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OBSERVATIONS ON MOVEMENTS OF WILD TROUT IN TWO MICHIGAN STREAM DRAINAGES[1]

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Abstract

This report deals with the migration of wild brook trout and brown trout, over 7 inches long, in the Hunt Creek and upper Au Sable River systems. Between 1934 and 1967 we jaw-tagged 3,320 brook trout, 5,615 brown trout; anglers reported catching 346 of the brook trout, 480 brown trout.

Brook trout were recaptured close to where they had been tagged and released--91% within one mile, the remainder within 11 miles.

Migration of brown trout (in the Au Sable system) was more variable. Seven- to 13-inch browns stayed mostly (75-88%) within one mile of tagging sites. Most browns over 13 inches in the North and South Branches Au Sable migrated several miles (some up to 10 to 40 miles), but in the Main Au Sable 90% of the big browns were less than one mile from tagging site.

Spring-tagged trout gave 1.8 times as many returns as fall-tagged fish. Brook trout recoveries were 97% within the first year after tagging; whereas 67% of the reports for browns came within the first year, and 33% after 2 to 5 years.

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The data reported on here were gathered from two neighboring drainages in the north-central part of the lower peninsula of Michigan, both of which have harbored wild trout for much of the present century. Information on movements of wild brook trout (Salvelinus f. fontinalis) are given for Hunt Creek, a tributary of the Thunder Bay River. The movements observed among wild brook trout and wild brown trout (Salmo trutta) are listed for the North Branch of the Au Sable, Main Au Sable, and South Branch of the Au Sable River. Hunt Creek differs noticeably from the other streams in that it is much smaller in physical dimensions and flow; at the time of observations there it contained only wild brook trout. My objective was to determine if there were any significant movement patterns among the wild brook trout and brown trout in these four streams.

Description of experimental areas

Hunt Creek

Shetter (1950, 1961) described the physical characteristics and fish fauna of this small headwater brook trout stream. The headwater spring lies at above 1,080 feet above sea level, and the stream drops 288 feet in its 11-mile course before it joins the Thunder Bay River, according to the 1955 U.S.G.S. map of the Comins Quadrangle.

North Branch Au Sable River

This stream heads a few miles east of Otsego Lake in Otsego County, and flows southeasterly for about 33 miles. It rises at an elevation of 1,268 feet and drops over 200 feet before it joins the Main Au Sable River. The physical characteristics and fish fauna were described by Shetter (1937) in some detail. The uppermost 7 miles above Dam 2 in Otsego County is marginal trout water because of numerous lakes which empty into it above this point.

Main Au Sable River and South Branch Au Sable River

Hendrickson (1966) described the physical characteristics of the Main Au Sable River, including detailed maps (pp. 10, 11, 47-52). This stream is formed by the junction of Kolke Creek with Bradford Lake outlet about 3 miles north of Frederic, at an elevation of 1,247 feet above sea level. The uppermost 35 miles (to Wakeley Bridge) drops 204 feet.

The South Branch of the Au Sable heads in Lake St. Helen, about 12 miles southeast of Roscommon. Its twisting course is through rather flat cedar swamps and tag alder valley until it reaches Roscommon. Here, about 22 miles below Lake St. Helen, the stream receives the inflow of Robinson Creek, and supports some trout, as well as numerous rough fish and warmwater game fish, such as northern pike, yellow perch, and numerous common suckers and minnows. From Roscommon

to Chase Bridge (about 6 miles) is somewhat of a transition zone, and trout become more abundant. From Chase Bridge to the confluence with the Main Au Sable, about 15 miles, trout are the dominant species. The river course below Chase Bridge flows through alternate high shaded banks lined with alder and elm, or moderate banks with stands of mixed swamp conifers; long stretches of firm sand are interspersed with gravel and rubble riffles. Pertinent elevations for many sites are listed in Table 1.

Pertinent physical characteristics of the experimental waters

Stream gradients

The slope of the four streams was examined in some detail, utilizing available U.S.G.S. maps. Percentage of slope was calculated for the various stream sections, where tagging and most recoveries were made, after the manner employed by Huet (1938) for the Belgian Lesse (drop in feet/distance between points, expressed as a percentage). The data are listed in Table 2.

Hunt Creek has a much steeper average gradient (0.50%), followed by the North Branch (0.15%), Main Au Sable (0.12%), and South Branch (0.09%).

Stream flows

Data on stream flows in the four streams were furnished me by Dale Pettingill of the Grayling office of the Surface Water Branch, Water Resources Division, U. S. Geological Survey of the Department of the Interior. The average July flows (cubic feet per second) in the respective streams were as follows:

Hunt Creek, at Z bulkhead--22.5 c.f.s. (for the period 1944-1965).

Main Au Sable, 1,500 feet above Stephan's Bridge--136 c.f.s. (1963-1966),

at Grayling, US-27 Bridge--46 c.f.s. (1942-1965).

South Branch Au Sable at Smith's Bridge--134 c.f.s. (1959-1966).

North Branch Au Sable near Kellogg's Bridge--143 c.f.s. (1959-1966).

There is little difference between the flow of the experimental parts of the three branches of the Au Sable, but all are six to seven times greater than that observed in Hunt Creek.

Stream temperatures

The average monthly temperatures are shown in Table 3. Au Sable drainage average temperatures were obtained from numerous readings of a hand thermometer at random times between 8 a.m. to 11 p.m. In certain years, Hunt Creek average temperatures were similarly derived from records taken at the lower bulkhead; in other years, average monthly temperatures were calculated from average daily temperatures read off a thermograph chart. Hunt Creek was coolest

in all of the months of the trout season (averages 52° to 56°). The three Au Sable drainage streams appear to be about the same temperature in May (55° to 58°), but diverge somewhat as the season progresses (June, 61° to 65°; July, 63° to 67°; August, 60° to 65°; and September, 56° to 67°). In all of these streams, temperatures in excess of 75° F. will occur, late in the day, during extremes of air temperature (85° to 95°) in midsummer.

Hindrances to trout movement

There are no artificial barriers to impede trout movements on the South Branch of the Au Sable drainage.

On the Main Au Sable, a low head dam (approximately 5 feet) at the US-27 Bridge appeared to limit upstream migration. No recaptures of tagged trout were reported above this point. Low-head water control dams on the East Branch of the Au Sable at the State Fish Hatchery at Grayling were something of a barrier, but not entirely, as one tagged brown trout recapture was reported upstream.

The only barrier to movement on the North Branch Au Sable is the remains of an ancient lumbering dam at Dam 2 (about 4-foot head).

Hunt Creek was partially blocked at a number of points in the upper waters by beaver dams, and in the period 1949-1965, bulkhead traps were operated on the experimental stream portion of the Hunt Creek Fisheries Research Station. When fish were trapped in these

devices they were, however, passed on in the direction of movement. A 4-foot head dam at the old rearing station site has been in existence during the time period described herein.

Methods

Capture of fish for tagging

During the 1934-1936 investigations in the North Branch, wild brook trout were captured by a 60' x 6' x 3/8-inch (bar measurement) seine. No anaesthetic was used in the tagging operation.

Native brook trout were captured in Hunt Creek in the period 1945-1950 with 110/220 volt, 4.5 ampere, 2,500-watt alternating current electrofishing gear. Tagging operations were carried on coincident with spring and fall population studies in the $2\frac{1}{2}$ miles of Hunt Creek Fisheries Research Station experimental water. Ether and urethane were used as anaesthetics during marking.

In the 1959-1966 markings on the Au Sable drainage, wild brook trout and wild brown trout were captured at a number of sites (see Table 1, tagging done at underlined locations) by means of direct current electrofishing gear (220 volt, 10.9 amperes, 2,500 watts). In the Main Au Sable and the South Branch Au Sable, fish were tagged only during the fall months, but in the North Branch Au Sable, tagging was carried on both during spring and fall population study operations. Most of these fish were anaesthetized with MS-222 (Tricaine methanosulfate) before marking and liberation.

Tagging procedure and tags used

Wild trout were marked by affixing a Monel metal tag around the mandible, as described by Shetter (1936). As experience was gained, however, it was found unnecessary to cut a slit in the gular membrane for tag insertion. The tags used were of four sizes: for 7.0-11.9 inch trout the tag measured, when flattened, 35 x 3.5 mm. (weight--0.35 grams); for 12.0 - 19.9 inch trout the dimensions were 58 x 3.5 mm. (weight--0.70 grams); for trout larger than 20 inches the tag dimensions were 76 x 3.5 mm. (weight--0.85 grams). Some of the 1934-1936 North Branch brook trout were marked with the so-called "fingerling" tag which was 20 x 2 mm. (weight--0.16 grams).

