in the celluloid plate. The ends of the wire are then firmly twisted together.

About 1920, Gilbert adapted the ear tag used by sheep ranchers and cattlemen for use in marking investigations. This "strap" or "clip-type" tag is made from monel metal or duralumin, and is shaped much like an isosceles triangle open at one end of the base. On the long side opposite the short base is a lock-hole. To fasten the tag firmly, the base of the triangle is passed through this lock-hole (Fig./) and bent down flush with the long side by means of special pliers designed to clinch the tag to some part of the fish's body in a single operation. Many thousands of the various species of the salmon in the Pacific have been marked by attaching these tags to the gill-cover or the caudal fin rays, and also large numbers of cod along the New England coast. The use of the tag has been considered successful in both localities.

The most recent development in marking techniques is the belly tag, devised by R. A. Nesbit (1933). The "belly" tag consists of a thin strip of celluloid on which a serial number is printed, along with an address to which information concerning the recovery is to be forwarded. The tag is inserted in coelom of the fish by an incision from the exterior.

Another method of marking fish so that they may be identified on possible recapture is to clip two or more fins. This will not yield individual data, but will provide information of a mass nature. It is a method which has also been widely used in many salmon and trout investigations on the Pacific coast.

SUMMARY OF METHODS DEVELOPED

Although the general method of marking salmon employed by Atkins and Archer yielded fair results, it must have been a rather cumbersome and time-consuming task to attach the tags by means of small wires. The application of the tags to the fins was not the most permanent location on the body of the fish, and many tags must have been lost once the fish were freed. Since Atkins found that aluminum tended to become brittle when immersed in sea-water, and substituted platinum for his mark, the cost of the tags must have become almost prohibitive. The best development of this type of tag is represented by the so-called "modern" Archer tag for salmon, according to Graham (1929). Calderwood used a slight modification of this tag in marking Scottish salmon in a series of experiments in the early 1900's. Except in this particular work, this type of tag has not seen very much use.

The "button" type or "disc" type of tag in its several forms has been widely used with considerable success, especially in the flatfish investigations of the North Sea, the Baltic, and in Icelandic waters. This type of tag is carried by flounders rather permanently, and without injury to the marked fish, because the flounders are hardy and tough-skinned. There is little danger of infection to the wound, and the tag can be easily seen. Toaning (1933) described an aid to the application of the button tag which consisted of a hollow needle through which the connecting wire could be threaded, thus making it easier to pierce the gill cover or flesh of the subject.

The "strap" or "clip" type of tag was not changed in form from that used by the cattlemen and the sheepmen, though smaller sizes are made for use in tagging fish. It is relatively easy to fasten to the fish and resists the action of sea water very well, especially when made of monel metal. This tag when fully lettered and numbered varies in cost, depending on the size of tag, from $15 to $35 per thousand.

The internal tag or "belly tag" as developed by Nesbit is no doubt the best method for tagging certain species of fish which have delicate external features, such as the Pacific Herring (Clupea pallassii). Rounsefell and Dahlgren (1933) found it to be the best suited for this species. They also evolved a unique method for recovering steel belly tags from the offal of the packing plants by means of powerful electro-magnets.

According to an article in the Journal du Conseil (Anonymous, April, 1932) there were at the date of publication some 27 institutions in 14 countries of the world engaged in the marking of fish. The types of tags in use were divided as follows: 23 of the "tie-on" or "twist-on" variety (now outmoded); 6 of the "button" type; 7 different kinds of "strap" or "clip" tags; 3 different kinds of internal tags; 1 external celluloid tag of the strap type. It should be noted that all organizations reported as engaged in marking at that time offered a reward for information concerning the recovery of any marked fish.

THE RELATIVE ADEQUACY OF THE VARIOUS METHODS OF MARKING FISH

The chief aim of this discussion is to compare the practicability of the various types of tags as used in the solution of problems in the natural history of fishes. The types of tags discussed are the "button" type, the "strap" type, and the "belly" tag. The advantages and disadvantages of marking by fin-clipping are also presented. Lastly, the jaw-tag method of applying the "strap" tag is reviewed, and certain hatchery experiments concerning the jaw tag are described.

The results of various workers who have tagged fishes show that no one mark or means of applying the mark may be used on all species of fish with equal success. Schroeder (1930, p. 13) tagged cod on the lower jaw (not describing the details of the method, however), but obtained no better results than by tagging on the caudal peduncle; the same general method has given the best results in the Michigan investigations. Pacific Coast salmon investigators had excellent recovery percentages by using the strap tag attached to the base of the caudal fin though they had relatively few recoveries on fish free over 200 days; Greeley's experiment on brook trout (pp 22-26), using the same manner of attachment, indicated that this method was a failure where brook trout were concerned. Dahlgren (1936) has demonstrated that the "belly" tag as applied and recovered by the means at his command is the only possible way of obtaining migration and survival data on the Pacific herring; it is doubted that many "belly" tags would be discovered by the fishermen in Michigan, and the chance of freshwater fish so marked becoming infected would presumably be greater than of marine fish.

In marking experiments the investigator should consider just what results are to be sought, how resistant the species to be marked is to handling, how many are to be marked, and by what method and how long after marking it is expected that the fish may be recovered. One method of marking will doubtless be better than the others. Part of the investigator's problem is to determine which method is the better. In Michigan the answer to the problem has been found in the jaw-tag method of applying the strap tag (p.6), and in fin-clipping. It is not claimed that these methods represent the highest developments in marking technique, but the jaw-tag method of marking has yielded better results than previously obtained in the state by other methods of applying the "strap" tag.

The "Button" or "Disc" Type of Tag

The "button" tag has been used most successfully on marine fishes, chiefly in the North Seas and adjacent areas. It has been used mostly on flat-fishes of the family Pleuronectidae. The variations of the button tag are numerous (See Journal du Conseil, 1932, Vol. VII, No. 1), but the best combinations seem to be ebonite or vulcanized rubber, or celluloid discs connected by silver wire, or nickel pins.

The most successful points of application appear to be in the dorsal musculature of the fish just below the dorsal fin or the bony gill cover. In order to affix the tag, the flesh, or bony gill cover is pierced for the silver wire or by the pin. In salt water this operation does not lay the fish open to infections, but it is feared that freshwater fish so tagged would often become diseased. For this latter reason, the button tag has not been used in the experiments in Michigan waters.

The "Strap" Type of Tag

The strap tag has been more widely used in North American waters, possibly since it was manufactured on this continent originally for sheep and cattle marking, and was early applied to the marking of fish by Gilbert. Several different species of fish have been marked in various ways, by means of the strap tag with varying degrees of success. Pacific salmon were marked by Gilbert (1923), Rich and others by applying the "strap" tag to the dorsal portion of the basal rays of the caudal fin. In one of their experiments a recovery percentage of 35% was obtained (Gilbert and Rich, 1925). Schroeder (1930) who marked cod off the New England coast by applying strap tags to the caudal fin, obtained a total recovery percentage of 3.5 per cent from 24,739 marked cod. Pacific halibut were marked by attaching the "strap" tag to the opercular bones on the eyed side of the fish (Thompson and Herrington, 1930). A total recovery percentage of 22.7 per cent was made on 9,289 tagged halibut between 1925 and 1928.

In the earlier tagging experiments in Michigan (pp.43-68), the strap tag was used, and applied through either the base of the caudal fin or the gill cover. The greater number were tagged through the opercle, especially in the later years. Of the approximately 20,000 Michigan fish thus marked, only 2.1 per cent were recovered (by sport fishermen).

The "Belly" or Internal Tag

The belly tag, developed by Nesbitt (1933), has been used with fair success on marine fishes, especially the Pacific herring (*Clupea pallassii*). In experimental work on this fish, internal tags are inserted through a slit in the abdominal wall. These tags are made of nickel-plated iron which can be picked up by a strong electro-magnet located in the reduction plants. Mortality was found to be slight (Rounsefell and Dahlgren, 1933), and the "belly" tag has proven by experiments to be the best method for use on herring.

The latest, and certainly the most scientific method for recovering tagged fish, has been developed by Dahlgren (1936) for detecting "belly" tagged Pacific herring. Several million herring are handled daily in reduction plants, and the examination of the catch for marked specimens by hand-cleaning would be impossible. With the aid of Dr. C. E. Magnusson, Professor of Electrical Engineering at the University of Washington, Dahlgren developed the "electronic detector", by which the metal tag in a fish unbalances the electro-magnetic fields of two sets of paired coils previously arranged in balanced opposition; this "disbalancing" is amplified and relayed to a control circuit which operates a mechanical device for isolating the tagged individual.

Although the belly tag gave satisfactory results in one short-time experiment on trout in Connecticut (Cobb, 1933), this author reported that 155 of 200 controls in which the celluloid "belly" tags were inserted died, many of them from gonadal inflammation caused by the tags. In experiments with the "belly" tag conducted at the Federal Hatchery located at Northville, Michigan, in the spring of 1933, several belly tags inserted as directed by Cobb (1933) were found to have been forced out through the ventral body wall of the rainbow trout within a period of less than one month, although the tag incision had healed perfectly. A better controlled experiment conducted by Greeley in 1932 and 1933 (data unpublished) at the State Hatchery at Harrietta was complicated by an attack of farunculosis which killed both belly-tagged fish and controls. The results of these experiments, given in more detail on pp. 22-31, suggest that in this method of marking the necessary incision may be a focus of infection.

Another disadvantage in the use of the belly tag on game fishes is the fact that it is not externally visible. This disadvantage is particularly great where all or part of the returns are made by sport fishermen. Dahlgren (1936) surmounted this difficulty with his magnetic detectors, and Cobb successfully conducted a lottery to encourage the return of tags; but neither of these methods of obtaining recoveries would be practicable for Michigan. Belly tagging was therefore not considered as a feasible method to be used in the tagging work in Michigan.

Fin-Clipping as a Marking Method

Marking fish by cutting off one or preferably two or more fins has been practiced extensively in several Pacific coast salmon investigations. The method consists simply of the excision of the fins, cutting very close to the base of the fins to preclude regeneration. It is desirable that two fins be clipped so as to make the recognition of the marked fish easy and certain; it has been found (Marsh and Cobb, 1909) that in nature as many as 11 of 12,700 mature red salmon had their adipose fins missing or imperfect. Several specimens were also observed which had either their right or left ventral fins missing. During the fall of 1936, I observed that 8 out of 5,000 hatchery-reared rainbow trout fingerlings examined had no adipose fins. Davidson (1934) has very adequately demonstrated that fin-clipped pink salmon do not regenerate their fins sufficiently so that they will not be recognizable as marked fish.

When data of a mass nature is desired, fin clipping has been demonstrated to be a suitable method. The only equipment involved is suitable clipping tools, such as a high grade pair of manicure shears. Two workers can mark 2500 or more fish in eight hours. However, recovered fish can be recognized only as one of many individuals from a single marking. At the present time two experiments involving this method of marking are in progress in Michigan waters pp. 139-140.

<u>Experiments on Tagging Methods</u>

In the early tagging experiments in the natural waters of Michigan (pp. 43-68) the strap tag (No. 3 size) was applied with relatively little success to the caudal fin or gill-cover of the fish. Therefore Dr. John R. Greeley began some hatchery experiments to attempt to find a method of applying the strap tag which would not be detrimental to the wellbeing of the fish, and which would remain attached over longer periods of time.

In September, 1931, Dr. Greeley and Gerald McCrimmon marked 650 brook trout yearlings and 698 brook trout fingerlings at the State Hatchery, Harrietta, Michigan in the following ways:

(a) All fingerlings were marked with the fingerling size "strap" tag on the right gill cover;

(b) 100 yearlings were marked with fingerling tags on the left gill cover and No. 3 tags on the right gill cover;

(c) 100 yearlings were marked with No. 3 tags on the left gill cover;

(d) 100 yearlings were marked with fingerling tags on left gill cover;

(e) 100 yearling brook trout were marked with fingerling tags on left subopercle;

(f) 100 yearling brook trout were marked with No. 3 tag between subopercle and preopercle;

(g) 50 yearling brook trout were marked with fingerling size tags at the dorsal base of the caudal fin rays;

(h) 50 yearling brook trout were marked with fingerling size tags at the ventral base of the caudal fin rays;

(i) 50 yearling brook trout were marked with fingerling size tags on the dorsal fin.

All of the tagged fish were misadvertently placed in one large pond with 5,000 untagged brook trout, many of which were 10 to 12 inches long; consequently there probably occurred considerable loss from cannibalism. No daily mortality records on the experiment were kept. When the large holding pond was examined in May, 1932, none of the tagged fingerlings were found. That a large number of yearlings had lost their tags, was evidenced by scars. Of the 59 brook trout that still bore their tags, 20 were marked with No. 3 tags and 39 with fingerling tags. All were tagged on the gill cover; none of the fish tagged at the base of the caudal fin, or on the dorsal fin were recovered. Many of those tagged on the gill cover were found to be carrying the tag quite loosely, and in some, holes in the opercles had been worn so large that the tags were about to be lost. Some of the tagged fish were undoubtedly planted out by the hatchery, since one of them (No. 15843) was reported as recovered in Bear Creek, Manistee County, on May 11, 1932.

In a subsequent experiment carried out at the Harrietta Hatchery, Dr. Greeley obtained more conclusive results. The fish were tagged in October, 1932, and were examined in May, 1933. Yearling brook trout 4 to 7 inches long were tagged with the celluloid belly tag, the No. 3 strap tag, and the fingerling strap tag, and were retained in two concrete-sided hatchery ponds approximately 18 x 75 feet in size. Daily mortality records were kept. The 844 tagged fish were held in the upper of the two ponds, while 619 untagged fish were kept as controls in the lower pond. Brook trout were tagged as follows: On the gill cover, 443; around the jaw bone, 97; through the jaw bone, 103; "belly" tagged, 201. The results of these respective taggings are presented in Table 1.

Table 1

SUMMARY TABLE TO SHOW THE RESULTS OF BROOK TROUT TAGGING EXPERIMENTS AT THE HARRIETTA HATCHERY, 1932-1933.

Loss of tag was indicated by scars; those with uncertain scars are included, but of the total marked the percentage with uncertain scars is indicated by inferior figures.

Point of application of tag	Size of fish when tagged Oct. 24, 1932 (inches)	No. of fish tagged	Per cent dead from Nov.-Apr.		Per cent of individuals on May 19, 1933			
			Tag lost	With Tag	Missing	Dead, tag lost	Alive: Tag lost	Alive: With tag
Body cavity	4 to 8 1/8	201	0	84	16	0	0	0
Left gill-cover	3½ to 7 3/4	443	0	24	7	14_3	54_{12}	1
Through jaw-bone	4¼ to 7	103	23	24	16	0	37	0
Around jaw-bone	4 3/8 to 6	97	2[a]	37	5	0	9[a]	47
Control	3½ to 8 1/8	619	25		...	...	...	...

[a] Jaw bone broken.

In this experiment, the belly-tag method of marking was a complete failure (Table 1) due to an epidemic of faruncolosis. The mortality of the fish so tagged was much higher than the death of the controls or of the fish tagged by other methods. The results, however, clearly demonstrated that where there is a concentration of disease germs in the water, belly-tagged fish are easily infected, as the belly-tagged fish showed tissue degeneration characteristic of faruncolosis about the point of insertion of the belly tags.

Considering the number of fish alive at the conclusion of the experiment and still carrying their tags, gill-cover tagging was also demonstrated to be almost a complete failure (Table 1). Concerning the effect of the tags on the gill covers, Greeley wrote (original report, unpublished);

"Some of the fish had succeeded in tearing the tags loose. In many other instances the loss can be interpreted to results of a continual irritation of the bone which develops a sore with some mucous. The hole in the bone gradually enlarges until the tag falls out. Larger trout with tougher bone might be expected to retain a tag longer than those used in this experiment, but irritation of the bone might be expected wherever bone is pierced by metal. It is probable that the decomposition of the opercle leading to loss of tags involved bacterial action and that the bacterial action was accelerated in the hatchery pond because of crowding and contagion. Much evidence is available, however, to indicate that fish in natural waters lose their gill-cover tags through a similar wearing away of the bone".

Creaser and Delavan (report unpublished) had similar difficulties in making tags hold more than two months on the gill covers of northern pike. Wunder (1935) also reports as unsuccessful experiment in gill-cover tagging of carp and tench with metal and celluloid button tags.

Since the jaw bone offers an even firmer point of attachment than the gill-cover, tags were fastened to 103 fish so that the tags penetrated but did not encircle the jaw bone. This method of application was also proven to be a failure (Table 1). Apparently, no matter how firm the bone, if it is pierced by metal an irritation is caused which eventually wears away the bone and causes the tag to be lost.

Encircling the lower jaw bone with the strap tag so that it hung downward but did not pierce the bone gave the best results (Table 1). The number of surviving fish bearing jaw-tags at the conclusion of the experiment is much higher than for any of the fish marked in other ways. All were subject to the same conditions, since all tagged fish were kept in the same pond for the duration of the experiment.

Again I quote from Greeley's original report (unpublished);

"Where the tags had not been spread, irritation of the jaw-bone was always noted. When the fish had grown, the jaw was pinched, and in extreme cases had given away, leaving the fish with a broken jaw. Spreading of the tag appears highly desirable. Most of the lot which had the tags opened out to give more space showed practically no irritation to the jaw."

Despite the epidemic of farunculosis which complicated the interpretation of the results of the experiment, the jaw tag method of marking brook trout stands out as superior to the other methods tried. Consequently this method of tagging was followed in the subsequent work in Michigan, including all of the intensive experiments on the North Branch of the Au Sable River.

In October 1, 1933, Dr. Greeley and I further tested the jaw-tag and belly-tag methods of marking fish. In the experiments conducted at the Federal Hatchery at Northville, Michigan, The fish used were rainbow trout 9.5 to 11.87 inches long, averaging 10.8 inches (total length). Fifteen trout were tagged around the left jaw with the fingerling size tag; 15 trout were similarly tagged with the No. 3 size tag; and 15 were marked with the belly tag (10 more were later added to this group). All belly-tagged fish were marked further by means of a No. 3 size tag on lower right jaw. Care was taken to spread all tags applied to the jaw, after locking them to allow jaw growth. No loss of jaw-tags was noted except in the fingerling tag experiment (Table 2), in which 3 fish were found to have lost their tags when examined on January 11, 1934. Until this time all tagged fish had been retained in one pool without any other fish, so they were readily available for counting. The condition of the belly-tagged fish on January 11, 1934 was excellent. All the wounds had healed. It is of interest, however, that two "belly" tags were found on the bottom of the retaining pool, and one fish was observed to have the tag protruding through the midline of the belly well ahead of the pelvic fins. On handling, the tag was forcibly ejected by the fish's efforts to escape. Some of the rainbows were ripe at this time, many of the males yielded milt while being handled. Pressure resulting from enlargement of the gonads may have been the cause which forced the tags from the fish.

On June 8, 1934, an attempt was made to check the condition of the tagged fish, but unfortunately the tagged rainbow had been moved from their original pond. Some had been placed with untagged stock and others had been removed to larger ponds which could not be examined.

A final attempt to check the tagged fish was made on November 1, 1934, a full year or more after the date of tagging. Some of the rainbow stock had been removed to large earthen wintering ponds which could not be drawn down or seined, The remaining tagged fish were mixed with untagged fish in one retaining pool. This mixed stock was examined as carefully as possible for fish bearing tags or scars from tags. Mr. Widmeyer, Hatchery Superintendent at Northville, stated that no mortality of tagged fish had been found. Since all the tagged fish could not be examined, the results indicated in Table 2 are minimum figures, especially for the fish marked on the lower jaw with No. 3 strap tags. It is very likely that even more than the observed 47 per cent[a] of the fish marked above the jaw with this size of strap tag retained their identifying mark through the intervening year. The lower indicated survival of fish tagged about the jaw with the fingerling strap tag (33 per cent) suggest rather strongly that these small tags fitted too closely at the time of application to the jaw of the ten-inch trout. Several of these fish on subsequent examination had the jaw broken by the constricting tag; none of the fish bearing No. 3 tags had broken jaws. If the jaw is not broken, its growth probably forces the tag to open and become lost.

To determine what effect the internal tags had on the organs of the fish,

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[a]Since all belly-tagged fish carried jaw tags on their right jaw to identify them as belly-tagged fish, these may also be considered in the jaw tag survival. This gives a total of 40 fish bearing No. 3 strap tags on the jaw; of these 40 I was able to examine 19 on November 1, 1934.

one of the belly-tagged rainbow trout was killed and examined on November 1, 1934. The fish chosen was a female 12 5/8 inches long (total length), having grown 1 5/8 inches after being tagged on October 17, 1933. This fish was slit from anus to isthmus and opened. The tag was found located in an anterior-posterior plane. The anter end of the tag barely touched the posterior ends of the pyloric caecae. Slight adhesions had formed between the tag and the vasceral peritoneum in the region of the caecae. The posterior portion of the tag lay alongside and in contact with the developing eggs which partially filled the coelom at this time. However, not all tags were so satisfactorily placed as this one, since three tags are known to have been forced out of the fish. These results are consistent with those of Cobb (1933).

Two other hatchery experiments gave even more conclusive evidence that the jaw-tag method of marking trout would yield a relatively high survival of tagged fish over at least a 6-month period. On October 7, 1935, 100 hatchery brook trout fingerlings in the Northville Hatchery were measured and marked with the "fingerling" tag by the jaw-tag method. 100 fish of the same stock were taken at random and measured but not tagged. The average total length of both lots of untagged and tagged fish was 4.00 inches. On April 2, 1936, 83 of the tagged fish were found. The 17 missing fish were probably taken by merganser ducks during the severe winter weather, as the retaining pool was only partially covered, and Hatchery Superintendent Widmeyer reported that several mergansers had been seen feeding in the hatchery pools during January and February, 1936. The average size of the tagged fish on April 2, 1936, was 6.8 inches total length. The surviving fish were in good condition, and very little inflammation of the jaws could be noted. The average size of a random sample of 100 untagged fish on April 2, 1936, was 6.6 inches.

Table 2

SUMMARY OF BELLY-TAGGING AND JAW TAGGING EXPERIMENTS ON RAINBOW TROUT AT FEDERAL HATCHERY, NORTHVILLE, MICHIGAN

Fish tagged October 1 and 31, 1933 - last examination November 1, 1934.

Where tagged	Number tagged Oct. 1,1933	Present Oct. 10,1933	Present[2] Jan. 11 1934	Present[2] June 8 1934	Present[2] Nov. 1 1934	Percent of total marked found Nov. 1 1934
Abdominal cavity and around jaw bone	15	15	25[1]	19	16	64
Around jaw bone (#3)	15	15	15	7	3	20
Around jaw bone (Finger)	15	15	12	9	5	33
Total	45	45	52	35	24	44

[1] Ten more fish had been belly-tagged on Oct. 31, 1933, all 25 belly-tagged fish were then tagged around their right jaw so that they could be identified as belly-tagged fish.

[2] Entire tagged stock not available to examination because of hatchery work in progress.

In another experiment initiated at the Paris Hatchery January 4, 1936, 202 yearling brown trout of an average total length 8.8 inches were marked and placed in a covered concrete raceway with 53 unmarked yearling brown trout of an average total length 8.7 inches. The jaw-tag method of marking was used, but the tag was of slightly different construction from the usual "strap" tag (see p. 7). These fish were examined in March, 1936, and again in June, 1936 (Table 3). Of the 202 fish marked, 24 had died between January and June, leaving 178, or a survival of 88 per cent. The mortality was highest (23 deaths) during the severe cold weather of February, 1936, and was possibly aided by the rough edges of the unmilled experimental tags. Despite these factors, however, this experiment gave the highest survival rate of any of the hatchery experiments thus far conducted.

From the results of these tagging experiments conducted at the Northville, Harrietta and Paris hatcheries, it is concluded:

1. Strap tags applied to the basal rays of the caudal fin of brook trout, or to the dorsal fin do not long remain in place.

2. The belly-tagging method of marking trout is feasible, but has the following disadvantages:

(a) The belly tags cannot be seen externally;

(b) The tags may be forced from the body cavity and lost;

(c) The operation of incision permits any pathogenic microorganism present in the water easy entrance to the internal organs while the wound is healing, as demonstrated in the Harrietta experiment of 1932-1933.

(d) Belly tags are not easy to apply to trout because of the extreme activity of the fish.

3. The jaw tag method of encircling the strap tag around the mandible has proven far superior to the earlier method of attaching the strap tag to the gill-cover (Tables 1, 3).

4. If strap tags of sufficient size are affixed by the jaw-tag method, they will be carried by the fish for periods of one year or longer (Table 2). Field experience has subsequently shown that trout ranging from 3 to 6 inches can be successfully jaw-tagged with fingerling size strap tags. Larger trout carry a No. 3 size strap tag successfully.

Of the methods of fish-marking tried, those which present most advantages and fewest disadvantages are the jaw-tagging method and the fin-clipping method. Both methods are now in use in Michigan tagging experiments, the choice depending on whether data of detailed or of a mass nature are desired. The button tag has never been tried, since it was assumed that the insertion of the tag in the flesh would present an open avenue for infection. The "belly" tag has not been used in the field experiments for the same reason, and also for other reasons outlined above.

Effect of Jaw Tags on Growth of Trout

The effect of tagging on growth presents a problem that should be considered in the use of tagging as a method for studying the growth of fish. Two European workers (Wunder, 1935; Debrosses, 1935) have expressed the opinion that tagging of carp (*Cyprinus carpio*), and rouget (*Mullus barbatus*), on the gill-cover and on the caudal peduncle respectively, had slowed the growth of these species. An analysis of the effect of jaw-tagging on the growth of trout, in experiments conducted at the Federal Hatchery at Northville, and at the State Hatchery at Paris indicate, on the contrary, that the jaw-tagging method of marking trout does not slacken their growth.

The details of these experiments have already been presented on pp. 28 to 30. Both experiments showed little difference between the growth of the tagged and untagged fish over a six month period and the differences noted favored the tagged individuals. From these results (Table 3) it appears safe to conclude that jaw-tagging does not interfere with the growth of brook and brown trout, at least under hatchery conditions. This may or may not be true in natural waters. Insofar as could be determined from a study of the literature, this is the first systematic study of the effect of tagging on the growth of marked fish.

Table 3

RESULTS OF HATCHERY EXPERIMENTS TO DETERMINE THE EFFECT

OF JAW-TAGGING ON GROWTH RATE.

Item	Tagged		Untagged[5]	
	Number	Av. Total length (inches)	Number	Av. Total length (inches)
Northville Hatchery Brook Trout				
Measured Oct. 7, 1935	100	4.0	100	4.0
Remeasured Apr. 2, 1936	83[1]	6.8	100	6.6
Paris Hatchery Brown Trout				
Measured Jan. 4, 1936	202	8.8	53	8.7
Remeasured Mar. 18, 1936	179[2]	8.9	52	8.8
Remeasured June 19, 1936	178[3]	9.5	56[4]	9.1

[1] 17 fish probably lost through merganser predation.

[2] 23 tagged fish and 1 untagged fish lost during severe winter weather in February.

[3] One tagged fish died in June.

[4] Evidently raceway not fish-tight, and 4 brown trout jumped over retaining screens onto the experimental raceway.

[5] All untagged fish chosen at random from same stock as the tagged fish.

TAGGING AND MARKING FISH AS A METHOD IN BIOLOGICAL INVESTIGATION

Several important kinds of data pertaining to fisheries may be obtained most readily and with greatest accuracy by marking experiments. The percentage of the population removed by a fishery can often be computed after marking a portion of the population. The known number of marked individuals placed in the water, and the percentage of marked individuals in the catch, provide a basis for the calculation of the total stock and of the percentage of the stock that is removed by the fishery over a given period of time. Population estimates may be computed in other ways (Shetter, 1937), but at least in the sea and in large inland bodies of water, tagging or marking experiments probably will prove most feasible from the standpoint of time and expense involved. Although migrations and movements of certain stocks of fish have been determined by other means, such as the analysis of scale characteristics (Runnström, 1936), positive and clear cut data on migrations is obtained more easily by marking experiments. Growth may be determined by measuring the same population of fish at several different times and comparing the average measurements at the different periods, or by computations from scale measurements. A more direct means of studying the growth, however, is to directly compare the lengths of marked fish on recovery with their lengths at the time of tagging. This method of growth determination presupposes that the rate of growth of the fish is not altered by the marking process. This seems to be true of trout (see pp. 28 to 30).

