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Madison, Wisconsin

FISH MANAGEMENT DIVISION

Management Report No. 12

A STUDY OF MIGRATORY LAKE-RUN TROUT IN THE BRULE RIVER, WISCONSIN

Part I

BROWN TROUT

By

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INTRODUCTION

The Brule River, located in Douglas County in the northwestern part of the state, has long been recognized as one of the most famous rivers of Wisconsin. A colorful past history involving early explorers, trappers, traders, missionaries and loggers has been well documented and recorded (Jerrard, 1956). The early and recent history of the Brule River also includes substantial reference to fish.

Although the earlier travelers reported large numbers of trout, it was not until the early 1870's that an avid interest developed in the trout fishery. Shortly thereafter the Brule River became famous for its fabulous brook trout fishing. This earlier fame has continued through the years and still persists today. However, in recent years the distinction is no longer attributed to the brook trout fishery, but is associated with the fishing for trophy-size trout. Each year trophy brown trout Salmo trutta fario and rainbow trout Salmo gairdneri irideus migrate from Lake Superior into the Brule River to spawn. Anglers from all parts of the United States and from all walks of life, including several of our nation's presidents, have journeyed to the Brule River to test their trout fishing skills.

A reported decline in the trout fishery in the late 1930's prompted an intensive study, which was conducted by a team of specialists from the University of Wisconsin and the Conservation Department in the early 1940's. Following these efforts only periodic creel censuses and limited surveys have been conducted.

As is often the case with an intensive fishery, management is necessary. But before effective management can be applied, characteristics and habits of the fish, as well as their environment have to be known.

In 1961 an intensive study was initiated with the purpose of learning more about the migratory trout and their habits. This report covers details learned during the four years of intensive study from 1961 through 1964, as well as limited data collected in 1965.

PHYSICAL CHARACTERISTICS OF THE BRULE RIVER

The comprehensive study conducted in the early 1940's adequately described the Brule River and its watershed (Wisconsin Conservation Department - 1954).[1] Although more than 20 years have elapsed since this study, very few significant changes have occurred. Pertinent details necessary for background are presented here.

The Brule River lies primarily within forested lands throughout its entire length. The only exception is some interspaced farm lands along parts of the river north of U.S. Highway 2. The boundary of the Brule River State Forest encompasses all of the stream and of the overall 52,000 gross acres within the boundary, the state currently owns 30,175 acres. Since the original establishment of this state forest in 1907, there has been a continued effort on the part of the Conservation Department to acquire available lands to protect and preserve the outstanding natural beauty of this river. Approximately 20 miles of the river is now in public ownership.

[1] The eleven papers covering the various phases of the early 1940 Brule River study were bound into book form and released under the title "The Brule River Douglas County" by the Wisconsin Conservation Department in 1954.

The Brule River, based upon a current measurement, is 48 miles in length and flows in a northerly direction into Lake Superior (Fig. 1). From its source to the lake, Bean and Thompson (1944) reported a total fall of 420 feet. The upper 29 miles of the river has a drop of only 92 feet, an average fall of 3 feet per mile. The lower 19 miles has a fall of 328 feet, an average drop of 17 feet per mile. The total drainage area of the Brule River is 190 square miles (Bean et al, 1944).

The best available flow data is from a gauging station located at the state ranger station, which is above the Little Brule River tributary but below the other major tributary stream, Nebagamon Creek. The readings obtained at this gauging station are reported by the U.S.G.S. (1964) to cover a drainage area of 113 square miles of the total 190 square miles. United States Geological Survey records show a 22 year average flow of 169 cubic feet per second, with a maximum flow of 1,520 and a minimum of 67 cubic feet per second. The volume of flow on the lower river is naturally greater, but unfortunately no measurements have ever been made there. Part of the Brule's value as a trout stream as well as a trout nursery can be traced to the relatively stable base flow (Fig. 2).

Under normal conditions the water in the Brule River is colorless and clear. During periods of heavy rain or runoff the water in the upper river becomes tea colored as a result of swamp drainage, and in the lower river the water becomes extremely turbid from the red clay soil that distinguishes the lower part of the drainage basin. Starting in the general vicinity of the Ranger Station there is a gradual transition in soil type, from the sandy soils found to the south, to a clay loam and heavy red clay which extends all the way to Lake Superior.

The water is medium hard with methyl purple alkalinity readings ranging from 49 at Stone Bridge to 60 ppm at the mouth. The pH readings vary from 6.3 to 7.2 in the upper sections and 7.4 to 7.8 in the lower river.

Although there is considerable variation in water temperature, ranging from the low 30's in winter to the mid 70's in the lower river in summer, trout are found throughout the entire length of the stream.

The characteristics of the upper and lower sections of the Brule River are strikingly different. The upper river from its source downstream to the Cedar Island area flows through a broad, flat wilderness bog valley rich in springs. At Cedar Island the river passes through a series of shallow, naturally formed lakes created by glacial till barriers in the bed of the stream. The largest of these lakes is Big Lake, which is one mile in length and 19 acres in size. In this area the river valley begins to narrow and bog swamp shoreline changes to more firm banks. At this point there is also a noticeable increase in gradient. Starting just above Winneboujou and continuing on downstream past the ranger station the river becomes a series of short rapids. From U. S. Highway 2 downstream to just above Coop Park the river meanders through an area referred to as the "meadows". Here the flow is slower and there are many deep pools with excellent instream cover. From the Coop Park area all the way to Lake Superior the river drops very sharply. This stretch of the river is almost a continuous rapids. There are some deeper pools between rapids or in the more defined bends. The river valley here is very narrow with rather steep, oftentimes exposed, red clay banks.

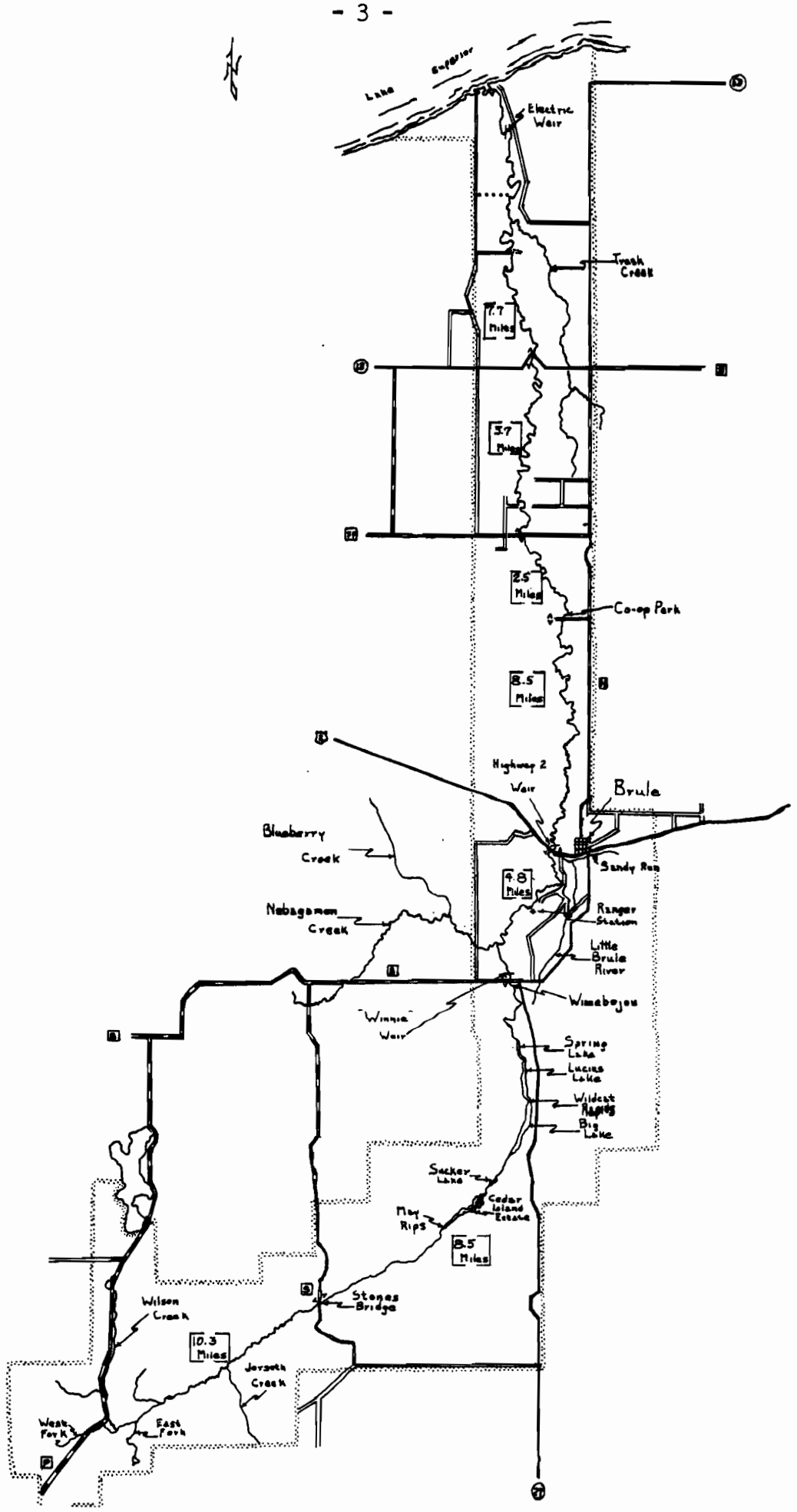


Fig. 1. Map of the Brule River showing stations referred to in this report

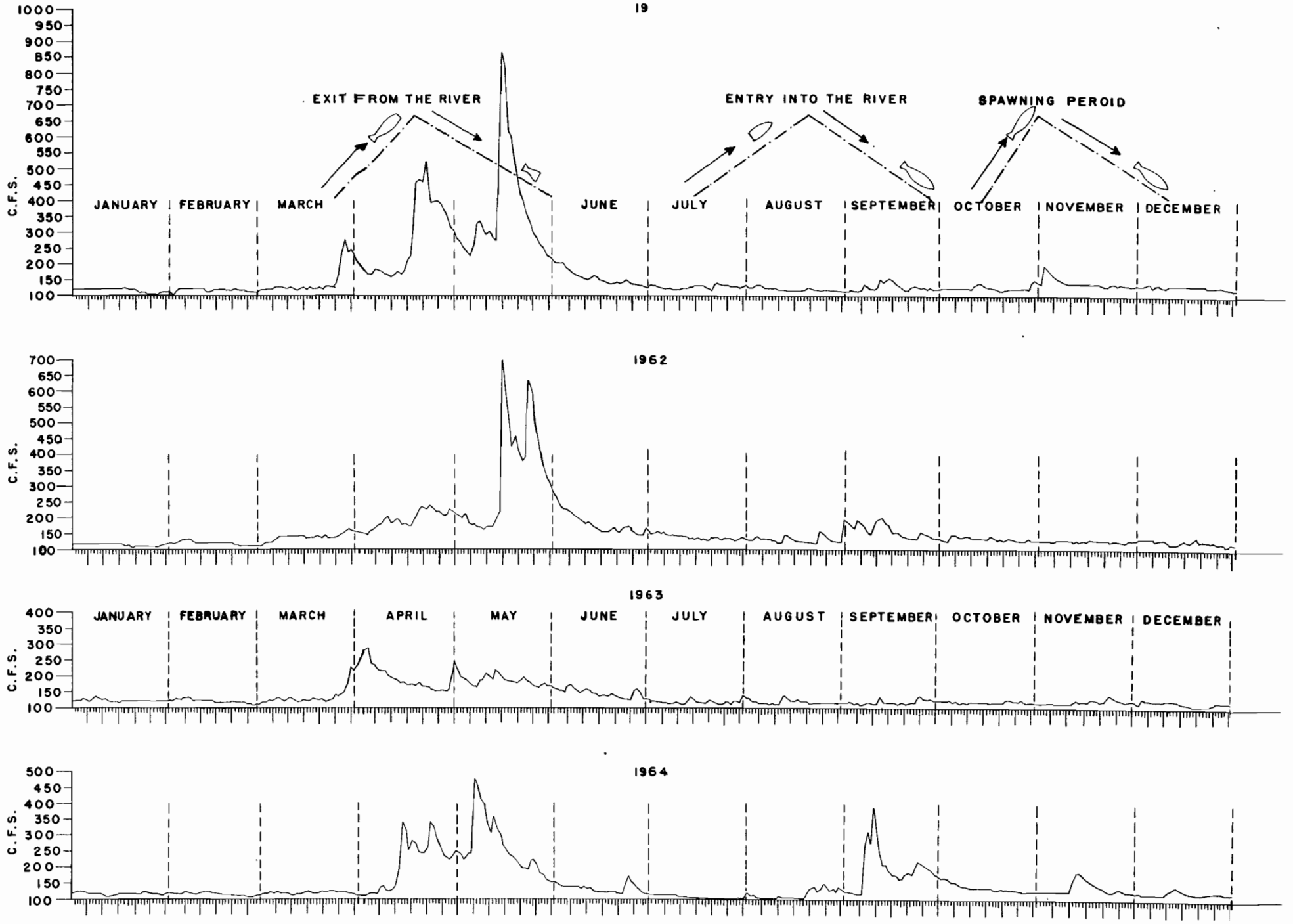


FIGURE 2. A HYDROGRAPH FOR THE BRULE RIVER FOR THE GAUGING SITE AT THE RANGER STATION.

MIGRATORY BROWN TROUT HISTORY

The only trout species originally inhabiting the Brule River was the brook trout (Salvelinus fontinalis). Early stocking records show that brown trout fry were first introduced in the Brule River in 1920 (O'Donnell 1945). Through the years brown trout in varying numbers and sizes have been stocked either annually or periodically (Table 1). From the casual movement of stocked fish between the Brule River and Lake Superior, a strain of brown trout with strong migrating tendencies has evolved. Although migrating brown trout have been observed and have been known to spawn in the river for many years, early dates and records are lacking. O'Donnell and Churchill (1954) reported four specimens of "sebago" (brown trout) taken during stream survey operations.

For years the migratory or lake-run brown trout was called a "sebago" or "sebago salmon". The main reason for the confusion was that a brown trout living in the environment of Lake Superior changes drastically in coloration and markings and no longer resembles a typical stream brown trout. A brown trout in Lake Superior or fresh from the lake has a greyish-silvery sheen. The markings become an irregular pattern of darker colored crosses or checks, more pronounced on back and sides and gradually fading toward the underside.

From 1943 through 1959 "sebago salmon" were harvested commercially from Lake Superior with a peak harvest of 9,159 pounds reported in 1955 (Table 2). In 1951 Daly definitely established that the so-called sebago was in reality a lake-run or migratory brown trout. When clarification in the identity of this species occurred, sportsmen insisted, and the Department recommended, that the brown trout be removed as a commercial species. In late 1955 the Wisconsin Conservation Commission took action to remove this species from the commercial list. Since its removal from the commercial fishery, the only harvest has been through a more limited sport fishery. For years the only migratory brown trout taken in the Brule River were caught incidental to rainbow (steelhead) fishing during the special spring and fall trout seasons.[1]

FISH SAMPLING METHODS

In order to study the migratory trout it was necessary to sample the population. The methods used to capture trout in this study were mechanical fish weirs and electro-fishing gear. All of the fish sampling was done in the Brule River or immediately off the mouth in Lake Superior. Information was also obtained from angler reports of fish caught in the river and Lake Superior and from commercial fishermen.

Fish Weirs

The first mechanical weir used in this study was constructed in the summer of 1961 just below the Winnebojou bridge on County Trunk Highway "B" (Fig. 3). In this report this weir is referred to as the "Winnie Weir". The reasons for selecting this location were (1) accessibility for building and tending the weir; (2) it was above the major tributaries which reduced the possibility of flood damage; (3) it was below some of the major spawning areas; and (4) the water level and river bottom were suitable for construction of this type of weir.

[1] A special season for hook and line fishing of migratory trout is provided which opens before the regular trout season in the spring and extends beyond the normal closing in the fall.

TABLE 1

Brown Trout Stocking Record in the Brule River

	Year	Number	Size
1-	(1920 - 1924	10,800	fry
	(1925 - 1929	94	no size given
	(1930 - 1934	124	no size given
	(1935 - 1939	36,555	no size given
2-	(1938	175	yearlings
	(1940	50,000	fingerlings
	(1941	100,000	fingerlings
	(1942	57,853	fingerlings
	(1942	1,519	adults
	(1946	6,750	legals - (7" fish)
	(1947	5,500	legals
	(1948	5,000	legals
	(1949	6,000	yearlings
	(1950	8,400	yearlings
	(1951	8,400	yearlings
	(1952	8,400	yearlings
	(1953	7,958	yearlings
	(1954	4,000	yearlings
	(1960	750	yearlings and fingerlings
3-	1964	92	adults - 16-20"

1-O'Donnell (1945).
2-Stocking records - Northwest Area Headquarter files.
3-Brown trout removed from Brule Hatchery head pond.

TABLE 2

Commercial Harvest of Brown Trout, Harvested as Sebago Salmon - from Lake Superior.

Year	Pounds	Year	Pounds
1943	172	1952	4,401
1944	168	1953	7,302
1945	43	1954	649
1946	0	1955	9,159
1947	0	1956	
1948	0	1957	0
1949	15	1958	0
1950	8,921	1959	3
1951	3,860		

Source: Wisconsin Conservation Department commercial fishing statistics.

The Winnie Weir was located approximately 29.2 miles upstream from the mouth of the Brule River. This weir was somewhat different in design than the modified two-way weir of the Platte River, Michigan type used by O'Donnell and Churchill in 1943-44. The Winnie Weir consisted of a stationary screen angled slightly upstream with a fish trap located at either end. The traps, which were 4 feet wide, 6 feet long and 3 feet high, were designed to catch fish from only one direction and were so positioned in the weir. The rods making up the weir were spaced to provide $\frac{1}{2}$ inch openings.

This weir required considerable attention to keep the screen and traps clean. This was particularly true during the period of leaf fall. At such times, continual removal of leaves was necessary to keep the weir from washing out. In early December ice formation plugged the weir screen and the Winnie Weir washed out.

Although the Winnie Weir was lost, valuable experience was gained in weir operation and design. A weir was then designed which incorporated "safety valve" features in the form of gates that could be raised or removed entirely during times of adverse conditions. The rods in the weir gates could also be removed as desired which provided for openings greater than $\frac{1}{2}$ inch.

The newly designed weir was constructed in the summer of 1962 at a site 200 yards north of U. S. Highway 2. In this report this weir is referred to as the Highway 2 weir. This weir is 4.8 miles downstream from the Winnie Weir site and 24.4 miles upstream from Lake Superior. The reason for changing the weir location was that many migratory brown trout did not move upstream as far as the Winnie Weir. Then too, the design of weir offered more flexibility in operation, thus reducing the possibility of flood or ice damage.

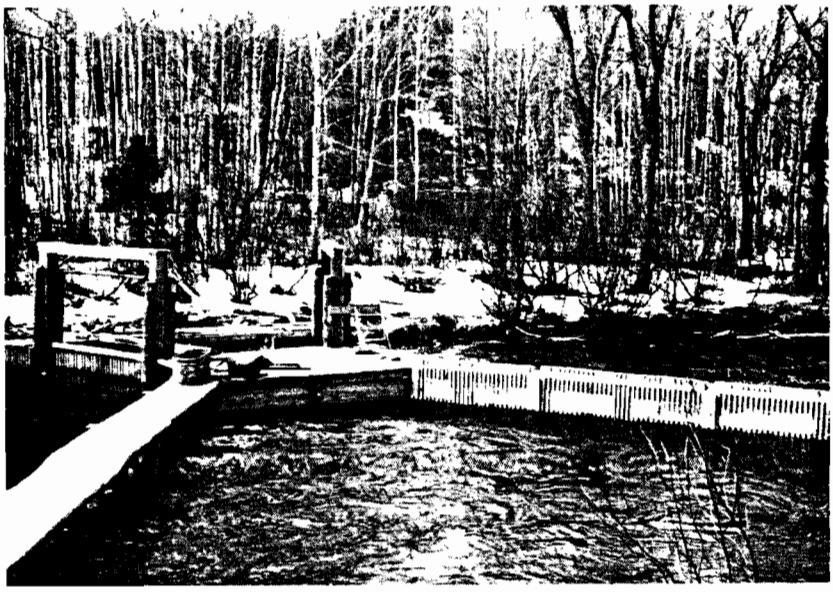
This weir had a series of 8 gates, 8 feet long by $3\frac{1}{2}$ feet high, extending across the river. The weir screen was again angled slightly upstream. The fish traps were the same ones used at the Winnie Weir, with one trap positioned on each end of the weir screen. Alongside of the downstream trap a small opening was provided so that boat traffic could get past the weir. We found that it was necessary to close off this opening at night or whenever the weir was in operation because fish were using this passageway as an escape route to get by the weir.

Although the operation of the Highway 2 Weir was sometimes limited, this weir was used successfully in the succeeding years of this study. In periods of high water, adverse weather or heavy leaf fall, the gates were either raised or removed thus reducing the danger of damage to the weir. The operations of these weirs are chronicled in Table 3.

During this study the U. S. Fish and Wildlife Service operated an electro-mechanical weir on the Brule River. This weir is located about one mile upstream from the mouth. It was put in operation in May of 1957 and has been operated each year since then. The annual period of operations, which covers the sea lamprey (Petromyzon marinus L.) spawning run, extends from early spring until mid or late summer.

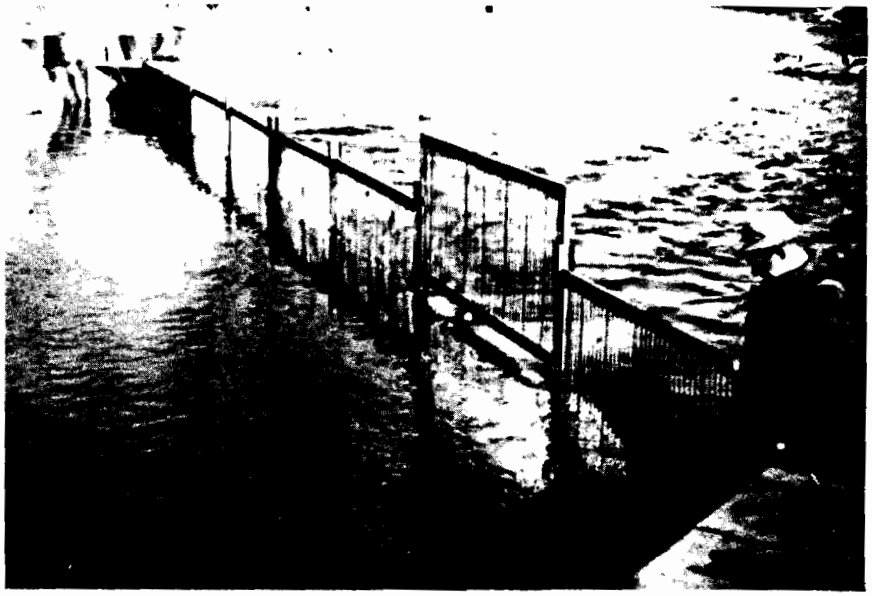
When in operation this weir constitutes a complete barrier to any fish moving upstream. The only way fish can get past this weir is to enter the fish traps and then be removed and carried upstream past the electrical fields. Some of the data reported here, was obtained from the operational records of the sea lamprey weir, through the courtesy of U. S. Fish and Wildlife Service personnel.