In the actual marking process, captured trout were confined in a 15-gallon washtub of fresh stream water until an adequate number were accumulated. They were then anaesthetized with MS-222 in small groups (5 - 12) in a separate pail. Total lengths were measured on a board calibrated in tenths of an inch, following which the tag was applied, and the trout returned to the stream. The length of time elapsing from capture to release seldom exceeded 15 minutes. Under the cool to frigid air and water temperatures prevailing during Michigan falls and springs, losses from confinement and handling were rare. One man tagged the fish, while a recorder listed lengths, tag numbers, and species as they were put on the fish.

Recovery procedures

Although numerous recaptures were made with electrofishing gear, for this study only those tagged fish retaken by anglers were utilized. Fishermen generally penetrated to all parts of the respective drainages in their angling efforts, and recaptures of marked trout reported by them is assumed to provide an unbiased measurement of trout movements.

Anglers were encouraged to report captures of tagged fish by streamside posters, newspaper articles, radio announcements, and word-of-mouth. Those who sent in data by mail, or requested it verbally, were furnished information concerning movement and growth of the fish on which they reported.

The tagging information and the recovery data for each individual tag recovery were recorded on a keysort card to facilitate detailed examination of the data by stream, species, size of fish, season of marking, etc. The basic information consists of a list of tagged fish with individual length measurements marked at several sites on various dates with which a list of tag recoveries made at numerous subsequent sites and dates may be compared.

Some of the limitations which are placed on the interpretation of the observed results are:

1. In determining distances moved by tagged trout recaptured by anglers we were dependent on the accuracy of the location

description of the recovery site furnished by the angler. Such descriptions were utilized in conjunction with the map-measured distances between the sites listed in Table 1. Many of the anglers' descriptions were very accurate; others could be plus or minus one mile in instances where only township, range, and section were listed.

2. The variation in minimum legal length (7 inches, 9 inches, 10 inches) among the various portions of the Au Sable drainage in 1960-1966 undoubtedly reduced the expectation of recapture for a tagged fish marked and released at less than 9 inches or 10 inches. In turn, this might decrease detection of significant movement made. This limitation did not apply to the 1934-1936 North Branch or the 1945-1950 studies on Hunt Creek, nor the tagging done in the County line-Eaman's portion of the North Branch in 1960-1966.

Attention is called to the fact that the discussion of movement in the pages to follow pertains to wild brook trout and brown trout marked at the size of 7.0 inches, total length, or larger. All such fish were in their second fall of life, or older. Various other practical considerations influenced the decision to limit the minimum size of fish marked to 7.0 inches, particularly in the 1960-1966 period.

Data treatment

The numbers of fish in each length grouping for each stream were summed by species and season of tagging, and the recapture locations of each tag recovery from the various groupings of tagged fish were tabulated as to distance and direction of movement (see Tables 4 and 6) and totaled for the tables.

The numbers of fish tagged, and the tag recaptures later reported by anglers, are the summation of activities for the time periods indicated in Tables 4 and 6. For many of the tagging localities, in certain years, not enough fish of a species were tagged or recovered for valid statistical examination. However, when data for all years were summed for the various streams, species, seasons, and length groupings, the appropriate chi-square test (Snedecor, 1956) was utilized to determine statistical significance or non-significance of differences.

Results

Wild brook trout, North Branch Au Sable, 1934-1936

In the course of doctoral research, the author marked numerous brook trout of all sizes in the North Branch in several of the same approximate areas covered later by the 1960-1966 investigations. Data concerning tagged brook trout 7.0 inches or larger at tagging in the months of September, October, and November, 1934 and 1935, were extracted from the thesis material and are shown in Table 4. A total of

421 brook trout were tagged, of which 18 were later reported by anglers (4.3%). All were recaptured the first season following tagging, and 17 of the 18 were caught before June 30.

The distribution at recapture was: 10 recoveries were within 1 mile of the release point (56%), while two were noted 1 to 3 miles upstream (11%), and six were caught 1 to 3 miles downstream (33%).

Wild brook trout, Hunt Creek, 1945-1949

Native brook trout larger than 7.0 inches were tagged in the semi-annual spring and fall population studies conducted on the experimental portions of Hunt Creek between 1945 and 1949. In this period a total of 135 were marked in the spring of the year (almost all in April of which 67 were later retaken by anglers (49.6%). Fall marking (usually September, but some October) amounted to 438 fish; anglers later reported 92 recaptures (21.0%). Over one-half of the recaptures were taken during the first 37 days of the trout season, while about four percent were caught in the second season after tagging.

Table 4 lists the details of the spring and fall taggings on Hunt Creek. All recaptures were taken within 1 mile of the release point, regardless of season of tagging. The barrier weirs and bulkhead traps, which became operable in the spring of 1949, might have inhibited movements of fish marked in 1949. However, 13 recaptures from 135 trout tagged at various sites in lower Hunt Creek in the fall of 1947 (data

included in fall marking of Hunt Creek in table) showed a pattern of stability similar to that already described, even though impeded by barriers to a lesser degree.

Wild brook trout, Main Au Sable and South Branch Au Sable River, 1960-1963

On the Main Au Sable River, 222 wild brook trout were tagged in the fall seasons, of which anglers later reported recapture of eight fish (3.6%), all during the first season after tagging; 5/8 of them during the first 37 days of the trout season. Seven of the eight recaptures were recovered at the tagging site, while the remaining tag recovery was caught 1.7 miles downstream from the release point.

On the South Branch Au Sable, 97 wild brook trout were tagged in 1960-1963, during fall seasons, of which eight tag recoveries (8.2%) were later turned in (only six with usable migration data, Table 4). Six of the eight were creeled during the first 37 days of the following trout season, two in the second season after tagging.

There was some suggestion the South Branch brook trout tended to move somewhat more than in the other streams. Only three of the six were retaken within 1 mile of the tagging site; one was caught about 2 miles downstream, one about 4 miles upstream, and another 11 miles upstream in Robinson Creek.

Wild brook trout, North Branch Au Sable River, 1960-1964

The most intensive investigations were conducted on this stream between Dam 2 and Kellogg's Bridge. A total of 1,162 wild brook trout were marked in the falls of 1960-1963 (September, October, November), and 835 fish were tagged during spring operations (March and April) in 1961-1964 (Table 4). Later recoveries by angling yielded 66 recaptures of fall-tagged brook trout (5.7%) of which only two were taken in the second season after tagging. From the spring markings, 87 recaptures (10.4%) were later reported, of which 86 were creeled during the first season after tagging, one during the second season following marking. Of the 135 recaptures with usable location data, 109 fish were captured at or within 1 mile of the tagging site (81%), 15 fish were noted at points 1 to 7 miles upstream (11%), and 11 were caught at points 1 to 3 miles downstream (8%).

Table 4 and Figure 2, which combine brook trout data for all four streams, summarize what I believe to be the movement characteristics for wild brook trout, 7.0 - 12.9 inches long at tagging, in the headwater and upper drainages of interior lower peninsula streams. Most of the population (88%) is stable to a high degree because the stream habitat is such that the brook trout have desirable temperatures, shelter, food, and spawning facilities relatively close at hand. There was no evidence of large numbers of fish moving from one part of the stream to another at any time of year, in contrast to the spawning migrations of

rainbow trout or Atlantic salmon. The small fraction (12%) of fish which moved 1 to 11 miles may have been forced by population pressure to seek out new territories; however, among the brook trout, none left their original stream drainage.

In the North Branch experiments, separated by some 30 years in time, angler recaptures percentages were of the same approximate magnitude. Distribution of recoveries at recapture indicated that there was little, if any, difference between the two time periods in migration patterns.

Although Hunt Creek differs from the other streams most strikingly in its ecological characteristics, the pattern of stability of brook trout larger than 7 inches was the same as noted for the Au Sable drainage; i.e., once the size of 7 inches is attained most brook trout (50 to 100 percent in the various experiments) are found within 1 mile of the point where they are first observed, and none were noted to move more than 11 miles from the tagging site.

Other implications of the wild brook trout data

The recapture pattern in time during the trout season for the 346 wild brook trout recaptures is shown in Table 5. There was some variation between streams, possibly induced by varying numbers of tagged fish available and differing seasonal angling pressures. However, when grouped, about 65% of the wild brook trout recaptures were made during the first 37 days of the trout season immediately following tagging,

15% in June, 16% in the July-September period, and 4% during the second season after tagging.

