By Certified Mail
March 23, 2006

IN THE OFFICE OF ENDANGERED SPECIES

U.S. FISH AND WILDLIFE SERVICE

UNITED STATES DEPARTMENT OF THE INTERIOR

Supplemental Submission in Support of
Petition for a Rule to List the Anadromous Coaster Brook Trout
(*Salvelinus fontinalis*) under the Endangered Species Act,
16 U.S.C. Sec. 1531 et seq. (1973) and as Amended

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May 23, 2006

Mr. T. J. Miller
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re: Salmon Trout River Coaster Brook Trout Petition (dated February 22, 2006; received March 1, 2006)

Dear Chief Miller,

On behalf of Petitioners Huron Mountain Club ("HMC"), Sierra Club and Marvin Roberson, I am pleased to submit the attached supplemental materials in support of our Endangered Species Act Petition for the Salmon Trout River Coaster Brook Trout (*Salvelinus fontinalis*) ("Coasters"). In addition, please accept the following comments in support of the petition. Our comments seek to summarize the attached supplemental materials and their relevance to the petition.

We believe that the Service's action on the petition will be governed by the resolution of two questions: (1) whether the Salmon Trout River ("STR") Coaster is a "Distinct Population Segment" ("DPS"), within the meaning of 16 U.S.C. § 1532 (16); and (2) whether the South Shore population of Lake Superior Coasters (which are known to breed today only in the STR) is "endangered" within the meaning of 16 U.S.C. § 1532 (6). In our view the attached scientific reports conclusively answer both questions in the affirmative.

1. <u>Background</u>.

Coasters were once Lake Superior's most celebrated fish. Until the mid 1800s, Coaster Brook Trout were found in at least 105 streams in the Lake Superior basin, including more than

30 streams in Michigan.[1] By 1900 Coaster populations had been widely reduced. Id. As early as 1921, it was observed that "the trout [coasters] along the southern shore are approaching extinction. . . ."[2] Given the Coasters' early and widespread decimation, it is surprising that they survived at all. They did so only in two carefully protected refugia: Isle Royale National Park and Wilderness Area, and the STR.

In response to an apparent recent decline in the STR Coaster population, HMC many years ago instituted catch-and release fishing regulations for its members. HMC later urged the State of Michigan to close the river to all fishing when spawning adults are present, which has been done. HMC also supported the State's recent tightening of lake harvest regulations.

Also, in 2000, the Huron Mountain Wildlife Foundation initiated a series of grants to Dr. Casey Huckins of Michigan Technological University who, in collaboration with Dr. Edward Baker of the Michigan DNR, launched a long-term study of the STR Coaster. The study is ongoing, and has several goals. Broadly speaking, the study is designed to expand our understanding of Coaster ecology, populations, and genetics. Attachments A, B, and C to this letter are reports issued by Dr. Huckins and Dr. Baker presenting the results of their research.

As part of their research, the study team also took tissue samples (adipose fin clips) for genetic analysis. Dr. Kim Scribner (Michigan State University) has recently reported the results of that analysis in Scribner et al., *Metapopulation Composition And The Influence Of Stocking On Resident And Migratory Brook Trout In Michigan Tributaries Of Lake Superior,* A Final Report Submitted to The National Fish and Wildlife Federation. Dr. Scribner's report is attached to this letter as Exhibit D.

2. <u>Coaster Genetics</u>.

Even before the results of Dr. Scribner's genetic analysis were available, biologists "appreciate[d] that the Lake Superior Coaster population(s) may be unique and comprise an 'evolutionarily significant unit(s)' and, as such, require consideration as a discrete group."[3] This

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[1] Newman & Dubois, *Status Of Brook Trout In Lake Superior*, Lake Superior Technical Committee, (March, 1996) citing Behnke, R. 1994, *Coaster Brook Trout and evolutionary "significance"* (About Trout), Trout (Autumn 1994). Pp. 59-60.

[2] Shiras, G. r. 1921. *The wildlife of Lake Superior, past and present: the habits of deer, moose, wolves, beavers, muskrats, trout and feathered wood-folk studied with camera and flashlight.* Pages 130 ff. in The National Geographic Magazine.

[3] Newman & Dubois, *Status Of Brook Trout In Lake Superior*, Lake Superior Technical Committee, (March, 1996) citing Behnke, R. 1994, *Coaster Brook Trout and evolutionary "significance"* (About Trout), Trout (Autumn 1994). Pp. 59-60.

view has been confirmed by Dr. Scribner's analysis. That analysis consisted of measuring allele frequency[4] among: (a) STR Coasters; (b) STR resident Brook Trout; (c) Brook Trout populations in several other area Lake Superior tributaries; and (d) exotic Brook Trout strains commonly used in stocking area streams. Exh. D. at 3-5.

Scribner et al. found, first, that the genetic integrity of STR Coasters has not been compromised by interbreeding with hatchery brook trout. Id. at 8.

Second, Scribner et al. found that "allele frequencies of [two separate samples of STR Coasters] differed significantly from those of the stream resident adults (exact tests; P<0.05)," indicating that STR Coasters are reproductively isolated (and thus genetically distinct) from stream resident Brook Trout. Exh. Id. at 7; see also id. at 8 ("Data also show that resident and coaster brook trout from the Salmon Trout River are not part of a single and randomly mating population.")

Finally, Scribner et al. found that STR Coasters are reproductively isolated from brook trout populations in neighboring streams, indicating that they evolved uniquely in the STR.

> Collectively, analyses of relationships between coaster and resident brook trout show that coasters originated from the Salmon Trout River. Our data do not support the hypothesis that coaster brook trout are nomadic and migrate and breed in multiple populations.

Id. at 8.

3. STR Coasters as a Distinct Population Segment.

The Service has determined that the "discreteness" of a population segment "refers to the isolation of a population from other members of the species and is based on two criteria—(1) marked separation from other populations of the same taxon resulting from physical,

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[4] Exh. D at 5 ("Estimates of variance in microsatellite allele frequency among resident brook trout population, between resident and coaster life history forms from within the Salmon Trout River, and among natural populations and hatchery strains widely used in the region were quantified using F-statistics (Weir and Cockerham 1984) implemented in program FSTAT. Measures of genetic distance (Cavalli-Sforza and Edwards 1967) were also estimated for all pair-wise comparisons of natural and wild populations using program PHYLP (Felsenstein 1993). Genetic relationships based on genetic distance were characterized in the form of a neighbor-joining tree (Saitou and Nei 1987) and visualized using program TREEVIEW (Page 1996). Statistical support for individual nodes of the tree were obtained based on 1000 bootstrap replicates conducted using PHYLP.")

physiological, ecological, or behavioral factors, including genetic discontinuity; and (2) populations delimited by international boundaries." 63 Fed. Reg. 31647, 31649.[5] Applying these criteria, there is no question that STR Coasters are "discrete":

- They are separated from Coaster populations in the Nipigon River area by an international boundary and by great distance.
- They are physically separated from the only other known Coaster population in the United States -- that which breeds on and around Isle Royale -- by a distance of over 100 Km.[6], and a landmass impediment (the Keweenaw Peninsula).
- Coasters are distinguished from stream resident Brook Trout by behavior -- i.e., anadromy -- and by physiology (they grow much larger, and may be longer-lived).
- Dr. Scribner has shown that the STR Coaster is reproductively (and thus genetically) isolated from all other area Brook Trout populations.

4. The Condition of the Existing Coaster Population.

The Huckins-Baker study team measured the population of adult Coasters by capturing them in weir traps as they migrate upstream to spawn. It is important to note that the count produced by this technique probably represents less than the entire population, because in each year the weir traps have been less that fully effective for at least some period of time, as follows:

Year	Number of days traps deployed	Number (%) of days traps fully effective at capturing migrating Coasters	Source
2000	115	90 (78%)	Exh. A at 5.
2001	91	88 (97%)	Exh. A at 5.
2002	128	92 (72%)	Exh. A at 5.
2003	97	60 (62%)	Exh. B at 7.
2004	(see Note)		
2005	131	101 (77%)	(see Note)

(2004 Note: In 2004, weir traps were not used. Instead, migrating fish were directed past an underwater camera and counted visually. See Exh. C at 2.)

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[5] (June 10, 1998) (Determination of Threatened Status for the Klamath River and Columbia River Distinct Population Segments of Bull Trout).

[6] Research indicates that Coasters do not stray far from their natal streams. See L. E. Newman, R. T. Novitsk, J. T. Johnson, and R. G. Johnson, *Defining Habitat Use and Movement Patterns of a Reintroduced Coaster Brook Trout Population in Lake Superior* (http://baby.indstate.edu/isb/publications/abstracts2/session1-2.htm).

(2005 Note: Source -- C. Huckins, *personal communication*. The report for the 2005 season is in draft. When finalized, we will forward a copy to your offices.)

In addition, it is possible that some number of Coasters migrated upriver after ice and snow forced the team to remove the weir traps. For both reasons, the data produced by the study likely represents an under-counting of the total migrating STR Coaster population.

Nonetheless, the study has confirmed the observed decline in the STR population, versus earlier decades. It has also confirmed the precarious nature of the extant STR coaster population. Total counts of spawning adults have been as follows:

Total Number of Large Upstream Brook Trout Migrants Observed, Salmon Trout River, 2000-2005

	≥300 mm TL
2000	**161**
2001	**93**
2002	**65**
2003	**13**
2004	**118**
2005	**149**

Exh. A at 11 (2000-2002 data); Exh. B at 4-5 (2003 data); Exh. C at 2 (2004 data); Dr. C. Huckins, *personal communication* (2005 data). The data establish that the average annual spawning population is less than 200 individuals, and that in some years the spawning population has been considerably less than 200 individuals.[7] We submit that a spawning population of this size is unquestionably "endangered" within the meaning of 16 U.S.C.§ 1532 (6). Compare 63 Fed. Reg. 42757 [8] ("It is estimated that between 50 and 125 bull trout spawn throughout the Jarbidge River basin annually"); 63 Fed. Reg. 31647, 31650 [9] ("The Service considered a

[7] To roughly estimate a correction for the days of weir trap dysfunction, we could, for example, extrapolate the total population of spawning Coasters based on catch-per-unit-effort (CPUE -- See Exh. A at 12). Assuming that the total migration season is 122 days (August-November), the results for the years 2000, 2001, 2002, 2003, 2004, and 2005 are 218, 129, 86, 26, 140 (including 19 observations in July), and 180, for an annual average of 130.

[8] (August 11, 1998) (Emergency Listing of the Jarbidge River Population Segment of Bull Trout as Endangered).

[9] (June 10, 1998) (Determination of Threatened Status for the Klamath River and Columbia River Distinct Population Segments of Bull Trout).

subpopulation 'strong' if . . . 500 spawners likely occur in the subpopulation, . . . and 'depressed' if less than 500 spawners likely occur in the subpopulation . . .").

In addition, if Kennecott's planned sulfide mine underneath the headwaters of the STR goes forward (see http://www.michigan.gov/deq/0,1607,7-135-3311_4111_18442-130551--,00.html), the virtual inevitability of acid mine drainage and other impacts will place the STR Coasters in immediate peril, plainly creating emergency conditions.

5. STR Coaster Significance.

In addition to the discreteness of a Population Segment, and to the status of the DPS's population (its "conservation status"), the Service also considers, in evaluating an ESA petition, the "significance" of the DPS.[10] "Significance" is determined "either by the importance or contribution, or both, of a discrete population to the species throughout its range." Id. Four criteria determine significance:

"(1) persistence of the discrete population segment in an ecological setting unusual or unique for the taxon;

(2) evidence that loss of the discrete population segment would result in a significant gap in the range of the taxon;

(3) evidence that the discrete population segment represents the only surviving natural occurrence of the taxon that may be more abundant elsewhere as an introduced population outside its historic range; and

(4) evidence that the discrete population segment differs markedly from other populations of the taxon in its genetic characteristics."

Id. It is clear that STR Coasters are, by these measures, of enormous "significance":

(1) The STR preserves a population (anadromous Lake Superior Brook Trout) whose ecological setting is unusual and unique when compared with Brook Trout habitats and life histories generally;

(2) Loss of the STR Coaster DPS would result in a "significant gap in the range of the taxon" -- i.e., its extermination from the Continental United States;

[10] 63 Fed. Reg. 31647, 31649 (June 10, 1998) (Determination of Threatened Status for the Klamath River and Columbia River Distinct Population Segments of Bull Trout).

(3) In the Continental United States, STR Coasters "represent[] the only surviving natural occurrence of the taxon." Exh. D at 2 ("The Salmon Trout River in the Upper Peninsula of Michigan represents the only known viable population of coaster brook trout along the south shore of the Lake Superior basin.")

(4) Dr. Scribner has proven that the STR Coaster "differs markedly from other populations of the taxon in its genetic characteristics."

6. Conclusion.

For these reasons, as well as those stated in the petition, we urge the Service to grant the petition. With all respect, Chief Miller, we believe that, under the Service's settled analytical framework, it would be difficult to imagine a more compelling candidate for ESA protection. And while the "charisma" of a species is not a formal element in the evaluation of an ESA petition, we submit that the historic, economic and aesthetic value of the Coaster is not irrelevant. The Coaster once was, and conceivably could again be, a magnet for anglers from across the country.[11] It is emblematic of the distinctive wildlife of the Lake Superior region. And it is an animal of surpassing beauty.

We hope that the Service finds the attached materials, and our discussion of them, useful in its consideration of our petition. If there is any additional useful information that we might provide, please do not hesitate to contact the undersigned.

Peter Kryn Dykema
Secretary, Huron Mountain Club

[11] Exh. A at 2 (Coasters were "an important species that attracted countless anglers to the region," citing Roosevelt, R. B. 1865. *Superior fishing - The striped bass, trout, and black bass of the northern states*. Originally published by G.W. Carleton. Minnesota Historical Society Press, St. Paul.

Final Report to the Huron Mountain Wildlife Foundation
for Phase I of our Research Conducted on the

"*Ecology of Coaster Brook Trout in the Salmon Trout River, Marquette County, Michigan*"

2000-2002

Casey J Huckins
Michigan Technological University

Edward A. Baker
Michigan Department of Natural Resources

May 2004

Abstract

The Salmon Trout River, Marquette County, Michigan hosts the only known remnant breeding population of coaster brook trout (*Salvelinus fontinalis*) along the entire south central shore of Lake Superior and is thus an important site for information about the ecology of coasters for basic science as well as for application throughout the Lake Superior basin. Research on the population and community ecology of coasters in the Salmon Trout River was funded for three years by the Huron Mountain Wildlife Foundation (HMWF) beginning in May 2000 and ending May 31, 2003. This research has been directed by Dr. Casey Huckins, Michigan Technological University (MTU) and Dr. Edward Baker, Michigan Department of Natural Resources (MiDNR) with the majority of the field work conducted by MTU graduate student Darren Kramer and numerous field assistants (Jason Frentress, Jessica Popik, Wes Ripley, Terri Grout and Erik North). Although coaster brook trout (coasters) were the primary focus of this research program, the research was conducted with a community and habitat perspective for a more holistic understanding of coaster ecology and the ecology of the Salmon Trout River in general. Although still in its infancy, the general knowledge of coaster ecology has been greatly enhanced through this research program on the Salmon Trout River. Prior to this research, little quantitative information was available on the abundance, seasonal dynamics and demographics (e.g., size-structure) of the population(s) of brook trout that reproduce in the Salmon Trout River. Through our research we have gathered evidence that the Salmon Trout River hosts a small remnant population of breeding coaster brook trout. We have determined that juvenile brook trout were generally outnumbered by juveniles of exotic salmonids within study reaches of the lower river. Thus competition from exotic species poses a potential limit on the growth rate of this population. Substantial angling induced mortality of the adults while they roam the coast of Lake Superior waters between Huron Bay and Presque Isle, Marquette was also documented. Based on the growth and size-structure of the returning coasters, we estimate that under the current fishing regulations for Michigan waters of Lake Superior, approximately 86 % of the migrating coasters are of legal size and vulnerable to the recreational fishery and the majority of fish enter this size in the year of their first reproductive season. This mortality at the adult (lake dwelling) stage, coupled with potential biotic interactions with exotics at the juvenile stage may partially explain the low catches and the apparent decline of returning coasters into the river during this study.

Introduction

Over 70 species of fish were native to Lake Superior (Scott and Crossman 1973), and approximately four dozen species were common to the lake habitat in particular (Lawrie 1978). Of this latter sub-group, lake-dwelling brook trout (*Salvelinus fontinalis*) were one of two native salmonines (trout and salmon) and an important species that attracted countless anglers to the region (Roosevelt 1865). These fish were referred to as "coasters" due to the propensity of the adults to live in coastal waters of Lake Superior where they attained great size (Becker 1983). Brook trout are known to undergo migrations from coastal habitats into tributary rivers and streams for reproduction, feeding or refuge (Northcote 1997), a journey during which they are highly susceptible to anglers. Lake Superior historically supported coaster populations in possibly well over 100 tributaries (Newman et al. 1999) with at least 46 populations in U.S. rivers; however, by the late 1800s and early 1900s coaster populations were reduced to a few scattered remnants (Hansen 1994). Shiras (1921) noted that large numbers of coasters were taken by anglers from fall aggregations and that

> *"the trout [coasters] along the southern shore are approaching extinction, a tragedy assured by the improvident custom of catching the remnant [trout] at the mouths of spawning streams".*

By the early 1900's, the coaster brook trout fishery in Lake Superior had collapsed (Hansen 1994, also reviewed in Newman and Dubois 1996) and the great lake was in the midst of losing populations of this unique form of brook trout for which it had achieved earlier fame. Early observers of the lake and its fish were foreshadowing the potential fate of Lake Superior coasters around the mid 1800s with statements such as,

> *"the waters are somewhat fished out"* (Roosevelt 1865), in reference to tributary waters around Marquette.

