STEELHEAD

OF THE

MINNESOTA NORTH SHORE

MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF FISH AND WILDLIFE

MINNESOTA DEPARTMENT OF
NATURAL RESOURCES

TECHNICAL
BULLETIN
NUMBER 11

MARCH 1974

STEELHEAD OF THE MINNESOTA NORTH SHORE

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Section of Fisheries

Supported in part under
ANADROMOUS FISH ACT (P.L. 89-304) PROJECT AFS-3
AND FEDERAL AID IN FISH RESTORATION ACT,
D-J PROJECT F-20-R

Cover Photo by
CHARLES CURTIS
Duluth Herald-News Tribune

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ACKNOWLEDGMENTS

The authors are indebted to; Charles R. Burrows for his direction and encouragement throughout the study, to Warren J. Scidmore and Dr. Thomas E. Waters for their assistance and suggestions in preparation of the manuscript; and to R. E. Schumacher who participated in the initial planning and field work.

Special thanks to John Dobie for providing some of the photographs; to Ron Morreim for preparation of figures; to the personnel at French River Area Fisheries Headquarters for assistance and equipment; and to Dean Ash for his capable fieldwork.

Segments of this study were supported by the Anadromous Fish Act (P.L. 89-304), Project AFS-3, and the Federal Aid in Fish Restoration Act, Dingle-Johnson Project F-20-R.

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STEELHEAD OF THE MINNESOTA NORTH SHORE

Introduction

Perhaps the most colorful, and certainly one of the most successful introductions of a non-native species, the steelhead trout[1] of the Great Lakes, has attracted an ever growing number of devoted angling enthusiasts. First introduced into Minnesota waters along the North Shore of Lake Superior from 1895 to the early 1900's, this transplanted native of the West Coast of North America rapidly became established as a popular sport fish.

While the life history characteristics of the steelhead in the West Coast streams of North America tributary to the Pacific Ocean are well documented, information on steelhead in the Great Lakes is more limited. Aspects of the steelhead life history in Lake Michigan have been described by Greely (1933) and Stauffer (1972). In Lake Huron similar work has been reported by Wainio (1962), Dodge and MacCrimmon (1970), and Berst and Wainio (1967). Phenotypic characteristics of rainbow trout in the Great Lakes have been described by Bidgood and Berst (1967) who found that although there were limited morphometric differences in the trout from four widely separated Great Lakes watersheds, meristic characters between wild and cultured stocks in these watersheds did not differ significantly.

In Lake Superior published information on the life history of the steelhead has been available only in recent years. Niemuth (1970) reported on steelhead in the Brule River of Wisconsin and Kwain (1971) contributed additional information from Batchawanna Bay in eastern Lake Superior.

This report provides further information on the life history and the fishery for steelhead along the Minnesota North Shore.

To effectively manage this growing fishery, a measure of its magnitude and the ability of the streams to provide the steelhead which support it was required. Smith and Moyle (1944) who conducted an extensive biological survey of the North Shore streams and prepared the first comprehensive trout management plan for these streams reported that "upstream spawning migrations of the anadromous species are prevented in most streams by falls near the mouth." These falls limit the spawning and rearing capacity of many streams for steelhead.

Characteristics of North Shore Streams

The portion of the Lake Superior watershed lying in Minnesota is small and steep, extending only 15 to 25 miles back from the lake shore and sloping so rapidly toward the lake that some streams descend 1,300 feet from their

[1]Steelhead trout are a rainbow trout (*Salmo gairdneri* Richardson) form which spends its adult life in the sea or large inland lakes and ascends tributary streams to spawn.

source to the level of discharge. The last 400 feet of descent is accomplished in the lower one to three miles in a series of high falls and steep cascades. These falls are barriers to upstream migration of the steelhead and the portions of most of the streams accessible to the fish are short. Within this watershed there are 59 streams with a total of 132.3 miles of stream accessible to steelhead (Figure 1). The amount of water available varies from a tenth of a mile or less in many streams to as much as 70 miles in the Knife River. The streams of the North Shore and the amount of water available to steelhead are listed in Table 1.

The streams beds are composed, for the most part, of ledge rock, boulders, rubble, and gravel. Sand is rare and accumulated organic bottom in the lower reaches is confined to the estuaries. Stream flow throughout the watershed is primarily from surface runoff. With few lake and swamp areas, the water storage capacity of the watershed is limited and extreme fluctuations in stream flows result. Army Corps of Engineer records for Devils Track River near Grand Marais, for example, show seasonal fluctuations in flow from less than two cfs during the winter to 505 cfs during the spring.

Table 1. Lake Superior steelhead streams in Minnesota

Name	Tributary Number	Location of Mouth			County	Miles of Steelhead Water
		Township	Range	Section		
Nemadji	S-1	T-47	R-15	S-19	Carlton	35.0
Chester	S-3	T-50	R-14	S-23	St. Louis	0.1
Tischer	S-4	T-50	R-14	S-13	St. Louis	0.1
Lester	S-5	T-50	R-13	S-8	St. Louis	0.9
Talmadge	S-7	T-51	R-12	S-19	St. Louis	1.1
French	S-11	T-51	R-12	S-17	St. Louis	0.2
Schmidt	S-12	T-51	R-12	S-17	St. Louis	0.1
Sucker	S-15	T-51	R-12	S-10	St. Louis	2.0
Knife	S-17	T-52	R-11	S-31	Lake	70.0
Stewart	S-19	T-53	R-10	S-29	Lake	0.9
Silver	S-21	T-53	R-10	S-21	Lake	0.2
Encampment	S-22	T-53	R-10	S-11	Lake	0.5
Crow	S-23	T-53	R-10	S-1	Lake	1.9
Castle	S-25	T-54	R-9	S-33	Lake	0.8
Gooseberry	S-26	T-54	R-9	S-22	Lake	0.8
Twin Points	S-27.1	T-54	R-9	S-13	Lake	0.2
Split Rock	S-29	T-54	R-8	S-7	Lake	0.7
Unnamed	S-30	T-54	R-8	S-5	Lake	0.1
Beaver	S-35	T-55	R-8	S-12	Lake	0.2
Palisade	S-37	T-56	R-7	S-22	Lake	1.2
Baptism	S-38	T-56	R-7	S-14	Lake	0.9
Little Marais	S-44	T-57	R-6	S-21	Lake	0.1
Dragon	S-44.1	T-57	R-6	S-21	Lake	0.3
Manitou	S-45	T-57	R-6	S-11	Lake	0.1
Little Manitou	S-46	T-57	R-6	S-2	Lake	0.5
Caribou	S-47	T-58	R-6	S-36	Lake	0.1
Sugar Loaf	S-48	T-58	R-5	S-29	Cook	0.1
Last	S-49	T-58	R-5	S-16	Cook	0.1
Unnamed	S-50	T-58	R-5	S-15	Cook	0.1
Two Island	S-51	T-58	R-5	S-11	Cook	0.1
Cross	S-52	T-58	R-4	S-6	Cook	0.3
Temperance	S-53	T-59	R-4	S-32	Cook	0.1

Name	Tributary Number	Location of Mouth			County	Miles of Steelhead Water
		Township	Range	Section		
Onion	S-56	T-59	R-4	S-12	Cook	0.1
Rollins	S-57	T-59	R-3	S-5	Cook	0.1
Poplar	S-58	T-60	R-3	S-33	Cook	0.1
Lutsen	S-60	T-60	R-3	S-25	Cook	0.1
Jonvick	S-61	T-60	R-2	S-19	Cook	0.1
Spruce	S-62	T-60	R-2	S-15	Cook	0.1
Indian Camp	S-63	T-60	R-2	S-11	Cook	0.7
Cascade	S-64	T-60	R-2	S-1	Cook	0.1
Cutface	S-65	T-61	R-1W	S-34	Cook	0.4
Rosebush	S-66	T-61	R-1W	S-25	Cook	0.1
Devils Track	S-67	T-61	R-1E	S-13	Cook	1.3
Durfee	S-68	T-61	R-2E	S-8	Cook	0.1
Cliff	S-69	T-61	R-2E	S-10	Cook	0.1
Kimball	S-70	T-61	R-2E	S-10	Cook	1.6
Stone	S-71	T-61	R-2	S-2	Cook	0.1
Kadunce	S-72	T-61	R-2	S-22	Cook	0.3
East Colville	S-73	T-62	R-2	S-32	Cook	0.5
Brule	S-75	T-62	R-3	S-34	Cook	1.5
Myhr's	S-76	T-62	R-3	S-26	Cook	0.1
Flute Reed	S-77	T-62	R-4	S-20	Cook	0.3
Carlson	S-79	T-62	R-4	S-10	Cook	0.5
Farquhar	S-80	T-62	R-4	S-11	Cook	0.2
Reservation	S-81	T-62	R-5	S-6	Cook	3.6
Unnamed	S-83	T-63	R-5	S-35	Cook	0.1
Hollow Rock	S-84	T-63	R-5	S-25	Cook	0.1
Unnamed	S-86	T-63	R-6	S-9	Cook	0.1
Grand Portage	S-87	T-63	R-6	S-4	Cook	0.1
Total — 59 Streams						132.3 Miles

The Study Streams

The two streams selected for detailed study, the Kimball and Kadunce, are located east of Grand Marais, Cook County, Minnesota. These streams have good access, support known steelhead runs and are well utilized by fishermen. They are similar in size and are approximately one mile apart, a situation which provided an opportunity to obtain comparative population data and assessment of the "homing or straying" of returning spawners from two stream populations.

Kimball Creek drains an area of about 15 square miles in Township 61, 62, and 63 North, Range 2 East of Cook County. The drainage area is underlain with basic Keweenawan lava flows and intrusives. These rocks in the lower half of the drainage basin are covered with stony water-worked soils and in the upper half with glacial drift. The forest cover is largely aspen, birch, and spruce, and the stream banks are thickly lined with alder.

Three small lakes, Boys, Mink, and Kimball are the sources of the stream. There are also four small tributaries which provide inconsequential flows. The creek is approximately seven miles long, passing through several beaver dams near the headwaters and over several falls, the largest about 10 feet high. After passing over the falls, the creek enters a steep-walled canyon and drops rapidly to Lake Superior (Figure 1).