Winnie Weir

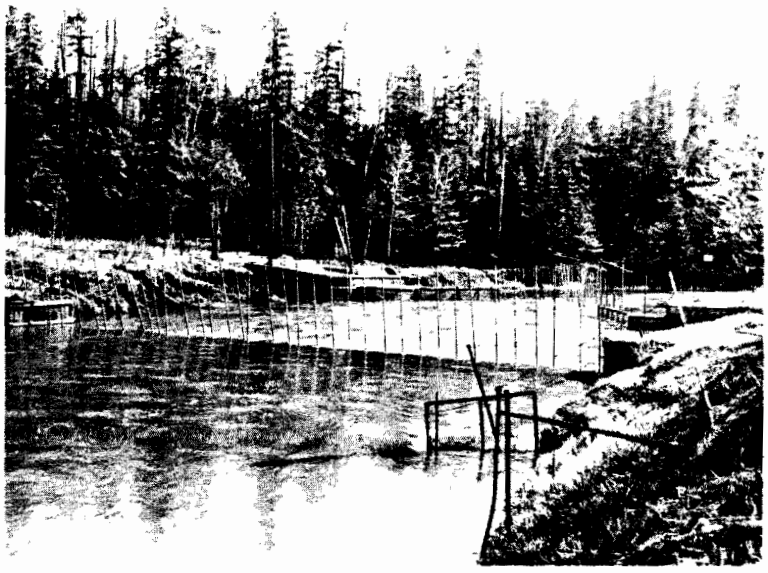


Two-way weir and fishtrap used in 1943 by O'Donnell

Fig. 3. Fish weirs used in the Brule River



Highway "2" Weir



U.S. Fish and Wildlife Service - Sea Lamprey Weir

Fig. 3 (Cont.)

TABLE 3

Resume of the Annual Weir Operations During the Brule River Migratory Trout Study

1961 Winnie Weir	Weir construction was completed August 9 and weir was placed in operation on this date. The weir was operated continuously to December 7, when ice damaged the weir causing a washout. Damaged weir was removed from the river.
1962 Highway "2" Weir	Weir construction was completed on August 15 and weir was placed in operation on this date. August - (Weir in full operation entire month) September - Alternate rods were removed from 5½ gates because of high water and leaf fall. From September 22 on, canoe passage was closed off at night when trout were observed escaping through this opening. From mid-September on, gates were raised during daylight hours to reduce cleaning and caretaking work, during period of heavy leaf fall. October - Weir operated entire month - except gates raised during daylight hours until mid October because of leaf fall. November - Weir operated entire month. December - 1-7, weir in operation - December 8-18, gate out due to slush ice. December 18 to December 22, weir operated - December 22, gates pulled out for the season.
1963 Highway "2" Weir	February - Weir operated 6 to 8 and 13 to 20. March - Weir operated 4 to 8 and 20 to 31. Gates pulled March 31 due to high water. April - 1-8 (No operation - high water). April 8-30 (Weir in full operation). May - (1 to 22 continuous operation), May 22 to 25 gates temporarily out for painting. May 26-31 operated. June - (continuous operation entire month), July - Continuous operation entire month. July 18 first migratory brown captured. August - Continuous operation entire month. September - 1-11 full operation. 11-13 gates out high water, heavy leaf fall. September 13-30 continuous operation - gates raised during daytime. October - Continuous operation. Gates raised during daytime - during period of heavy leaf fall. November - Continuous operation. Gates pulled December 1 for season because of ice formation.
1964 Highway "2" Weir	January - 3-9 weir operation. January 10 - ice formation caused washout of downstream trap. April - 7-12 weir operated. April 12 gates pulled, high water. May and June - No operation. July - 8-10, 13-31 full operation. July 27 first migratory brown captured. August - Full operation entire month. September - Weir operated - 1-5, 14-19, 29-30, other periods not operated because of flood and high water. October - Operated entire month, except October 2-3, heavy leaf fall - high water. Gates out during daylight hours. November - 1-19 full operation. November 20 gates pulled for season due to ice.

Electro-Fishing Gear and Methods

Most of the electro-fishing operations conducted in the lower part of the river were done with a boat mounted shocking unit, commonly referred to as a boom shocker (Fig. 4). Earlier in the study all of the electro-fishing was done with (A.C.) alternating current unit. This unit was powered by a 230 volt, 2500 watt, three-phase A.C. generator with electrodes suspended from booms extending out in front of a flat bottom work boat. Later in the study a modified direct current boom shocker unit was developed and used. This unit was powered with a 230 volt, 2500 watt generator, with the positive and negative electrodes suspended in front of the boat. The direct current shocking unit was generally as effective in sampling migratory trout and this type of electrical current proved to be easier on these larger fish. In using the A.C. unit most of the fish were knocked out or lost consciousness, a condition referred to by Deichelbohrer (1961) as electro-narcosis. The D.C. powered unit has the phenomenon of electrotaxis, (Deichelbohrer et al, 1961) where the fish moves toward the anode or positive electrode. The trout were dipped as they approached or swam near the positive electrode and very seldom were the fish stunned or completely knocked out. The boom shocker is a large bulky unit which restricted its use to areas of the river deep enough and large enough for motor boat navigation.[1]

A fish sampling survey in the upper river was done with conventional stream shocking unit (persons wading the river, carrying hand electrodes). The 230 volt A.C. generator already mentioned was used as the electrical power source. Three hand electrodes were used to obtain better coverage of the river.

Electro-fish sampling operations in the lower river were conducted on a random basis or as time and other work permitted. All boom shocker work was conducted during daylight hours. The technique used was to motor upstream as far as reasonable navigation permitted (approximately 1½ miles) and shock downstream to the mouth and just off the mouth in Lake Superior, weather permitting. The success of each shocker run depended primarily on the number of trout in the lower river at the particular time a run was made. The catch varied from 0 fish to as many as 40 large trout on a single shocker run (Table 4). On several trips 20 or more migrant browns were captured. In some instances other trout were observed or turned up but escaped before being netted.

Most of the trout captured during shocking operations were tagged. Date of tagging, location and other pertinent data or observations such as deformities, lamprey scarring and the like were also recorded. The tagged fish were released in the general area of capture and were then free to move either up or downstream as they so pleased.

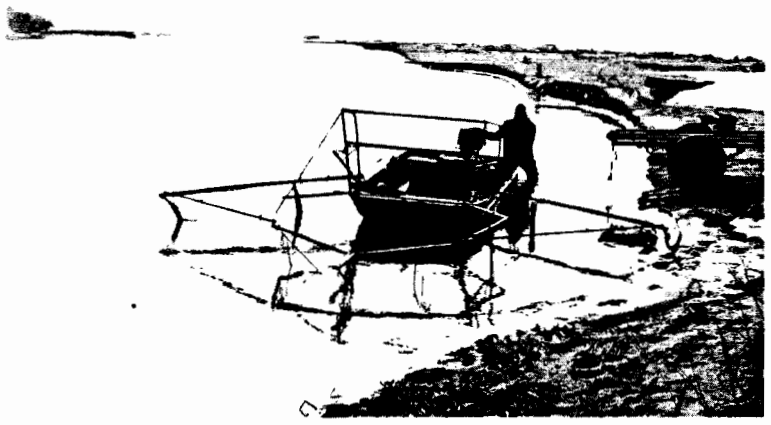
Fish Tagging

One of the purposes of this study was to determine movement of these migratory trout while in the river and in Lake Superior. To accomplish this a majority of the trout captured were tagged so they could be readily identified. Most of the trout were tagged with Peterson disk tags. This type of tag has been used by Hallock, Van Waert and Shapovalov (1961) in their study of the rainbow trout in California; Hacker (1957) in his study of lake trout in Big Green Lake, Wisconsin; Thorsteinson and Merrell (1961) in a salmon tagging study in Alaska waters, and by many other fishery workers.

[1] Outboard motors and motor boat navigation is prohibited on most of the Brule River by local town ordinance, but approval was obtained to use the outboard powered boom shocker in the Brule River during this study.

Alternating current boom shocker unit

A. C. boom shocker and stream shocker units



Direct current boom shocker unit

Fig. 4. Electro-fishing equipment used in fish collecting operations in the Brule River.

TABLE 4

Migratory Brown Trout Captured in the Lower Brule River
With Electro (Boom Shocker) Fishing Gear

Time Period	1961	1962	1963	1964	1965
July 1 - 7	--	--	--	6 (1)**	--
July 8 - 15	--	--	--	3 (1)	13 (2)
July 16 - 23	--	--	--	--	--
July 24 - 31	56 (3)	--	7 (2)	12 (1)	--
Aug. 1 - 7	25 (2)	0 (1)	36 (3)	--	--
Aug. 8 - 15	23 (2)	6 (2)	21 (1)	21 (1)	--
Aug. 16 - 23	2 (1)	15 (2)	--	27 (1)	--
Aug. 24 - 31	19 (4)*	7 (2)	5 (1)	15 (2)	--
Sept. 1 - 7	--	6 (1)	20 (1)	--	--
Sept. 8 - 15	35 (2)	0 (1)	1 (1)	9 (3)	3 (1)
Sept. 16 - 23	5 (1)	--	19 (3)	0 (2)	12 (2)
Sept. 24 - 30	--	0 (1)	--	4 (2)	0 (2)
Oct. 1 - 7	0 (1)	--	8 (2)	0 (2)	1 (1)
Oct. 8 - 15	--	--	--	1 (3)	0 (3)
Oct. 16 - 23	--	--	4 (1)	0 (2)	2 (2)***
Oct. 24 - 31	--	--	--	1 (2)	0 (2)

Number in parenthesis indicates number of survey trips - made during the time period.

* On 2 trips no migratory brown trout were captured.

** Trout captured but not tagged.

*** Spawned-out fish.

The Peterson disk tag was used because it was fairly easy to attach and it showed up very well on the fish. The disks were made of laminated, cellulose material and were ½ inch in diameter and 0.040 inches thick. One disk was numbered and inscribed with a return address, while the opposing disk was blank. The brown trout were tagged with bright red tags. German and LaFaunce (1955) reported that some adult rainbow trout tagged with red disk tags were molested by other fish to a point of causing weakness, fungus and even death. Whenever their experimentally tagged fish moved about they were susceptible to attack by other fish snapping and striking at the red tag. Many observations of released tagged brown trout at the Highway 2 weir failed to show any such attacking tendencies. Recaptured and recovered brown trout also failed to show evidence of such attacks.

Nickel pins were used to attach the two opposing disks to the fish's body. Some experimentation was done to determine the best position for attaching the tag. Throughout most of the study the disk tags were attached immediately below and toward the anterior end of the dorsal fin (Fig. 5). Hacker et al (1957) in his lake trout studies attached Peterson disk tags anterior to the caudal fin above the spine. Some trout were tagged in this body area on a trial basis. However, because of vigorous activity of the tail during spawning and possibility of tearing out the tag, the position of tag was changed back to the dorsal area.

Some problems were encountered in using the Peterson disk tag. Tags that were attached too loosely sometimes resulted in fish collecting vegetation and other debris on the tag and pin. Fishermen reported catching trout by having their line entangled around the pin holding the tag. Brown trout naturally seek thick instream cover (brush, stumps, logs) when hiding. Some tags were recovered from such places in the river, having pulled loose from the fish. Experience indicated it was better to attach the tag as tightly as possible. On the other hand disks attached too tightly would eventually cut into the skin and flesh leaving a rather unsightly wound. Some anglers catching tagged fish did complain and others merely mentioned tag wounds when sending in fish tags.

Faced with this problem, an attempt was made to reduce the cutting effect of the tag by placing a protective pad under each of the disks. The pads were simply inserted on the nickel pins as the tag was applied to the fish. The pads used were made of heavy duty rubber electrical tape. A cork borer 5/8 inch in diameter was used to make the rubber disks. These inexpensive rubber pads were easy to use, lasted well and substantially reduced the cutting effect of the Peterson disk tag. Many tag returns were received from anglers with the rubber pad still positioned beneath the disk.

A small number of brown trout were also tagged with aluminum jaw tags placed around the mandible. This type of tag was no easier to apply, was difficult to see, and was too small to fit around the mandible of large trout, so its use in this study was limited.

It was necessary to anesthetize these large powerful trout in order to handle them. MS-222 (Sandoz) proved to be the most successful anaesthetic for immobilizing these large fish. Once quiet, the trout were tagged, measured, weighed, sexed and scale samples removed. The fish were then placed into a floating screen box in fresh water until fully revived before being released.

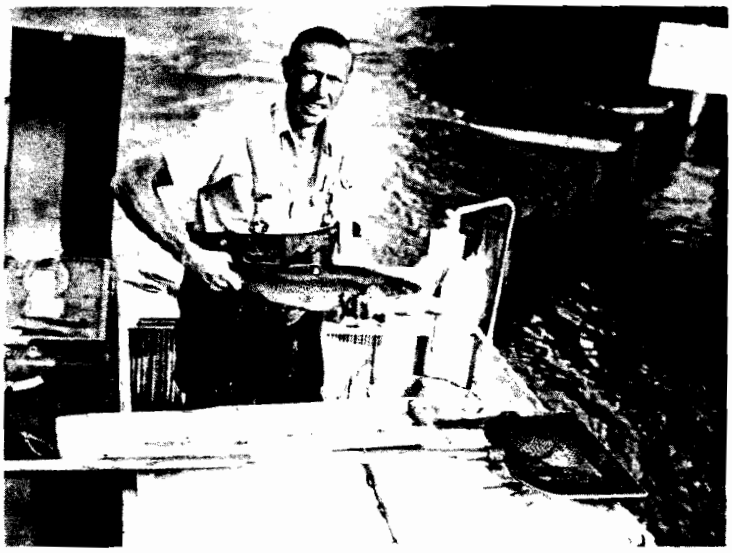


Fig. 5. A brown trout marked with a Peterson disk tag.

Except for ripe fish, sex was determined mainly from observation of external physical features. Male trout have longer heads, a distinctly hooked lower jaw, and a flatter body. The head of the female trout is shorter, more rounded, and the body more robust. Another helpful characteristic used in sexing these trout was in the removal of scales for scale samples. Scales from male trout were invariably more difficult to remove than those from the female fish.

Determination of sex by the methods described was a matter of judgment and therefore subject to error, but an internal examination of a large number of fish showed a high degree of reliability.

ENTRY AND MOVEMENT OF MIGRATORY BROWN TROUT

Entry Into the Stream

Migration of brown trout from Lake Superior into the Brule River begins in early July. Electro-fishing operations conducted from early July through late fall, showed that the peak of the brown trout run occurs in August (Fig. 6). By mid-September most of the migrant browns have entered the river. From late October on, the few browns captured were generally spawned-out fish moving downstream.

What prompts these migratory browns to move into the spawning stream so early (July-August) remains a puzzling question. Spawning at the earliest does not start until October and the distance from Lake Superior to the spawning grounds is not that great so as to require such early movement. Observations indicate that these fish do little or no feeding while progressing upstream, so this is not considered a factor. A possible reason may be that the warm waters of the Brule River at this time of year, in contrast to cold Lake Superior, may be an attraction. The warmer water temperatures may aid or accelerate the development of the reproductive organs.

Stuart (1953) in his study of migratory brown trout in Scotland suggested that the advent of heavy rains and resulting spate (floods) which bring about changes in the quality of the water may be important stimulus causing brown trout to migrate. Somewhat greater trout movement into the Brule was also noted at times of high, turbid water. However, this did not seem to be the only trigger to induce trout movement because even when there is little or no rain in July and August, and the water becomes low and clear, migratory brown still moved into the river in significant numbers. In the Brule River, entry and migration evidently occur as a result of strong stimuli prevalent during July and August, whether it be warmer water, photoperiod, time of year, rains, or a combination of these and other possible factors.

Many anglers have been concerned about the condition of the mouth of the Brule River. Some people feel that at times of low water levels and low flow the outlet becomes so shallow that these large trout cannot or will not enter the river. The mouth and a long sandbar at the mouth are fully exposed to the wind and wave action of Lake Superior. The force of wave action on this loose sand material often changes the position and depth, but never has the mouth been sealed off so as to prevent fish from moving in if they so desired.

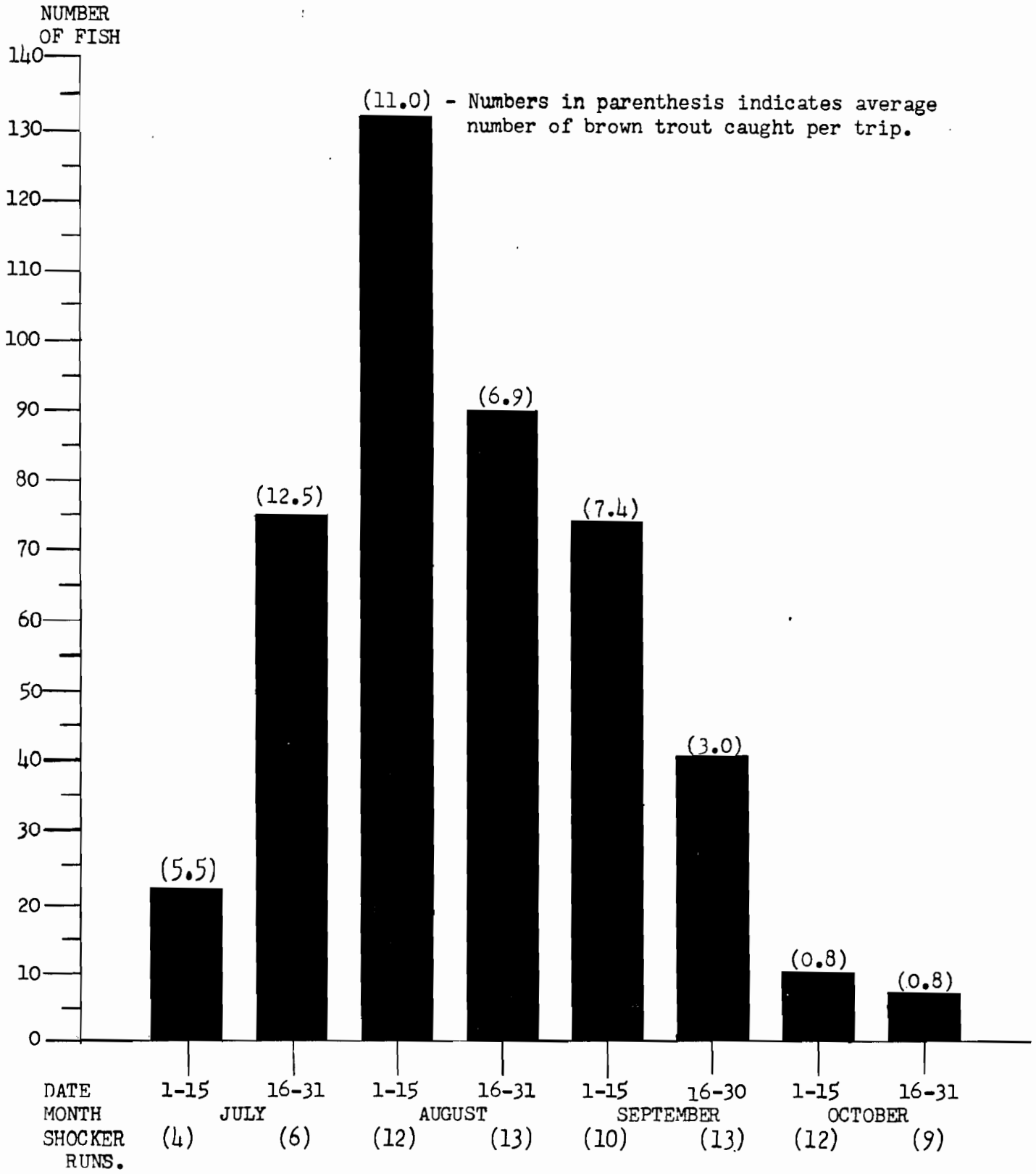


Fig. 6 Record of migratory brown trout entry into the Lower Brule River by monthly periods - 1961-1965.

Repeated survey work in the lower river showed that regardless of conditions at the mouth, or the flow of the river, migratory trout continued to enter the stream. The 1963 trout run definitely proves that these trout enter the river even under seemingly adverse conditions because normal runs were encountered in this low-water year. Shallow, clear water, however, does reduce daytime entry. On several occasions, when such conditions existed, brown trout were observed and captured on the delta just off the mouth. These fish were undoubtedly waiting for darkness before moving into the river. Except for periods of high turbid water, fish movement into and even in the river, is more prevalent during periods of lower light intensity.

Upstream Movement

From the recapture of tagged fish at the upstream weirs and also from angler returns we were able to determine to some extent movement upstream. The time interval for tagged trout recaptured at the Winnie Weir (29 miles upstream) varied from 12 to 100 days (Table 5). The average time based on nine tagged fish recaptured was 40 days. At the Highway 2 Weir (24.5 miles upstream) the time interval varied from 14 to 84 days. The average time based on 7 tagged fish recaptured was 37 days. The shortest time interval recorded for brown trout movement upstream was 6 days. This occurred in July of 1964 at the time the sea lamprey weir was shut down for the season. Six days after the electrical sea lamprey barrier was removed migratory brown trout were captured at the Highway 2 Weir. No migratory brown trout had been passed upstream past the barrier prior to the time it was shut down.

Further information on upstream movement was obtained from tagged fish caught in the river by fishermen. Data showing the location, date of catch, and the time lapse in number of days between tagging and capture is presented in Fig. 7. The angler-caught trout showed an erratic pattern of upstream movement similar to that of tagged trout recaptured at the weirs. Some individual fish demonstrated a rapid movement up river. One fish was caught 15.5 miles upstream 4 days after tagging, an average rate of movement of 4 miles per day. Another fish was caught 9 days later some 20 miles upstream, averaging more than 2 miles per day.

The recorded movement of tagged fish may not be a valid indication of the normal movements of these trout. Tagged fish were subjected to electrical shock, handling and tagging in the lower river, which could certainly alter their behavior pattern. In addition, it was not determined or known how long a tagged fish may have been in an area before being caught by a fisherman or before entering the weir fish traps.

The available information suggests that brown trout entering the Brule tend to move upstream through the lower one-third of the river rather quickly. Even though many trout continue their movement upstream there is a definite tendency for many brown trout to "bunch up" and remain in the slower, quieter waters, and deeper pools found in the "meadows" area. This is particularly true in late summer and early fall prior to spawning.

TABLE 5

Characteristics of the Fish and Time Interval of Migratory Brown Trout Captured and Tagged in the Lower River and Recaptured at the Upstream Weirs

Tag Number	Date Tagged	Length	Weight	Sex	Recaptured		Time Interval
					Date	Location	
415*	7-24-61	23.3	5.2	Female	11-1-61	Winnie Weir	100 days
1515	8-3-61	18.0	2.8	Female	10-6-61	Winnie Weir	68 days
1554	8-8-61	20.4	3.8	Male	9-10-61	Winnie Weir	33 days
1641	8-28-61	24.5	6.0	Male	10-2-61	Winnie Weir	35 days
1649	8-28-61	20.7	3.6	Female	9-30-61	Winnie Weir	33 days
1969	9-12-61	23.6	5.6	Female	9-29-61	Winnie Weir	17 days
1970	9-12-61	18.8	2.5	Female	10-29-61	Winnie Weir	39 days
1973	9-12-61	23.1	5.0	Male	9-24-61	Winnie Weir	12 days
1976	9-12-61	25.4	7.2	Male	10-5-61	Winnie Weir	23 days
3254	7-9-63	21.9	5.0	Female	7-24-63	Highway 2 Weir	15 days
3375	8-2-63	20.4	3.7	Female	8-20-63	Highway 2 Weir	18 days
3477	8-7-63	23.6	5.4	Male	9-3-63	Highway 2 Weir	27 days
3589	8-13-63	24.3	6.9	Male	9-10-63	Highway 2 Weir	28 days
4616	7-24-64	21.3	4.1	Female	8-10-64	Highway 2 Weir	14 days
4819	8-20-64	20.6	5.1	Female	11-12-64	Highway 2 Weir	84 days
4877	8-25-64	23.7	5.9	Male	11-4-64	Highway 2 Weir	71 days

* Aluminum jaw tagged fish.