It is neither within the scope nor purpose of this thesis to attempt a review of the many valuable tagging and marking experiments which have been conducted in the past. Some of the more outstanding work will be reviewed briefly, however, to illustrate the use of tagging and marking experiments in solving problems of migration, growth, fishing mortality and population estimates.

Migration

At Wood's Hole, Massachusetts, Smith (1902) tagged adult cod with small copper tags attached to the fish by a wire through the bases of the fins. Of the 4,019 cod tagged, 140 or 3.5 per cent were recaptured between 1897 and 1901. From this experiment Smith concluded that cod of Long Island Sound in the Nantucket shoals area did not migrate north of Cape Cod, but tended to move south and west toward the New Jersey coast during the winter months.

Schroeder (1930) repeated the work of Smith in a more extensive experiment, marking 24,739 adult cod caught chiefly by hand lines. The "strap" tags were attached to the base of the caudal fin. Of those tagged, 858, or 3.5 per cent were recaptured. These recoveries confirmed the findings of Smith, and further definitely established the winter migration of southern New England cod as far south as the Carolinas.

The cod migrations of the northwestern Atlantic have been worked out in considerable detail by Hansen, Jensen, and Tåning (1935) and by Tåning (1934). Many other excellent migration studies of commercially important species of Icelandic and Danish waters were also summarized in these same papers. Tåning summarized marking experiments on the cod in the region of the Faroe Islands, in the region of Iceland and in the region of Greenland. The fish were marked with the button type of tag made of ebonite. Of 6183 fish marked in the region of the Faroes between 1904 and 1932, 35 per cent (2189) were recovered, none more than 100 miles distant. Since only 2 of the cod marked at Iceland or Greenland have ever been recovered at the Faroe fishing grounds, this lack of recoveries from Icelandic waters may indicate that the mature cod stock in the Faroe Islands is indigenous to the locality.

In the region of Iceland, 6420 cod and codlings were marked between 1905 and

1933, 3803 on the spawning grounds and 2617 outside of the spawning grounds. Of the former group 8 per cent were recovered, and of the latter, 22%. None of the fish marked outside of the spawning grounds were recovered anywhere outside of Icelandic fisheries. Sixteen of the cod marked on the Iceland spawning grounds wandered extremely far; 12 were recovered on the West Greenland Coast, 1 off Newfoundland, 1 between Iceland and Greenland, and 2 off the Faroe Islands. It is contended by Tåning (1934) that the fish migrating westward between the two islands follow the Iceland-Greenland ridge, which separates the cold polar waters from the warmer Atlantic currents. This westward migration is interpreted as a food-seeking migration. These far-reaching movements of cod tagged in Icelandic spawning waters suggest that the waters off western Iceland are the center of dispersal for the cod, and that much of the cod supply of the northwestern Atlantic is supplied by these breeding grounds.

Cod tagged in the waters of Greenland have shown a reverse movement (Hansen, Jensen and Tåning, 1936) to that of the Iceland stock. Between 1924, and 1933, 6811 cod were marked in many localities of West Greenland, and 772 in East Greenland. Of these 2 groups 5.2 per cent and 1 per cent, respectively were recaptured. Of the cod tagged in West Greenland, 197 were recovered on Icelandic fishing grounds, but only 6 of the fish tagged at East Greenland migrated to Iceland. The remainder were taken locally in Greenland's fisheries. The majority of relatively stationary recoveries were made from fish tagged in Greenland fjords. The migration south and then eastward to Iceland usually took place between October and April. These results further strengthen theories already advanced by Tåning (1934) concerning cod migration between Greenland and Iceland, and also show that Greenland probably has a local stock of cod which spawn along the southwestern coast of the island.

The migratory habits of the 5 species of Pacific salmon which inhabit the Alaskan waters of the Pacific from the Alaskan Peninsula to the Alaska-British Columbia boundary have been studied in detail for many years by tagging experiments. From the results of these numerous experiments (Gilbert, 1923; Gilbert and Rich, 1925; Rich, 1926; Rich and Suomela, 1927; Rich and Morton, 1929; S. H. Thompson, 1930; Rich, 1932 and others) the migration routes of the several species of salmon in various localities have been determined, so that the source of the stock upon which the local fisheries are prosecuted is known. Since the salmon are an important natural resource to both Canada and Alaska, knowledge concerning their source and migration routes is valuable, in that it supplies data needed for sound regulation of the fishery.

Recoveries from salmon tagged in Canadian waters of the Pacific have yielded supplementary information as to the migratory habits of the adult fish. The recoveries from tagging experiments of Williamson and Williamson and Clemens (1927, 1932) demonstrated that the spring salmon might need be protected by legislation of international scope, since the fishing conducted at any one point on this fish, if not controlled, might seriously deplete the supply of several areas.

Several studies on the migration of the salmon from the fry stage to maturity have been made in salmon streams of the United States, Alaska and Canada. Since no type of tag which could be applied to the fry would remain attached through the life span of the fish, fry marking has been, and still is carried on by means of clipping two or more fins. Experiments (Rich and Holmes, 1929; Davidson 1934) have proven that the clipped fins will not regenerate if properly excised. Rich and Holmes experimenting on Columbia River Chinook salmon noted, as evidence favoring the "parent stream" theory, that marked fish were recovered from the streams where they were placed as marked fry. The authors infer (p.262) that returning adults will come back from the sea to the main stream of the river system in which they spent their fry period, but, as borne out by recoveries from some of their marking experiments, some of these fish may not choose to spawn in the tributary where their fry period was spent. None of the 632,500 fin-clipped Chinook salmon marked between 1916 and 1927 were retaken in any other stream than the Columbia or its tributaries.

Migrations of the pink or humpback salmon have been studied by Davidson (1934) in both United States and Alaskan waters; fin-clipping was used by Davidson as a means of identifying specimens from known hatchery releases. From 86,000 marked pink salmon released, 33 were recovered on the spawning migration 2 years after marking. Davidson concluded that the return of the pink salmon to their parent stream was dependent on the number of streams suitable for the spawning of pink salmon in the immediate vicinity of the true parent stream. This was borne out especially by 2 recoveries made from 2 neighboring streams in addition to 8 recoveries from the Duckabush River (Washington), in which the marked fry were originally liberated. In the Alaskan experiment, marked fish were recovered only in the stream where marked. This pink salmon stream, Snake Creek (on Etolin Island) was relatively remote from other pink salmon streams of the region. It must be remarked that far-reaching conclusions regarding the return of marked fish to their parent streams have been made on the basis of the recovery of very few fish.

Growth Studies

Although growth rates of most fishes may be determined through a study of the scales, comparison of measurements made on tagging and on recapture probably afford a more accurate measurement of the growth in the intervening period, especially where scale readings are difficult. The growth rate month by month during the warm season may be determined by the use of marked fish but not by the scale methods which relies on the annuli laid down in the winter or spring. After determining the growth rate of cod by both scale studies and from measurements on recoveries of tagged cod, Schroeder (1930) regarded the latter method as the more accurate. He found that cod between 17 to 24 inches long grew approximately 4 inches yearly, while cod 25 to 35 inches long grew approximately 2½ inches per year. He discovered also that the growth during the summer was faster than the growth from the fall to the following spring.

Peterson (1894, 1896) was one of the earliest fisheries biologists to make use of marking fish to learn their rate of growth. He conclusively demonstrated by marking experiments which portions of the Limfjord in Denmark produced the fastest growth of plaice after the transplantation of that species from the North Sea.

Similarly, Borley (1912) demonstrated by a 26% recovery on 1,003 tagged fish that plaice which had been moved from the Dutch Coast to the Dogger Banks in the North Sea grew in length no less than twice as much as fish of the same age which had not been moved from the Dutch coast. Their weight was 3½ times greater than it would have been had they been left in their native waters. It was estimated that this transplantation doubled the monetary value of these fish. Experiments of like nature were conducted by Lee and Atkinson (1912), Garstang (1912) and Johansen (1915).

Mortality due to the Fishery

Especially in commercial species, information on mortality due to the fishery is of great value in regulating the intensity of the drain on the stock or in planning measures to meet this drain. Petersen (1896) marked approximately 1 of every

7 of 82,500 transplanted plaice put into Thisted Broad in the Limfjord. Fishermen recovered marked and unmarked fish in the ratio of 1 to 5, which clearly indicated that virtually the entire stock of plaice in Thisted Broad was derived from the transplantation.

Plaice-marking experiments by Johansen (1915) showed that Danish, English, German and Dutch fishermen removed approximately 57 per cent of the plaice stock off the West Coast of Jutland in the North Sea, because 770 recoveries were effected on 1350 button-tagged plaice, marked between 1903 and 1912. The Danish fishermen captured 85 per cent of the recoveries, the English 9 per cent, the Germans 5 per cent, and the Dutch 1 per cent. Lee and Atkinson (1912) estimated the mortality due to the fishery on the English plaice grounds by marking experiments, and placed this mortality at approximately 37 per cent, since 504 marked fish were recovered from 1372 that had been liberated. The results of Borley (1912) indicated a fishing mortality of 26 per cent on the Dogger Bank.

Recoveries of tagged salmon in Alaskan waters have shown that commercial fisheries place a rather heavy drain on these species on the way to their spawning grounds. Gilbert and Rich (1925) estimated from the results of marking red salmon along the Alaskan Peninsula that at least 36 per cent of the spawning runs of mature adults were being taken by commercial fishermen. In southeastern Alaska, Rich and Morton (1929) showed that commercial fisheries took approximately 45 per cent of the Karluk River red salmon run, as 317 tagged red salmon were recovered by commercial fishermen from a total of 700 marked fish.

Estimation of the Population

The approximate fish population of a body of water may be calculated if the investigator knows how many marked fish have been placed in the water, how many marked fish were recovered, and if he also knows how many unmarked fish were caught at the same time during which the marked fish were recovered. Schroeder (1930) estimated the average adult cod population of Nantucket Shoals to be between 3,000,000 and 4,500,000 fish. Population estimates could also have been made on the plaice in various portions of the North Sea had the investigators cared to do so, since the essential data were available from their numerous marking experiments. Smith (1902) estimated the poundage of cod present between southern New Jersey and southern Massachusetts as 500,000,000 pounds, based on the known commercial take, the weight of the total number of cod tagged, and the known weight of the recovered cod.

Needham (1936) has used a similar method to estimate the rainbow trout population of Convict Lake in California. Planted fish were marked by clipping the adipose and left pelvic fins. The number of marked and unmarked fish was obtained from an intensive creel census of the anglers using the lake. Needham estimated that there were 3653 rainbow trout in Convict Lake after the hatchery fish had been planted. Population estimates of a like nature are discussed further on pp. 75 and 76. The combination of marking with an intensive creel census should be used more often in connection with the analysis of sport fisheries since angling, together with hunting, is the indirect source of income for many otherwise non-productive sections of the country. Both the amount of these resources and the annual drain on the resources should be known, in order that proper management may be practiced.

Determination of the Proper Time to Plant Hatchery Fish

From marking experiments on both "fall" and "spring" run chinook fingerlings, Rich and Holmes (1928) proved that hatchery fingerlings reared from "spring" fish returned in larger numbers when held for a year before release. Hatchery fingerlings reared from "fall" run chinooks returned in larger numbers when released as soon as the ylk sac was absorbed than did those released during the following summer. This same experiment rather conclusively proved that the time of entering fresh water is a heritable character. This was proven by hatching eggs from "spring" run chinook salmon in creeks known to support previously only "fall" run stock and marking the fingerlings hatching from these eggs. The recoveries of these marked fingerlings at maturity occurred only during the "spring" run. The reverse operation was performed with the "fall" run chinooks, and they were recovered only in the fall of the year.

In Germany, Bahr (1935) has recommended that in the stocking of sea trout and brown trout in German coastal waters only fish that are at least 2 summers old be used. This recommendation was based on the results of several marking experiments in which brown trout and sea trout of different ages were marked and released; a much higher percentage of marked second-summer fish were recovered than of marked first-summer fish.

In many states including Michigan it is the present policy to plant most of the hatchery output of brook and brown trout in the fall of the year (or early winter) as advanced fingerlings, since the cost of feeding and the risk of carrying these fish over the winter is rather heavy. The Institute for Fisheries Research has an experiment in progress at the present time to determine what percentage of hatchery brook trout planted in the fall survive the rigors of the winter and later reach the angler's creel. Approximately 9,700 hatchery brook trout fingerlings were fin-clipped before planting in the North Branch of the Au Sable River in Crawford County. Recoveries of marked fish by seining will be carried on during the coming years, and the projected creel census on the stream should furnish data on the number of hatchery fish taken by the angler. Other information will be available from this study, for instance, population estimates, dispersal from point of planting and average rate of growth.

The investigations in Michigan, discussed later in this report, provide further examples of the solution of fishery problems by means of tagging experiments. These demonstrations, confirming such results as are outlined above, give ample evidence of the successful use of various marking methods in biological investigations.

EARLIER TAGGING WORK IN MICHIGAN WATERS

The tagging of fishes in the public waters of Michigan was started in 1928 when Dr. Jan Metzelaar began to mark the three species of stream trout in an attempt to learn something of their migratory habits in the waters of the state. Unfortunately his activities were cut short two years later by his untimely death. Thereupon the tagging work was carried on by Dr. John R. Greeley and Gerald McCrimmon of the staff of the Institute for Fisheries Research, which was formed in 1930. Several of the hatchery supervisors and various of the fish and game clubs of the state also aided in the tagging program. One excellent marking experiment on northern pike was carried on under the direction of Dr. Charles W. Creaser of Wayne University, and Charles Delavan of Alma, Michigan, on the Pine River in the vicinity of Alma.

Serially numbered strap tags were used in all these earlier experiments. Until the "fingerling" size strap tag was developed by the Salt Lake Stamp Company at the instigation of Dr. C. L. Hubbs in 1930, the tag most commonly used was the No. 3 size (Fig. 1). During this early work the tag was attached through the basal rays of the caudal fin, or through the gill cover of the fish. For larger fish, especially the rainbow trout, it was found necessary to punch a hole in the heavy gill-cover with a paper punch or a shoe-makers awl before inserting the tag.

From 1928 to 1933 inclusive, 20,023 fish of ten different species found in Michigan waters were tagged. Of these, 415 or 2.1 per cent were later recovered. These recoveries, and the reports thereon, were furnished through the cooperation of the fishermen and of the spawn-taking crews at various of the power dams on the west side of the state. Table 4 lists for each species the number of fish tagged, the number of fish recovered, and the percentage of recovery obtained in the earlier experiments.

The experiments which had sufficient returns of marked fish on which to base any conclusions will be described in more detail. The more successful experiments were those on the wall-eyed pike in the Inland Water Route, on the raimbow Trout in the Manistee River system, on the brook trout in the tributaries of the Manistee River system and in the Au Sable River system, and on the northern pike in the Pine R iver in Gratiot County.

Table 4

SUMMARY OF FISH TAGGED AND RECOVERED 1928 TO 1933.

Species	Number tagged	Number recovered	Recovery percentage
Rainbow trout	5501	176	3.2
Brook trout	7095	153	2.2
Brown trout	1403	25	1.8
Lake trout	100	0	0
Wall-eyed Pike	2784	37	1.3
Northern Pike	144[a]	23	16.0
Small-mouth bass	277	1	0.4
Perch	1151	0	0
Suckers	1563	0	0
Muskellonge	1	0	0
Crappie	4	0	0
Totals	20,023	415	2.1

[a] 465 additional northern pike were tagged, but the recovery data on these fish are not available.

<u>Tagging Experiments on Adult Rainbow Trout in the Manistee River System.</u>

Tagging experiments on the rainbow trout were carried on in 1929, 1930 and 1931, chiefly on the Manistee River system. Most of the fish tagged were wild spawners captured in a fish trap located at the foot of Junction Dam in Manistee County, on the Big Manistee River. From this point they were transported to Hodenpyl Dam above Junction dam, or to the Stronach Dam on the Pine River (see Map 1) where they are tagged and released. Spawning fish were also captured at Pine Creek, another tributary of the Big Manistee in Manistee County, below Junction Dam. On the Little Manistee River, spawning fish were captured and tagged at a weir operated for spawn-taking at Fox's Bridge in the northwest corner of Lake County. The fish tagged were not stripped. They were marked by attaching the No. 3 size strap tag on the opercle.

The number of trout tagged each year at the 5 most important localities is shown in the upper part of Table 5. Of the 4,341 fish marked, 166 recoveries (3.8%) were reported, 137 in the Manistee stream system and 14 in Lake Michigan or other streams tributary to Lake Michigan; 15 were found dead near the point of release or were reported with insufficient data. The routes followed and the approximate distances travelled by these tagged rainbow trout are indicated on Map 1, which shows their distribution within the Manistee River system after release, and on Map 2, which shows the distribution of the individuals which were recovered in Lake Michigan and its tributaries other than those of the Manistee system.

A more detailed analysis of the recoveries of the tagged fish each year at various points is given in the lower part of Table 5. In the following paragraphs separate discussions are given of the tagged fish that were released at several localities: Junction Dam and Hodenpyl Dam on the Big Manistee River, Stronach Dam on the Pine River, Pine Creek Rearing Station on Pine Creek, and Fox's Bridge on the Little Manistee in Lake County (see Map 1.).

Hodenpyl Dam Releases.--The total recovery percentage for the 200 rainbow trout tagged and released above Hodenpyl Dam was 2.5%. Of the 5 recaptures, 1 was caught in Fletcher Creek, a tributary of the Big Manistee entering above Hodenpyl Dam; 2 were recaptured in the backwaters of Junction Dam, and 2 were caught just below Hodenpyl Dam. All these fish were recaptured within the year of tagging and release (1931). All except the 1 retaken in Fletcher Creek must have passed downward over Hodenpyl Dam or through the turbines.

Stronach Dam Releases.--The total recovery percentage for the 1119 tagged rainbow released above Stronach Dam on Pine River was 7.7%. Of the 86 fish recaptured (1 with incomplete data), only 16 had gone downstream over or through the power dam. Of the 69 recovered above the dam, 33 were taken from the backwaters of the dam, 21 alive and 12 dead, and 36 were secured from $\frac{1}{2}$ to 40 miles upstream, whence they had obviously moved to spawn in the Pine River or its upper tributaries (see Map 1). Some of the trout recovered in the backwaters above the dam had probably migrated upstream to spawn and had then returned to the pond. One of the fish taken upstream was recovered a year after release, and one two years afterward. These 2 fish has presumably spent the intervals between spawning periods in the pond above Stronach Dam.

Of the 16 recovered trout that had moved downstream over or through Stronach Dam, 2 were caught just below this dam; 5 were caught above Junction Dam on the Big Manistee; 3 were taken below Junction Dam (one of these, taken a year later, had made so considerable a growth as to indicate that it had probably moved out into Lake Michigan and back); 2 were taken in Pine Creek, showing they had passed through or over both Stronach and Junction Dams and had continued down the Big Manistee and up by Pine Creek; 3 were taken in the Big Manistee above its confluence with the Pine River (these went down the Pine River over Stronach Dam and then up the Manistee River to the point of capture); 1 fish taken on the Wisconsin side of Lake Michigan had negotiated both dams before swimming across or around Lake Michigan.

Junction Dam Releases.--The total recovery percentage for the 1902 rainbow trout released at Junction Dam, located just below the confluence of the Upper Manistee and Pine River was 2.5%. Of the 519 released during the 3 years below this dam, the 2 that were recovered were both caught in Pine Creek, which enters the Manistee below Junction Dam. Most of these fish probably migrated down into Lake Michigan soon after their release. Of the 46 recaptures of the 1183 marked trout released above the dam, 6 were recovered below Junction Dam, and 38 above it (2 had no data). The marked fish that had stayed above the dam distributed themselves as follows: 3 were caught at the foot of Hodenpyl Dam, the next barrier upstream on the Big Manistee; 2 were caught in Slagle Creek, a tributary entering the Big Manistee between the two dams; 16 were caught at the foot of Stronach Dam on the Pine River; and 17 were caught in the backwaters of Junction Dam on the Big Manistee. Two of the latter were taken approximately one year later.

The 6 recovered fish which had moved downstream through or over Junction Dam were recaptured as follows: 3 just below Junction Dam; 1 in Pine Creek, a tributary of the Big Manistee entering downstream from Junction Dam; 2 in Lake Michigan, 1 off Oostberg, Wisconsin, and 1 in Pentwater Lake, on the Michigan side.

Pine Creek Releases.--The total recovery percentage for the 346 rainbow tagged and released at Pine Creek Station was 1.4%. Only 1 of the 5 recoveries was made in Pine Creek. The 4 other recoveries were obtained in Lake Michigan or in tributaries to Lake Michigan other than those of the Manistee drainage. There were no dams to interfere with movements of the fish between Pine Creek and Lake Michigan.

Fox's Bridge Releases.--Fox's Bridge is located in the northwest corner of Lake County on the Little Manistee River. No dams which are barriers to fish migrations are located on this stream. Tagging was carried on here only in the early spring of 1929.

The total recovery percentage on the 974 rainbow trout tagged and released at Fox's Bridge was 2.3%. Of the 22 tagged fish recovered, 8 were secured upstream, one as far as the dam at Luther. Four of these 8 fish were recovered more than a year later, indicating that they had quite likely returned to the Little Manistee to spawn after having gone back to Lake Michigan in late summer. Of the 7 caught in the Little Manistee below the point of tagging, all except 1 were taken in the year of tagging, probably as they were dropping back to the lake after spawning. The 7 other individuals, recovered at various points along the shore of Lake Michigan, showed the widest spread of any of the releases, for they were returned from Kenosha, Oostberg, and Manitowoc, Wisconsin, and from Grand Traverse Bay, North Manitou Island, Pentwater Lake, and W hite Lake on the east side of Lake Michigan.

Conclusions from the Tagging Experiments on Adult Rainbow Trout.--The migration routes portrayed on Maps 1 and 2 and the preceding discussions of the various releases lead to the following conclusions on the migratory habits of adult rainbow trout in Great Lakes waters:

1. The rainbow trout migrates more widely in both stream and lake than any other of the Michigan fishes studied.

2. Releases above impassable dams such as Junction Dam on the Big Manistee, and at Stronach Dam on the Pine, show that spawning fish will seek out remote tributaries in which to spawn, if these tributaries can be reached.

3. Recoveries at points below dams of tagged fish which had been released above these dams prove definitely that adult rainbow trout are able to migrate passively or actively over the dams, or through the turbines.

4. The fact that some fish were recaptured in the backwaters of certain dams approximately one year after they were released there suggests either that the backwaters provide a suitable habitat for life between spawning periods, or that the dam is a partially effective barrier to their downstream movement. The first possibility seems the more plausible since a fairly large number of recovered fish had moved downstream through or over the dams.

5. The upstream recoveries of rainbow trout tagged at Fox's Bridge on the Little Manistee indicate that such streams, having no dams in their courses, provide better spawning facilities for fish running in from the lake than do the streams which are dammed. In the Little Manistee, the adult rainbows are able to freely seek out the upper stretches which provide the natural spawning situations. Considering the condition of the fishways on the Junction, Stronach and Hodenpyl dams, such movements would be scarcely possible on the Big Manistee River, unless the fish were transported above all 3 dams.

6. The recoveries of tagged rainbow trout at Junction Dam on the Big Manistee River tend to confirm the "parent stream" theory, which states that the anadromous fish return to the stream in which they were born to perform their own spawning. At Junction Dam in 1930, 12 of the tagged rainbows that were captured below the dam had been tagged and released in 1929 above Junction Dam (Table 5). Their growth of 2 to 7 inches in the intervening year suggests strongly that these fish had all migrated to Lake Michigan and had returned to the Manistee River to spawn. From the Stronach Dam releases of 1929, 3 tagged rainbow were also taken

in 1930 at the foot of Junction Dam. It is very probable that they too had moved to Lake Michigan and were attempting to return to their natural spawning grounds. Many more of the adult rainbow trout marked and released in the Manistee River system in 1929 probably returned to Junction Dam in 1930, according to the following report from J. P. Marks, then in charge of the egg taking operations at Junction Dam:

"We also found over 50 fish that had lost their tags, as where the tags were placed the gill cover was infected and town out." There is evidence, however, that some of the adult rainbows instead of returning to their parent stream wander into other drainages; 2 adult rainbows tagged and released at the Pine Creek station in 1929 are recorded as recaptured in 1930 in 2 other streams, Betsy River, north of the Manistee River, and Muskegon River at Newaygo Dam, at a considerable distance from Lake Michigan.

7. The recovery of rainbow trout tagged off Pt. Washington, Wisconsin, by Lester Smith, a commercial fisherman of that port, lends weight to the theory that western Michigan streams are the usual spawning grounds of the Lake Michigan rainbows. Three of these rainbows tagged off Port Washington have been recovered at Junction Dam, approximately 125 miles from their point of release on the Wisconsin side of Lake Michigan. Two other rainbow trout tagged by Smith have been recovered on the east side of Lake Michigan, one off Muskegon, and one off Grand Haven. The latter fish travelled at least 87 miles in 7 days.

Miscellaneous Tagging Experiments on Rainbow Trout

Numerous minor taggings on rainbow trout undertaken from 1928 to 1932 inclusive yielded almost no definite results. Usually the number of fish tagged was too few to give any reasonable expectation of an adequate number of recoveries by anglers, especially since the reporting was voluntary and without reward and since the experiments were scattered and not vigorously publicized. The data are given in Table 6.

Table 5

DATA ON RELEASE AND RECOVERY OF TAGGED RAINBOW TROUT IN THE MANISTEE RIVER SYSTEM

Recoveries for each category are given consecutively for the years 1929, 1930, and 1931. The number of fish recovered at approximate point of release are given in bold face type. Recoveries made upstream are indicated above the bold face figures; recoveries made downstream, are given below the bold face figures. Some complexity is introduced into this arrangement because of recoveries and releases made in tributary streams. Consult Maps 1 and 2.