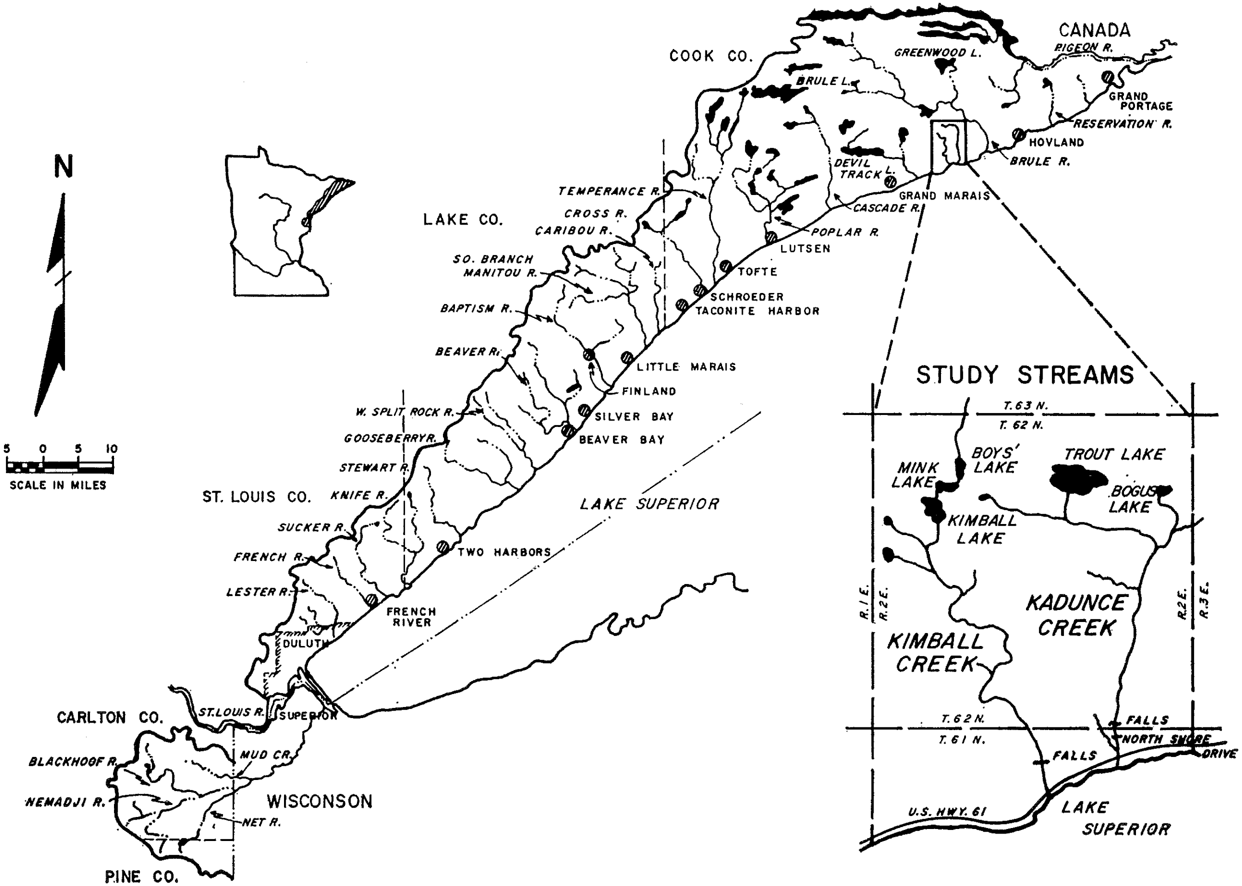

Figure 1. Minnesota's Lake Superior Watershed.

Kimball Creek is a soft water stream, ranging in total alkalinity from 32.5 to 48.7 ppm with a median pH of 7.4. Plankton is sparse, the bottom fauna is fairly abundant, and aquatic plants are occasional in the headwaters area (Smith and Moyle, ibid.).

The upstream barrier to migrating steelheads is 8,395 feet from Lake Superior. The accessable portion has an average width of 20.8 feet, an average depth of 9.7 inches with a gradient averaging 2.35 feet per 100 feet of stream. Staff gauge readings during the six-year study period, showed water fluctuations of about six feet. The physical characteristics of Kimball Creek are summarized in Table 2 and the species of fish present are listed in Table 3.

Kadunce Creek also drains an area of about 15 square miles in Township 61 and 62 North, Range 2 East of Cook County. The lower portion of the drainage basin is underlain with rhyolite flows and the upper portion with diabase. These rocks are for the most part covered with lake-deposited soils. The stream bottom near the headwaters is mostly clay and sand. The stream flows through a rocky gorge near the mouth where the bottom is largely boulder, rubble, and gravel. About a mile above the mouth, the stream enters an area of exposed bedrock and passes over a series of waterfalls, the highest of which is about 10 feet. In the lower portion of the rocky stretch the stream passes through a rhyolite canyon with vertical walls as high as 80 feet. The surrounding country is covered with a second-growth forest of aspen and birch and the stream is about 35 percent shaded with alder, black ash, cedar, and birch.

Kadunce Creek is approximately seven miles long with four tributaries, and has its source in Trout Lake, Township 62 North, Range 2 East. The light brown water of Kadunce Creek is soft, having a total alkalinity ranging from 15.4 to 36.3 ppm and with a slightly acid median pH of 6.9. Plankton is sparse in the lower reaches, and aquatic plants, while absent in the lower reaches, cover 10 to 20 percent of the bottom in headwater pools and beaver dams. Bottom organisms are moderately abundant in the headwater areas (Smith and Moyle, ibid.).

A partial barrier to upstream steelhead movement is present approximately 1,400 feet upstream from Lake Superior (Figure 2). This barrier is a 6-foot falls. The total barrier, a 10-foot falls, is found 2,727 feet upstream from Lake Superior. Overall the stream averages 19.3 feet in width, 9.5 inches in depth, with a gradient of about two feet per 100 feet of stream. Staff gauge readings indicate water fluctuations of about two feet. Other physical characteristics are shown in Table 2 and the fish species present are listed in Table 3.

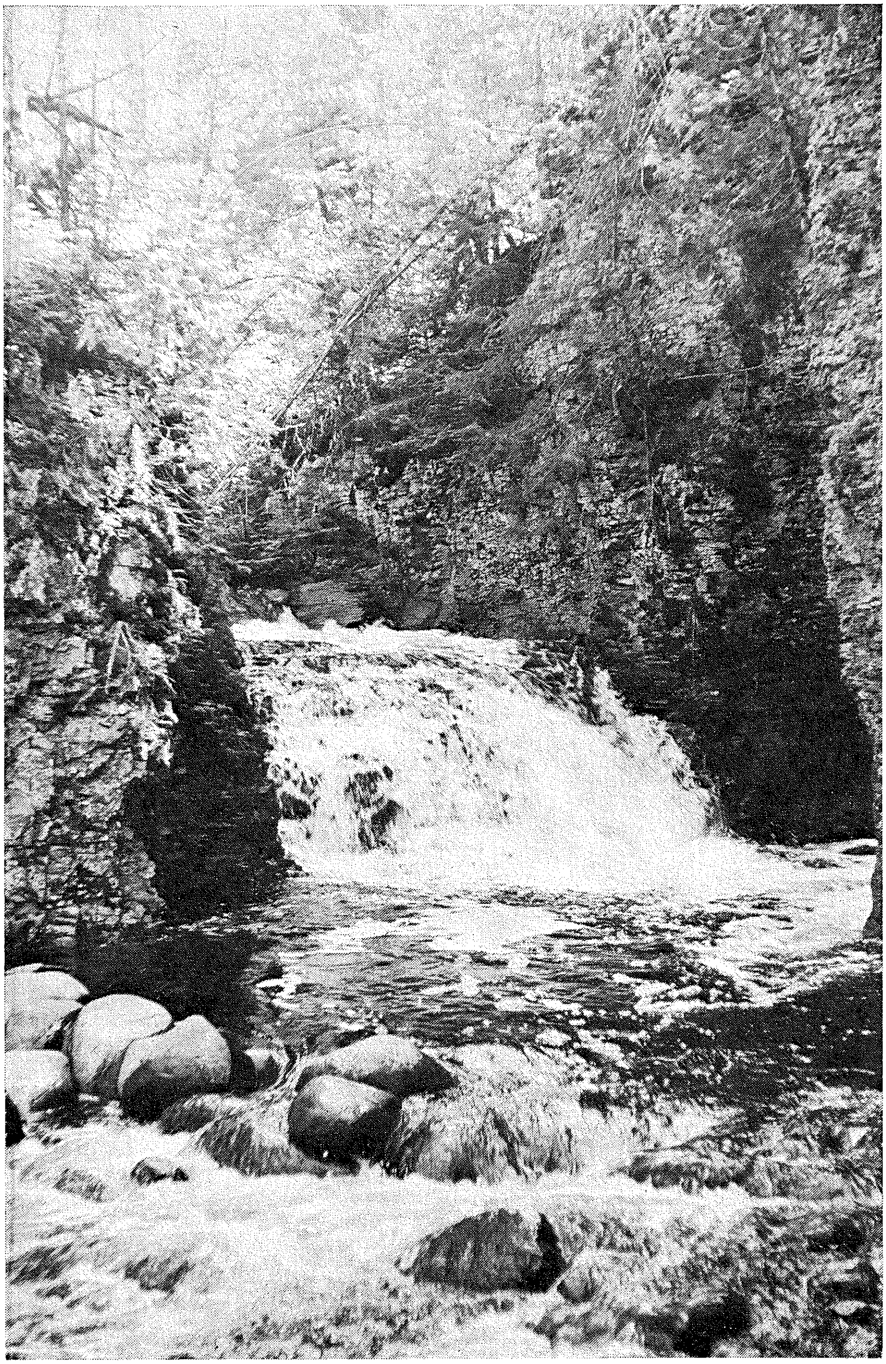

Figure 2. Lower falls on Kadunce Creek following alteration to permit ascent of spawning steelhead.