The paucity of brook trout recaptures in any of the streams later than the first trout season after tagging, regardless of the time of tagging, emphasizes the futility of attempting to protect brook trout in these and similar streams after they reach a total length of 7 inches. If they are not harvested by man, some other mortality factor eliminates most of them before they reach trophy proportions. This is also born out by the relatively few 5-and-6-summer-old brook trout noted to date from scale collections in Michigan trout streams.

Also, in the Hunt Creek and North Branch brook trout tagging, where fish were marked in both the fall and the spring seasons, consistently greater recapture percentages were noted for spring-tagged than for fall-tagged fish. (Hunt Creek, chi-square = 40.76, 1 d.f.; North Branch, chi-square = 14.77, 1 d.f., $P<0.005$ in both instances.) These results reinforce the conclusion that mortality between autumn and the following spring is of significant proportions. In Hunt Creek, 2.1 spring-tagged brook trout were recaptured for each fall-tagged brook trout; in the North Branch, the ratio was 1.8 spring-tagged fish to each fall-tagged brook trout. In general, these observations suggest an over-winter mortality among wild brook trout 7 inches and larger in these two streams of approximately 50 percent.

Wild brown trout, Main Au Sable River, 1959-1963

A total of 1,713 brown trout, ranging from 7.0 to 21.5 inches, were tagged at four locations on the Main Stream during the falls of 1959-1963. Recaptures have been reported every season since then by anglers; to date (August, 1967) recoveries amount to 214, or 12.5 percent of the number tagged (Table 6). About two-thirds of the recoveries were captured during the first season after tagging, the remainder were reported in the following four seasons (Table 7).

Of the 214 Main Stream brown trout recaptures on file, 212 reports listed usable locality data. Over three-fourths (78%) were later reported from the tagging area. Downstream migrants (10 fish) amounted to 5 percent, while upstream migrants (37 fish) made up 17 percent of the total recoveries (Table 6). Tagged downstream migrants moved distances of less than 1 mile to as much as 9 miles; tagged upstream migrants were retaken as far upstream as 9.8 miles from the tagging site. One 9.5-inch brown trout tagged at Allison's was recaptured the next season in a tributary of the East Branch of the Au Sable, approximately 4 miles upstream.

As indicated in Table 6, the great majority of brown trout in the Main Stream, after reaching 7 inches, live within a mile of where they are first observed. The tagged individuals which move were not reported to move over 10 miles, either upstream or downstream. There may be a slightly greater tendency toward upstream movement than to downstream travel.

Wild brown trout, South Branch Au Sable, 1961-1963

A total of 366 wild brown trout (size range, 7.0 - 22.5 inches total length) were tagged at four sites on the South Branch during the falls of 1961-1963. Recaptures by anglers during 1962-1966 totaled 32, or 8.7 percent (Table 6). Nineteen (19) recaptures were reported in the first season after tagging, while 13 came into anglers' creels during the second, third, and fifth seasons following marking (Table 7).

Usable locality data were given for 30 of the 32 tag recoveries. Their distribution at recapture suggests some tendency toward wandering, as only 12 were retaken at the tagging site (40%), while 11 (36.7%) were found from 1-1/2 to 8 miles upstream (two in Robinson Creek, 7.5 miles above Mar-la-bar tagging site), while seven tagged individuals (23.3%) were reported from points 0.5 to 24 miles downstream (the latter was a specimen recaptured at Burton's Landing on the Main Stream). As observed in the Main Stream, more fish moved upstream than downstream.

Wild brown trout, North Branch Au Sable River, 1960-1964

The 1960-1964 fall tagging of brown trout on the North Branch totaled 2,197 fish ranging from 7.0 to 22.3 inches, total length. From the 1961 through 1966 angling seasons, 131 recaptures were reported, or a return of 6.0 percent (Table 6). Their recovery pattern in time was similar to that noted for the fall brown trout taggings in the other two streams--(chi-square = 3.609, 6 d.f., $0.75 < P < 0.50$) almost three-

fourths of the recaptures were made during the first season after tagging, the remainder in the second through the fifth seasons following tagging (Table 7).

Spring-tagged brown trout were available to the same angling pressure which operated on the fall-marked brown trout. During the springs of 1061-1964 a total of 889 fish 7.0 to 23.4 inches, total length, were jaw-tagged. The trout seasons of 1961-1966 yielded 103 recaptures by anglers, or 11.6 percent. The recapture pattern in time for spring-tagged brown trout was not significantly different from that observed for fall-tagged fish (chi-square = 1.758, 3 d.f., $0.75<P<0.50$); about two-thirds were taken during the first season after marking, the remainder during the second through the fourth seasons following marking (Table 7). Further, there was no significant difference in the temporal distribution at recovery of spring-tagged North Branch brown trout and fall-tagged brown trout from all three streams (chi-square = 0.452, 3 d.f., $0.95<P<0.90$). When the recaptures were grouped by time period of recovery and fishing regulation type (special restrictions, normal restrictions), no significant differences were found for either fall or spring-tagged North Branch brown trout (fall chi-square = 4.19, 3 d.f., $0.25<P<0.10$; spring chi-square = 1.16, 3 d.f., $0.90<P<0.75$).

A significantly higher fraction of spring-tagged North Branch brown trout were recaptured by anglers than were fall-tagged individuals (103/889 spring, 131/2,197 fall; chi-square = 27.76, 1 d.f., $P<0.005$).

The same general situation was noted in brook trout. About 1.9 spring-tagged brown trout were later retaken for each fall-marked fish.

The geographical distribution of 119 fall-tagged and 95 spring-tagged North Branch brown trout are shown in Table 6. The location of recapture of brown trout 7 inches and longer, one to five seasons after marking was: for fall-tagged fish, 69.7 percent within 1 mile of the tagging site; 11.2 percent at points upstream from 1.1 to 9.1 miles; 19.1 percent downstream as far as 42 miles. The distribution of spring-tagged fish was: 70.6 percent within one mile of the tagging site, 16.8 percent at points upstream as far as 7.1 miles, and 12.6 percent were later reported as far as 10.5 miles downstream. As noted in the returns from the Main and South Branch Au Sable, no pronounced upstream or downstream movement occurred. No spring-tagged fish were reported from streams other than the North Branch, whereas fall-tagged recaptures were later caught in Crapo Creek outlet, Chub Lake Outlet, West Branch Big Creek (Crawford County), Main Au Sable River, and South Branch Au Sable River. The maximum migration noted was 41.5 miles (from Dam 4 on the North Branch to Beaver Creek, a tributary of the South Branch of the Au Sable).

Movement of various size classes tagged

The relationship between size at tagging and movement after release was examined on each stream by applying a 3 x 3 chi-square test to the inch-group data, after combining all recoveries in each line of Table 6

into appropriate Upstream-No Migration-Downstream categories.

For fall-tagged brown trout in the Main Au Sable, there was no significant difference between the fractions of recoveries made in the three geographical categories among the three size groupings (chi-square = 5.884, 4 d.f., $0.25<P<0.10$). However, the distribution in space of fall-tagged brown trout in the South Branch was significantly different among the three size groupings. A noticeably higher fraction of fish larger than 10 inches moved upstream and downstream in this river (chi-square = 17.51, 4 d.f., $P<0.005$).

On the North Branch, the spatial distribution at recovery of fall-tagged and spring-tagged brown trout was similar (chi-square = 3.759, 2 d.f., $0.25<P<0.10$). However, when the recaptures for the respective seasons were examined by inch-groups, there were significant or "suggestive" differences among the fractions of recaptures moving in the various inch-groups. Among fall-tagged brown trout, fish larger than 13.0 inches had a greater tendency toward downstream movement, whereas those 7.0 - 12.9 inches were more equally distributed around the tagging sites (chi-square = 20.24, 4 d.f., $P<0.005$). Among the spring-tagged brown trout, 7.0 - 9.9 inch fish had a greater tendency toward upstream movement, whereas the fish larger than 10 inches were rather uniformly distributed around the marking locality (chi-square = 8.678, 4 d.f., $0.10<P<0.05$).

The question of movement differences among fish of the same size groups in the three branches of the Au Sable was also examined by

chi-square analysis. For 7.0 - 9.9 inch brown trout, movement patterns for all three streams were similar (chi-square = 4.896, 4 d.f., $0.50<P<0.25$). For 10.0 - 12.9 inch and for 13.0 + inch brown trout the movement patterns were measurably different in the three streams (10.0 - 12.9 inch fish--chi-square = 24.68, 4 d.f., $P<0.005$; 13.0 + inch fish--chi-square = 21.87, 4 d.f., $P<0.005$).