Today viable coaster populations are known to exist on or around Isle Royale, in the Salmon Trout River, Marquette County, MI, and in several Canadian watersheds, with the most robust population(s) in the Nipigon River region of Ontario (Hansen 1994), also the site of the world record brook trout (14.5 pounds) caught in 1981 (Behnke 2002). Although overharvest played a major role, the loss of suitable spawning and rearing habitat in streams due to logging, and interactions with non-native salmonids likely added to the coaster decline in the Great Lakes. Faced with losing viable populations of coasters, an international team of Lake Superior basin management agencies and stake-holders was formed making the rehabilitation of coaster brook trout a priority (Newman et al. 1998). This team was composed of members of the Great Lakes Fishery Commission (GLFC), the Departments of Natural Resources in Michigan (MIDNR), Wisconsin, and Minnesota; the National Park Service, the Ontario Ministry of Natural Resources, the United States Fish and Wildlife Service, Tribal Agencies and others. Their efforts were guided by the development of fish community objectives for Lake Superior that set a goal of restoring depleted stocks of native fish species, including coaster brook trout (Busiahn 1990). The GLFC finalized "A Brook Trout Rehabilitation Plan for Lake Superior" (Newman et al. 1998) as an initial unifying step toward rehabilitation of coaster brook trout populations. The plan included the goal to "maintain widely distributed, self-sustaining populations in as many of the original, native habitats as practical" and identified approximately 118 streams and rivers that possibly hosted historic spawning runs of coasters. Rehabilitation and maintenance of populations required a thorough understanding of their needs and limitations.

The Salmon Trout River is the only river along the south shore of Lake Superior that continues to host a documented spawning population of coaster brook trout. Public access to the Salmon Trout population of coasters was limited due to their natal waters flowing through the private property of the Huron Mountain Club. Although coasters received extensive fishing pressure in the early days of the club, they were protected relative to other populations and this was likely part of the reason this population has persisted. Due to the early decline of coaster brook trout, information on their habitat needs, population structure and ecological dynamics is rare, which necessitates the need for scientific research on coaster brook trout and amplifies the value of the Salmon Trout River population for science, management and Lake Superior heritage.

In this study, we investigated the biology and ecology of coaster brook trout in the Salmon Trout River of Marquette County, MI. In particular, our objectives were to: 1) assess the current status of potamodromous (lacustrine-adfluvial) brook trout and the composition of the fish community in the Salmon Trout River, 2) gather information and gain insight into the ecology of coaster brook trout, 3) collect tissue samples for determination of brook trout genetic composition and structure in the river, 4) characterize juvenile salmonid composition and abundance and quantify habitat conditions at selected survey sites within the river, and 5) begin examination of the spawning site habitat selection by coaster brook trout. We used a combination of passive counting weirs deployed into the Salmon Trout River and active electrofishing surveys to sample the fish assemblage. Due to a lack of observed spawning sites in the river during this study, we were unable to address our final objective. Considering that the study and rehabilitation of coaster brook trout in Lake Superior is a stated goal of international, federal, state, tribal and nonprofit agencies and organizations, data on the basic biology and ecology of coaster brook trout in the Salmon Trout River will be of major importance both locally and regionally in the northern Great Lakes.

Salmon Trout River, Marquette County

The Salmon Trout River watershed is located in northwest Marquette County in the Upper Peninsula of Michigan. The Salmon Trout River drains approximately 12,690 hectares of mostly forested land. The headwaters of the Salmon Trout River lie in the Yellow Dog Plains about 10 land miles south of Lake Superior and about 245 m above the elevation of Lake Superior (Bullen 1986, Gough 2001). The upper reaches of the Salmon Trout River and its tributaries above the Lower Falls are relatively high gradient streams but the river gradient is much lower below the Lower Falls. The Lower Falls are a barrier to upstream fish migration and thus represent the upstream limit of coaster distribution. The Salmon Trout River from the Lower Falls to Lake Superior is approximately 12 km long, the gradient is low with a bed dominated by sand substrate, and a riparian corridor of mature hardwood and mixed conifer forest. Much of the lower Salmon Trout River watershed is privately owned by the Huron Mountain Club and public access to the lower river is limited.

Although the Salmon Trout River has received relative protection from public angling and therefore lighter fishing pressure than public waters, many fish were taken from the river in the early years of the Huron Mountain Club. For example, from 1938-1940 over 1,000 trout were taken per year (Smith 1942) although the composition of the catch is unknown (i.e. numbers of coasters, small brook trout (wild or hatchery), rainbow trout, etc.). The coaster spawning run was reported to be significant in the 1930s, but still greatly diminished from earlier highs (Smith

1942). Although quantitative data are lacking, the decline in coaster abundance in the Salmon Trout River likely continued through the 1980's while "rainbow trout (steelhead) have at least maintained and perhaps increased their abundance" (Bullen 1986)

Overview of Research Methods

The primary approach of this research program has been to install and monitor temporary fishing weirs using trap nets designed to sample up-stream and down-stream migrating fish throughout the late summer and fall migration. The traps were checked daily, and all fish were identified, measured and returned to the river in the direction of migration. Lengths and weights were recorded for all captured salmonids (e.g., brook trout and coho salmon, *Oncorhynchus kisutch*) as well as for most other collected fish. Scale samples for aging and fin samples for genetic analysis (and for marking of captured individuals) were collected from all brook trout.

Over the course of the three years of this project, we have found that maintaining the sampling weirs on a river as dynamic as the Salmon Trout River has proven to be a challenge, yet in general we have been successful. With each successive year, the study team worked to improve the design and operation of the traps. The structure of the weirs needed to be strong enough to withstand daily fluctuations in flow and the added stress associated with gathering leaves and debris, and at the same time weak enough that it would partially collapse during extreme discharge events. As of the 2002 field season, we achieved a reasonable balance between structural rigidity and designed failure of the structure. Meeting this balance, however, meant that there were days when the weirs were not functional or "fishing" during high discharge events or extreme debris flows. In addition to the weir improvements, the improvements made to the collection end of the traps (i.e., metal collection barrels or "cod ends" with hinged access ports) were by all appearances highly successful at reducing stress and discomfort of detained fish. These improvements also made the job of checking the traps during high water much easier and dramatically safer for the researchers. To compliment the trap-net surveys that were aimed at sampling the spawning adults, we also conducted electrofishing surveys in the upstream waters to characterize the abundance, composition and distribution of young-of-the-year (YOY) and older juvenile salmonids.

Summary of Research Activities

1. Weir surveys to sample migrating fish were conducted in 2000, 2001, and 2002

In July, 2000 we deployed a counting weir consisting of two trap nets at the site of the old lamprey weir to sample up- and down-stream migrating fish. Snow and ice on the river necessitated the removal of these traps on November 20. These traps effectively sampled the river for 90 of the 115 nights of operation during the season (Table 1). In 2001, a counting weir was again placed at the site of the old lamprey weir in July and an additional set was deployed downstream in August near the river mouth. The upstream weir was so rarely operational due to

Table 1. Start dates and end dates of the sampling season for the counting weirs deployed at each location on the Salmon Trout River during the 2000-2002 seasons. The status of the traps and the cumulative duration in days that each status condition occurred during the duration of the sampling season.

Year	Location	Start Date	End Date	Status	Status Duration (days)	Sampling Duration (days)
2000	Lamprey Weir Site	7/29	11/20	DOWN	25	115
2000	Lamprey Weir Site	7/29	11/20	SAMPLING	90	115
2001	Lamprey Weir Site	7/8	10/26	-	111	111
2001	River Mouth Site	8/26	11/25	DOWN	3	91
2001	River Mouth Site	8/26	11/25	SAMPLING	88	91
2002	Lamprey Weir Site	7/2	11/6	DOWN	36	128
2002	Lamprey Weir Site	7/2	11/6	SAMPLING	92	128
2002	River Mouth Site	8/17	10/30	DOWN	28	75
2002	River Mouth Site	8/17	10/30	SAMPLING	47	75

either erosional damage around and under the rigid structure or due to animals chewing large holes in the trap netting to the extent that the status of the weir was not recorded (Darren Kramer personal communication). A beaver dam downstream of the weir at the Lamprey Weir site also appeared to have partially blocked the upstream migration of fish in 2001 (Darren Kramer personal communication). The downstream nets were removed from the river November 25 and apparently sampled the river 88 of 91 days. Trap nets were deployed in July, 2002 at the lamprey weir and removed November 6 with 92 sampling nights during the 128 day span. Trap nets were deployed near the mouth in August 2002 and removed on October 30 due to heavy snows and high water levels. Sampling conditions were difficult during the 2002 field season due to frequent high water events and an exceptionally prolonged period of leaf drop from the deciduous trees in the watershed causing numerous collapses of the weirs. Scouring under and around the weir at the old lamprey weir site due to leaf build-up necessitated the removal of this weir in mid-October, several weeks earlier than it was dismantled in 2001. The weir at the river mouth experienced these problems as well and fished for 47 of the 75 nights of operation in 2002, which was nearly half that of the previous year.

2. Electrofishing surveys

In addition to the trap net surveys, we also conducted electrofishing surveys of the fish community of the Salmon Trout River in 2000, 2001 and 2002 with the goal of estimating abundances of salmonid YOY and older juveniles. For these surveys, a section of the stream at

least 100 m long was blocked with nets to limit the movement of fish into and out of the study reach. Within each reach we conducted multiple collection passes using the electrofishing equipment. After each pass fish were identified, measured, counted and then released outside the study area.

In 2000, one electrofishing survey was conducted in October below Murphy's Bridge. We completed three collection passes using a barge-mounted electrofisher along approximately 169 m of the stream and collected all observed fish. This sampling occurred later in the season than we would have preferred due to scheduling complications initiated by the departure of the graduate student originally on the project.

In 2001 and 2002 we again conducted depletion surveys within the Salmon Trout River, however we expanded the surveys to include seven sites. Study sites were named based on known landmarks or locations along the river (e.g., Below Christy Pool1 and 2, Gate House Bridge 1-3 down stream of the 550 bridge, and Murphy's Point Short and Long were below Murphy's Point Bridge. Murphy's Point Long was a longer site at the same location as Murphy's Point Short.

Summary of Research Results

1. The Salmon Trout River, Marquette County, is a biologically unique river along the south central shore of Lake Superior and supports a relatively intact assemblage of fish species.

The fish community of the Salmon Trout River is an interesting assemblage of at least 30 species that were identified in the counting weirs during the 2000-2002 research seasons (Table 2). This tally includes two species of bullhead (*Ameiurus sp.*) that were identified in different years by people checking the traps. We can not be sure of the identification of black bullheads (*A. melas)*, but we have a specimen of brown bullhead (*A. nebulosus*) in the reference collection for the Salmon Trout River, which confirms their presence. The Salmon Trout River is within the range of both the brook stickleback (*Culae inconstans*) and ninespine stickle-back (*Pungitius pungitius)*, but they were reported in different years and we can not verify their identification. We have also lumped slimy and mottled sculpins together because field identification to the species level of large numbers of individual sculpins was too time consuming. In our first year of research on the Salmon Trout River, we identified 18 species of fishes at the counting weir located at the site of the old lamprey weir. An additional 6 species were identified the following year, which was most likely the result of our deployment of the downstream weir near the mouth of the river. The weir near the mouth was more likely to collect species typically found in lacustrine low-flow habitat at the interface between the lake and the river. Among them were sticklebacks, logperch (*Percina caprodes*), spottail shiner (*Notropus hudsonius*), walleye (*Sander vitreum*) and yellow perch (*Perca flavescens*). In 2002 we captured one individual each of smallmouth bass *(Micropterus dolomieu*) and pink salmon *(Oncorhynchus gorbuscha*) along with many individuals of bluntnose minnow *(Pimephales notatus).*

During the three years of surveys we captured 5031 white sucker (*Catostomus commersonii*) in the weirs making them the most abundant fish captured in the weirs (Table 3). Longnose dace (*Rhynichthys cataractae*) were a close second with 4910 individuals. Brook trout (*Salvelinus fontinalis*) were the most abundant salmonid in our sampling. We identified at least 949 brook

trout in the weir samples, 630 of which were less than 300 mm (~12 inches) in total length (TL). We captured 588 coho salmon (*O. kisutch*), of which only 76 were less than 300 mm TL. In contrast, we captured only 205 rainbow trout (*Onchorynchus mykiss*) in the same surveys. In addition to the number of individuals of a given species or functional group in a system, the cumulative mass or biomass of that species is informative of the production of the ecosystem and its surrounding habitats. Although brook trout were the numerically dominant salmonid in the weir samples, coho salmon were the biomass dominants with ~560 kg of coho recorded. This was approximately 165% more mass than that of the brook trout (~212 kg) that was recorded. This difference reflects the relative size-structure of the "population" of each species and that more small individuals of brook trout were observed relative to the number of small coho salmon detected. Coho salmon juveniles generally migrate out to the lake as age 1 fish and then return to their natal stream to reproduce at age 3 or age 4 (Scott and Crossman 1973). Thus, in contrast to brook trout populations, which may be either migrants or stream residents in the Salmon Trout River, intermediate age and therefore size coho, would not abound in the river. The observed biomass of rainbow trout (~52 kg) reflects a similar pattern to coho and suggests that the population in the Salmon Trout River mostly displays the steelhead life history with adults developing in the lake system rather than in the river.

Evaluation of the current fish community of the Salmon Trout River is benefited by historical surveys of the river system that provide a species richness comparison over approximately 60 years. Of the approximately 30 species detected in our surveys, at least 19 of them were noted to be present in the river over 50 years ago by Lloyd Smith (1942). In his dissertation research, Smith reported 31 species of fish living in the Salmon Trout River. Thus, while the richness has remained, the composition has changed somewhat. Some of the discrepancies between current and previously reported species richness are likely due to differences in collection techniques and species lumping. For example, our passive weirs were not likely to capture the two native lampreys or johnny darters (*Etheostoma nigrum*) noted in Smith's surveys. However these species were also not detected in our electrofishing surveys. We also lumped the sculpins into one group while Smith noted three species of *Cottus sp.* In addition to four native species including walleye, rock bass (*Ambloplites rupestris)*, smallmouth bass (*Micropterus dolomieui)*, and black bullhead, we identified five exotic species from the Salmon Trout River that were not noted in the 1942 survey including: sea lamprey (*Petromyzon marinus)*, coho salmon (*Oncorhynchus kisutch)*, king (Chinook) salmon (*O. tschawytscha*), pink salmon (*O. gorbuscha*), and brown trout (*Salmo trutta*). These new species have likely altered the competitive and predative interactions in the Salmon Trout River. We did not capture blacknose shiners (*Notropis heterolepis*), mimic shiners (*Notropis volucellus*), troutperch (*Percopsis omiscomaycus*), lake herring (*Coregonus artedi*), lake chub (*Couesius plumbeus*), sturgeon sucker (most likely now referred to as longnose sucker, *Catostomus catostomus*) or finescale dace (*Phoxinus neogaeus*). Considering their overlap of rough characters, it is possible that finescale dace were mixed in with northern redbelly daces (*Phoxinus eos*) that we collected. These two species are also known to hybridize producing only females with characters intermediate between the two parent species (Page and Burr 1991). The lake chub could have been mistaken by the field crew as pearl dace (*Margariscus margarita*) because they are superficially similar.

Table 2. Species detected in the counting weirs deployed near the mouth of the Salmon Trout River (Lower) and near the Lamprey Weir site (Upper) in 2000-2002. The total number of individuals (bold) captured moving upstream (UP) and downstream (Down) and the cumulative biomass are shown for each year. The lower weirs near the river mouth were not deployed in 2000 (NA).

Species	SITE	Migration Direction	2000 Number	2000 Biomass (kg)	2001 Number	2001 Biomass (kg)	2002 Number	2002 Biomass (kg)
black bullhead (*Ameiurus melas)*	LOWER	UP	**NA**	NA	**8**	1.29	**0**	0
	UPPER	UP	**3**	0.29	**1**	0.05	**0**	0
bluegill (*Lepomis macrochirus)*	UPPER	UP	**0**	0	**0**	0	**1**	0.02
bluntnose minnow (*Pimephales notatus)*	LOWER	UP	**NA**	NA	**0**	0	**230**	0.26
		DOWN	**NA**	NA	**0**	0	**15**	0.03
brook- or ninespine stickle-back (*Culae inconstans, or Pungitius pungitius)*	LOWER	DOWN	**NA**	NA	**2**	-	**1**	-
brook trout (*Salvelinus fontinalis)*	LOWER	UP	**NA**	NA	**97**	59.55	**30**	18.66
		DOWN	**NA**	NA	**20**	1.50	**5**	0.11
	UPPER	UP	**282**	146.06	**25**	1.96	**338**	36.12
		DOWN	**15**	2.56	**87**	0.96	**14**	0.26
brown bullhead (*Ameiurus nebulosus)*	LOWER	UP	**NA**	NA	**0**	0	**35**	6.63
	UPPER	UP	**0**	0	**0**	0	**6**	1.02
brown trout (*Salmo trutta)*	LOWER	UP	**NA**	NA	**1**	2.09	**1**	3.35
		DOWN	**NA**	NA	**0**	0	**1**	0.05
burbot (*Lota lota)*	LOWER	UP	**NA**	NA	**57**	15.54	**35**	7.24
		DOWN	**NA**	NA	**96**	1.84	**43**	3.55
	UPPER	UP	**36**	3.56	**5**	0.17	**53**	2.53
		DOWN	**6**	0.25	**9**	0.04	**4**	0.01
coho salmon (*Oncorhynchus kisutch)*	LOWER	UP	**NA**	NA	**369**	388.03	**48**	60.41
		DOWN	**NA**	NA	**7**	3.80	**6**	10.03
	UPPER	UP	**123**	91.42	**3**	3.20	**28**	22.88
		DOWN	**2**	0.02	**1**	0.01	**0**	0
common shiner (*Luxilus cornutus)*	LOWER	UP	**NA**	NA	**341**	5.22	**1292**	7.76
		DOWN	**NA**	NA	**1035**	8.32	**198**	1.55
	UPPER	UP	**22**	0.37	**157**	0.74	**498**	2.59
		DOWN	**38**	0.38	**59**	0.30	**49**	0.34
creek chub (*Semiotilus atromaculatus)*	LOWER	UP	**NA**	NA	**1**	0.03	**1**	-
	UPPER	UP	**17**	0.36	**2**	0.03	**46**	1.12
		DOWN	**2**	0.09	**0**	0	**3**	0.08
emerald shiner (*Notropis atherinoides)*	LOWER	UP	**NA**	NA	**12**	0.02	**0**	0
		DOWN	**NA**	NA	**90**	0.08	**1**	-
	UPPER	UP	**1**	0.01	**0**	0	**0**	0
golden shiner (*Notemigonus crysoleucus)*	UPPER	UP	**1**	0.01	**0**	0	**0**	0
		DOWN	**0**	0	**1**	-	**0**	0
king salmon (chinook) (*O. tschawytscha)*	LOWER	UP	**NA**	NA	**2**	8.32	**0**	0
	UPPER	UP	**1**	-	**0**	0	**0**	0
lake trout (*Salvelinus namaycush)*	LOWER	UP	**NA**	NA	**0**	0	**1**	0.11
	UPPER	DOWN	**1**	0.17	**0**	0	**0**	0