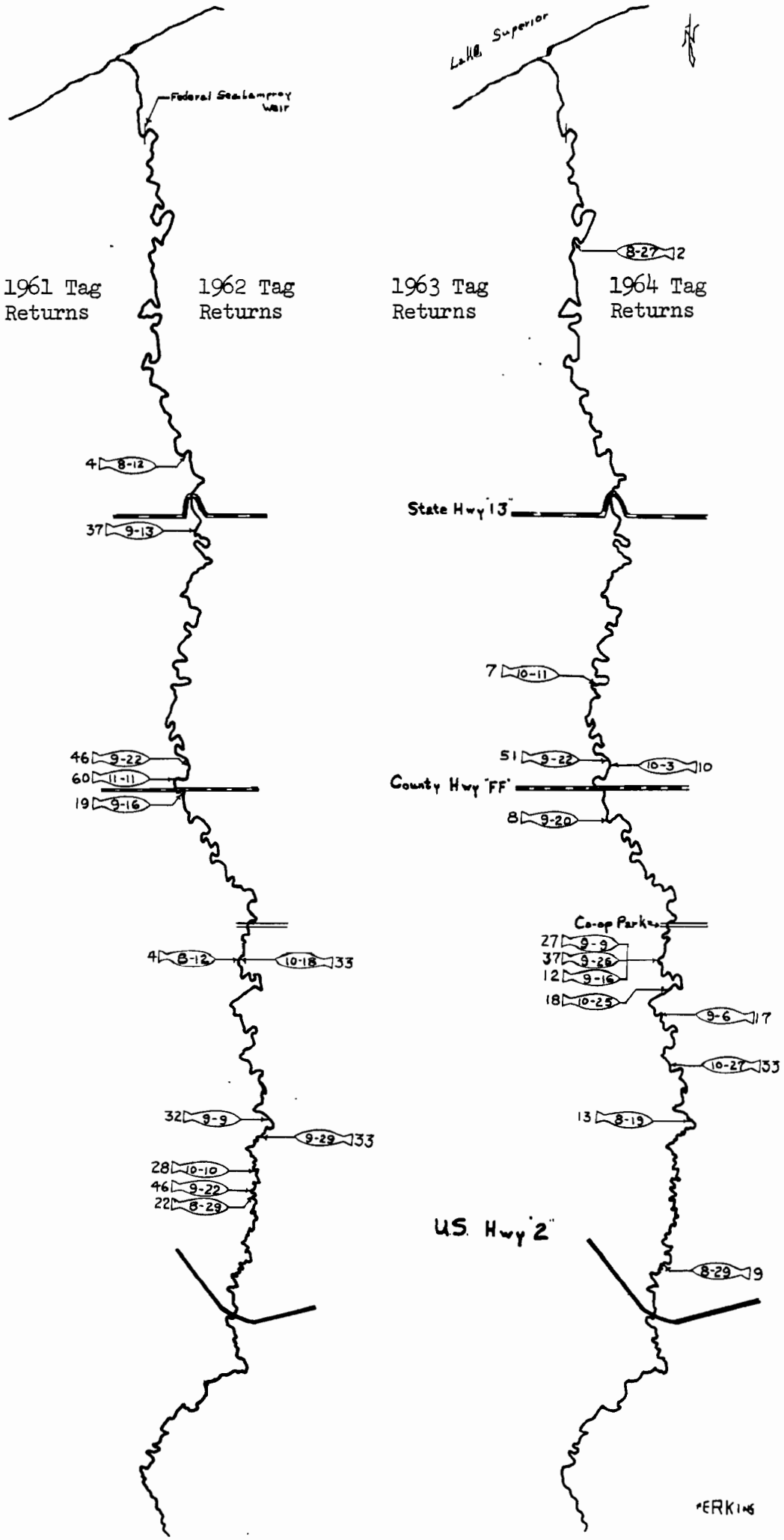


Fig. 7. Upstream location of angler-caught migrating brown trout tagged in the lower Brule River during survey operations. (Date of capture is presented inside of the fish symbol; number outside is interval in days from time of tagging to capture.)

THE CATCH OF BROWN TROUT AT THE UPSTREAM WEIRS

Winnie Weir (Upstream Catch)

The Winnie was operated from August 9 through December 6, 1961. During this period of operation 1,436 brown trout were captured in the trap as they moved upstream (Table 6). The catch consisted of 502 males, 917 females, and 17 unsexed trout. Most of the brown trout captured were migratory fish, although a few 13-to-14 inch resident stream brown trout were included. The greatest upstream movement occurred during September and October, with 89 percent of the males and 76 percent of the females captured during these months; however there was still a small upstream movement in December. In the short time the weir was operated in December, 20 ripe females were captured, still moving upstream to spawn.

The number of adult brown trout captured constituted an excellent spawning population, yet many additional trout spawned below and never traveled this far upstream.

Highway 2 Weir (Upstream Catch)

The Highway 2 Weir was put in operation August 16, 1962 and was used during the remainder of the study period. The catch of brown trout moving upstream at this weir varied considerably over the three-year period of operation. The total catch was 386 in 1962; 1,255 in 1963, and 333 browns in 1964. The variation in catch was a reflection of weir operations rather than trout abundance. In 1962, the upstream catch consisted of 157 males, 228 females and one unsexed fish. Although the weir was operated only the latter half of August, 38 percent of females captured that year were taken in this period. Here again, ripe fish were still moving upstream in December.

The best sample of brown trout captured at the Highway 2 Weir was in 1963. The catch of brown trout (1,255) was more comparable to the first years catch at the Winnie Weir when 1,436 browns were captured. The reasons for the increased sample were (1) the weir was ready to operate in July so that earlier moving fish were caught; (2) water conditions permitted almost continuous operations during the period of upstream movement. The 1963 upstream catch consisted of 441 males, 794 females and 18 unsexed fish. The largest monthly catch occurred in August when 57 percent of the total catch of both female and male trout was captured. There was still a strong upstream run of female browns in November when 99 fish were captured.

The catch of browns in 1964 was only 333, 162 males and 171 females. Although the best catch of brown trout was taken during the month of August, the heavy run which occurred in August of 1963 did not materialize in 1964. September operations were severely hampered because of high water and large numbers of trout probably moved upstream at that time, because the numbers of trout observed on the spawning grounds were as abundant as in other years.

There were a number of factors which seemed to influence trout movement and the resulting catch at the weirs.

(1) Brown trout movement in the river was generally greatest when a rise in water level occurred. For example, the most trout caught on any one day was August 17, 1963 - when 95 browns were captured. It was raining at the time and

TABLE 6

The Monthly Catch of Brown Trout Captured in the Traps on Their Upstream Movement at the Fish Weirs Operated on the Brule River

	Upstream											
	Winnie Weir			Highway 2 Weir								
Year	1961			1962			1963			1964		
Sex	Male	Female	Unknown	Male	Female	Unknown	Male	Female	Unknown	Male	Female	Unknown
January											1	
February												
March												
April												
May												
June												
July							29	65	4		1	
August	36	78	2	49	87		251	453	12	126	109	
September	187	304		53	39		74	94	4	4	9	
October	260	397	11	38	36	1	69	83		12	6	
November	18	118	4	11	56		18	99		20	46	
December	1	20		6	10							
Yearly Total	502	917	17	157	228	1	441	794	20	162	171	0

the water was gradually rising and becoming turbid. Brown trout were observed working along the weir screen and were actually entering the trap while trout already in the trap were being processed. On September 10, 1961 under similar conditions, 76 trout were captured at the Winnie Weir. As the water cleared and the level dropped, the catch of trout would also decline.

(2) Movement of trout was minimal during bright sunny days, especially when the water was low and clear. The curtailed movement under these conditions permitted the raising of the weir gates during the day, which was particularly advantageous at times of heavy leaf fall. Late in the fall limited daytime movement was observed on dark days or toward evening.

(3) Trout movement was also better on darker nights. Fish catches were consistently greater on cloudy nights or during periods of subdued light. On bright moonlight nights trout activity was very limited and many times the traps would be empty the next morning. Ruggles and Ryan (1964) reported that the downstream movement of small Pacific salmon into guiding louvers was greatest during hours of darkness.

(4) The main task in operating the weirs was to keep the screen and traps clear of leaves and other debris. At times of heavy leaf fall the weir had to be cleaned at intervals of from one to every two or three hours. This frequent activity, plus the use of a light, would continually disturb any trout working the screen. The trout would temporarily retreat into the darkness, or to escape cover, returning again when cleaning activities ceased.

Even though the job of cleaning the weirs did disturb these fish, the catch of trout in September and early October (period of heavy leaf fall) at the Winnie Weir was very good and considerably better than at the Highway 2 Weir for the same time period. The observations suggest that the physical characteristics of the river immediately below the respective weirs had considerable bearing on the trapping results. Below the Winnie Weir the river was shallow and fast with rapids-like conditions for 200 to 300 yards. Except for the cover of darkness there was really no place for these large trout to hide or stay. Therefore once a trout started moving through this shallow area it continued its movement in spite of any disturbances or interruptions, rather than retreat the long distance back downstream to protective cover. In contrast to these conditions, immediately below the Highway 2 Weir there was a deep run (long pool - 4-to-5 feet deep) with good overhanging cover, which provided excellent escape and hiding cover. Another similar run and a river bend pool were located less than 150 yards downstream. Fish frightened from the weir could drop back into the nearby protective seclusion of these pools for an indefinite time before trying again to move upstream.

Stream Recapture of Tagged Fish

The movement of trout tagged at the weirs and later recaptured in subsequent spawning runs revealed some interesting patterns relative to time of movement. Unfortunately the number of recaptures was comparatively small so the movement patterns presented might be merely coincidental. However, it should be emphasized that these trout were free to move and enter the weir traps as they so desired. Sampling at the weirs was also done intermittently which also could have some bearing on the number of recaptures. The relocation of the weir sites also injects an unknown factor in comparing the time of capture and recapture since there was a difference of 4.8 miles between weirs. Trout recaptured after an elapse of one and two years have been included in this analysis (Table 7).

As normally would be expected, there was considerable variation in date of capture from one year to the next. The greatest difference was a female fish captured 48 days later and a male fish captured 40 days earlier than the previous year. Both of these trout were tagged and recaptured at the same weir. The most precise movement exhibited by these fish was 4 trout captured and tagged at the Highway 2 Weir between August 15-17, 1963 and recaptured between August 14 and 20 in 1964. The time variation for these trout was only 1 to 3 days and in both years these fish were moving upstream well in advance of the spawning period. Brown trout, numbers 3713 and 3729 were both tagged on the same day (August 17) in 1963, and both were recaptured on the same day (August 20) the following year. Another trout tagged November 7, 1963 was recaptured only 5 days later on November 12 in 1964. Some of the trout tagged at the Winnie Weir in 1961 and recaptured at the Highway 2 Weir in 1962 showed a well timed schedule of movement considering the difference in weir locations. Here again there was a matter of only a few days difference in dates of capture for some fish.

These fish also showed some tendency to move about the same time each year. Trout that migrated upstream early (August - September) one year usually moved early the following year and trout moving later (October - November) showed up later.

Most of the trout recaptured two years after tagging showed up earlier. Recapture dates varied from 15 to 30 days earlier, but most of the two-year tagged trout were tagged at the Winnie Weir and recaptured at the Highway 2 Weir. Under the circumstances an earlier recapture date would be anticipated if these migrating trout followed the movement pattern as determined from the other tagged recaptures.

SIZE OF MIGRATORY BROWN TROUT

Trout captured during the study were measured for total length to the nearest 0.10 inch and weighed to the nearest 0.10 pound. The size of migratory brown trout captured in the Brule River ranged from a minimum of about 15 inches to over 31 inches. The average size was about 22 inches. The length frequency and size distribution of 4,025 trout sampled during the study from all areas of the river is presented in Fig. 8. The number of females in the sample was 2,567 or 63.8 percent - compared to 1,458 or 36.2 percent males. The peak of the mode for female trout occurred at 21.0 - 21.4 inches, while the peak for male trout was fairly constant from 22.0 to 23.4 inches.

Further information on the size of migratory brown trout is provided in Table 8 and Figs. 9 and 10. These compilations are based on fish captured moving upstream at the weirs prior to spawning. The average weights presented in Table 8 show relatively little difference between sexes for most size groups. This information should be helpful to the angler in estimating more accurately the weight of the fish he catches.

The weight ranges (Figs. 9-10) show considerable variation for both sexes in some of the size groups. This is a reflection of the various shapes and sizes of individual fish comprising the overall population. Some fish were long and slim while other specimens were short and robust. Some physically deformed fish were included in the sample and oftentimes these fish made some difference in the weight ranges.

TABLE 7

Comparison of Dates of Capture and Recapture of Brown Trout at the Weirs - One and Two Years After Tagging

Tag Number	Date Tagged	Tagging Location	Sex	Date Recaptured	Recapture Location	Time Difference in Days
1627	8-25-61	Winnie Weir	Female	8-16-62	Hwy. 2 Weir	9 days earlier
1675	8-31-61	Winnie Weir	Female	9-4-62	Hwy. 2 Weir	4 days later
2147	9-23-61	Winnie Weir	Female	9-8-62	Hwy. 2 Weir	15 days earlier
2402	10-6-61	Winnie Weir	Female	9-12-62	Hwy. 2 Weir	24 days earlier
2491	10-8-61	Winnie Weir	Male	10-9-62	Hwy. 2 Weir	1 day later
2618	10-12-61	Winnie Weir	Female	10-16-62	Hwy. 2 Weir	4 days later
2622	10-12-61	Winnie Weir	Female	11-3-62	Hwy. 2 Weir	22 days later
2692	10-17-61	Winnie Weir	Female	11-15-62	Hwy. 2 Weir	29 days later
2897	8-29-62	Hwy. 2 Weir	Female	10-16-63	Hwy. 2 Weir	48 days later
3005	10-16-62	Hwy. 2 Weir	Male	11-10-63	Hwy. 2 Weir	25 days later
3172	12-2-62	Hwy. 2 Weir	Male	10-23-63	Hwy. 2 Weir	40 days earlier
3607	8-15-63	Hwy. 2 Weir	Female	8-16-64	Hwy. 2 Weir	1 day later
3631	8-16-63	Hwy. 2 Weir	Female	8-14-64	Hwy. 2 Weir	2 days earlier
3713	8-17-63	Hwy. 2 Weir	Female	8-20-64	Hwy. 2 Weir	3 days later
3729	8-17-63	Hwy. 2 Weir	Female	8-20-64	Hwy. 2 Weir	3 days later
4455	11-7-63	Hwy. 2 Weir	Male	11-12-64	Hwy. 2 Weir	5 days later
4532	11-22-63	Hwy. 2 Weir	Female	11-2-64	Hwy. 2 Weir	20 days earlier
				2-YEAR INTERVAL		
1825	9-8-61	Winnie Weir	Female	8-17-63	Hwy. 2 Weir	22 days earlier
1850	9-10-61	Winnie Weir	Male	8-22-63	Hwy. 2 Weir	18 days earlier
1942	9-11-61	Winnie Weir	Female	8-27-63	Hwy. 2 Weir	15 days earlier
2020	9-16-61	Winnie Weir	Female	8-23-63	Hwy. 2 Weir	28 days earlier
2091	9-20-61	Winnie Weir	Male	8-25-63	Hwy. 2 Weir	26 days earlier
2403	10-6-61	Winnie Weir	Female	10-25-63	Hwy. 2 Weir	19 days later
3175	12-4-62	Hwy. 2 Weir	Female	11-2-64	Hwy. 2 Weir	30 days earlier

Number of fish captured in succeeding years within:	Tagged and Recaptured	
	Same Weir	Different Weirs
10 days of date of original capture -	5	4
11 to 19 days of date of original capture -	-	4
20 to 29 days of date of original capture -	2	6
More than 30 days of date of original capture-	3	

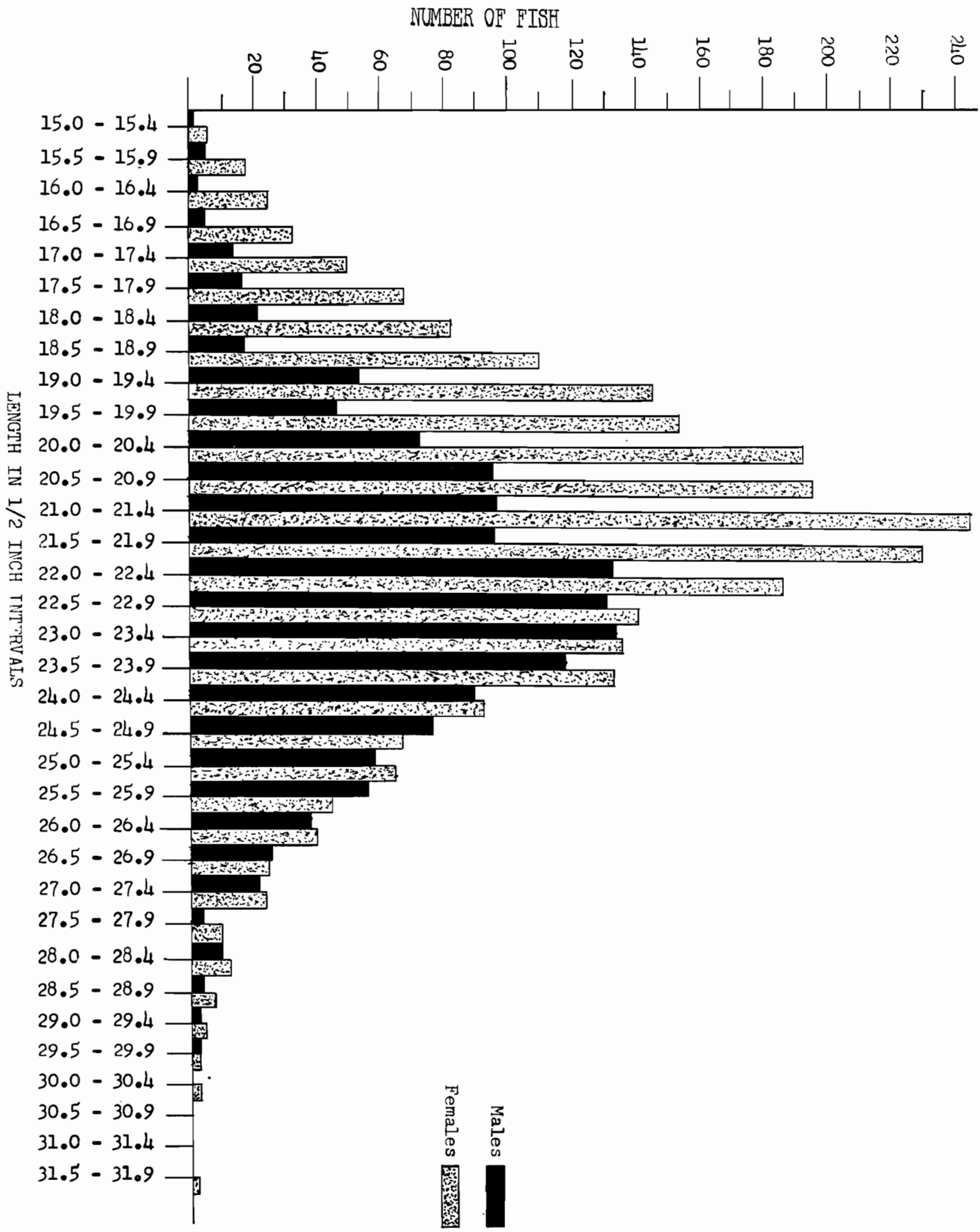


Fig. 8. Length frequency and size distribution of migratory brown trout captured in the Brule River

TABLE 8

A Comparison of Average Weight and Weight Range of Male and Female Migratory Brown Trout Captured in the Brule River Weirs Between 1961 and 1964

Length	Sex	Number of Fish	Average Weight	Weight-Range
15.0-15.9	M	7	1.4	1.2 to 2.0
	F	13	1.8	1.4 to 2.2
16.0-16.9	M	3	2.0	1.9 to 2.2
	F	37	2.6	1.5 to 3.0
17.0-17.9	M	14	2.4	2.0 to 3.1
	F	68	2.4	1.7 to 3.9
18.0-18.9	M	22	2.8	2.1 to 4.0
	F	102	2.8	1.9 to 4.3
19.0-19.9	M	68	3.1	2.1 to 4.3
	F	170	3.2	2.0 to 5.2
20.0-20.9	M	113	3.6	2.0 to 5.5
	F	223	3.6	2.2 to 5.4
21.0-21.9	M	114	4.2	3.3 to 5.5
	F	234	4.1	2.2 to 6.0
22.0-22.9	M	158	4.7	3.4 to 6.8
	F	152	4.3	3.3 to 6.8
23.0-23.9	M	142	5.2	3.4 to 7.5
	F	141	5.1	3.3 to 7.2
24.0-24.9	M	84	6.1	4.6 to 7.5
	F	64	6.2	4.4 to 7.9
25.0-25.9	M	46	6.8	5.3 to 8.6
	F	38	6.9	4.6 to 8.5
26.0-26.9	M	37	7.5	5.7 to 8.9
	F	24	7.7	5.7 to 9.2
27.0-27.9	M	10	7.8	5.0 to 9.1
	F	14	8.6	7.4 to 9.8
28.0-28.9	M	6	9.3	8.3 to 14.6
	F	5	9.5	7.5 to 10.8
29.0-29.9	M	2	9.2	8.3 to 10.1
	F	5	11.0	9.6 to 11.7
30.0-30.9	M	0		
	F	1	11.4	11.4
31.0-31.9	M	0		
	F	2	13.1	12.8 to 13.5

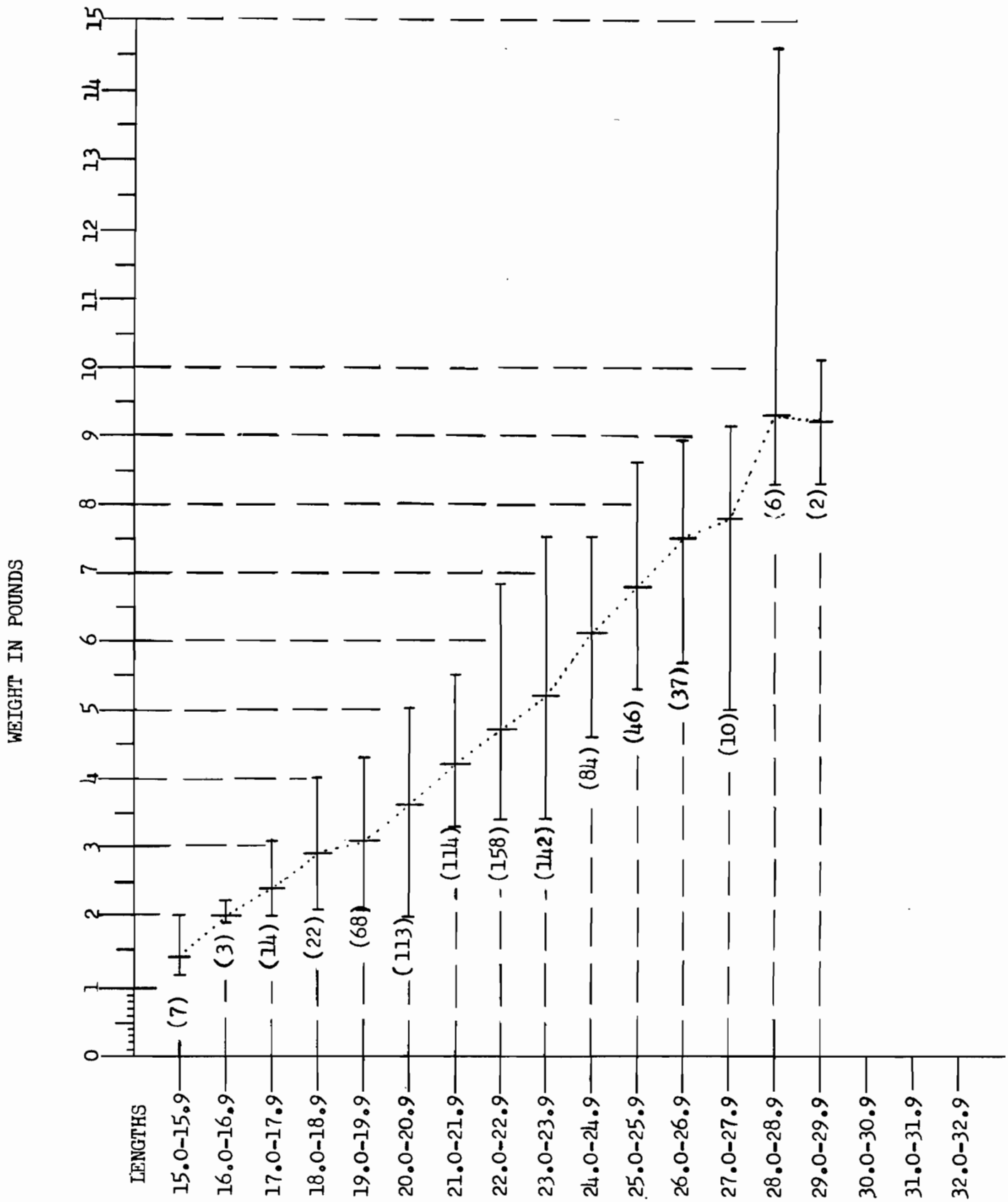


Fig. 9. Weight range and average weight of male migratory brown trout. Figure in parenthesis is the number of trout in the sample.