Table 2. Physical characteristics of Kimball and Kadunce Creeks

Stream	Length to Barrier (Feet)	Area (Acres)	Ave. Width (Feet)	Ave. Depth (Inches)	Percent Composition		Percent Bottom Type			
					Pool	Riffle	Ledge	Boulder	Gravel	Muck
Kimball	8,395	4.01	20.8	9.7	13	87	7	76	17	0
Kadunce	1,400[1]	.67	20.8	9.5	15	85	7	53	39	1
	1,327[2]	.55	17.9	9.5	32	68	14	44	42	0

[1]To partial barrier
[2]From partial to total barrier

Table 3. Species of fish taken by electrofishing in Kimball and Kadunce Creeks

Species		Kadunce	Kimball
Sea lamprey	*Petromyzon marinus* Linnaeus	X	X
Rainbow trout (Steelhead)	*Salmo gairdneri* Richardson	X	X
Brown trout	*Salmo trutta* Linnaeus	X	X
Brook trout	*Salvelinus fontinalis* (Mitchill)	X	X
Central mudminnow	*Umbra limi* (Kirtland)	X	
Northern redbelly dace	*Phoxinus eos* (Cope)	X	X
Finescale dace	*Phoxinus neogaeus* Cope	X	X
Brassy minnow	*Hybognathus hankinsoni* Hubbs	X	
Fathead minnow	*Pimephales promelas* Rafinesque	X	X
Blacknose dace	*Rhinichthys atratulus* (Herman)	X	X
Longnose dace	*Rhinichthys cataractae* (Valenciennes)	X	X
Creek chub	*Semotilus atromaculatus* (Mitchill)	X	X
Pearl dace	*Semotilus margarita* (Cope)		X
Longnose sucker	*Catostomus catostomus* (Forster)	X	X
Burbot	*Lota lota* (Linnaeus)	X	X
Brook stickleback	*Culaea inconstans* (Kirtland)	X	X
Walleye	*Stizostedion vitreum vitreum* (Mitchill)		X
Mottled sculpin	*Cottus bairdi* Girard		X
Slimy sculpin	*Cottus cognatus* Richardson	X	X

Methods

Stream surveys were conducted on all of the 59 North Shore streams to determine which were important spawning streams and to evaluate their spawning and rearing capacity for steelhead trout. Pertinent information was also collected on their physical and biological characteristics.

On the Kimball and Kadunce which had been selected for detailed study, a weir and trap at the mouth of each stream was maintained during the spring migration to monitor all steelheads moving in or out of the stream. Steelheads over 12 inches in length were marked with a nylon dart tag or Peterson disc tag. Those under 12 inches were finclipped to indicate stream and year of capture. An anesthetic (MS-222) was administered before marking and a fungicide dip (Malachite green, 1:15,000) was used following marking. All migrants were weighed, measured, and scale sampled for life history information.

Figure 3. Trap on Kimball Creek used to monitor spawning steelhead entering stream and smolts leaving stream.

Trapping began in the spring of 1961 on both streams with floating barge-type traps with webbing leads. These traps were not effective at flood stages and were replaced in 1962 with traps utilizing a permanent timber base and metal "A" frames with removable rods for leads (Figure 3). These traps were operated on Kimball Creek from 1962 to 1964, and on Kadunce Creek from 1962 to 1965. Although they were much superior to the barge-type traps they were also inoperative during some high water periods which frustrated attempts to obtain complete enumeration of the runs during all years.

Assessment of populations of resident juvenile steelhead in the spawning streams was carried out by electrofishing with a 110 volt AC portable generator and block seines to establish a measure of stream carrying capacity. All steelhead taken by electrofishing were measured, weighed, finclipped according to year and stream, and scale sampled. If fish had been previously finclipped, they were recorded, remarked, weighed, and measured.

A census of the steelhead anglers was conducted during the spring spawning run on the study streams from 1961 thru 1967. Fifteen other important streams along the North Shore were also censused in various years during this period to determine the general distribution of angling pressure and the quality of angling for the North Shore streams as a whole. This census covered the period from ice-out, about April 15, to June 1 and was designed to contact virtually all anglers using the selected streams during the census period. Counts and contacts with anglers using other streams along the North Shore were also made at intervals throughout the census period to obtain supplementary catch and pressure data. Length, weight, and scales of angler-caught steelhead were collected whenever possible. During trapping and creel census operations, water temperatures, cloud cover, barometric pressure, rainfall, stream staff gauge readings, and condition of the stream was recorded.

Aging of the steelhead was done by the scale reading method. Since it was desired to record the details of the life history of individuals, the age of the steelhead was divided into time spent in the streams as a juvenile and time spent in Lake Superior as an adult. The notation system used by Shapovalov and Taft (1954) was adopted for this report. This system uses the sign N/N to separate years of stream life from years of lake life. For example, a six year old steelhead which had spent three years in the stream and three years in Lake Superior would be designated as 3/3 (Figure 4). Because the steelhead were captured in the spring spawning run prior to annulus formation, the outer margin of the scale was counted as the last annulus.

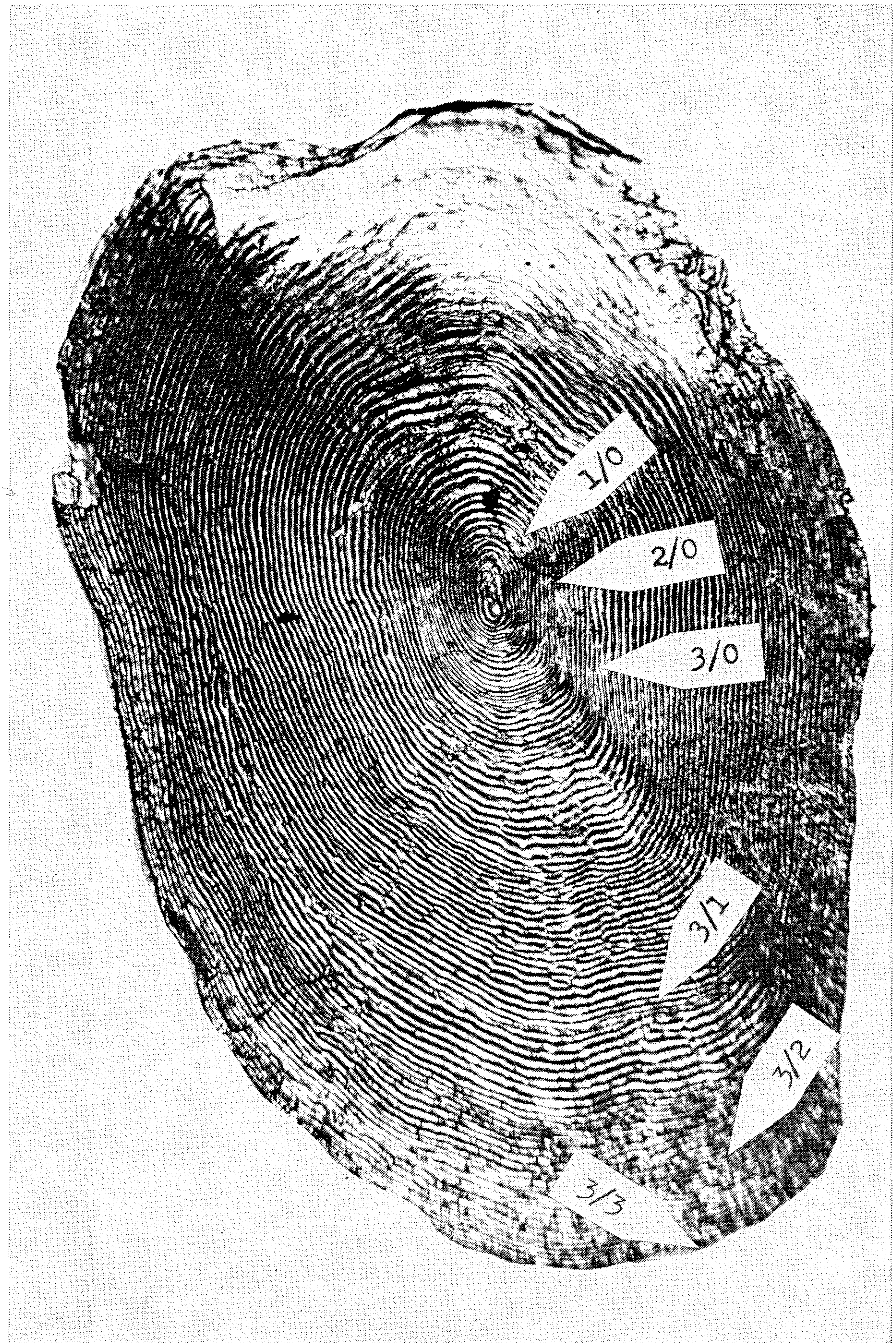

Figure 4. Scale from six year old steelhead showing three years of stream life and three years of lake life.

LIFE HISTORY OF LAKE SUPERIOR STEELHEAD

Reproduction

Time of Spawning Migrations

The entry of the first spawning steelhead into North Shore streams is governed by the spring ice breakup and during the study years the date of first entry of steelhead into the study streams varied from April 16 to May 4. The earliest entries recorded were April 16 in Kadunce Creek and April 19 in Kimball Creek.

Although entry of steelhead intent on spawning ranged from April through mid-June in the study streams, over 50 percent of the run had occurred by May 20th and was about 80 percent completed by May 30th in four of the five study years (Table 4). The initial appearance of ripe females in the study streams occurred during the last week of April and the last ripe females appeared during the middle of June. Reports from other streams along the North Shore indicated occasional steelhead spawning activity as late as July. The first spent females were observed during the first week in May.

Table 4. Steelhead spawning migrants counted through upstream trap, Kimball and Kadunce Creeks, 1961-1965. Percent of each run by period is shown in parenthesis

Period	1961	1962	1963	1964[1]	1965
April 21-30	7 (10.8)	15 (12.2)	12 (5.6)	6 (27.3)	2 (2.8)
May 1-10	10 (15.4)	26 (21.1)	94 (44.1)	0	10 (14.1)
May 11-20	17 (26.2)	41 (33.3)	36 (16.9)	7 (31.8)	16 (22.5)
May 21-30	18 (27.7)	15 (12.2)	40 (18.8)	1 (4.5)	31 (43.7)
May 31 - June 9	10 (15.4)	16 (13.0)	30 (14.1)	8 (36.1)	10 (14.1)
June 10-19	3 (4.6)	10 (8.1)	1 (0.5)	0	2 (2.8)
Total	65	123	213	22	71

[1]Incomplete returns from Kimball Creek not included.

Variation in steelhead spawning habits have been noted in the Great Lakes. Kwain (ibid.) reported that the steelhead in Batchawana Bay of Lake Superior were also spring spawners as were steelhead in the Brule River, Wisconsin, (Niemuth ibid.). However, the Brule River steelhead enter the stream in the fall and over-winter there. In Lake Huron, Dodge and MacCrimmon (ibid.) reported an extended spawning season of steelhead with two runs, one spawning during the winter months and one spawning during early spring.

Fall-run steelhead also occur periodically in Minnesota streams. These fish generally appear during October and November moving upstream during periods of increased flow from fall rains. The runs occur sporadically, depending on the amount of precipitation and stream conditions. The fish comprising the runs are adults, but no fall spawning has been observed. The harsh winter conditions in the streams, low flows and heavy ice, preclude any overwintering and the fish generally return to Lake Superior before freeze-up.

Factors Influencing Time of Spawning Migration

Entry and upstream movements of steelhead on the North Shore were influenced by weather conditions, with the initial spawning runs being associated with the ice breakup and increased stream flow from snow melt.