Table 2, Continued

logperch (*Percina caprodes*)	LOWER	UP	**NA**	NA	**2**	0.02	**0**	0
		DOWN	**NA**	NA	**13**	0.14	**5**	0.05
longnose dace (*Rhinichthys cataractae*)	LOWER	UP	**NA**	NA	**14**	0.13	**33**	0.30
		DOWN	**NA**	NA	**2338**	17.26	**1223**	8.05
	UPPER	UP	**40**	0.40	**50**	0.30	**324**	2.89
		DOWN	**299**	2.58	**161**	1.12	**292**	2.46
northern pike (*Esox lucius*)	LOWER	UP	**NA**	NA	**2**	1.77	**1**	0.61
		DOWN	**NA**	NA	**5**	3.56	**2**	1.45
	UPPER	UP	**10**	1.47	**5**	0.26	**28**	3.48
		DOWN	**5**	0.30	**0**	0	**0**	0
northern redbelly dace (*Phoxinus eos*)	UPPER	UP	**0**	0	**4**	0.01	**15**	0.03
		DOWN	**0**	0	**9**	0.01	**0**	0
pacific lamprey (*Petromyzon marinus*)	LOWER	UP	**NA**	NA	**1**	0.10	**5**	0.71
		DOWN	**NA**	NA	**1**	0.19	**0**	0
	UPPER	UP	**4**	0.35	**6**	0.79	**60**	7.99
		DOWN	**1**	0.15	**11**	1.21	**4**	0.45
pink_salmon (*Oncorhynchus_gorbuscha*)	LOWER	-	**NA**	NA	**0**	0	**1**	-
pearl dace (*Margariscus margarita*)	LOWER	UP	**NA**	NA	**71**	0.85	**87**	0.23
		DOWN	**NA**	NA	**505**	5.35	**24**	0.09
	UPPER	UP	**51**	0.75	**35**	0.38	**326**	2.50
		DOWN	**9**	0.06	**29**	0.25	**14**	0.16
pumpkinseed (*Lepomis gibbosus*)	LOWER	UP	**NA**	NA	**1**	-	**1**	0.02
		DOWN	**NA**	NA	**1**	0.01	**0**	0
	UPPER	UP	**4**	0.07	**0**	0	**2**	0.02
		DOWN	**2**	0	**0**	0	**0**	0
rainbow trout (*Oncorhynchus mykiss*)	LOWER	UP	**NA**	NA	**23**	5.24	**2**	0.11
		DOWN	**NA**	0	**8**	0.59	**2**	0.07
	UPPER	UP	**80**	44.29	**4**	0.52	**30**	0.70
		DOWN	**4**	0.13	**47**	0.05	**5**	0.14
rock bass (*Ambloplites ruprestris*)	LOWER	UP	**NA**	NA	**8**	0.14	**3**	0.01
		DOWN	**NA**	NA	**5**	0.18	**3**	0.16
	UPPER	UP	**4**	0.06	**0**	0	**0**	0
		DOWN	**2**	0.02	**0**	0	**0**	0
smallmouth bass (*Micropterus dolomieui*)	LOWER	UP	**NA**	NA	**0**	0	**1**	0.01
sculpin (*Cottus sp.*)	LOWER	UP	**NA**	NA	**1**	0.01	**1**	-
		DOWN	**NA**	NA	**1**	0.01	**5**	0.02
	UPPER	UP	**9**	0.08	**3**	0.02	**25**	0.22
		DOWN	**4**	0.04	**11**	0.06	**7**	0.06
spottail shiner (*Notropis hudsonicus*)	LOWER	UP	**NA**	NA	**8**	0.04	**425**	1.20
		DOWN	**NA**	NA	**146**	0.29	**93**	0.59
	UPPER	UP	**0**	0	**2**	-	**0**	0
		DOWN	**0**	0	**3**	-	**0**	0
walleye (*Stizostedion vitreum*)	LOWER	UP	**NA**	NA	**22**	0.41	**5**	0.06
		DOWN	**NA**	NA	**12**	0.28	**5**	0.09
white sucker (*Catostomus commersonii*)	LOWER	UP	**NA**	NA	**1136**	46.79	**1453**	28.85
		DOWN	**NA**	NA	**1186**	43.92	**862**	29.90
	UPPER	UP	**57**	2.10	**28**	10.37	**219**	7.72
		DOWN	**9**	0.12	**2**	0.02	**12**	0.26
yellow perch (*Perca flavescense*)	LOWER	UP	**NA**	NA	**1**	0.04	**161**	0.56
		DOWN	**NA**	NA	**5**	0.11	**95**	0.48

Table 3. Total number and cumulative biomass of fish of each species captured in the counting weirs on the Salmon Trout River during the 2000-2002 research seasons. Species are listed in order of decreasing abundance.

Species	Number of Individuals	Cumulative Biomass (kg)
white sucker *(Catostomus commersoni)*	5031	171.477
longnose dace *(Rhinichthys cataractae)*	4910	36.567
common shiner *(Luxilus cornutus)*	3772	28.324
pearl dace *(Margariscus margarita)*	1151	10.625
brook trout *(Salvelinus fontinalis)*	951	211.698
spottail shiner *(Notropis hudsonius)*	677	2.125
coho *(Oncorhynchus kisutch)*	588	560.212
burbot *(Lota lota)*	346	34.762
yellow perch *(Perca flavescens)*	262	1.189
bluntnose minnow *(Pimephales notatus)*	245	0.288
rainbow trout *(Oncorhynchus mykiss)*	205	51.844
emerald shiner *(Notropis atherinoides)*	104	0.107
pacific lamprey *(Petromyzon marinus)*	93	11.943
creek chub *(Semotilus atromaculatus)*	72	1.711
unidentified sculpin *(Cottus sp.)*	67	0.509
northern pike *(Esox lucius)*	58	12.894
walleye *(Sander vitreum)*	44	0.842
brown bullhead *(Ameiurus nebulosus)*	41	7.651
northern redbelly dace *(Phoxinus eos)*	28	0.054
rock bass *(Ambloplites rupestris)*	25	0.579
logperch *(Percina caprodes)*	20	0.212
black bullhead *(Ameiurus melas)*	12	1.636
pumpkinseed *(Lepomis gibbosus)*	11	0.122
brown trout *(Salmo trutta)*	3	5.487
king salmon *(Oncorhynchus tschawytscha)*	3	8.320
brook Stickleback *(Culae inconstans)* or ninespine stickleback *(Pungitius pungitius)*	3	0.007
golden shiner *(Notemigonus crysoleucas)*	2	0.016
lake trout *(Salvelinus namaycush)*	2	0.280
bluegill *(Lepomis macrochirus)*	1	0.017
pink salmon *(Oncorhynchus gorbuscha)*	1	0.800
smallmouth bass *(Micropterus dolomieui)*	1	0.005

2. **Captures of brook trout in the Salmon Trout River suggest the spawning population of coasters is likely small. Captures of large brook trout have declined in recent years, resulting from either sampling inefficiencies or declines in the abundance of migrating fish.**

Throughout the three years of this study a small number of individual migrating and potentially spawning coasters (i.e., the animals of primary interest in this study) have been captured in the trap nets suggesting the remaining spawning population is small and likely in need of protection (Table 4). It must be recognized that the number of individuals we captured is a minimum estimate of the population size rather than an absolute estimate and that the actual population of coaster brook trout in the Salmon Trout River is larger than our number of captured individuals. The number of captures must be considered within the context that we were not able to sample all of the migrating fish due to occasional net failures. For example, the primary weir (river mouth site) was not operational during much of September or October in 2002 and we determined that it was sampling 47 days and nonfunctional for 28 days due to high water overtopping the nets or knocking over one or both of the weir wings. Adding to the likely underestimation of the abundance of migrating salmonids, these net failures occur during high discharge events when migrants are likely to move in greater frequency.

Table 4. Total number of individual brook trout captured in the trap nets in 2000, 2001 and 2002 and the number of those that were ≥300 mm (~12 in.) and ≥ 400 mm (~14 in.) total length (TL). Note that in 2000 only the trap nets at the lamprey weir site were deployed, whereas trap nets at both the lamprey weir site and the river mouth site were deployed in 2001 and 2002.

Year	Individuals Captured	Individuals ≥ 300 mm TL (recaps from previous years)	Individuals ≥ 400 mm TL (recaps from previous years)
2000	**299**	**161**	**101**
2001	**247**	**93 (18)**	**62 (15)**
2002	**403**	**65 (11)**	**36 (9)**

The fish that were captured each year were largely individuals that had not been captured previously in our study. For example, of the 62 brook trout ≥ 400 mm TL that were caught in 2001, only 15 of those fish were obviously captured previously in 2000. These fish would likely have been large enough in 2000 to make the migration suggesting that we simply did not detect their presence and therefore tag them. This supports the assertion that the Salmon Trout River hosts a larger breeding population than simply the number of individuals that were caught each year. However, the largest number of upmigrating large brook trout we observed in the Salmon Trout River was 161 individuals in 2000. This small number of captured brook trout is put into perspective when we consider it in the context of historical accounts of the catch of coasters from the Salmon Trout River. For example, Carl Hubbs wrote in 1929,

> "*these superb trout* [brook trout in the Salmon Trout River] *abounded in the nineties* [1890s], *when pioneer anglers often reported daily catches of one hundred to three hundred for a small party fishing in the river.*"

Thus, a single day's catch of coasters coming into the river from Lake Superior could have commonly removed upwards of twice the number of fish we captured with traps in an entire

spawning season. Although we can not quantify historic take of coasters from Lake Superior because early catch records did not distinguish brook trout from lake trout, there is little wonder why coaster populations diminished through out the basin.

As observed for brook trout, we also detected substantially fewer large coho salmon migrating up the Salmon Trout River in 2002 relative to 2001 (Table 5).

Table 5. Number of individual coho salmon captured in trap nets in 2000, 2001 and 2002 and those that were ≥300 mm total length. Note that in 2000 only the trap nets at the lamprey weir site were deployed, whereas trap nets at both the lamprey weir site and the river mouth site were deployed in 2001 and 2002.

	Individuals Captured	> 300 mm (12 in.)
2000	**127**	**73**
2001	**380**	**368**
2002	**82**	**71**

To compliment the direct comparisons of total numbers of fish captured each year, a more accurate way to track the yearly abundances of fish is to present the number of individuals in the catch relative to the amount of effort expended to capture the fish or rather catch-per-unit-effort (CPUE). In this case, our effort was reflected by the number of nights the weirs were recorded as being operational such that the wings were not down nor were there medium to large holes in the wing nets (Table 1). For example, the CPUE at the river mouth site for up-migrating brook trout that were at least 300 mm total length was 1.0 fish/trap-night in 2001 and 0.4 fish/trap-night in 2002 (Table 6). This decrease in CPUE may be within the natural yearly variation in run size for coaster brook trout or it may indicate a decrease in the abundance of spawning coaster brook trout over time in the Salmon Trout River. For comparison with brook trout CPUE, in 2001 CPUE for up-migrating coho salmon at least 300 mm in total length in the river mouth trap was 3.9 while in 2002 the estimated CPUE was approximately 0.7 fish/trap-night. Thus, the relative

Table 6. Catch-per-unit-effort (CPUE) of brook trout (BKT) and coho salmon (CO) in the counting weirs between 2000 and 2002. Trap 1 is the trap at the old lamprey weir site that samples upmigrating fish and trap 3 is the analogous trap at the river mouth site. Days are total sampling trap-nights. CPUE values shown are for totals, individuals ≤ 300 mm, ≥300 mm and ≥400 mm total length, respectively.

Year	Species	Trap	Trap-nights	CPUE Total	CPUE ≤ 300 mm	CPUE ≥300 mm	CPUE_ ≥400 mm
2000	BKT	1	89	2.9	1.2	1.7	1.0
2001	BKT	1	111	0.2	0.2	0.0	0.0
2002	BKT	1	92	3.7	3.3	0.4	0.2
2001	BKT	3	89	1.3	0.3	1.0	0.7
2002	BKT	3	47	0.6	0.2	0.4	0.3
2000	CO	1	90	1.3	0.5	0.7	0.7
2001	CO	1	111	0.0	0.0	0.0	0.0
2002	CO	1	92	0.2	0.1	0.2	0.1
2001	CO	3	89	4.0	0.1	3.9	3.6
2002	CO	3	47	0.8	0.1	0.7	0.7

CPUE of large, reproductive size brook trout and coho captured in the river mouth net suggest that the abundance of spawning coho salmon is likely 4-times or 2-times the abundance of spawning coasters based on data from 2001 and 2002, respectively. In addition, the CPUE of coho in 2002 decreased more sharply from the CPUE in 2001 (75% decrease), than did the CPUE for large up-migrating brook trout in 2002 decrease from that in 2001 (50% decrease).

3. **Length frequencies of brook trout captured in the Salmon Trout River represented a broad distribution of total lengths, and individuals embarking on the upstream migration were generally longer than 300 mm TL.**

A broad distribution of brook trout lengths was detected in upstream nets in 2000 (Fig. 1). Across the years of the study, the largest brook trout in the Salmon Trout River were just over 500 mm or approximately 20 " TL with most of the individuals being shorter, between 300 and 500 mm TL. An important question to answer with this research is how long brook trout are when they migrate up the river in the fall. The nets deployed at the lamprey site in 2001 were largely ineffective (Table 1) due to a downstream beaver dam (D. R. Kramer, personal communication) and persistent erosion holes under the nets that likely allowed fish to circumvent the traps. It is also possible that the perpendicular-to-water-flow design of that deployment was less effective at directing fish into the collection section. The nets deployed at the mouth sampled these lacustrin-adfluvial migrators, which displayed a peak in lengths beyond approximately 300 mm (~12 inches) total length although many shorter brook trout were also detected. Although fewer large brook trout were detected in 2002 (Table 2), substantially more small brook trout individuals were sampled in 2002 suggesting yearly variation or improvements in our net design.

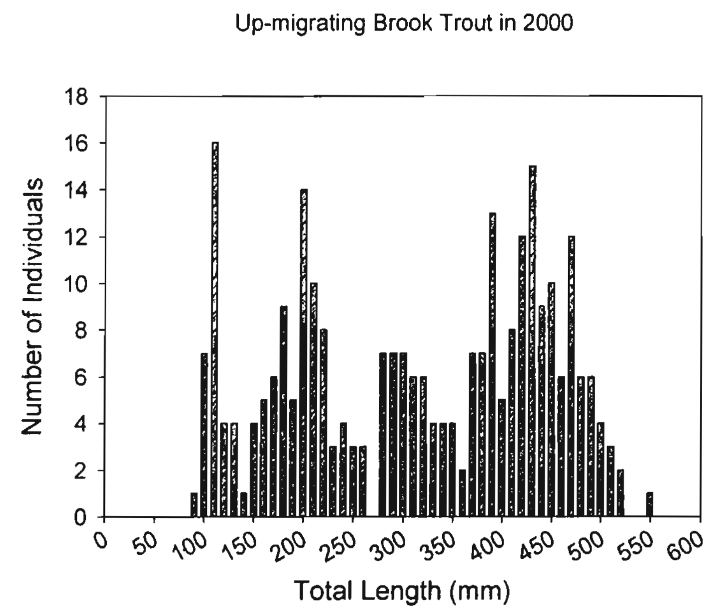


Figure 1. Length frequency of brook trout captured while migrating upstream at the old lamprey weir site in the Salmon Trout River in 2000.

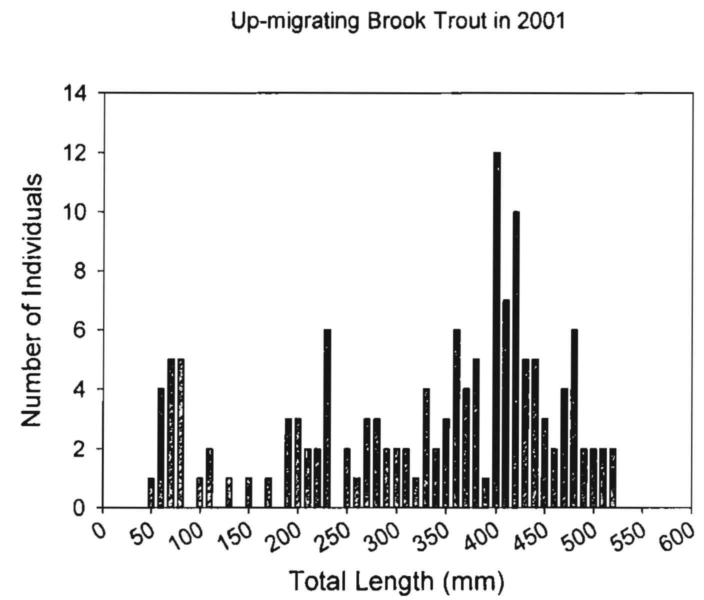
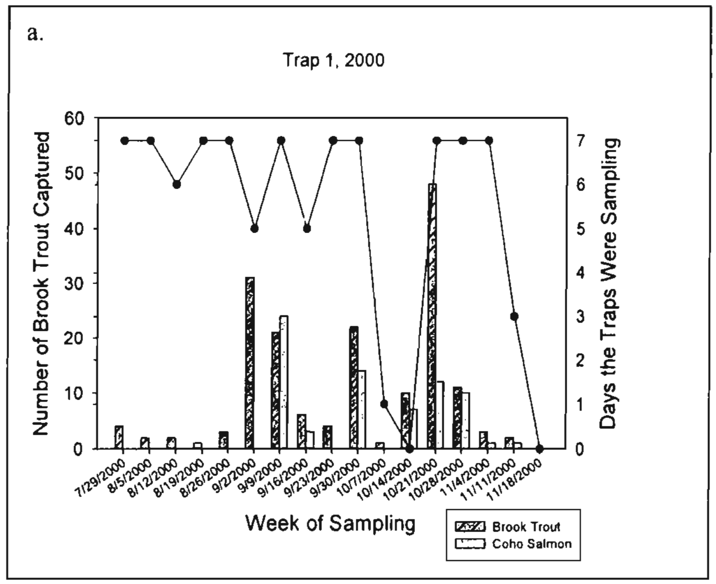


Figure 2. Combined length frequency of brook trout captured while migrating upstream in the Salmon Trout River in 2001. Except for approximately 6 individuals, all the fish longer than 300 mm TL were captured at the mouth site.