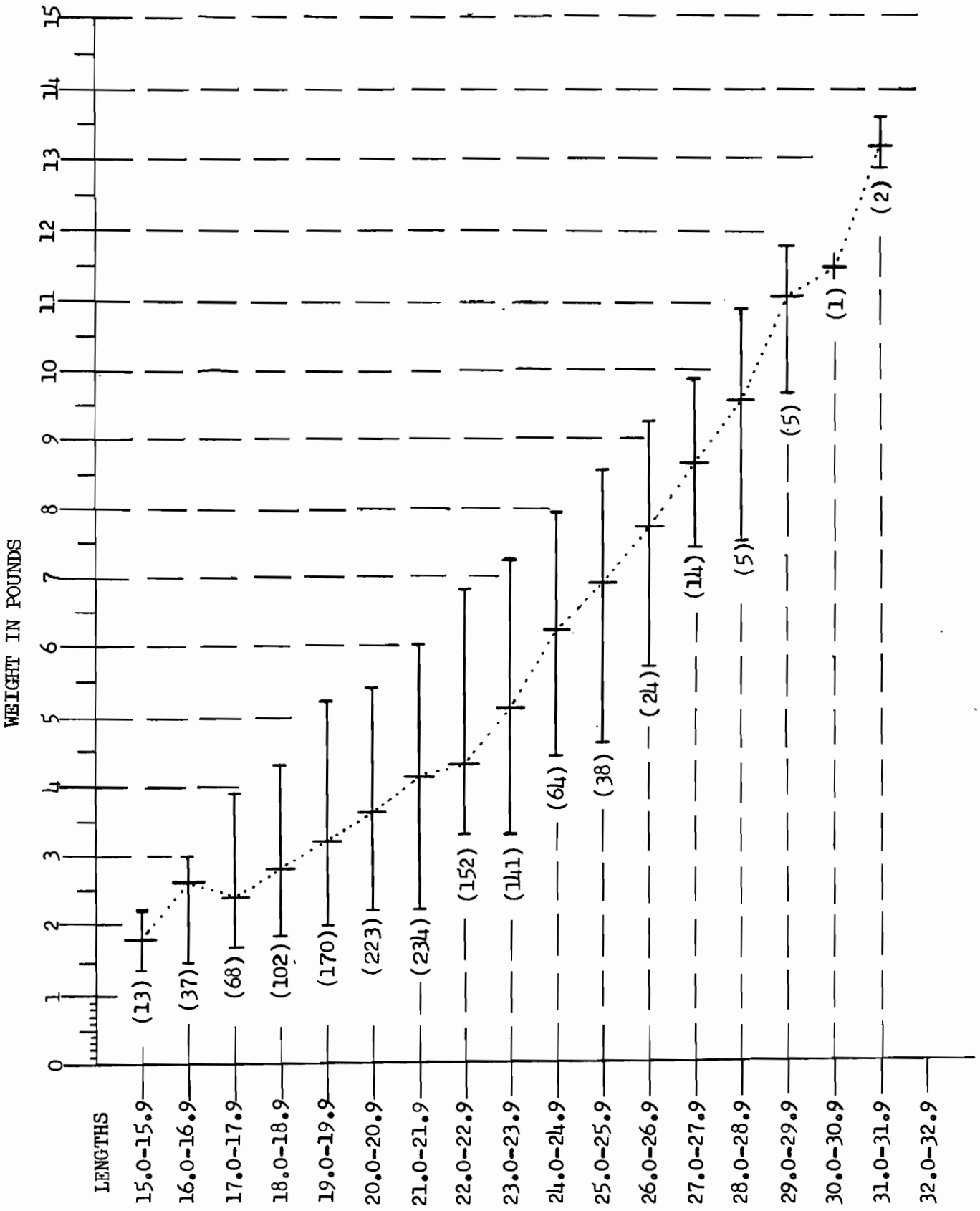


Fig. 10. Weight range and average weight of female migratory brown trout. Figure in parenthesis is the number of trout in the sample.

AGE AND GROWTH

Age determinations were made from an examination of scale samples. Many workers including Greeley (1948); Hartman (1959) and Hallock et al (1961) have used this method for aging migratory salmonoids.

Scale samples were collected from most of the trout handled. Scales were normally taken from an area above the lateral line and just posterior of the dorsal fin. As previously indicated, scales from female trout were easily collected, whereas the scales of male fish were so firmly imbedded in the tough skin that their removal was difficult. In larger males it was often times impossible to get a scale sample from the area described or anywhere else. Other places on the fish's body, such as toward the tail or near the head, were tried with varying degrees of success. When scales were secured from these areas, the scales were questionable in quality. The scales were pressed onto heated cellulous acetate slides and the resulting impressions were read with a microscope.

Scale samples were read in groups of 100 fish randomly selected from each year of the study. Not all of the scale samples within a given group could be read because of regenerated scales, washed-out centers, poor or incomplete scales, or incomplete outer margins.

The total number of brown trout sampled was 4,025 (1,458 males and 2,567 females) and of this total 19 and 22 percent respectively were aged.

Age was determined by the number of annuli present on a given scale but the ages are presented in summers of growth. Scale samples were taken late in the summer and through the fall after growth for the year was completed. The annual growth for migratory trout occurs during the time they spend in Lake Superior and not while the fish are in the river.

The growth pattern on the scales shows that the fish generally spend two years in the river. Growth in the river is slower and therefore the circuli and the first two annuli are more closely spaced. The young trout (parr) leave the parent stream either late in the second year or early in the third year of their life. The most rapid growth occurs in the third year, the first year in the lake environment. This is evident by the much wider spacing of the circuli on the scales. Growth in the ensuing years is good but nowhere nearly as rapid as in the third year.

Growth patterns on the scales can be used to distinguish between lake-run and resident stream fish. Resident trout show a more uniform and slower growth in contrast to the accelerated growth exhibited by lake-run trout.

Migratory trout that have participated in spawning activities develop spawning marks that are clearly evident on the scales. These scales showed the same areas of erosion and large clear streaks (spawning marks) described by Hartman (1959). Spawning marks coincide closely with annulus formation, even to a point of obliterating the annulus. In these instances the spawning mark was interrupted as the annulus. As the fish grow older the annulus or spawning marks are more closely spaced.

The length frequency distribution of aged male and female migratory brown trout is shown in Figs. 11 and 12. Both male and female brown trout first become spawners in the fourth year. The majority of the browns in the spawning population were fish in the fourth and fifth year. There was no evidence of younger - smaller migratory brown trout entering the river on a pre-spawning run as has been found in migratory rainbows.

The female spawning population consisted of 32.5 percent fourth year fish, 48.6 percent fifth year; 17.1 percent sixth year; and 1.8 percent seventh year fish. The composition of male spawners was 23.3 percent fourth year fish; 59.2 percent fifth year, and 17.5 percent sixth year fish. No seventh year males were found, and no brown trout were found more than seven years old. It is therefore assumed that seven years is the maximum life expectancy for these trout. This age limit agrees with that found by Greeley et al, (1948) in his study of the landlocked salmon - Salmo salar sebago.

Exceptional growth is attained by some individual fish. In 1963 a fisherman caught an 18 pound female brown trout. This fish was in its sixth year of life. The scales from this fish showed continued rapid growth each year after migrating to Lake Superior. Fish of this size are rare but it does demonstrate the tremendous growth potential of some of these trout. Even though these trout grow to a large size they are not old fish, a fact which is contrary to the thinking of some people.

A comparison of age, growth, size range and growth increment for both female and male trout are present in Table 9. In the 4th and 5th year male trout averaged slightly larger in size than females. By the sixth year the average size of both sexes was practically identical. The average growth increment in the 5th year was identical for both sexes. In the sixth year females showed a greater increase in both length and weight.

Further information on growth increment, shown in Table 10 is based upon a limited number of recaptured or recovered tagged trout. The growth increases presented were broken down into three time intervals; (1) fish tagged in the spring recaptured that same fall; (2) fish recaptured one year after tagging; (3) fish tagged in a given year and recaptured two years later. The growth increase of recaptured tagged brown trout was not as great in comparison to the increment shown in Table 7 for aged trout. In fact, one female trout actually showed a loss of a tenth of a pound in weight from one year to the next. The size increases for a one year interval (sexes combined) ranged 0.2 to 2.9 inches in length and from a minus 0.1 to plus 3.3 pounds in weight. Almost all of the recaptured tagged trout showed some increase in growth and outwardly appeared healthy and in good condition. Tagging may have affected the growth rate enough to cause the difference noted between tagged and the untagged fish sampled. The sample of recaptured tagged fish was quite small and therefore may not be a true indication of growth increment.

LAMPREY SCARRING

During the process of tagging, each fish was examined for any abnormal features - or unique characteristic. One feature that was noted and recorded was the incidence of lamprey scarring. Since these trout spend some time in Lake Superior, they are exposed to sea lamprey attacks and predation. A noticeable decrease in lamprey scarring occurred as the sea lamprey control program became more effective through the use of selective chemicals.

In 1961, 1,649 brown trout were examined and 245, or 14.8 percent were scarred. In 1962, 54 of 531 browns or 10.2 percent were scarred. In 1963, 71 of 1,461 fish or 4.8 percent were scarred and in 1964 only 10 of 544, or 1.8 percent were scarred. The reduction followed chemical control of lamprey larvae in streams tributary to Lake Superior. King (1965) reported that since 1961 there has also been a sharp decline in sea lamprey scarring of lake trout in Lake Superior.

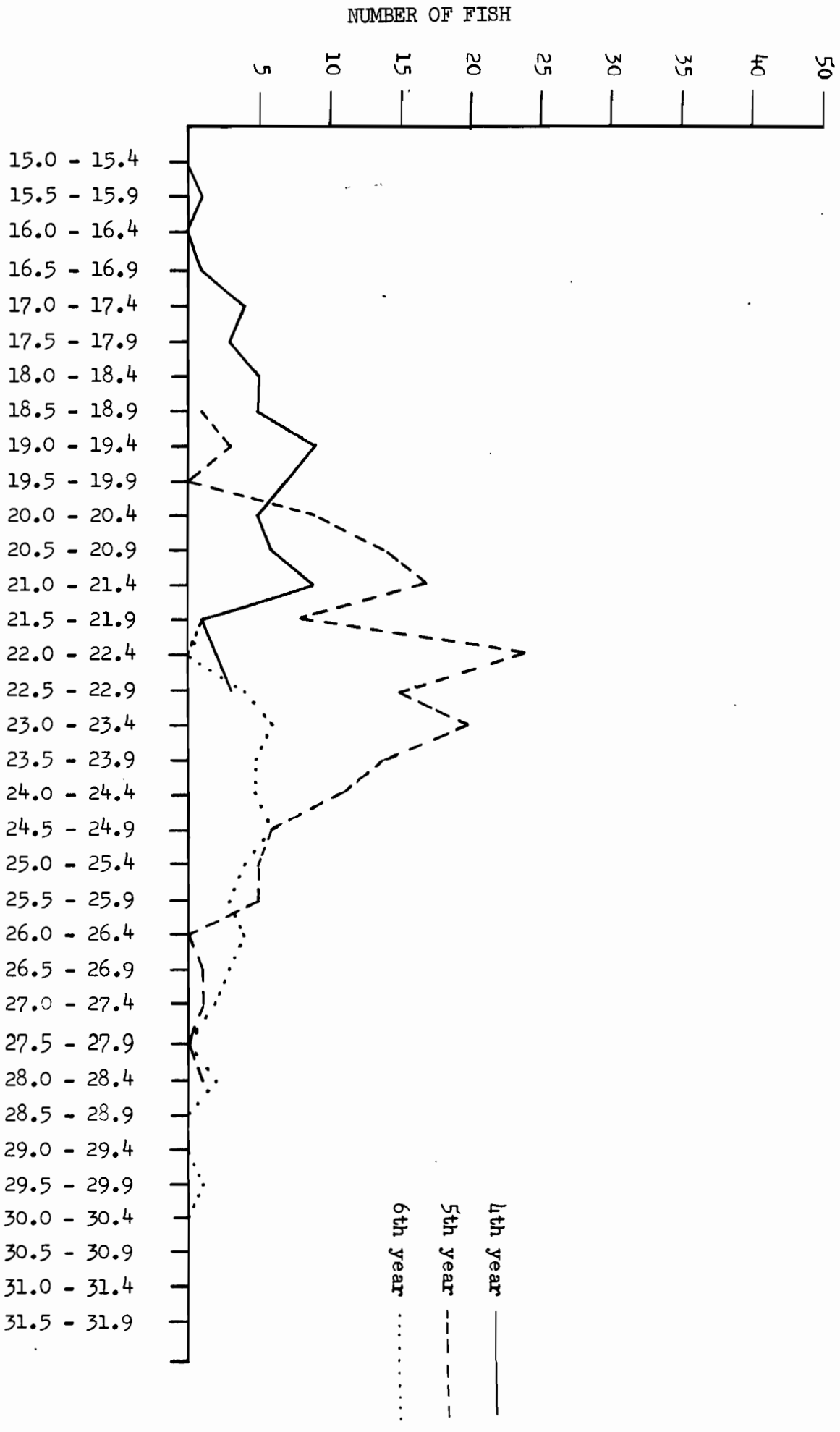


Fig. 11. Length frequency of male trout for separate ages.

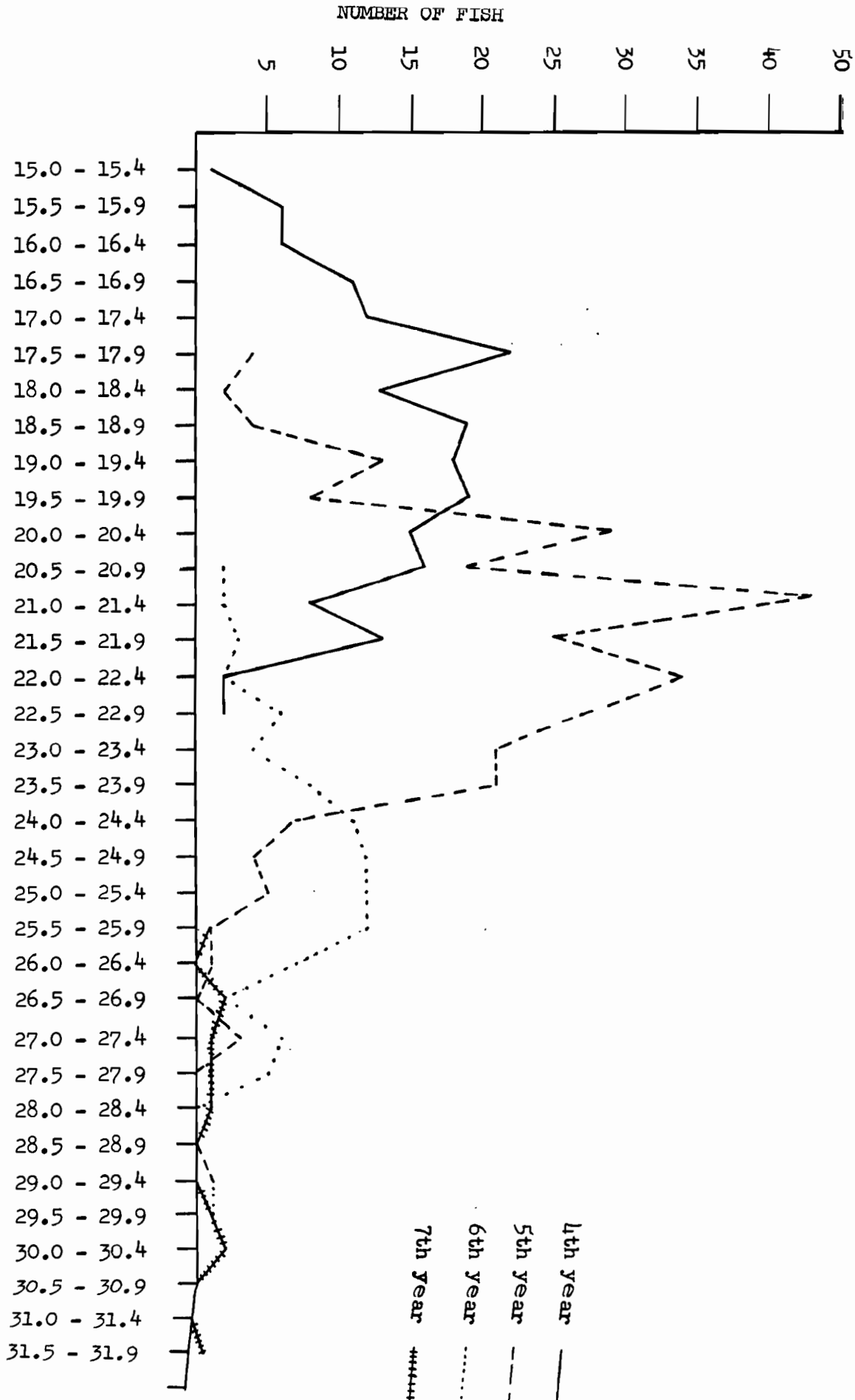


Fig. 12. Length frequency

TABLE 9

Range and Mean Lengths and Weights of Migratory Brown Trout of Various Ages

Age Group	4th Year		5th Year		6th Year		7th Year	
Sex	Male	Female	Male	Female	Male	Female	Male	Female
Size Range (Inches)	15.6-22.9	15.6-22.8	18.5-28.0	17.5-29.0	21.9-29.7	29.9		25.5-31.5
Weight Range (Pounds)	1.6-6.0	1.6-5.4	2.6-11.5	2.0-11.0	4.0-14.6	2.9-10.5		7.0-13.9
Average Length (Inches)	19.6"	18.9"	22.5"	21.8"	24.8"	24.7"		28.4"
Sample Size	61	183	167	273	46	97		10
Average Weight (Pounds)	3.4#	3.0#	4.9#	4.5#	6.6#	6.6#		9.8#
Sample Size	56	166	163	244	46	95		10
Growth Increment			2.9	2.9	2.3	2.9		3.7
Weight Increment			1.5	1.5	1.7	2.1		3.2

TABLE 10

Growth Increment Recorded for Recaptured Tagged Trout

Time Interval	Number and Sex	Length in Inches		Weight in Pounds	
		Range of Length Increase	Average Increase	Range of Weight Increase	Average Increase
*Spring to fall - less than 1 year interval.	4 males	0.9 to 2.8	1.9	(1-fish) 1.3	1.3
	1 female	1.3	1.3		
One year Interval	7 males	1.5 to 2.9	2.3	0.9 to 2.3	1.5
	16 females	0.2 to 2.1	1.4	-0.1 to 3.3	1.3
Two year Interval	2 males	2.8 to 3.9	3.4	1.8 to 2.4	2.1
	6 females	3.0 to 4.3	3.5	(5 fish) 2.2 to 3.7	2.7

* Brown trout - trapped and tagged at the Federal Sea Lamprey Weir by operating personnel. Streamer type tag was used, attached below the dorsal fin.

A majority of the scars observed on these trout were from previous wounds that had healed. Most of the scarred fish examined had only one scar. When the scarring incidence was higher, it was not uncommon for some of the larger and older fish to have multiple scars.

A few trout were captured that had fresh lamprey wounds. Occasionally a trout was captured in the lower river during boom shocking operations with a sea lamprey still attached. In these instances the sea lamprey undoubtedly attacked the trout while in Lake Superior and was carried along by the fish into the river. Stauffer (1964) mentioned that a sea lamprey barrier constructed on the Black River in Michigan prevented upstream movement of feeding sea lampreys which entered the stream in the late summer and fall. In all of our boom shocker work in the lower Brule during the summer and fall period mentioned by Mr. Stauffer, we did not find feeding sea lampreys other than previously stated. Normally adult sea lampreys found in the Brule River were there to spawn and were no longer feeding or predaceous. Spawning sea lampreys were sometimes observed and captured during shocking operations conducted in July and August.

SPAWNING AREAS AND SPAWNING ACTIVITIES

Spawning Areas

The important spawning grounds are located south of U. S. Highway 2. This area can further be defined as starting approximately one mile south of Highway 2 and extending upstream to Mays Rips (Fig. 13). This section of the Brule is characterized as having areas of suitable gravel bottom in conjunction with a good flow of clean water. The spawning areas located in this part of the river have been classified as major and minor, based upon observations of utilization and suitability. In this area (Highway 2 to Stones Bridge) there is approximately 80 acres of water not including the acreage of Big, Lucius, and Spring lakes. A rough measurement of the spawning areas showed there is approximately 94,000 square feet or 2.15 acres of river either being used or suitable for spawning. Each year the same gravel beds are heavily used and at the peak of the spawning period hundreds of these large trout can be observed fulfilling the mission for which they came.

Some of the spawning areas reported by O'Donnell and Churchill (1954) are still heavily utilized today. Some areas which these workers reported as not being used or not having a suitable bottom are now heavily used for spawning. The expanded use of spawning areas is no doubt due to the increased numbers of migratory spawners.

Some redds and spawning activity were observed north of Highway 2 downstream to just above Coop Park. Through this part of the river spawning is more widely scattered and less intense in comparison to the upper spawning grounds.

The stream bottom of the Brule River from Mays Rips upstream to Stones Bridge is very heavily silted and from Stones Bridge upstream the bottom type is primarily sand. These sections of the river afford little in the way of suitable spawning grounds for trout. Observations on trout movement as reported by Fallis and Niemuth (1962) showed migratory brown trout movement in this area to be minimal. A two-way fish weir located just below Stones Bridge was operated continually from April, 1958 through December 5, 1960 and in the three years only 61 brown trout were passed upstream during the spawning season.