The movement characteristics of wild brown trout larger than 7.0 inches on the three streams may be summarized briefly as follows: on the Main Au Sable, brown trout larger than 7 inches are quite stable from 3/4 to 7/8 of the fish were later recaptured at the marking site. About 5 percent later moved downstream; about 15 percent upstream, but none more than 10 miles in either direction.

South Branch brown trout appeared to move about more, with the possible exception of the 7.0 - 9.9 inch fish (76, 20 and 0% of the recaptures in the three size groupings recaptured at the tagging locality). Upstream movements up to 8 miles, and downstream migrations as far as 24 miles were reported.

Among North Branch brown trout, there was an increasing tendency toward movement as the fish increased in size, both for spring- and fall-tagged fish (70, 53, 24% recapture at tagging site for fall marking; 62, 55, 27% recapture at tagging site for spring marking).

Comparison of brook trout and brown trout movements

The geographical pattern at recovery of 7.0 - 12.9 inch brown trout was tested against the distribution of the same size-group of brook trout in the North Branch, where adequate numbers of both species were marked and recovered. There was no significant difference between the species of the distribution of the recaptures (chi-square = 1.525, 2 d.f., $0.50<P<0.25$). The relationships described between brown trout movements and size at tagging are shown in Figures 3 to 6, as well as a comparison of movement between brook trout and brown trout.

Other implications of the brown trout data

On the North Branch, where we had both spring- and fall-marked fish subjected to the same angling pressure, significantly more spring-marked fish (1.9:1) were later reported than were fall-tagged brown trout.

The pattern of brown trout recapture in time was noticeably different than that recorded for the brook trout, for which species about 2/3 of all recoveries were made during the opening 37 days of the first season of availability, and about 3 percent during the second season. In contrast, about 1/3 of the brown trout recaptures were reported during April and May of the first season, about 1/3 during the remainder of the first season, and the remaining 1/3 during the second through the fifth season. This comparison is shown in Figure 7.

In comparing the movement patterns for wild brook trout and wild brown trout observed to date in the four streams with the ecological characteristics listed, there are no outstanding relationships. Proportionately, the most migration was noted for the brook trout and brown trout of the South Branch. The flow, slope, and temperature regime of this stream, however, are not greatly different than observed in the other two branches of the Au Sable. In general, the same proportion of trout moved upstream as downstream within any one stream. It is hypothesized that the small percentage of larger (13.0 + inches) brown trout noted to move 7 or more miles from the marking sites did so because larger fish need more living space and food, and these preferred living and feeding sites are limited. A complete explanation of such movements calls for correlation of movement of marked fish with more detailed measurements of the habitat characteristics and their seasonal changes.

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Table 1.--Tagging sites (underlined), river mileages between sites, and elevations of sites above sea level for Au Sable and Hunt Creek drainages. Mileages measured with map measurer on Department air photos enlarged to 3 inches = 1 mile.

North Branch			Main Stream			South Branch			Hunt Creek		
Site	Mileage	Feet above sea level	Site	Mileage	Feet above sea level	Site	Mileage	Feet above sea level	Site	Mileage	Feet above sea level
Dam 2	0	1,218	Grayling	0	1,121	Deerheart Rd.	0	1,103	Head	0	1,080
Dam 2 P.S.	0.6	1,210	East Br.	0.5	---	Chase Br.	1.2	1,104	Co. Line	1.1	995
Halfway P.S.	2.0	1,202	Allison	1.5	---	Mar-la-bar	3.5	1,100	Lower Trap	3.6	930
Dam 3 P.S.	3.2	1,190	Pullover	4.0	1,110	Downey's	7.1	980	Welch Br.	4.9	920
Co. Line	4.2	1,180	Burton's Ldg.	5.6	1,105	Dogtown	8.3	---	612 Br.	6.3	870
Black Hole P.S.	4.7	1,175	Wa-Wa-Sun	8.1	---	Smith Br.	10.3	962	Hall Br.	8.1	837
Twin Br. P.S.	6.6	1,165	Stephan Br.	9.8	1,075	Main Au Sable	16.1	---	Thunder Bay R.	11.0	792
Blanchard P.S.	6.9	1,160	Wakeley Br.	14.3	1,043						
Lovells	8.2	1,148									

(continued)

Table 1.--concluded

North Branch			Main Stream			South Branch			Hunt Creek		
Site	Mileage	Feet above sea level	Site	Mileage	Feet above sea level	Site	Mileage	Feet above sea level	Site	Mileage	Feet above sea level
Eaman's P.S.	11.1	1,124									
Mary Ann P.S.	11.6	1,121									
Dam 4 P.S.	13.7	1,102									
Kantagree	19.1	---									
Kellogg Br.	19.8	---									
Big Creek	20.8	---									
Canoe Camp	21.9	---									
Main Au Sable	26.0	---									

Table 2.--Percentage slope of the various portions of the streams where trout were tagged.

North Branch			Main Stream			South Branch			Hunt Creek		
Section	Length (in miles)	% slope	Section	Length (in miles)	% slope	Section	Length (in miles)	% slope	Section	Length (in miles)	% slope
Head-waters	7	0.13	Head-waters	18	0.13	Head-waters	28	0.03	Head-waters	1.1	1.63
Dam 2-Co. Line	4.2	0.17	Grayling-Burton's Landing	5.6	0.05	Deerheart-Downey	7.1	0.07	Experimental area	2.5	0.49
Co. Line-Eamans	6.9	0.15	Burton's-Wakeley Br.	8.7	0.08	Downey-Smith Br.[1]	3.2	0.11	Lower Hunt Creek	7.4	0.38
Eamans-Dam 4[1]	2.6	0.16									
Average		0.15	Average		0.12	Average		0.09	Average		0.50

[1] Slope of lower North Branch and lower South Branch was not calculated as this U. S. G. S. quadrangle map has not been completed.

Table 3.--Average monthly water temperatures (° Fahr.), Au Sable drainage and Hunt Creek.

Number of monthly readings are indicated in parentheses.

	MONTH						Calendar years observed
	April	May	June	July	August	September	
North Br. Au Sable							
Upper	48° (19)	58° (77)	64° (91)	66° (92)	65° (82)	67° (8)	1961-65
Middle	49° (21)	56° (115)	63° (113)	65° (120)	61° (115)	60° (29)	1961-65
Lower	48° (13)	55° (93)	63° (107)	65° (101)	62° (89)	61° (28)	1961-65
Main Au Sable							
Upper	53° (7)	57° (81)	65° (75)	67° (64)	65° (90)	63° (35)	1961-63
Lower	48° (11)	56° (129)	62° (123)	64° (124)	61° (92)	59° (53)	1961-65
South Br. Au Sable							
Upper	59° (3)	55° (42)	63° (52)	64° (61)	61° (35)	56° (9)	1961-63
Lower	50° (12)	57° (50)	61° (44)	63° (62)	60° (36)	59° (16)	1961-63
Hunt Creek							
Lower Trap	43° (137)	52° (152)	56° (147)	57° (148)	56° (154)	52° (139)	1961-65

Table 4.--Wild brook trout tagged and later recovered by anglers, Hunt Creek and Au Sable drainages, various periods, showing distances and direction moved.