4. **Brook trout and coho salmon migrating up the Salmon Trout River peaked in abundance in September and October, although the actual number of fish captured each year was highly variable.**

Spawning migrations of large (≥ 300 mm TL) brook trout and coho salmon into the Salmon Trout River occurred during an extended period between the end of July and into October (Fig. 3). The temporal patterns in the catch of up-migrating salmonids showed a peak in fish capture, and therefore movement, in September and October. In 2002, the pattern was not as clear due to the low numbers of fish captured. However, brook trout captures at the mouth site were more common during these fall months (Fig. 3a). Many of the days when migrating fish were not captured in the fall were due to the traps not being operational. In order to visualize this effect, for example, we can see that the major decrease in fish captures during the week of 10/07/2000 corresponded to a period of the traps being recorded as operational for only 1 day that week. Note that although we recorded the traps as inoperable the following week we still captured fish, suggesting that even with the wings of the weir down, fish sometimes were trapped or maybe they were trapped before the wings went down. This issue will necessarily add to the noise in the capture data.



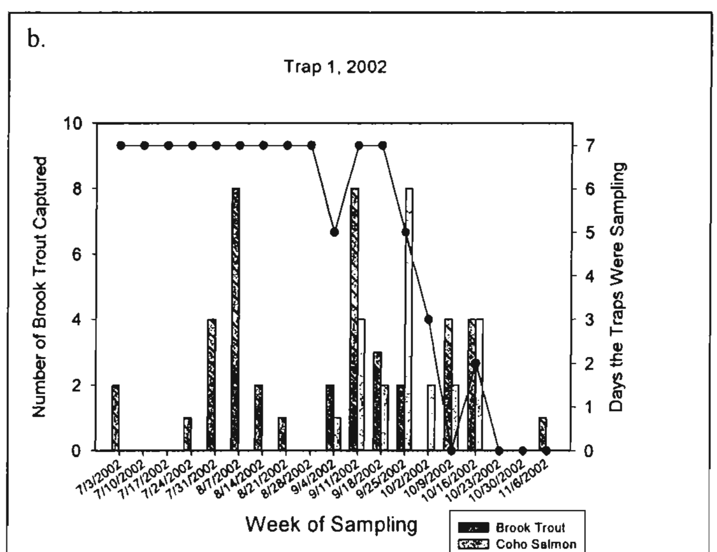


Figure 3. Number of brook trout (salmon bars) and coho salmon (grey) (≥ 300 mm TL) captured in trap 1 each week in 2000 (a) and 2002 (b) at the Lamprey Weir site. The dark circles represent the number of days in each week that the nets were effectively sampling.

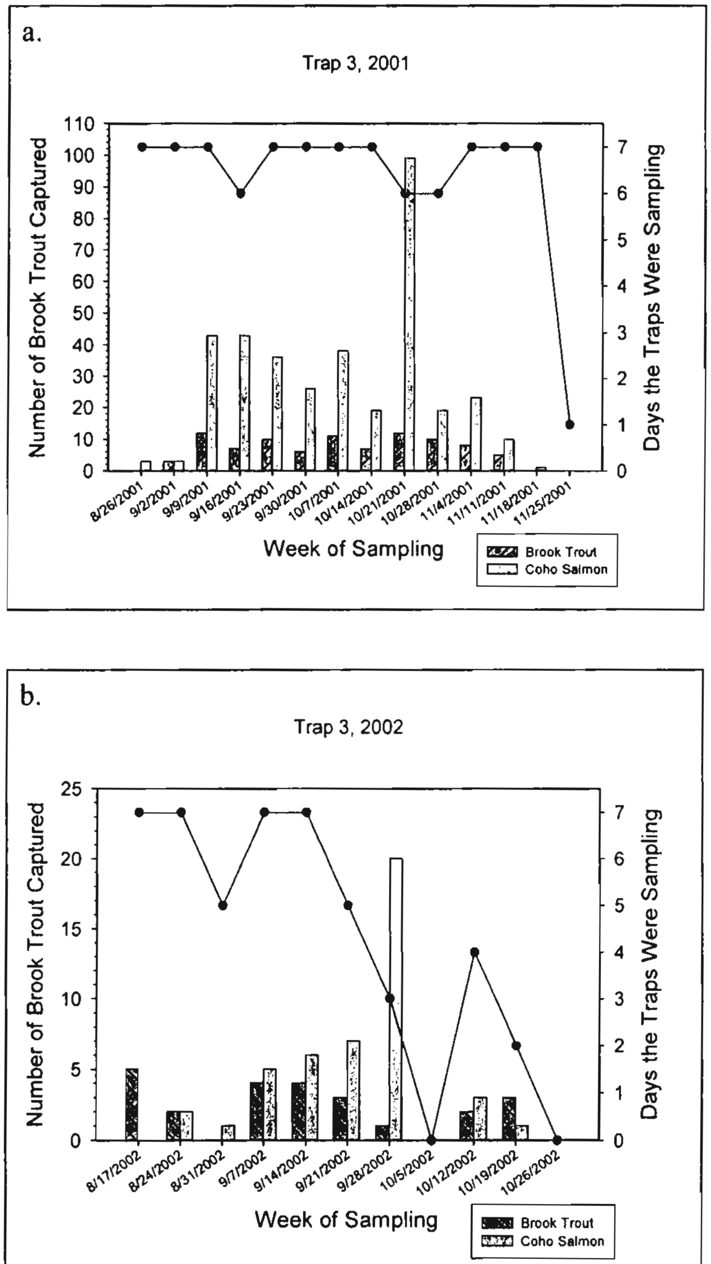


Figure 4. Number of brook trout (salmon bars) and coho salmon (grey) (≥ 300 mm TL) captured in trap 3 each week in 2000 (a) and 2002 (b) near the river mouth. The dark circles represent the number of days in each week that the nets were effectively sampling.

5. **Brook trout immigrating from Lake Superior into the Salmon Trout River appear to be generally at least three years old.**

Scale samples collected from 440 brook trout in the Salmon Trout River during the 2000-2002 field seasons were aged by counting the annuli on each scale (Fig. 5) and digitized to estimate the growth of the individual fish during each year. For this back-calculation technique we need to estimate the length at which brook trout first begin to grow scales. This value was estimated to be 35.2 mm based on it being the intercept of the regression of total length as a function of scale radius. This intercept value is close to the value of 28 mm proposed by Carlander (1969). In general, brook trout in the Salmon Trout River grow up to and in some cases, beyond 300 mm TL (~12") during their third year of life (i.e., age 2 fish) (Fig. 5). Considering that most brook trout immigrating from Lake Superior were over 300 mm TL, we can assume that most brook trout engaging in the upstream spawning run were at least in their third year of life.

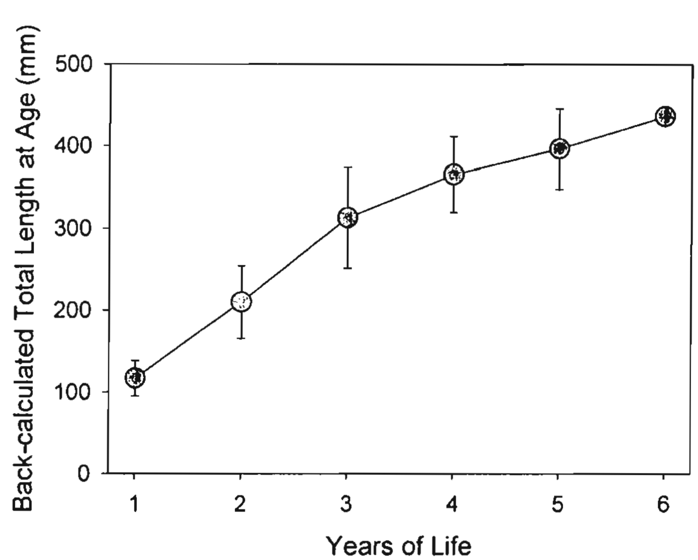


Figure 5. Total length of brook trout from the Salmon Trout River at the end of each year of life estimated by back-calculation from scale samples collected from 405 fish that were at least age 1. Error bars represent one standard deviation.

6. **The body condition of brook trout in the Salmon Trout River estimated as relative weights (Wr) suggests a high level performance and condition of individual fish. However, within the "population" the larger fish (TL ≥ 300 mm) may have reduced condition.**

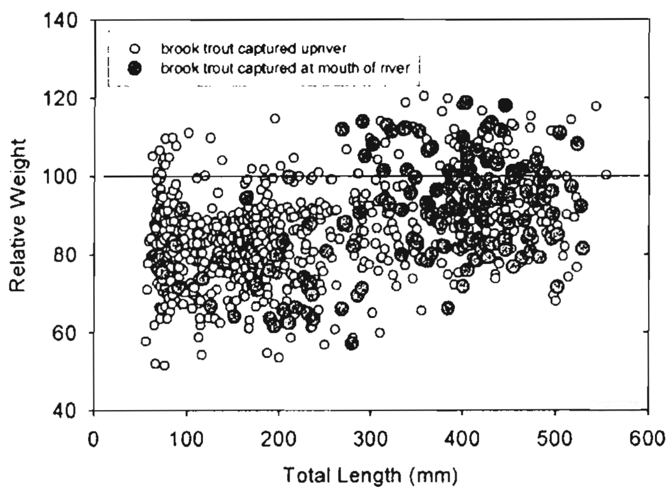


Figure 6. Relative weights (Wr) of 984 brook trout sampled from the Salmon Trout River, Marquette County in 2000-2002. Of these, 153 individuals were collected in the mouth weir as they migrated into the river from Lake Superior. (salmon color circles). The remainder of the brook trout were captured either outmigrating from the river or in the upstream weir at the lamprey wier site. The line of reference at Wr=100 suggests the relative weight of a typical brook trout proposed by Hyatt and Hubert (2001).

Brook trout relative weights (Wr) were predominantly below 100 (Figure 6) suggesting that overall, they were generally in poorer condition than an idealized brook trout. Smith (1942) suggested that the Salmon Trout River had low productivity and Lake Superior is known to be an unproductive lake. The relatively low productivity of the river and lake may explain the low Wr values for the Salmon Trout coaster brook trout. Wr appeared to increase with increasing fish length. In general, brook trout ≥ 300 mm TL tended to be of higher overall condition. We would expect that larger individuals would display greater condition prior to spawning because of the presence of maturing gonads. The small brook trout ≤ 300 mm that were captured as they immigrated into the river were in poorer condition than their riverine counterparts. As noted above, the Salmon Trout River is a relatively unproductive river. However, the productivity of the lower river may be higher than nearby Lake Superior waters and may explain the higher condition of river resident fish.

7. **Electrofishing surveys revealed that the juvenile salmonids in the Salmon Trout River were numerically dominated by introduced rainbow trout and coho salmon, but the composition varied across study reaches.**

Juvenile salmonids in multiple study reaches in the Salmon Trout River were generally dominated numerically by exotic species such as rainbow trout and coho salmon. The percent of brook trout in the samples across the seven study reaches and the two years ranged from a low 18.6% at Murphy's Point in 2000 to a high of 65% at the most upstream site below the gate house bridge in 2001. Overall, across all sites and years, the mean percent brook trout in the salmonid assemblage was 39.8 ± 5.6%. Rainbow trout were the overall numerically dominant salmonid accounting for 47.9 ± 4.7% along with 12.2 ± 4.3 % coho salmon. This dominance by rainbow trout juveniles was also noted to exist approximately 20 years prior to our surveys (Diana 1983). Our general impression of the fish community of the Salmon Trout River is that the abundance of juvenile salmonids is rather low. This may simply be a characteristic of this system, possibly reflecting low productivity overall, as the paucity brook trout in particular was noted by Enk (1977), "The sparseness of the brook trout population below the Lower Falls is immediately apparent".

Although we detected few brook trout juveniles in the river in general, the study sites below the 550 bridge (Below Gate House) were numerically dominated by brook trout, whereas the sites at Murphy's Point and Christy Pool were numerically dominated by rainbow trout (Fig. 7). Thus, the composition of the juvenile salmonids varied between the study reaches and the relative abundance of brook trout decreased upstream (Fig. 8).

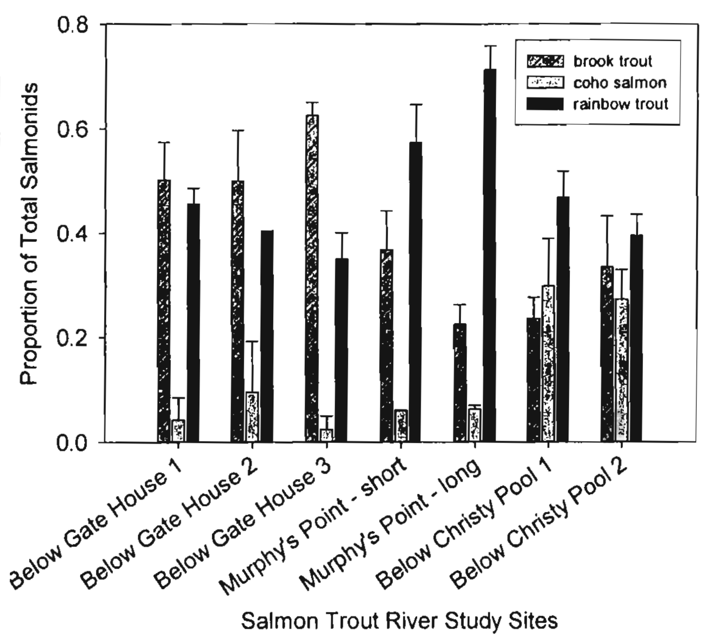


Figure 7. Proportions of the total salmonid catch that are composed of brook trout (salmon bars), coho salmon (silver bars) or rainbow trout (blue bars) during electrofishing surveys of the seven study sites on the Salmon Trout River. Values represent means (± 1 SE) for each site and species over two years of surveys in 2001-2002. Sites were 100 m long except for Murphy's Point Long, which was ~169 m long.

Coho salmon juveniles were not numerically dominant at any of the sites although they were more abundant further upstream just below Christy Pool. At the Christy Pool sites rainbow trout and coho salmon together comprised approximately 80% of the salmonid young of the year (YOY) assemblage and approximately 72% of all the salmonids. At the Murphy's sites, in both 2000 and 2001, rainbow trout comprised 70% of the YOY. Enk (1977) noted that below the lower falls of

the Salmon Trout River, the resident salmonid community was composed primarily of brook trout and "a few rainbow trout". Our study sites were largely below those surveyed by Enk (1977), and our Christy Pool sites were the only sites that were within his study area. However, the comparison of results suggests that the fish community has shifted over the past 20-25 to be numerically dominated by exotic salmonids. Abundances of salmonids other than brook trout were not reported in Enk (1977) so quantitative comparisons of species compositions can not be made.

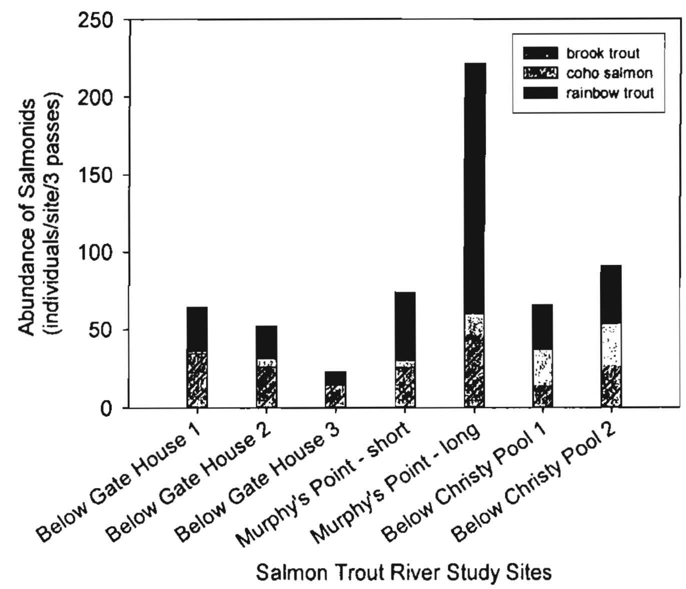


Figure 8. Mean abundances of brook trout (salmon bars), coho salmon (silver bars) and rainbow trout (blue bars) that were collected during three passes of electrofishing surveys of the seven study sites on the Salmon Trout River over two years of surveys in 2001-2002. The study reaches are ordered from the down stream sites below the Gate House to the up stream Christy Pool reach.

We captured relatively few rainbow trout in the counting weir surveys relative to their dominance in the electrofishing surveys. This suggests that brook trout are either more likely to be captured in our passive weirs possibly because they move more within the river, or they are more abundant in the lower reaches of the river below our electrofishing sites. We also captured very few large rainbow trout suggesting that they are largely displaying the potamodromous life history (i.e., they are steelhead rather than stream resident rainbow).

8. The majority of the reproductive Salmon Trout River coaster brook trout are vulnerable to angling in Lake Superior. Reporting of brook trout tagged in the Salmon Trout River that were caught by anglers suggests high mortality of coaster brook trout.