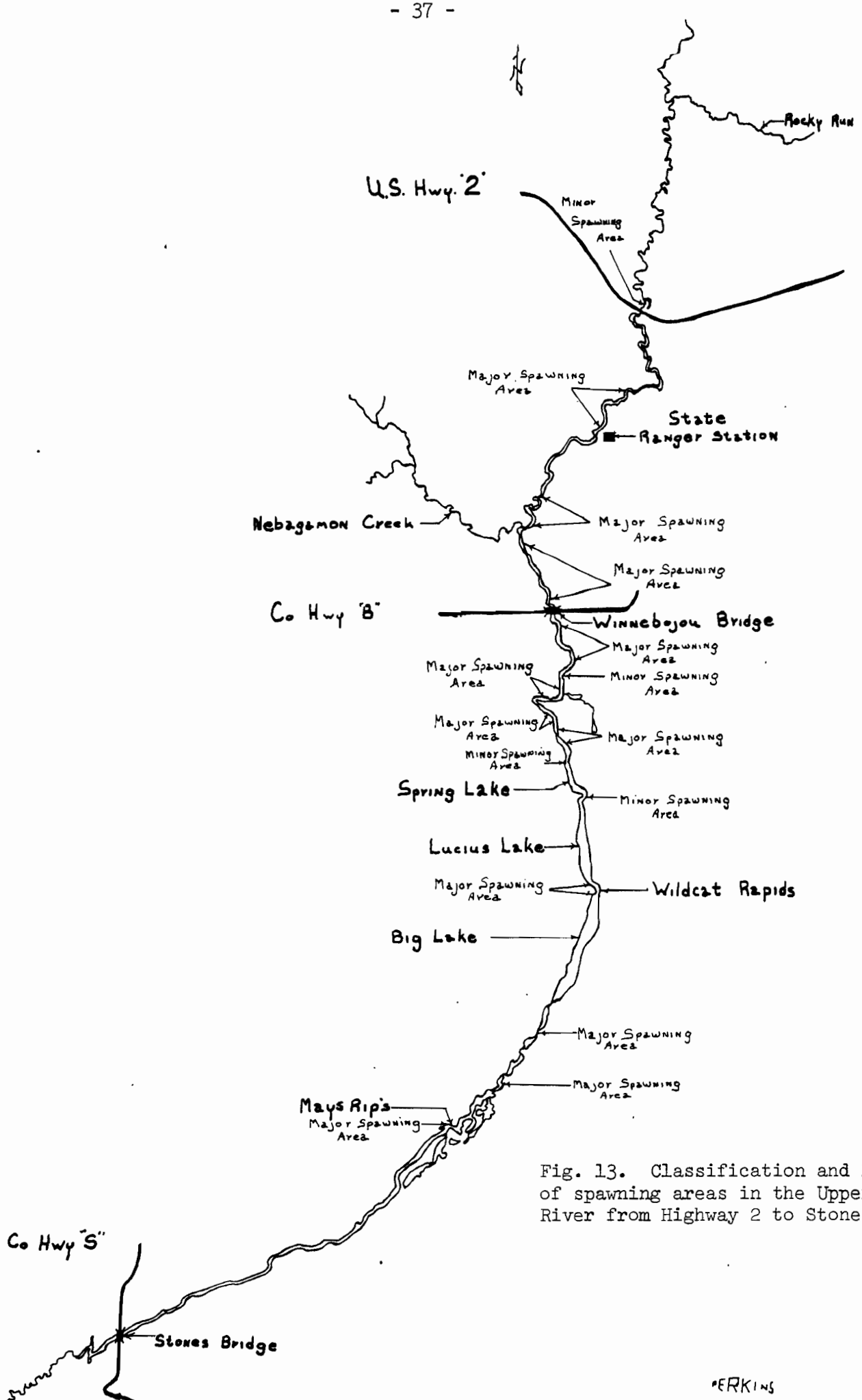


Fig. 13. Classification and location of spawning areas in the Upper Brule River from Highway 2 to Stones Bridge.

Migratory brown trout, including tagged fish have been observed spawning in the Little Brule River immediately below the Brule Trout Hatchery. The number of trout utilizing this area is small. This stream itself is small and good spawning gravel is rather limited.

A stream shocker survey of the lower section of Nebagamon Creek showed practically no movement of lake-run brown trout into this stream. Here again spawning areas for large size trout are limited.

Time of Spawning

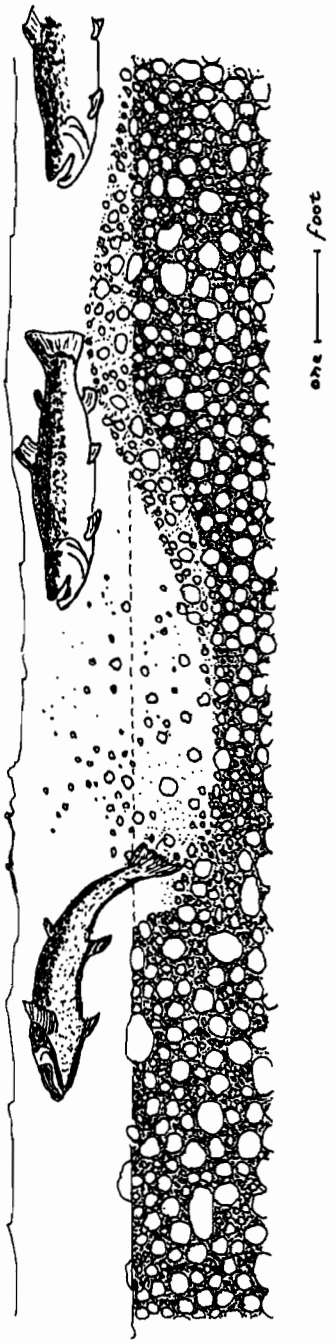
In many respects the spawning habits of these migratory browns approximates that of the Atlantic salmon, Salmo salar salar, as reported by Belding (1934). In the Brule River brown trout spawning activity starts around October 8, with females engaged in pre-spawning digging similar to that reported by Burner (1951) in his study of salmon spawning in the Columbia River. Spawning activity continues through the fall into early December. The peak occurs between mid-October and mid-November. The water temperatures during the spawning period will vary somewhat from year to year but will range from the mid 50's early in October to the mid 30's by early December.

The areas selected by the fish are those having a suitable gravel subtrate, a good flow of water to aerate the eggs, and some type of escape cover nearby. The location of redds in the stream varied, but in all cases exact location was primarily dependent upon the availability of suitable gravel (Fig. 14). The gravel in the spawning sites is generally irregular in shape but ranges from pea to grapefruit in size. The depth of water in which these trout spawned ranges anywhere from 6 to 48 inches. Many of the larger redds were located in midstream in areas of strong current and deeper water. Some smaller redds were located close to the stream banks and away from the main current but still within an area having a suitable water flow.

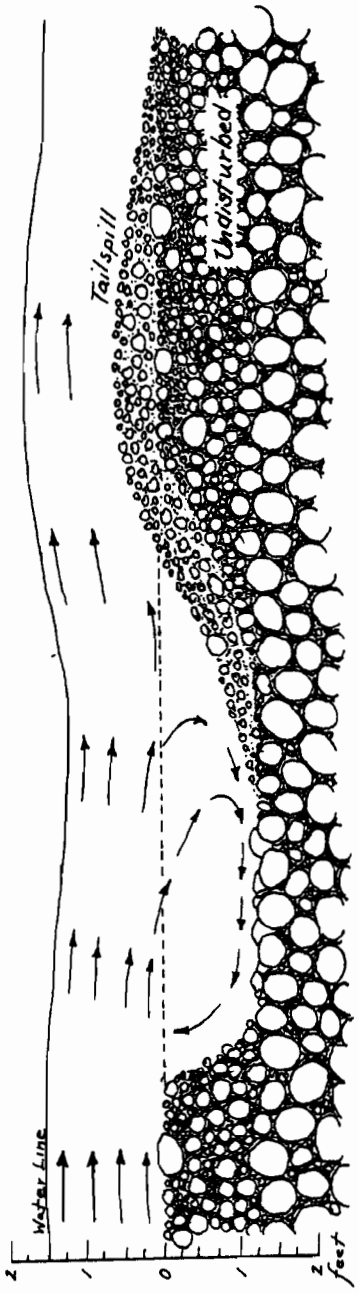
The water in the upper river is very clear and in some spawning areas rather shallow so nearby escape cover is desirable. When startled, these fish try to hide. Escape cover may be only a deeper, darker pool, but overhanging or instream cover is even more desirable. These fish take advantage of any available cover and have been observed using backwater or eddy pools covered with an accumulation of floating leaves and debris. Although only temporary in nature these leaf covered areas offer excellent protection at a time of year when it is needed. As many as a dozen or more large trout have been spooked from one of these leaf covered pools.

It is possible to approach spawning trout by drifting along quietly in a canoe or walking cautiously along the bank. However, the moment the fish sense one's presence there is a wild scramble for whatever escape cover is available. Fortunately in the fall of the year there is not much disturbance in this area of the river. Fishing is not allowed, the summer homes are normally vacant and canoe traffic is more limited. Although spawning activity is generally heavier during hours of darkness, it is not uncommon to see these trout very active during the daylight hours even on bright sunny days but especially on dark cloudy days.

Stuart (1953) reported that the largest fish run first and farthest upstream and spawn together. In the Brule River this was not necessarily true. Here the trout seemed to utilize the lower spawning grounds more intensely earlier in the spawning period. During October more trout and more spawning



Redd making. Female digging.



Typical currents in a redd.

Fig. 14. Migratory brown trout spawning redd (nest). Modified after the illustration by Burner (1951).

activity was noted in the section from the first major spawning area above Winneboujou downstream to below the Ranger Station. After October or by early November spawning activity in this area was negligible, whereas farther upstream in the Wildcat Rapids, Cedar Island area fish were still actively spawning.

The redds were easily recognized by the exposure of clean, lighter colored gravel. In the Brule River two distinct types of redds were observed, both types being made by migratory brown trout. In places where suitable gravel was limited, only one pair of fish would use the site. Under these circumstances the resulting redd was a typical, well defined, oval shaped nest. In contrast to these simple redds the other type observed could best be described as a community redd. Through the individual efforts of a number of fish spawning closely together no distinct nest was formed, but a large, deep excavation and tailspill resulted. Laterally some of these community redds were several feet wide and the pit three or four feet deep. It was not uncommon to see from 6 to 12 large trout at a time in a community redd. These larger redds were built in areas where the water as well as the gravel was deeper.

In places where the water was shallower but the gravel extensive, redds were not as large but were constructed in close proximity to one another. Some of the more suitable gravel riffles were completely covered with redds.

After spawning most of the trout vacated the immediate area of the spawning site. Many fish remained in the upper section of the river but retreated to deeper pools and areas of good instream cover. At times it was not uncommon to see from 25 to 50 or more large trout in a single pool which offered good protection. Stuart (1953) stated that the brown trout is generally a non-gregarious fish, rarely tolerating the close presence of another individual. This characteristic was not at all applicable to migratory brown trout in the Brule River. Here brown trout have been observed close together in large pools, moving upstream together in schools, spawning together, schooling together after spawning, and finally moving downstream in collective groups. Some fighting and other spawning commotion, such as driving off other fish was observed, but generally speaking these fish seem to be tolerant of one another.

FECUNDITY OF MIGRATORY BROWN TROUT

Information on fecundity of large brown trout is very limited. Data on fecundity was obtained from egg counts of the ovaries of five gravid females. The direct method of counting all of the eggs in a given ovary, was used. Females of various sizes were selected so as to determine any differences in egg production based upon size. The results of the egg counts made are summarized in Table 11.

The recorded counts generally agreed with those presented by Carlander (1953) for fish of comparable sizes. The counts showed that egg production increased as the size of the fish increased. Some variation was found in the number of eggs contained in each of the ovaries of an individual fish. The difference ranged from 78 to 472 eggs with a greater variation in larger fish. Some of the difference could have resulted from error on the part of the counter, since the eggs were only counted once. Brown and Kamp (1941) reported that the left ovary of the brown trout examined in the Madison River, Montana, was generally larger, heavier and contained more eggs. This could explain the differences we found in our count since the ovaries from four of the sample fish were not labeled. In the 17.5 inch female the ovaries were labeled when removed and the left ovary did have more eggs. Even though a limited number of egg counts

were made, the data does provide some indication of the reproductive potential of these migratory brown trout.

CONDITION OF SPAWNED-OUT TROUT

There was a noticeable change in the condition of the trout before and after spawning. Brown trout entering the Brule River were in excellent condition. Even trout that entered the river several weeks before spawning and lived without feeding, remained in good condition. Fish examined after spawning showed a change in body weight. This was particularly true of female trout and to a lesser extent in male fish. The body weight loss corresponded closely to the percentage of the gonads to the total body weight. Stuart et al, (1953) reported that gonads of female brown trout may account for up to 10 to 15 percent of the gross weight. Belding et al, (1934) reported that records of weight loss of female salmon after stripping was 24.1 percent of the total body weight and the weight of the testes at the time of spawning was 5 percent. Brown et al, (1941) reported the gonads of male brown trout comprised 1.7 percent of the body weight.

As previously stated, trout captured and tagged at the weirs were carefully weighed. Upon subsequent recovery we had an opportunity to check any differences in weight and condition. A sample of 66 females and 77 males was used to determine difference in pre-spawning and post-spawning body weight. The fish were either recaptured at the weirs or were fish that had died and were recovered.

The 66 female trout averaged 22.7 inches in length and varied from 16.0 to 29.4 inches. The fish varied from 1.7 to 10.2 pounds and averaged 5.2 pounds prior to spawning. The individual differences in weight loss varied from 0.3 to 2.0 pounds and averaged just over 1.0 pound. The percentage of body weight loss ranged from 11 to 38 percent and averaged 20 percent. The total weight of the females before spawning was 340.1 pounds and upon recovery these same fish weighed 270.8 pounds or a loss of 69.3 pounds.

The body weight loss for male trout was far less. In fact, 28 of the 77 males showed no weight change from time of tagging to recovery. The males average 22.6 inches and range from 16.8 to 28.5 inches in length. The fish ranged in weight from 1.7 to 8.7 pounds and averaged 4.9 pounds. Individual differences in weight varied from 0.0 to 1.0 pounds. The percentage of body weight loss ranged from 0.0 to 16.6 percent and averaged 4 percent. Prior to spawning these fish weighted 373.4 pounds and the combined weight at recovery was 357.4 pounds or a loss of only 16.1 pounds.

The body weight loss for brown trout in the Brule River generally agrees with data previously reported by other workers. Normally the condition of these spawned-out fish would be of little concern in the management of the population. However, there is little or no improvement in the condition of trout remaining in the river over winter. This is probably due to the cold water temperatures which reduces feeding activities and food requirements and also a lack of available food in the river to support concentrated numbers of large trout. This poor condition is reflected in the thin, flat, rather listless brown trout that are caught in the spring during the special early trout season. Whether the angler realized it or not, this is the type of brown trout available in the spring. One consoling factor is that in the spring these fish show a greater tendency to bite. By this time these trout should be more than ready to feed as they leave the river for the summer feeding grounds in Lake Superior. Most of these fish do not leave the Brule River until April, and by July or

TABLE 11

Fecundity of Five Female Migratory Brown Trout from the Brule River

Length of Fish	Weight of Fish	Egg Count Ovary I	Egg Count Ovary II	Ovary Difference	Total Egg Production
17.5 inches	1.8 pounds	1,020 (Right Ovary)	1,098 (Left Ovary)	78 eggs	2,118
20.5 inches	2.6 pounds	1,091	1,246	155 eggs	2,337
21.9 inches	4.4 pounds	1,551	2,023	472 eggs	3,574
24.8 inches	5.7 pounds	2,512	2,903	391 eggs	5,415
26.4 inches	8.4 pounds	3,548	3,990	442 eggs	7,538

August migratory browns are already returning. These fish not only recuperate any weight loss but also increase up to a pound or more in total weight during this short period.

BROWN TROUT NATURAL MORTALITY

For a number of years anglers as well as Department personnel reported finding large dead or dying brown trout during the fall in the Brule River. The number of dead trout reported was never large so there was no particular concern and no attempt was made to determine the extent of the mortality. In 1956, Mr. Stanley Kmiotek, former area biologist, examined three large brown trout that had been found. He reported that the fish had very pale livers, were inflamed internally and diseased. Bacterial cultures showed the fish to be infected with furunculosis. Lesions caused by this disease were also noted on the bodies.

Briefly, furunculosis is a bacterial disease, and if present is found in the blood and is carried to all parts of the body in the blood stream of a fish. Sometimes the symptoms of this disease are obvious to the naked eye and at other times it is necessary to make diagnostic tests to determine if the disease is present. The extent of the symptoms depends upon how long a fish lives after the disease is contacted or develops. The classic symptoms are the formation of lesions or swelling on the body which are filled with a red, pus-like material, internal inflammation of the body cavity and intestines and the discharge of blood and mucous from the vent. Warm blooded animals are not affected by this disease.

In the fall of 1960, Mr. Randolph Steuck, foreman at the Brule Trout Hatchery, reported seeing a number of dead brown trout during a canoe trip through part of the Upper Brule River. Efforts were made to recover dead trout in this area from late October to freezeup. That fall, 71 dead trout were collected. These fish, 62 males, 11 females, and 2 small unsexed stream trout, weighed 357.8 pounds and averaged 5.0 pounds. Examination of these fish showed the same symptoms reported by Kmiotek.

Many of the salmonoid fish are affected by furunculosis and this disease is widely known and reported in trout hatchery operations. Reported outbreaks of this disease in wild trout populations are more limited. Davis (1953) cited several references of reported outbreaks and losses of fish due to furunculosis in wild population. Davis further stated that among mature trout the disease is usually rare except during and shortly after spawning. This was certainly exemplified in the outbreaks of this disease in the Brule River.

One phase of the study was to determine the loss of migratory brown trout. Immediately the question arises, where does this disease come from and how does it get started? Mr. Paul Degurse, state fish pathologist, assisted in trying to find the answer. Bacterial cultures and blood samples were taken from migratory brown trout captured in various places in the river. Brown trout fresh from Lake Superior, as well as fish captured at the weirs were tested. In a number of the fish sampled positive reactions were obtained. It was concluded that many of these trout are actually carrying the disease. Therefore, under suitable conditions the disease could become active, thus killing the fish. The close contact some of these trout have with each other during the spawning run makes it rather easy for diseased fish to possibly infect other fish.

A combination of spawning stress, old age, and the disease itself may be important causes of mortality in these brown trout. During this study an effort was made to recover all the dead or dying brown trout found in an area from Stones Bridge down to the Coop Park bridge, a total distance of 22 miles by river. This section includes the major spawning grounds and the area immediately below. Periodic canoe trips were made through this part of the river to pick up all dead or dying trout that would not otherwise drift or be carried downstream (Fig. 14a). The 22 miles of river was divided into several shorter runs so that only part of the river was covered on one trip. The frequency of the canoe trips depended upon the number of dead trout found, visibility, and other duties. From the middle of October it was sometimes necessary to make three trips a week through the area from Big Lake down to Highway 2 to keep up with mortality.

Besides the brown trout recovered by canoe, dead or dying trout that drifted downstream were recovered at the weirs. By patrolling the river and actually looking for and collecting dead fish, plus catching weak, sick and drifting fish at the weirs, we had a good opportunity to determine at least to some extent the loss of trout. Even with this amount of effort the number of fish reported would have to be considered a minimum figure.

During the four-year period (1961-1964) 2,148 dead brown trout were recovered or recorded. Twenty-eight of these fish were in such poor condition when found (advanced decomposition, partially eaten or destroyed) that essential data could not be collected and were therefore included only in the numerical total. Data collected from the remaining 2,120 fish were used to compile a composite summary of the trout mortality. Normal procedure was to weigh, measure, sex and examine all fish recovered. Some fish, especially females, were cut open to determine extent of spawning prior to death or in a few instances to verify sex determinations. Usually females recovered before mid-October had not spawned, while those recovered after this date were spawned out.

Male fish were far more prevalent than females in the fish collections. Male trout comprised 68 percent (1,434 fish compared to 686 females) or 32 percent of the total collected. This would indicate that males were more susceptible or succumbed to the disease and rigors of spawning more readily than females. The total weight of the 2,120 fish recovered was 9,928.4 pounds. Again the male fish made up the bulk of the loss, 6,990.6 pounds or 70 percent compared to 2,937.8 pounds, or 30 percent for the females. There was only a slight difference in average size and weight between sexes. The males averaged 22.8 inches and 4.9 pounds compared to 22.3 inches and 4.3 pounds for the females. Some of the difference in weight could be attributed to the greater body weight loss by females during spawning. The combined overall average length and weight of the dead fish was 22.6 inches and 4.7 pounds. Records were kept on the recovery of both tagged and untagged trout. Tagged brown trout constituted 27 percent (571 fish) compared to 73 percent (1,549 fish) untagged fish for all trout recovered.

When this study first started some of the local people became apprehensive because of the occurrence of dead tagged brown trout in the Brule River. They felt that the tagging and handling of these fish was a direct cause of mortality. It was certainly possible that some trout could have died as a result of being handled and tagged. It was virtually impossible to know exactly what condition or how healthy each individual fish was when it was captured, or how a fish would react or overcome any unnatural treatment. Some trout that appeared to be sick or in poor condition were purposely tagged to see if they would recover and live or just how long they would survive.

Trout collected on canoe trips through the upper river.

Fig. 14a Samples of dead brown trout recovered from the Brule River.

A single days collection of dead brown trout.

A male brown trout with advanced stages of furunculosis.

Fig. 14a(cont.)

Some trout were found dead only a short time after tagging, while other fish tagged and handled in the very same manner and on the same day survived and were recaptured one and even two years later. Dead migratory brown trout also were recovered in several other spawning streams flowing into Lake Superior where none of the trout had been handled or tagged. A majority of the dead browns recovered either had noticeable symptoms of furunculosis or through presumptive tests showed positive results.

A summary of the annual trout mortality based upon recovered fish is presented in Table 12. The mortality ranged from a low of 296 fish (1,548.3 pounds) in 1964 to 694 fish (3,102.9 pounds) in 1963. The 1962 mortality was also quite high, 620 fish weighing 2,958.4 pounds, yet only 12 percent or 74 of the 620 fish recovered were tagged.

Due to the relatively high incidence of disease and the resulting mortality experienced in 1961-1962, Mr. Paul Degurse was again consulted for his help and suggestions. It was fully recognized that treatment and control of a disease of this nature in a wild fish population under natural conditions would be extremely difficult if not impossible. Therefore the work attempted in this respect was a very limited and purely experimental prophylactic treatment. Mr. Degurse prepared for our use a solution of chloramphenicol, a recognized antibiotic (Jones 1956) using 35 milligrams per milliliter, made up as a suspension in U.S.P. paraffin oil. Preparatory to use the suspension had to be well shaken and the solution was then injected into the abdominal cavity of the trout at a rate of one cubic centimeter per pound of body weight.

During the 1963 fish sampling and tagging operations 79 brown trout, 35 males and 44 females were injected with the chloramphenicol, antibiotic solution. It was the practice in this treatment to either inject all or most of the trout from a single day's catch or to inject alternate fish selected on a random basis. Of the 35 male fish injected only 3 were found that had died. Two of these males were injected on August 7, and were found on October 21 and 23. The other male fish was injected October 16 and recovered dead the following day. This fish did not appear to be in very good condition at the time of the injection, but was treated anyway to see what would happen.

Only 3 of the 44 females injected were later found dead. One of the females injected August 6 was found August 12; another fish injected October 22 was recovered January 9, 1964; while the other female trout injected October 22 was found dead November 14, 1964. In further evaluating this prophylactic treatment it was noted that in 18 instances trout not treated died, while injected fish handled at the same time or on an alternate basis survived.

As a result of the experiment no definite conclusion was reached because of the relatively small number of trout actually treated. However, there were indications that by using certain antibiotics it might be possible to curtail or even prevent the death of some of these trout, at least temporarily. Further experimental work along this line was not conducted because of the indefinite disposition or return of treated wild trout, the additional time and manpower required, and the absolute need for the work at this time. For a program of this type to be highly successful, large numbers of these brown trout would have to be captured and treated.

To what extent other factors such as water temperature and water levels influenced the mortality of brown trout was not definitely established. Data on both of these physical parameters are available for mortality periods for they were recorded daily when the weirs were in operation. In comparing these two factors it is interesting to note the difference in years of high and low mortality.

