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History of the fishes of the Bois Brule River System, Wisconsin, with emphasis on the salmonids and their management

Abstract *The Bois Brule River in Douglas County is one of Wisconsin's largest, best known, and most intensively studied trout streams. A diverse fish fauna of at least 63 species (11 of which are exotic, plus one cultured hybrid) has been collected from the watershed. However, only 21 are coldwater, riverine species with viable populations; the remainder are either lentic, warmwater forms found in lakes Minnesuing and Nebagamon, are Lake Superior species that only occasionally enter the lower river, or are locally rare. The fish fauna has been profoundly altered by species introduced both intentionally and accidentally, and by control efforts directed at the exotic sea lamprey* (Petromyzon marinus), *which have caused severe density and distribution reductions in two species of native lampreys. Once sustaining a population of native brook trout* (Salvelinus fontinalis) *as the only angling target, the river now provides angling opportunities for four species of exotic salmonids as well. Declines in several of the salmonid populations, especially during the last two decades, may be attributable to over-exploitation; consequently, fishery regulations have become increasingly restrictive. Top priority, however, will continue to be maintenance of excellent habitat and water quality. With fine riparian stewardship practiced by private landowners, coupled with the state stewardship land acquisition program within state forest boundaries, this focus appears to be sustainable. Other habitat management efforts have included in-stream habitat enhancement techniques, beaver* (Castor canadensis) *control and dam removal, dredging projects, and bank stabilization efforts in red clay areas prone to slippage.*

The Bois Brule River (hereafter referred to as the Brule River) in Douglas County is perhaps the most famous trout stream in Wisconsin (O'Donnell 1944). Its fame is related both to its rich history as an important water route, linking Lake Superior and the upper Mississippi River drainage, and its historic reputation for excellent trout fishing (O'Donnell 1944; Marshall 1954). Additionally, the river has long been renowned for its beauty and an intangible mystique that repeatedly draws anglers and canoeists alike back to its waters. Today the Brule River provides habitat for a diverse array of coldwater organisms in addition to the salmonids. As one of the larger spring-fed streams in the Midwest, it is a regionally unique resource deserving the highest level of protection.

The original renowned trout fishery of the Brule River bore little resemblance to the current fishery for five salmonid species. During the middle and late 1800s the river was widely acclaimed for its native brook trout *(Salvelinus fontinalis)* fishing; this fishery was comprised of both stream-resident and anadromous, or coaster[1], components. Unfortunately, this fishery had begun to decline sharply by the turn of the century (Jerrard 1956), probably from a combination of over-exploitation, habitat loss, and logging dam effects (O'Donnell 1944). However, subsequent introductions of steelhead (anadromous rainbow trout, *Oncorhynchus mykiss),* brown trout *(Salmo trutta),* and various brook trout strains, in combination with increasingly restrictive angling regulations and termination of extensive logging, helped bolster the fishery back into prominence. High quality trophy fisheries for anadromous brown trout, steelhead, and more recently, coho salmon *(Oncorhynchus kisutch)* and chinook salmon *(Oncorhynchus tshawytscha)* have since developed and are augmented by challenging upper river and tributary fisheries for stream-resident brook trout and brown trout.

Throughout the recorded history of this river, anglers have often voiced complaints related to perceived dips in the quality of fishing. In 1983 an advisory task force (the Brule River Committee) was formed in response to perceived declines in populations of both steelhead and brown trout. The committee was formed of Wisconsin Department of Natural Resources (WDNR) personnel and concerned citizens representing area sports clubs. Objectives for the committee were to identify and prioritize the most pressing fishery problems and formulate suggestions for remedial actions. Most of the problems identified pointed to a common need: to promptly initiate a long-term, comprehensive research project to provide quantitative data about the salmonid populations. Although the river had been the focus of much investigation since the 1940s (see section on ecological investigations), the descriptive information obtained was of limited value for guiding management actions. Late in 1983 the WDNR initiated a broadly based research initiative to provide the information on salmonid population dynamics needed to optimize management of the fishery.

This report grew out of the research effort initiated in 1983 and presents an historical sketch of the fish populations of the Brule River system along with the factors that have affected them over the last two centuries. Our emphasis regarding these objectives is focused primarily on the salmonids and their management, and secondarily on the exotic sea lamprey *(Petromyzon marinus),* because these species have received the most management and research attention. However, because these species are just part of a diverse fish community, we also summarize the information available, both historical and recent, for all fish species within the river system.