Steelhead ascended during both rising and falling stream levels, but ceased movement during floods. An examination of the relationship between peaks in the spawning run and water temperature, stream flow, cloud cover, and wind direction revealed no consistent corelation with any single factor. Rather, it appeared that runs were influenced by a combination of factors. For example, it was not possible to separate the effects of temperature and stream flow since rising water temperatures and rising stream levels occurred simultaneously following warm spring rains. Other factors, such as the proportion of the run that had already ascended during the season, previous flows and climatic conditions, maturity of the fish and turbidity of the water, are all factors which influenced the number of fish at any given period during the run.

Of the factors involved, the largest catches were associated with precipitation, steady or rising water levels and temperatures in the 38-45° F range. The catch per day was also higher during periods with northeast winds which are often accompanied by rainy weather.

Age and Size of Steelhead in Spawning Migration

Fourteen life history categories were represented in the spawning migrations (Table 5). However, only four of these contributed more than 12 percent of the run. These were 2/2's, 30 percent; 2/3's, 20 percent; 3/2's, 13 percent; and 3/3's, 12 percent. Together these four categories represented 75 percent of the total spawners. The largest single group of spawners in both study streams were steelhead which had spent two years in the stream and two years in the lake. The majority of adult steelhead examined (87 percent) were four and five years of age. The oldest fish examined was a seven-year-old female from Kimball Creek with a history of three years in the stream and four years in the lake. The amount of time these spawning adults had spent in the stream as juveniles varied from zero to three years. The majority, 61 percent, had spent two years in the stream before smolting. Only 12 percent had spent less than two years as stream-resident juveniles (Table 5).

Table 5. Sex and life history categories of steelhead in spawning runs, Kimball and Kadunce Creeks, 1961-1965

		Years in Stream/Years in Lake													
Year	Sex	0/3	0/4	1/1	1/2	1/3	1/4	2/1	2/2	2/3	2/4	3/1	3/2	3/3	3/4
1961	Male	1	—	—	—	2	—	1	13	3	—	5	3	—	—
	Female	—	1	—	—	1	—	—	17	4	—	2	3	2	—
1962	Male	—	—	7	1	5	—	14	6	6	—	3	2	1	—
	Female	—	—	—	2	8	—	3	15	20	1	—	6	5	—
1963	Male	—	—	—	3	1	—	9	29	6	2	1	12	10	—
	Female	—	—	—	5	3	—	2	20	36	8	1	22	32	1
1964	Male	—	—	—	—	1	—	2	4	—	—	—	—	—	—
	Female	—	1	—	1	2	—	2	5	1	—	—	1	—	—
1965	Male	—	—	—	1	—	—	1	10	—	—	1	3	—	—
	Female	—	—	—	1	3	1	1	14	12	3	—	5	3	—
Total		1	2	7	14	26	1	35	133	88	14	13	57	53	1
% Composition		.2	.5	1.6	3.1	5.8	0.2	7.9	30.0	19.8	3.1	2.9	12.8	11.9	0.2
% Composition by stream life		1		11				61				27			
		0 Years in Stream		1 Year in Stream				2 Years in Stream				3 Years in Stream			

Niemuth (ibid.) also found spawning steelhead from the Brule River to be composed chiefly of fish in their fourth and fifth years of life and that the majority of the spawners there had also spent two years in the stream before smolting.

Batchawana Bay spawning steelhead, however, were composed of younger fish, chiefly those three and four years of age which had spent a shorter period of time in the stream as juveniles. Thirty-eight percent had spent one year in the stream, 59 percent spent two years, and only three percent had remained in the stream for three years. (Kwain ibid.)

Comparison of the sizes of Kimball and Kadunce steelhead by sex and life history category showed no consistent difference between streams. Females from both streams appeared to be equal or slightly larger in size than males in most life history categories (Table 6). However, the difference in mean length betwen the sexes was significant at the .05 level only for Kadunce Creek steelhead. (Unpaired observations and unequal variance, Steel and Torrie, 1960).

The growth of the steelhead is influenced by the two life history periods, the amount of time spent in the stream as a slow-growing juvenile, and in the lake as a fast-growing adult. Fish that emigrated from the stream as small young-of-the-year or yearlings spent proportionally more time in the lake than later emigrants of the same year class and reached a greater total length at a given age (Figure 5). However, because the early emigrants are of small size at smolting, they usually must spend an extra year or two in the lake to

Table 6. Mean length of steelhead by sex and life history, Kadunce Creek and Kimball Creek, 1961-1965. Number of fish examined in parenthesis

	Total Length (Inches)				
	Kadunce		Kimball		
Age	Male	Female	Male	Female	Mean Both Streams
1/1	13.8 (6)	—	15.2 (1)	—	14.5 (7)
2/1	15.1 (17)	17.3 (7)	14.3 (10)	16.4 (1)	16.3 (35)
3/1	16.9 (5)	17.8 (2)	16.2 (5)	15.2 (1)	16.8 (13)
3/1	16.9 (5)	17.8 (2)	16.2 (5)	15.2 (1)	16.8 (13)
1/2	17.4 (3)	18.1 (4)	17.8 (2)	17.9 (5)	18.0 (14)
2/2	20.7 (36)	21.1 (41)	19.8 (26)	22.0 (30)	20.8 (133)
3/2	22.2 (7)	22.1 (17)	20.5 (13)	21.5 (20)	21.9 (57)
0/3	20.0 (1)	—	—	—	20.0 (1)
1/3	21.4 (8)	22.4 (12)	21.4 (1)	21.3 (5)	22.0 (26)
2/3	22.4 (7)	23.2 (38)	23.1 (8)	23.4 (35)	23.3 (88)
3/3	—	25.1 (13)	24.2 (10)	24.4 (30)	24.9 (53)
0/4	—	21.9 (2)	—	—	21.9 (2)
1/4	—	24.3 (1)	—	—	24.3 (1)
2/4	—	26.9 (7)	26.0 (2)	26.9 (5)	26.7 (14)
3/4	—	—	—	26.0 (1)	26.0 (1)
Mean Length	19.2 (90)	22.2 (144)	20.0 (78)	22.8 (133)	21.7 (445)

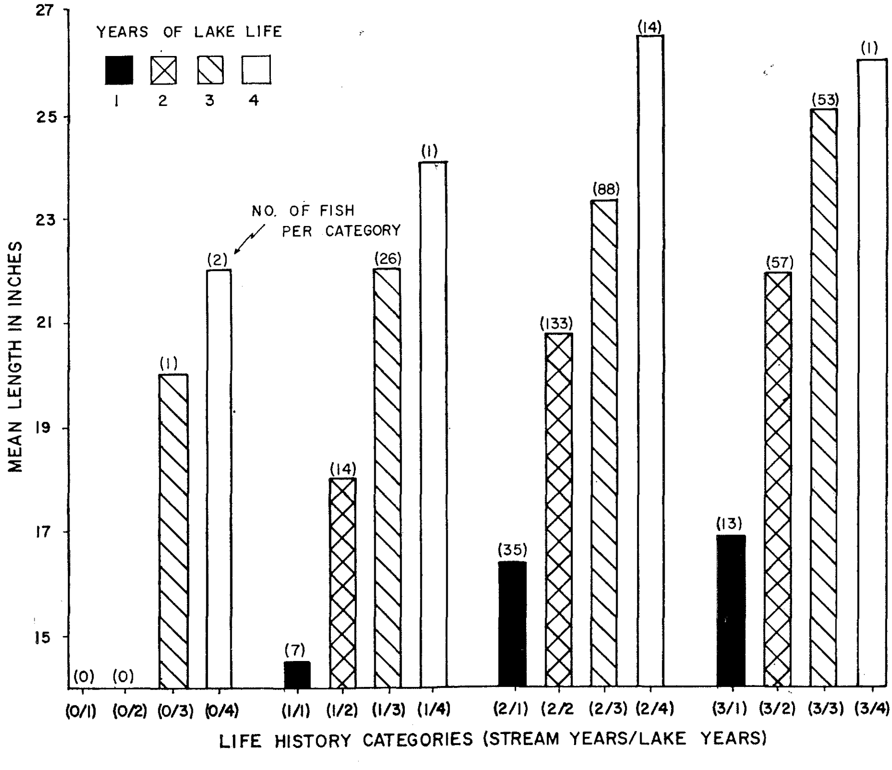

Figure 5. Mean length at maturity for 445 Lake Superior steelhead adults, by life history category, from Kimball and Kadunce Creeks, 1961-1965.

reach maturity. The later, larger emigrants, with their advantage in smolt size produced larger adults after any given number of years in the lake. Based on the actual return of all mature fish, the older emigrants came back as larger fish and in far greater numbers than did the younger emigrants (Figure 5). The maximum number of adults came from fish that emigrated at two years of age and spent two or three years in the lake before returning to spawn.

Comparisons of spawning North Shore steelhead with those from other regions of Lake Superior indicate some differences in size and age. Steelhead from Kimball and Kadunce Creeks appear to be larger at ages three through six and smaller at age seven than steelhead from Wisconsin and Ontario waters (Niemuth, ibid.) and (Kwain, ibid.).

Sex Ratios

The sex ratio of spawning run adults in Kimball Creek varied from 1.1 males to one female in 1961, to one male to 2.5 females in 1963. At Kadunce Creek the sex ratio varied from one male to 1.2 females in 1962, to one male to 2.5 females in 1965. The average sex ratio of steelhead from both streams, combining all seasons, averaged one male to 1.6 females.

Although the overall ratio was fairly close, there were considerable differences within a season and between the various life history categories (Table 5). The earlier maturing males predominate in the younger life history categories while females predominate among the fish of greater total age. Males were more numerous among fish of total ages two and three while the ratio was about equal among fish of total age four. At total ages five and older, females were the most numerous.

There appeared to be a close relationship between the sex ratio and the length of time the spawning steelhead spent in the lake (Table 7). Among the spawners spending one season in the lake, males were the most abundant. For those spending two seasons in the lake, the sex ratio was nearly equal, while females outnumbered males among the steelhead which had spent three or more seasons in the lake. The decrease in males with total age and with time spent in the lake suggests a shorter life span and higher mortality among males.

Table 7. Sex ratio of upstream migrant steelhead by life history categories, Kimball and Kadunce Creeks, 1961-1965

	Years in Stream/Years in Lake								
	1/1	2/1	3/1	1/2	2/2	3/2	1/3	2/3	3/3
Male	7	27	10	5	62	20	9	15	10
Female	—	8	3	9	71	37	17	73	43
Average Ratio (Males to Females)		4.0 to 1 1 season in lake			1 to 1.3 2 seasons in lake			1 to 3.9 3 seasons in lake	

Although the life history category and sex composition of the run varied throughout the season, males predominated in the early part of the run while females predominated in the later stages, indicating an earlier ripening among males in a given season.