The current fishing regulations for brook trout in Michigan waters of Lake Superior allow a daily catch of three fish of at least 10 inches in total length (http://www.michigan.gov/documents/16360_fishing_87588_7.pdf). This minimum length limit would protect only approximately 14% of all the brook trout that we captured as they migrated into the Salmon Trout River from Lake Superior during the survey seasons of 2001 and 2002 (Fig. 10). During the field seasons of 2000-2001, a small effort was undertaken to begin to track individual brook trout that were captured in the Salmon Trout River. For example, when individual fish were captured moving in a down-stream direction after previously being sampled in up-stream traps, a floy-tag was inserted into the fish bearing a unique code. In total, 33 brook trout were floy-tagged over the two year period. Their mean (± 1 SD) total length and mass were 397.5 ± 72 mm and 805.8 ± 412.3 g, respectively. Of these tagged fish, four were later reported as being taken from the lake the following calendar year by either anglers (three fish) or netting operations (one fish). The latter was returned to us by a commercial fishing company that reported it purchased the fish from a tribal operation that captured the fish in August, 2002. The three fish angled from Lake Superior were taken in February, 2001 from Huron Bay; in April, 2002 along the Big Bay breakwall; and in June, 2002 near Presque Isle. The fish were between 414 and 446 mm total length at the time of tagging indicating they were in their fourth year of life or older so they were of reproductive age (Fig. 11) and likely spawned at least once prior to their capture. Based on these floy tag returns, the mortality of Salmon Trout River coasters in Lake Superior due to fisheries is approximately 12.1 % overall with 9.1% mortality due to recreational fisheries. This estimate does not account for other potential sources of reporting error such as captured fish not being reported, tag loss or natural mortality, which would increase the estimate of mortality due to anglers. If a tag loss rate of 20% (Ebener and Copes 1982, Muoneke 1992) and a non-reporting rate of 70% (Matlock 1981, Green et al. 1983) are assumed then estimated exploitation of Salmon Trout River coasters was at least 19.3 %. Following the availability of 2 mm soft-VI Alpha tags, we marked individual fish with this technique and two of these

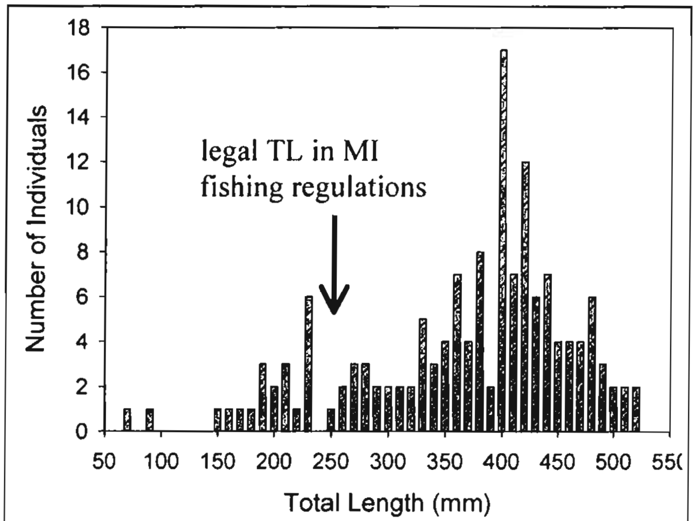


Figure 10. Length frequency of the brook trout captured in the counting weir while they were migrating into the Salmon Trout River from Lake Superior during the 2001-2002 research seasons. The arrow identifies the 10" (~254 mm) minimum length of brook trout that could be legally caught in Michigan waters of Lake Superior.

marked fish were taken by anglers. One was reported angled in February, 2002 near the Big Bay Marina breakwall and the other was taken in May, 2003 near the Little Huron River. Two additional coasters were reportedly taken off the Huron River in February 2004 (George Madison, personal communication) and these fish were potentially of Salmon Trout River origin.

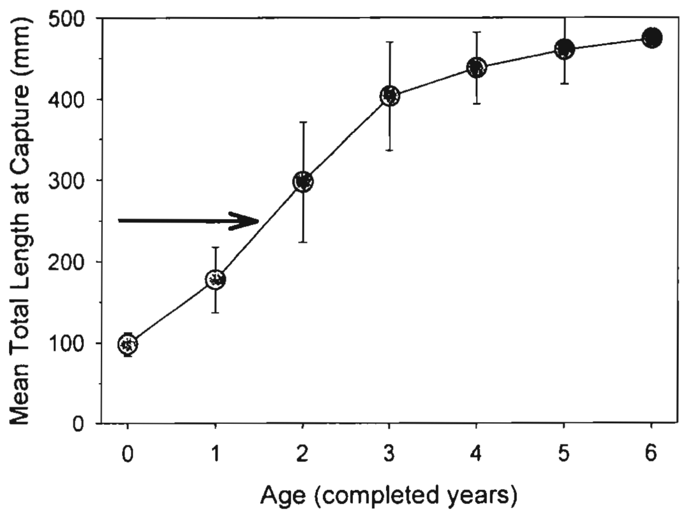


Figure 11. Mean total length (mm) of various ages 438 brook trout when they were captured in the Salmon Trout River. Age estimates are based on reading scale samples. Error bars are 1 standard deviation from the mean. The arrow highlights the length and age at which brook trout are vulnerable to angling under the current Lake Superior fishing regulations for Michigan.

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Year-End Report to the Huron Mountain Wildlife Foundation for research conducted toward the proposal entitled, "*Long term research on Salmon Trout River coasters: coho competition PhaseII*"

July 12, 2004

by

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1. Summary of Actions and Accomplishments During This Period

A. Project goals and objectives as set forth in the grant contract.

This year end report addresses our objectives, accomplishments and problems encountered during year one of Phase II of our research on the Salmon Trout River, Marquette County, MI. Our goals were to 1) continue our investigations of the ecology of coasters and the fish community of the river 2) initiate our experimental removal of coho salmon adults for the purposes of exploring its effects on brook trout and 3) conduct an experiment to assess competition between introduced juvenile coho salmon and brook trout. We also proposed to continue our research on the genetic structure of brook trout in the Salmon Trout River, but this aspect of the project is funded through other sources.

B. Summary of Accomplishments and Results in Year 1.

The following is a summary of our research accomplishments in 2003 in chronological order. Research on this project was directed by Casey Huckins and Ed Baker and primarily implemented by Joshua Blankenheim who is conducting research on this project in partial fulfillment of the requirements for his Master's Degree. Justin Hanisch, a Biological Sciences major from MTU, served as an intern research assistant with us throughout much of the early summer. Terri Grout served as the primary field assistant for the year.

Juvenile Competition Experiment:

Our research actions toward this project in 2003 began in June as we prepared to conduct an experiment on competition between young of the year brook trout and coho salmon in the Salmon Trout River. The primary objective was to examine the presence and relative strength of intra- and interspecific competition influencing the brook trout juvenile assemblage of the Salmon Trout River. Although the experiment was not able to be completed due to several limiting factors, it was designed to compliment the yearly surveys of juvenile salmonids as well as the scheduled removal of adult coho salmon. Initially Justin and I repaired nets, selected the

site and installed the netting to create nine enclosures (Fig. 1). Josh assisted with the final labor intensive task of installing sandbags around the perimeter of each enclosure to attempt to block exit by the experimental fish. Each enclosure was 1.5 meters by 1.5 meters and the experiment was a target-neighbor design (Table 1).

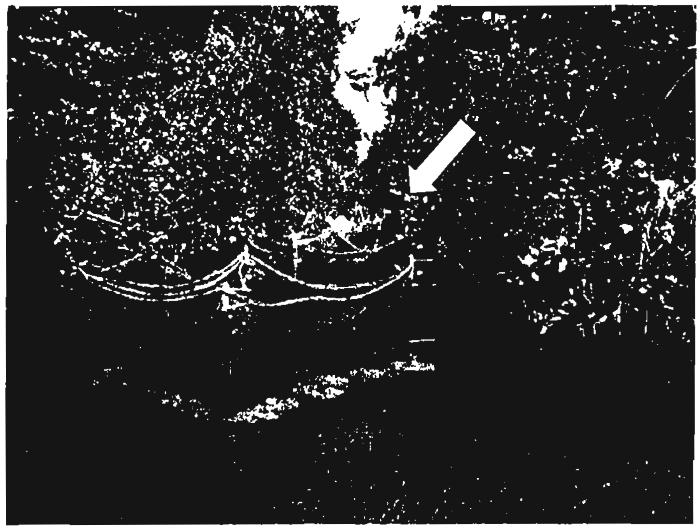

Figure 1. Experimental enclosures deployed below the Gate House Bridge on the Salmon Trout River in 2003. For scale, Justin is visible standing beside a distant enclosure shown by the arrow.

Table 1. Experimental design with two densities and three replicates of each treatment. Targets are juvenile brook trout at slightly higher than ambient densities (N) in the river (N = 3 individuals in each enclosure).

	Fish Abundance		**total**
Treatment	**brook trout**	**coho salmon**	**all species**
1) target only	N	0	N
2) target + brook trout	2N	0	2N
3) target + coho	N	N	2N

Several brook trout were captured with electrofishing gear and placed into the enclosures on the 26th of June to test the design of the experiment. However, on July 7th the enclosures were checked with electrofishing gear and the fish had escaped and were no longer in the enclosures. It appeared as though the mesh had stretched slightly, allowing the small fish to wiggle through. Subsequent attempts to initiate the experiment were stifled by rainfall and extreme high water events that raised the water level above the top of the enclosures, allowing the fish another way to escape (Fig. 2). Thereafter, shocker failures and low numbers of observed fish irrecoverably hindered our continued attempts at conducting the experiment within time constraints.

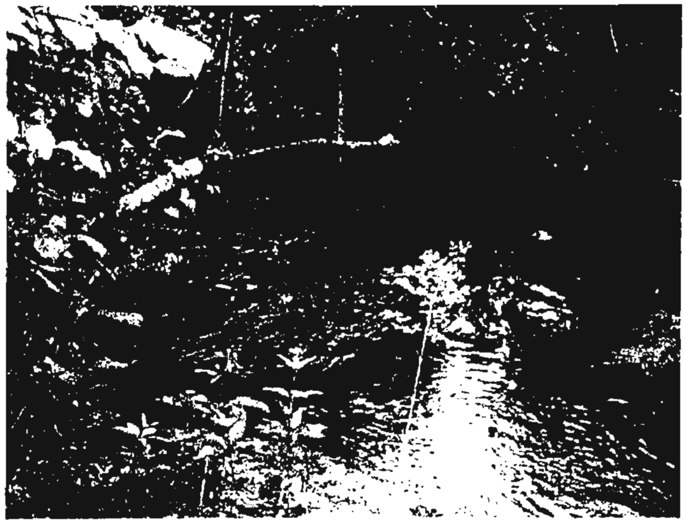
Figure 2. Experimental enclosures on July 21, 2003 during an extreme high water event on the Salmon Trout River. Note the faint hint of the yellow rope underwater along the top of the enclosure near the middle of the image.

Coaster Assessment and Coho Salmon Removal: counting weirs

In order to assess daily and seasonal trends in water temperature and how they relate to fish movement, we redeployed temperature loggers in the Salmon Trout River between July 8th and 11th. The loggers were placed at each of the six electrofishing sites plus one logger at the lamprey weir site, one logger at the mouth and one logger near the gatehouse bridge. The temp loggers were removed between October 31st and November 6th. The temp logger at the gatehouse was left in place over winter.

Our continued assessment of Salmon Trout River coasters and fish communities in 2003 began with our deployment of the counting weir at the site of the old lamprey weir on July 24. As we had done in 2002, we built the counting weir using a modified trap net with fish-directing wings made of netting. One modification we attempted in this year was implemented to reduce damage by animals chewing holes in the nets, which has hindered us every year that we have conducted research on the Salmon Trout River. In order to attempt to reduce this damage along the waterline we attached chicken fencing to the netting so that it extended approximately 1 foot above and below the waterline on each side. Unfortunately this modification only transferred the damage to lower areas on the nets under water making the daily repairs even more difficult so the wire was removed.

On August 19, we completed the deployment of the counting weir near the mouth of the river. We thankfully had the assistance of a number of club members during this construction and the extra hands and ideas were greatly appreciated. The river is relatively wide at the mouth,

and over 100 sandbags had to be placed across the river to hold the wings in place. The efforts of the volunteers saved us hours of hard work.

The data collection procedure was basically the same as before. Every fish of all species was measured to the nearest millimeter and weighed to the tenth of a gram. Scale samples were taken from all salmonids greater than 80 mm for aging, and the adipose fin of brook trout were clipped and saved for genetic analysis. Brook trout 250 mm or greater received a unique identification tag (2.5mm VI soft alpha tag). The fluorescent tag was inserted underneath the skin behind the eye so that it was visible in the event that it was captured later.

In this first year of the second phase of our research, we instituted major change to the trapping protocol this year, which included the planned removal of all captured adult coho salmon. The coho removal, which was approved by the Michigan DNR (MIDNR) and the Huron Mountain Club, was instituted to assess possible inhibition of brook trout success through interactions with coho salmon. The removed coho salmon were going to be donated to Little Brothers Friends of the Elderly, an organization that helps people in the Keweenaw area although not enough carcasses were collected to do so.

In the summer of 2003, captures of large salmonids were noticeably low (Fig. 3, 4) relative to past years. As summer turned to fall, catches of large brook trout did not increase as

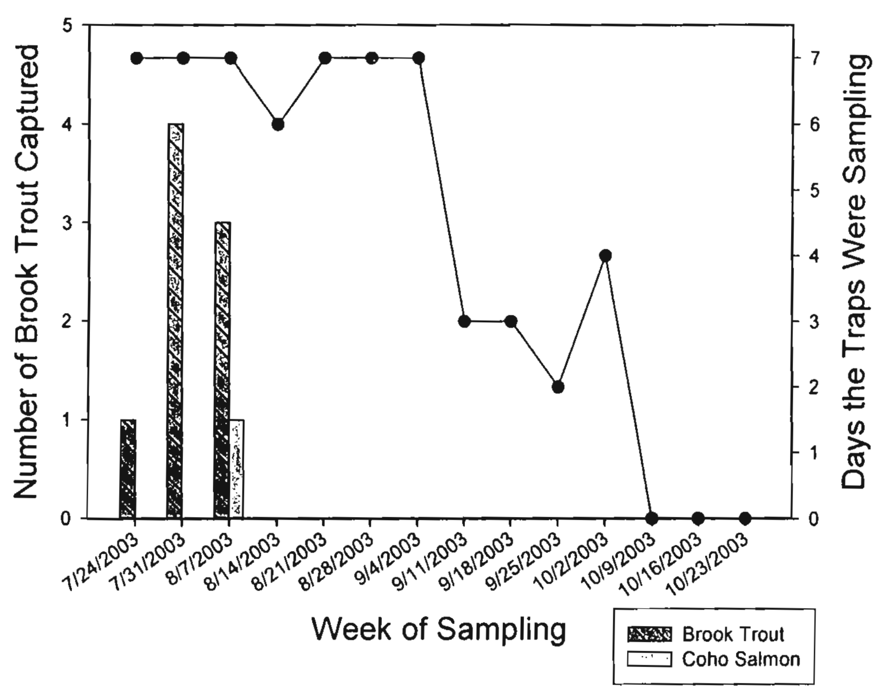

Figure 3. Weekly captures of large (≥ 300 mm total length) brook trout (salmon colored bars with hash marks) and coho salmon (grey bars) in the upstream net located at the old lamprey weir site on the Salmon Trout River in 2003. The solid line represents the number of days per week the weir was determined to be working properly and without major holes.

we had expected. For clarification of these low catches, we checked with local anglers and MIDNR fisheries researchers to see assess the catches they were observing. All local anglers we approached reported lower than normal catches of coastal and adfluvial trout and salmon. MiDNR officials reported a similar view of low to nonexistent fall runs of salmonids in local

waters (personal observation, Ed Baker MIDNR). The suspected reason for the low catches we received from all parties was that the late summer and fall had been relatively warm so the fish were less likely to move. Our impression of the river conditions during the late summer and fall of 2003 matched these suggestions that the water temperatures were warm. However, monthly mean water temperatures gathered from submerged temperature loggers at the lamprey weir site suggest monthly temperatures were in line with mean temperatures in previous years (Fig. 5). The late summer and fall did appear to be relatively calm with fewer climatic events that would be expected to trigger migrations of fall spawning salmonids (personal observations).

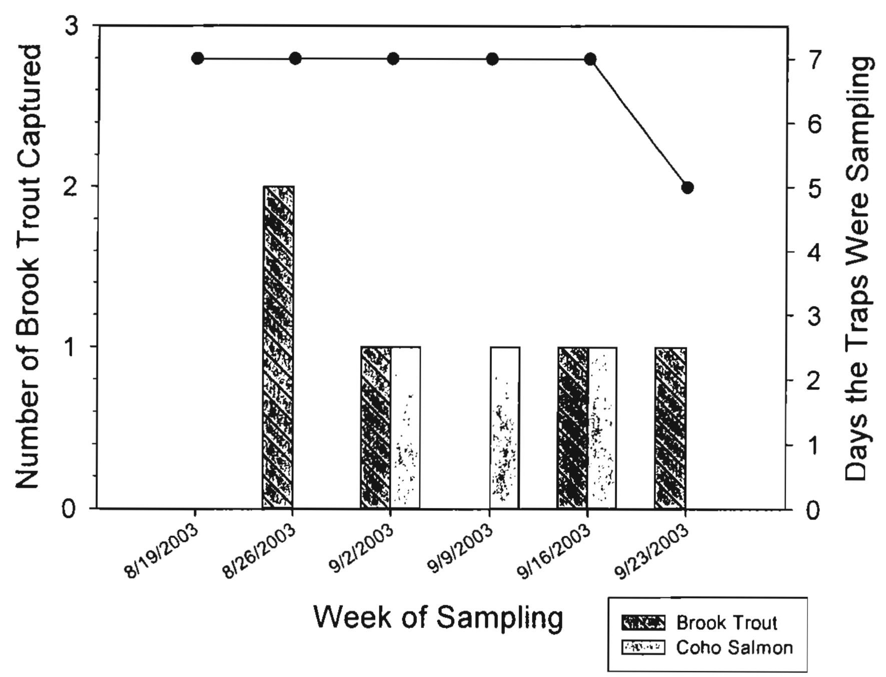

Figure 4. Weekly captures of large (≥ 300 mm total length) brook trout (salmon colored bars with hash marks) and coho salmon (grey bars) in the downstream net located at the river mouth weir site on the Salmon Trout River in 2003. The solid line represents the number of days each week the weir was determined to be working properly.