	Locality where tagged fish were released						
No. of tagged fish released:	Manistee R. above Hodenpyl Dam	Pine R. above Stronach Dam	Manistee R. at Junction D. Above	Manistee R. at Junction D. Below	Pine Creek Station	Little Manistee R. at Fox's Bridge	Total fish tagged:
1929	...	492	474	119	346	974	2405
1930	...	380	465	100	...	...	945
1931	200	247	244	300	...	...	991
Totals	200	1119	1183	519	346	974	4341
Locality where recovered:							Total recoveries by point of recovery
Manistee River							
Fletcher Creek	-,-,1						-,-,1
Above Hodenpyl Dam	-,-,-	-1-	....				- 1 -
Below " "	-,-,2		-,1,1				-,1,3
Slagle Creek	.....	-,1,-	1,1,-				1,2,-
Above Junction Dam Pond	.....	3,1,-	....				3,1,-
Pine River		.....	....	....	....	....	.....
Above Stronach Pond	.....	20,7,6	....				20,7,6
Stronach Pond	.....	3,10,4	....				3,10,4
Below Stronach Dam	.....	2,1,-	3,13,1				5,14,1
Manistee River	.....	.....	....	....	....	....	.....
Junction Dam Pond	-,-,2	3,-	-,-,1				3,-,3
Below Junction Dam	.....	-,4,-	11,3,-	2,-,-			13,7,-
Pine Creek		1,-,-	1,-,-	2,-,-	1,-,-		5,-,-
Little Manistee R.	.....	.....	....	....	....	....	.....
Above Fox's Bridge		....	....		....	8,-,-	8,-,-
At Fox's Bridge						-,-,-	-,-,-
Below Fox's Bridge		.....	....		....	7,-,-	7,-,-
Lake Michigan		-,1,-	-2,-		2,- -	7,-,-	9,3,0
Betsy River		.....	....		1,- -		1,-,-
Muskegon River		.....	....		1,- -		1,-,-
Died or data deficient		1,12,-	-,2 -				1,14,-
Total recoveries by point of release	-,-,5	33,38,10	16,22,3	4,-,-	5,-,-	22,-,-	80,60,18

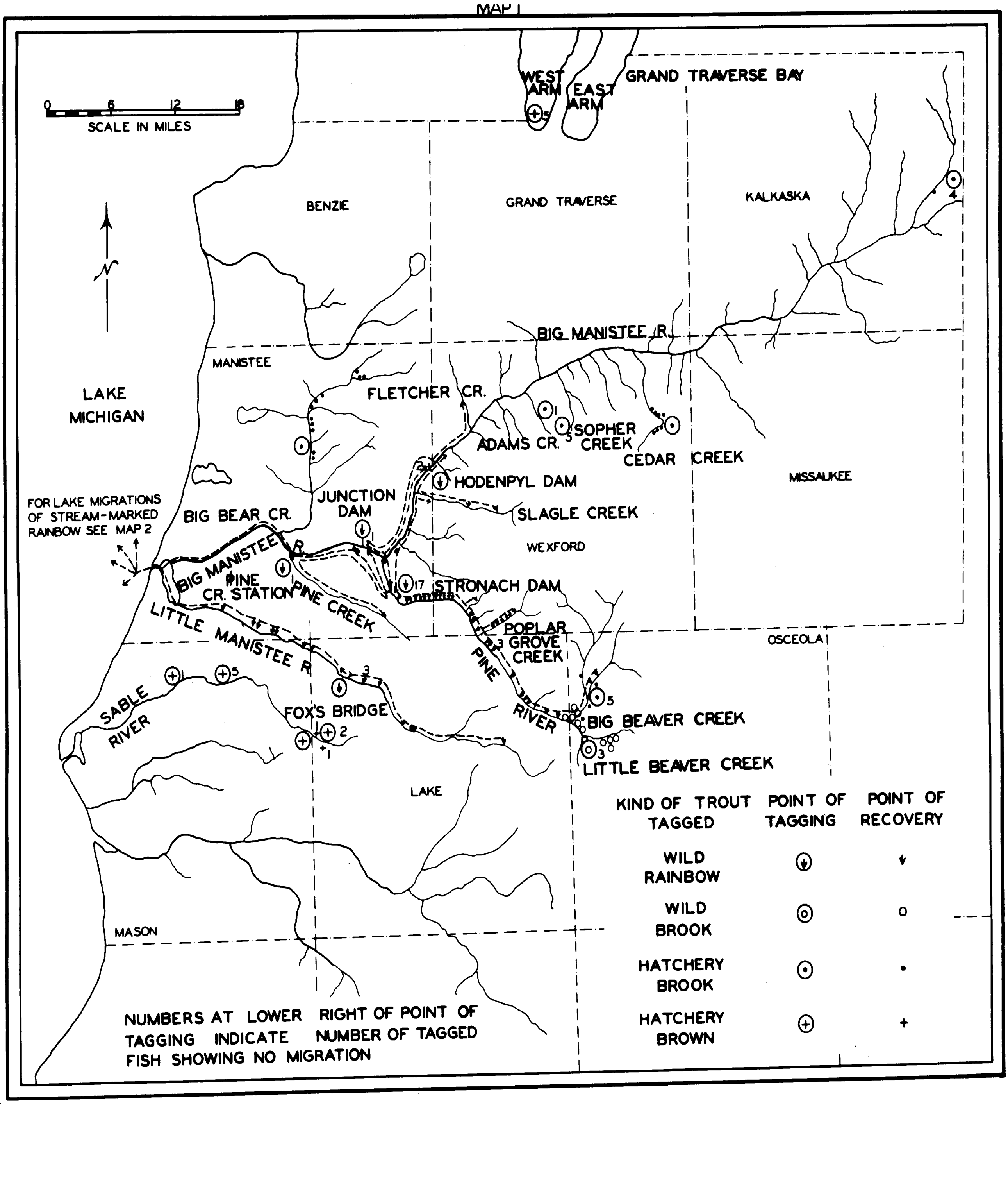
Table 6

MISCELLANEOUS RAINBOW TAGGING EXPERIMENTS IN MICHIGAN

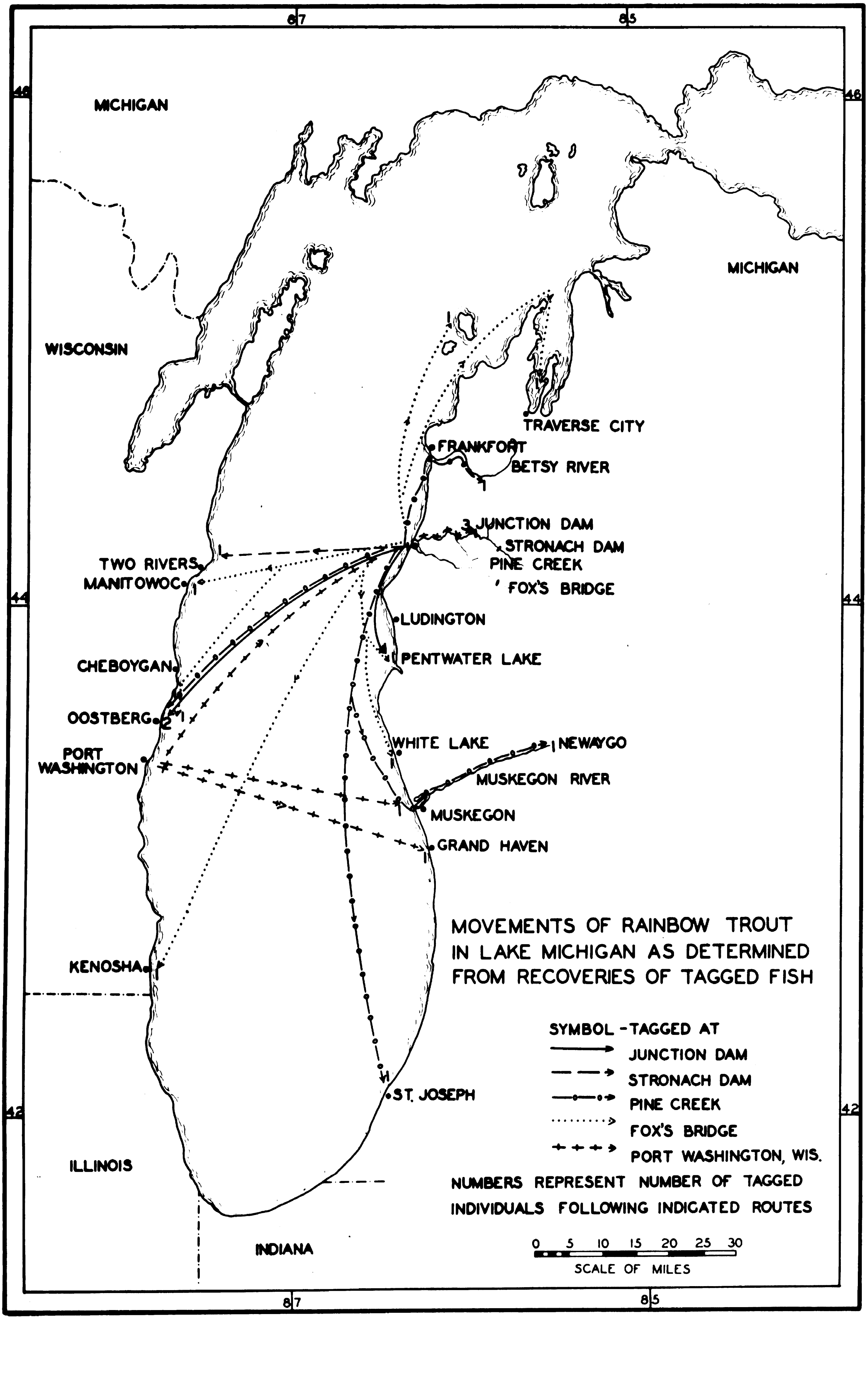
(A) - Adult fish; all other immature
* - Recovered twice, 6 and 12 days apart
S - Same locality
U - Upstream in Little Muskegon River near Howard City
? - Recovery data inadequate.

Year tagged	Year Recovered	Stream	County	Number tagged	Number Recovered	Recovery percentage
1928	1929	Sauble River	Mason	1(A)	1(S)	100.0
1928	-	Danaher Creek	Lake	9	-	0
1928	-	Baker Creek	"	15	-	0
1928	-	East Twin Creek	"	4	-	0
1928	-	Tank Creek	"	15	-	0
1928	-	Weldon Creek	"	1	-	0
1929	1929	Pere Marquette	Mason	502(A)	3?	0.6
1929	-	" "	"	74	-	0
1929	-	Hamlin Lake	"	1(A)	-	0
1930	1930	Little S. Br. Pere Marquette	Newaygo	4	1*	25.0
1930	-	Middle Brm. Pere Marquette		2	-	0
1930	1930	Little Manistee	Lake	80	2(S)	2.5
1930	1930	Big Beaver Creek	Osceola	18	2(S)	11.0
1930	-	Twin Creek		2	-	0
1930	-	McDuffy Creek		1	-	0
1931	-	Little Manistee	Lake	165	-	0
1931	-	Pere Marquette	Mason	4(A)	-	0
1932	1932	Muskegon R. (Croton)	Newaygo	14(A)	1(U)	7.1
1932	-	Muskegon R. (Big Rapids)	Mecosta	15(A)	-	0
1932	-	Muskegon R. (Hardy)	Newaygo	12(A)	-	0
1932	-	Muskegon R. (Newaygo)	Newaygo	22(A)	-	0
1932	-	Burt Lake	Cheboygan	100	-	0
1932	-	Sturgeon R.	"	99	-	0
Totals				1160	10	0.9

MAP I


SCALE IN MILES
0 6 12 18
GRAND TRAVERSE BAY
WEST ARM
EAST ARM
BENZIE
GRAND TRAVERSE
KALKASKA
BIG MANISTEE R.
MANISTEE
LAKE MICHIGAN
FLETCHER CR.
ADAMS CR.
SOPHER CREEK
CEDAR CREEK
HODENPYL DAM
MISSAUKEE
JUNCTION DAM
SLAGLE CREEK
FOR LAKE MIGRATIONS OF STREAM-MARKED RAINBOW SEE MAP 2
BIG BEAR CR.
BIG MANISTEE R.
WEXFORD
PINE CR. STATION
PINE CREEK
STRONACH DAM
LITTLE MANISTEE R.
POPLAR GROVE CREEK
PINE RIVER
OSCEOLA
SABLE RIVER
FOX'S BRIDGE
BIG BEAVER CREEK
LITTLE BEAVER CREEK
LAKE
MASON
NUMBERS AT LOWER RIGHT OF POINT OF TAGGING INDICATE NUMBER OF TAGGED FISH SHOWING NO MIGRATION
KIND OF TROUT TAGGED
POINT OF TAGGING
POINT OF RECOVERY
WILD RAINBOW
WILD BROOK
HATCHERY BROOK
HATCHERY BROWN

MAP 2


MICHIGAN
WISCONSIN
MICHIGAN
TRAVERSE CITY
FRANKFORT
BETSY RIVER
JUNCTION DAM
STRONACH DAM
PINE CREEK
FOX'S BRIDGE
TWO RIVERS
MANITOWOC
LUDINGTON
PENTWATER LAKE
CHEBOYGAN
OOSTBERG
WHITE LAKE
NEWAYGO
PORT WASHINGTON
MUSKEGON RIVER
MUSKEGON
GRAND HAVEN
MOVEMENTS OF RAINBOW TROUT IN LAKE MICHIGAN AS DETERMINED FROM RECOVERIES OF TAGGED FISH
KENOSHA
SYMBOL - TAGGED AT
JUNCTION DAM
STRONACH DAM
PINE CREEK
FOX'S BRIDGE
PORT WASHINGTON, WIS.
ST. JOSEPH
ILLINOIS
NUMBERS REPRESENT NUMBER OF TAGGED INDIVIDUALS FOLLOWING INDICATED ROUTES
INDIANA
0 5 10 15 20 25 30
SCALE OF MILES
87
85
46
44
42

Brook Trout Migrations

In comparison with the rainbow trout, the brook trout of Michigan appears to be a fish of limited migratory habits (with the probable exception of brook trout inhabiting northern peninsula streams flowing into Lake Superior). Between 1928 and 1933, 7,095 brook trout were marked; of this number, 153 were later recovered. The details of tagging and recovery are summarized in Table 7.

In the Manistee River drainage, it will be noted that both hatchery and wild brook trout tended to move in a rather limited manner in the tributaries of the Manistee River, and did not move down into the larger stream (see Map 1).

Perhaps the most significant recoveries are the results obtained from the tagging of 414 wild brook trout in the spawning beds of Little Beaver Creek in Osceola County in the fall of 1930. Of these fish, 14 were caught by fishermen in the following fishing season, 1931, and had dispersed as follows: 4 were taken in the Little Beaver, 4 had run down the Little Beaver then a short distance up the Big Beaver above the confluence of the two streams, 2 were caught in the Big Beaver below the confluence of the two streams, 1 was caught in the Pine River below the junction of the Pine and the Big Beaver, and 3 were captured in the Pine River above the confluence of Big Beaver Creek and the Pine River. According to these records none of the fish had moved more than 8 miles (see Map. 1). The experiment indicates that this spawning area in Little Beaver Creek probably serves as a breeding ground for many of the wild brook trout of the connected streams, but only within a radius of approximately 8 miles.

All recoveries of hatchery brook trout that were tagged and released in the Manistee River system were made in the same stream in which they were planted. Nearly all recoveries of tagged fish from plantings in Adams, Sopher, and Cedar Creeks in Wexford County and from the Little Pine River in Osceola County were made during the fishing season following release in the immediate vicinity of the point of release. Tagged hatchery brook trout released in Bear Creek, Manistee County, showed a tendency to move more, particularly in an upstream direction, but still stayed within the confines of the stream.

Hatchery brook trout tagged and released in the Au Sable River system showed a somewhat greater tendency to move out of the region of release, particularly in a downstream direction. Two individuals made extensive migrations in comparison with other tagged brook trout that were recovered. One tagged in the fall of 1928 in the North Branch of the Au Sable migrated into and down the main Au Sable, then up Big Creek in Oscoda County. Another, tagged during the winter of 1931 in the Main Stream of the Au Sable near the mouth of the South Branch of the Au Sable, moved approximately 25 miles up the South Branch of the Au Sable to the town of Roscommon.

Recoveries of tagged brook trout released in the headwaters of the Pigeon River indicated that Wild Brook trout were decidedly non-migratory, whereas the few hatchery fish recovered had all moved downstream, one as far as the mouth of the Little Pigeon River up which it had proceeded a few miles farther. The contrast is not very conclusive since recovery reports were received on only 4 of the 886 hatchery brook trout tagged, and on only 8 of 290 wild tagged brook trout.

Although 1019 adult hatchery brook trout were marked and released in the Upper Peninsula in 6 streams tributary to Lake Superior, only 2 recoveries were reported. This very low proportion of returns tends to confirm the general supposition that the brook trout in the northern drainage of the Upper Peninsula move out into Lake Superior when mature, and return to the streams in late summer prior to the spawning season. The paucity of returns, however, may have resulted in part from the small amount of fishing in the streams where tagged fish were released.

Of 6 hatchery brook trout, all adults, tagged and released in the North Branch of the Boyne River, Charlevoix County, in 1929, 3 showed no migration, and 3 moved a short distance downstream.

Of the brook trout tagged and released in numerous other Michigan streams from 1928 to 1933, too few recoveries were reported to justify drawing any conclusions as to the migrations in those streams. Most of these experiments yielded no recoveries at all, or only 1 to 3 returns.

The data in Table 7 make it obvious that the brook trout do not migrate as widely as do the rainbow trout. It will be noted, however, that some individuals wandered much farther than most of the others. Metzelaar (1929) stated that large mature hatchery brook trout tended to move the farthest of any of the brook trout tagged. This view was only partially confirmed after the recoveries had been analyzed as to type (hatchery or wild), and as to the size of the fish and the distance migrated (Tables 8 and 9). Although a large number of recoveries of 12 to 17 inch fish were made between 6 and 27 miles away from the point of release, an even larger number of them showed no migration, or moved only 1 or 2 miles. None of the recovered wild brook trout had moved as far as some of the hatchery brook trout; the most migrant wild fish as indicated by the records had moved only 10 miles, whereas 7 of the tagged hatchery fish were recovered farther than 20 miles from the point of release. The few wild brook trout recovered (34) showed some correlation between the size of the fish and the distance moved; the smaller ones (6 to 10 inches long), with 3 exceptions, moved 2 miles or less, whereas fish 10 to 14 inches long, with 1 exception, moved from 3 to 10 miles after being tagged and released. A possible explanation for the greater movements of the hatchery fish lies in the method of planting these fish. When the hatchery fish were tagged and released, from 25 to 880 were released in a limited area, where the trout population already established probably occupied the suitable home territories for adult trout to such an extent that the introduced fish were forced to migrate considerably in order to locate their own territories.

That brook trout do not spread farther and farther away from the point of release is shown in Tables 10 and 11, in which the distance moved has been compared with the days between release and recapture. The relative stability of the brook trout is very conclusively indicated. With few exceptions the plantings and taggings were made in fall and mid-winter, so no legal fisherman could return them in much less than 75 days. The fact that the great majority were caught so close to the point of release between 75 and 300 days later strongly indicates that this species of trout is relatively sedentary in its habits.

The summary of the recoveries of tagged brook trout, both wild and hatchery fish (Table 7), indicate that about 47 per cent did not move; 28 per cent moved an average of 4.8 miles downstream; 11 percent moved an average of 3.6 miles upstream; and 8 per cent moved down one stream and up another for an average distance of 9.6 miles; 6 per cent had insufficient data. It is tentatively concluded that about one-half of the total population of brook trout occupies a given limited area continuously, while the other half moves predominantly in a downstream direction for short distances. Cobb (1933), although finding that a higher percentage of the hatchery brook trout that were tagged in Connecticut were stationary, also determined, for most streams, that a larger percentage of recovered fish had moved downstream than had moved upstream.

Table 7

SUMMARY OF BROOK TROUT TAGGING AND RECOVERY IN MICHIGAN WATERS, 1928 TO 1933

In the column headed "Number Marked", the fish tagged are distinguished as hatchery (H) or wild (W). The numbers in parenthesis in the following columns indicate the average distance travelled by the fish.

Year Tag-ged	Year Recov-ered	Stream	County	No. marked	Direction and Distance Moved: Down-stream	No migration	Up stream	Down one stream & up another	No data	Total number recovered	Recovery percentage
1928	1929	Green Cr.	Marquette	99(H)	1(4)					1	1.0
1928	1929	E. Br. Escanaba R.	"	93(H)	1(1)					1	1.1
1928	-	Cherry Cr.	"	100(H)							0
1928	-	Chocolay R.	"	99(H)							0
1928	-	Yellow Dog R.	"	96(H)							0
1928	-	Salmon Trout R.	"	562(H)						1	0
1928	1929	Main Au Sable	Crawford	217(H)	4(3)	1				5	2.3
1928	1929	Upper Au Sable	"	173(H)	1(5)	8	1($\frac{1}{4}$)			10	4.6
1928	1929	S. Br. Au Sable	Roscommon	139(H)		1	1(17)			2	1.4
1928	1929	Big Creek	Crawford	98(H)		1			1	2	2.0
1928	1929	N. Br. Au Sable	"	229(H)	2(5)			1(25)		3	1.3
1928	1929	E. Br. Au Sable	"	75(H)	1(8$\frac{1}{2}$)				1	2	2.7
1928	1929	Bear Creek	Manistee	172(H)	1(1)	2	8(3 1/8)		1	12	7.0
1928	1929	Sopher Creek	Wexford	130(H)		5				5	3.8
1928	1929	Cedar Creek	"	154(H)		7				7	4.5
1928	1929	Little Pine	Osceola	147(H)	2(3$\frac{1}{4}$)	7	1($\frac{1}{2}$)	1(2)		11	7.5
1928	1929	Adams Cr.	Wexford	113(H)		1				1	0.9
1928	1929	Weldon	Mason	5(W)		1				1	20.0
1928	1929	Clam River	Missaukee	78(H)	1(2$\frac{1}{2}$)				1	2	2.5
1928	-	S. Br. Pine R.	Wexford	147(H)							0
1928	-	East Twin Cr.	Lake	5(W)							0
1928	-	Kinne Cr.	"	14(W)							0
1928	-	Tank Cr.	"	12(W)							0
1928	-	Sweetwater Cr.	"	7(W)							0
1928	-	Buck Creek	Mason	6(W)							0
1928	-	Blood Cr.	Lake	14(W)							0
1928	-	Manistee R.	Crawford	43(W)							0
1929	1930	Pigeon River	Otsego	290(W)	1(3)	7				8	2.8
1929	1930	Boyne River	Charlevoix	50(H)	3(2/3)	3				6	12.0
1929	1930	Camp River	Emmet	43(H)		2				2	4.6
1929	1930	Acme Creek	Gr. Traverse	50(H)		2				2	4.0
1929	-	E. Br. Black R.	Montmorency	82(W)							0
1929	-	Wilson Creek	"	21(W)							0
1929	-	Bunner Cr.	Otsego	10(W)							0
1929	-	Quick Cr.	Otsego	3(W)							0
1929	-	Bear Cr.	Emmet	110(W)							0
1930	1930	Big Beaver Cr.	Osceola	69(W)	1(10)	4				5	7.2
1930	1930	Lincoln Cr.	Lake	15(W)	1(1$\frac{1}{2}$)					1	6.7
1930	1930	McDuffy Cr.	Newaygo	48(W)	1(8)					1	2.1

Table 7 (cont.)

Year Tagged	Year Recovered	Stream	County	No. marked	Direction and Distance Moved: Downstream	No migration	Up stream	Down one stream & up another	No data	Total number recovered	Recovery percentage
1930	1931	Little Beaver	Osceola	414(W)	3(4)	4		7(3)		14	3.4
1930	1931	Baldwin Cr.	Lake	146(W)	1(1)	2			1	4	2.7
1930	1931	Silver Cr.	"	112(W)		1(?)				1	0.9
1930	1931	Beaver Cr.	Crawford	50(H)	1(8)					1	2.0
1930	-	Barker Cr.	"	27(W)							0
1930	-	Baker Cr.	Lake	38(W)							0
1930	-	Twin Creek	"	3(W)							0
1930	-	Robinson Cr.	Roscommon	48(H)							0
1930	-	Middle Br. P.M.	Newaygo	1(W)							0
1930	-	West Twin Cr.	Lake	6(W)							0
1930	-	Hoxey Cr.	Wexford	55(W)							0
1930	-	Poplar Creek	Wexford	27(W)							0
1930	-	Lambert Creek	Lake	19 (W)							0
1930	-	Sanborn Cr.	"	44(W)							0
1930	-	Butterfly Cr.	"	4(W)							0
1930	-	Grassy Lake Cr.	Newaygo	6(W)							0
1930	-	McCarty Creek	Lake	9(W)							0
1930	-	Honey Creek	Livingston	1(W)							0
1930	-	Goose Creek	Kalkaska	21(W)							0
1930	-	L. S. Br. P.M.	Newaygo	2(W)							0
1930	-	Peese Creek	"	2(W)							0
1930	-	E. H'dwtrs.	Kalkaska	12(W)							0
		Manistee									0
1930	-	E. Br. Au Sable	Crawford	74(H)							0
1930	-	Little Manistee	Lake	36(W)							
										3	18.5
1931	1931	Upper Au Sable	Crawford	16(H)	1(1)	2		1(25)		2	2.3
1931	1931	Main Au Sable	"	87(H)		1			2	9	13.2
1931	1931	S. Br. Au Sable	Roscommon	68(H)	6(9)	1			1	3	7.3
1931	1931	W. Br. Big Creek	Oscoda	41(H)	2(7½)					1	4.0
1931	1931	Beaver Creek	Crawford	25(H)	1(3)				1	3	8.6
1931	1931	Big Creek	Crawford	35(H)		2	2(6½)			4	6.3
1931	1931	N. Br. Au Sable	"	63(H)	1(8)	1				5	20.0
1931	1931	Manistee R.	"	25(H)	1(2)	4	1(1)	1(16)		3	12.0
1931	1931	Thunder Bay R.	Montmorency	25(H)	1(1½)		3(1½)			3	10.0
1931	1931	Rifle River	Ogemaw	30(H)						3	8.8
1931	1931	Cedar River	Gladwin	34(H)	1(½)	2					6
1931	-	Robinson Cr.	Roscommon	25(H)							0
1931	-	Bunner Cr.	Otsego	26(W)							0
1931	-	Sweetwater Cr.	Lake	127(W)							0
1931	-	Pere Marquette	Oceana	3(W)							
								1(26)		4	0.5
1932	1933	Pigeon River	Otsego	886(H)	3(12 1/3)						
							available				6
1933	-	Cedar River	Gladwin	602(H)	Data	not yet	17(3.6)	12(9.6)	10	154	2.16
Totals				7095	43(4.8)	72					
							17(3.6)	5(19)	9	119	
	Hatchery				35(4.3)	53		7(3)	1	35	
	Wild				8(5.4)	19					

Table 8
RELATIONSHIP BETWEEN TIME FREE AND THE DISTANCE MOVED FOR THE 35 RECOVERIES OF TAGGED WILD BROOK TROUT

The numbers in parenthesis in the totals indicate fish with deficient recovery data.

Miles travel-led	Time between release and recovery by fishermen, in days							Totals
	1-5	6-10	11-25	26-50	51-75	76-150	151-300	
0	4						15	19
1-2		1					6	7
3-5							3	3
6-10	1				1		3	5
Totals	5	1	-	-	1	-	27(1)	34(1)

Table 9
RELATIONSHIP BETWEEN TIME FREE AND DISTANCE MOVED FOR THE 119 RECOVERIES OF TAGGED HATCHERY BROOK TROUT

The numbers in parenthesis in the totals indicate fish with deficient recovery data.

Miles travel-led	Time between release and recovery by fisherman, in days							Totals
	1-5	6-10	11-25	26-50	51-75	76-150	151-300	
0			2	3	6	6	36	53
1-2				1	5	3	17	26
3-5					1	2	7	10
6-10					5	5	4	14
11-20					1	1	2	4
21-30						1	2	3
Totals			2	4	18(3)	18(2)	68(4)	110 (9)

Table 10

RELATIONSHIP BETWEEN SIZE OF HATCHERY BROOK TROUT ON RECOVERY AND THE DISTANCE TRAVELLED

Numbers in parenthesis indicate recoveries with deficient data.

Miles travel-led	Size of recovered fish at time of tagging in inches						Totals
	6-7 7/8	8-9 7/8	10-11 7/8	12-13 7/8	14-15 7/8	16-17 7/8	
0	1	28	11	8	9		57
1-2		8	3	6	6		23
3-5		6	1	1	3		11
6-10		2		3	7	1	13
11-20				1	1		2
21-30	1	1	1	1	1		5
Totals	2	45	16	20	27	1	111(8)

Table 11

RELATIONSHIP BETWEEN SIZE OF WILD BROOK TROUT ON RECOVERY AND THE DISTANCE TRAVELLED

Numbers in parenthesis indicate recoveries with deficient data.

Miles Travel-led	Size of recovered fish at time of tagging in inches				Totals
	6-7 7/8	8-9 7/8	10-11 7/8	12-13 7/8	
0	7	9	1		17
1-2	3	3			6
3-5		2	2	1	5
6-10		1	3	1	5
Totals	10	15	6	2	33(2)

Brown Trout Migrations

Tagged brown trout to the number of 1403 were marked between 1928 to 1933 and released in about 25 different localities, but only 25 were recovered (Table 12). The largest number of returns came from the Sauble River in Lake and Mason Counties, where 243 hatchery brown trout were tagged and liberated in 1928. In this stream the brown trout were rather sedentary, as 8 of the tagged fish were caught during the following fishing season (1929) in the general locality of release, 1 had moved slightly upstream (See Map 1). One brown trout tagged in McCarty Creek (a tributary of the Sauble River), probably on the spawning beds, was caught the following spring in the Main Sauble River. This recovery may indicate that the favorable tributaries are used as spawning areas by mature fish which inhabit the Main Sauble River during the remainder of the year.

Six recoveries made from a release of 154 tagged hatchery brown trout at the Leelenau-Grand Traverse county line in Traverse Bay showed no movement over a period of 105 to 266 days. The single recovery from the brown trout tagging in Crystal Lake, Benzie County, had moved a short distance up Cold Creek, which enters Crystal Lake at the town of Beulah.

One of the wild brown trout tagged and released in the Little Manistee River in September, 1930, was recovered 264 days later at the exact spot of release.

The few recoveries which have been turned in seem to indicate that the brown trout in most of the streams of Michigan is relatively stationary during the greater part of the year, and undertakes rather limited spawning migrations. More tagging and recovery of brown trout is necessary before their migratory habits in Michigan waters can be definitely established.