Since the sex ratio and life history categories are associated, some fluctuations occur in the representation of the life history categories during the spawning run (Table 8). These changes are not great, but there is an initial run of most of the life history categories from the last of April to about mid-May, followed by a general decline. The most numerous 2/2 fish, however, persist more strongly in the run over a longer period than the other life history categories.

Table 8. Seasonal distribution of life history categories of spawning steelhead Kadunce and Kimball Creeks 1961-1963, expressed as the mean number trapped by period. Range in parenthesis.

Kadunce Creek

	2/1		2/2		2/3		3/2		3/3	
Date	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
April 21-30	0.7	(0-2)	1.0	(0-2)	2.0	(0-5)	0.3	(0-1)	0	(0)
May 1-10	2.3	(0-5)	4.0	(0-7)	3.0	(1-4)	1.0	(0-2)	0.3	(0-1)
May 11-20	1.7	(0-4)	3.7	(3-4)	3.3	(1-7)	2.0	(1-3)	2.0	(0-3)
May 21-31	0.3	(0-1)	4.0	(3-6)	1.7	(0-3)	1.3	(1-2)	0.3	(0-1)
June 1-10	0	(0)	1.7	(1-2)	0.3	(0-1)	0.3	(0-1)	0.3	(0-1)
June 11-20	0.6	(0-1)	0.7	(0-1)	0	(0)	0	(0)	0.3	(0-1)

Kimball Creek

	2/1		2/2		2/3		3/2		3/3	
Date	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
April 21-30	0	(0)	1.0	(0-2)	0.3	(0-1)	1.0	(0-3)	.3	(0-1)
May 1-10	2.3	(1-4)	5.3	(1-10)	6.7	(0-19)	2.3	(0-7)	7.7	(0-23)
May 11-20	0.7	(0-1)	4.3	(2-8)	1.3	(1-2)	2.3	(2-3)	1.3	(0-3)
May 21-31	0.7	(0-2)	4.3	(2-6)	3.7	(3-5)	2.3	(0-5)	3.0	(1-5)
June 1-10	0	(0)	4.0	(1-6)	1.7	(0-5)	2.0	(0-5)	2.0	(0-5)
June 11-20	0.3	(0-1)	0	(0)	0.7	(0-2)	0	(0)	0	(0)

Repeat Spawners

One objective of the study was to determine the incidence of repeat spawning and the numerical importance of repeat spawners in the spawning runs of a particular stream. Among Pacific Coast steelhead, repeat spawning ranges from 5 to 31.3 percent for winter steelhead and 4.4 to 6.3 percent for summer steelhead with the incidence of repeat spawning decreasing from south to north (Withler, 1966).

To assess the importance of repeat spawning, 131 adult post-spawning steelhead were tagged as they returned to Lake Superior from the two streams.

Of these, only eight (6 percent) could be accounted for in spawning runs one to three years later. Since six of the eight repeat spawners returned to the stream in which they previously spawned, this suggests the incidence of repeat spawning is low if homing to natal streams is strongly developed.

No steelhead were observed on spawning runs more than twice. Two steelhead, however, were captured two years after their initial spawning run and one was captured three years later. It is not known if these steelhead had spawned during the interim period in some other stream.

The physical condition of the spawners after their first spawning run and the incidence of lamprey mortality may influence steelhead survival and the chance to spawn again. Although few dead or moribund steelhead were observed during the spawning runs, the battered and weakened condition of the steelhead that were observed in the downstream migration could well result in death after the fish returned to the lake. Lamprey populations were also high during this study period, and the lampreys' selection of larger and older trout has been noted by Berst and Wainio (ibid.).

While the incidence of repeat spawning observed is likely a minimal figure for the Lake Superior Steelhead, repeat spawning would have to increase many-fold to be a significant factor in the production of steelhead in the study streams, since the age distribution in the spawning runs indicate that the bulk of the runs are most likely fish which are spawning for the first time.

Repeat spawning in the North Shore study streams appears to be considerably less than that found in other Great Lakes areas. Kwain (ibid.) found 26 percent of the adults examined in Batchawanna Bay of Lake Superior spawning for the second time with one five-time spawner recorded, while Dodge and MacCrimmon (ibid.) found repeat spawners in Bothwells Creek, Lake Huron, comprising 52 and 75 percent of two spawning populations.

Spawning

Reports by Shapovalov and Taft (ibid.) and Briggs (1953) on Pacific Coast steelhead spawning behavior cover this subject in considerable detail. Limited observations of spawning steelhead in North Shore streams revealed no notable differences. Like the Pacific Coast steelhead, the Lake Superior female steelhead chose the redd site which was typically near the head of a riffle and composed of medium and small gravel. The site was usually close to the point where a smooth pool broke into a riffle. Although this was typical, considerable individual variation was noted. In most cases, however, the redd site was selected so as to be rarely exposed by dropping water levels.

As noted by Shapovalov and Taft (ibid.) and Briggs (ibid.) the female was usually accompanied by one or more males. The female dug the redd by turning on her side and fanning her tail. Depending on the size of the female, the pit or depression was 4 to 12 inches in depth. During the egg deposition, the female lowered her vent into the pit, the male moved into position beside her, and the eggs and milt were extruded simultaneously. Immediately afterward, the female covered the eggs by turning on her side and fanning her tail on each side of the pit. According to the above authors the spawning act may be repeated several times over the span of a week depending on various factors, including stream conditions and ripeness of the fish.

It is estimated in both these reports that more than 95 percent of the eggs are successfully fertilized and buried in the redds.

Egg Production

Steelhead from various streams along Minnesota's North Shore were collected over the period 1960-1966 to determine fecundity. The total egg production was determined by weighing both ovaries and then weighing and counting approximately 25 percent of the eggs in each ovary. The females ranged from 19 to 29.5 inches in total length and weighed 2.25 to 9.0 pounds, with a mean length of 23.1 inches and a mean weight of 4.1 pounds. The mean total egg count for both ovaries was 3,170.

The fish produced an average of 771 eggs per pound of body weight, with 21 (72%) of the 29 fish producing between 650 and 900 eggs per pound. The number of eggs per pound of fish was fairly constant and did not change over the size range of fish examined, or with the index of condition. The total number of eggs increased directly with the length (Figure 6) and with the weight of each fish. The number of eggs produced by North Shore steelhead at a given length is less than for Pacific Coast steelhead, as reported by Shapovalov and Taft (ibid.).

Post-Spawning Behavior

The spent steelhead which have not succumbed to old age, disease, parasites, predators, spawning rigors or anglers, descend the stream to Lake Superior in the same season. These downstream migrants were monitored through traps until it appeared the majority of spawners had returned to the lake. This was about mid-June. Spent fish began moving back to Lake Superior the first week of May with the peak movement occurring during the last part of May and the first part of June (Table 9). The time spent in the stream by adults varied from a few hours to as much as 38 days with an average length of stay of 10.5 days.

Approximately three times as many females as males were taken in the downstream trap compared to 1.7 times as many in the upstream trap. It would appear males were subjected to greater angling and natural mortality

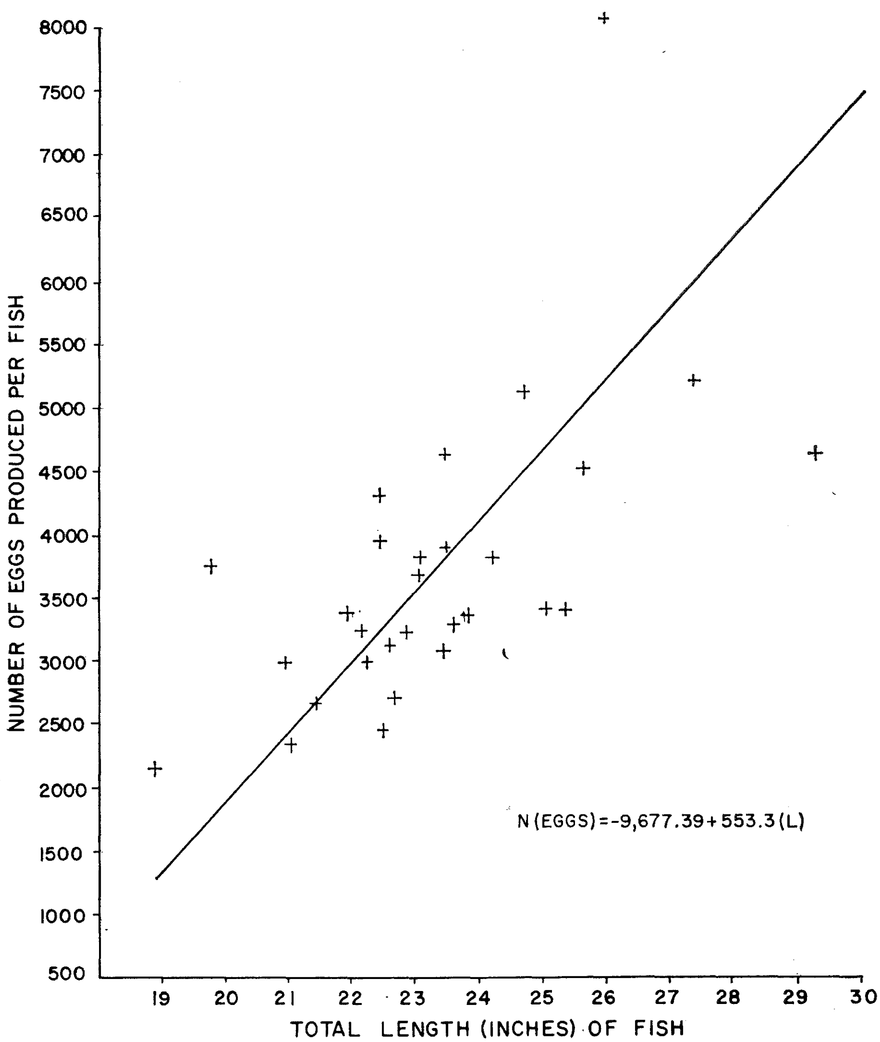

Figure 6. Egg production of Lake Superior steelhead from various Minnesota North Shore streams.

during the spawning period. This mortality may account, in part, for the dominance of females among the older spawning steelhead.