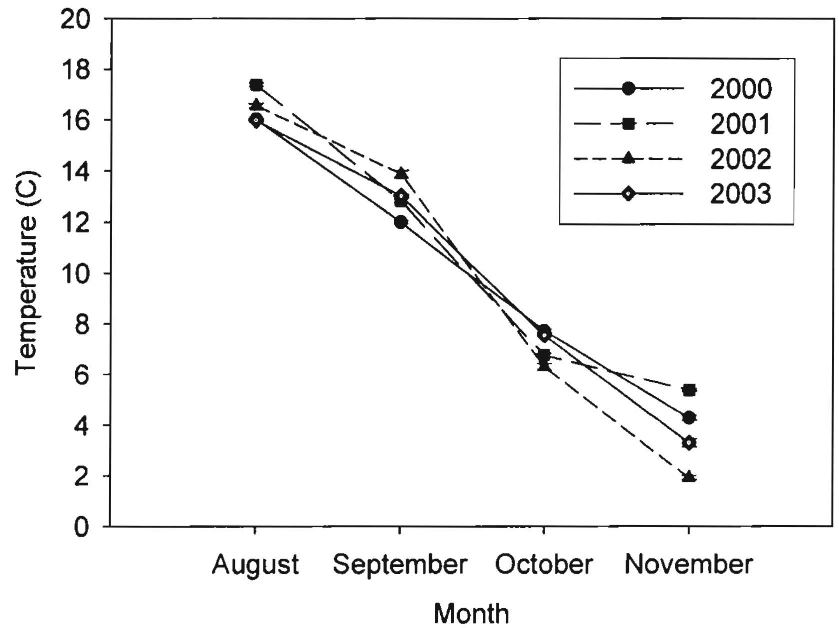

Figure 5. Mean monthly water temperatures of the Salmon Trout River, Marquette, Co. in 2000-2003. Data was collected from loggers recording temperatures every half hour near the old lamprey weir site. Error bars are one standard error.

In early September, Josh observed three river otters swimming in the region of the river mouth weir. This discovery prompted the immediate construction of a cover of bars for the traps to deter otters from swimming into the traps. The subsequent week he noticed large scales (presumably from white suckers) and the heads of burbot and suckers nearby log indicating they had been eaten by some animal. While we have no evidence that the otters were getting the fish from the traps, these observations lead to our conservative decision to dismantle the traps at the river mouth on September 28th. The mouth weir was operational for only 40 days. The counting weir at the lamprey weir site was left deployed.

On the night of October 10th we added an underwater video camera to our setup at the lamprey weir. The purpose of this was twofold: to study the diel patterns of fish movement and to identify if predators were swimming into the traps. The video camera was placed at the entrance to the upstream trap and was hooked up to a VCR on shore so that nighttime footage could be recorded. The video camera was powered by a small Honda gasoline generator and was operated several nights a week until mid November. We had difficulties getting good footage with the camera due to turbidity and particles in the river reflecting and absorbing our camera lights severely limiting the images we could capture. Images captured in the daylight were clear and covered a large area. However, the camera's lighting system casts a rather narrow but bright beam of light that illuminated an area of approximately 10" in diameter.

Although limited, the video footage was consistent with the trapping results. It revealed few fish of any species moving upstream. On one night two large brook trout were seen

swimming up to the trap entrance, but neither entered. One seemed spooked by something and the other simply turned away and went out of view. The trapping was discontinued on October 28th, and the camera was pulled on November 20th although relatively few nights of filming were fully successful. By this time the water was consistently high and often times unworkable.

The lack of large brook trout was both a disappointment and a concern. The general trend over the past few years has been fewer and fewer large brook trout. Only 84 brook trout were captured for the season, and only 24 were of tagging size. Additionally, no adults were observed returning from previous years. There seemed to be a lack of a coho salmon run as well this year. Only four adult coho were captured for the entire season, down considerably from 2002. The low catches were likely related to the observed larger scale lack of fall spawning migrations of salmonids in the region. They could also in part be due to problems with the weirs being damaged or made inoperative by the actions of large mammals such as beaver chewing on the nets. Although the lamprey weir was deployed for 97 days throughout the summer and fall, the weir was found to have hole caused by chewing animals on 24 days, 10 days of which included large holes most likely caused by beaver and muskrat. This problem was verified as a concern when Josh spooked a large brook trout from below the lower steps at the lamprey weir into the near wing. He worked his way along the wing to force the fish into the trap, but did not locate the fish. He exited the stream, and when he stepped on the upper steps the fish darted out from underneath them. When Josh investigated the wing he found an 18 inch diameter hole through which the fish most likely easily navigated.

We also struggled in our attempt to keep the trap operational during water fluctuations while also having planned failure during extreme high water events. Without the planned failure in the design, severe damage to the weirs results requiring much downtime and effort to rebuild the structure. In 2003, one or both wings were fully or partially knocked down by high water or the leaf-off period (it began about October 10th and lasted several weeks) on 27 days. Scouring along the bottom of the nets also occurred due to the deep sand in the Salmon Trout River and occasionally the wing would not be secure at the bottom. Clearly animal damage to the wings and high water/scouring was a problem and could limit our ability to fully interdict migrating coho salmon.

Electrofishing Surveys of Juvenile Salmonids

The other major focus of our research on the Salmon Trout River was the electrofishing surveys of juvenile salmonids. The purpose of our electrofishing surveys was primarily to study juvenile salmonid abundance, composition and distribution. We used the 3-pass depletion approach for collecting data for abundance estimates on all six study reaches on the river (three sites below the Gate House Bridge, one site at Murphy's Point and two sites near Christy Pool) starting August 14, 2003. Ed Baker's crew was instrumental in providing people and additional equipment for this work. Ideally we wanted to complete all sites in the summer, but because of equipment problems, weather, and juggling equipment between the Salmon Trout project, MiDNR projects and the Keweenaw project we shocked the last site on the Salmon Trout October 10th. The sites surveyed in October include Murphy's Point, Below Christy's Pool 2, and Below Gate House 3. Overall the patterns of abundance were largely consistent with the results of surveys in previous years except for generally lower abundance of rainbow trout juveniles and more coho salmon juveniles in the Christy Pool sites (Fig. 6). On October 22nd Josh and Mike Fawcett from the MiDNR were able to gather additional tissue samples from brook trout above the lower falls as well. The data were collected above the falls because it is deemed impassable to downstream fish and would provide an interesting comparison for our ongoing genetic analyses.

We will repeat the surveys in 2004 and this data will be the focus of Josh's thesis on habitat use and distribution patterns of juvenile salmonids. We also were able to survey three other streams outside of the Club property, including Big Pup and Compeau Creeks and the Little Huron River. Data from these rivers will be used for comparison with data from the Salmon Trout River.

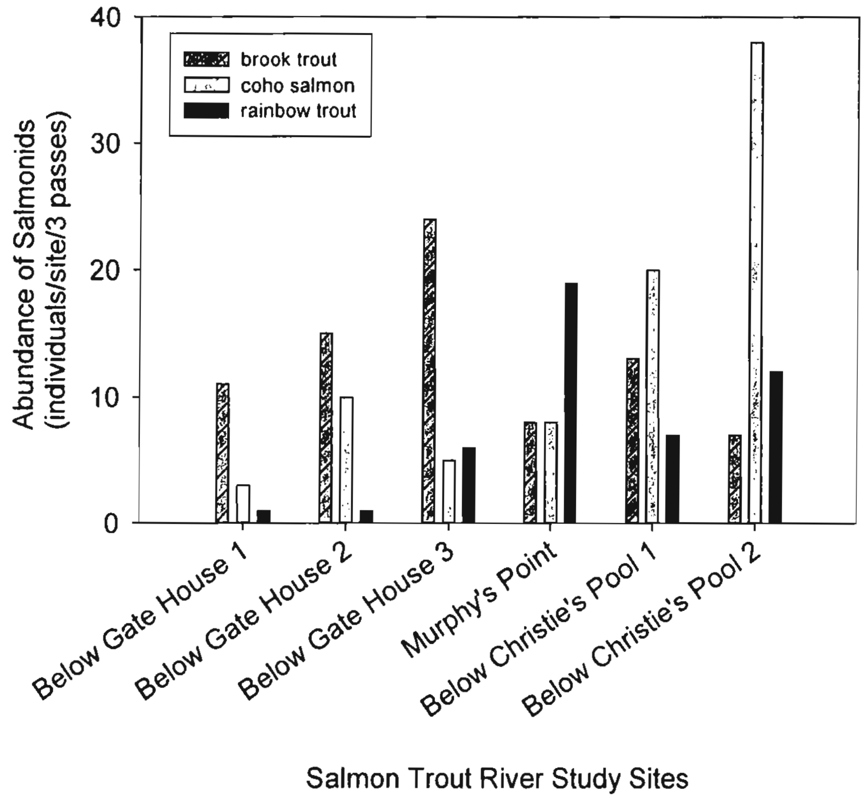

Figure 6. Abundances of juvenile brook trout, coho salmon and rainbow trout (steelhead) in the Salmon Trout River in 2003 across six survey sites. Each reported abundance reflects the total number of individuals captured in three blocked electrofishing passes.

Spawning Site Survey

In this project, we have always had the goal of learning more about the use of spawning sites on the Salmon Trout River. In years past we had observed aggregations of large individuals in the river, but we had not identified actual spawning redds. On several occasions in 2003, Josh had noticed a few large fish holding above the area where the enclosures had been placed and also slightly downstream from Christy's Pool. On Oct. 30, Casey Huckins and Ed Baker canoed the STR from the Christy pool trail down to the lamprey weir site. First we walked up toward the falls and on our way were able to watch coasters spawning. As we headed up we noted a

large depression in the sand and upon inspection found a few eggs. As we watched from the shore small brook trout appeared in the pool nearby. Then they were joined by a very large brook trout, and then another until there were at least six large brook trout (undoubtedly coasters) mingling in a mid-channel pool with smaller brook trout watching from the periphery. We continued our walk upstream noting apparent spawning redds here and there, some with and some without obvious eggs on the surface. On our way back along the trail we observed larger individuals digging nests and defending territories. We then canoed downstream in the continued drizzle and noted two additional large aggregations of coasters, one with at least four large fish and the other with possibly eight fish. These latter two groups were not observed spawning nor did we see any redds nearby. Conditions for observing fish were poor given the drizzle and snowfall on the water and the turbid water conditions so it is promising that we saw the fish and the spawning activities that we did.

2. **Summary of Remaining Actions To Be Taken**

There are a few components of the research that are ongoing throughout the non-fieldwork period, including continued data analysis. We will continue to age the fish scale samples that were collected. We will also continue to analyze the abundance and habitat data.

3. **Problems Encountered During This Period.**

The major problem we encountered during our research in 2003 was the arrival of otters in the region of the river mouth weir and the likely threat they could pose to trapped fish. Upon consultation with MiDNR wildlife biologists we learned that otters are notoriously difficult to live trap for relocation and that the likelihood of success would be minimal without danger to the trapped animal or its offspring.

As a result of the low catches and the arrival of the otters we discussed the issue with members of the Fish Committee (Peter Dykema and Pam McClelland) and we decided to initiate the 2004 research season with only a passive camera to observe fish migrations in the absence of capture devices. We will make more firm plans as we observe the patterns of free swimming brook trout.

We also endured major research hardship attempting to survey the fish community in the presence of animals that chew and damage the nets. In previous years we attempted to alleviate this problem by using chain link fencing faced with smaller mesh netting however this more rigid structure produced a different set of hardships in the form of major work required to rebuild the structure after high water damage. The sandy bottom of the Salmon Trout River also poses the continued problem of a shifting bottom scouring under and around the nets allowing for fish to escape past the nets. This was also a problem with the chain link weirs.

Annual Progress Report: Long-term research on coaster brook trout in the Salmon Trout River: coho competition phase

May 19, 2005

by

Casey Huckins

regarding research conducted by

Casey Huckins[1],
Josh Blankenheim[1]
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Summary

During the summer and fall of 2004 we conducted research on the Salmon Trout River and neighboring Marquette County rivers to continue to develop our understanding of the population and community ecology of coaster brook trout (*Salvelinus fontinalis*) in the Lake Superior watershed. Our research goals in Phase II of our research program were to 1) continue the population survey of migrating coaster brook trout and other salmonids in the Salmon Trout River, 2) remove adult coho salmon captured during their spawning migration and 3) characterize the associations among the assemblage of juvenile salmonids and the physical stream habitat. We accomplished goals 1 and 3 in 2004. Efforts toward goal 2 (removal of adult coho salmon) were obstructed by river otters appearing near our collection weirs. In the absence of evidence of harm caused by the otters, we conservatively elected to cease retaining migrating fish in the counting weirs, which negated our ability to remove coho salmon. Instead underwater video surveillance allowed us to detect at least 118 large brook trout moving upstream in the Salmon Trout River from July to mid November. Based on their large size these fish were most likely coasters migrating up from Lake Superior. In early November at least 26 of these migrating brook trout were observed in spawning aggregations at three locations on the river.

We also conducted research toward goal 3 by surveying and quantifying physical stream habitat and juvenile salmonids in 6 study reaches in the Salmon Trout River as well as sites in 5 additional rivers in the region. We detected very few associations between salmonid abundance and stream habitat characteristics within the Salmon Trout River except for more young of the year brook trout being found in the lower study sites (e.g., below the Gate House Bridge) that had sandy substrates. In the across-river comparison we observed that relative to juveniles of other salmonids, brook trout were more abundant in the smaller rivers with more abundant instream cover, and rivers with smaller substrates. The specific results of the salmonid-habitat associations were detailed in the Master's Thesis[1] by Joshua Blankenheim that resulted from this research funded by the Huron Mountain Wildlife Foundation.

[1]Blankenheim, J. E. 2005. Relationships between stream characteristics and juvenile salmonid community composition in six northern Michigan streams. Master's Thesis. Michigan Technological University. Houghton, Michigan.

Report on 2004 Research Activities

The Salmon Trout River coaster project moved forward with a productive summer of research in 2004. Our goals for the 2004 research season were to 1) continue the population survey of migrating coaster brook trout and other salmonids in the Salmon Trout River, 2) remove adult coho salmon captured during their spawning migration and 3) characterize the associations among the assemblage of juvenile salmonids and the physical stream habitat. However, due to circumstances beyond our control, we were forced to alter our research protocol resulting in our ability to accomplish goals 1 and 3. Our efforts toward goal 3 culminated in the completion of a Master's Thesis[1] by Joshua Blankenheim.

Near the end of the 2003 research season, our study site located at the mouth of the Salmon Trout river was visited by river otters, which necessitated the early closure of the weir-based surveys of salmonid migration that year. Although we had no evidence that the resident otters harmed any salmonids, we needed to be conservative toward protecting the limited coaster brook trout population while continuing to collect valuable population data. Upon consultation with Huron Mountain Club Fish Committee members, we decided employ a passive technique for monitoring the coaster population during the 2004 research season rather than physically retaining migrating fish in collection weirs for assessment. At the old lamprey weir site we deployed a series of wing nets similar to those deployed in previous years; however, these nets directed migrating fish past an underwater video camera rather than into a collection chamber. This experimental video based survey technique provided a valuable baseline assessment of the coaster migration in the absence of human intervention (i.e. fish were free to swim freely through the chute past the camera). After an initial couple weeks of adjustment, this camera recorded nightly footage from June 25 through November 17, 2004 when Josh dismantled the weir. The first large brook trout recorded by the camera was detected on July 5 and during the surveillance season we observed 214 "large" brook trout (see e.g., Figure. 1) moving upstream and 96 individuals moving in the downstream direction. If we assume that all downstream swimming fish were also counted as they swam upstream, the net upstream passage of large brook trout (ostensibly coaster brook trout) consisted of 118 individuals. In addition to the brook trout that were detected, 119 coho salmon were observed moving upstream and 19 coho were observed moving downstream during the summer and fall suggesting a net migration of 100 individuals.

As observed in previous years when our surveys were based on capturing and counting migrating coasters, our camera surveillance detected a peak of coaster migration in September and October (Figure. 2). One goal of this research was to identify any diel pattern in the movement of migrating salmonids; however, fish appeared to move anytime between dusk and dawn. At least two of these brook trout displayed adipose fin clips indicating they were returnees from previous years. With our current camera equipment it was difficult to discern such detail so some

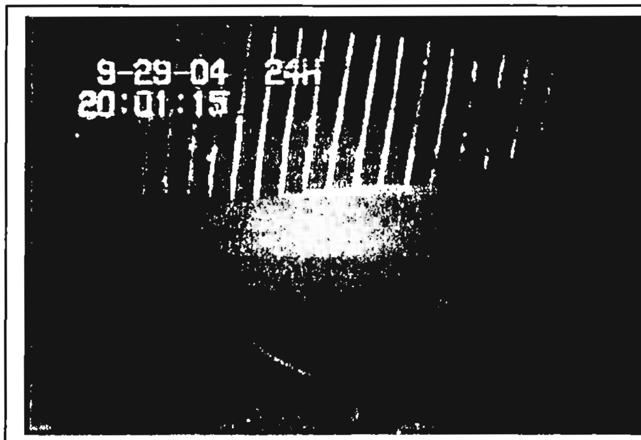

Figure 1. Still frame of a large brook trout imaged in slow motion as it migrated upstream through the camera weir on the Salmon Trout River. The grid lines in the back are spaced 2 cm. apart.

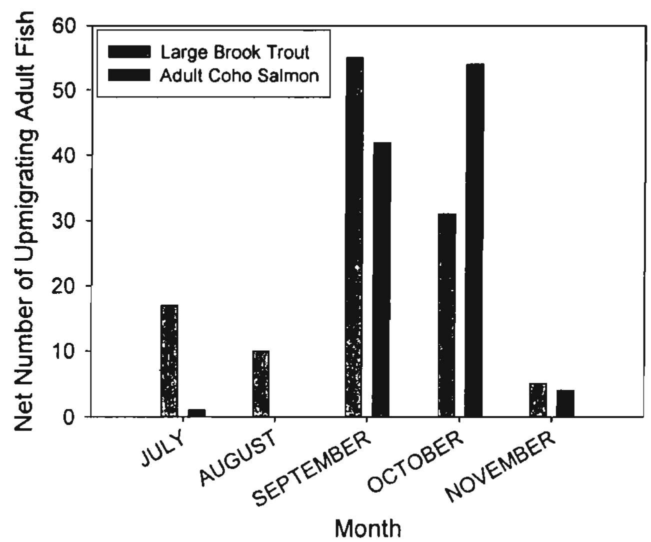

Figure 2. Net number of large brook trout and coho salmon detected each month during the camera surveillance season of 2004. Net number equals the difference between the up-migrating and down-migrating individuals detected.

of the other individuals could have also been returnees detected in previous years.