TABLE 12

A Summary of Dead Brown Trout, Both Tagged and Untagged Fish, Recovered in the Brule River from 1961-1964

	Sex	No. of Fish	Avg. Length	Avg. Weight	Total Lbs.	No. of Fish	Avg. Length	Avg. Weight	Total Lbs.	No. of Fish	Total Lbs.
1961	Males	134	22.7	4.8	643.8	200	22.0	4.4	877.4	334	1,521.2
	Females	122	22.2	4.4	533.4	62	23.0	4.5	278.5	184	811.9
	Unsexed					17*				17*	No weight
										(535)	
							1961 Grand Totals			518	= 2,333.1
1962	Males	39	22.9	4.9	192.6	410	22.8	5.0	2,040.5	449	2,233.1
	Females	35	21.6	4.3	150.8	136	22.0	4.2	574.5	171	725.3
	Unsexed					3*				3*	No weight
										(623)	
							1962 Grand Totals			620	= 2,958.4
1963	Males	97	23.1	4.9	480.0	315	22.7	4.6	1,463.4	412	1,943.4
	Females	107	22.1	4.2	447.2	170	22.3	4.1	698.1	277	1,145.3
	Unsexed					5			14.5	5	14.2
							1963 Grand Totals			694	= 3,102.9
1964	Males	20	22.5	5.2	104.7	219	23.8	5.4	1,188.2	239	1,292.9
	Females	17	21.5	4.3	72.8	37	23.3	4.9	182.6	54	255.4
	Unsexed					3*				3*	No weight
										(296)	
							1964 Grand Totals			293	= 1,548.3

* Fish found but not included because of advanced decay.

For comparative purposes the data for October were used, because this is when the peak of spawning occurs and the mortality the highest. The daily water temperatures and water levels taken at the Highway 2 Weir for 1962-63-64 are presented in Table 13. Water temperatures were taken each day between 7:30 and 9:00 a.m. at the time the traps were fished. Water level readings were taken from a gauge placed in the stream when the weir was built. The water level gauge was arbitrarily placed in the stream and the resulting readings are significant only on a comparative basis.

The morning water temperature readings for October, 1962, ranged from a high of 58 to a low of 40 degrees and averaged 47 degrees. The October 1963 water temperatures ranged from 58 to 41 degrees averaging 50 degrees. In 1964 the October readings ranged from a high of 50 to a low of 38 degrees. The monthly average was only 44 degrees. There was a 6 degree difference in the monthly average water temperature in 1963, a year of high mortality, as compared to 1964, a year of low mortality. There was only a 3 degree difference in 1962 as compared to 1964, but the mortality in 1962 was still very high.

In Table 13(a) the daily morning water temperature readings are expressed in number of days during the month in which the temperature fell within a certain range. There were some definite differences from one year to the next in comparing temperature days. Using 45°F. as a dividing point, there were 21 days in 1962, 26 days in 1963, and only 12 days in 1964 in which the daily morning temperatures were 45 degrees or above. Occurrence of the highest mortality in the warmest fall is consistent with experimental observations of others. David et al, (1953) stated that the probable optimum temperature for furunculosis development was from 50 to 60°F. Therefore it is reasonable to assume that the nearer the water temperatures are to the optimum the greater the chance for an increased mortality.

No correlation between mortalities and water levels was noted. In two years with similar water levels, mortalities varied greatly, and in a low water year they were high. The October water gauge readings are also presented in Table 12. In 1962 the readings ranged from 0.30 to 0.46 and averaged 0.35. In 1963 the water levels ranged from .14 to a high of only 0.20 and a monthly average of only 0.15. The 1964 levels ranged from 0.20 to a high of 0.80 and averaged 0.37. The figures shown in parenthesis are flows in cubic feet per second as recorded at the U.S.G.S. gauging station on that particular date.

There was considerable difference in water levels in 1963 as compared to 1962 and 1964. The differences in water levels in 1962 and 1964 were relatively small, yet there was considerable variation in the mortality.

These data indicate that water levels are less significant than water temperatures as possible factors influencing the mortality of brown trout.

MIGRATORY BROWN TROUT POPULATION ESTIMATE

It was indeed unfortunate that a significant number of these large brown trout died each year during the spawning run. Physically speaking these dead trout were a total loss and could only be buried after collection of data. However, through the recovery of both tagged and untagged trout we were able to determine to some degree the magnitude of the spawning population in the area above the Highway 2 Weir.

TABLE 13

Daily Water Temperatures and Levels Recorded at the Highway 2 Weir for the Month of October 1962 - 1963 - 1964

Date	October Water Temperatures Taken at the Weir Between 7:30 and 9:00 a.m. 1962	1963	1964	Water Levels Recorded at the Weir 1962	1963	1964
1	50°	50°	50°	.34	.16 (120)	.60
2	48	52	50	.34	.16	.80 (209)
3	50	50	40	.34	.14	.60 (178)
4	58	49	44	.42	.14	.50
5	52	54	45	.44 (143)	.14	.50 (166)
6	52	54	43	.38	.14	.50
7	52	54	44	.42	.14	.40
8	52	50	44	.46	.14	.40
9	51	50	40	.42	.14	.40
10	51	50	44	.40 (136)	.14	.40 (136)
11	51	50	44	.42	.14 (113)	.40
12	48	47	44	.37	.14	.30 (129)
13	50	48	46	.32	.14	.40
14	52	50	48	.32	.14	.40
15	52	52	49	.32	.14	.40
16	52	52	50	.40	.14	.40
17	46	58	50	.36	.14	.40
18	46	51	45	.34	.14	.40
19	46	52	42	.31	.14	.30
20	46	52	40	.31	.14	.30
21	44	50	40	.30	.15	.30
22	46	54	41	.36	.18 (123)	.30
23	44	54	41	.34	.20	.27
24	40	56	41	.30	.17 (117)	.28
25	40	52	44	.30 (129)	.17	.26
26	40	48	45	.30	.14	.26
27	40	44	47	.30	.16	.24
28	40	42	43	.30	.16	.23
29	41	41	38	.30	.16	.22
30	42	44	39	.30	.15	.20
31	43	44	43	.30	.15	.20

Figures in parenthesis are flows in cubic feet per second as recorded at the U. S. Gauging Station.

TABLE 13(a)

Number of Days During the Month of October When the Water Temperature Recorded Fell Within the Temperature Ranges Shown

Temperature Range	Number of Days		
Year	1962	1963	1964
35 to 39 degrees	0	0	2
40 to 44 degrees	10	5	17
45 to 49 degrees	7	4	8
50 to 54 degrees	13	20	4
55 to 59 degrees	1	2	0

A population estimate was made based upon the Peterson (1896) mark and recovery method. Estimates were computed for both male and female brown trout comprising the spawning population in the 1962 and 1963 runs. From the available data the male segment of the spawning population in 1962 was estimated at 2,168 fish with a range of from 1,577 to 3,154 based upon 95 percent confidence limits (Snedecor, 1946). The female population was estimated at 1,292 fish with confidence limits ranging from a lower limit of 1,040 to an upper limit of 1,561. The estimate for male trout was not as good as for the females because of relatively low ratio of tagged to untagged fish.

The 1963 male population was estimated at 1,725 with 95 percent confidence limits ranging from 1,466 to 2,120 fish. The number of females in 1963 was estimated at 1,985 with the confidence limits ranging from 1,790 to 2,252 fish. A comparison of the 1963 estimate with the 1962 estimate shows an increase in female and a decrease in male trout. Considering the fact that in 1961 over 1,400 and in 1963 over 1,200 of these large trout were handled during sampling operations at the weirs, the number of spawners could reasonably be as high as the population estimates indicate. From the estimate data it is also reasonable to assume that the population of migratory spawning brown trout in the upper river could range from a minimum of 2,500 or 3,000 to 4,000 or more fish.

Applying the population estimate figure to the spawning population provides a basis for determining the reproductive potential. These female brown trout average around 4.5 pounds. The fecundity figures previously given indicate that a trout of this size will produce around 3,500 eggs. Using an average of 1,500 females, which falls within the population estimate figures, the potential egg production would be 5,250,000 eggs.

DISPERSAL OF BROWN TROUT AFTER SPAWNING

Downstream Movement

The dispersal of brown trout after spawning is quite erratic. Some trout remain in the area above Highway 2 for an indefinite period, even over winter, while other fish tend to move slowly downstream seeking out the deeper pools. The downstream movement starts immediately after spawning and continues into early winter. Some information on downstream migration was obtained from weir operations (Table 14). Weir operations during the late fall were often very limited or curtailed because of weather conditions, but each fall there was evidence of some downstream movement of spawned-out brown trout.

Although there is downstream movement from the spawning areas in the fall, there is little evidence of a brown trout migration from the Brule River at this time. Boom shocker operations conducted in the lower river throughout the fall into late November produced only an occasional spawned-out brown trout. O'Donnell et al,(1954) reported only limited fish movement after the water temperature dropped below 40°F. Fallis et al, (1962) also reported little or no fish movement during the cold winter months when water temperatures were in the lower 30's. A decrease in trout movement was also noted when water temperatures dropped below 40 degrees in the fall.

Water temperatures in the spring were not an influential factor in trout movement. At this time of year downstream movement of migratory brown trout closely followed the ice breakup. The spring breakup on the Brule River occurs in late March or early April. In late March of 1963 conditions were favorable to permit limited operation of the Highway 2 Weir. From this operation and personal

TABLE 14

Catch of Migratory Brown Trout in Downstream Traps at the Weirs

	Winnie Weir						Highway 2 Weir					
Year	1961			1962			1963			1964		
Sex	Male	Female	Unknown	Male	Female	Unknown	Male	Female	Unknown	Male	Female	Unknown
January											3	
February												
March							17	20				
April								1			7	
May												
June												
July								2	1			
August				3	1						3	
September							1	1				
October	3	1		17	20		2	8		2	5	
November	3	4		8	10		2	27		11	44	
December	1			7	22							

observations on canoe trips a downstream spring movement of brown trout from the upper river was evident.

In the spring these migratory browns are apparently quite anxious to leave the stream because downstream movement throughout the entire Brule River is very rapid. An example of the rapidity of spring movement was a female trout tagged at the Highway 2 weir on March 29, 1963. This fish was caught 2 days later on March 31, at a point 21.5 miles downstream. Another trout tagged on the same day was caught the following day 8.5 miles downstream.

By the end of April or early May almost all of these brown trout have left the river. Fishermen report catching an occasional straggler in late May and even early June, but by late spring migratory brown trout are few and far between. The overall rapid downstream movement exhibited by these browns in the spring is in almost direct contrast to the generally more prolonged upstream movement which many of these trout display in the fall.

Additional information on dispersal and downstream movement is presented in Figure 15. This information is based upon tagged fish reported by anglers from 1962 through 1965. As shown by the date of catch, almost all of the fish were caught either in late March or during the month of April. In a normal spring, (the river being ice free) the outgoing browns are widely distributed throughout the lower section of the river. The 1964 catch clearly indicates the wide distribution. Ten of the 15 trout were caught on the same day, April 4, yet these fish were taken from various locations on the river, covering an overall distance of 16 miles.

The special spring trout season has on occasion opened before the ice was completely gone out of the river. This condition prevailed in 1965 when the river was open only down as far as Coop Park. The fishermen were concentrated in this area and made an excellent catch of trout. Once the ice starts to break up it takes only a few days for the main channel to become totally ice free. Therefore, fishing results are generally better if the early spring season opens shortly after the ice goes out or while the ice is going out. If the river opens early, many brown trout leave the stream before the angler has a chance to fish for them.

In the spring of 1966 the river opened early and was completely ice free several days before the special spring season started. The resulting angler catch of migratory brown trout during the 1966 spring season was very poor.

Experienced fishermen recognize the wonderful opportunity to catch these brown trout by following the ice break, so spring weather conditions and resulting breakup time are important factors governing fishing success.

DISPERSAL - BROWN TROUT IN LAKE SUPERIOR

Information on the distribution of migratory brown trout from the Brule River in Lake Superior is based upon tag returns from 1962 through early 1966. Although returns are limited, they do provide some idea as to patterns of movement and early summer distribution. Most returns came from angler-caught fish taken while sport trolling in Lake Superior. Two tagged fish were captured in commercial fishing nets and the tag from another tagged trout was found entangled in a net.

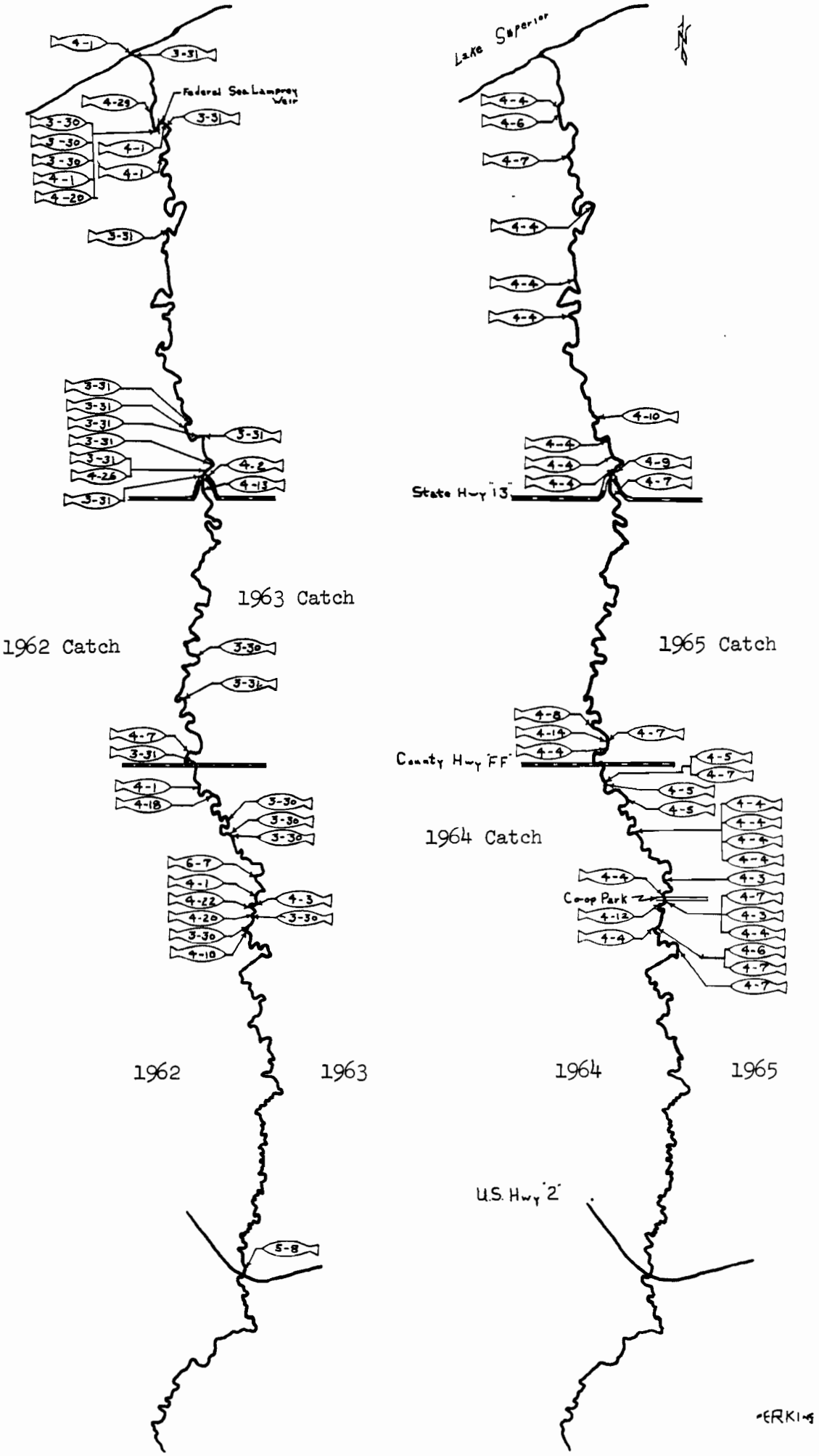


Fig. 15. Approximate location of angler caught migratory brown trout showing spring downstream dispersal and movement. (Date of catch is presented inside of the fish symbol.)

The tag returns show a well scattered distribution along the south shore and around the Apostle Islands (Fig. 16). The location of catch also shows a definite eastward movement and a noticeable tendency to concentrate in some of the more defined bay areas along the south shore. These are areas where much of the sport fishing takes place. At the present time only limited fishing (trolling) takes place off the mouth or to the west of the Brule River. Therefore, with the absence of both sport and commercial fishing in this area, it is not definitely known whether trout move in a westerly direction after leaving the river.

The available evidence suggests that an easterly movement is more likely. This direction of dispersal may be influenced by the strong surface currents of Lake Superior, which flow in an easterly direction along the south shore and toward the Apostle Islands (Fig. 17).

Trout leaving the Brule River can move with the current along the south shore until a suitable summer location is reached. Pycha, Dryer and King (1965) found a similar eastward movement of stocked lake trout, indicating that the dispersal of planted lake trout may be strongly influenced by the surface currents.

Brown trout returning to the Brule River in the fall would be swimming against the current. Hasler (1960) hypothesized that the homing ability of anadromous species might be connected with the organic odor of the home stream. If this is a key factor, the easterly direction of the surface currents would certainly aid these brown trout in locating the Brule River.

These brown trout move considerable distances from the Brule River as indicated by the catch records. Distances from the mouth of the Brule River to the various locations are as follows: Bark Point, 30 miles; Frog Bay, 60 miles; Houghton Point near Washburn, 75 miles; and the Bad River, 85 miles. These are direct line measurements. When the twenty or more river miles is considered, some of these fish travel from 50 to over 100 miles.

CREEL CENSUS AND HARVEST

Fall Creek Census Results

In spite of the fame and importance of the Brule River as a trout stream, only minor fishery studies have been conducted since the comprehensive work of the early 1940's. Because of the special early and late fishing seasons, in addition to the regular trout season, there has always been considerable interest in the fishery of the Brule River. Most of the effort has been directed toward the collection of information on the harvest of trout. Except for a creel census report published by O'Donnell in (1945) all of the creel census data from the Brule River is contained in memoranda or informal unpublished reports which are in the Northwest Area Headquarters files.

In reviewing the previous creel census work most of the effort was short term, such as opening weekends or periodic daily creel censuses. Brasch (unpublished) 1950 and Daly (area memorandum report) 1954 carried out more intensive creel census studies during the special trout seasons. Brasch's creel census efforts were aimed at an evaluation of the special fall season which started in 1948. The regulation governing the special fall trout season on the Brule River from 1948 to the present day are shown in Table 15.

Daly's efforts were actually directed toward an evaluation of the harvest of migratory brown trout in the Brule River. In 1954 the special fall season started

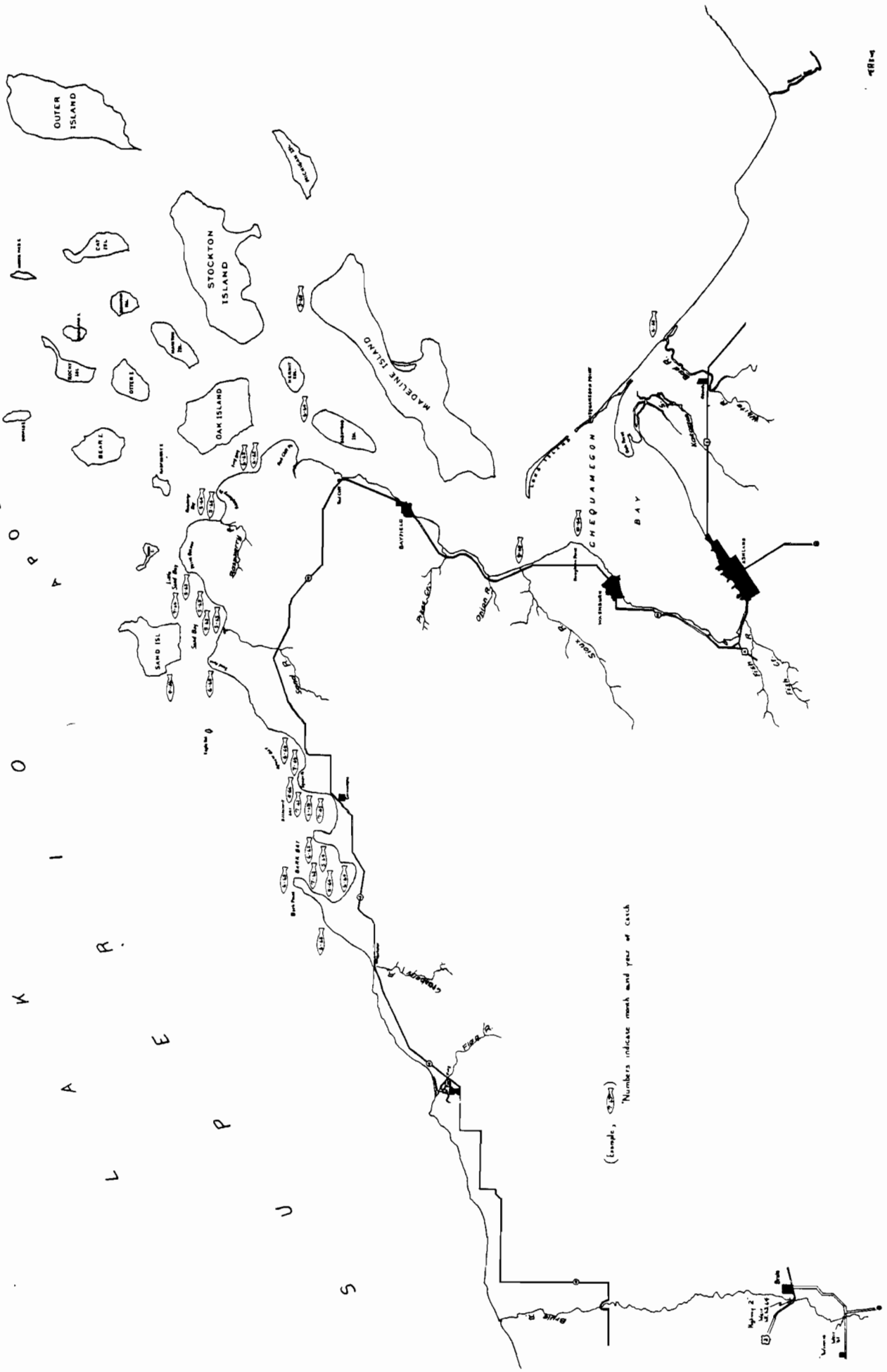


Fig. 16. Reported locations of migratory brown trout caught in Lake Superior that were tagged in the Brule River.