Table 12
SUMMARY OF BROWN TROUT TAGGED AND RECOVERED IN MICHIGAN 1928-1933

In the column headed "Number Marked" the fish tagged are distinguished as hatchery (H) or wild (W). The numbers in parenthesis in the following columns indicate the average distance travelled by the fish.

Year Tagged	Year Recovered	Stream	County	No. marked	Direction and Distance Moved: Downstream	No migration	Up stream	No data	Total no. recovered	Recovery percentage	Time out, days
1928	1929	Traverse Bay	Leelanau	154(H)		5		1	6	3.9	105-266
1928	1929	Crystal Lake	Gr. Traverse	73(H)			1(2)		1	1.4	at least 50
1928	1929	Little Manistee	Lake	97(H)		1			1	1.0	195
1928	1929	Sauble R.	Lake & Mason	243(H)	1(2)	8	1(3½)		10	4.1	147-177
1928	1929	Bear Creek	Manistee	99(H)		1			1	1.0	176
1928	1929	Slagle Cr.	Wexford	98(H)			1(6)		1	1.0	217
1928	1929	Boardman R.	Gr. Traverse	98(H)		1			1	1.0	187
1928	-	N. Br. Lincoln	Mason	96(H)						0	
1928	-	Manistee R.	Missaukee	100(H)						0	
1928	-	Platte R.	Benzie	99(H)						0	
1928	-	Danaher Cr.	Lake	9(W)						0	
1928	-	Baker Cr.	"	13(W)						0	
1928	-	East Twin Cr.	"	1(W)						0	
1928	-	Tank Cr.	"	3(W)						0	
1929	-	Pere Marquette	Mason	6(W)						0	
1929	-	Bear Creek	Emmet	3(W)						0	
1930	1930	L. S. Br. P.M.	Newaygo	42(W)		2			2	4.8	6-7
1930	1931	Little Manistee	Lake	8(W)		1			1	12.5	264
1930	1931	McCarty Creek	"	82(W)	1(1)				1	1.2	at least 150
1930	1931	Baldwin Cr.	"	9(W)						0	
1930	-	Baker Cr.	"	2(W)						0	
1930	-	Sanborn Cr.	"	28(W)						0	
1930	-	Stoney Cr.	"	2(W)						0	
1930	-	McDuffy Cr.	Newaygo	7(W)						0	
1930	-	Pettibone Cr.	Oakland	1(W)						0	
1930	-	N. Br. Manistee	Kalkaska	22(W)						0	
1930	-	Beaver Cr.	Crawford	6(W)						0	
1931	-	Pere Marquette	Oceana	1(W)						0	
1933	-	Cedar River	Gladwin	1(H)						0	
Totals				1403	2(1.5)	19	3(3.8)	1	25	1.78	

Movements of Wall-eyes in the Inland Water Route

The greatest number of recoveries of tagged wall-eyed pike have been made from transference experiments in the Inland Water Route. The source of the wall-eyes used in these experiments was the Cheboygan Dam near the mouth of the Cheboygan River, where many of the wall-eyes and northern pike, some small-mouthed bass and a few muskellunge were taken in the spring of the year as their spawning migration was blocked at the foot of the dam. Of the 213 fish caught in 1931 at the Cheboygan Dam, tagged and released above the dam, 3, ~~14~~ or 1.4 per cent were reported captured. More extensive returns were obtained from the experiments in 1932, when 2,154 wall-eyes caught at the dam, were either released just above the dam after tagging, or were transferred by tank after tagging to other points in the Cheboygan River system (see Map 3). Of these 2154 fish only 29 or 1.3 per cent were reported as caught. The 32 individuals that were caught in both years varied in length, when tagged, from 11 to 21.5 inches (averaging 15.6 inches), and when recovered had been free from 9 to 193 days (average 74.6 days).

The movements of the recovered fish as shown on Map 3 indicated that they tended to disperse in all directions from all points of release (except Black Lake, the outlet of which is dammed, and Douglas Lake from which lakes no recoveries have been reported, although 100 and 90 tagged fish respectively were released in these lakes). Some of the fish merely transferred over the dam continued their upstream migration to points of capture as far distant as Crooked Lake off Ponshewaing.

The fact that one marked wall-eye placed above the Cheboygan Dam was recovered west of Cheboygan in the Straits of Mackinac suggests that a portion of the wall-eye population leaves the Inland Water Route after spawning. This supposition is confirmed by recaptures of fish made at the Cheboygan Dam released as far inland as Ponshewaing on Crooked Lake.

The small percentage of recoveries of these tagged wall-eyes in the Inland Water Route (Table 13), and the fact that no returns were reported after the year of tagging, suggests that a large number of tagged fish lost the metal marks from their gill-covers, or that there is a heavy mortality of adult fish, or that a large number of the fish which may have been taken by anglers were not reported (this latter possibility is supported by some evidence).

The results of the tagging experiments on the wall-eyes in the Inland Water Route indicate that the yield of the sport fishing throughout these waters may be increased by transferring the fish over the Cheboygan Dam during their spawning run.

Miscellaneous Wall-eye Tagging Experiments

Few or no recoveries have been made of wall-eyes tagged in other experiments (also listed in Table 13). One recovery was made from 14 wall-eyes tagged in Hamlin Lake, but the data were inadequate. One recovery was made from 177 wall-eyes tagged in Saginaw Bay shortly after the tagged fish were released, in the same vicinity. Of the 3 tagged fish recovered from those released at several points on the Muskegon River, 2 had not moved and 1 had travelled from the Big Rapids Dam Pond to below the Rogers Dam, crossing or going through two dams enroute. All 3 had been free from approximately mid-April to late July of the same year. Of the 53 tagged wall-eyes released in Van Ettan's Lake and 1 in Cedar Lake, Alcona County, no returns were obtained.

Table 13

SUMMARY TABLE, WALL-EYE TAGGINGS AND RECOVERY, 1929 TO 1932.

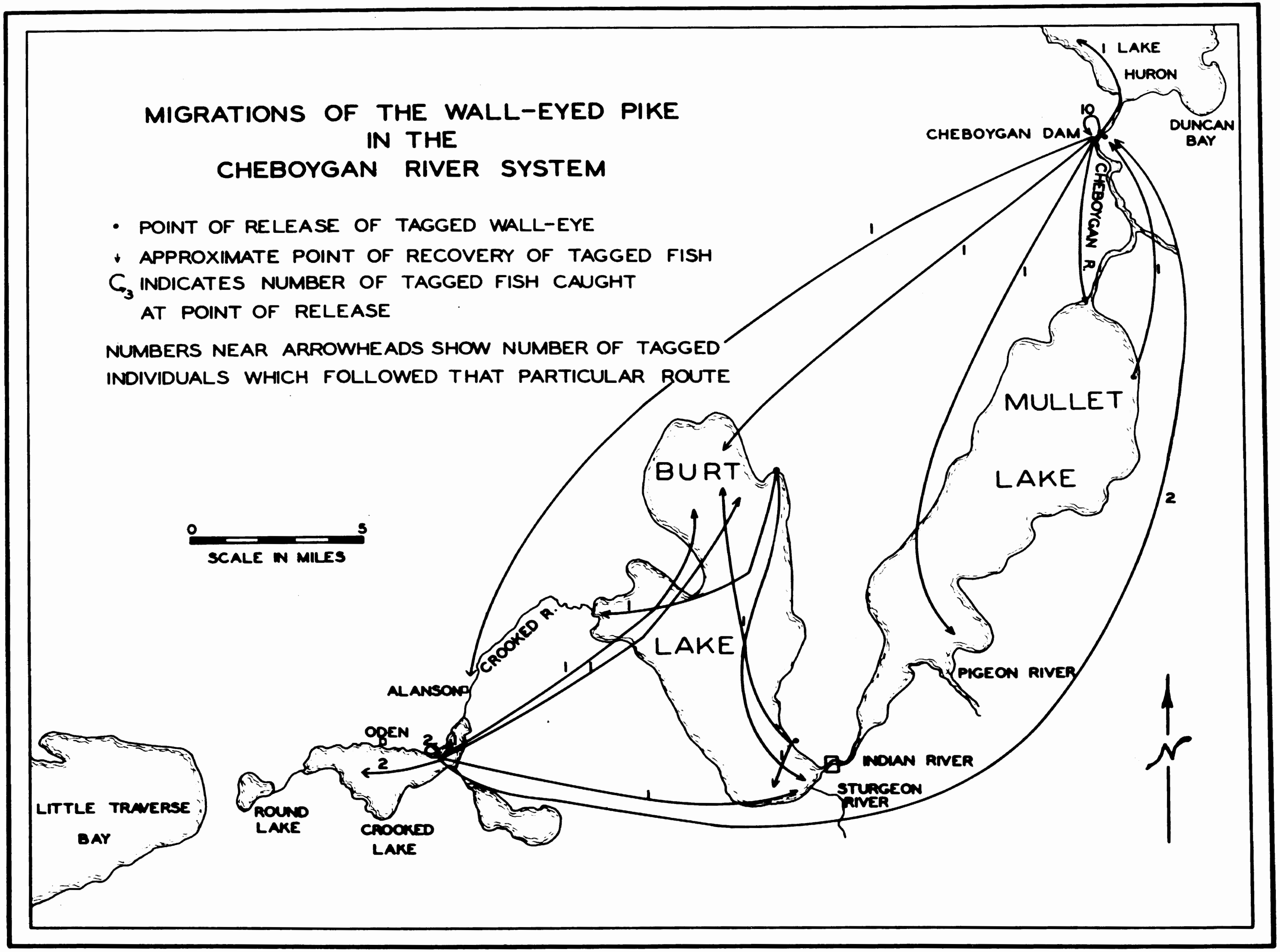
Year	Locality	County	Number tagged	Number recovered	Recovery percentages
1929	Saginaw Bay	-	177	1	0.6
1930	Hamlin Lake	Mason	14	1	7.1
1931	Cheboygan R.	Cheboygan	213	3	1.4
1931	Van Ettan L.	Iosco	53	0	0
1931	Cedar Lake	Alcona	1	0	0
1932	Cheboygan R. system	several	2154	29	1.3
1932	Muskegon R.	Above Big Rapids Dam	17	1	5.9
1932	"	Above Hardy Dam	66	1	1.5
1932	"	Above Croton Dam	47	1	2.1
1932	"	Above Newaygo Dam	42	0	0
Total			2784	37	1.3

Northern Pike Migrations

In only one locality has tagging of northern pike been successful (Table 14). Of 34 northern pike tagged and released with the wall-eyes in the transference experiments in the Inland Water Route, 12 in the Pere Marquette River, and 14 in Hamlin Lake, none have ever been reported captured. The best experiment to determine the migrations of this fish was conducted on the Pine River in Gratiot County by Dr. C. W. Creaser of Wayne University, and John Delavan of Alma, Michigan. The results of their work in 1932 have been reported to the Department of Conservation and may be summarized, but the results of their work for 1933 and 1934 have not yet been presented. In the latter years, 300 and 165 northern pike were respectively tagged.

In the Pine River experiment of 1932, mature pike in search of spawning

MAP 3



MIGRATIONS OF THE WALL-EYED PIKE
IN THE
CHEBOYGAN RIVER SYSTEM
• POINT OF RELEASE OF TAGGED WALL-EYE
APPROXIMATE POINT OF RECOVERY OF TAGGED FISH
C3 INDICATES NUMBER OF TAGGED FISH CAUGHT AT POINT OF RELEASE
NUMBERS NEAR ARROWHEADS SHOW NUMBER OF TAGGED INDIVIDUALS WHICH FOLLOWED THAT PARTICULAR ROUTE
0
5
SCALE IN MILES
LAKE
HURON
DUNCAN BAY
CHEBOYGAN DAM
10
CHEBOYGAN R.
MULLET
LAKE
BURT
LAKE
CROOKED R.
ALANSON
ODEN
PIGEON RIVER
INDIAN RIVER
STURGEON RIVER
LITTLE TRAVERSE
BAY
ROUND LAKE
CROOKED LAKE
N
1
2

grounds were captured in the early spring (April) as they congregated below an impassible fish chute at the Alma Dam. The pike were measured and tagged on the gill-cover with a No. 3 strap tag before being released in the backwaters above the dam. Of the 84 pike tagged during the rescue operations in 1932, 23 were known to have been recaptured by sport fishermen.

The recoveries in 1932 showed that the northern pike travels rapidly when on its spawning migration. Two recoveries were made as far as 25 miles upstream approximately 38 days after being tagged. However, the majority of the recaptures (19 of 23) were made within a mile of the dam from 15 to 20 days later, indicating that if these fish had gone far upstream to spawn they returned to the dam backwaters to spend the late spring and summer months.

The recovery percentage for 1932 of 27.4 suggests that the sport fishery above the dam at Alma was increased by approximately 250 northern pike because of the rescue operations, assuming that tagged and untagged fish were caught in the same proportions, since 750 northern pike were moved over the dam. Another advantage of this transference of fish from the St. Louis Pond to the Alma pond is that these fish were placed in unpolluted waters presumably more suited to spawning. The experiment indicates that a large proportion of the fish so transferred remained above the dam.

Table 14

SUMMARY OF TAGGINGS AND RECOVERIES OF NORTHERN PIKE, 1929 to 1934

Year	Locality	County	Number tagged	Number recover-ed	Recovery percentage
1929	Pere Marquette R.	Mason	12	0	0
1930	Hamlin Lake	"	14	0	0
1931	Cheboygan R.	Cheboygan	11	0	0
1932	Cheboygan R.	"	5	0	0
1932	Inland W. R.	Several	3	0	0
1932	Douglas L.	Cheboygan	2	0	0
1932	Muskegon R.	Above Big Rapids Dam	3	0	0
1932	Muskegon R.	Above Hardy Dam	10	0	0
1932	Pine River	Alma	84	23	27.4
1933	" "	"	300	Data not available	
1934	" "	"	165	Data not available	
Total			144	23	16.0
			465	Data not available	

Miscellaneous Tagging Experiments

Small-mouthed Bass

A total of 277 small-mouthed bass have been tagged in the public waters of Michigan, but as only 1 recovery has been reported no conclusions may be drawn concerning their migratory habits. Small-mouthed bass have been tagged in the following waters:

1931-32	Cheboygan River system	181
1930	Hamlin Lake, Mason County	5
1931	Long Lake, Alpena County	39
1931	Cedar Lake, Alcona County	24
1931	Brownlee Lake, " "	12
1931	Guilford Lake, Iosco County	16
Total		277

The 181 bass tagged in the Cheboygan system in 1931-32 were a part of the experiment discussed under the heading of walleyes. The sole recovery was of 1 from the 39 tagged in Long Lake.

Perch

No recoveries were reported from the tagging of 1151 perch in four different lakes in Michigan, all in 1931. The numbers tagged were:

988 in Birch Lake, Antrim County

101 in Van Ettan's Lake, Iosco County

61 in Hubbard Lake, Alcona County

1 in Burt Lake, Cheboygan County.

The unsuccessful experiment in Birch Lake was conducted to determine whether Great Lakes perch transplanted into one point in an inland lake survive and are caught, whether they disperse through the lake in which planted, and whether their characters are changed by the new environment.

Lake Trout

In 1929, 100 lake trout ranging in size from 8 to 13 inches, and about 2½ years old, were tagged and planted in Glen, Elk and Torch and Leelanau lakes, 25 being planted in each lake. None were ever reported as recovered, as might have been expected.

Suckers

For some reason, 1563 suckers were tagged and released after capture at the Walhalla weir in Mason County on the Pere Marquette River, in April, 1929. None were again reported.

Black Crappie

Four black crappie were marked along with northern pike on the Pine River at the Alma Dam in 1932, but none were recovered.

Muskellunge

One muskellunge was marked in the experiment at the Cheboygan Dam in 1931, but was not recovered.

EXPERIMENTAL STUDY OF THE MOVEMENTS OF RAINBOW TROUT OVER BEAVER DAMS IN TRIBUTARIES OF THE PINE RIVER

In the investigation of the relation between beaver and trout, a tagging experiment was conducted by J. Clark Salyer and the writer to determine whether or not rainbow trout pass over beaver dams in the course of their upstream migrations to spawning beds. Salyer (1934) had observed dams in which trout had evidently been trapped as they had attempted to swim through the maze-like construction of the base of the dam. For this experiment 609 rainbow trout, obtained from the State Hatchery at Paris, were tagged by the jaw-tag method. These tagged rainbows were distributed on June 13, 1934 among three different tributaries of the Pine River, all of which had beaver dams in their courses (Table 15). Some were placed above all the dams, others were placed in the dam ponds, and some were placed downstream below all the dams.

Table 15

DATA ON TAGGING AND RECOVERY OF RAINBOW TROUT USED IN EXPERIMENTAL STUDY OF MOVEMENTS OF RAINBOW TROUT OVER BEAVER DAMS

Where planted	No. planted	No. recovered	Percentage recovered
Poplar Grove Creek, Wexford Co.	218	12	5.5
Nigger Creek, Osceola Co.	176	4	2.2
Sprague Creek, Wexford County	215	-	-
Total	609	17[a]	2.7

[a] No data available on the exact location of planting of one of the recoveries.

None of the recoveries were made upstream from the point of tagging. Three of them, taken in the Pine River, had left the tributary in which they were planted (Table 16).

All of the returns made on the tagged rainbows planted in Nigger Creek were of fish which had been planted in or above the several beaver dams on this stream. All were taken below the dam farthest downstream, and 2 of them were recovered in Pine River.

Of the tagged rainbows placed and recovered in Poplar Grove Creek, 5 showed no migration, and 7 had moved downstream. Of those showing no movement, 4 had been placed below all the dams, and 1 had been placed in the second dam pond. Of the 7 showing downstream migration, 3 had been planted in the dam ponds and 4 had been planted below the dam farthest downstream. The 1 fish on which no exact locality of planting was available must also have moved downstream, because it was taken below all points of liberation.

Of the 17 recoveries made, 12 or 71 per cent were made at points below the dams located farthest downstream on the tributaries in which the fish was planted. The remaining 5 or 29 per cent were taken in the same locality where they were released. Only 1 of these was recovered from a beaver dam pond (the same one in which it had been planted). All the others were taken where planted in localities below the dam farthest downstream. No tagged fish were recovered upstream from any point of planting.

The evidence suggests that the rainbow trout move out of beaver dams by going downstream over or through the dams. The fact that no tagged rainbows were recovered above beaver dams when planted below beaver dams would also lend considerable weight to the conclusion that they are not able to pass beaver dams in upstream movements. The reason for their failure to surmount the dams lies most probably in the general construction of the beaver dam, which usually is too wide and too high and cluttered with debris to permit a fish to have a long, clear run preparatory to a successful final leap.

The results of this experiment, while not supported by a large number of returns of marked fish, demonstrate a useful means of applying the tagging method to problems in the applied biology of fishes.

SUMMARY TABLE OF INFORMATION ON RECOVERIES OF TAGGED RAINBOW RELEASED IN BEAVER DAMMED TRIBUTARIES OF THE PINE RIVER

All tagged rainbows planted on June 13, 1934

Planted:	Tag No.	Length at tagging (inches)	Date of recovery	Days free	Direction travelled	Increase in length (inches)
	22380	7.500	8/2/34	52[a]	Downstream	1.500
Nigger	22690	8.375	8/5/34	55	Downstream	0.125
Creek	22153	10.500	8/1/34	88[a]	Downstream	1.750
	22222	6.375	5 - 36	700	Downstream	6.125
	22333	7.500	6/25/34	12	No migration	1.000(?)
	22197	7.500	6/25/34	12	No migration	.250
	22188	7.750	7/1/34	17	Downstream	.250
	22116	9.250	7/1/34	17	Downstream	1.250(?)
	22306	9.000	7/1/34	17	Downstream	-----
Poplar	22102	8.500	7/9/34	26	Downstream	.750
Grove Creek	22124	7.500	7/9/34	26	No migration	.373
	22120	8.000	8/20/34	68	No migration	.500
	22491	7.500	8/26/34	74	Downstream	.750
	22293	7.625	8/26/34	74	Downstream	1.375(?)
	22214	7.625	7/1/35	382	No migration	4.125
	22302	6.750	5/16/35	336	Downstream	3.000
Uncertain	22215	6.875	7/9/35	390[a]	Downstream	2.625

[a] These recoveries were made in the Pine River; all other recoveries were in the stream in which the fish were planted.

TAGGING EXPERIMENTS ON WINTERGREEN LAKE

In 1931, Dr. Miles D. Pirnie, Director of the Kellogg Bird Sanctuary, invited the Institute for Fisheries Research to participate in fishery experiments at Wintergreen Lake, a 20-acre lake located on the sanctuary property in northeastern Kalamazoo County. Since this lake provides an ideal location for controlled marking experiments in a natural body of water, tagging of some of the fishes in Wintergreen Lake was undertaken as one of the projects. The lake is under the complete control of the Sanctuary, and all parties who fish there are obliged to turn in a report on their fishing to Dr. Pirnie. There is thus an excellent means of obtaining records of all tagged fish caught, and also knowing the number of untagged fish taken at the same time.

The first marking was conducted on October 27, and 28, 1931, by Dr. John R. Greeley, using 131 large-mouthed bass fingerlings furnished by the State Hatchery at Hastings, Michigan (Report of the Institute for Fisheries Research No. 102, unpublished). These bass, ranging in size from 3 to 8 inches total length, were marked with the "fingerling" size tags on the left sub-opercular bone. No recoveries of these bass marked as fingerlings have ever been reported.

Approximately 100 fish were marked during the first week-end in May, 1935, after which date the tagging was carried on by D. L. Allen and F. R. Lyman of the Sanctuary staff, as opportunity presented, during the remainder of the summer. During 1936, tagging was continued by Homer Bradley of the Sanctuary staff in the month of June, assisted for 4 days by the Institute. A small number of the fish marked were tagged on the lower jaw following the method described for trout (p.6), but the majority of the fish, which were mostly centrarchids, were marked by applying the strap tag (either No. 3 or "fingerling" size) around the maxillary bone. The species marked and the number marked during 1935 and 1936 are summarized in Table 17.

Table 17

NUMBER AND SPECIES OF FISH TAGGED IN WINTERGREEN LAKE, 1936 and 1935

Species tagged	Year of tagging 1935	1936	Total
Large-mouthed bass	284	217	501
Pumpkinseed	158	14	172
Bluegill	214	5	219
Perch	20	3	23
Pumpkinseed x bluegill	4	2	6
Dogfish	2	-	2
Brown bullhead	-	1	1
Total	682	242	924

Table 18

RECORD OF ANGLER'S CATCH BETWEEN AUGUST 3, 1935 AND APRIL 30, 1936, FOR WINTERGREEN LAKE

Species	Number of legal fish caught	Catch per acre*	Number of tagged fish caught
Bluegill	1079	54	14
Large-mouthed Bass	5	0.25	1
Yellow Perch	428	22.4	...
Common Sunfish	92	4.6	...
Totals	1604	80	15

*Area of lake = 20 acres.

Calculation of Bluegill Population

Since the total number of bluegills tagged was known (Table 17), and as the catch records (Table 18) for the winter of 1935-1936 were available, it was possible to compute the bluegill population from the results of recoveries of tagged fish during the winter fishing season. The available number of tagged bluegills was set at 202, as 5 had died or had been caught off during the summer, and the 7 undersized fish were eliminated from consideration because almost no undersized fish were taken in the winter fishing. Substituting the values resulting from markings and recoveries by fishing in the following formula used by P. R. Needham (1936, p. 45), $y = (b + c)\frac{a}{b}$, where y = total number of fish in lake,

a = number of marked fish available

b = number of marked fish caught

c = number of unmarked fish caught,

we have

$$y = 1079 \times \frac{202}{14} = 15,543.$$

The bluegill population of legal size in Wintergreen Lake may be set at approximately 15,543, or about 780 legal-sized bluegills per acre. These figures rest on the assumptions that there has been no loss of tags by fish, and that both tagged and untagged fish are caught in the same relative frequency.

This figure of 780 legal-sized bluegills per acre in Wintergreen Lake, obtained by a tagging experiment, agrees closely with estimates of the bluegill population of two other lakes in southern Michigan, obtained by counting the dead fish after an almost complete winter kill during the severe winter of 1935-1936. These estimates, applying chiefly to bluegills of legal size, were of 650 per acre for Green (Stoffer's) Lake and of about 700 per acre for Mud

Lake, both on the Waterloo Project area in Jackson County. The estimates were obtained from counts of the dead fish along sample stretches of the shore, made by Gerald P. Cooper and R. W. Eschmeyer of the Institute for Fisheries Research, and reported by Cooper (Institute Report No. 351), and from measurements of the total shore-line and acreage of these lakes as surveyed by Mr. Coburn of the Waterloo Project. The winter-kill counts are presumably somewhat low, because any dead fish which lay on the bottom of deep water were not counted.

Calculation of Large-Mouthed Bass Population

Many more large-mouthed bass than bluegills were tagged (Table 17), but only 5 (1 marked and 4 unmarked) were caught during the winter ice-fishing of 1935-1936 (Table 18). However, during the summer of 1936 a larger number of both marked and unmarked large-mouthed bass were caught, so an attempt to compute their abundance was made on the basis of recoveries made during that period. This computation was complicated by the fact that the number of marked fish was being increased by continued tagging during the month of June, 1936. The average number of marked fish available was determined and this figure used instead of the total number of marked fish available; all data used in the calculation are embodied in Table 19. Employing the formula used for the bluegill calculations (p. 75), the total population of large-mouthed bass of legal size (10 inches total length) in Wintergreen Lake on August 27, 1936, was computed to be 3900, about 195 per acre.

This per acre estimate compares favorably with calculations of winter-killed populations of large-mouthed bass in two lakes of southern Michigan. By this method Gerald P. Cooper (Report of the Institute for Fisheries Research, No. 351, unpublished) estimated the adult large-mouthed bass population of Green (Stoffers) Lake, Jackson County to be 197 per acre, and that for Park Lake, Clinton County, to be 188 per acre.

Table 19

DATA USED IN ESTIMATING THE LARGE-MOUTHED BASS POPULATION OF WINTERGREEN LAKE

Except as indicated in footnotes, all unmarked fish caught were tagged and released alive.

Date Fished 1936	Unmarked fish caught for tagging	Marked fish caught	Marked fish available
June 4	26	1	265
June 11	18	3	291
June 15	40[1]	4	309
June 16	38	...	334
June 17	67[2]	10	372
June 18	38[3]	6	431
July 3	4[4]	0	463
July 24	5[4]	2[4]	463
Aug. 27	7[4]	0	461
Total	243	26	3389
Ave.			377

[1] Of these 15 were released without being tagged.

[2] Of these 3 escaped unmarked; 5 bearing signs of previous tagging were re-tagged.

[3] Of these 2 died, 4 bearing signs of previous tagging were re-tagged.

[4] These fish were removed by anglers.

Two other winter-killed lakes were estimated to have only one-fourth as many legal sized- large-mouthed bass per acre.

Growth of Bluegills in Wintergreen Lake as Determined from Recoveries of Tagged Bluegills

Evidence from a relatively small number of adult bluegills recovered shortly after tagging (after an average time of 8 days) suggests that this species does not grow during the early summer (Table 20). Recoveries made through the ice during winter fishing, of bluegills that had been tagged for an average of 248 days, indicate a slight growth of millimeter per 100 days of freedom, or approximately 3.6 millimeters per year (Table 21). The ages of the bluegills when recovered by ice fishing were 5 to 7 winters, which is close to the maximum age of bluegills in Michigan waters. Advanced age may explain the small growth shown by these particular fish.