Although we would like to observe larger numbers of coasters in the spawning run up the Salmon Trout, we were encouraged by the promising numbers of spawning sized coasters detected in the Salmon Trout this year. In support of this indication of a decent spawning migration, on November 4, 2004 Ed Baker and I waked sections of the river and detected multiple coaster aggregations and spawning activities by coasters. We observed spawning aggregations of coasters above Christy Pool, near Murphy's Point and below the Gate House Bridge. Overall, across these sites we counted at least 26 large brook trout that likely were "coasters" accompanied by many smaller brook trout. On November 8, Josh Blankenheim also detected spawners and spawning activities below Christy Pool. Although the number of adult coasters we observed was below the magnitude we would like to see in the Salmon Trout River, these observations suggest another generation of coasters was being produced in 2004. This generation of future spawners and the current population will receive more protection than their ancestors by being protected by the new twenty inch minimum length limit in place in the 2005 fishing regulations for Michigan waters of Lake Superior.

As part of our research program, we also continued our surveys of the fish communities and river habitat characteristics of the Salmon Trout River, Big Pup Creek, Little Garlic River, Compeau Creek, the Little Huron River and the East Branch of the Huron River. The examination of the question of how salmonid abundances, growth and species composition relate to the physical habitat of these neighboring streams formed the foundation of Josh Blankenheim's Masters Degree at MTU, which he defended on April 18, 2004. In his thesis he examined the relationships between stream attributes and the abundances of juvenile salmonids [age-0 and age-1 brook trout, age-0 coho salmon (*Oncorhynchus kisutch*), and age-0 and age-1 rainbow trout/steelhead (*O. mykiss*)]. These data were collected using habitat surveys conducted on July 19-29, 2004 and multi-pass electrofishing surveys of fish assemblages conducted on August 3-25, 2004. Age-1 coho salmon were captured in only the Little Huron River so we were unable to include them in the analyses.

In general, the Salmon Trout River hosted low densities of juvenile salmonids relative to the other study rivers. Densities of age-1 salmonids (brook trout and rainbow trout) in the Salmon Trout were only 25% as high as those in Compeau Creek, which was the river with the next lowest density of age-1 salmonids (Figure. 3). The only YOY (age-0) salmonids we detected in Big Pup Creek and Compeau Creek were brook trout and only Compeau Creek had

total YOY salmonid densities lower than those detected in the Salmon Trout River (Figure. 4). The highest densities of age-1 and YOY salmonids were detected in the Little Huron River and they were respectively, 24 times and 22 times the densities that we detected in the Salmon Trout River (Figure. 3 and Figure. 4, respectively).

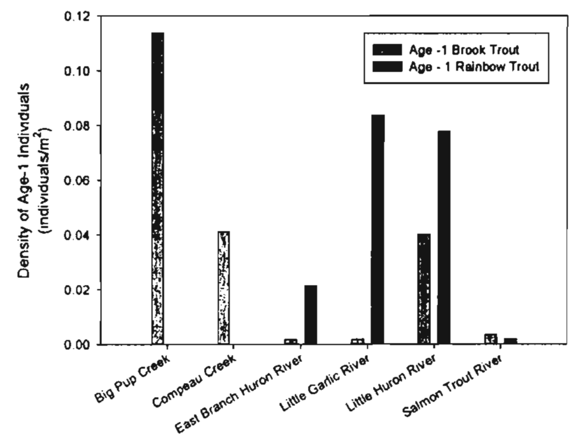

Figure 3. Densities of age-1 brook trout and rainbow trout detected in the 2004 electrofishing surveys of the six study rivers.

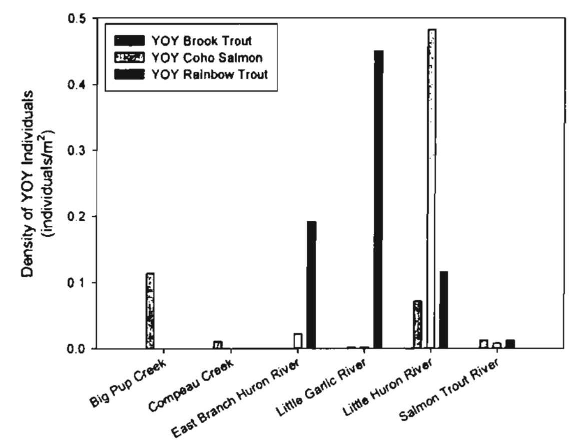

Figure 4. Densities of YOY brook trout, coho salmon and rainbow trout detected in the 2004 electrofishing surveys of the six study rivers.

Our across-river analysis revealed that juvenile brook trout were most abundant in small streams, streams with more abundant instream cover such as large woody debris (LWD) and those with smaller substrate[1]. Juvenile rainbow trout were most abundant in rivers with riffles, larger substrate, and little woody debris. Higher densities of young of the year (YOY) coho salmon were found in rivers covered by more overhanging vegetation.

Surprisingly, these across-river relationships were generally not observed at the reach scale across sites within the Salmon Trout River[1]. Within the Salmon Trout River, more YOY brook trout were observed in the more downstream sites that had more fine substrates. This pattern somewhat matches the across-river results indicating more juvenile brook trout were detected in streams with smaller-sized substrates. The general lack of associations between juvenile salmonid abundances and river habitat at small scales (100 m) within the Salmon Trout River likely suggests that the species-specific abundances of juvenile salmonids in the Salmon Trout River are controlled by larger scale mechanisms that determine population abundances of species rather than by smaller-scale mechanism of habitat use within a river. However, it might also suggest that similar spatial variation could also exist in the other rivers we surveyed.

Within the Salmon Trout River, the juveniles of brook trout, coho salmon and rainbow trout were distributed across the six survey sites and a site below Christy Pool appeared to have the highest density of age-1 brook trout (Figure 5). However, the Christy Pool sites also hosted the lowest densities of YOY brook trout whereas the greatest density of YOY brook trout was detected in the second Below Gatehouse site (Figure 6). This spatial distribution of juvenile salmonids is largely similar to the pattern detected in 2003 except for the higher densities of brook trout and lower densities of coho salmon juveniles detected in the upstream sites (i.e., Christy Pool) in 2004. Total densities of YOY (age-0) and age-1 salmonids of each species detected at each of the study sites revealed the pattern of Murphy's Point being dominated by

rainbow trout and higher relative densities of brook trout juveniles being observed below the Gatehouse Bridge (Figure 7), which is consistent with results of the 2003 survey. Given this consistency of the spatial pattern of juvenile salmonid species across the study sites in the Salmon Trout River, it is interesting that we were generally unable to detect linear relationships between species abundances and river habitat characteristics.

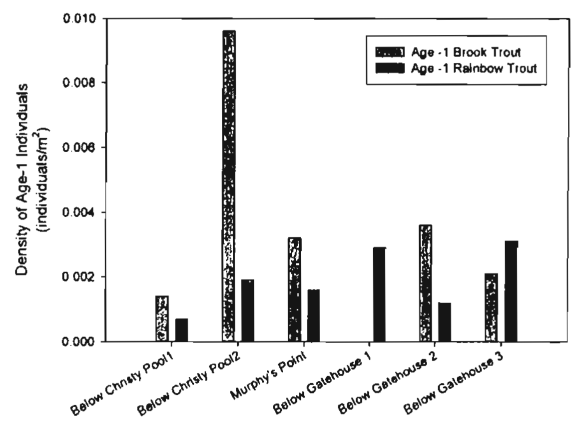

Figure 5. Densities of age-1 brook trout and rainbow trout detected in the 2004 electrofishing surveys of the six study reaches on the Salmon Trout River.

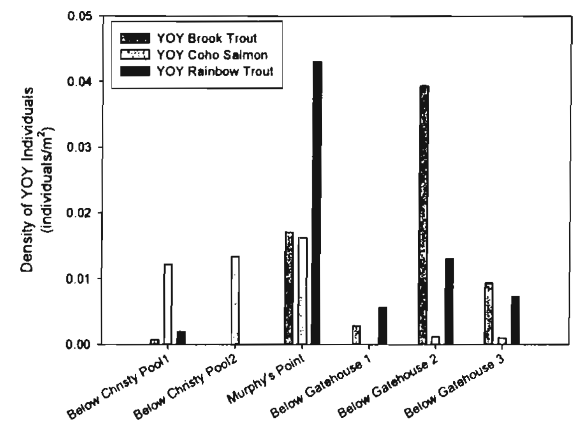

Figure 6. Densities of YOY brook trout, coho salmon and rainbow trout detected in the 2004 electrofishing surveys of the six study reaches on the Salmon Trout River.

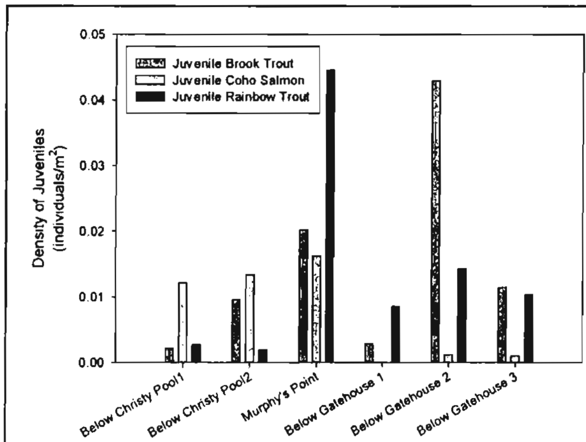

Figure 7. Densities of juvenile salmonids (age-0 and age-1) detected in the 2004 electrofishing surveys of the six study reaches on the Salmon Trout River.

METAPOPULATION COMPOSITION AND THE INFLUENCE OF STOCKING ON RESIDENT AND MIGRATORY BROOK TROUT IN MICHIGAN TRIBUTARIES OF LAKE SUPERIOR

A Final Report Submitted to The National Fish and Wildlife Federation

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Introduction

Fish community objectives for each of the Great Lakes and in most natural systems embrace ecological concepts of stability, balance, and sustainability. Conservation and sustainability of valuable fishery resources within these lakes and their tributaries relies on production from wild or naturalized populations, and increasingly, on fish produced by hatcheries. Management plans recognize the need to preserve biodiversity, because of the ecological significance of ecosystem complexity (Tilman 1999), and in terms of social, cultural and economic benefits. These management plans also recognize the value and need for maintaining diversity by conserving locally adapted strains or life history forms, and ensuring that strains of fish being stocked are matched to the environments they are to inhabit. The importance of maintaining the viability, integrity, and diversity of natural stocks and of the successful implementation of enhancement programs underlies the need for greater information on stock relationships and the degree of, or potential for, interactions among hatchery and wild individuals.

Brook trout (*Salvelinus fontinalis*) are a notable feature of the native aquatic community in the Upper Great Lakes, and represent a major focus for restoration across the basin. Brook trout were historically an important and abundant species along coastal shores and in tributaries across the upper Great Lakes basin. One life history form of brook trout referred to as a 'coaster' is known to undergo migrations from lacustrine habitats into tributary rivers and streams for reproduction, feeding or refuge. During upstream migrations from Lake Superior, adult coasters were highly susceptible to anglers, and by the early 1900's this highly adapted and prized coaster brook trout life history type had all but disappeared. Coaster restoration is a stated federal, state, tribal and international goal. Objectives for Lake Superior and research priorities for the entire Great Lakes basin outline the need for evaluation of the current population structure, habitat conditions, genetic profiles, affects of hatchery supplementation and potential impediments to restoration of coaster brook trout.

The direction of restoration initiatives for coaster brook trout in Lake Superior will be dictated in part by information on current distribution and abundance. Research has been hampered by the paucity of direct observational data on movements between streams by resident brook trout and of the movements by coaster brook trout among drainages. We presently lack a means of distinguishing hatchery from wild individuals, the degree of reproductive isolation between stream-resident and migratory forms, and of the potential influence of stocking on the recruitment of populations targeted for restoration. Use of molecular genetic markers has proven successful at circumventing these problems.

The Salmon Trout River in the Upper Peninsula of Michigan represents the only known viable population of coaster brook trout along the south shore of the Lake Superior basin. The Salmon Trout River coaster population has persisted although it is much smaller than historically. Hubbs (1929) noted that in the 1890's a small party of anglers fishing the river could harvest several hundred brook trout in a single day. However, the maximum annual catch of migrating brook trout in fish weir traps in the Salmon Trout River from 2000-02 was less than 200 (Huckins and Baker, in review). The Salmon Trout River coaster population has been subjected to the same stresses that have been implicated in the demise of coasters lake-wide (harvest, habitat destruction,

exotic species), but may have been afforded some protection from excess harvest because the river lies within the boundaries of the privately owned Huron Mountain Club. As the only known coaster population on the south shore of Lake Superior, the Salmon Trout coasters represent a potentially important source for recolonization of other rivers. The Salmon Trout River coaster population may also be important for future stocking efforts if the coaster life history is shown to be under some genetic control.

Brook trout of both life history forms and from various broodstock sources have been widely stocked across the basin. Domestic brook trout strains stocked in Michigan include Assinica, Owhi, and Temiscamie. Since 1999 Michigan has also stocked several Lake Superior tributaries with brook trout that were progeny of known coaster populations (Figure 1). In several streams in the Pictured Rocks National Lakeshore the Tobin Harbor coaster strain brook trout was stocked from 1999-2004. The Tobin Harbor coaster strain is from Tobin Harbor on the northeast end of Isle Royale. The wild Tobin Harbor fish spawn on rocky shoals in Tobin Harbor but are not known to ascend any streams for spawning. Siskiwit strain brook trout have been stocked into 2 streams that flow into Keweenaw Bay as well as directly into Keweenaw Bay. Siskiwit strain brook trout are also from Isle Royale and ascend the Siskiwit River to spawn. The Nipigon strain of coaster brook trout has been stocked in the Gratiot River, Keweenaw County, Michigan and Little Carp River in the western Upper Peninsula of Michigan. The Nipigon strain of coaster is from Lake Nipigon in Ontario, Canada. Jumbo River strain brook trout have been stocked directly into Keweenaw Bay and several Keweenaw Bay tributaries. The Jumbo River brook trout are progeny of wild brook trout from the Jumbo River, a Lake Superior tributary in the upper peninsula of Michigan. Jumbo River brook trout are stream residents (i.e., do not exhibit the coaster life history).

There is intense interest to ascertain whether stocking of different strains of resident and coaster brook trout has been successful and what effects stocking has had on population relationships across the southern shores of the basin. Concerns over impacts of releasing cultured fishes into the environment have accelerated in recent years, and impacts of such releases occur both at the community level, at the population level by changing demographic parameters, or by affecting population genetic characteristics. Changes in genetic characteristics of populations following often repeated introduction scenarios can lead to reductions in effective population size, hybridization and disruption of adapted genotypes.

In light of these concerns, our objectives were to document whether there is evidence of hybridization between wild and planted fish, to determine whether stocking programs are contributing to the recruitment of brook trout, and to determine genetic relationships among stream resident populations in Michigan tributaries to Lake Superior and relationships between resident and migratory life-history forms.

Methods

Study area and field collections

Brook trout were sampled from 9 streams in each of 2 regions of Michigan's Upper Peninsula (Figure 1). Streams were selected because they supported wild self-sustaining brook trout except the Gratiot River, which was selected because it has repeatedly been stocked with Nipigon coaster strain brook trout. With the exception of Big Pup Creek, all

of the sampled streams afford fish access to Lake Superior. Big Pup Creek is isolated from Lake Superior by a dam and impassable waterfalls. We also collected adipose fin tissue from brook trout above the lower falls in the Salmon Trout River, which poses an impassible barrier to fish movement beyond approximately 10 km upriver.

We sampled brook trout using electrofishing gear from all sampled streams. In addition, in the Salmon Trout River we collected fish with traps (one near the mouth and one approximately 3 km upstream) that were used to monitor fish movement (Huckins and Baker, in review). Brook trout captured in the river mouth trap as they left Lake Superior were definitive coaster brook trout. Brook trout defined as stream residents were those individuals captured earlier in the summer that were large enough to be lake-dwelling if they had been coasters. Captured fish were measured and weighed and the adipose fin was clipped for later genetic analysis. Adipose fins were placed into cryovials and covered with nondenatured EOTH.

We also conducted genetic analysis on three hatchery brook trout strains that have been recently stocked in nearby streams and Lake Superior waters. Assinica strain brook trout is a domesticated strain that the Michigan DNR stocks in streams and small lakes in the Lake Superior watershed. The Assinica brood stock is maintained at the Marquette State Fish Hatchery and tissue samples were collected from fish at the hatchery. The Nipigon strain of brook trout has been stocked in the Gratiot River (Figure 1). The Michigan DNR obtains Nipigon strain brook trout eggs from the Red Cliff Tribal Fish Hatchery in Red Cliff, Wisconsin each year and the fish are raised at the Marquette State Fish Hatchery until they are stocked. Tissue samples from Nipigon strain fish were collected from fish at the Marquette State Fish Hatchery prior to stocking. The Jumbo River strain of brook trout, a stream resident strain, has also been recently stocked directly into Keweenaw Bay, Lake Superior and into Keweenaw Bay tributaries. Jumbo River strain brook trout are raised in the Keweenaw Bay Tribal Hatchery and originated from wild brook trout collected from the Jumbo River (Figure 1) in 1998-99. Tissue samples from Jumbo River strain brook trout were supplied by the Keweenaw Bay hatchery.

Laboratory genetic analyses

Samples were dried in individual sampling tubes. The DNA was extracted from all samples using QIAGEN DNeasy kits (QIAGEN, Valencia, California, USA). Samples were then quantified using a spectrophotometer, and diluted to working concentrations of 20ng/μl.