Stream and season tagged	Inch-group tagged	Number tagged	Number recovered		Percent recovered	Miles moved upstream					Miles moved downstream				
			1st season	2nd season		11	7	3	1	0	0	1	3	7	11
North Branch 1934-1935	7.0- 9.9	407	18	---	4.4			2	1	3	6	6			
Fall	10.0-12.9	14	---	---	0.0										
Totals		421	18	---	4.3			2	1	3	6	6			
Hunt Creek 1945-1949	7.0- 9.9	423	84	5	21.0				11	68	10				
Fall	10.0-12.9	15	3	---	20.0					3					
Totals		438	87	5	21.0				11	71	10				
Spring	7.0- 9.9	132	64	2	50.0				7	53	6				
	10.0-12.9	3	1	---	33.0					1					
Totals		135	65	2	49.6				7	54	6				
Main Au Sable 1960-1963	7.0- 9.9	220	8	---	3.6					7		1			
Fall	10.0-12.9	2	---	---	0.0										
Totals		222	8	---	3.6					7		1			

(continued)

Table 4.--concluded

Stream and season tagged	Inch-group tagged	Number tagged	Number recovered		Percent recovered	Miles moved upstream					Miles moved downstream				
			1st season	2nd season		11	7	3	1	0	0	1	3	7	11
South Branch 1960-1963															
Fall	7.0- 9.9	96	6[a]	1[a]	7.3		1	1		2		1			
	10.0-12.9	1	---	1	100.0					1					
Totals		97	6	2	8.2		1	1		3		1			
North Branch 1960-1964															
Fall	7.0- 9.9	1,121	62[b]	2	5.7			1	4	8	36	1	5		
	10.0-12.9	41	2	---	4.9			1			1				
Totals		1,162	64	2	5.7			2	4	8	37	1	5		
Spring	7.0- 9.9	818	83[b]	1	10.3				8	14	36	11	6		
	10.0-12.9	17	3	---	17.6				1		2				
Totals		835	86	1	10.4				9	14	38	11	6		
All Fall		2,340	183	9	8.2		1	3	6	20	121	17	13		
All Spring		970	151	3	15.9				9	21	92	17	6		
Grand Total		3,310	334[c]	12[a]	10.4		1	3	15	41	213	34	19		

[a] No locality data--1 fish [b] 9 fish [c] 19 fish

Table 5.--Temporal distribution of brook trout recaptures, Hunt Creek and Au Sable drainages, various periods, by anglers. Percentages are given in parentheses.

Stream and time period	Season	Time of recapture				Totals
		1st season after marking			2nd season	
		April & May	June	July-Sept.		
N. Br. Au Sable 1934-1935	Fall	9 (50)	8 (44)	1 (6)	0 (0)	18
Hunt Creek 1945-1949	Fall	50 (55)	11 (12)	26 (28)	5 (5)	92
	Spring	35 (52)	13 (19)	17 (26)	2 (3)	67
Main Au Sable 1960-1963	Fall	5 (63)	2 (25)	1 (12)	0 (0)	8
S. Br. Au Sable 1960-1963	Fall	6 (75)	0 (0)	0 (0)	2 (25)	8
N. Br. Au Sable 1960-1964	Fall	54 (82)	6 (9)	4 (6)	2 (3)	66
	Spring	65 (75)	14 (16)	7 (8)	1 (1)	87
Totals		224 (65)	54 (15)	56 (16)	12 (4)	346 (100)

Table 6.--Summary of wild brown trout tagged, and later recovered by anglers, Au Sable drainage, 1959-1967.

Stream, and season of tagging	Inch-groups tagged	Number tagged	Number recovered		Percentage of recovery	Number moving miles upstream						Number moving miles downstream						? Locality	Total recoveries
			1st season	2nd thru 5th seasons		42	11	7	3	1	0	0	1	3	7	11	42		
Main Au Sable	7.0- 9.9	1,243	72	68	11.3		4	8	4	14	103			4	2			1	140
Fall	10.0-12.9	336	39	13	15.5		1	1	3		45	1			1				52
	13.0-	134	16	6	16.4			1		1	17	1			1			1	22
Totals		1,713	127	87	12.5		5	10	7	15	165	2		4	4			2	214
S. Br. Au Sable	7.0- 9.9	214	7	8	7.0		2		1		10							2	15
Fall	10.0-12.9	111	7	3	9.0		1		4		2	1	1			1			10
	13.0-	41	5	2	17.1		2	1					1	1	2				7
Totals		366	19	13	8.7		5	1	5		12	1	2	1	2	1		2	32
N. Br. Au Sable	7.0- 9.9	1,454	50	22	4.9			4	3	5	45	2	2			3		8	72
Fall	10.0-12.9	475	23	9	6.7		1			4	16	3	3	2		1		2	32
	13.0-	268	19	8	10.1			3	1	2	6	1	3	1	3	5		2	27
Totals		2,197	92	39	6.0		1	7	4	11	67	6	8	3	3	9		12	131

(continued)

Table 6. --concluded

Stream, and season of tagging	Inch-groups tagged	Number tagged	Number recovered: 1st season	Number recovered: 2nd thru 5th seasons	Percentage of recovery	Number moving miles upstream: 42	11	7	3	1	0	Number moving miles downstream: 0	1	3	7	11	42	? Locality	Total recoveries
N. Br. Au Sable	7.0- 9.9	516	37	22	11.4		1	6	4	6	34	2		1	1			4	59
Spring	10.0-12.9	261	23	8	11.9				2	4	16	1	5	1				2	31
	13.0-	112	8	5	11.6				3	1	3		1	2	1			2	13
Totals		889	68	35	11.6		1	6	9	11	53	3	6	4	2			8	103
All fish	7.0- 9.9	3,427	166	120	8.3		7	18	12	25	192	4	2	5	3	3		15	286
	10.0-12.9	1,183	92	33	10.6		3	1	9	8	79	6	9	3	1	2		4	125
	13.0-	555	48	21	12.4		2	5	4	4	26	2	5	4	7	5		5	69
Grand Total		5,165	306	174	9.3		12	24	25	37	297	12	16	12	11	10		24	480

Table 7.--Temporal distribution of brown trout recaptures, Au Sable drainage, 1960-1967, by anglers. Percentages are given in parentheses.

Stream	Season tagged	1st season after tagging			2-5 seasons later	Totals
		April-May	June	July-Sept.		
Main Stream	Fall	70 (33)	41 (19)	26 (12)	77 (36)	214
South Branch	Fall	9 (28)	6 (19)	4 (12)	13 (41)	32
North Branch	Fall	53 (40)	23 (18)	18 (14)	37 (28)	131
North Branch	Spring	36 (35)	21 (20)	11 (11)	35 (34)	103
Totals		168 (35)	91 (19)	59 (12)	162 (34)	480

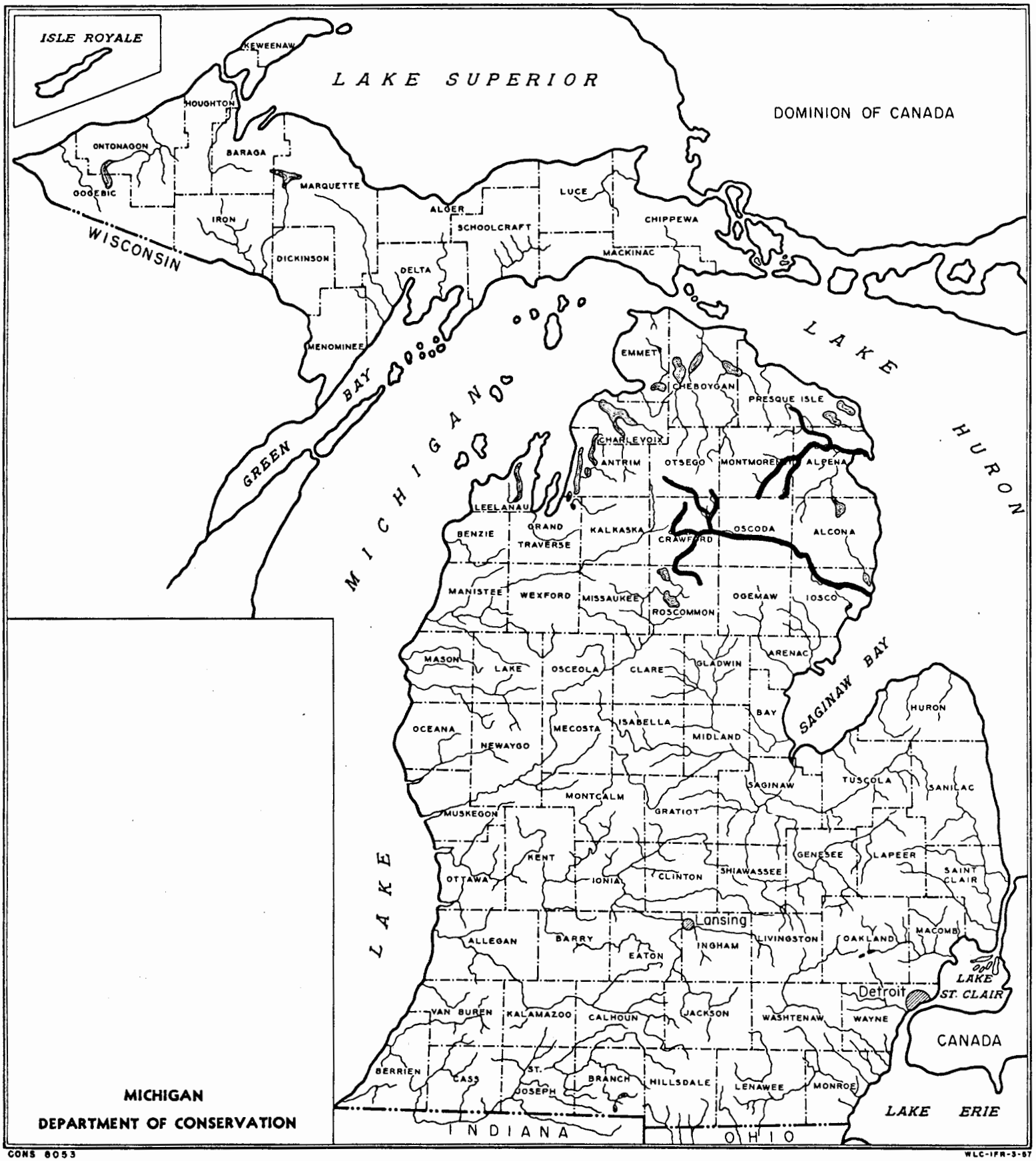

Figure 1. The upper Au Sable River system in Crawford County and Hunt Creek in Montmorency County, where study was made.