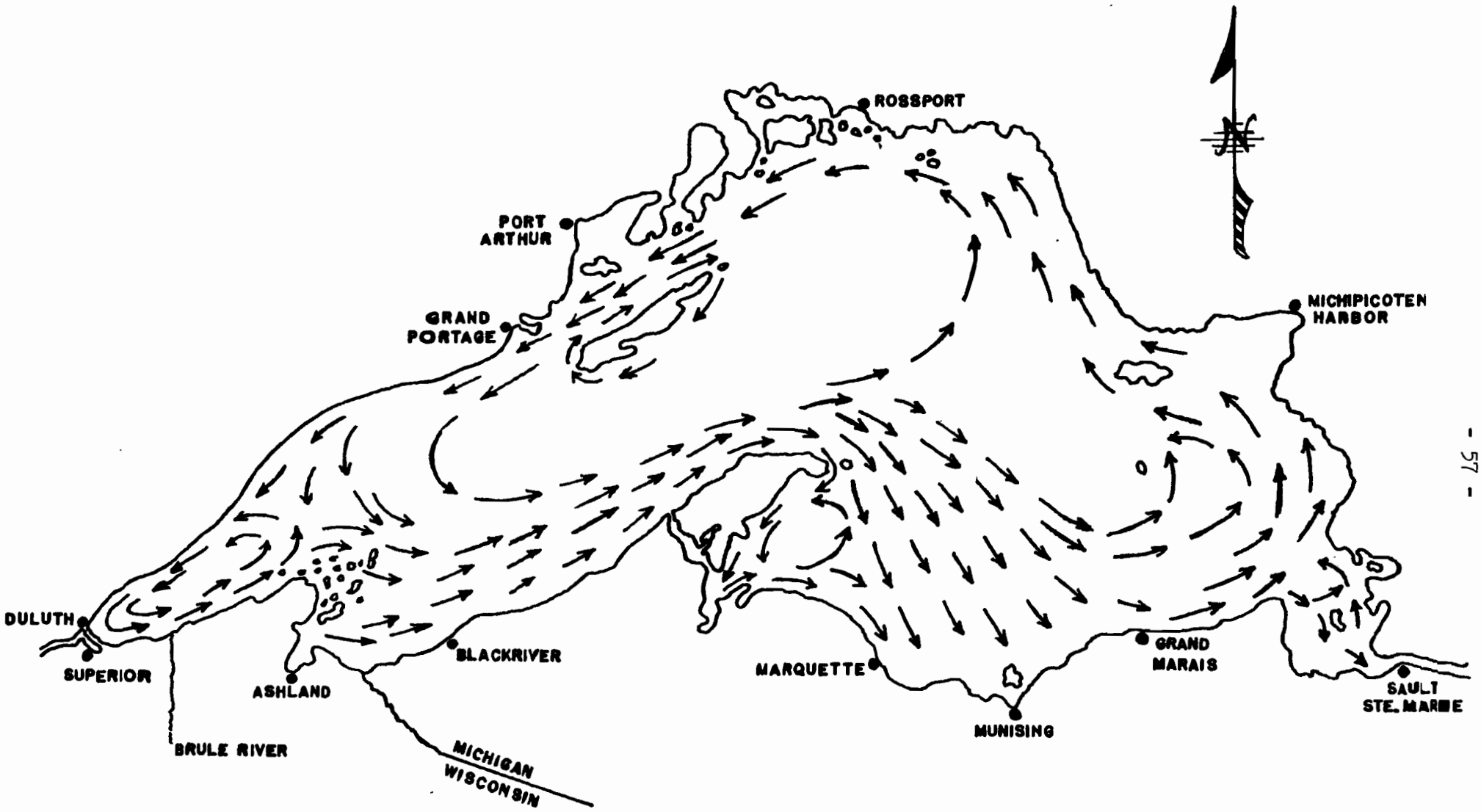


Fig. 17. Surface currents in Lake Superior. (Modified, after figure presented by Pycha, Dryer & King 1964)

TABLE 15

Regulations Governing Fishing on the Lower Brule River During the Special Fall Trout Seasons.[1, 2]

Year	Season Dates	Size Limit	Bag Limit
1948	Oct. 15 - Nov. 15	13 inches	5
1949	Oct. 15 - Nov. 15	13 inches	5
1950	Oct. 15 - Nov. 15	13 inches	10
1951	Oct. 1 - Nov. 15	13 inches	10
1952	Oct. 1 - Nov. 15	13 inches	10
1953	Oct. 1 - Nov. 15	13 inches	10
1954	Sept. 8 - Nov. 15	13 inches	10
1955	Sept. 8 - Nov. 15	13 inches	(10) Not more than 10# and 1 fish
1956	Sept. 8 - Nov. 15	13 inches	(10) "
1957	Sept. 8 - Nov. 15	13 inches	5
1958	Sept. 8 - Nov. 15	13 inches	5
1959	Sept. 8 - Nov. 15	13 inches	5
1960	Sept. 8 - Nov. 15	13 inches	5
1961	Sept. 8 - Nov. 15	13 inches	5
1962	Sept. 8 - Nov. 15	13 inches	5
1963	Sept. 8 - Nov. 15	13 inches	5
1964	Sept. 8 - Nov. 15	13 inches	5
1965	Sept. 16 - Nov. 15	13 inches	(5) Of which only 2 may be rainbows
1966	Sept. 16 - Nov. 15	13 inches	(5) "

[1] Area of the stream open during the special seasons is from the mouth upstream to U. S. Highway 2.

[2] Special fall season opens the day after the regular trout season closes, thus provided a continuous fall season.

on September 8, the day after the regular trout season closed. Since 1954 the special fall season has always started the day after the close of the regular season regardless of the dates. This change has provided the angler with a better opportunity to take full advantage of the availability of these migratory brown trout.

The results of the creel census mentioned showed a very light harvest of migratory brown trout. In O'Donnell's report there is no reference at all of any migratory brown trout being caught. However, in the late 1930's, and even through the 1940's there was very little definite information available as to the overall status of the migratory brown trout population. Brasch reported that in the 1949 special fall season only 7 lake-run brown trout were counted. From what we have learned of the habits of these browns, the season dates for the first six years of the special fall season did not effectively provide for the harvest of brown trout. Daly reported a harvest of 43 brown trout over 13 inches. His creel census covered a period from August 28 through November 15. Even with a concerted effort to cover the special fall season, the reported harvest was still very small.

The poor harvest of migratory brown trout through the years in the Brule River could be attributed to a number of influential background factors. Traditionally, the Brule River has been considered a migratory rainbow trout (steelhead) stream. For years angler attitude, interest and fishing emphasis has been inclined toward the steelhead fishery. Even the first special fall trout seasons on the Brule River provided a better opportunity for harvesting migratory rainbows than migratory brown trout. For many years, the few brown trout taken by the anglers during the fall seasons were caught incidental to rainbow trout fishing. Even the extension of the special fall trout seasons starting in 1954 did not materially arouse angler interest or create a big increase in fishing pressure. The apparent lack of success in catching these migratory brown trout did little to encourage additional fishing pressure. Perhaps one of the biggest factors responsible for the low brown harvest was the overall lack of basic knowledge of the migratory brown trout population and the habits of these fish.

In all of the previous creel census work the method used to obtain information was personal contact and interviews. Good coverage by this method is quite difficult because of the many access points on the 25 miles of river open to fishing during the special season.

During this current study a creel census was also conducted in an effort to obtain information on the harvest of migratory trout. Due to manpower limitations, a voluntary trout registration system was tried, instead of the usual angler contact method. As an added incentive to encourage anglers to register their fish, cash awards were offered.

The trout registration creel census was sponsored by the Douglas County Fish and Game League of Superior, Wisconsin which appropriated $200.00 per year for a three-year period to carry out this phase of the study. This organization also provided publicity posters during the first year.

In the first year (1962) this creel census was conducted for a 10-week period from September 1 through November 15. In 1963 and 1964 the registration period was extended to thirteen weeks starting in mid-August and continuing through the close of the season. Over the fall season $10.00 weekly awards were made and after the close of the season two final awards were presented. In 1962 the two final awards were $50.00 and in 1963-64 the final awards were decreased to $35.00 because of the longer weekly coverage.

The recipients of these cash awards were determined by weekly drawings of all trout registered during a given week. Winners of the final awards were also determined by drawings made from all of the trout registered during the season.

Anglers were informed of the voluntary trout registration through local news releases but mainly through posters placed at all of the access roads and in various business establishments in the Brule River area. These posters provided the angler with information concerning awards, the simple rules, and where to register all eligible trout (Fig. 18).

In 1962 only one registration station was set up and this was at the Shell Service Station located in the village of Brule. This station was open 24 hours a day, seven days a week so there was ample opportunity for anglers to register their fish. The one checking station at Brule was inadequate because many anglers from the Duluth, Minnesota - Superior, Wisconsin area traveled to and from the Brule River via State Highway 13 and therefore never reached Brule to register their fish.

To get better coverage of the catch, a second registration station was established in 1963 and 1964, the O'Brien Service Station in (Itasca) Superior. This station was also open every day of the week, but closed around 10:00 p.m. The checking stations were provided with a scale for weighing the fish, a measuring board, registration cards and location maps.

The location maps provided the opportunity to record the site of a catch by zone. The 25 miles of river open to fishing during the special season was divided into three zones, a zone 1 extended from the mouth of the Brule upstream to Highway 13, (a distance of 7.7 miles), zone 2 included the area from Highway 13 upstream to the Coop Park bridge (a distance of 8.2 miles), and zone 3 covered the area from Coop Park upstream to Highway 2, a distance of 8.5 miles.

The overall response of the fishermen to this type of voluntary creel census was rather good but there were mixed reactions on the part of some anglers toward this system. Some fishermen did not register their fish because of the possible revelation of fishing secrets, fishing locations and the potential increase in angling competition through good fishing reports. Other fishermen registered all or nearly all of the trout caught during the season. As a matter of pride, some legal but smaller-sized trout were not always registered.

The voluntary registration of brown trout during the three years was 134 in 1962, 195 in 1963, and 104 browns in 1964. These figures represent a minimum harvest.

From angler reports and informal interview it is very likely that the actual harvest of brown trout may have been several times greater than the registration figures given.

Even though a voluntary method of creel census was used, the recorded catch was considerably greater than that reported by Daly in 1954. The increase in catch is a reflection of a gradual change in attitude and interest on the part of the angler toward the lake-run brown trout. These trout are notoriously difficult to catch in the fall, but because of their earlier arrival in the stream, they have expanded tremendously the opportunity of catching a trophy trout. More and more fishermen are becoming aware of the migratory habits of these browns and are taking advantage of their availability. Even though this fishing is very frustrating, fishing pressure has increased steadily in the past few years.

BRULE RIVER - TROUT FISHERMEN

Register Your TROUT For Cash Awards -
$10.00 Weekly Award -
Two $35.00 Final Awards -
Winners Will Be Determined by Drawings

Rules

1. Starts August 18 - continues for 13 weeks -
2. Open to all fishermen -
3. Trout must be caught in Brule River -
4. All trout (brooks, browns, rainbows - "steelheads" 13 inches and over are eligible -)
5. All weekly winners will be eligible for final awards -
6. Checks will be mailed to the winners -

SPONSORED BY THE
DOUGLAS COUNTY FISH AND GAME LEAGUE
OF SUPERIOR, WISCONSIN
IN COOPERATION WITH
THE WISCONSIN CONSERVATION DEPARTMENT

FISHERMEN: YOUR COOPERATION IS REQUESTED AND APPRECIATED
REGISTER YOUR TROUT AT:

SHELL SERVICE STATION BRULE, WIS.
O'BRIEN'S SERVICE STATION (ITASCA)
SUPERIOR, WIS.

BRULE RIVER TROUT REGISTRATION

Register EACH trout on individual card

Please Print -

NAME OF ANGLER _____

COMPLETE ADDRESS _____

KIND (check 1) BROOK BROWN RAINBOW
LENGTH OF FISH _____

WEIGHT OF FISH _____ DRESSED _____ UNDRESSED ____
ZONE WHERE TROUT WAS CAUGHT (see map) _____
Date _____ Signed _____

Remarks or comments on back

Fig. 18. Information contained on the announcement posters and the trout registration cards used in the voluntary creel census conducted on the Brule River in the special fall seasons in 1962-1963-1964.

The seasonal registration of brown trout by weekly periods and by zone of catch is presented in Fig. 19. There was considerable variation in weekly registrations from a high of 48 trout in the first week of the 1963 census to zero fish in the weekly period of September 27 to October 3, 1964. At the end of the fall season there was some variation in number of days in a registration period. For example, the final registration period in 1962 included 11 days, whereas the final period in 1963 covered only 5 days. The longer registration period in the final week of the 1962 season resulted in a very pronounced peak in the registered catch.

The catch of brown trout is influenced by several factors which may account for some of the variation in the weekly catch as well as the total harvest. In August and through most of September the angler interest and resulting fishing efforts are directed toward the brown trout. The creel census showed that 64 percent of the 433 brown trout registered were caught prior to October. Starting in late September and early October there is a noticeable shift of interest and fishing pressure from the brown trout to the incoming rainbows.

The reason for reduced fishing appears to be that throughout much of the fall period many of these brown trout are in the upper river (closed area) and are temporarily unavailable to the angler.

Also the condition of the river has significance. If the water is low and clear, fishing results are generally poor. Even slightly higher, turbid water increases the enthusiasm of the anglers and greatly enhances their chances of catching a trophy trout. In fact, many anglers try to gauge their fishing efforts by the condition of the stream, fishing when conditions are favorable, and staying away when conditions are poor.

Most anglers completed the information requested on the trout registration cards. One of the items, was to list the zone in which the trout was caught. Fig. 19 clearly shows that the majority of the brown trout were taken in zones 2 and 3. The catch was divided as follows: zone 1 - 8 percent; zone 2 - 29 percent; zone 3 - 63 percent. The available habitat (deeper pools, slower water flow, and more instream cover) found in zone 3 is a very desirable feature for these trout and therefore zone 3 becomes an area of concentration. The ardent brown trout fishermen recognize this fact so this zone is more heavily fished.

Size of Creeled Fish

Space was provided on the registration cards for length and weight data. As a part of the formality of registering their trout, the fishermen had to weigh and measure each fish and record the information. From the measurements provided by the fishermen a size distribution was prepared (Fig. 20). The trout registered ranged from the minimum legal length of 13 inches to slightly over 32 inches. Trout in the 13 and 14 inch size range were more than likely resident stream trout that were taken while fishing for lake-run browns. Although trout 28 inches and over are present in the runs, few fish this size are caught.

The average length of all brown registered was 21.7 inches. The average length as computed on an annual basis was very consistent, 21.7 inches in 1962, 21.6 inches in 1963 and 21.9 inches in 1964.

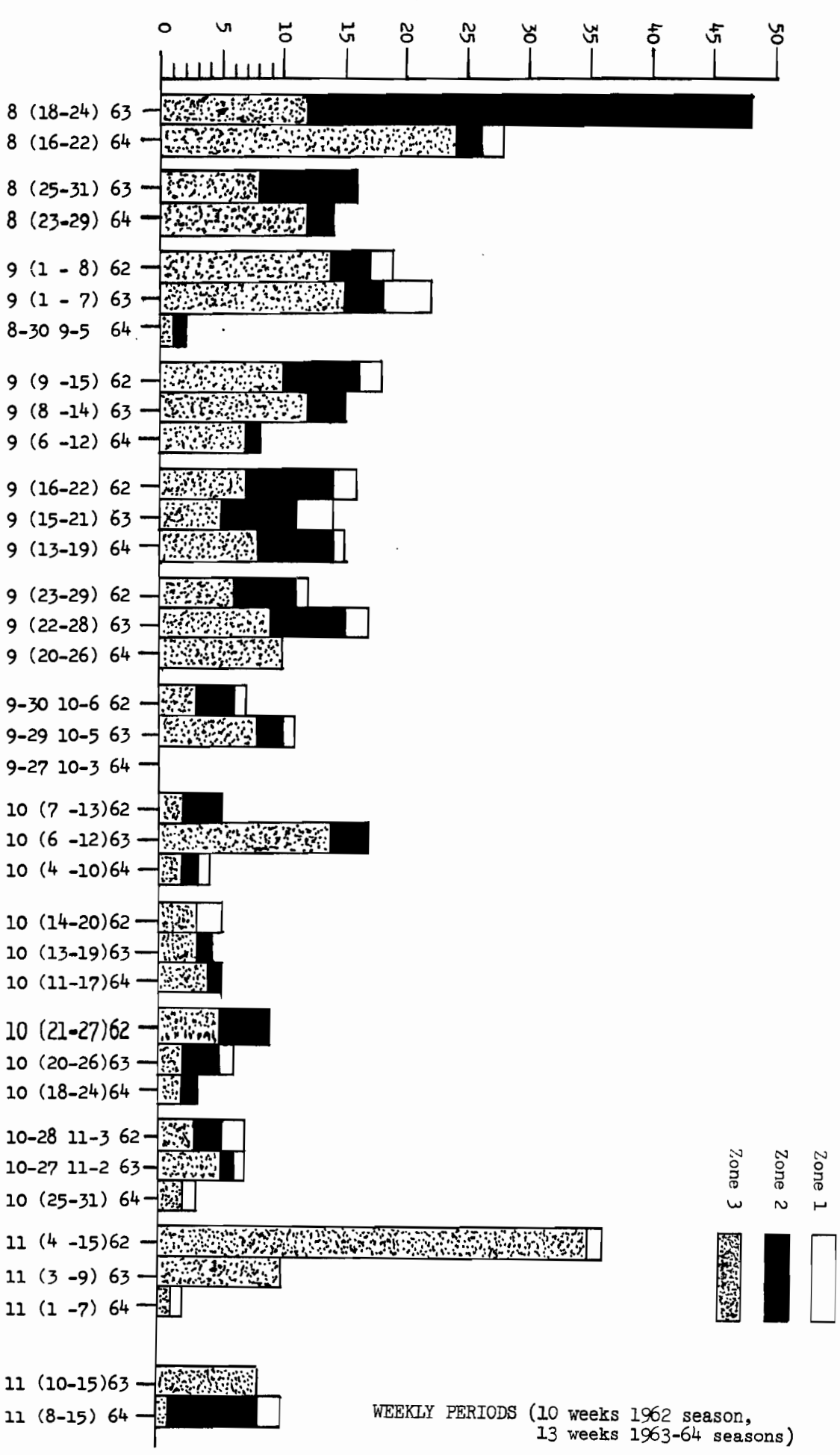


Fig. 19. Record of the weekly catch of brown trout by zone, during the fall fishing period in the Brule River.

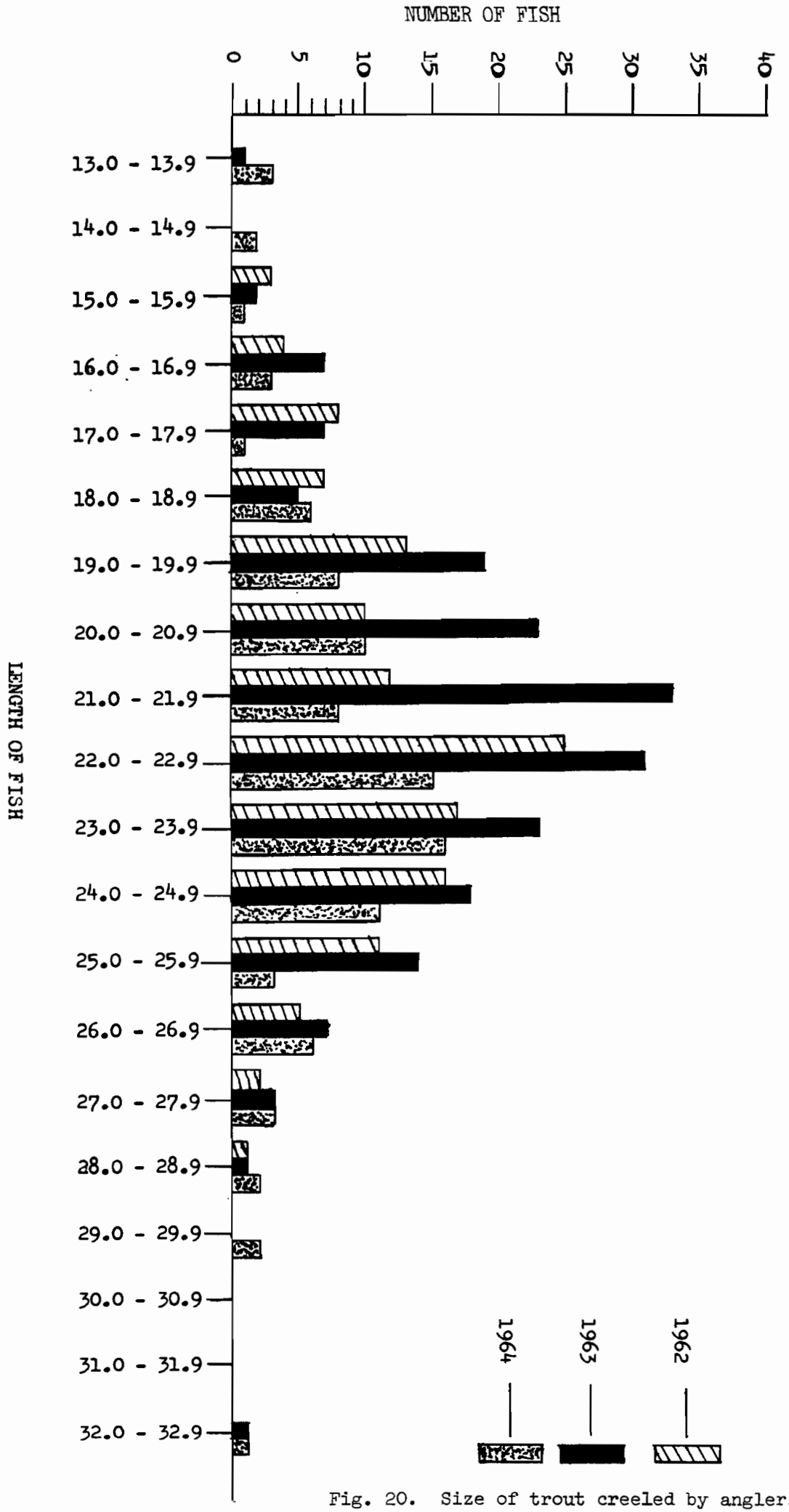


Fig. 20. Size of trout creeled by anglers

Fishermen in weighing their fish were asked to designate whether the fish was dressed or whole. On this particular point the anglers were a little careless, as the weights given were not always definite. Poundage figures were therefore obtained by totaling the exact weights shown on the registration cards. The weight of brown trout harvested was 588 in 1962; 844 in 1963; and 456 in 1964, or a total of 1,888 pounds. These are minimum figures, but it is interesting to compare these figures with the total weight of dead brown trout recovered the same year. The poundage of dead brown trout recovered in 1962, 1963, and 1964 was 2,958; 3,103; and 1,548 pounds respectively. Each year the mortality poundage figure was considerably higher than the registered poundage figure.

Spring Creel Census Results

Some information on the harvest of brown trout in the spring was obtained by conducting a creel census on the opening day of the special spring trout season. The special spring season opens on the Saturday nearest April 1.

In the spring, as these migratory browns are leaving the river, they display a ravenous appetite and a definite willingness to feed. If these browns are still present in the river and water and ice conditions are favorable, the resulting catch is rather good. There is generally a heavy turnout of anglers for the opening of the special spring season as shown by the car counts and angler interviews (Table 16). The angler checks showed a catch of 50, 65 and 25 brown trout respectively in 1962, 1963 and 1964. These fish were all taken on the first day of the season. When compared to the registered fall season catch of 134 browns in 1962, and 101 browns in 1964, it is quite apparent that fishing for migratory brown trout is better in the spring. However, at this time of the year these fish are available for only a short period, as they leave the river as soon as conditions permit.

MOVEMENT OF SMALL (PARR) TROUT

In a migratory trout population it is only natural that a majority of the offspring will eventually leave the home stream. Information on the movement of smaller trout was collected during this study but the emphasis was more limited. Most of the data were obtained more or less incidental to sampling operations conducted for the larger migratory trout. Smaller trout were captured at both of the weirs (Table 17). The screen and traps at the Winnie Weir had a mesh small enough to capture all but 2-3 inch fingerling trout. A number of smaller brown trout were captured during the fall ranging in size from 6.1 to 9.4 inches. The relatively small sample showed that the greatest movement occurred in September.

Additional information on the trends of downstream movement of smaller brown trout was obtained from the operation of the Highway 2 Weir. The information for 1963 provides the best data because of the more continual operation of the weir. However, the screen in the Highway 2 Weir was only partly effective in directing smaller fish into the traps. The removal of alternate rods from the weir screen in $5\frac{1}{2}$ gates resulted in a spacing of approximately 1-3/8 inches. This wider spacing allowed smaller trout to pass through the weir. In the $2\frac{1}{2}$ gates closest to the downstream trap the spacing between the rods was only $\frac{1}{2}$ inch which made this portion of the weir effective in directing small trout into the downstream trap. Observations on the downstream movement of smaller trout showed that fish of this size tend to frequent areas of reduced current and shallower water. Because of habit some smaller trout were caught at the Highway 2 Weir in spite of the limitations described.

TABLE 16

Opening Day Creel Census Special Spring Trout Season on the Brule River in 1962, 1963, and 1964.