Methods

This report represents a compilation of information taken from a variety of sources including data collected by the authors during various phases of a multifaceted salmonid research project on the Brule River during 1983–93, file data from the WDNR Brule Area and Superior offices, and numerous published sources. Works by O'Donnell (1944), Holbrook (1949), Marshall (1954), and Jerrard (1956) were instrumental in providing information about human development within the Brule River Valley and the historic trout fishery. Physical and chemical information for the mainstem[2] and tributaries were summarized from several sources. Fish distribution information was obtained either during WDNR fishery surveys over the last decade or from the sources acknowledged in Table 1. Both WDNR file data and published accounts of species distributions were used except in a few cases where they were clearly inconsistent with established information on statewide distributions (Becker 1983; Fago 1992). Collections from 44 sampling stations located throughout lotic areas of the river system during 1987–91 (DuBois et al. in press) targeted juvenile and stream-resident salmonids and were made with standard WDNR stream electrofishing units using 220 volt direct-current generators; electrofishing surveys prior to about 1980 used less efficient (on salmonids) alternating-current generators. Spawning runs of anadromous salmonids were examined with a viewing window and sea lamprey trap at the sea lamprey barrier/fishway (hereafter referred to as the barrier/fishway – Fig. 1). Smolts were studied with an inclined-screen trap (DuBois et al. 1991) below[2] the barrier/fishway.

Sport fishery statistics were summarized from WDNR creel surveys conducted in 1973, 1978–79, 1984, and 1986 on the mainstem from Stone's Bridge to the mouth, in 1990 on the lower river[2] only, and in 1992 on the upper river[2] only. Random, stratified, timed-interval designs —also known as bus route designs (Jones and Robson 1991)—were used to obtain completed trip interviews at major access points in 1986, 1990, and 1992; earlier access-point surveys were not stratified according to anticipated angling pressure. Information requested from each angler included the length of time fished, fishing methods used, data about the catch, and perceptions of the fishing experience. Creeled salmonids were measured to the nearest 0.1 inch and scale-sampled as needed for age analysis.

The Physical Setting

The 47-mile-long Brule River drains a watershed of about 130 square miles and flows north into Lake Superior (Fig. 1). The average discharge near the WDNR Brule Area Headquarters on the river's midsection is 169 ft3/sec with extremes ranging from 67 to 1,520 ft^3/sec (Niemuth 1967); this flow regime is relatively stable for a large stream in Wisconsin (Bean and Thomson 1944; Sather and Johannes 1973). The upper sections of river originate in, and flow through, a large conifer bog surrounded by a sandy outwash plain known as the "pine barrens." This area acts as a sponge by absorbing a high percentage of the rainfall entering the region, and then delivering it to the stream through numerous springs at a uniform rate (Bean and Thomson 1944). The high input of spring flow is the defining feature of the river system. This uniform source of abundant ground water creates stable flows and a moderated thermal regime, which is

Table 1. Relative abundance and distribution of fish species of the Brule River system

Common Name	*Scientific Name*	*Origin*	*Relative Abundance*[1]	*Information sources*[2]
PETROMYZONTIDAE				
Silver Lamprey	*Ichthyomyzon unicuspis*	Native	R	AU; SG; LB; MC; US
Northern Brook Lamprey	*Ichthyomyzon fossor*	Native	R	CH; OD; US
Sea Lamprey	*Petromyzon marinus*	Exotic	C	AU; LB; MC; MO; WI
LEPISOSTEIDAE				
Longnose Gar	*Lepisosteus osseus*	Native	R	MO; WI
ANGUILLIDAE				
American Eel	*Anguilla rostrata*	Exotic	R	AU; FB
CYPRINIDAE				
Common Carp	*Cyprinus carpio*	Exotic	R	LB
Golden Shiner	*Notemigonus crysoleucas*	Native	O	AU; FB; GR; LB; MC; MO; WI
Creek Chub	*Semotilus atromaculatus*	Native	C	AU; FB; GR; LB; MC; MO; OD; WI
Pearl Dace	*Margariscus margarita*	Native	U	AU; FB; MO; WI
Finescale Dace	*Phoxinus neogaeus*	Native	R	MO; WI
Northern Redbelly Dace	*Phoxinus eos*	Native	O	AU; FB; MO; OD; WI
Lake Chub	*Couesius plumbeus*	Native	C	MC, MO, OD; WI
Blacknose Dace	*Rhinichthys atratulus*	Native	C	AU; FB; GR; LB; MO; OD; WI
Longnose Dace	*Rhinichthys cataractae*	Native	A	AU; FB; GR; LB; MC; MO; OD; WI
Hornyhead Chub	*Nocomis biguttatus*	Native	C	MC; LB; MO; WI
Common Shiner	*Luxilus cornutus*	Native	C	AU; FB; LB; MC; MO; OD; WI
Emerald Shiner	*Notropis atherinoides*	Native	R	FB; LB; MO; OD; WI
Spottail Shiner	*Notropis hudsonius*	Native	O	AU; GR; LB; MC; MO; WI
Mimic Shiner	*Notropis volucellus*	Native	U	AU
Blacknose Shiner	*Notropis heterolepis*	Native	R	FB; MO; WI
Brassy Minnow	*Hybognathus hankinsoni*	Native	U	AU; FB; MO; WI
Bluntnose Minnow	*Pimephales notatus*	Native	O	FB; GR; MO; WI
Fathead Minnow	*Pimephales promelas*	Native	U	AU; FB; GR; MO; WI
CATOSTOMIDAE[3]				
Silver Redhorse	*Moxostoma anisurum*	Native	O	AU; MO; OD; WI
Shorthead Redhorse	*Moxostoma macrolepidotum*	Native	O	AU; LB; MC; MO; OD; WI
White Sucker	*Catostomus commersoni*	Native	A	AU;FB;GR;LB;MC;MO;OD;WI
Longnose Sucker	*Catostomus catostomus*	Native	C	AU; LB; MC; MO; OD; WI
ICTALURIDAE				
Black Bullhead	*Ameiurus melas*	Native	U	AU; FB; LB; MC; MO; OD; WI
Brown Bullhead	*Ameiurus nebulosus*	Native	R	MO;WI
Yellow Bullhead	*Ameiurus natalis*	Native	R	FB; MO; WI
Tadpole Madtom	*Noturus gyrinus*	Native	R	OD
Stonecat	*Noturus flavus*	Native	O	AU; MC; MO; WI
ESOCIDAE[4]				
Northern Pike	*Esox lucius*	Native	C	AU; FB; GR; LB; MC; MO; OD; WI
UMBRIDAE				
Central Mudminnow	*Umbra limi*	Native	C	AU; FB; GR; MO; OD; WI
OSMERIDAE				
Rainbow Smelt	*Osmerus mordax*	Exotic	O	AU; MC; MO; OD; WI
SALMONIDAE				
Atlantic Salmon	*Salmon salar*	Exotic	R	AU; LB
Brown Trout	*Salmo trutta*	Exotic	A	AU;FB;GR;LB;MC;MO;OD;SC;WI
Chinook Salmon	*Oncorhynchus tshawytscha*	Exotic	C	AU; LB; SC; WI
Coho Salmon	*Oncorhynchus kisutch*	Exotic	A	AU; LB; SC
Steelhead	*Oncorhynchus mykiss*	Exotic	A	AU;FB;GR;LB;MC;MO;OD;SC;WI