The physical condition of the steelhead also changed in the post-spawning period. The energy used in ascending the stream and during spawning resulted in a weight loss for both males and females. The weight loss as reflected by the Index of Condition ("C" factor) was computed by sex for the upstream and downstream migrants in the study streams. Kadunce Creek steelhead post-spawning "C" factor was reduced 9.5 percent (33.86 to 30.65) for

Table 9. Adult steelhead in downstream traps by sex and season, Kimball and Kadunce Creeks, 1962-1965

Date	1962 M	1962 F	1963 M	1963 F	1964 M	1964 F	1965 M	1965 F	Total M	Total F
April 10-20	—	—	—	—	—	—	—	—	—	—
April 21-30	—	—	—	—	—	—	—	—	—	—
May 1-10	1	—	3	—	—	—	—	—	4	—
May 11-20	3	9	1	2	—	—	—	—	4	11
May 21-31	5	10	2	25	—	1	—	2	7	38
June 1-10	5	5	3	33	—	2	1	—	11	40
June 11-20	7	8	—	1	3	2	—	1	10	12
Total	23	32	9	61	3	5	1	3	36	101

females and 9.4 percent (34.65 to 29.65) for males. Kimball Creek steelhead had a slightly larger reduction in "C" factor with the males averaging 10 percent (34.65 to 29.65) and the females 14 percent (32.17 to 28.87) reduction in the Index of Condition. The greater reduction among Kimball Creek fish may reflect the longer distance the steelhead ascend on their spawning run in this stream.

Hatching and Emergence of Fry

The time required for steelhead eggs to hatch varies from about 19 days at an average temperature of 60° F. to 80 days at an average temperature of 40° F. (Shapovalov and Taft, ibid.). Hatching time, at temperatures found along the North Shore, ranged from 30 to 60 days. No information was gathered on hatching success during the study but work on the Pacific Coast indicates that 60 to 80 percent of the eggs deposited hatch successfully (Briggs, ibid.; Shapovalov and Taft, ibid.).

The steelhead fry began to emerge from the gravels approximately two to three weeks after hatching, first appearing in late June and early July. The time of emergence varied considerably and was probably influenced by many factors including time of egg deposition, depth of burial in gravel, amount of siltation and water temperatures.

Stream Life of Juvenile Steelhead

Abundance and Age Distribution

The juvenile steelhead, following emergence, took up residence in the shallow gravel areas of the stream. At first the steelhead tended to school in these areas but as time passed the schools broke up and individuals selected territories which they defended. Large differences in size were noted among the small steelhead soon after emergence. These differences were largely the result of the prolonged spawning season and variable hatching and emergence dates. Soon after emergence, a decline in the numbers of fry in the streams was noted which was not entirely accounted for by emigration. As the summer season progressed, the growing steelhead juveniles moved into deeper water but still preferred the moderately faster water of the stream rather than the quiet pools.

During the period July 13 to July 25, 1961, traps were operated in the study streams to monitor the downstream movement of young-of-the-year steelhead. In the 12-day period a total of 32 young-of-the-year were trapped in Kimball Creek for a catch rate of 2.7 per day. In the same period, 69 young-of-the-year were trapped in Kadunce Creek for a catch rate of 5.7 per day. While this downstream movement of young-of-the-year may vary considerably from year to year depending on density of steelhead in the stream and water conditions, it is of interest to note that the largest emigration was from Kadunce Creek, which in 1961 and most other years, had the smallest standing crop of late summer young-of-the-year (Table 10). This emigration from Kadunce Creek may reflect greater competition for food and space since this stream carries a much larger population of brook trout and miscellaneous other species.

The mean total standing crop of all fish per acre in the study streams during late summer amounted to 2,332 fish weighing 33.5 pounds in Kadunce Creek and 3,570 fish weighing 42.3 pounds in Kimball Creek. Juvenile steelhead in Kadunce Creek represented 70 percent in number and 59 percent in weight of the total standing crop. In Kimball Creek juvenile steelhead represented 90 percent in number and 84 percent in weight of the total standing crop of fish (Table 10). The larger standing crop of steelhead in Kimball

Table 10. Late summer standing crop of juvenile steelhead and other fishes in number and pounds per acre. Kimball and Kadunce Creeks, 1960-1963

Kimball Creek

Year	No. of Stations	Acres	Steelhead No.	Steelhead Wt. (lbs.)	Brook No.	Brook Wt. (lbs.)	Brown No.	Brown Wt. (lbs.)	Other[1] No.	Other[1] Wt. (lbs.)
1960	4	0.54	3,759	44.1	9	0.7	4	1.3	263	2.4
1961	7	1.03	3,518	34.3	6	0.2	1	0.2	159	3.5
1962	7	1.03	2,549	35.5	16	0.2	0	.0	359	4.3
1963	7	1.03	3,450	20.3	17	0.6	1	0.2	150	2.0
Mean N per acre			3,319	35.8	12	1.7	6	1.7	233	3.1

Kadunce Creek

Year	No. of Stations	Acres	Steelhead No.	Steelhead Wt. (lbs.)	Brook No.	Brook Wt. (lbs.)	Brown No.	Brown Wt. (lbs.)	Other[1] No.	Other[1] Wt. (lbs)
1960	4	0.68	2,537	20.7	94	7.2	0	0	728	16.0
1961	5	0.83	1,277	13.1	45	2.6	0	0	300	7.7
1962	5	0.83	1,461	23.9	136	2.8	0	0	621	8.3
1963	5	0.83	1,292	20.8	186	4.1	1	.2	648	6.0
Mean N per acre			1,642	19.6	115	4.2	1	0.2	574	9.5

[1]Other includes minnows, sculpins, suckers, and burbot

Creek may reflect somewhat more productive water and as previously noted, smaller populations of potential competing species. The principal other species associated with the steelhead in these streams were brook trout, brown trout, minnows, sculpins, suckers and burbot.

Despite differences in the total standing crop of juvenile steelhead in the two streams the age-class compositions were quite similar (Table 11) and were also similar to those found by Stauffer (ibid.) in Black River, Michigan where the autumn steelhead population was 68 percent age zero, 29 percent age one and 3 percent age two fish.

Table 11. Total number and percent composition by age group of juvenile steelhead, Kadunce and Kimball Creeks, late summer 1960-1963

	Kadunce					Kimball				
Year	YOY	I	II	III	Total	YOY	I	II	III	Total
1960	1,587	108	29	1	1,725	1,753	178	95	5	2,031
1961	783	265	11	1	1,060	2,986	545	84	9	3,624
1962	854	425	75	1	1,355	1,853	841	86	6	2,786
1963	706	322	61	2	1,091	2,775	873	137	10	3,795
Total	3,930	1,120	176	5	5,231	9,367	2,437	402	30	12,236
Mean	983	280	44	1	1,309	2,342	609	100	8	3,059
Percent Composition	75	21	3	1	—	77	20	2	1	—

The decrease in numbers between resident juvenile year classes while obviously due in part to downstream emigration, also represents an in-stream mortality component of unknown magnitude.

Only one resident juvenile was found which had spent more than three years in the stream. This individual was fin-clipped as a yearling in Kadunce Creek in 1962 and recaptured in the same stream, as an 8.3 inch four-year-old. The fish apparently never emigrated and was finally caught by an angler.

The mean standing crop of juvenile steelhead in the study streams, of 3,177 per mile in the Kadunce and 6,586 per mile in the Kimball, was greater than reported for other streams on Lake Superior. In the Brule River, Wisconsin, the population of juveniles over six inches was estimated at 412 per mile and juveniles under six inches at 2,688 fish per mile. However, the Brule also contained an estimated 2,789 juvenile brown trout per mile (Niemuth ibid.).

The juvenile steelhead in the study streams were of smaller size than those reported from other Great Lakes tributaries. Kadunce Creek juveniles collected during late summer averaged 2.0 inches in length at age zero, 4.4 inches at age one, 5.9 inches at age two, and 7.2 inches at age three. Stauffer (ibid.) reported the size of juveniles in Black River, a tributary to Lake Michigan, as 2.9 inches at age zero, 6.4 inches at age one, and 9.2 inches at age two. Sizes of juvenile rainbow trout in Batchawana Bay of Lake Superior were also larger than found in Minnesota streams (Kwain, ibid.). The slower growth of juveniles in the study streams may be a reflection of their population density and the relatively low food producing capabilities of the streams (Smith and Moyle ibid.).

Emigration of Smolts

As the juvenile steelhead approach the time to leave the stream and return to the lake they become silvery in color and in early May begin moving downstream. The downstream movement of the smolts was monitored with traps between May 1 and July 23 for three years (1961-1963) on Kimball Creek and for four years (1961-1964) on Kadunce Creek. During this time a total of 1,064 smolts were examined to determine the age and size of the emigrants. With the exception of 1961, the bulk of the smolt emigration had occurred by June 18. No consistent periodicity of movement by emigrants of different ages was detected and peaks in movement of different ages varied between streams and from year to year. The catches from the two streams are therefor combined in Table 12.

Table 12. Number of juvenile steelhead (smolts) emigrating downstream by period from Kimball and Kadunce Creeks to Lake Superior, 1961-1964

Period	1961	1962	1963	1964[1]	Total
May 1-7	—	—	70	—	70
May 8-14	—	—	99	—	99
May 15-21	—	34	48	20	102
May 22-28	—	25	97	8	130
May 29-June 4	—	75	162	19	256
June 5-11	—	11	93	111	215
June 12-18	21	22	43	46	132
June 19-25	—	—	—	—	—
June 26-July 2	—	—	—	—	—
July 3-9	50	—	—	—	50
July 10-16	6	—	—	—	6
July 17-23	4	—	—	—	4
July 24-30	—	—	—	—	—
Total	81	167	612	204	1,064

[1]Kadunce only

These catches do not represent the total downstream movement of smolts since the traps were not operated for the entire season nor were they completely effective at all times during the trapping operation. The catch does, however, show the pattern of downstream movement during the peak period of smolt emigration and represents the minimum number of juvenile steelhead produced that survived to emigrate to the lake.

Stauffer (ibid.) reported that the downstream movement of smolting steelhead in Black River Michigan occurred between May 21 and June 30, at night, on subsiding water levels and at water temperatures of 9-17° C. General observations on the North Shore streams indicate a similar response in these streams.

Size and Age of Emigrating Smolts

The emigrating smolts varied in size from 2.5 to 9.5 inches in length and from one to three years of age (Table 13). Age one smolts averaged 4.3 inches in length while age two and age three fish averaged 5.4 and 7.0 inches respectively.