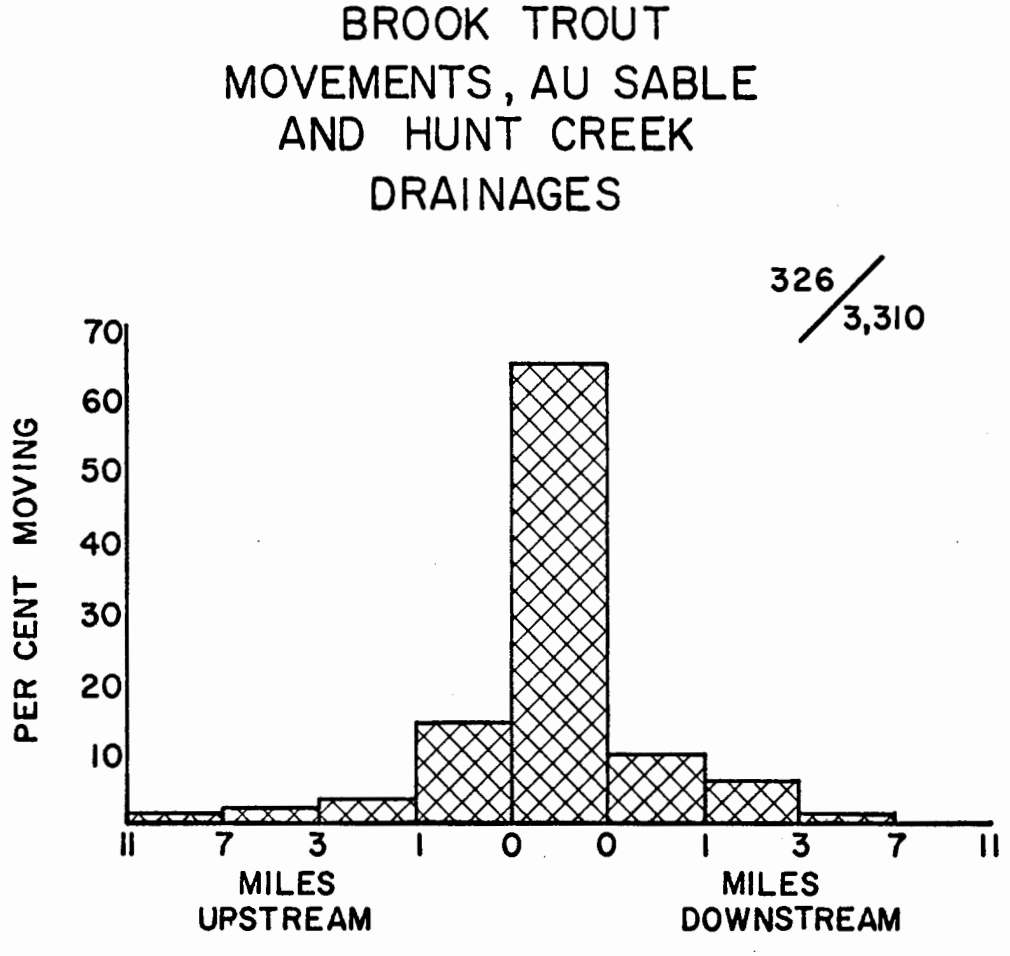
BROOK TROUT
MOVEMENTS, AU SABLE
AND HUNT CREEK
DRAINAGES
326/3,310
PER CENT MOVING
70
60
50
40
30
20
10
11 7 3 1 0 0 1 3 7 11
MILES UPSTREAM
MILES DOWNSTREAM