Table 20

GROWTH OF BLUEGILLS IN WINTERGREEN LAKE BETWEEN MAY 3 AND AUGUST 3, 1936, AS INDICATED BY RECOVERIES OF TAGGED BLUEGILLS

Five records are excluded because their measurements at time of recovery were smaller than at time of tagging

Tag number	Total length of tagging mm.	Growth mm.	Days free
26254	234	0	8
26065	240	0	20
26243	235	0	2
26245	249	0	2
26247	227	0	2
26251	234	0	2
26134	241	0	9
26248	243	0	2
26075	229	0	17
26070	255	0	19
26253	237	0	2
Totals	2618	0	87
Averages	238	0	8

GROWTH OF BLUEGILLS IN WINTERGREEN LAKE BETWEEN MAY 3, 1935 AND APRIL 30, 1936, AS INDICATED BY RECOVERIES OF TAGGED BLUEGILLS

Four records are excluded because their measurements at time of recovery were smaller than at time of tagging

Tag Number	Total length at tagging mm.	Growth mm.	Days free	Age (winters)
26223	240	5	244	VII
26614	232	3	236	V
26156	235	0	242	-
26181	230	1	247	V
26089	234	2	255	V
26112	236	4	248	-
26185	233	6	273	VI
26603	240	1	236	VI
26129	245	1	246	-
26207	240	1	253	VI
Totals	2365	24	2480	VI
Averages	236.5	2.4	248.0	VI

Growth Large-mouthed Bass as Determined from Recoveries of Tagged Individuals

That the growth of legal-sized large-mouthed bass in Wintergreen Lake is slow is indicated by the measurements of 12 tagged fish recovered from 355 to 420 days after being marked. The data (Table 22) show an average of only 2 mm. per 100 days, or approximately 8 millimeters per year. These results are not inconsistent with the calculations of the growth of large-mouthed bass in Wintergreen Lake made by Gerald P. Cooper by means of the scale method. Cooper gives the average total length of 3 bass of age-group III to be 287 mm., of 26 bass of age group IV to be 297 mm., of 37 bass of group V to be 305 mm. and of 4 bass of group VI to be 323 mm. The annual growth increments are thus indicated to be 10 mm. between age groups III and IV; 8 mm. between groups IV and V (the only interval represented by an adequate number of specimens on either side), and 18 mm. between group V and VI.

Little can be said concerning the movements of these species, except that they are observed to move into shallow waters along the shore of the lake in late April, May and June to spawn, and that in the winter they are caught in water ranging from 5 to 25 feet in depth.

Table 22

GROWTH OF LARGE-MOUTHED BASS IN WINTERGREEN LAKE AS INDICATED BY RECOVERIES OF MARKED BASS

Tag number	Total length at tagging, mm.	Growth, mm.	Days free	Age (winters)
26027	308	1	408	...
27472	250	5	420	IV
27468	298	7	383	IV
27521	225	19	375	III
27526	326	4	369	...
27545	384	2	369	...
27561	331	9	372	V
27583	298	5	355	...
27462	282	15	383	IV
26126	343	13	396	V
27517	301	13	376	IV
27486	270	7	380	...
Totals	3616	100	4586	
Average	301.3	8.3	382	IV

TAGGING EXPERIMENTS ON THE NORTH BRANCH OF THE AU SABLE RIVER

The author's marking experiments, designed to elucidate further the migration and growth of wild brook trout in Michigan streams, were begun in the summer of 1934. After some rather unsuccessful attempts to seine trout for tagging in the Pigeon River and the West Branch of the Sturgeon River it was decided that the new tagging experiments should not be spread as previously over the entire state, but should be confined to one stream that presented conditions favorable for the investigation. The North Branch of the Au Sable River in Crawford and Otsego counties was selected for the following reasons:

(1) This trout stream contains a relative abundance of brook trout, also some brown trout and a few rainbow trout.

(2) Since the stream is easily seined, the trout can be caught in large numbers for tagging, and individuals previously marked may be readily recovered. The conditions that facilitate seining here are the shallow water, the relatively clean bottom and the moderate current (for a trout stream).

(3) Because this stream is heavily fished by sportsmen who appreciate scientific work and who are unusually willing to cooperate in the investigation, recoveries of tagged fish caught by anglers are obtainable in relatively large numbers.

(4) The "North Branch" has long been famous as one of Michigan's best trout streams, and is supposed to have suffered a great depletion of the trout population in recent years. Therefore any study basic to an improved fish management of the stream would be a contribution of practical value.

The North Branch of the Au Sable River for most of its length runs in a southerly direction through the northeastern and eastern portions of Crawford County, Michigan. Its headwaters are located in Otsego County a few miles to the east of Otsego Lake. The claim by some that the stream was formerly an outlet for this lake appears doubtful. At present the upper headwaters are augmented by the outlets of Chub and Guthrie Lakes in Otsego County, and the middle portion receives the waters of Crapo Lake, just north of the Crawford Otsego county line. Throughout its course in Crawford County the stream is wide and relatively slow-flowing for a trout stream. In its course of about 33 miles (including all but the most minor curves) the stream drops about 175 feet, from an elevation of about 1250 feet at the headwaters to an elevation of 1075 feet at its junction with the Main Au Sable. The swiftest section of the stream is near Dam 4, about 8 miles below Lovells.

With the exception of a few small areas of cedar swamp which border the stream, the greater part of the country on both banks of the North Branch consists of an open jackpine plain. The dominant shade tree along the bank is the poplar; other trees present are cedar, jack-pine and other conifers in lesser numbers, and a small amount of birch. Back from the river banks one finds the typical plant associations of the jack-pine plain as described by Davis (1936). From about two miles below Lovells to about 10 miles above the town, the stream parallels an almost unbroken, steep moraine 40 to 75 feet high, and at places runs along the base of the slope.

Almost all of the seining in the North Branch was done between the town of Lovells and Dam 2, a distance of approximately 12 miles by road (Map 4). In this stretch the stream varies in width from 45 to 140 feet, and exceeds a depth of 5 feet only in the pool below Dam 2 and at the old lumber mill pool at Lovells.

The bottom of the North Branch varies with the fall of the river. The slower portions tend to be sandy and to support a luxuriant growth of fine-leafed pondweed, Potomogeton filiformis. In the shoreward portions of such stretches the bottom is usually black muck covered with detritus. In the swifter reaches the bottom is usually of gravel varying from particles slightly larger than peas to stones four to five inches in diameter. Throughout the whole length of the river much "down" timber is scattered in the stream bed, and watersoaked saw-logs half-covered with sand and muck remind the angler of the days when lumbermen drove their winter cuttings to the mill at Lovells. Below the town of Lovells long, slow flowing, areas of shallow water are interspersed with shorter swifter stretches of fast water, the latter portions usually being terminated by a hole 4 to 6 feet deep, wherever there is a slight bend in the channel.

The temperature gradient of the North Branch of the Au Sable is higher than is usually found in a typical trout stream, since it is an extremely wide stream, and the shallower portions are relatively unshaded for many hours on a summer day. Warm tributary waters from the lakes already mentioned probably support and increase to a certain extent the high daily temperatures which often rise to above 72° F. on hot summer afternoons. However, the middle portion of the stream between Dam 2 and Dam 4 is made habitable for trout by the presence of much spring seepage from the banks and from the many inflowing springs. This spring water lowers the stream temperature during the might to a level more suitable for trout. In the lower portions of the North Branch, stream examination cards (data unpublished) record temperatures of 70° F. in late June, 1924, in the regions of Dam 4 and Kellogs Bridge. Winter temperatures of the North Branch vary slightly according to the severity of the winter weather. Unless there are prolonged periods of sub-zero air temperatures, the main channel does not freeze over, and the stream temperatures may vary during the day from 34° to 38° F. Long periods of sub-zero weather, during which "anchor ice" forms and collects behind obstructions in the current, often lead to the formation of surface ice; the temperature of the stream is then close to the freezing point, varying from 32° to slightly over 33° F. Data on temperature observations on the North Branch are given in Tables 23, 24 and 25.

The fish fauna of the North Branch is rather large for a trout stream, and varies somewhat in the different sections, both in the number and abundance of species. The lower portion in the region of Dam 4 and Kellog's Bridge was characterized by Hubbs and Metzelaar in 1924 (unpublished stream survey) as having a fish "fauna typical of a swift but medium warm stream", although some trout were taken in their seinings. They recommended that no trout be planted in that portion of the stream. The presence of northern pike and brown bullhead in their list of fish seined suggest that this lower portion of the North Branch may be rather marginal trout water.

In the middle portion of the stream (between Dam 2 and Dam 4), Hubbs and Metzelaar recorded a typical trout stream association of fishes from seinings at the Twin Bridges. Brook trout, common suckers and black-nosed dace were about equally abundant, and brown trout were present. Rainbow trout are infrequently taken in this section by fishermen.

During the seinings of 1934, 1935 and 1936, large-mouthed bass, perch and rock bass were occasionally collected near the Twin Bridges. These species most likely wander down from the tributary lakes for which they are all recorded.

Table 23

TEMPERATURE READINGS (FAHR.) FOR JULY 1 - 27, 1936, AND AUGUST 19 - 25, 1936 AT TWIN BRIDGE CAMP, NORTH BRANCH AU SABLE RIVER

First figure given is air temperature, second is water temperature

Date	Time of reading: 7:30 A.M.	Noon	6:30 P.M.
July 1 -	63-57	79-68	76-68
2	75-63	77-69	67-74
3	59-58	78-69	66-72
4	61-57	-	-
5	-	-	70-73
6	75-57	84-67	75-74
7	83-60	95-73	90-79
8	85-65	100-81	75-76
9	88-67	96-76	83-77
10	85-67	99-80	75-78
11	67-67	99-80	88-80
12	88-68	96-78	98-82
13	86-68	100-80	91-82
14	79-69	90-75	77-76
15	73-62	87-74	72-75
16	73-60	86-71	85-72
17	73-60	85-71	84-70
18	74-61	75-68	69-71
19	75-63	72-71	75-70
20	70-69	76-70	72-72
21	70-68	75-69	74-70
22	60-58	84-71	74-70
23	67-59	67-69	70-70
24	69-60	77-71	69-70
25	70-59	75-69	80-70
26	67-58	74-69	75-70
27	59-59	-	-
Aug.19	-	-	70-67
20	64-56	72-66	72-67
21	60-55	70-62	70-64
22	65-58	68-63	74-68
23	65-60	72-64	71-68
24	61-59	69-62	75-65
25	52-55	55-57	-

Table 24

TEMPERATURE READINGS (FAHN.) FOR OCTOBER 27 TO NOVEMBER 13, 1935 AT AKRON CLUB, NORTH BRANCH OF AU SABLE RIVER

First figure given is air temperature, second is water temperature

Date	Time of reading 8:30 A.M.	Noon	6:00 P.M.
Oct. 27	- -	54, 46	58, -
28	52, -	66, 52	64, -
29	46, 48	- 52	52, 50
30	44, 47	54, 50	47, 49
31	-, 47	59, 49	- 52
Nov. 1	38,48	38, 47	24, 44
2	28, 41	51, 45	33, 44
3	35, 44	42, 44	40, 44
4	40, 45	42, 47	39, 45
5	36, 44	34, 45	33, 43
6	33, 42	40, 40	33, 42
7	42, 43	40, 44	40, 44
8	29, 42	- -	59, 44
9	36, 42	57, 51	46, 47
10	49, 46	54, 49	46, 46
11	30, 43	31, 44	30, 42
12	30, 41	37, 40	29, 42
13	29, 41	31, 42	29, 41

Table 25

TEMPERATURE READINGS (FAHR.) FOR FEBRUARY 21 TO FEBRUARY 25, 1936 AT LOVELLS, NORTH BRANCH OF AU SABLE RIVER

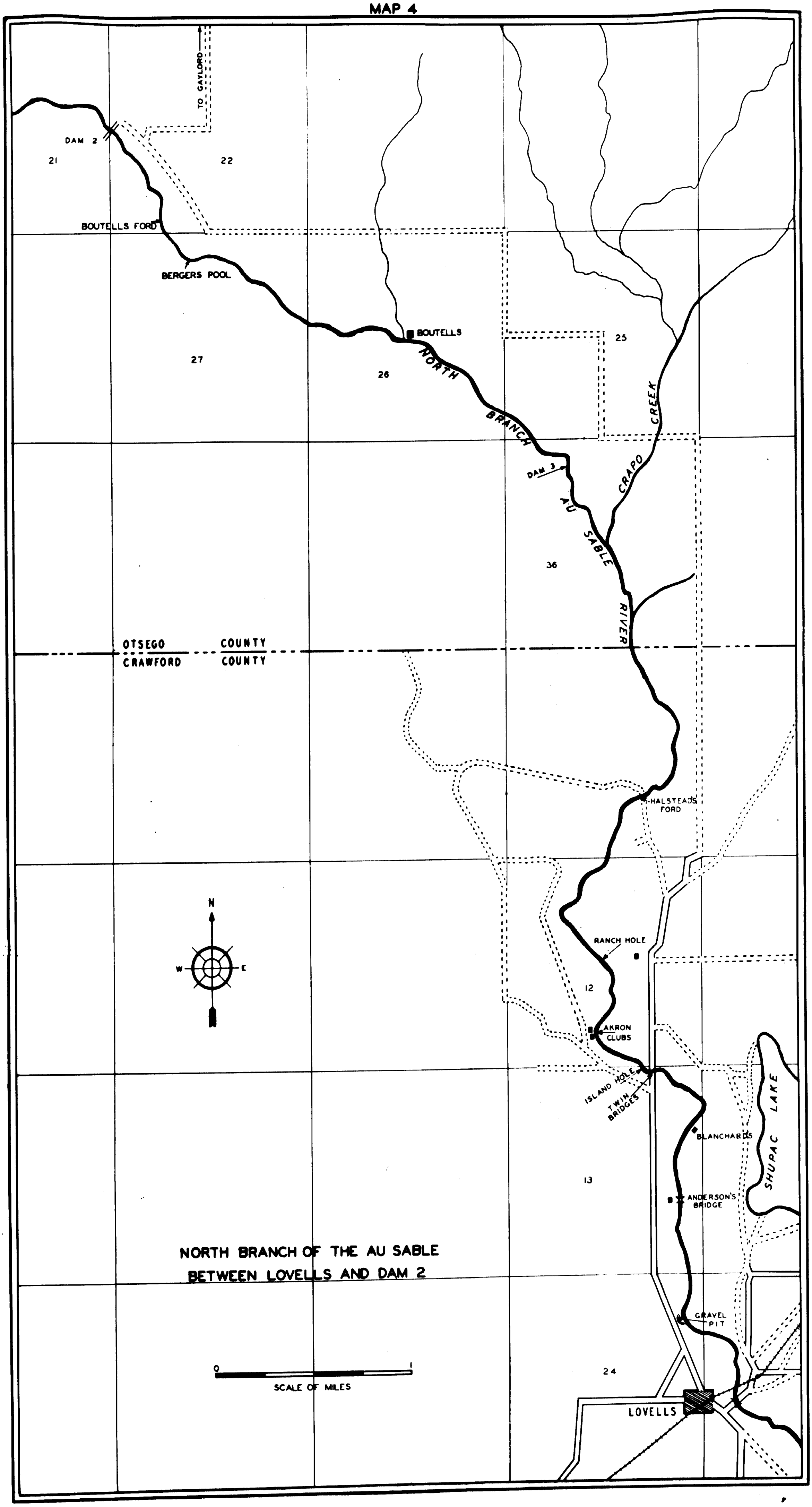
Date	Time of reading 7 A.M.	Noon	7 P.M.
Feb. 21	-15, 33	19, 34	19, 33
22	-22, 32	19, 33	13, 33
23	4, ...	36, ...	33, ...
24	35, 35	45, 35	39, 35
25	30, 33	38, 34	

No seining was done by the writer in the upper portion of the river above Dam 2 (Fig. 11), but this portion has been carefully observed from a boat for about 3 miles above the dam for likely places to seine trout. Large schools of common suckers, many minnows, and several rock bass were seen, suggesting that the flat and sluggish stream course above Dam 2 provides a habitat more suited to warm-water fish than to trout.

A chemical analysis of the water near the Twin Bridges on July 22, 1934, indicated conditions favorable for fish life. Samples taken at 9:00 A.M. when the air was 76° F. and the water 64°F., yielded the following results: dissolved oxygen, -11.0 p.p.m.; free carbon dioxide, 4.0 p.p.m.; pH, 8.3.

The following list of fishes has been recorded for the North Branch of the Au Sable River: brook trout (Salvelinus f. fontinalis), brown trout (Salmo fario), rainbow trout (Salmo gairdnerii irideus), large-mouthed bass (Aplites salmoides), rock bass (Ambloplites rupestris), yellow perch (Perca flavescens), northern pike (Esox lucuis), Menominee whitefish or pilot (Prosopium quadrilaterle), common sucker (Catostomus c. commersonnii), hog sucker (Hypentelium nigricans), common shiner (Notropis cornutus frontalis), black-nosed shiner (Notropis heterolepis), blunt-nosed minnow (Hyborhynchus notatus), northern mimic shiner (Notropis volucellus volucellus), creek chub (Semotilus a. atromaculatus), river chub (Nocomis biguttatus), black-nosed dace (Rhinichthys atrotulus meleagris), long-nosed dace (Rhinichthys cataractae), fine-scaled dace (Pfrille neogaeus), northern dace (Margariscus margarita nachtreibi), brown bullhead (Ameiurus nebulosus), Johnny darter (Boleosoma nigrum nigrum), rainbow darter (Poecilichthys caeruleus), Iowa darter (Poecilichthys exilis), least darter (Microperca punctata), brook stickleback (Eucalia inconstans), muddler or miller's thumb (Cottus bairdii, Cottus cognatus), mud minnow (Umbra limi), lamprey (Ichthyomyzon fossor).

MAP 4



TO GAYLORD
DAM 2
21
22
BOUTELLS FORD
BERGERS POOL
BOUTELLS
27
26
25
NORTH BRANCH
AU SABLE RIVER
CRAPO CREEK
DAM 3
36
OTSEGO COUNTY
CRAWFORD COUNTY
HALSTEADS FORD
N
W
E
RANCH HOLE
12
AKRON CLUBS
ISLAND HOLE
TWIN BRIDGES
BLANCHARDS
SHUPAC LAKE
13
ANDERSON'S BRIDGE
NORTH BRANCH OF THE AU SABLE
BETWEEN LOVELLS AND DAM 2
GRAVEL PIT
0
1
SCALE OF MILES
24
LOVELLS

Tagging of trout by the jaw-tag method was started in the North Branch on July 25, 1934, and was continued at every opportunity until November 2, 1936. During this period, 100 days were spent on the North Branch in either tagging or recovering the fish that had previously been tagged. (More time would have been spent on the river at more regular intervals if other duties had allowed). The distribution of the tagging and recovery activities in the field is shown in Table 26.

During this three-year period, 4120 brook trout, 180 brown trout and 10 rainbow trout were tagged (Table 27). Except for 500 hatchery[a] fish tagged and placed in the North Branch in May, 1936, all fish tagged were wild fish seined from the stream. Of the fish tagged, 1080 brook trout, 23 brown trout, and two rainbow trout were recovered (Table 28). The total of 1105 fish recovered gives the rather satisfactory recovery of 25.6 per cent.

The data on the brook trout are discussed first and at greatest length because most of the fish tagged and recovered have been of this species (Tables 27 and 28). The distribution of the recoveries by year of tagging and by year of recovery, and by number of times each fish was recovered, both according to the two methods of recovery, are shown in Table 29.

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[a] Of 500 hatchery brook trout tagged and released in the North Branch in May, 1936, 27 were recovered by fishermen; 21 of the recoveries were made within 5 days of release, and 6 recoveries were made from 25 to 87 days later. None of these had moved more than an eighth of a mile from the point where it was released; thirteen recoveries by seinings during the year reveal no information regarding their movements, as there are too few from which to draw conclusions. Because so few of these hatchery fish have been recovered, no attempt has been made to analyze the data concerning them separately. These data have been included with those for the wild fish in all calculations. It is hoped that in the future better success will be had in recovering these fish, to obtain a comparison of their movements and growth with those of the wild fish. Such information would be valuable in planning an intelligent stocking program.

Table 26

NUMBER OF DAYS DEVOTED TO FIELD WORK ON THE NORTH BRANCH OF THE AU SABLE RIVER BY MONTHS AND YEARS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
1934							3	3	10		3	19
1935		3		4		4		9	2	1	13	36
1936	2	1	2		4	3	26	4		1	2	45
Total	2	4	2	4	4	7	29	16	12	2	18	100

Table 27

SUMMARY OF NUMBER OF TROUT TAGGED IN NORTH BRANCH AU SABLE BY SPECIES AND BY YEARS

Year of tagging	Species tagged			Total by years
	Brook	Brown	Rainbow	
1934	1551	51	6	1608
1935	1467	116	4	1587
1936	1102	13	-	1115
Total for 3 years	4120	180	10	4310

Table 28

SUMMARY OF RECOVERIES ON TROUT TAGGED IN NORTH BRANCH AU SABLE RIVER, 1934 TO 1936.

Item	Species			Total
	Brook	Brown	Rainbow	
Total tagged	4120	180	10	4310
Total recovered	1080	23	2	1105
Percentage recovery	26.2	12.8	20	25.6

Table 29

SUMMARY OF SINGLE AND MULTIPLE RECOVERIES OF BROOK TROUT BY YEAR OF TAGGING AND YEAR OF RECOVERY

The total recoveries by seining and by anglers are listed; the recoveries made by fishermen are indicated by the inferior figures.

No. of times recovered	Tagging year (above) & recovery year (below) 1934 / 1934	1934 / 1935	1934 / 1936	1935 / 1935	1935 / 1936	1936 / 1936	1934 / '35, '36	Totals	Percentage of total
1	232_{29}	56_{31}	2_{2}	221_{38}	109_{27}	186_{32}		806_{159}	$74.63_{19.7}$
2	65_{5}	15_{12}		43_{2}	31_{12}	32_{2}		186_{33}	$17.22_{17.7}$
3	34_{9}	4_{3}		14	9_{3}	11_{3}	1_{1}	73_{19}	$6.76_{26.0}$
4	7	2_{2}	2_{2}	1			1	13_{4}	$1.20_{30.8}$
5	1			1				2	$0.19_{...}$
Totals	339_{43}	77_{48}	4_{4}	280_{40}	149_{42}	229_{37}	2_{1}	1080_{215}	$100.00_{19.9}$

Of the 1080 brook trout recovered 74.6 percent were recovered only once, 17.2 per cent twice, 6.8 per cent 3 times, 1.2 per cent 4 times, 0.2 per cent five times. Approximately 80 per cent of the recoveries were obtained by seining, and 20 per cent were returned through the courtesy of the anglers. Although the fishermen were kept informed regarding the experiment by frequent personal contacts and by posters (Fig. 3) placed along the river in the vicinity of Lovells, at various camps and at the bridges in the region, and were thus urged to turn in reports on all tagged fish caught, it is believed that about 20 per cent (probably not more than 25 per cent) of the legal sized trout they caught were unreported, and that most of the undersized tagged fish caught by them were not reported.

Movement of the Brook Trout

Most information was obtained on the summer and fall migrations of the brook trout of the North Branch because more tagged fish were recovered during these seasons than during the winter and early spring. In the summer, records of tagged fish were obtained by seining, and additional records were available from fishermen during the open trout season; in the fall large numbers of trout were readily seined from the spawning beds for examination for tags.

In the treatment of the data obtained on migration by summer and fall seining, the data lent itself rather conveniently to the calculation of a migration index, which indicates the tendency of the fish marked in a given locality to move to another stated locality. The calculation of such indices and their orderly tabulation presents the true migrational tendencies of the species in that body of water, since the fishing effort and the available number of marked fish, as well as the actual number of marked fish caught are considered.

Schroeder (1930, p. 13) realized that the intensity of the cod fishery on Nantucket shoals had a direct bearing on the proportion of marked fish recaptured, but had insufficient data on which to calculate any index figures. Thompson (1930) has demonstrated a definite relationship between the actual number of tagged halibut recovered and the possible number of tagged fish that probably would be recovered by the intensity of the fishery, especially on the halibut grounds off the southern coast of the Alaskan Peninsula. Although the results of calculations relating to brook trout migrations are expressed in a manner differing from that employed by Thompson, the basic factors considered have been the same, namely, the number of tagged fish recovered, number of tagged fish available, and number of units of fishing effort used to effect a recovery.

The proper interpretation of the above-mentioned factors is of considerable importance, as may be illustrated by a hypothetical example. Suppose 100 tagged fish are released at point T on a stream, and assume that in their dispersion 70 move upstream and 30 move downstream from point T. If the investigator now makes 10 seine hauls at point R downstream and only 1 seine haul at point R^1 upstream, he has a much greater possibility of recovering fish which have moved downstream. Assume also that in 10 seine hauls at R, 20 tagged fish are recovered, while at point R^1, 5 tagged fish are taken in the single seine haul. On the basis of the number of recovered fish alone it would appear that there was a stronger tendency for the fish to move downstream than upstream.

If the results just given were weighted by the available number of tagged fish and the number of units of fishing effort used at each location, the true migration indices from point T to points R and R^1 would be obtained. In determining the migration index the number of marked fish recovered per unit of fishing effort at a given point is divided by the number of marked fish available from a given point of tagging; the result of the division is multiplied by 1000 for the sake of convenience. This procedure may be expressed as a formula, such as:

$$M = 1000 \frac{\frac{A}{B}}{C} = \frac{1000A,}{BC} \qquad (1)$$

in which

M = migration index from any given point of tagging T
to any given point of recovery R,
A = number of tagged fish recovered at point R,
B = number of units of fishing effort at point R,
C = total number of fish tagged at point T.

Substituting the hypothetical values given above in (1) we find the migration index from point T to point R downstream to be 20, whereas the upstream migration index from point T to point R^1 is 50. In other words, instead of a greater tendency toward downstream movement as conjectured from the unweighted data, there is actually indicated 2.5 times as much tendency for the fish to move upstream as downstream.

In the event that the total number of tagged fish available is changed by addition of more tagged fish, or decreased by the removal of tagged fish by fishermen, the formula must be modified to present the true conditions. For such circumstances, the formula used in determing the migration index may be expressed as:

$$M = \frac{1000\ A}{BC + B_1C_1 + B_2C_2 + \ldots\ldots B_nC_n}, \qquad (2)$$

where A and M are the same as for (1) and

$B =$ number of units of fishing effort used in attempting to recover the original total number of tagged fish.

$B_1 =$ number of units of fishing effort used in attempting to recover the original total number of tagged fish plus whatever tagged fish have been added since, and/or minus the number which have been removed,

$B_n =$ number of units of fishing effort used in attempting to recover final total number of tagged fish,

$C =$ the original number of fish tagged at point T,

$C_1 =$ the original number plus the added number and/or minus the removed number of tagged fish at pointT,

$C_n =$ the grand total of fish marked at point T, minus the numbers removed.

Another hypothetical example will serve to clarify the use of this latter formula. Suppose the following conditions exist:

Trout tagged in Hole T		Tagged Trout Recovered in Hole R	
July 8	47	July 10	1 trout in 2 seine hauls
July 14	53	July 11	No trout in 1 seine haul
	100	July 25	4 trout in 1 seine haul
		July 27	7 trout in 1 seine haul
			12

Substituting the hypothetical values above in (2) we have

$$M = \frac{1000 \times 12}{(3 \times 47) + (2 \times 100)} = \frac{12000}{341} \doteq 35.$$

Wherever the data permitted, the formula in its simplest form (1) was used. This was possible for the recoveries made on the spawning beds, during which season the available number of tagged trout remained constant. The formula as stated in its more complex for (2) was used in the treatment of summer and early fall movements, since both fishermen and investigators were sometimes daily altering the available number of tagged fish. Calculation of migration indices on recoveries made in the years following tagging was not attempted, since so many of this category of recoveries were made by fishermen, whose fishing effort could not be evaluated because no intensive creel census was taken at that time.

Data on the winter and early spring movements have remained scanty despite efforts to capture brook trout by seinings in those seasons. Only 3 recoveries of tagged fish have been made on the North Branch during the month of February, usually the coldest month of the winter. In the following discussion of the seasonal movements of the brook trout, the data on the summer movements are presented first, followed by the available information on the probable movements of the brook trout in winter and in early spring.

MIGRATION

<u>Summer Migrations</u>

In studying the migration of brook trout in the North Branch of the Au Sable

River, recoveries both by fishermen and by seining were used. The fishermen's records were considered to be sufficiently accurate as to place of capture of the marked trout, and were especially valuable when made early in the open trout season. Many of the trout tagged during the preceding years were taken by anglers at this time of year.

The recovery cards for fish caught in the year when tagged were first sorted into three groups, for 1934, 1935 and 1936 respectively. Each of these groups was further sorted by month of tagging and month of recovery. For each of the latter classes, the total number recovered, the percentage moving downstream and average miles moved, the percentage showing no migration, and the percentage moving upstream and the average miles moved, have been calculated. The results of these sortings and calculations are presented in Tables 30, 31 and 32. The total number of fish recovered as listed in these tables exceed the total recoveries shown for the corresponding time periods in Table 28, since in order to use all available data, multiple recoveries were broken down (each recovery on a single fish was used wherever it fitted into its proper place, and it may have fitted into more than one monthly category in a single year period). For example, a brook trout tagged in July, 1934, and recovered successively in August, September and November is listed in three different places in Table 11, and properly so, since the repeated recoveries represented a minute component of the movements of the population in those respective time periods.