The size distribution of the smolts emigrating at any particular period during the season was quite similar and there was no apparent relationship between time of movement and the size or age of the fish. During 1962-1964, the mean age composition of the emigrating smolts was 31 percent age one, 57 percent age two and 12 percent age three fish. In contrast, 88 percent of the spawning adults in these streams had a history of two or three years of stream life. The apparent better survival to adults of fish that smolt at ages two and three is probably related to their larger size at emigration.

Table 13. Length distribution and percent composition by age class of steelhead smolts checked through downstream traps, Kimball and Kadunce Creeks, 1962-1964

	Number of Smolts			
Length (Inches)	I	II	III	Total
2.0-2.9	2	—	—	2
3.0-3.9	32	—	—	32
4.0-4.9	76	64	—	140
5.0-5.9	53	146	1	200
6.0-6.9	1	81	24	106
7.0-7.9	—	14	29	43
8.0-8.9	—	2	11	13
9.0-9.9	—	1	—	1
Total	164	308	65	537
Percent Composition	31	57	12	
Mean Length	4.3"	5.4"	7.0"	

Lake Michigan steelhead smolts emigrating from Black River were similar in length to Minnesota fish for age one smolts (4.4 inches), but were considerably larger at ages two and three (7.0 and 8.8 inches respectively). The faster growth here resulted in smolting at an earlier age with the majority (64 percent) of the downstream emigrants composed of age one fish (Stauffer, ibid.).

Shapovalov and Taft, (ibid.) and Stauffer, (ibid.) report that the considerable overlap in sizes and ages of the smolts appears to be related to the variable spawning and hatching dates and to the differences in growth in the nursery stream, with the faster growing juveniles smolting at an earlier age. Faster growth of juvenile rainbow in Batchawana Bay of Lake Superior also resulted in earlier smolting (Kwain, ibid.). Of the 118 smolts he examined during their downstream emigration, 39 percent were age one (length 5.2 inches), 56 percent were age two (length 7.2 inches), and 5 percent were age three (length 9.6 inches).

Survival of Juveniles to Smolts and Adults

During the study years, 1,499 juvenile and smolt steelhead in Kadunce Creek and 3,138 juvenile and smolt steelhead in Kimball Creek were finclipped to distinguish stream and year. The survival of 2,576 of these juveniles, marked during 1961 and 1962, to emigrating smolts was estimated from recaptures in the downstream traps. Since smolting steelhead with one, two or three years in the stream may be derived from the same year class, and the age at emigration is variable, survival rates become quite complex.

It was found survival to smolting increased with age and size, ranging from 2.5 percent for young-of-the-year steelhead to 8.4 percent for age two steelhead (Table 14). Noted earlier, 57 percent of the smolts in the downstream emigration were age two (Table 13). Survival to this age-class during the two years of monitoring was very low with only one of the 234 young-of-the year marked (0.4 percent) surviving to smolt at this age. The survival rate is considered minimal since the traps were operated only during the major emigration period from May 1 to mid-June and later emigrations were not monitored. However, observations on these North Shore streams had indicated that in most years, the bulk of the downstream movement had occurred by mid-June. Although there was no observable mortality, handling and marking these small fish may have also influenced survival despite the considerable care that was exercised to prevent injury.

Table 14. Survival of marked juvenile steelhead age groups to smolt stage, Kimball and Kadunce Creeks, 1961-1962

Juvenile Age-Group	Number Marked	Age Groups of Smolts Marked as Juveniles and Captured in the Downstream Trap			Total	Percent Survival to Smolt Stage
		I	II	III		
0[1]	234	5(2.1%)	1(.4%)	—	6	2.5
I	2,036	—	122(6.0%)	7(.3%)	129	6.3
II	275	—	—	23(8.4%)	23	8.4
III	31	—	—	—	0	0
	2,576				158	6.1

[1]Young-of-the-year steelhead

Eight of the marked juveniles survived two years in the streams before emigrating to Lake Superior. One juvenile, marked as a young-of-the-year, emigrated at age two, and seven juveniles marked at age one emigrated at age three. The stream-life survival rate of these eight smolts was 0.4 percent. Over-winter survival to smolt stage ranged from 2.1 percent for young-of-the-year to 8.4 percent for age-class two. Survival through two winters to smolt stage was 0.4 percent for all age-classes. The poor survival of young-of-the-year steelhead to smolt stage in these streams is a reflection of the comparatively low food producing capabilities of the streams (Smith & Moyle ibid.), the extreme water level fluctuations and the harsh winter conditions. In winter time, reduced flows and stream icing can markedly reduce the capacity of many of these streams to support fish.

In Kimball Creek the known survival of smolts to adults in subsequent spawning runs ranged from 2.8 to 3.0 percent. The known overall survival of marked Kimball Creek juveniles, to adults on their first spawning run, was 0.76 percent. Kadunce Creek smolt survival to adults ranged from 0.5 to 2.2 percent with a known overall survival of all marked juveniles of 0.47 percent (Table 15).

Table 15. Survival of marked juveniles to adults in Kimball and Kadunce Creeks, 1961-1964

Kimball Creek

			Adults — Spring Spawning Run			
			Survival Marked Smolts to Adults		Overall Survival Marked Juveniles to Adults	
Year	Juveniles Marked in Stream Late Summer	Smolts Marked and Released in Downstream Trap[2]	N	Percent	N	Percent
1961-62	776	213	6	2.8	6	.63
1962-63	1,021	327	10	3.0	10	.77
1963-64	876	—[1]	—	—	8	.91
Total	2,673	540	16	2.9	24	.76

Kadunce Creek

			Adults — Spring Spawning Run			
			Survival Marked Smolts to Adults		Overall Survival Marked Juveniles to Adults	
Year	Juveniles Marked in Stream Late Summer	Smolts Marked and Released in Downstream Trap[2]	N	Percent	N	Percent
1961-62	304	43	0	0	0	0
1962-63	475	277	6	2.2	6	.89
1963-64	309	204	1	0.5	1	.21
Total	1,088	524	7	1.3	7	.47

[1]Trap not operated for downstream smolts.
[2]Includes previously marked smolts captured in downstream trap plus additional smolts marked at downstream trap.

The known survival rates of juveniles and smolts to adults is minimal since the returns represent only those marked steelhead which were recovered in traps and by anglers. The actual survival could well be much greater since most of the streams were not monitored or censused in adult years.

Survival to the creel of planted rainbow trout in Lake Superior has been reported by Hansen and Stauffer (1971). Three strains of one to three year old smolt-size rainbow trout (6 to 10 inches long) were planted in various areas in Michigan waters of Lake Superior during 1955-1959. Most of the recoveries were by anglers in spawning streams within two years of the planting date. These volunteer recoveries for the Lake Superior plants averaged 0.9 percent and ranged from 0.3 to 1.5 percent.

Survival of marked presmolt and smolt-size rainbow trout planted into Minnesota North Shore streams tributary to Lake Superior, has ranged from 0.7 percent for young-of-the-year (2.3 inches long at stocking) to 3 percent for yearlings (8.7 inches long at stocking). All the fish recovered by anglers one to four years after stocking exhibited lake growth. These survival rates, should be considered minimal since they are based on partial census of only a portion of the North Shore streams and volunteer returns by anglers.

Homing and Straying

Although the homing and straying of steelhead in West Coast lakes and streams has been described in some detail by several authors, including Shapovalov and Taft (1938), and Lindsey, Northcote and Hartman (1959), there is little published information on this aspect of the life history of the Great Lakes steelhead. Niemuth (ibid.) reported that adult steelhead tagged in the Brule River in Wisconsin were captured by anglers and commercial fishermen at widely scattered locations in Lake Superior, indicating that these fish ranged over much of the lake. However, homing or straying on subsequent spawning runs was not reported.

The close proximity of Kimball and Kadunce Creeks (one mile) offered an opportunity to observe steelhead homing and the straying of steelhead between streams. During the years 1961-1964, 524 smolt steelhead in Kadunce Creek and 540 in Kimball Creek were fin-clipped at emigration for identification should they return to these streams as adults. These smolts were marked to distinguish the year of marking and stream of origin.

Of the marked smolts in Kimball Creek there were a total of 24 recoveries as adults in five years following initial marking. Of those which were recaptured, 18 (75 percent) were captured in their natal stream and six (25 percent) were taken by anglers in other streams. Three of the strays returned to Kadunce Creek and three to the Devils Track River. These streams are the next adjacent streams on either side of Kimball Creek. At

Kadunce Creek, only seven of the marked steelhead smolts were accounted for in three years after marking. Six had returned to Kadunce Creek and one had strayed to the Arrowhead (Brule) River, the next stream east. The returns of marked smolts were too limited to provide an assessment of possible homing tendencies. However, of the eight tagged repeat-spawning steelhead which were recovered, six returned to the stream of their initial spawning experience. In the years following the study no tagged or marked fish were ever reported from these or other North Shore streams. This would tend to suggest that those steelhead adults which do return, tend to return to streams of previous spawning experience.

Factors Contributing to Steelhead Mortality

Deaths from natural causes among Lake Superior steelhead can be broadly assigned to the general categories of diseases and parasites, predation, and physical injury from the rigors of spawning. There is, however, no quantitative data on their relative or total effects.

Disease did not appear to be prevalent among North Shore Lake Superior steelhead. During the course of the study, a few individuals were observed showing symptoms of the common trout disease, furunculosis, but the incidence of the disease was low, and was more prevalent among the fall-run steelhead than among the spring-run. This drop in incidence may reflect a greater over-winter mortality among the infected fish. Niemuth (ibid.) also noted that steelhead in the Brule River in Wisconsin were relatively free of the disease although brown trout occupying the same waters had a high incidence of infection. From the small number of infected fish noted, it does not appear that furunculosis is a major cause of steelhead mortality.

Internal parasites were common in Lake Superior steelhead, but their effect on steelhead survival is unknown. Common nematodes or roundworms found included *Echinorhynchus lateralis* from the intestine and liver, and *Cystidicola stigmatura* from the swim bladder. Common cestodes or tapeworms found in the intestines included the genus *Eubothrium* and an unusual helminth, a larval tapeworm of genus *Diphyllobothrium,* was found in the eye of one steelhead.

During their juvenile life in the stream steelhead are exposed to predation by other fish and fish-eating birds. Fish species predacious of young steelhead are present in the streams and included sculpins and burbot, as well as other trout. Fish-eating birds inhabiting steelhead waters included common loon, mergansers, and kingfishers. Losses in steelhead production from these predators likely occurs chiefly during their first summer in the stream and although these predators could well inflict significant mortality in localized areas the overall effect on steelhead production is unknown. As previously noted, the overall survival of juveniles to the smolt stage is low with major losses apparently occurring during the over-winter periods.