Nine microsatellite markers were employed including Sfo23, Sfo12, and Sfo18 (Angers et al. 1995), Sco19 (Taylor et al. 2001), C24, D75, C28 (T. King, unpubl. data). Loci were amplified using polymerase chain reaction (PCR) in 10 μl or 25 μl reaction volumes including PCR Buffer (10 mM Tris-HCl at pH 8.3, 1.5 mM $MgCl_2$,50 mM KCl, 100 μg/mL gelatin, 0.01% NP-40, and 0.01% Triton-X 100), 80 μM dNTPs, (Sfo18-Perkin Elmer 10x PCR Buffer II (Roche, Indianapolis, Indiana); Sco19-LGL buffer (10 mM Tris-HCl at pH 8.5, 1.5 mM $MgCl_2$, 50 mM KCl, 100μg/mL nuclease-free BSA, 0.04% Tween 20)), 10 pmol of forward and reverse fluorescently-labeled primers, 0.25 units of Taq polymerase, $MgCl_2$ (Table 1), dimethyl sulfoxide (DMSO) and 40 or 100 ng of DNA. Two sets of three primer pairs were co-amplified: Sfo23, C24, D75 and Sfo8, C28 and Sfo12. Thermocycler conditions included a 2-min denaturation at 94°C followed

by 35-42 cycles of 1-min at 94°C, 1-min at locus-specific annealing temperature, (Table 1) and 1-min at 72°C with an additional 5-min at 72°C. A Perkin Elmer GeneAmp 9600 (Boston, Massachusetts) was used for Sfo18 and Sco19. Conditions for these included a 2-min denaturation at 94°C followed by 15 cycles of 1-min at 94°C, 35-sec at locus-specific annealing temperature, and 10-sec at 72°C with an additional 20 cycles of 45-sec at 94°C, 35-sec at locus-specific annealing temperature, and 10-sec at 72°C. Following electrophoresis on denaturing 6.5% polyacrylamide gels, PCR products were visualized using a LI-COR 4300 (Lincoln, Nebraska). 6% polyacrylamide gels were used for Sfo18 and Sco19; products were visualized on a FMBIO II laser scanner (Hitachi Software Engineering Co, Alameda, California). Genotypes were scored based on 20 base-pair standards and individual standards of known genotypes.

Statistical Analyses

Estimates of allele frequency and measures of genetic diversity within populations (observed and expected heterozygosity, and allelic richness) were obtained using the program FSTAT (Goudet 1995). Measures of deviation of population genotype frequencies from Hardy-Weinberg expectations were estimated using Fisher's exact tests Guo and Thompson (1992) implemented in program GENEPOP (Raymond and Rousset 1995). P-values associated with Hardy-Weinberg exact tests were adjusted for multiple comparisons using sequential Bonferroni corrections (Rice 1989). Pair-wise coefficients of relatedness among individuals within each population sample were calculated using the program Kinship, version 1.3.1 (Goodnight and Queller 1989), and were summarized as the mean across all pair-wise comparisons for each population sample. Coefficients provide a measure of relatedness between two individuals, and are estimated based on the proportion of alleles shared between individuals, adjusted based on population allele frequencies.

Estimates of variance in microsatellite allele frequency among resident brook trout population, between resident and coaster life history forms from within the Salmon Trout River, and among natural populations and hatchery strains widely used in the region were quantified using F-statistics (Weir and Cockerham 1984) implemented in program FSTAT. Measures of genetic distance (Cavalli-Sforza and Edwards 1967) were also estimated for all pair-wise comparisons of natural and wild populations using program PHYLP (Felsenstein 1993). Genetic relationships based on genetic distance were characterized in the form of a neighbor-joining tree (Saitou and Nei 1987) and visualized using program TREEVIEW (Page 1996). Statistical support for individual nodes of the tree were obtained based on 1000 bootstrap replicates conducted using PHYLP.

Natural populations surveyed along the southern shore of Lake Superior were composed to 2 geographically disjunct groups of populations in the Kewanaw Region and in a south-eastern region (Fig. 1). Accordingly, analyses to quantify spatial relationships among resident forms in the natural populations were conducted using a hierarchical analysis of variance, apportioning variance in allele frequency between regions, among populations within region, and within populations. Hierarchical analyses were conducted using the program Genetic Data Analysis (GDA; Lewis and Zaykin 2001).

We used Mantel tests (Smouse et al. 1986) implemented in program PASSAGE (Rosenberg 2000) to estimate the overall relationship between genetic distance (Cavalli-

Sforza and Edwards 1967) and geographic distance based on matrices constructed from all pair-wise comparisons within each region. We used ArcView geographic information systems (GIS) software to measure minimum distance between the mouths of rivers where we sampled brook trout. Distance was measured along the shoreline between river mouths except for the distance measured from the Lovells Creek mouth to the Huron River mouth which was measured across the open waters of Keweenaw Bay and Huron Bay. Significance of correlations between genetic and geographic distance was evaluated through randomization (1,000 permutations).

To further quantify genetic affinities of individuals and populations, we used the Bayesian clustering method of Pritchard et al. (2000), implemented in the program STRUCTURE. The program uses multilocus genotypes to infer population structure and to assign individuals probabilistically to populations. We estimated the probability of the data given each inferred number of clusters (K) where K varied from 1 to 10. No prior population information was used. Improvement in goodness of fit for each K was evaluated using likelihood ratio tests and a ΔK statistic based on the rate of change in the log probability of data between successive K values (Evanno et al. 2005). Results are based on 1,000,000 Markov Chain Monte Carlo iterations following a burn-in period of 100,000 iterations and 2 repetitions of each value of K.

Relationships between individuals of different life history phenotypes (coaster vs resident) sampled within the Salmon Trout River were assessed using pair-wise estimates of variance in allele frequency (F_{st}). We used program STRUCTURE to ascertain whether there was evidence for significant sub-structuring within the stream and whether phenotype correlated significantly with probability of assignment to different genetic clusters if present. We also sampled recruits from a cohort produced from adults sampled. We used individual assignment tests (Paetkau and Strobeck 1995) implemented in program MLE (Topchy et al. 2004) to assign juveniles to either resident or coaster phenotypes and thus assess the relative contributions of both phenotypes to recruitment.

Results

Variation within and among natural populations

Summary measures of genetic diversity were generally high but variable across the wild populations surveyed (Table 1). Allelic richness was generally higher in populations from the Keweenaw Region relative to populations in the SE region. Inbreeding coefficients were highly variable across populations and were generally positive indicating an excess of homozygotes. Genotype frequencies of stream resident brook trout from several rivers deviated from Hardy-Weinberg expectations due to an excess of homozygotes (Table 1). Samples from the Gratiot River (3 of 9 loci), Compeau Creek (4 of 9 loci), and the Salmon Trout River (3 of 9 loci) were most notably deviant.

Populations of brook trout were genetically structured at microgeographic and regional scales (Table 2). Analyses of variance in allele frequencies revealed that a significant portion of variance in allele frequency was apportioned between regions (mean θ_P=0.008) and among populations within region (mean θ_S=0.063). Genetic affinities quantified based on inter-population genetic distance also revealed structuring, consistent with region of affiliation (Keweenaw Peninsula vs SE; Figs. 1 and 2). Despite the general trend for population allele frequencies to vary on a macro-geographic scale

(between regions), we found no evidence for isolation by distance. The correlation between inter-population genetic distance and geographic proximity was not statistically significant (r=0.077, P=0.338).

Several interesting relationships were evident based on the genetic affinities revealed in Figure 2. First, brook trout from the upper portion of the Salmon Trout River above a waterfall were characterized by allele frequencies (data not shown) more similar to other SE region populations than those of resident and coaster brook trout sampled from below the falls. Close genetic relationships between populations could be attributed to historical stream capture across upstream headwater areas. Secondly, different samples of brook trout from the lower Salmon Trout River (below the falls) including adult stream residents, adult coasters, and juveniles cluster with high confidence (100% bootstrap support). Finally, coasters were identified either as they entered the river or on the basis of morphology when sampled further up-stream. Allele frequencies between these 2 samples were indistinguishable (results of exact tests; data not shown), whereas allele frequencies of both samples of coaster brook trout differed significantly from those of the stream resident adults (exact tests; $P<0.05$). Allele frequencies of juveniles sampled were intermediate relative to resident and coaster adults (Fig. 2) suggesting a mixture of juveniles produced by either parental phenotype.

Bayesian analysis of individual assignment - An additional Bayesian analysis was conducted to determine the most likely number of genetic clusters most consistent with the genotypic data. Analyses were conducted without regard to knowledge of population of origin. Analyses indicated that 7 genetic clusters were most consistent with the data. Posterior probabilities of individual membership were strongly tied to population of origin. Brook trout from Big Pup Creek, Compeau Creek, Lowell Creek and Brewery Creek formed individual genetic clusters. Fish from the Salmon Trout River, Big Garlic River, and Huron River were members of an additional genetic cluster. Populations from Schlot Creek, the Gratiot River, and the Upper Salmon Trout River appear to be mixtures of fish whose posterior probabilities indicated they were from different genetic clusters.

Bayesian analysis of fish from the Salmon Trout River - Results indicate that there were 2 genetic clusters most consistent with the data. Posterior probabilities of individual assignment indicated that fish sampled from above the falls in the upper river comprised 1 cluster. Fish below the falls (resident adults, coaster adults, and juveniles) generally comprised a second genetic cluster. Interestingly, 8 individuals collected from the lower river were characterized by posterior probabilities of upper river membership ($P>0.95$) indicating that they were likely down-stream migrants from the upper river population. This rate of unidirectional dispersal is particularly noteworthy. Movements of this magnitude appear to be insufficient to homogenize allele frequencies as evident by the different orientation of the upper-river and lower-river samples in the population distance tree (Fig. 2).

Genetic relationships between coaster and resident phenotypes – Only 1 native population of coaster brook trout is verified to exist along the southern shore of Lake Superior. Genetic affinities of coaster brook trout place them unambiguously as part of the Salmon Trout River population (Fig. 2). Exact tests indicate that both samples of

coaster brook trout differ significantly in allele frequency from resident brook trout ($P<0.05$). However, the magnitude of variance as evidenced by pair-wise θ (0.0164) was considerably smaller than pair-wise comparison between resident populations of different streams (mean $\theta=0.059$; range 0.0164 to 0.0926). The mean θ characterizing variance in allele frequency of Salmon Trout River coaster brook trout and all other resident brook trout (mean $\theta=0.083$; range 0.0164 to 0.1121) was considerably higher, reflecting a more pronounced level of genetic divergence relative to other stream resident populations, as suggested based on clustering of the Salmon Trout River samples relative to other streams (Fig. 2). Collectively, analyses of relationships between coaster and resident brook trout show that coasters originated from the Salmon Trout River. Our data do not support the hypothesis that coaster brook trout are nomadic and migrate and breed in multiple populations. Data also show that resident and coaster brook trout from the Salmon Trout River are not part of a single and randomly mating population.

Genetic relationships between wild and hatchery brook trout – There appears to be minimal if any impact of hatchery stocking on resident or coaster brook trout. Comparisons of population allele frequencies with those of Nipigon and Assinica hatchery strains revealed a much larger estimate of genetic divergence than evidenced among the natural populations (pair-wise comparisons of native brook trout with Assinica and Nipigon; mean $\theta=0.142$, range 0.111-0.204 and mean $\theta=0.160$, range 0.136-0.192, respectively). Nipigon strain brook trout were stocked into the Gratiot River. However, allele frequencies between river resident and Nipigon brook trout were highly statistically different ($\theta=0.1414$, $P<0.05$). Plants of coaster brook trout from the Nipigon strain do not appear to have contributed reproductively to populations into which they were planted (e.g., Gratiot River).

Genetic affinities between Jumbo strain brook trout and native populations was much stronger (mean $\theta=0.069$), due in part from shared regional origin. The Jumbo River is a tributary of a Michigan Upper Peninsula stream (Ontonagon River). Pair-wise estimates of θ for several resident populations from the western Keewanaw Peninsula and the Jumbo strain are consistent with either gene flow between wild fish from the Ontonagon River and Keewanaw Peninsula streams or genetic representation of Jumbo River strain brook trout in wild populations [Schlot Creek ($\theta=0.030$), and the Gratiot River ($\theta=0.017$)].

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Table 1. Summary measures of genetic diversity for wild brook trout populations from Michigan tributaries to Lake Superior.

Measures of genetic diversity	Keweenaw Region			SE Region							
	Gratiot River (N= 47)	Brewery Creek (N=57)	Schlot Creek (N=40)	Lowell Creek (N= 46)	East Branch Huron River (N= 29)	Upper Salmon Trout River (N= 23)	Lower Salmon Trout River (resident) (N=9)	Lower Salmon Trout River (coaster) (N= 68)	Big Pup Creek (N= 50)	Big Garlic River (N= 19)	Compeau Creek (N=58)
Observed heterozygosity	0.712	0.744	0.738	0.687	0.692	0.712	0.703	0.627	0.744	0.736	0.674
Expected heterozytosity	0.800	0.749	0.772	0.715	0.728	0.787	0.715	0.628	0.755	0.752	0.763
Allelic richness	14.56	13.22	12.78	11.11	11.22	11.22	6.67	7.56	10.77	8.78	11.67
Inbreeding coefficient	0.111	0.006	0.045	0.039	0.050	0.098	0.017	-0.001	0.015	0.022	0.118
Mean relatedness	-0.001	0.005	0.003	0.002	0.004	-0.001	0.002	0.008	0.001	0.001	0.008
Loci deviating from Hardy-Weinberg expectations	3	0	0	0	1	1	3	0	0	1	4

Table 2. F-statistics summarizing apportionment of genetic variance assayed using 9 microsatellite loci for 9 stream resident and 1 coaster brook trout populations from 2 regions along the southern shore of Lake Superior.

	Variance partitioning			
Locus	Alleles within individuals	Among individuals within populations	Among populations within regions	Among regions
	F-Statistics			
	f	F	θ_S	θ_P
Sfo23	0.054	0.099	0.049	0.006
Sfo8	0.085	0.132	0.052	0.007
Sfo12	0.183	0.255	0.089	0.009
Sfo18	0.030	0.062	0.033	-0.005
Sco19	0.051	0.104	0.056	0.001
Ots1	-0.041	0.033	0.071	0.002
D75	0.031	0.117	0.089	0.034
C24	-0.007	0.036	0.043	0.010
C28	0.104	0.184	0.089	0.007
mean	0.052	0.112	0.063	0.008
95% CI	0.088-0.019	0.152-0.078	0.077-0.052	0.016-0.003

Fig. 1. Map of sampling locations for resident and coaster brook trout in the upper peninsula of Michigan. Numbers represent stocking locations for different hatchery strains of brook trout.

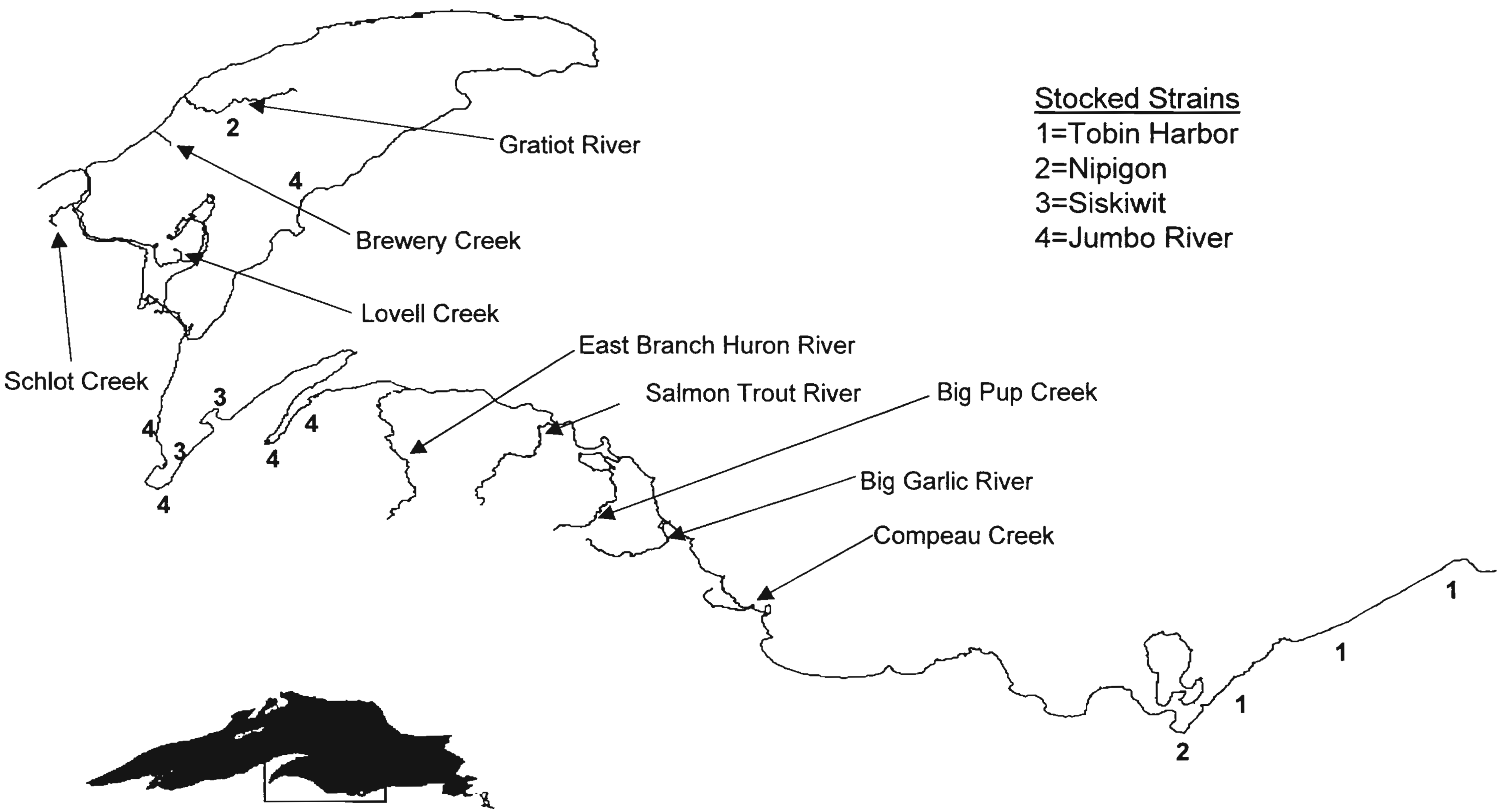

Fig. 2. Diagram showing genetic relationships among populations of brook trout from the upper peninsula of Michigan. Clustering is based on genetic distances using the neighbor-joining algorithm. Numbers on the nodes of individual branches reflect measures of statistical support for population relationships based on bootstrapping over 1000 replicates.