The analysis of the recoveries made within the year of tagging (Tables 30, 31 and 32) show the migrational tendencies of brook trout in the North Branch through the last 8 months of the year. With the exception of January, 1936, practically no recoveries have been made before late April in any one year. The results for 1934 and 1935 agree well, but those for 1936 recoveries of fish tagged in the same year differ quite markedly. The difference may, I think, be partially attributed to the severe heat-wave of mid-July in 1936. The location of tagging work and of the subsequent seinings in this year probably also affected the results. Therefore, the results of the three tables were combined into one table of grand averages (Table 33), in which the same monthly categories of tagging and recovery for the different years ~~are~~ were combined.

Table 30.

DATA ON THE MOVEMENTS OF BROOK TROUT TAGGED AND RECOVERED IN 1934

The average distances travelled, in miles, is indicated in parenthesis

Month tagged	Month recovered	Number recovered	Percentage of recovery		
			Recovered downstream	Showing no migration	Recovered upstream
July	July	36	22 (0.06)	67	11 (1.10)
July	Aug.	135	6 (0.35)	83	11 (0.62)
July	Sept.	62	21 (0.50)	60	19 (0.50)
July	Nov.	48	31 (0.40)	11	58 (0.59)
Aug.	Aug.	57	- -	100	- -
Aug.	Sept.	53	8 (0.58)	81	11 (0.33)
Aug.	Nov.	18	45 (0.40)	-	55 (0.30)
Sept.	Sept.	89	4 (0.60)	91	5 (0.10)
Sept.	Nov.	84	15 (0.19)	33	52 (0.65)
Nov.	Nov.	6	- -	67	33 (0.24)

Table 31

DATA ON THE MOVEMENTS OF BROOK TROUT TAGGED AND RECOVERED IN 1936 AND IN JANUARY, 1936

The average distances travelled, in miles, is indicated in parenthesis.

Month tagged	Month recovered	Number recovered	Percentage of recovery: Recovered downstream	Percentage of recovery: Showing no migration	Percentage of recovery: Recovered upstream
June	June	10		90	10 (0.12)
June	July	2	50 (0.25)		50 (1.50)
June	Aug.	35	36 (0.32)	48	16 (0.16)
June	Sept.	8	13 (3.00)	50	37 (0.12)
June	Nov.	33	21 (0.75)	30	49 (1.60)
Aug.	Aug.	33	13 (0.50)	69	18(0.10)
Aug.	Sept.	100	4 (0.10)	92	4 (0.35)
Aug.	Nov.	82	19 (0.44)	35	46 (0.60)
Sept.	Nov.	21	9 (0.75)	29	62 (0.30)
Nov.	Nov.	28	29 (0.70)	65	7 (0.20)
June	Jan.	6	16 (0.12)	17	67 (0.43)
Aug.	Jan.	16	37 (0.32)	13	50 (0.40)
Sept.	Jan.	2	50 (1.12)		50 (0.06)
Nov.	Jan.	52	19 (0.31)	54	27 (0.08)

Table 32

DATA ON THE MOVEMENTS OF BROOK TROUT TAGGED AND RECOVERED IN 1936

The average distances travelled, in miles, is indicated in parenthesis

Month tagged	Month recovered	Number recovered	Percentage of recovery		
			Recovered downstream	Showing no migration	Recovered upstream
March	July	1	100 (0.06)		
May	July	29		86	14 (0.70)
May	Aug.	5		20	80 (0.39)
May	Nov.	6		100	
July	July	142	15 (0.51)	58	27 (0.64)
July	Aug.	22	31 (0.21)	55	14 (0.06)
July	Nov.	21	14 (0.60)	67	19 (0.60)

Table 33

GRAND SUMMARY OF BROOK TROUT RECOVERED IN SAME YEAR AS TAGGED (EXCEPT JANUARY), 1934, 1935, 1936

Average distance travelled in miles is indicated in parenthesis.

Month tagged	Month recovered	Number recovered	Percentage of recovery: Recovered downstream	Showing no migration	Recovered upstream
March	July[6]	1	100 (0.06)		
May	July[6]	29		86	14 (0.70)
May	Aug.[6]	5		20	80 (0.39)
May	Nov.[6]	6		100	
June	June[5]	10		90	10 (0.12)
June	July[5]	2	50 (0.25)		50 (1.50)
June	Aug.[5]	35	36 (0.32)	48	17 (0.16)
June	Sept.[5]	8	13 (3.00)	50	37 (0.12)
June	Nov.[5]	33	21 (0.75)	30	49 (1.60)
June	Jan.[5]	6	16 (0.12)	17	67 (0.43)
July	July[a]	178	16 (0.39)	60	24 (0.68)
July	Aug.[a]	157	10 (0.28)	79	11 (0.53)
July	Sept.[4]	62	21 (0.50)	60	19 (0.50)
July	Nov.[a]	69	26 (0.43)	28	46 (0.59)
Aug.	Aug.[b]	90	4 (0.50)	89	7 (0.10)
Aug.	Sept.[b]	153	5 (0.34)	88	7 (0.45)
Aug.	Nov.[b]	100	23 (0.43)	29	48 (0.54)
Aug.	Jan.[5]	16	37 (0.32)	13	50 (0.40)
Sept.	Sept.[4]	89	4 (0.60)	91	5 (0.10)
Sept.	Nov.[b]	105	14 (0.26)	32	54 (0.57)
Sept.	Jan.[5]	2	50 (1.12)		50 (0.06)
Nov.	Nov.[b]	34	23 (0.70)	65	12 (0.22)
Nov.	Jan.[5]	52	19 (0.31)	54	27 (0.08)

[a] 1934 + 1936 (Tables 11, 13)
[b] 1934 + 1935 (Tables 11, 12)

[4] 1934 (Table 11)

[5] 1935 (Table 12)

[6] 1936 (Table 13)

Summer Movements

Brook trout tagged and recovered during the summer of the same year tended to remain in the locality of tagging, and did not move any great distance during that time, seldom more than 1.5 miles. Both the unweighted data and weighted migration indices (Tables 34, 35, 36 and 37) support this conclusion. Perhaps the best evidence is shown by the migration indices calculated for the periods July and August, 1934, for September, 1934, for August and September, 1935, and for July, 1936. These periods have been so grouped because seining was more or less continuous, and enough recoveries were made on which reliable indices could be calculated, and the periods represented rather distinct units of tagging and recovery activity. As the number of tagged fish available for recovery was being altered throughout the periods just mentioned, the formula $Y = \frac{1000\ A}{BC + B_1C_1 + \ldots B_nC_n}$ was used (see p.93) to calculate the various migration indices. That there was very little movement between the holes during July and August, 1934 (Table 34), is evidenced by the very high indices recorded for fish recovered in the holes where they were tagged. There was considerable interchange between the Spring House Hole and the Spring Hole, which possibly should have been considered as one locality due to their proximity (see Table 34).

Migration indices calculated for September 1934 (Table 35) show that, in general, there was still little movement, as the higher migration indices are still recorded for fish tagged and recovered in the same hole. However, brook trout tagged in the Island Hole were beginning to move about (probably in search of spawning grounds), and a few of the Spring House fish were doing likewise. Further evidence that the Spring and Spring House populations might be considered as a unit will be noted here, as the interchange between these localities is practically the same.

Migration indices calculated for the period of late August and September, 1935, (Table 36) agree well with results of calculations for the previous year. Brook trout which had been tagged earlier in the summer were found for the most part to be in the locality of tagging. There had been some interchange between the Island Hole and the Ranch Hole, and between the holes in the region of Andersons (Spring House, Spring, Andersons Barn, Turkey Hole), as previously indicated.

Migration indices computed for July, 1936, on brook trout tagged and recovered within that month differed markedly (Table 37) from results obtained during the summer months of 1934 and 1935, as considerable shifting between holes was evident during this month. This may have been the result of the extreme heat during the month of July (Table 23) which undoubtedly forced the trout to move about more than usual at this season, in search of cooler waters. Although temperature data are not available for the summer months of 1934 and 1935, it is certain no such extreme temperatures occurred during the summers of those years.

Table 34

JULY-AUGUST 1934 BROOK TROUT MIGRATION INDICES NORTH BRANCH AU SABLE RIVER

The first figure in the parenthesis indicates the average number of tagged fish available, the second number indicates the average number of tagged fish captured per seine haul.

Where Recovered	Total of Seine hauls	Where tagged: Ranch	Island	Spring House	Spring
Ranch (0.625)[a]	5(or 4)	183 (107-19.6)	0 (77.6-0.0)	1 (156.8-0.2)	0[1] (37.5-0.0)
Island (1.000)	4	2 (113.25-0.25)	104 (77.25-8)	13 (154-2)	0 (50-00)
Spring House (0.06)	4(or 3)	5 (105-0.5)	0 (70.25-0.0)	31[2] (152-4.67)	0[2] (433-0.0)
Spring	3(or 2)	0 (109.67-0.0)	0 (76.67-0.0)	29 (152-4.33)	73[3] (20-1.5)

[1] Based on 4 seine hauls

[2] Based on 3 seine hauls

[3] Based on 2 seine hauls.

[a] These figures indicate the distance in miles between the localities of tagging and recovery.

Table 35

SEPTEMBER, 1934 BROOK TROUT MIGRATION INDICES NORTH BRANCH AU SABLE RIVER

The first figure in the parenthesis indicates the average number of tagged fish available, the second figure indicates the average number of tagged fish recovered per seine haul.

Where Recovered	Total seine hauls	Where tagged: Halstead's	Ranch	Island	Twin Bridge	Blanchard's	Spring House	Spring	Anderson's Bridge
Halstead's (0.75)[a]	1	-	0 (123-0)	0 (185-0)	0 (8-0)	0 (40-0)	0 (170-0)	0 (55-0)	0 (6-0)
Ranch (0.625)	5	0 (45-0)	10 (122-1.2)	0 (140-0)	0 (8-0)	0 (40-0)	0 (162.4-0)	0 (66.8-0)	0 (6-0)
Island (0.125)	5	0 (45-0)	10 (123-1.2)	113 (145.6-16.4)	83 (8-0.67)	0 (40-0)	5 (164-0.8)	3 (68.4-0.2)	0 (6-0)
Twin Bridge (0.500)	2	-	0 (122-0)	7 (140-1)	-	-	0 (155-0)	0 (55-0)	-
Blanchard's (0.375)	3(or 4)	0 (45-0)	0 (123-0)	13 (182.3-2.3)	0 (8-0)	26[1] (67.5-18)	5 (184.67-1)	3 (95.67-0.33)	0 (6-0)
Spring House (0.06)	3(or 4)	0 (45-0)	0 (123-0)	2[2] (201.5-0.5)	0 (8-0)	0 (77.3-0)	19 (172.3-3.3)	14 (94.33-1)	0 (6-0)
Spring (0.125)	3	0 (45-0)	0 (123-0)	0 (181-0)	0 (8-0)	0 (67.3-0)	12 (86.75-2)	18 (76-1.33)	0 (6-0)
Anderson's Bridge	4	0 (45-0)	0 (123-0)	1 (209.75-0.25)	0 (8-0)	0 (81.25-0)	1 (186.5-0.25)	0 (100.25-0)	0 (6-0)

[1] Based on 4 seine hauls

[2] Based on 4 seine hauls

[a] These figures indicate the distance in miles between the localities of tagging and recovery.

Table 36

MIGRATION INDICES FOR AUGUST-SEPTEMBER, 1935, BROOK TROUT NORTH BRANCH AU SABLE

The first figure in the parenthesis indicates the average number of tagged fish available, the second figure indicates the average number recovered per seine haul.

Locality of Recovery	Total no. seine hauls	Locality of Tagging											
		Berger	Halstead's	Ranch	Island	Twin Bridge	Blanchard's	Spring House	Spring	Anderson's Bridge	Anderson's Barn	Turkey Hole	¼ mi. below And. Br.
Berger (5.00)[5]	2	15 (32-0.5)	0 (21-0)	0 (37-0)	0 (43.5-0)	0 (28-0)	0 (10-0)	0 (19-0)	0 (114-0)	-	0 (34-0)	0 (15-0)	0 (10-0)
Halstead's (0.75)	4	0 (32-0)	119 (21-2.5)	0 (54-0)	0 (93.5-0)	0 (19-0)	0 (22.5-0)	0 (31-0)	0 (126-0)	0 (24-0)	0 (64-0)	0 (29-0)	0 (10-0)
Ranch (0.50)	2	0 (32-0)	0 (21-0)	95 (42-4.0)	6 (80-0.5)	0 (31-0)	0 (22.5-0)	0 (20-0)	0 (126-0)	0 (24-0)	0 (89-0)	0 (28.5-0)	0 (10-0)
Island (0.125)	8	0 (32-0)	0 (21-0)	2 (55-0.125)	126 (67-8.38)	0 (28-0)	0 (22.5-0)	0 (21-0)	0 (120-0)	0 (24-0)	0 (95-0)	0 (34.5-0)	0 (10-0)
Twin Bridge (0.50)	2	0 (32-0)	0 (21-0)	0 (47-0)	0 (43.5-0)	85 (24-2)	0 (10-0)	0 (15-0)	0 (75-0)	0 (24-0)	0 (72.5-0)	0 (42-0)	0 (10-0)
Blanchard's (0.375)	3	0 (32-0)	0 (21-0)	0 (47-0)	0 (49-0)	0 (28-0)	33 (10-.33)	0 (35-0)	0 (126-0)	0 (24-0)	0 (97-0)	0 (42-0)	0 (10-0)
Spring House (0.06)	4	0 (32-0)	0 (21-0)	0 (54-0)	0 (77-0)	0 (28-0)	0 (22.5-0)	79 (16-1.2)	7 (101-0.75)	0 (24-0)	3[1] (85-0.25)	0 (35-0)	0 (10-0)
Spring (0.125)	4	0 (32-0)	0 (21-0)	0 (50-0)	0 (75-0)	0 (27-0)	0 (22.5-0)	16 (16-0.25)	61 (98-6)	42 (24-2)	28[1] (80-2.25)	0 (28.5-0)	0 (10-0)
And. Barn (0.06)	5	0 (32-0)	0 (21-0)	0 (50-0)	0 (62-0)	0 (26-0)	0 (22.5-0)	0 (19-0)	2[1] (123-0.25)	0 (24-0)	46[2] (75-36)	0 (26-0)	0 (10-0)
Turkey Hole	5	0 (32-0)	0 (21-9)	0 (50-0)	0 (71-0)	0 (19-0)	0 (22.5-0)	0 (21-0)	0 (121-0)	0 (24-0)	5[3] (85-0.4)	139[4] (24-3.3)	18[3] (11-0.2)

[1] Based on 4 seine hauls

[2] Based on 5 seine hauls

[3] Based on 5 seine hauls

[4] Based on 3 seine hauls

[5] These figures indicate the distance in miles between localities of tagging and recovery.

Table 37

MIGRATION INDEX OF BROOK TROUT TAGGED AND RECOVERED IN JULY, 1936

Figures in parenthesis indicate total number of recoveries except as explained in the footnotes.

Hole where recovered	No. of seine hauls	Number of fish tagged at each given hole							
		Halsteads	Akron	Island	Blanchards	Spring House	Spring	Barn	Turkey
		3	142	82	24	30	89	12	7
Halstead's (125)	3	0	0	0	0	0	0	0	0
Akron (0.125)	8	0	41[x] (102-3.125)	18 (12)	47 (9)	13 (3)	10 (7)	0	0
Island (0.625)	9	37 (1)	0	2[x] (62-0.22)	0	0	1 (1)	9 (1)	0
Blanchard's (0.375)	4	0	2 (1)	0	0	0	3 (1)	0	0
Spring (0.125)	5	0	3 (2)	16[x] (24.4-0.4)	8 (1)	27 (4)	98 (44)	17 (1)	0
Barn (0.06)	4	0	0	0	23 (2)	8 (1)	6 (2)	125 (6)	71 (2)
Turkey	2	0	4 (1)	0	0	50 (3)	0	0	357 (5)

[x] Indices in these cases determined by using average number of fish available, and average number of tagged fish recovered/seine haul since fish were tagged between various seinings in these holes.

Fall Movements

Both weighted and unweighted data relating to the position of the brook trout in early November, during the spawning season, indicate clearly that the fish had dispersed markedly since the summer. This dispersal tended to be slightly greater upstream than down (Table 33). A marked preference was exhibited for the Akron Club spawning beds, and for the spawning beds in the region of Anderson's (See Summary Table 41). In 1934 (Table 38) recoveries of tagged fish at the Akron Club were made from all tagging localities located downstream and from one locality upstream. Recoveries in the region of Anderson's were, with 1 exception, all fish which had been tagged in these closely-related holes. One fish tagged in the Island Hole had moved downstream to Anderson's Bridge to spawn. At the extreme upper end of the middle section of the river, at Boutell's Ford (½ mile below Dam 2), one recovery was made of a trout tagged at Halstead's Ford, indicating a movement upstream of about 5 miles.

In 1935 (Table 39), similar results were obtained, even though the data were augmented by an increased number of seining and tagging localities. Some random distribution was noted.

The results of the seinings in November, 1936 (Table 40) were inadequate, since we arrived after the brook trout had spawned and consequently made few recoveries of tagged fish. However, those brook trout that were recovered suggest a distribution similar to that obtained during the spawning seasons of 1934 and 1935.

In general, most of the spawning fish sought spawning areas located close to their summer range. Those fish which moved relatively far may have had to do so because of competition for the available areas suited for spawning, since the best spawning grounds, in the Anderson region and at the Akron Club were both the scenes of intense spawning activity.

- The position of the summer range as related to the nearest and most suitable spawning ground may very possibly determine the movement of the fish (upstream or downstream or no movement) when the spawning season arrives. The marked preference for the Akron Club spawning beds in 1934 and 1935 already mentioned, although no fish were tagged on these beds during the summers of those years, definitely proves that this location serves as one of the best nursery sites for many of the naturally-reared brook trout of the middle portion of the stream. The same statement applies to the region of Andersons.

Table
38

MIGRATION INDICES, NOVEMBER 1934, FOR BROCK TROUT IN THE NORTH BRANCH OF AU SABLE

Inferior figures indicate number of tagged fish recovered

Hole where recovered	No. of seine hauls	Number of fish tagged at each given hole										
		Boutell's Ford	Bergers	Halsteads	Ranch	Akron Club	Island	Twin Bridge	Blanchard's	Spring House	Spring	Anderson's Bridge
		0	0	45	123	0	218	8	120	208	114	108
Boutell's Ford (6.125)[a]	5	0	-	4_1	0	-	0	0	0	0	0	0
Ranch (0.500)	5	-	-	0	2_1	-	0	0	0	0	0	0
Akron (0.75)	12	-	-	0	6_9	-	10_{26}	6_1	3_7	5_{12}	5_7	1_1
Blanchard (0.375)	2	-	-	0	0	-	0	0	50_{12}	2_1	4_1	0
Spring House (0.06)	1	-	-	0	0	-	0	0	0	14_3	18_2	37_4
Spring (0.06)	1	-	-	0	0	-	0	0	0	28_6	26_3	19_2
Andersons Bridge	4	-	-	0	0	-	1_1	0	2_1	4_3	11_5	21_9

[a] These figures indicate number of miles between the tagging and recovery localities.

Table 39

NOVEMBER 1935 MIGRATION INDICES FOR BROOK TROUT IN NORTH BRANCH AU SABLE

Inferior figures indicate the number of tagged fish recovered

Hole where recovered	No. of seine hauls	Number of fish tagged at each given hole: Boutell's	Berger	Halsteads	Ranch	Akron Club	Island	Twin Bridge	Blanchard's	Spring House	Spring	Anderson's Bridge	Anderson's Barn	Turkey
		28	44	66	62	0	190	34	35	65	160	24	108	42
Boutell's (0.375[a])	5	0	14_3	0	3_1	-	0	0	0	0	0	0	0	0
Berger (5.75)	1	0	91_4	0	0	-	0	0	0	15_1	0	0	0	0
Ranch (0.50)	6	0	0	0	0	-	1_1	0	0	0	0	0	0	0
Akron (0.125)	19	0	0	0.8_1	4_5	-	5_{18}	5_3	3_2	2_2	4_{11}	2_1	1_3	3_2
Island (0.125)	3	0	0	5_1	0	-	30_{17}	0	0	5_1	0	0	0	8_1
Twin Bridge (0.5)	1	0	0	0	0	-	0	67_2	0	0	0	0	0	0
Blanchards (0.375)	3	0	0	0	0	-	0	0	29_3	0	4_2	0	0	0
Spring House (0.125)	2	0	0	0	0	-	0	0	0	0	23_7	0	5_1	12_1
Anderson's Bridge (0.06)	8	0	0	2_1	0	-	0	0	0	0	4_5	22_5	8_7	0
Anderson's Barn (0.06)	8	0	0	2_1	0	-	0.7_1	0	0	0	7_8	0	25_{22}	3_{22}
Turkey	1	0	0	0	0	-	0	0	10_1	10_1	0	0	0	24_1

[a] These figures indicate the number of miles between the tagging and the recovery localities.

Table 40

MIGRATION INDEX NOVEMBER, 1936, FOR BROOK TROUT IN NORTH BRANCH OF AU SABLE

Inferior figures indicate the number of tagged fish recovered

Hole where recovered	No. of seine hauls	Number of fish tagged at each given hole									
		Bergers	Halsteads	Akron	Island	Twin Bridge	Blanchards	Spring	Andersons	Turkey	Lovells
		0	9	137	81	0	23	89	87	7	25
Bergers (6.25)[a]	1	-	0	0	0	-	0	0	0	0	0
Akron (0.125)	10	-	22_2	7_{10}	1_1	-	13_3	0	0	0	0
Island (0.125)	3	-	0	0	0	-	0	0	0	0	0
Twin Bridge (0.5)	4	-	0	0	0	-	0	0	0	0	0
Blanchards (0.44)	2	-	0	0	0	-	0	0	0	0	0
Spring (0.125)	2	-	0	0	0	-	0	0	0	0	0
Anderson's Barn (0.06)	2	-	0	0	0	-	22_1	0	34_6	0	0
Turkey	1	-	0	0	0	-	0	0	0	0	0

[a] These figures indicate the number of miles between the tagging and recovery localities.

Table 41

MIGRATION INDICES NOVEMBER 1934, 1935, 1936, FOR BROOK TROUT IN NORTH BRANCH OF AU SABLE

Inferior figures indicate the number of tagged fish recovered

Hole where recovered	Total No. seine hauls	Number of fish tagged at each given hole												
		Boutell's Ford	Bergers Pool	Halsteads	Ranch	Akron	Island	Twin Bridge	Blanchards	Spring House	Spring	Andersons Bridge	Andersons Barn	Turkey
		28	44	120	191	137	492	45	178	269	356	136	197	49
Boutell's F. (0.375)[a]	10	0	7_{3}	1_{1}	0.5_{1}	0	0	0	0	0	0	0	0	0
Bergers Pool (5.00)	2	0	45_{4}	0	0	0	0	0	0	2_{1}	0	0	0	0
Halstead (0.75)	0	-	-	-	-	-	-	-	-	-	-	-	-	-
Ranch (0.50)	11	0	0	0	0.5_{1}	0	0.2_{1}	0	0	0	0	0	0	0
Akron Club (0.125)	41	0	0	0.7_{3}	2_{14}	2_{10}	2_{43}	2_{4}	2_{12}	1_{14}	1_{18}	0.4_{2}	0.4_{3}	1_{2}
Island (0.125)	6	0	0	1_{1}	0	0	6_{17}	0	0	0.6_{1}	0	0	0	3_{1}
Twin Bridge (0.50)	5	0	0	0	0	0	0	9_{2}	0	0	0	0	0	0
Blanchard's (0.375)	7	0	0	0	0	0	0	0	12_{15}	0.5_{1}	1_{3}	0	0	0
Spring House (0.06)	3	0	0	0	0	0	0	0	0	4_{3}	8_{9}	10_{4}	2_{1}	7_{1}
Spring (0.06)	3	0	0	0	0	0	0	0	0	8_{6}	3_{3}	5_{2}	0	0
Andersons B. (0.06)	12	0	0	0.7_{1}	0	0	0.3_{2}	0	0.5_{1}	0.9_{3}	3_{13}	9_{14}	3_{7}	0
Andersons Barn (0.06)	10	0	0	0	0	0	0	0	0.6_{1}	0	2_{8}	0	14_{28}	2_{1}
Turkey	2	0	0	0	0	0	0	0	0	2_{1}	0	0	0	10_{1}

[a] These figures indicate the number of miles between the tagging and recovery localities.

Winter and Early Spring Migrations

The first indication that there must be some winter movement of the fish away from the general region above and below Lovells was obtained by seinings on April 7 and 8, 1935. Only two legal brook trout and three fingerling brook trout were taken in approximately 50 hauls with a 60 foot seine. Air temperatures ranged from 53 to 40° F.; the water was 46° F. at 6 P.M. on both days. The seine hauls were made as far upstream as Dam 2 (10 miles above Lovells), and as far downstream as Kellogg's Bridge (about 10 miles below Lovells), and at all points between Dam 2 and Lovells where brook trout had been tagged and recovered during the previous summer. Since Dam 2 is an almost impassable barrier to upstream migration of trout, it seems probable that the many trout found in the middle portion of the stream during the preceding summer and fall had moved far downstream during the winter.

The capture of 77 tagged brook trout in January, 1936, on or very close to the spawning beds indicates that these fish remain in their summer and fall range, probably until the onset of severe cold weather. At the time of the January seinings, mild temperatures (above 32° F.) prevailed; during the month of December (1935) there had been practically no low temperatures. An almost unbroken period of low temperatures (0 to -25 F.) was apparently responsible for an emigration of the trout from the area previously occupied. Only about 1/25 as many trout were captured in February as were taken in January, and even fewer were caught in March (Table 42).

Since these seinings were made both well above and well below the localities of tagging (so far as time and road conditions permitted), as well as near the spawning beds, it seems assured that the trout had largely moved out of the middle portion of the North Branch.

Seinings in April and May, 1936 (Table 42) showed a gradual return of the trout to the area that was seemingly deserted during the cold weather. Recoveries of tagged trout by fishermen during late April, May and June of 1936 in the regions found barren during the winter definitely supported the conclusion that there had been a return movement to the middle portion of the stream (Table 44). Similar results were obtained from brook trout tagged in 1934 and recovered by fishermen in May and June of 1935 (Table 43). In both "early" seasons, from a total of 76 tagged fish recovered, 40, or 52.6 per cent were recovered an average distance of 3.3 miles downstream from where they were last seen in the previous year; 16, or 21.1 per cent were caught where they were released the preceding year; and 20, or 26.3 per cent were captured an average distance of 1.6 miles upstream from the point where they were last seen in the previous year (Table 45).

Since the majority of these "early" season recoveries were made at points downstream from release, or at the locality of tagging (where practically no fish were found during the winter months), it is concluded that the winter movements of the brook trout are downstream. This conclusion is further supported by the recovery in the spring of 1936 in Big Creek in Oscoda County, on the southern side of the Au Sable drainage below the North Branch, of one brook trout that had been tagged in 1935 in the North Branch. A similar migration was recorded from the earlier tagging experiments (p.57 Table 7). The recoveries of these particular brook trout suggest that a part of the brook trout population move downstream during the winter as far as the Main Au Sable, a distance of approximately 18 miles below Lovells, and that some of them continue their winter migration some distance down the Au Sable.

The alternate hypothesis that the trout hibernate in the localities where they are found during the summer is supported by observations during February, 1936.

At the Akron Club, a 10-inch brown trout, several fingerling brook trout, and several black-nosed dace were found in a state of semi-hibernation under the surface ice at the mucky weed-choked shoreline. At the Lovells Road Bridge an 8-inch brook trout was found in a like habitat. Since other similar habitats along the river yielded no fish, it was concluded that only a small portion of the abundant population of the summer wintered over in this section of the stream.