Lamprey predation on lake trout in the Great Lakes is well known and has been associated with the collapse of that fishery, (Lawrie, 1970). It is also likely an important factor in adult steelhead mortality in Minnesota waters at the present time, judging from the observed mark rates which are comparable to those associated with the decline of lake trout.

The incidence of lamprey marks on steelhead over 15 inches in total length from Minnesota waters of Lake Superior has been recorded since 1957 and has ranged from 13.4 percent marked in that year to a high of 34.4 percent in 1961. With the advent of lamprey control measures by agents of the Great Lakes Fisheries Commission, lamprey activity steadily declined until 1967, when, as a result of reduced funding, control measures were reduced and an increase in marking occurred (Table 16).

Table 16. Lamprey marks on Lake Superior steelhead, over 15 inches in total length, Minnesota waters 1957-1973[1]

Year	Number Fish Examined	Number Marked	Percent Marked
1957	126	17	13.5
1958	133	18	13.5
1959	257	38	14.8
1960	171	57	33.3
1961	128	44	34.4
1962	193	37	19.0
1963	294	49	11.7
1964	224	34	15.2
1965	278	37	13.2
1966	271	35	12.9
1967	185	18	9.7
1968	66	10	15.2
1969	26	6	23.1
1972	281	75	26.7
1973	461	82	17.8

[1]Steelhead examined from trap, angler, and incidental commercial catches.

In contrast to the relatively high lamprey activity in Minnesota waters of Lake Superior, Niemuth (ibid.) reported only nine out of 700 migratory rainbow examined bore lamprey marks in the Brule River, Wisconsin, during 1961-1965. Dodge and MacCrimmon (ibid.) also reported lower lamprey marking rates on rainbow trout in the Nottawasaga River, a tributary to Lake Huron. During the period 1961-1967, approximately 7.1 percent of the spawning rainbow over 16 inches they examined had one or more lamprey marks. The incidence of marks reached a maximum of 17.2 percent there in the spring of 1962, then declined to 1.3 percent in the fall of the same year.

This decline coincided with the lampricide treatment of the Nottawasaga River and adjacent lamprey spawning streams during 1960 and 1961. The incidence of marked fish remained low for four years then increased substantially, after presumed recruitment of lampreys during 1966 and 1967.

Mechanical injury to steelheads associated with ascending the stream and the act of spawning are an obvious source of mortality. Of the few dead and moribund spawners examined, ruptured swim bladders, ovaries, spleens, and kidneys were noted. Hemorrhage of the heart and other internal organs as well as a general internal breakdown was also found. These injuries may cause an immediate or delayed mortality among the spawners and probably accounts, in part, for the low percentage of repeat spawners.

THE NORTHSHORE STEELHEAD FISHERY

North Shore streams have long been noted for their trout fishing. Winchell (1880) described an intensive sport fishery for brook trout in the Duluth area in 1879 when access to the fishing waters in the lower portions of the streams was possible only by boat. Following the successful introduction of rainbow trout near the turn of the century, the fishery became increasingly dominated by the steelhead form. At the present time, steelhead probably account for more than 90 percent of the stream trout taken below the barrier falls.

As the sport fishery developed and fishing pressure increased, regulations were established to govern the harvest. In 1953 the first regulations recognizing the specialized nature of the fishery were adopted. These regulations permitted a special season on 24 of the principal streams. Fishing was allowed to the first natural barrier within ¾ miles of the mouth from April 1 to October 30 with a bag limit of 10. Minor adjustments were made between 1953 and 1966 when all streams on the North Shore were included and the season was extended to November 30th. The bag limit of 10 was also modified to permit no more than three trout over 16 inches in length. In 1972 the closed season was eliminated since the previous period of closure had little effect on the fishery.

The greatest fishing pressure, and the greatest portion of the annual steelhead harvest occurs during the spring spawning runs, from ice out to about mid-June when fishermen are attracted by the prospect of taking steelhead which may exceed 12 pounds. During the summer when most adult steelhead have returned to the lake, there is little to attract anglers, and few steelhead are taken. Angler interest revives in the fall when steelhead again appear in or near the mouths of the streams. This "fall run" is minor compared to the spring spawning run and many of the streams are inaccessible to the steelhead because of low water or gravel barriers at the stream mouths.

The Study Streams

A census of fishermen during the spring spawning run was conducted for seven successive years on Kimball Creek and for six years on Kadunce Creek to determine the general quality of angling, the quantity of fish harvested, and the escapement of spawners.

Angling pressure and harvest of steelhead from these streams between April 15 and June 1 varied considerably between years and streams. However, the extremes in angling pressure, about three-fold, occurred in the same years on both streams as did the year of the largest harvest. The lowest fishing pressure on both streams occurred in 1961 when there were 114 trips to Kimball Creek and 220 trips to Kadunce Creek while the highest fishing pressure for both streams was in 1966 when there were 402 trips to Kimball Creek and 601 trips to Kadunce Creek. The greatest harvest of steelhead in both streams was in 1962 when 69 were taken at Kimball and 82 were taken in Kadunce Creek.

The mean annual catch of 48 steelhead in Kadunce Creek and 56 in Kimball Creek represented an average catch rate of 0.13 and 0.11 fish per man-hour respectively. Angling pressure and catch data for these streams are shown in Table 17.

Table 17. Angling pressure, harvest, and catch rate for steelheads from April 15 to June 1, Kimball and Kadunce Creeks, 1961-1967

Kimball Creek

Year	Total Angling Trips	Total Manhours	Total Catch	Catch per Manhour
1961	114	294	53	0.18
1962	205	503	69	0.14
1963	246	584	64	0.11
1964	163	364	48	0.13
1965	129	301	51	0.17
1966	402	575	56	0.10
1967	228	371	52	0.14
Mean	212	427	56	0.13

Kadunce Creek

Year	Total Angling Trips	Total Manhours	Total Catch	Catch per Manhour
1961	220	374	33	0.09
1962	441	554	82	0.15
1963	222	258	32	0.15
1964	221	343	60	0.17
1966	601	806	40	0.05
1967	386	484	43	0.09
Mean	349	470	48	0.11

The total harvest of steelhead in these streams appeared to be more a function of angling pressure than fishing success. Years with the greatest total harvests tended to be those years in which fishing pressure was the greatest while fishing success, in terms of catch per man-hour, tended to decrease as pressure increased.

Although steelhead weighing 12 pounds were recorded during the census on North Shore streams the average size of fish taken in Kadunce and Kimball Creeks was 2.2 and 2.8 pounds respectively.

To determine the extent of harvest of female steelhead prior to spawning, fish from angler catches were examined during two years of the census to note their spawning condition. It was found that fifty to sixty percent of the females caught by anglers in both streams had not yet spawned. Although this is a substantial removal of potential spawners, the rate of removal does not appear to be excessive in light of the large numbers of young-of-the-year steelhead found in the study streams. The principal factor limiting production in these streams is their ability to support and over-winter these juveniles to the smolting stage.

The North Shore

There are 59 streams on the Minnesota North Shore which attract steelhead spawning runs and they provide about 132 miles of water accessible to these fish. The amount of stream available to the steelhead ranges from as little as 65 feet in Onion Creek to as much as 70 miles in the Knife River.

To assess the magnitude and the characteristics of the fishery exploiting the steelhead, fifteen North Shore streams in addition to the study streams, were censused in various years between 1961 and 1967. The streams were representative of the entire shore and covered not only some of the major fishing streams, but also some of the minor ones. The census coverage was extensive, and virtually all anglers using the streams during the spring fishing period were contacted.

The streams, which had a total of nine miles of steelhead water, received widely varying angler attention during the two and a half month census period from April 15 to June 1. For example, the number of angler trips ranged from 16 to over 2,300 per season and the catch varied from 2 to 319 steelhead per stream (Table 18). Overall, the average number of angler trips per season was 263 per stream during which 580 man hours were spent catching an average of 52 steelhead. The average catch rate for all streams in all seasons was 0.14 steelhead per hour.

In general the heaviest fishing pressure occurred on that portion of the North Shore from Duluth to the Baptism River. The distribution anglers

Table 18. Spring steelhead angling pressure and harvest April 15 to June 1 from Minnesota North Shore streams, 1961-1967

Stream	Number of Years Censused	Miles of Stream	Angler Trips Mean	Angler Trips Range	Man Hours Mean	Man Hours Range	Catch (N) Mean	Catch (N) Range	Catch (N) Per Man Hour Mean	Catch (N) Per Man Hour Range
Devils Track	6	1.32	461	274-1,140	1,085	745-1,952	71	27-161	0.07	0.05 -0.12
Split Rock	5	0.69	430	113- 753	1,278	382-2,209	73	9-143	0.06	0.05 -0.10
Cascade	3	0.13	268	135- 417	361	131- 578	12	2- 36	0.03	0.005-0.06
Durfee	3	0.04	65	15- 89	50	16- 89	16	5- 32	0.30	0.24 -0.36
Rose Bush	3	0.03	93	41- 128	150	39- 170	18	2- 36	0.10	0.05 -0.21
Arrowhead (Brule)	3	1.50	256	122- 493	486	204- 800	33	17- 54	0.07	0.004-0.11
Baptism	2	0.93	530	419- 641	1,282	639-1,925	114	59-169	0.09	0.09
Palisade	2	1.19	110	97- 123	260	253- 266	48	36- 60	0.19	0.14 -0.24
Gooseberry	2	0.77	139	124- 153	343	262- 423	34	23- 45	0.10	0.09 -0.15
Silver	2	0.17	170	129- 210	287	150- 424	27	9- 45	0.09	0.06 -0.11
Stewart	2	0.85	563	375- 751	1,637	953-2,321	188	57-319	0.10	0.06 -0.14
Beaver	2	0.16	192	167- 216	375	282- 469	45	16- 74	0.11	0.06 -0.16
Flute Reed	1	0.30	70	—	92	—	7	—	0.08	—
Encampment	1	0.50	125	—	209	—	59	—	0.28	—
Sucker	1	0.38	471	—	802	—	35	—	0.04	—
Total Miles		8.96								
Mean		0.60	263		580		52		0.14	

appeared to be more related to the nearness of population centers than to the quality of angling or the number of streams available.

A rough projection of the census data from all 17 streams indicates that each spring 20,000 to 22,000 anglers fished for steelhead on the North Shore and spent over 50,000 man hours catching 5,000 to 8,000 steelhead.

Angling for steelhead along Minnesota's North Shore is regarded as a "trophy fishery". While the quantity of fish taken is low, with a catch rate of one fish for approximately every seven hours of fishing, the chance of catching steelhead of twelve pounds or larger in the picturesque gorges of the North Shore streams provides an exciting angling experience.

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