Figure 2

MOVEMENT PATTERN, ANGLER RECAPTURES,
7.0 - 9.9 INCH BROWN TROUT, AU SABLE DRAINAGE

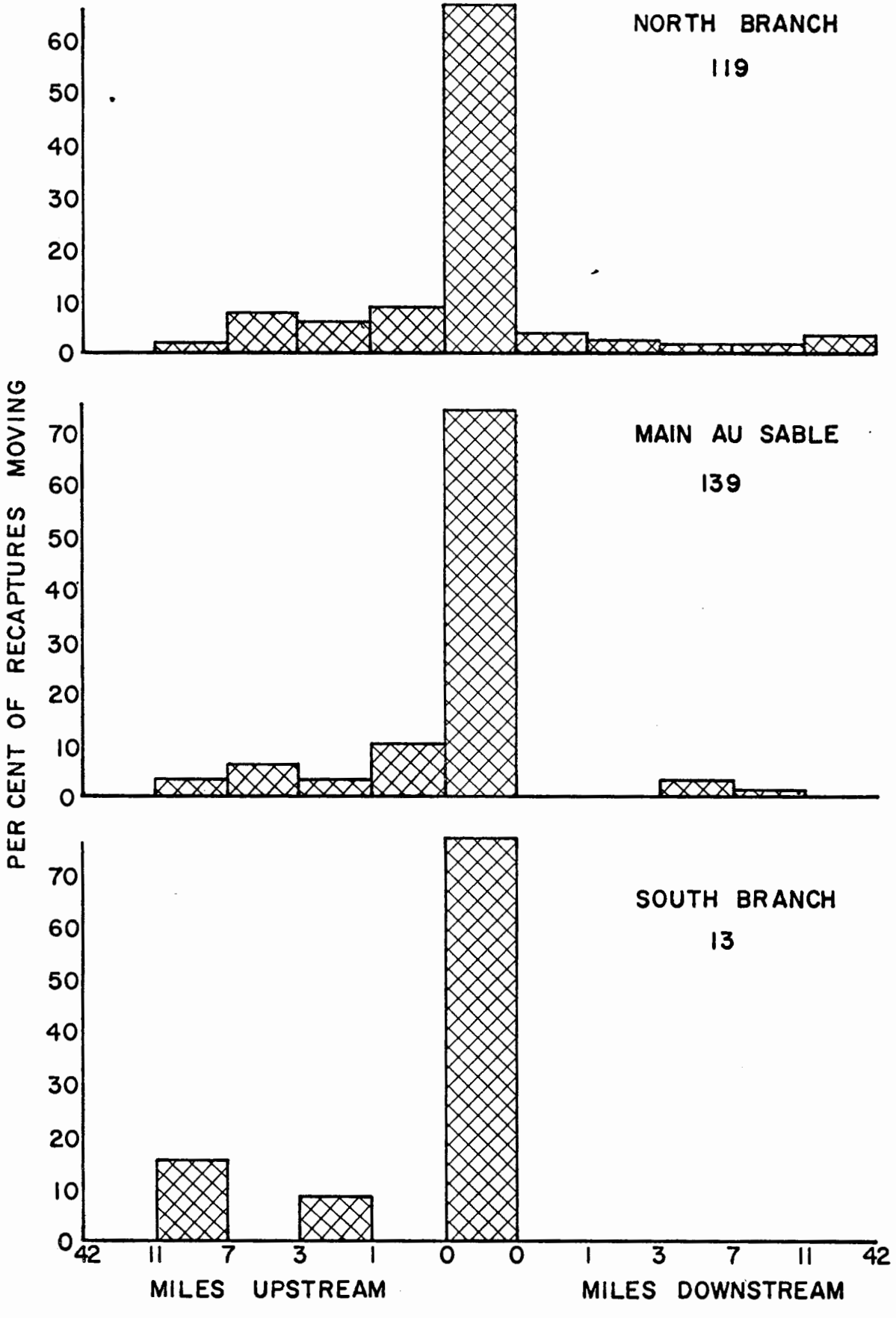

Figure 3

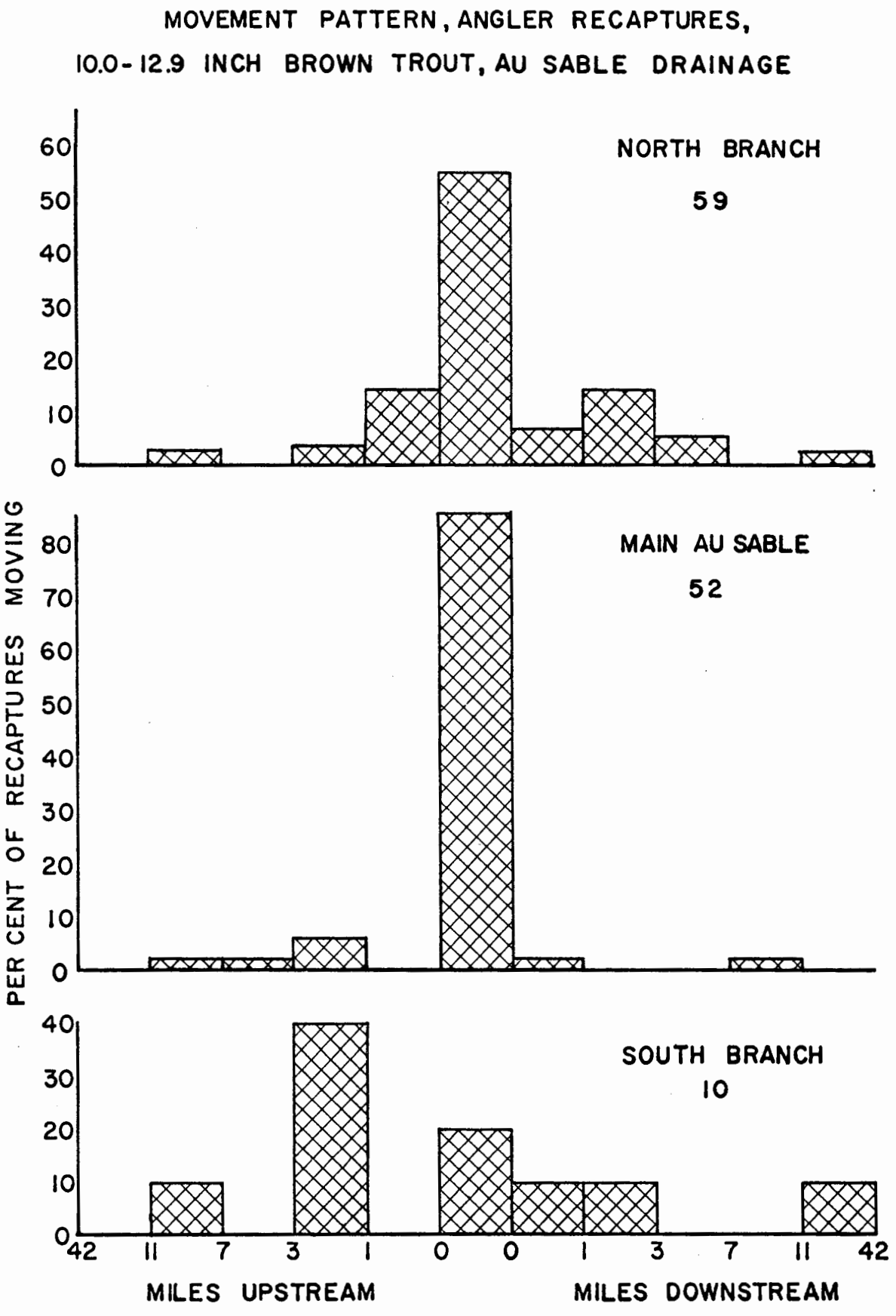
MOVEMENT PATTERN, ANGLER RECAPTURES,
10.0-12.9 INCH BROWN TROUT, AU SABLE DRAINAGE
NORTH BRANCH
59
MAIN AU SABLE
52
SOUTH BRANCH
10
PER CENT OF RECAPTURES MOVING
0
10
20
30
40
50
60
70
80
42
11
7
3
1
0
0
1
3
7
11
42
MILES UPSTREAM
MILES DOWNSTREAM

Figure 4

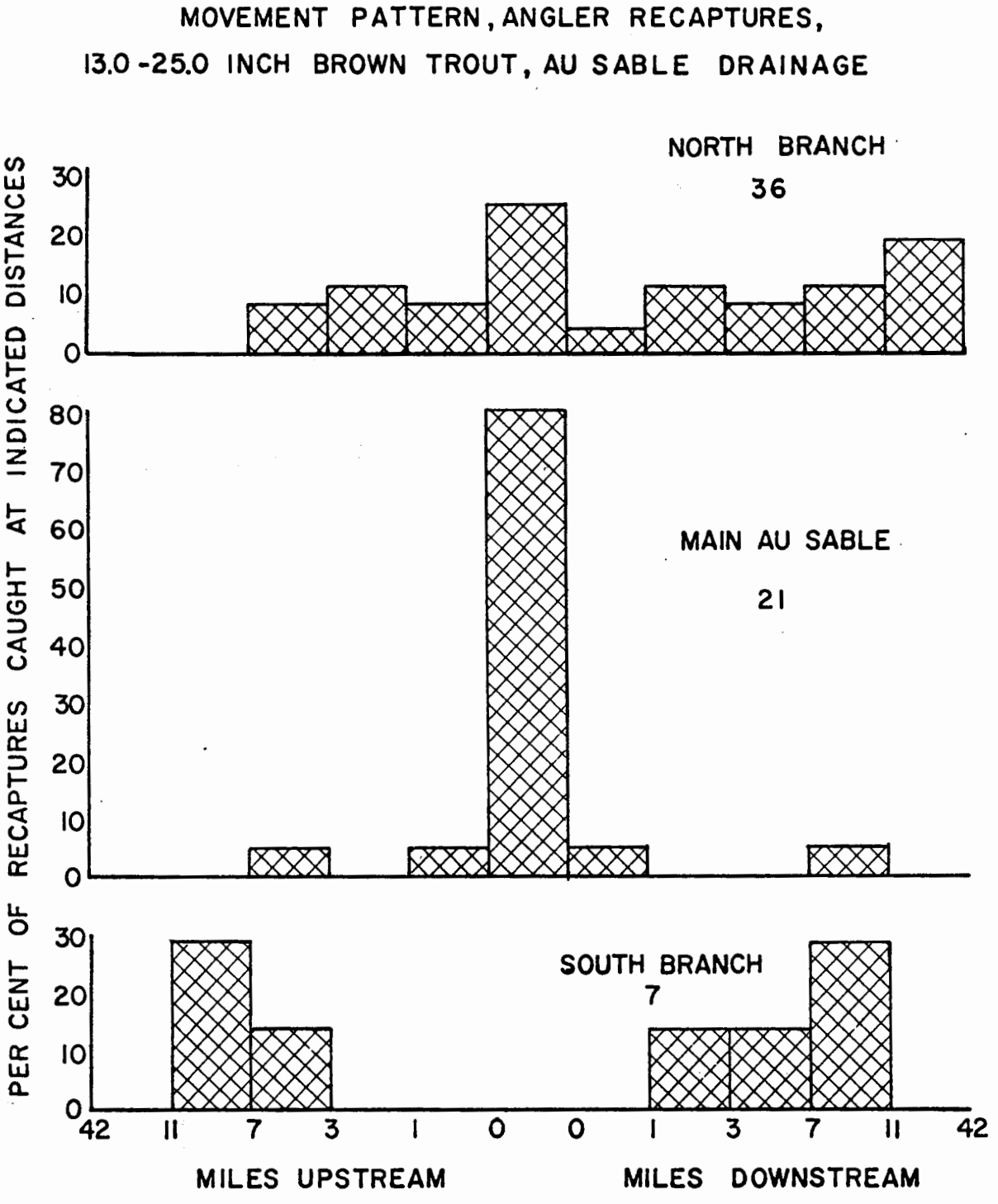
MOVEMENT PATTERN, ANGLER RECAPTURES,
13.0-25.0 INCH BROWN TROUT, AU SABLE DRAINAGE
NORTH BRANCH
36
MAIN AU SABLE
21
SOUTH BRANCH
7
PER CENT OF RECAPTURES CAUGHT AT INDICATED DISTANCES
30
20
10
0
80
70
60
50
40
30
20
10
0
42 11 7 3 1 0 0 1 3 7 11 42
MILES UPSTREAM
MILES DOWNSTREAM