Another possibile explanation for the disappearance of the trout in the middle portion of the North Branch during the cold weather is that they were consumed by the mergansers which frequent the stream at such a time. Fragments of a tag were taken in the stomach of one merganser collected on the North Branch in February, 1936, and mergansers taken on the trout streams of the state at that time were found to have fed largely on trout (Leonard and Shetter, 1937).

Further research is called for, to determine definitely whether most of the brook trout are absent during very cold weather from their usual summer ranges in Michigan trout streams like the North Branch, and if so whether their absence is due to death or to migration.

Recoveries in midsummer and fall of brook trout which had been tagged in the year previous to capture, were usually taken within $1\frac{1}{2}$ miles from the locality where they were tagged. These recoveries indicate that the brook trout population of the Lovells region returns approximately to the same locality each summer (Table 46). About 26 per cent were found upstream from the point of tagging, 41 per cent were found where tagged, and 33 per cent were downstream from where they had been tagged the previous year.

Six out of eight of the recoveries made on brook trout tagged on the spawning beds in November and recovered during the breeding season in the following November, were retaken at the same spawning ground (Table 46).

Of the Six brook trout which were recovered after having been free over two winters, one was retaken in the original hole where it was tagged, 1 was recovered only 3/8 of a mile downstream, and the other 3 were recovered 1/8, 5.6 and 11 miles upstream.

Table 42

ABUNDANCE OF BROOK TROUT IN SEINE HAULS DURING MID-WINTER AND EARLY SPRING, 1936, IN THE NORTH BRANCH OF THE AU SABLE RIVER, MICHIGAN

Month	No. of hauls[1]	Total trout captured	Av. no. trout per haul	Remarks
January	11	About 900	About 80	Close to normal summer size range.
February	12	43	3.0	About 5% legal trout (7 inches)
March	14	11	0.8	All less than six inches long.
April	15	55	4.0	About %5 legal fish.
May	21	336	16.0	Less than 10% legal fish.

[1] All hauls were made with a 30' x 6' seine with 3/8 inch mesh, bar measurement.

Table 43

OVER-THE-WINTER RECOVERIES MADE DURING 1935, ARRANGED TO SHOW MIGRATION TRENDS. (FISHERMEN'S RETURNS AND RECOVERIES FROM SEININGS BY THE INSTITUTE FOR FISHERIES RESEARCH ARE INCLUDED).

Month tagged 1934	Month recovered 1935	No. of recoveries	Recovered downstream		No migration		Recovered upstream	
			No.-%	Av.mi.	No.-%	Av.mi.	No.-%	Av.mi
Sept.	May	1					1-33	0.50
Nov.	May	2	1-33	0.75	1-33			
July	June	6	4-67	1.30			2-33	1.50
Aug.	June	2	1-50	0.12			1-50	1.75
Sept.	June	11	5-45	0.80	4-37		2-18	2.00
Nov.	June	8	3-37.5	0.33	3-37.5		2-25	0.50
July	Aug.	5	2-40	1.75	2-40		1-20	0.06
Sept.	Aug.	5	2-40	0.38	1-20		2-40	0.63
Nov.	Aug.	6	1-13	0.25			5-87	0.87
July	Sept.	2			1-50		1-50	1.625
Sept.	Sept.	2	1-50	0.12	1-50			
July	Nov.	2	1-50	0.12			1-50	0.12
Sept	Nov.	4	2-50	0.37	2-50			
Nov.	Nov.	5			4-80		1-20	1.25

Table 44

NORTH BRANCH OF THE AU SABLE RECOVERIES, TAGGED IN 1935, RECOVERED IN 1936

Month tagged 1935	Month recovered 1936	No. recovered	Recovered downstream		No migration		Recovered upstream	
			No.-%	Av.mi.	No.-%	Av.mi.	No.-%	Av.mi.
June	April	1	1-100	0.60				
Aug.	April	4	2-50	1.60	2-50			
Sept.	April	2	2-100	0.11				
June	May	5	2-40	1.13	2-40		1-20	0.13
Aug.	May	11	6-55	0.39	1-9		4-36	2.70
Sept.	May	5	2-40	12.00	1-20		2-40	1.75
Nov.	May	9	8-89	1.00			1-11	3.25
Aug.	June	6	1-17	0.75	2-33		3-50	1.04
Nov.	June	3	2-67	1.25			1-33	1.50
Aug.	July	10	3-30	1.07	5-50		2-20	0.06
Sept.	July	1			1-100			
Nov.	July	15	4-27	0.85	9-60		2-13	0.78
Aug.	Aug.	3	2-67	0.71			1-33	0.13
Sept.	Aug.	1	1-100	1.25				
Nov.	Aug.	3	3-100	0.59				
June	Sept.	2			1-50		1-50	0.25
Aug.	Nov.	1					1-100	0.06
Nov.	Nov.	3	1-33	1.25	2-67			

Table 45

EARLY SEASON OVER THE YEAR RECOVERIES, 1935 AND 1936 NORTH BRANCH AU SABLE BROOK TROUT

Month tagged	Month recovered	No. recovered	Recovered downstream		No migration	Recovered upstream	
			No.-%	Av. mi.	No.-%	No. - %	Av. mi.
June '35	Apr. '36	1	1-100	0.60			
Aug. '35	Apr. '36	4	2-50	1.60	2-50		
Sept. '35	Apr. '36	2	2-100	0.11			
June '35	May '36	5	2-40	1.13	2-40	1-20	0.13
Aug. '35	May '36	11	6-55	0.39	1-9	4-36	2.70
Sept.*	May*	6	2-33	12.00	1-17	3-50	1.30
Nov.*	May*	11	9-82	0.97	1-9	1-9	3.25
July '34	June '35	6	4-67	1.30		2-33	1.50
Aug.*	June*	8	2-25	0.50	2-25	4-50	1.22
Sept. '34	June '35	11	5-45	0.30	4-37	2-18	2.00
Nov.*	June*	11	5-45	1.05	3-27.5	3-27.5	0.83
Total		76	40-52.6	3.3	16-21.1	20-26.3	1.6

*These results obtained by combination of like tagging and recovery periods in 1934, 1935 and 1936.

Table 46

"LATE" SEASON OVER THE YEAR RECOVERIES, 1935 AND 1936, NORTH BRANCH AU SABLE BROOK TROUT

Month tagged	Month recovered	No. recovered	Recovered downstream		No migration	Recovered upstream	
			No. - %	Av. mi.	No. - %	No. - %	Av. mi.
Aug. '35	July '36	10	3-30	1.07	5-50	2-20	0.06
Sept. '35	July '36	1			1-100		
Nov. '35	July '36	15	4-27	0.85	9-60	2-13	0.78
July '34	Aug. '35	5	2-40	1.75	2-40	1-20	0.06
Aug. '35	Aug. '36	3	2-67	0.71		1-33	0.13
Sept.*	Aug.*	6	3-50	0.67	1-17	2-33	0.63
Nov.*	Aug.*	9	4-44	0.50		5-56	0.87
June '35	Sept. '36	2			1-50	1-50	0.25
July '34	Sept. '35	2			1-50	1-50	1.63
Sept. '34	Sept. '35	2	1-50	0.12	1-50		
July '34	Nov. '35	2	1-50	0.12		1-50	0.12
Aug. '35	Nov. '36	1				1-100	0.06
Sept. '34	Nov. '35	4	2-50	0.37	2-50		
Nov.*	Nov.*	8	1-12.5	1.25	6-75	1-12.5	1.25
Total		70	23-33	0.77	29-41	18-26	0.60

*These results obtained by combination of the tagging and recovery periods in 1934, 1935, 1936.

Growth Rate of Brook Trout in the North Branch of the Au Sable River

Since certain European writers (Wunder, DeBrosses, 1935) have expressed the opinion that tagging on the gill cover and caudal peduncle of coarse fishes reduces the growth rate, the effect of jaw tagging on the rate of growth of trout was tested in two hatchery experiments, as detailed on p. 31-32. The general results in these experiments agree in indicating that there is little difference in the growth rate of tagged and untagged trout, at least under hatchery conditions, when the jaw-tag method is used. Certainly, then, growth studies by means of this tagging method should be considered valid.

In studying the growth rate of wild brook trout in the North Branch, only those measurements of recoveries of tagged fish taken by the writer or other members of the staff of the Institute for Fisheries Research were used. Thus all recoveries made by fishermen were eliminated, since it was obvious that a large number of fishermen's measurements were not very accurate. Often a trout was reported as gaining an inch in a week, or as losing a half-inch in three days.

Most of the seining in the North Branch was done between June and September, inclusive, and in November and January. Tagging and recovery were carried on at the same time over the duration of the experiment. For this reason it was difficult to assemble for many length groups an adequate number of recoveries of trout which had been free over similar periods of time.

The only solution seemed to lie in assembling the records of recovery in length groups of two inches and setting up three arbitrary time periods "summer" (June to early September); "Fall" (late September to mid-November); and "Early Winter" (mid-November to mid-January). Only recoveries on fish which had been both tagged and recovered within one of these periods were considered.

Growth on these particular fish was computed as the average increase per day, calculated by dividing the average increase of all fish in one category by the average number of days these fish had been free between the times of measuring, (Tables 47, 48, 49, 50, 51, 52, 53, and 54).

Only in January, 1936, was it possible to obtain enough recoveries to provide data for computations on "Early Winter" Growth. Fall growth was not computed for 1936 because no fish were tagged at the end of the summer. No data are available for calculating the growth in the earlier months of the year.

From Tables 47, 48 and 49 it will be observed that "Summer" growth as found by measurements of recovered tagged fish was consistent in the three years. Brook trout two to eight inches in total length gained about 0.1 inch per ten days (Table 53). The number of recoveries which were from eight to ten inches total length was considerably less, but those available indicate that these fish grew at the rate of about 0.07 inch per 10 days, although their growth varied in the three different summers.

Measurements on the fall recoveries (Tables 50, 51 and 53) show that the rate of growth is less than that of the summer period. Recoveries made in January, 1936, show that the early winter growth is the least of all. There was, however, a measureable increment of growth between the spawning season and mid-January (Table 52) of about 0.02 to 0.03 inches per 10 days. The rate of growth for the early winter period seems to be about the same for all length groups.

Table 47

"SUMMER" GROWTH, 1934, OF THE BROOK TROUT IN THE NORTH BRANCH OF THE AU SABLE

Increase is given in one hundredths of an inch.

Length group	No. of trout recovered	Av. no. days out	Av. increase per day per fish x 10
2-3 7/8	-	-	-
4-5 7/8	17	38.8	0.11
6-7 7/8	188	30.9	0.11
8-9 7/8	14	21.7	0.09

Table 48

"SUMMER" GROWTH, 1935, OF THE BROOK TROUT IN THE NORTH BRANCH OF THE AU SABLE

Increase is given in one hundredths of an inch.

Length group	No. of trout recovered	Av. no. days out	Av. increase per day per fish x 10
2-3 7/8	24	24.2	0.09
4-5 7/8	58	23.2	0.09
6-7 7/8	55	44.4	0.09
8-9 7/8	8	16.5	0.04

Table 50

"AUTUMN" GROWTH, 1934, OF THE BROOK TROUT IN THE NORTH BRANCH OF THE AU SABLE

Increase is given in one hundredths of an inch.

Length group	No. of trout recovered	Av. no. days out	Av. increase per day per fish x 10
2-3 7/8	-	-	-
4-5 7/8	46	50.0	0.06
6-7 7/8	29	53.5	0.05
8-9 7/8	9	54.4	0.02

Table 49

"SUMMER" GROWTH, 1936, OF THE BROOK TROUT IN THE NORTH BRANCH OF THE AU SABLE

Increase is given in one hundredths of an inch.

Length group	No. of trout recovered	Av. no. days out	Av. increase per day per fish x 10
2-3 7/8	-	-	-
4-5 7/8	73	34.9	0.15
6-7 7/8	118	18.6	0.11
8-9 7/8	4	4	0.00

Table 51

"AUTUMN" GROWTH, 1935, OF THE BROOK TROUT IN THE NORTH BRANCH OF THE AU SABLE

Increase is given in one hundredths of an inch.

Length group	No. of trout recovered	Av. no. days out	Av. increase per day per fish x 10
2-3 7/8	42	49.0	0.05
4-5 7/8	10	50.6	0.14
6-7 7/8	7	55.0	0.06
8-9 7/8	2	50.5	0.25

Table 52

"EARLY WINTER" GROWTH, 1935-36, OF THE BROOK TROUT IN THE NORTH BRANCH OF THE AU SABLE
Increase is given in one hundredths of an inch.

Length group	No. of trout recovered	Av. no. days out	Av. increase per day per fish x 10
2-3 7/8	1	61.0	0.02
4-5 7/8	31	60.6	0.03
6-7 7/8	14	60.3	0.02
8-9 7/8	6	60.5	0.03

Table 53

GRAND AVERAGE OF "SUMMER" GROWTH OF BROOK TROUT IN THE NORTH BRANCH OF THE AU SABLE(1934, 1935, 1936 DATA COMBINED)
Increase is given in hundredths of inches.

Length group	No. of trout recovered	Av. no days	Av. increase per day per fish x 10
2-3 7/8	24	24.2	0.09
4-5 7/8	148	30.7	0.12
6-7 7/8	361	28.9	0.10
8-9 7/8	26	17.4	0.07

Table 54

GRAND AVERAGE OF "FALL" GROWTH OF BROOK TROUT IN THE NORTH BRANCH OF THE AU SABLE (1934, and 1935 DATA COMBINED)

Increase is given in hundredths of inches.

Length group	No. of trout recovered	Av. no. days	Av. increase per day per fish x 10
2-3 7/8	2	49	0.05
4-5 7/8	56	50.1	0.07
6-7 7/8	36	53.8	0.05
8-9 7/8	11	53.7	0.06

Calculation of Population by means of Tag Recoveries

Since the total number of brook trout, both tagged and un-tagged, was recorded for 13 representative seine hauls during the spawning season of 1935 (Nov. 1-14), an attempt may be made to calculate the brook trout population of that portion of the North Branch in which these seine hauls were made. The number of tagged brook trout in the stream at the time of the 1935 spawning season may be set at 2,437 if the following assumptions[a] be made:

(a) no tags were lost from the fish,

(b) no tagged fish died,

(c) all tagged fish captured by fishermen were reported.

From 13 carefully counted seine hauls at several different points within 1 3/4 miles 483 untagged brook trout and 69 tagged brook trout were captured. The estimate of the brook trout population of this 1 3/4 miles of river is made by means of the following computation, using the formula explained on p. 75:

Estimated population of brook trout (4 to 10 inches long) in 1 3/4 miles of stream seined =

$$(483 + 69)\ \frac{(2437)}{69} = 19,496$$

From this result it may be determined that the number of 4 to 10 inch brook trout per mile of stream in the region of the Twin Bridges was (approximately) 11,140. Using this figure, and the approximate average width of the stream as determined in the field work, the number per acre of brook trout of the same size range is estimated to have been approximately 800.

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[a] In the three years spent on the stream only one fish bearing a tag has been found dead, and only one has been found with a broken lower jaw indicating the loss of the tag.

Population estimates for the years 1934 and 1936 were not made. In 1934, although the number of tagged fish was known, accurate information on the number of untagged fish in the seine hauls was not kept. In 1936, comparatively few recoveries were made because the writer was not on the stream in time to catch the spawning season at its peak. Any calculations of the population intensity made from such meager data would not be reliable.

THE ANGLING HISTORY OF THE NORTH BRANCH, WITH COMPUTATIONS ON THE PERCENTAGE OF THE LEGAL BROOK TROUT POPULATION REMOVED BY ANGLERS.

The Angling History of the North Branch of the Au Sable

Prior to 1880, the Au Sable River System was famous for grayling (*Thymallus tricolor*) fishing it afforded the sportsman of the United States. Brook trout were not native to the Au Sable System, according to the uniform testimony of old-time residents and of early writers. Hallock (1873, p.208), for instance, wrote that brook trout did not occur in tributaries of Lake Huron south of Thunder Bay, which is north of the mouth of the Au Sable River.

It must have been about 1884 that the grayling virtually disappeared from the Au Sable System, because in the spring of that year Rube Babbitt attempted to capture mature males and females for artificial cultivation, but could not obtain a single adult fish in a 20-mile stretch of the Main Au Sable below Grayling (Sixth Biennial Report of the State Board of Fish Commissioners for 1883-1884, p. 33). Probably one of the last grayling caught was taken in 1900, and sent to the Museum of Zoology of the University of Michigan. Several factors probably contributed to the elimination of the grayling, such as log-running during the spawning season, and poaching (Sixth Biennial Report of the State Board of Fish Commissioners for 1883-1884, pp. 33-34). Mershon (1923), observing the grayling from the fisherman's viewpoint claimed that competition and predation from the rainbow and brook trout was the deciding factor in the elimination of the grayling, (p.170-171), and also mentioned that over-fishing played a part (p.170).

With grayling fishing on the decline, the Michigan Fish Commission (Six Biennial Report of the State Board of Fish Commissioners for 1883-1884) decided to stock brook trout in the Au Sable River System, and in March, 1885, Rube Babbitt planted 20,000 brook trout fry in the Main Stream at Grayling, Michigan (7th Biennial Report of the State Board of Fish Commissioners from Dec. 1, 1884 to Dec. 1, 1886, p. 114). Many thousands have since been planted by State and Federal agencies.

It was approximately at this time that rainbow trout (Salmo gairdnerii irideus) were introduced in large numbers (Bower, 1911, p. 197) into the Au Sable River System, although Bower mentions a small planting of rainbow in the "middle seventies", which are recorded neither on State nor Federal planting records. They probably were planted, however, since L. D. Norris of Battle Creek, Michigan, is credited with having caught several eight inch "salmon" during the summer of 1877 (Mershon, 1923, p. 179).

Brown trout (Salmo fario) were first planted in the Au Sable River System in 1891 (Tenth Biennial Report of the State Board of Fish Commissioners from Oct. 1, 1890 to Dec. 1, 1892, p. 203). Both brown and rainbow trout have been heavily stocked in many parts of the Au Sable System.

All three species of trout are now caught in the North Branch of the Au Sable, although the number of brown trout caught has increased, and the number of rainbow has decreased, according to the creel census records and angler's reports.

According to Mershon (1923), rainbows were not common in anglers' catches even in 1900 on the North Branch. He records that on May 12-14, 1900, of 1,038 trout taken all were brooks except four rainbows, and these rainbow were caught 3 miles below Dam 4 (p. 165). It is unfortunate that Mershon's records were not more detailed, but between 1900-1910 he did not record his trout catches by species. One entry in Mershon's personal diary in 1913 shows that the rainbow had evidently increased, since in that year the Au Sable Trout and Game Club took 449 brook trout and 445 rainbows during the open season.

By 1926, the ratio of brook to rainbow had changed to 4 to 1, according to the records of M. B. Trautman, Assistant Curator of Fishes, University of Michigan Museum. It was also about this time that Mershon indicated in his diary that the brown trout was beginning to show up in the anglers catches - a fact that he and many since have long and violently bemoaned.

At present, the fisherman's catch in the North Branch above Lovells consists almost entirely of brook and brown trout in the approximate ratio of 4 to 1, according to anglers. Only occasionally are rainbows still taken. Of approximately 3810 wild trout caught and tagged above Lovells, only 180 were brown trout and 10 were rainbows (Table 27). The small ratio of brown trout seined may be attributed to their wariness and to their habit of lying in relatively unseinable water.

Mershon's diary gave yearly records for the catch of his lodge, and these records are here reproduced (Table 55), by his permission.

Mershon also tried to estimate the fishing yield of legal trout per year for the North Branch for the year 1909-1913 inclusive. These estimates were made by contacting various clubs, private lodges, and the hotel at Lovells. I believe them to be fairly accurate, since fewer people by far fished the river then than in recent years. These estimates, showing great fluctuation with a large catch every other year, are shown in Table 56.

The only present-day figures available to compare with records kept by Mershon are those of the General Creel Census, which since 1928 has yearly included entries for the North Branch. These catch records of individual anglers were obtained by a presumably random sampling, but in some years a few records were taken, or the entries were not distributed evenly over the entire trout seasons. Although the creel census records (Table 57) are not directly comparable with the records of Mershon (Table 55), they most certainly indicate that more fish were caught per fisherman in the early 1900's than are caught by the anglers of today. It is possible that the total catch is as great, but it is probably spread over a greater number of creels. Certainly the stream is fished by a greater number of fishermen than in the time treated by Mershon's records. The projected intensive creel census on the North Branch will provide data on the total catch that will be valuable for comparison with Mershon's figures.

Table 55

YEARLY CATCH OF LEGAL TROUT FOR HIGH BANKS LODGE, NORTH BRANCH OF AU SABLE RIVER

Taken from the records of W. B. Mershon. No fishing during the month of June, according to records.

Year	May[a]	July Aug.[b]	Total	Remarks
1911	661	86	747	8 inch limit - flies only.
1912	441	334	775	" " " " "
1913	682	147	829	" " " all baits
1914	408	122	530	" " " " "
1915	584	162	746	" " " " "
1916	806	278	1084	7 inch limit - all baits
1917	442	305	747	" " " " "
1918	816	73	889	" " " " "
1919	869	254	1123	" " " " "
1920	875	131	1006	" " " " "
1921	557	272	829	" " " " "
1922	333	49	382	8 inch limit " "
1923	149	54	203	" " " " "
1924	13	237	250	" " " " "
1925	61	224	285	" " " " "
1926	178	107	285	" " " flies only
1927	331	169	500	" " " all baits
1928	233	238	471	7 inch limit all baits
1929	104	244	348	" " " " "
1930	169	157	326	" " " " "
1931	244	135	379	" " " " "
Average	426	180	606	

[a] 6 to 9 fishermen usually fished in this month, but their actual fishing time was not recorded.

[b] Records state that rarely more than 2 people fished in these months.

Table 56

TOTAL CATCH OF TROUT FOR THE NORTH BRANCH OF THE AU SABLE, 1909 to 1915 INCLUSIVE AS ESTIMATED BY W. B. MERSHON.

Season	Total trout catch
Apr. 15 to Aug. 15, 1909	18,181
"Season" of 1910	31,061
"Season" of 1911	18,532
"Season" of 1912	28,924
"Season" of 1913	15,269[a]
Average	22,399

[a]In this year, the Au Sable Trout and Game Club recorded 449 brook trout, 445 rainbow trout.

Table 57

SUMMARY OF YEARLY CREEL CENSUS RECORDS FOR THE CATCH OF LEGAL TROUT IN THE NORTH BRANCH OF THE AU SABLE

Trout season	Fishermen hours	Recorded catch of legal trout			Catch per hour
		Brook	Brown	Rainbow	
1928	91	105	3	3	1.2
1929	188	117	20	3	0.7
1930	73.5	34	3	3	0.5
1931	112	102	20	4	1.1
1932	...	...	..	...	...
1933	89.5	94	62	7	1.8
1934	17.25	5	..	...	0.3
Total	571.25	457	108	20	1.0

Fishing Intensity on the North Branch of the Au Sable River as Computed from Recoveries of Tagged Brook Trout by Fishermen

Computations based on the recoveries of marked trout by anglers on the North Branch may be taken to indicate the fishing intensity on this stream. It is true that not all recoveries of marked fish have been reported, but it is believed that at least 75 per cent have been returned.

For the years 1934, 1935 and 1936, it is calculated that 49, 29, 11 per-cent respectively of the marked legal brook trout were caugth by the fishermen (Table 58). These computations are based solely on fish which were of legal size (7 inches or longer) at the time of tagging and which were recovered during the season in which they were tagged, since it was not certain how many under-sized fish would grow to legal size during the course of the season. The reasons for the decline in the percentage of trout removed may be that the number of fishermen-days decreased in reference to the population of brook trout, or that the fishermen during the period were less successful in catching brook trout, or that fewer tags were reported from year to year. However, this decline is so large as to indicate that there probably occurred a definite increase in the stock of fish.

The percentage of tagged fish (of legal size when tagged) that were taken by fishermen during the season following that of tagging was also computed (Table 59). In the 1935 trout season, 439 legal brook trout were supposedly available from 1934 tagging activities; of these 24, or 5.5 per cent were caught. In the 1936 trout season, or 467 legal brook trout theoretically available from 1935 taggings, 19, or 4.1 per cent were taken by anglers.

Approximately 29 per cent of the legal fish available were captured in 1935 (Table 58). If it is assumed that the percentage of removal would be constant for legal fish tagged in 1934 and recovered in 1935, 29 per cent or 127 of the

439 available legal tagged fish should have been recovered in 1935. However, fishermen reported the capture of only 5.5 per cent (24 of 439). This discrepancy (Table 59) possibly indicates a mortality of 81 per cent of the legal stock between one fishing season and the next. From recoveries of legal fish in 1936 tagged in 1935, by similar calculations, a mortality of 63 per cent is indicated.

Any conclusions from the data just presented are rendered uncertain by the following factors:

(a) Migration by fish out of the area. This source of error is relatively unimportant because of the many recoveries of tagged fish taken in the same general locality as much as one year later, and the insignificant number of returns from great distances.

(b) Loss of tags from the fish. This objection is partially valid, since the small fingerling tags were extensively used in 1934 to tag both legal and under-sized fish (see p. 27).

(c) Incomplete returns from the fishermen. It is known that not all returns were reported by fishermen.

No definite conclusions are drawn from the data under discussion in this section. However, this discussion has been presented to outline a possible method for the evaluation of the effect of the sport fishery on a stock of fish. The proper way to solve this general problem of "fishing take" would be to conduct an intensive creel census in conjunction with the marking experiments. This joint study would yield a close estimate as to the number and percentage of legal fish removed from the stream during the course of the season.

Table 58

CALCULATED PERCENTAGE OF THE LEGAL (7 inches) TROUT POPULATION REMOVED

BY ANGLERS IN 1934, 1935 and 1936.

Calculations based only on trout which were legal (7 inches) at time of tagging and which were recovered in the same fishing season. Inferior figures indicate numbers of days from which the percentages are derived.

Year	Number of legal brook trout tagged	Number of legal brook trout tag- caught	Percentage of total no. of tagged fish taken by anglers	Calculated percentages of all legal trout caught
1934	259	34	15.8_{40}	49_{125}
1935	292	33	18.6_{84}	29_{132}
1936	447	28	8.6_{104}	11_{137}

Table 59

CALCULATED PERCENTAGE OF THE LEGAL TROUT POPULATION LOST TO THE

ANGLER BETWEEN TWO SEASONS

Inferior figures are percentages of the total number of tagged fish available.

Year	Total no. of legal tagged fish available from preceding yr.	Expected[a] total catch tagged fish from preceding year	Actual catch legal fish tagged during preceding yr.	Not reported	Calculated percentage legal fish lost to anglers
1935	439	127_{29}	$24_{5.5}$	103	81
1936	467	51_{11}	$19_{4.1}$	32	63

[a] These percentages are derived from Table 58 assuming that the percentage as indicated should apply to all legal fish.

MOVEMENTS AND GROWTH OF THE BROWN AND RAINBOW TROUT IN THE NORTH BRANCH OF THE AU SABLE AS DETERMINED BY TAGGING EXPERIMENTS

Only scant information was obtained concerning the migration and growth of brown trout in the North Branch of the Au Sable River, because only 180 individuals of this speces were tagged, and because the percentage of returns (12.8 per cent) was only half that recorded for the brook trout. None of the 15 brown trout recaptured during the year of tagging showed any migration whatsoever. They were usually captured only a few days after tagging, and for this reason little could be learned of their growth.

Eight recaptures made during the fishing season following the one in which they were tagged showed that the brown trout grew considerably in length between November and the following June (Table 60). It will be noted that two fish were recovered 300 days later in the exact hole where they were released after tagging. A similar record was found in the earlier tagging work on the Little Manistee River. These similar records suggest that individual fish may have favorite home ranges to which they return each year, or in which they spent the entire year.

The recovered brown trout which had been free for the longest time had grown from 8 inches to 14 inches in 660 days, and had moved downstream about 3 miles into deeper water in the Old Mill pool at Lovells.

Of the 10 rainbow trout which were tagged in the course of the investigation on the North Branch, only 2 were recovered, both in 1935. Both had been tagged in June. One recovered in September had grown from 6.75 to 7.875 inches; the other, recovered in November, had grown from 6.25 inches to 8.00 inches. Both were caught in the hole where they were tagged.