Year and Opening Date	U.S. Hwy. 2 to Lake Superior Car Count	Calculated Number of Anglers	Junction U. S. Hwy. 2 & C.T.H. "H" Car Count	Calculated Number of Anglers	Average Anglers Per Car	Total Hours Fished	Average Hours Fished	Fish Caught	Size Range	Average Size
1962 March 31	418 cars 10:00 a.m. to 12:00 noon ground survey	974	200	466	2.33	3,237	6.9	Brown 50	13.0-24.9	19.2"
								Rainbow 78	13.0-23.3	17.1"
1963 March 30	524 cars aerial survey 10:00 a.m. to 11:00 a.m.	1,284	240	589	2.45	3,595	6.1	Brown 65	15.4-28.0	21.2"
								Rainbow 11	13.6-24.6	16.4"
1964 April 4	418 cars aerial survey 10:00 a.m. to 11:00 a.m.	1,003	135	324	2.4	1,873	5.8	Brown 25	13.1-24.7	21.2"
								Rainbow 39	13.0-28.0	19.8"

TABLE 17

Downstream Catch of Small Brown Trout in the Brule River Weirs

Month	Winnie Weir Number	Winnie Weir Size Range	Highway 2 Weir Number	Highway 2 Weir Size Range
Jan.				
Feb.				
Mar.			17	8.4 - 11.0
Apr.			29	7.4 - 10.3
May			45	6.5 - 9.0
June			1	6.5
July			2	10.9 - 12.0
Aug.			33	6.0 - 7.7
Sept.	36	6.1 - 9.1	41	7.2 - 7.8
Oct.	12	6.5 - 9.4	8	7.0 - 10.5
Nov.	12	6.5 - 8.1		
Dec.	6	7.0 - 9.1		

The 1963 weir catch showed a definite downstream movement of smaller brown trout both in the spring and again in the fall. In some instances the small trout captured were merely counted and released with only the minimum and maximum size recorded. Small brown trout captured in the spring of 1963 ranged in size from 6.2 to 11.0 inches. The average length, based upon a sample of 73 trout, was 8.7 inches. Age analysis showed that most of these fish were starting their third year of life, having spent the past two years in the parent stream.

The best daily catch of small browns occurred on April 11, 1964 when 34 fish were recorded. These fish ranged in length from 7.6 inches to 10.8 inches and in weight from 70 to 184 grams. The average length was 8.8 inches and the average weight was 101 grams.

Brown trout captured during the fall ranged in size from 6.9 to 10.5. A sample of 53 fish averaged 7.9 inches or 0.8 of an inch smaller than the spring fish. The fall fish were completing their second year of life in the stream.

Further information on the downstream movement of small trout was obtained from the operational records of the sea lamprey weir, observations, and electrofishing operations in the area of this weir. Although this weir is not designed to catch fish moving downstream a number of trout are caught. It is a known fact (based on marked fish) that some trout after passing through the electrical fields of this weir, will reverse direction and swim upstream, ending up in the weir traps. Migratory adults as well as small parr trout are captured due to this temporary reverse movement.

The trout captured in the sea lamprey weir traps were normally not marked when removed and released. Therefore, it was possible that some trout could have been captured and counted more than once. Although this possibility certainly existed, the chance of recounting the same fish was not considered great. The daily catch records showed an oscillating pattern of highs and lows. The greatest movement and resulting high catches were associated with increased water levels and turbidity. The catch would be high on the first occurrence of high water, but would taper off rapidly to few or no fish as the trout moved on through this area.

The catch records definitely show a downstream migration of small trout that starts in the spring and continues on into the summer (Table 18). Except for tagged fish, the trout captured at the sea lamprey weir are not measured individually. All trout handled are categorized as either less than, or more than 12 inches in length.

TABLE 18

Small Brown Trout (fish less than 12 inches in length) Captures at the Sea Lamprey Weir

Month	1963 No. of Fish	1964 No. of Fish	1965 No. of Fish
April	99	61	29
May	96	229	168
June	254	426	82
July (½ mo.)	301	124	205

Observations of trout activity in the area of this weir also indicated when a downstream movement of small trout is taking place. When such a movement occurs the river is actually alive with small trout. When there is little or no migration, fish activity is negligible and the weir trap catch is also very small.

The movement of small brown trout was further substantiated through the electro-fishing operation conducted in this part of the river. However, during these operations the emphasis was always directed toward the collection of larger migratory trout. When it was convenient or the opportunity readily presented itself, small trout were netted. Even though all of the small trout were not always collected, by mere observation, it was quite obvious when small fish were either present or conspicuously absent. The many shocker runs showed that other than during times of downstream migration, the population of small trout in this section of the river is very limited.

The overall downstream movement can best be summarized as a continual trickling of fish from the parent stream into Lake Superior. The number of fish does vary from day to day and from month to month but there is no denying the natural instinct of these trout to leave the home stream.

STREAM SURVEY OF THE UPPER BRULE RIVER

In addition to the migratory trout there is also a resident population of brown trout in the Brule River. This is evident from scale readings, angler caught fish and observations of smaller adult trout, particularly at spawning time. However, knowing that many brown trout produced in the stream eventually leave, an attempt was made to gather information on the trout population remaining in a portion of the upper Brule River. In November of 1963 a trout sampling operation was conducted through a section of the river from the old U. S. Highway 2 bridge upstream to Stones Bridge. This is an overall distance of 13.3 miles. Most of this area was surveyed with conventional stream electro-fishing gear. This method involves wading the stream and using hand electrodes to collect fish.

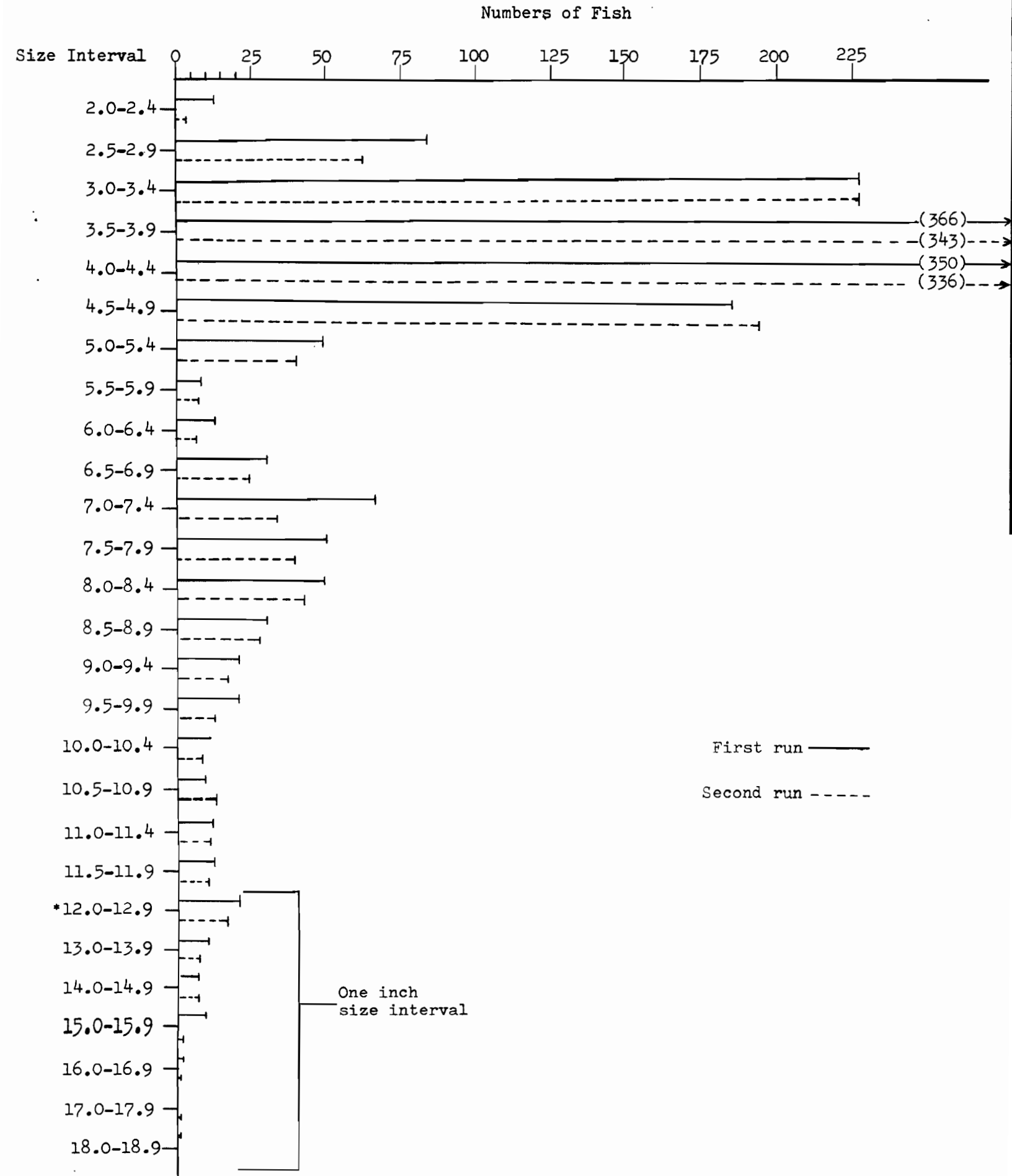
Surveying a stream the size of the Brule River with stream survey gear was rather difficult. Adequate coverage was sometimes limited due to excessive width and depth, as well as the volume and speed of flow in the rapids areas. In parts of Big and Lucius Lake as well as an unwadable area above Cedar Island, the boom shocker was used for sampling. Since this survey was conducted through the major spawning grounds all redds were carefully avoided and migratory trout were not collected.

The same 230 volt, 3-phase alternating current generator used as a power source for some of the boom shocker operations was used in the stream survey work. Three individual hand electrodes were used in an effort to obtain better coverage of the stream.

The primary aim of this survey was to collect and mark enough trout to make an estimate of the population. This objective necessitates a second run so the same area was surveyed twice. All trout, other than migratory fish, captured on the first run were marked with an appropriate clip for positive identification on the second run and to establish a marked to unmarked ratio.

On the initial run 1,603 brown trout were captured and marked. All of the trout captured were measured and the fish ranged from 2.2 to 18.2 inches,(Fig. 21).

Fig. 21. Length frequency distribution of brown trout captured during stream survey operations in a section of the upper Brule River.



A majority of the brown trout captured, 1,234 or 77 percent, were fingerling trout or less than 6 inches in length. The remaining 369 trout were 6 inches and over but only 46 of these fish were 12 inches or more in length.

The second shocker run produced 1,564 brown trout ranging in size from 2.3 to 17.8 inches. Included in the above total were 81 recaptures (45 fish less than 6 inches and 36 trout 6 inches and over). As in the first run a majority of the nonmarked trout captured (1,213 or 82 percent) were fingerling or sublegal trout. A six-inch size was used as a dividing point for making the population estimates. This size was used because of the almost natural division as shown in the length frequency and it is also the minimum size limit for trout during the regular trout season when this area of the stream is open for fishing.

A Peterson (1896) population estimate was made using the data obtained from the survey runs. The number of marked fish (recaptures) collected was not as good as had been anticipated and the percentage of recovery was rather low. The low recovery of marked fish, as well as all fish, was primarily due to size of the stream, but during the second run poor visibility due to dark cloudy weather along with snow and cold made the survey work even more difficult.

The brown trout population of fish 6 inches and over, for this section of the river, was estimated at 3,137 fish. The recapture rate for fish in the size bracket was 12 percent and 95 percent confidence limits range from a low of 2,214 to a high of 4,342 trout, Snedecor (1946). The estimate figure of 3,137 fish gives a density of 241 legal size trout per mile of stream. This density may seem rather low when at times observations would indicate an abundance of trout in this section of the river. While trout of this size group are fairly abundant in some areas, there are sections where legal size trout are few and far between. Then too, as has already been shown, many trout upon attaining legal size move downstream out of this area and eventually migrate out of the river entirely. The loss of trout (6 inches and over) through annual migration from the Brule River most certainly reduces the number available to the fisherman, which in turn has a definite impact on the fishery during the regular trout season.

A Peterson (1896) population estimate was also made of the brown trout less than 6 inches in size. However, the number of recaptures in this size group was only 45 fish which resulted in a recovery rate of only 3.7 percent. Although the estimate and confidence limits presented are based upon this relatively low rate of return, they do provide some idea as to the production of fingerling trout and also serve as a basis of comparison for future and more refined population estimates.

The population of smaller size brown trout was estimated at 35,867 with 95 percent confidence limits ranging from a low of 27,356 to a high of 47,471, Snedecor (1946). The estimate figure of 35,867 gave a density of 2,759 fingerling brown trout per mile of stream.

During the stream survey work, the greatest concentrations of fingerling brown trout were noted in areas of the stream having a good growth of aquatic vegetation associated with a good flow of water. These particular conditions were usually found along a definite channel or pronounced openings or pockets in a vegetation stand. The water depth in these places varied from only a few inches to over 2 or 3 feet. In areas of very dense aquatic vegetation and slow-sluggish flow few or no trout were found.

Aquatic vegetation, when available, and in the right location and condition, provides an important source of cover and living space for smaller trout.

SUMMARY AND CONCLUSIONS

This study clearly indicated that the Brule River has a substantial migratory brown trout spawning run. Electro-fishing (boom shocker) operations conducted in the area of the mouth showed that lake-run browns entered the Brule as early as mid-July. The run gradually increased to a peak in August, and thereafter decreased so that by mid-October the annual run was normally completed.

The shocker surveys also showed that brown trout movement into the river occurred even under seemingly adverse conditions. At times of low flow or during severe wind and wave action on Lake Superior the opening at the mouth often becomes very shallow and even shifts in location. Nevertheless these trout still moved into the river. The early appearance of these brown trout, together with extended fall trout season gives the interested anglers a good opportunity to fish for those trout.

Angler tag returns and data from recaptured trout showed an erratic pattern of upstream movement. However, movement through the lower 16 miles of the stream was generally quite rapid. There was a noticeable tendency for these trout to congregate in the portion of the river from Coop Park upstream to U. S. Highway 2. This section of the stream has many deeper pools, slower current, and heavy instream cover all of which provides very desirable habitat for brown trout.

The migratory brown trout population was also sampled at fish weirs (Winnie Weir used in 1961); (Highway 2 Weir used in 1962-63-64) located 29 and 24 miles respectively upstream from Lake Superior. Trapping records showed that brown trout movement to the primary spawning areas started in July but was greatest in August and September. Upstream migration continued throughout the fall and even into early December. The trapping results also showed that trout movement was greater at times of rising water levels and during periods of decreased light intensity, not only during daytime but also at night.

The recapture of previously tagged trout showed a definite homing tendency as browns tagged in the Brule returned to the Brule. A few tagged fish even displayed fairly precise timing in their return by varying only a day or so from one year to the next.

For the angler interested in fishing for large size trout these browns fit the category of trophy size fish very well. Migratory browns range in size from 15 to over 31 inches and average about 22 inches in length and $4\frac{1}{2}$ to 5 pounds in weight. Browns 3 to 10 pounds and occasionally fish 12 to 18 pounds are caught in the Brule River.

In spite of their size, examination of scales clearly shows that they are not very old fish and they have rather short life spans. No brown trout were found to be older than the 7th summer of life. Fish in their 6th and 7th summer were comparatively few in numbers and most of the older fish were females. The brown trout spawning run is comprised mainly of 4th and 5th summer fish.

The fish scales also provided information as to growth patterns. Most trout spend approximately two years in the parent stream before migrating to the lake. Growth in the stream is considerably slower when compared to that attained in the lake. Growth during the first year in the lake (normally the third summer) is very accelerated. After the third year, growth is still good but is somewhat slower. Increment in size of older trout as obtained from age, growth analysis and from the recovery of tagged fish showed gains of from 1 to 3 inches in length and from .2 to 2.3 pounds in weight. For many brown trout annual growth is

accomplished in a relatively short period of time. A majority of the fall spawning brown trout remain in the river overwinter and leave the following spring (late March or early April) as the river becomes ice free. By late summer (July or August) many browns return to the river. During upstream migration brown trout do little if any feeding so growth while in the river is nil.

Spawning activity usually commences in early October, and continues into early December. The spawning peak occurs between mid-October and mid-November. The primary spawning areas are located in the upper Brule River, starting about a mile south of U. S. Highway 2 and extending upstream to Mays Rip. Scattered throughout this section of the stream are areas of suitable gravel that are heavily utilized during the spawning period. The most desirable spawning sites for redd construction are those having (1) good gravel; (2) a good flow of water; (3) some nearby escape cover. It was estimated that the present migratory brown trout population utilizes or occupies 94,000 square feet or 2.15 acres of gravel bottom for spawning. Some limited spawning does occur in a few other places in the Brule River as well as in the Little Brule River, one of the main tributaries.

The size of migratory brown trout population using the spawning grounds south of U. S..Highway 2 was estimated to be between 2,500 to 4,000 trout. Fecundity of these fish was determined from actual egg counts. Egg production varied with the size of the female and range from slightly over 2,000 eggs for a 17.5 inch, 1.8 pound fish, to over 7,500 eggs for a 26.4 inch, 8.4 pound trout. An average size female trout (21.5 inches - 4.5 pounds) produces between 3,000 and 4,000 eggs. Potential egg production from a population of this size was calculated at 5,250,000 eggs.

After spawning there is a noticeable downstream movement of fish from the spawning areas. However, available evidence shows that spawned-out brown trout seldom migrate from the river in the fall.

There is a noticeable change in the condition of these trout from the time they enter the Brule in fall and the time they leave the following spring. Much of this change is directly associated with spawning and is particularly more noticeable in female trout. The average body weight loss for females was 20 percent and for males it was 4 percent. There is little or no improvement in condition after spawning and during the winter months they spend in the river. This then is the type of brown trout available to the angler fishing during the special spring trout season.

This study showed that at times there is a considerable loss of trout through natural mortality. The bacterial disease furunculosis was one of the main causes.

Tests indicated that some of these trout actually carry this disease and under suitable conditions the disease develops killing many trout. Annual losses range from a low of 1,548 pounds to over 3,100 pounds, and totaled 9,928 pounds for years observed. A total of 2,148 dead brown were recovered. Male fish sustained the heaviest loss as they represented 68 percent of the total.

The recovery of both tagged and untagged fish provided the basis for a population estimate. Tagged brown trout recovered represented 27 percent or 571 fish compared to the 1,549 untagged fish. The available evidence also suggests that the mortality is higher during a fall when water temperatures are warmer.

Information on the dispersal of brown trout from the Brule River into Lake Superior was obtained through the return of fish tags by anglers and commercial

fishermen. Brown trout leaving the Brule show a definite eastward movement toward the bay areas along the south shore and into Apostle Island region. Many of these brown trout travel 50 to 100 miles in their migration from Lake Superior to Brule River spawning areas.

Since these brown trout do spend some time in Lake Superior they are susceptible to attack and predation by the sea lamprey. Examination of brown trout handled showed a drop in the incidence of sea lamprey scarring from 14.8 percent in 1961 to 1.8 percent in 1964. The reduction closely followed the control of sea lamprey larvae in streams tributary to Lake Superior through chemical treatment.

Although angler interest as well as angler harvest has shown a definite increase, in comparison to years ago, creel censuses demonstrate the harvest of migratory brown trout is still very light.

A voluntary creel census conducted during the first three years of this study resulted in only 433 brown trout being registered. Even though this is a minimum harvest figure these fish weighed 1,888 pounds. Sixty three percent of the brown trout reported were taken from zone 3 which includes the area from Coop Park upstream to Highway 2. The average size of the brown trout registered was 21.7 inches. Early spring angling for brown trout produces far more fish for the effort than does fishing in the fall. The spring brown trout leave the river very rapidly and are therefore not available for any length of time, such as they are in the fall.

Many of the brown trout that are hatched and raised in the Brule River eventually leave the parent stream. A majority of the smolts migrate when they are completing their second year of life or just entering their third year.

Browns of this age range in size from 6 to 9 inches. There is some downstream movement in the fall but the available data shows a much greater movement in the spring and early summer. The migration of parr trout from the parent stream leaves a definite void in the stream population which is reflected in the fishery.

A stream shocker survey of the upper Brule River (Highway 2 to Stones Bridge) was conducted in an attempt to estimate the brown trout population. Estimates of the brown trout population 6 inches and over was 3,137 fish or a density of 241 fish per mile. The estimated population of brown trout fingerlings was 35,867 fish or a density of 2,759 fingerlings per mile of stream.

This survey work also revealed that certain areas of the stream have relatively few native trout of any size.

MANAGEMENT CONSIDERATIONS AND RECOMMENDATIONS

This study showed that there is a sizeable migratory brown trout run into the Brule River annually. These fish offer a challenging opportunity to any trout fishermen interested in trophy size trout. Angling for trout of this size and quality nowdays is limited, therefore these migratory trout constitute an important fishery resource. Even though fishing seasons have been extended to permit angling for these trout while on their spawning run, the present spawning population is more than adequate, and could stand further harvest without endangering the fishery.

Migratory brown trout are particularly vulnerable to increased harvest in the spring before the fish leave the river. Downstream migration out of the river is closely associated with ice breakup. At times the special spring trout season opens too late and the bulk of the browns are already out of the river. In view of these facts it would seem logical to make further adjustments in the opening date of the spring season. However, further liberalization of this type would also place additional pressure and potential harvest on the rainbow. At this time it is questionable whether the migratory rainbow should be subjected to further fishing prior to spawning.

Perhaps the information made available through this study will create a greater interest in the migratory brown trout and stimulate additional fishing pressure and greater utilization of these trophy trout.

Management Recommendations:

The following management practices are recommended for improving the value of the Brule River as a trout stream.

(1) With the development of more portable dredging equipment consideration should be given to possibly removing accumulated silt from both the river and in associated spring ponds. Specific areas in need of such work are:

   (a) Spring pond area above County Highway "P".

   (b) McDougal Springs area.

   (c) Area of the river above Mays Rip.

   (d) Main channel in Big and Lucius Lake.

   Disposal of the spoil may be a problem in this type of program.

(2) The experimental stream improvement work previously done below Stones Bridge should be continued and extended farther downstream as available material permits.

(3) Protective instream cover should be installed as needed in the area of the river below Big Lake downstream to U. S. Highway. In this clear water area there are many places with inadequate protective cover especially for larger size stream trout. The installation of any kind of improvement structures should conform with the natural appearance of the river.

(4) Spawning areas in the upper Brule River may appear to be quite extensive, but good spawning sites are actually limited and heavily utilized. Therefore, the spawning grounds especially in the upper river above Highway 2 to Mays Rip should be adequately protected and preserved.

(5) When further knowledge and methods become available for controlling the red clay slip banks and resulting erosion, efforts should be made to stabilize these banks. This is a serious problem, particularly in the lower river.

(6) This study definitely proved that fish migration is not curtailed by conditions at the mouth and since it is one of the basic concepts in the overall management of this river to preserve and perpetuate this stream in a natural state, it is strongly recommended that no breakwater or similar structure be constructed at the mouth of the Brule River.

An alternate proposal for a breakwater protective boat harbor and boat launching site in the vicinity of the Brule River has been previously submitted.

(7) The natural migration of parr trout from the river and the lack of catchable native fish in certain areas, together with the heavy fishing pressure exerted on the fishery (particularly in the upper river),it is recommended that trout stocking be continued to supplement the resident stream fishery. In light of the very heavy fishing pressure on the opening weekend of the regular trout season it is further recommended that the trout allotted to the Brule River be "split planted".

One half of the quota should be planted prior to the opening of the trout season and the remaining half should be stocked at a later date.

(8) Beaver should be kept at a minimum throughout the river, and that any resulting beaver dams (especially in the extreme upper river (Highway "P" to Stones Bridge)) be removed.

(9) Further studies should be conducted to determine the exact inter-relationship between the migratory brown and rainbow, particularly during the first years of life in the stream.

(10) A more complete creel census should be conducted to determine more exactly the current harvest of the migratory brown trout.

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