Figure 5

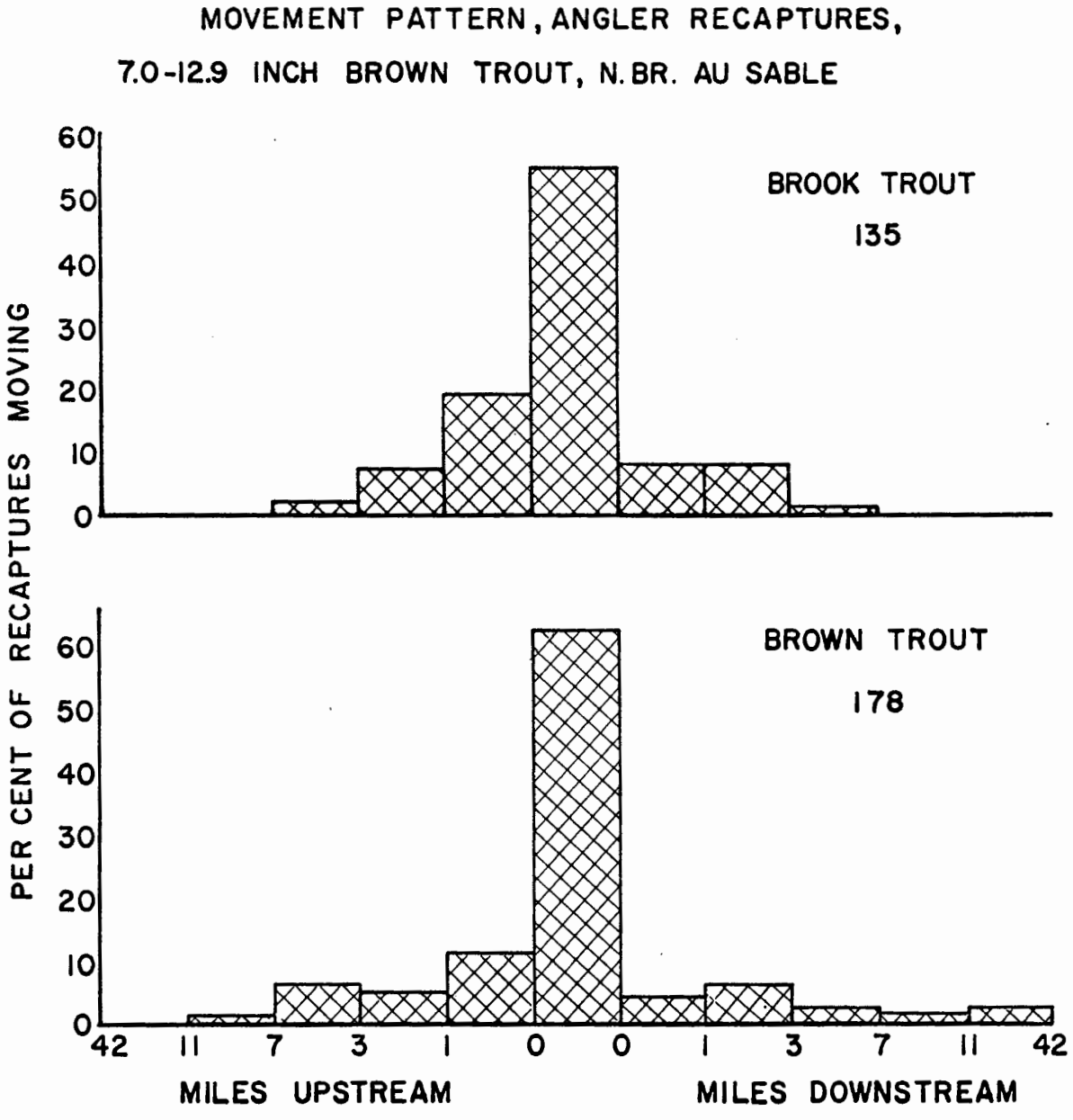
MOVEMENT PATTERN, ANGLER RECAPTURES,
7.0-12.9 INCH BROWN TROUT, N. BR. AU SABLE
PER CENT OF RECAPTURES MOVING
BROOK TROUT
135
BROWN TROUT
178
60
50
40
30
20
10
0
42 11 7 3 1 0 0 1 3 7 11 42
MILES UPSTREAM
MILES DOWNSTREAM

Figure 6

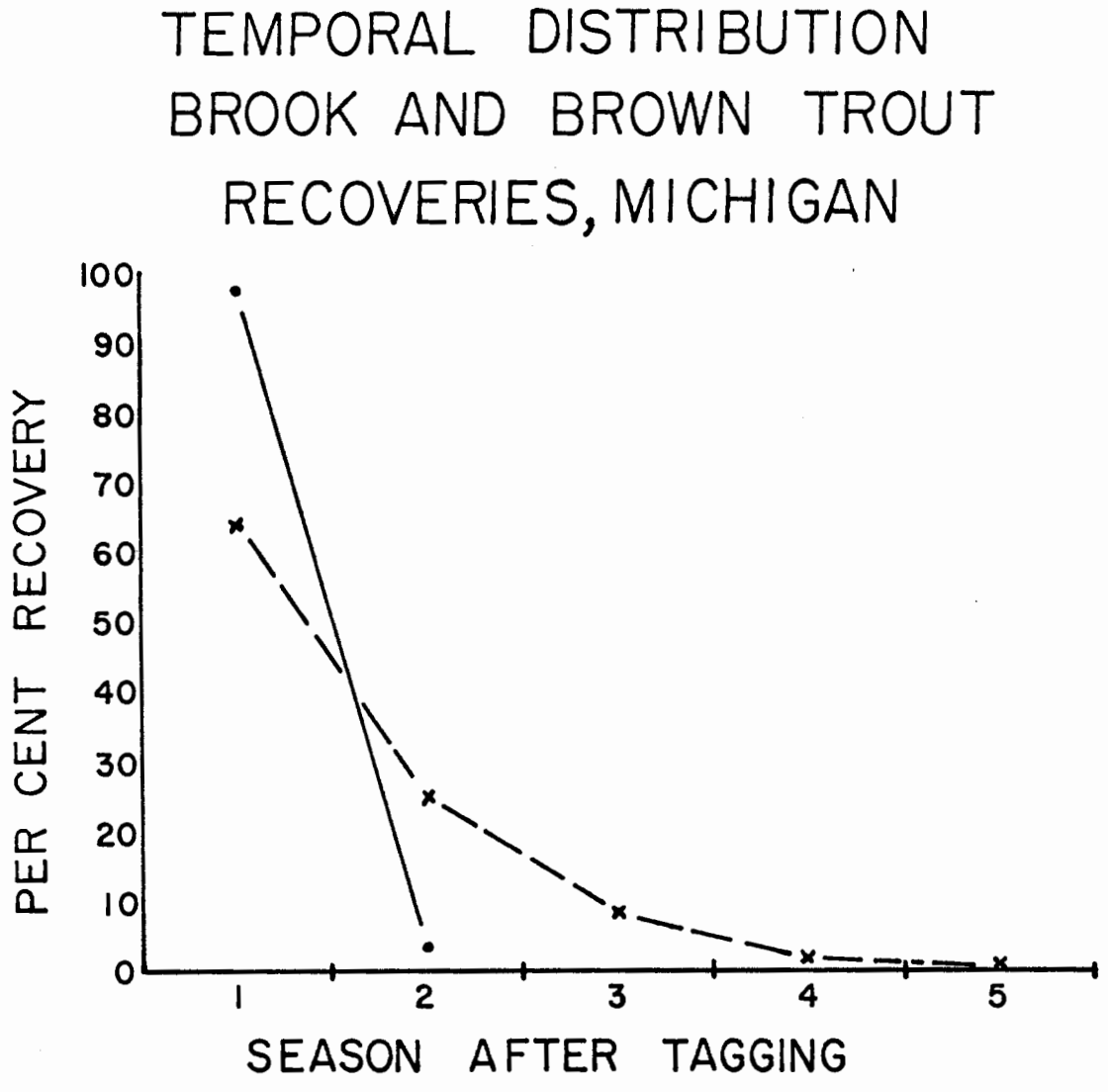
TEMPORAL DISTRIBUTION
BROOK AND BROWN TROUT
RECOVERIES, MICHIGAN
PER CENT RECOVERY
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
SEASON AFTER TAGGING

Figure 7