Table 60

GROWTH AND MOVEMENTS OF TAGGED BROWN TROUT OVER THE WINTER

Directions are given as downstream (D), upstream (U) and No migration (0)

Date of tagging	Date of recovery	Days free	Original length	Increase in inches	Direction and miles moved
9/18/34	7/4/35	289	4.625	4.125	U-6.0
7/27/34	11/4/35[a]	470	7.250	5.250	U-0.5
11/13/34	5/3/35	171	9.875	0.125	U-3.0
9/26/34	6/20/35	267	4.000	3.500	U-3.5
8/22/35	5/17/36	272	8.875	3.125	D-0.75
8/22/35	6/24/36	304	7.125	3.625	0
8/22/35	6/24/36	302	6.750	4.750	0
8/8/34	5/23/36[b]	660	8.000	6.000	D-3.0
Average		296	6.93	3.5	

[a] This recovery made by Institute for Fisheries Research, all others by fishermen.

[b] This recovery not included in averages.

THE BEARING OF TAGGING EXPERIMENTS ON FISH CULTURE AND FISH MANAGEMENT

It has been previously pointed out that marking experiments were first conducted chiefly because of curiousity concerning movements and growth of fish. However, aside from being a tool for natural history study, marking experiments can and should be more widely used in attempts to clarify problems which are essential to the efficient management of the game fish supply. Such experiments are particularly needed to place stocking policies on an effective and predictable basis.

Enough has been learned from the researches in Michigan and elsewhere to warrant the definite expectation that tagging or marking experiments, coupled with adequate recovery of marked fish by intensive creel census or by seining, will prove a practicable means of answering such questions as the following: What return to the angler's creel can be expected of trout stocked at different times of the year? What percentage of the advanced fingerlings stocked in the fall in different streams are lost over the winter and early spring? W hat would be the increased rate of survival (if any) if the fish were stocked just before or during the fishing season?

If this question were adequately answered, it might be determined whether a change in the stocking policy would justify the added cost of retaining the fish in rearing stations over the winter.

Results of marking experiments to determine the survival and growth of small fingerlings, or even fry, in certain feeder streams might warrant the utilization of these feeders as natural raceways. If favorable results were obtained from such experiments, the stocking program of a hatchery might be more economically spread over the entire year, and put in charge of a man specifically trained and responsible for the stocking operations.

What length of time after planting is required for a liver-fed hatchery trout to assume the colors, habits, and perhaps taste of a wild fish? What number of trout should be stocked in a given stream to avoid diminishing returns that result from overstocking? What percentage of the anglers' catch of trout is the result of natural reproduction rather than of stocking? How effective, therefore, is fish culture in maintaining the stock? What increase in natural reproduction can be effected by stream improvement? To what degree can the survival and growth of trout in the stream be increased by improvement methods? The answers to these questions are of vital importance to the fish culturist and fisheries technician, and tagging and marking experiments, properly applied present a means for their solution.

From the analysis of the recoveries on both wild and hatchery brook trout that were tagged and released in the earlier Michigan experiments, and from the results of the migration studies on the North Branch, it is evident that the legal-sized brook trout of the Lower Peninsula are very restricted in their migratory movements.

In order to insure a wide distribution of planted fish of legal or nearly legal size, it would therefore seem necessary to distribute the plantings extensively up and down the stream being stocked. Whether fry or fingerling trout planted at one point disperse widely through a stream system has not yet been learned, but could readily be determined by well-planned and executed experiments involving the marking of the fry or fingerlings and adequate recovery of the marked fish after they have grown to legal size.

Marking and tagging experiments now in progress in Michigan, or planned for the immediate future will, it is hoped, ~~will~~ answer some of these questions concerning the stocking of trout in Michigan streams. On the South Branch of the

Pine River, located in the Huron National Forest, fall (1936) and spring (1937) plantings of several hundred marked hatchery brook trout have been made and by means of an intensive creel census during the 1937 trout season data on the relative effectiveness of planting different sizes and at different seasons, in terms of fish taken by the angler, should be obtained. The North Branch of the Au Sable will also be subjected to an intensive creel census over about 8 miles of the stream. It is hoped to obtain further data on the effectiveness of fall planting, as 9700 hatchery brook trout fingerlings were released in the North Branch last October.

Another tagging experiment is projected for the Pine River (South Branch of the Big Manistee) during the summer of 1937. Twelve thousand adult trout will be planted in several ways in May, June, July, and August. Half of these fish (4,000 brook trout and 2,000 rainbow trout) will be tagged. In conjunction with the marking experiment there is to be an intensive creel census on the section of the river in which the plantings are to be made, so that an accurate estimate should be obtained of the catch by fishermen of legal-sized trout planted during the season.

Investigators concerned with lake and stream improvement have found that increased food production and shelter have resulted from their efforts to alter the ecological conditions of lakes and streams, but as yet there has been no clear-cut demonstration in Michigan that the total game fish population or catch of any improved lake or stream has been increased throughout its area or length as a result of altered environmental conditions. A carefully planned and well-conducted marking experiment, conducted before and after the installment of improvement devices, would furnish definite evidence as to the changes in the fish population if any does occur. Preferably the fish population should be estimated from the results of marking experiments for at least three years before the improvement devices are installed, and for three years after the installation, to avoid complications which might be introduced through natural fluctuations in the populations.

Where accurate knowledge on the percentage of the fish population taken by angling is desired, it will be necessary to conduct an intensive creel census jointly with the marking experiments. The author's study on the North Branch of the Au Sable furnished a rough estimate of the percentage of the total legal brook trout population, but more accurate figures than obtained for 1934, 1935 and 1936 would be desirable. To date, intensive creel censuses in Michigan have largely been confined to lakes (Eschmeyer 1935). They have contributed much information on the fish caught by anglers, and this information has proved to be of general interest and of value in fish management. Such intensive inventories of the catch should be extended to the streams of the state, or to the heavily fished portions of the more important streams, since little is known concerning the actual number of trout now being removed. The total actual catch, including the number of marked fish caught, should provide the means of estimating the drain on the stock of legal fish by the angler.

A minor contribution to fish-cultural practice will be made during the coming year by tagging the males of the brood bass at the Dwight Lydell State Hatchery at Comstock Park, Michigan. Heretofore, only an expert could distinguish the sexes before this species reached the peak of maturity, and hatchery operations were some times complicated and production lowered because of inability to segregate the sexes correctly to the spawning boxes. The marking of the male brood stock during the coming spawning season will eliminate this difficulty in the following year. Obviously the tagging of brood fish would be valuable in experiments involving selective breeding.

It has been demonstrated by the investigations on the North Branch that the seasonal history of a stock of fish may be followed closely by markings. As a result of these preliminary experiments, certain difficulties in field practice and in the analysis of the results have arisen that suggest the following procedures in future work along the same line:

(1) If possible, place all marked fish in the water at a given time before any recovery efforts are made.

(2) Determine by trial at which points fish (both marked and unmarked) are likely to be captured, both near the point of liberation, and at greater distances from this point. Sample all such localities at regular intervals. By so doing, calculation of rate of growth on the tagged fish recovered at sampling intervals will be easily and accurately computed, since more recoveries will fit a fewer number of time intervals on which growth will have to be calculated. Determination of migration indices will also be simplified because there will be a constant (except for fish removed by anglers) number of tagged fish available.

(3) In order to evaluate more closely the mortality of marked fish in natural waters, control experiments should be conducted at hatcheries concurrently with the field experiments, involving marked and unmarked fish of the same size and stock which were marked and released in nature.

(4) Marking experiments designed to evaluate fish cultural and fish management practices would be best confined to smaller streams, or to small sections of long streams, since the time, expense, and effort required to sample entire streams by intensive creel censuses or by netting would be very great.

SUMMARY

From marking experiments conducted at fish hatcheries, it has been proven that the jaw-tag method of marking trout is superior to the methods of tagging which were previously used in Michigan. Despite the fact that some of these hatchery experiments were complicated by disease and hatchery operation, results were obvious enough to warrant faith in the method. Later the adequacy of this method was substantiated by results from experiments in the natural waters of the state. However, more controlled experiments on the survival of marked and jaw-tagged fish over periods of time as long as 2 years or more would be desirable.

The earlier tagging work in Michigan waters in which the strap tags were attached to the gill-cover (or earlier to the caudal fin rays), and in which recoveries were obtained through the unrewarded cooperation of anglers, yield relatively little data, for only 2.1 per cent of the tagged fish were recovered. Results of an interesting nature were obtained even though these methods of attaching the mark were later proven to be inferior to that of jaw-tagging. A brief resume of the migratory habits of those species marked from which sufficient return have been made is here presented.

Movements of Adult Rainbow Trout (See Maps 1 and 2, Table 5).

The mature adult rainbows move in from Lake Michigan early in the spring to seek suitable gravel spawning beds in the tributary streams, usually in the middle and upper reaches of the streams. The time spent in the stream after spawning appears variable. Once spawning has been completed they return to Lake Michigan, as evidenced by the recoveries of fish at various points in Lake Michigan marked at the various dams and spawn-taking stations. The rainbow probably return as a rule to the same stream to spawn, but not always, as evidenced by recoveries of marked fish in streams other than that in which they were tagged. Some evidence has been accumulated to indicate that the rainbow are incapable of surmounting beaver dams in their spawning run. The recovery in the Manistee River of rainbow trout tagged near Port Washington, Wisconsin further strengthens the conclusion that the streams of western Michigan serve as the breeding ground for the rainbow trout stock of Lake Michigan.

Little is known concerning the movements of immature rainbow trout, since relatively few were tagged or recovered. In his studies on the breeding habits and growth of rainbow trout in Michigan, Greeley (1932, 1933) demonstrated by scale studies that the young of the rainbow usually spend two years in the stream of birth, but may spend as long as 3 or 4 years before migrating to Lake Michigan. The time of the movement to the lake was stated by Greeley to occur during the fall months, but possibly as late as May (p.362). The size reached by the immature rainbow is of importance, since it is the fish of this group which are more available to the sport fishery in the streams than they are as adults when scattered over the larger lakes. In many streams they do reach legal size (7 inches) before moving downstream, but in the Little Manistee River the number of under-sized fish far outnumber the legal rainbow.

Movements of Adult Hatchery and Wild Brook Trout

Although marked hatchery fish tended to move somewhat farther than did marked wild fish, as a generality the brook trout may be said to be relatively non-migratory, during the warmer seasons, especially in the Manistee River system (See Map 1). Short migrations are probably made in search of suitable spawning territory in the fall of the year, as demonstrated by the marking experiment on wild fish in Little Beaver Creek. The tendency of adult hatchery fish of large size to move farther than smaller wild fish has been attributed to the method of planting these fish, in large numbers in waters probably already occupied by a population of fish. In these earlier studies only inferential evidence is available on winter movements. Since in all the experiments on the Manistee River system, the hatchery fish were tagged and planted in the fall and recovered (with the exception of Bear Creek) at the point of release early in the following fishing season, it is concluded that the fish remained at the point of planting during the winter, or else returned to the point of planting following the onset of spring. None of the marked brook trout in any experiment were recovered farther than 30 miles from their point of release.

Movements of the Brown Trout

The few recoveries made of tagged brown trout suggest that this species is also stationary in its habits, possibly moving in the fall of the year in search of spawning grounds.

Movements of Wall-eyed Pike in the Inland Water Route

Recoveries of wall-eyes captured at the Cheboygan Dam on the early spring spawning run, and then marked and released at several points throughout the Cheboygan River system, definitely indicate that the wall-eyed pike dispersed indiscriminately throughout the Inland Water Route after release, some moving as far as 35 miles. Marked fish released in Crooked, and Mullet lakes and later caught at the Cheboygan Dam suggest that some of the wall-eyed return to Lake Huron after spawning. This evidence is further supported by the recovery in the Straits of Mackinac of a marked fish which had been liberated above the Cheboygan Dam. The continued sport fishery for these fish in all parts of the Inland Water Route suggests that this spawning run in the Cheboygan River augments the wall-eye stock inhabiting these waters, and the stock now present in these lakes may have originated from spawning runs of wall-eyes that normally returned to Lake Huron.

Movements of Northern Pike

Northern pike migrations also occur chiefly in the spring, usually in the month of April, when the mature individuals start to search for shallow, weedy marshes in which to conduct their breeding activities. In the Pine River in Gratiot County, this movement takes place in an upstream direction and marked individuals moved as far as 25 miles above the point of tagging. The majority, however, evidently spawned in the dam backwaters above Alma, as many were caught by fishermen at this point shortly after the opening of the fishing season. Northern pike inhabiting lakes probably seek out the nearest suitable marsh connected with the lake.

Tagging Experiments on Wintergreen Lake have yielded a small amount of information on the growth of the bluegill and the large-mouthed bass, but this information should be supported by further marking experiments on younger, smaller fish, as the fish recovered were all adults, nearing the maximum for age. The population of legal sized bluegills (6 inches or longer), and legal-sized large-mouthed bass (10 inches or longer) was calculated from the available creel census data involving the number of marked and unmarked fish caught. The population of legal sized bluegills was estimated to be approximately 780 per acre, and the legal-sized bass population was estimated to be approximately 195 per acre. These calculations compare favorably with estimates of the legal sized large-mouthed bass and blue-gill populations made on other Southern Michigan lakes after the severe fish mortality during the winter of 1935-1936.

The experiments on the North Branch of the Au Sable River, dealing with brook trout almost exclusively, showed that the movements and growth of a stock of fish can be followed over a period of time by marking and repeated seining. Periodic sampling, as by seining, is much more desirable than complete dependence on the co-operation of the fishermen, because more accurate and more extensive returns are obtained. Fisherman's recoveries are probably more important in determining the extreme limits of wandering of the stock, however.

It has been established that the brook trout population of the North Branch in the region of Lovells is relatively stable during the warmer months of the year, and that just before the spawning season (November) a movement slightly upstream usually occurs, depending on the location of the nearest spawning grounds. The adult fish may remain on or near the spawning beds until severe cold wather begins. On the basis of early season recoveries by fishermen in the years following tagging, a downstream movement of the trout population is postulated, supported by the great decrease in the number of trout caught per seine haul in areas where tagged fish are taken during the warmer months, also by one recovery reported from a stream on the south side of the Main Au Sable.

That they return to the same areas in the season following tagging has also been demonstrated by the recovery of an adequate number of marked fish in the places where they had been tagged in the previous year. The movements of the brook trout in the North Branch may be limited by the presence of Dam 2 upstream, and by the warm water fauna and ecological habitat known to exist in the lower stretches of the river.

The growth of brook trout within the year of tagging (usually between June and November) was determined for three different arbitrarily designated, "seasons", as explained on p. 121. Brook trout 2 to 8 inches in length made an average gain about 0.1 inch per ten days during the "summer" period, and the few fish of 8 to 10 inches in length made an average gain of about 0.07 inches per 10 days of "summer". "Fall" growth was slightly more than half of the "summer" growth, as it was about 0.06 inches per 10 days. "Early Winter" growth though very small, was measurable, as recoveries made in January, 1936, were found to have grown between 0.02 and 0.03 inches per 10 days since the preceding November.

No computations were made on fish recaptured in the year after tagging, since there were not enough fish which could be grouped in similar tagging and recovery periods. All data on which growth was computed were obtained from measurements made by the same individual on the marked fish when alive, eliminating any chance of error which might be involved in shrinkage at death.

The calculation of the brook trout population provides an estimate of the density of this species in this particular section of the stream. It was estimated that per acre there were approximately 800 brook trout 4 to 10 inches long. This estimate is open to criticism, since it is possible that the known number of tagged trout in the stream at the time of seining in November was miscalculated because of death to tagged fish, loss of tags from fish, and because not all tagged fish caught in the summer previous were reported. The latter source of error is probably the most serious, and the first two are probably almost negligible.

The angling history of the North Branch was presented, based largely on records obtained from the personal diary of W. B. Mershon. If the records of this gentleman are correct, trout fishing in the days gone by was several times better than it is now.

Data furnished by tag returns from fishermen formed the basis for tentative conclusions concerning the loss of the natural stock of brook trout to the fishermen for the years 1934, 1935 and 1936. In these years it was computed that 49, 29 and 11 per cent respectively of the fish which were legal at the start of the season were removed during the season. This decline suggests very strongly that there was an increase of the brook trout population through these three years.

By similar calculations on legal-sized fish brook trout tagged in 1934 and 1935, and recovered in 1935 and 1936, a mortality between the respective seasons of 81 and 63 per cent was indicated. Factors which complicate these calculations were outlined.

The movement and growth of the brown and rainbow trout in the North Branch were discussed briefly, since there were not an adequate number of recoveries on which to make any detailed analysis.

A discussion on the bearing of tagging experiments on fish culture and fish management was presented. In this discussion, it was pointed out that tagging and marking experiments, properly applied, can solve many of the problems vital to the continued success of a sound and economical fish management program. Suggestions for the general operating procedure whereby recovery data might be more accurately and more easily analyzed were also offered.

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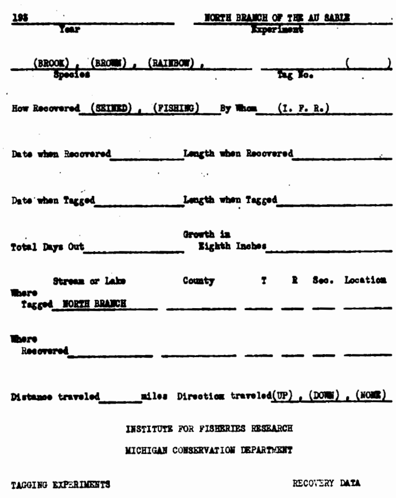
Illustrations.

Figure 1. No. 3 strap tag (upper), and fingerling tag (lower.) About 7/8 life size. Weight of No. 3 tag approximately $\frac{1}{4}$ gram, of fingerling tag, about 1/7 gram. (Photo by Ouradnik)



193 ____ Year NORTH BRANCH OF THE AU SABLE Experiment

(BROOK), (BROWN), (RAINBOW), Species ____ ( ) Tag No.

How Recovered (SEINED), (FISHING) By Whom (I. F. R.)

Date when Recovered ____ Length when Recovered ____

Date when Tagged ____ Length when Tagged ____

Total Days Out ____ Growth in Eighth Inches ____

	Stream or Lake	County	T	R	Sec.	Location
Where Tagged	NORTH BRANCH					
Where Recovered						

Distance traveled ____ miles Direction traveled (UP), (DOWN), (NONE)

INSTITUTE FOR FISHERIES RESEARCH

MICHIGAN CONSERVATION DEPARTMENT

TAGGING EXPERIMENTS RECOVERY DATA

Fig. 1- Card used to file information on the recovery of a tagged fish, Size 3 x 5 inches.

Figure 2. Cards used for filing information on recovery of a tagged fish; size 3 x 5 inches. (Photo by Ouradnik)

ATTENTION FISHERMEN!!

Over 3,000 Trout have been tagged in the North Branch. If you catch a tagged fish, please report tag number, length of fish, exact location caught, and species (brook, brown or rainbow) to

C.C.C. CENSUS CLERK -OR

Conservation Department *or* **Post Office**
Lansing, Michigan **Lovells, Mich.**

-or-

Institute for Fisheries Research
University Museums
Ann Arbor, Mich.

REASON FOR TAGGING

The tagging of the fish is done for your benefit!! Through tagging returns, the movements and growth rate of trout can be worked out. These facts should make possible more practical methods of stream improvement and stocking. Every Fisherman can aid this work by turning in tag numbers from any tagged fish caught. **LET'S WORK TOGETHER FOR BETTER FISHING!**

Figure 3. Posters used on the North Branch of the Au Sable.
(Photo by Ouradnik)

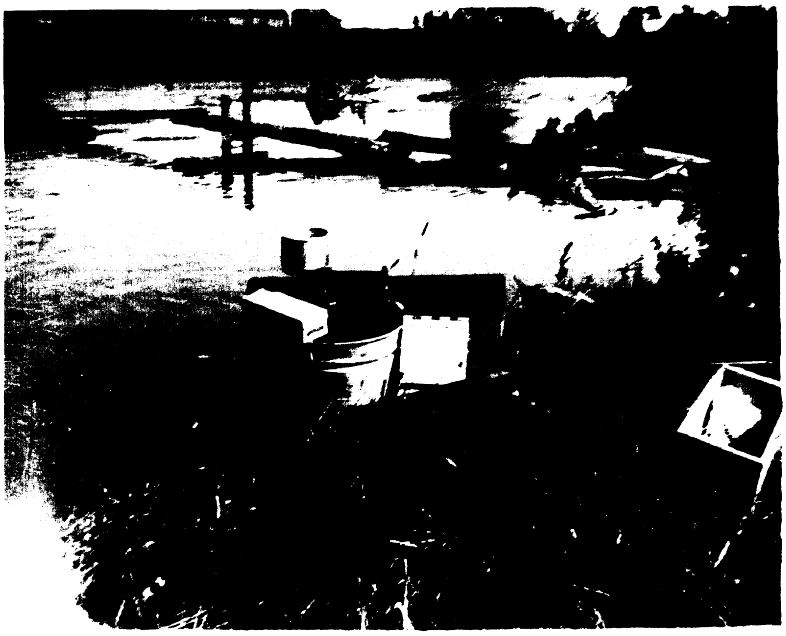


Figure 4. Equipment used in the experimental work, seine, measuring board, scale envelopes, balances, etc. (Photo by the author)

Figure 5. Drawing the 60 foot seine at the Island Hole deflector. (Photo by Jack Van Coevering)

Figure 6. Inspecting the catch. (Photo by Jack Van Coevering)

Figure 7. T he seine is bagged and the fish gently moved to a convenient place to sort them, preferably near a spring. (Photo by Jack Van Coevering)

Figure 8. This particular brook trout was recovered in the seine haul (Figure 5). It had been tagged approximately 1 year before. (Photo by Jack Van Coevering)

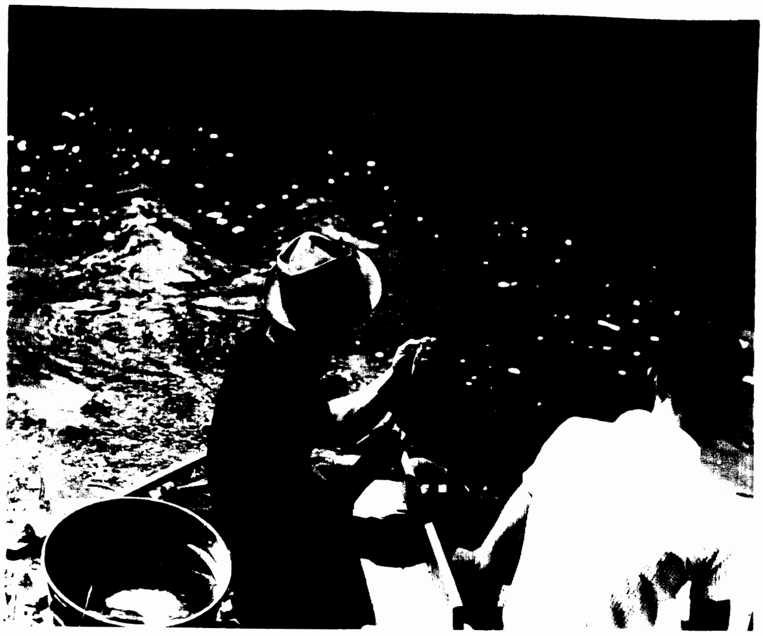


Figure 9. Tagging operations on the unmarked fish captured. (Photo by Jack Van Coevering)

Figure 10. Brook trout showing the No. 3 strap tag applied by the jaw-tag method. (Photo by Ouradnik)

Figure 11. North Branch of the Au Sable looking upstream from Dam. 2. (Photo by the author)

Figure 12. North Branch of the Au Sable looking downstream from Dam 2. (Photo by the author)

Figure 13. Looking upstream from Anderson's Bridge. Note the extensive stream improvement in this and in the next figure. (Photo by the author)

Figure 14. Looking downstream from Anderson's Bridge. Note the extreme width of the river here. (Photo by the author)

Figure 15. The Island Hole, where many trout were tagged, and later recovered by fishermen. (Photo by the author)

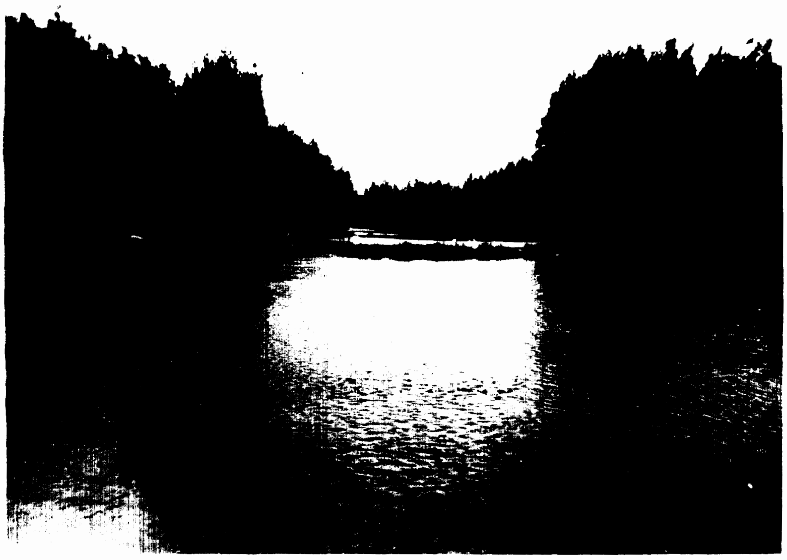


Figure 16. Looking downstream from the "Gravel Pit," a favorite spot to many of the fishermen on the North Branch. (Photo by the author)

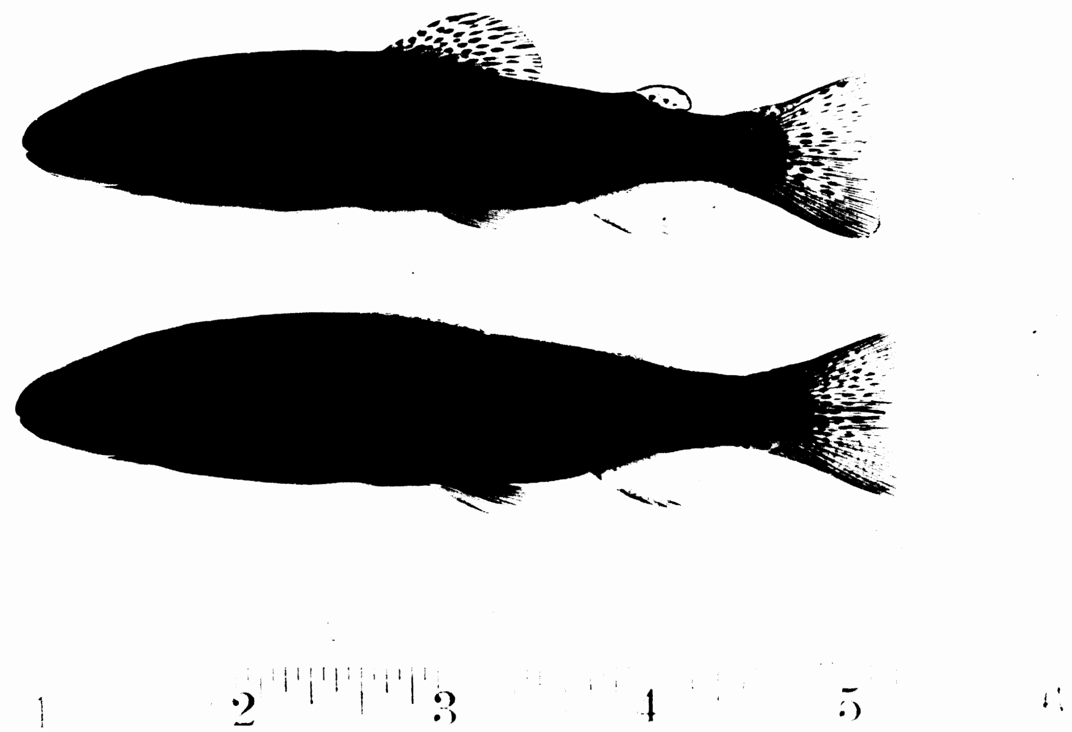


Figure 17. Showing a normal (upper) rainbow trout fingerling and a fin-clipped (lower) rainbow trout fingerling. (Photo by Ouradnik)

AIIM SCANNER TEST CHART #2

Spectra

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Greek and Math Symbols

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Black

Isolated Characters

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MESH HALFTONE WEDGES

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85

100

110

133

150