(Taxonomic names and order of families follows Robins et al. [1991].)

Main Areas of Distribution
lowest mile of the lower river; greatly reduced by lampricide treatments that began in 1959
lower two thirds of the mainstem and several tributaries prior to lampricide treatments that began in 1959; now Minnesuing and upper Nebagamon creeks
much of the mainstem and larger tributaries until restricted by the lamprey barrier in 1986; now below the barrier
one specimen reported from the lowest mile of the lower river
specimens reported from the estuary and Lake Nebagamon
lower river up to the lamprey barrier
the lowest few miles of the mainstem and Lake Minnesuing
scattered throughout the lower river; most common in slow water in the larger tributaries
lower river, Casey, Blueberry, and Wilson creeks, West Fork, and Lake Minnesuing
the lowest several miles of the lower river
lower river and most of the tributaries
lowest mile of the lower river
entire mainstem and Trask, Casey, and Blueberry creeks
riffle areas throughout the mainstem and in the larger tributaries
lowest mile of the lower river
lower river up to the lamprey barrier and Trask Creek
lower river up to the lamprey barrier and Lake Minnesuing
lower river up to the lamprey barrier
estuary
lowest mile of the lower river and Lake Minnesuing
lower river and larger tributaries
lowest mile of the lower river, Blueberry Creek, and Lake Minnesuing
lowest several miles of the lower river, Casey and Wilson creeks, Rocky Run, and the East Fork
lowest several miles of the lower river
lowest several miles of the lower river
entire mainstem and the larger tributaries
most common in the lowest several miles of the lower river but occasionally as far upstream as Winneboujou
slow, deep sections of the mainstem, Nebagamon Creek, and lakes Nebagamon and Minnesuing lowest mile of the lower river
lowest mile of the lower river and Lake Minnesuing
one specimen reported from the lower river at McNeil's Bridge
lower river below the lamprey barrier
lakes Nebagamon and Minnesuing, uncommonly reported from scattered lotic sections
midsection and lower river except for extreme lowermost section and most of the tributaries
lowest mile of the lower river
occurrence/extent of reproduction in the Brule River system is unknown; probably strays from others waters
the larger tributaries and most of the mainstem, except for the extreme uppermost and lowermost sections
midsection of the mainstem and Nebagamon and Blueberry creeks
upper river mostly above Stone's Bridge, Rocky Run, Blueberry Creek, Jerseth Creek, East Fork
entire mainstem (but less common in the extreme uppermost and lowermost sections) and the larger tributaries

Table 1. continued

Common Name	*Scientific Name*	*Origin*	*Relative Abundance*[1]	*Information sources*[2]
SALMONIDAE (CONT.)				
Pink Salmon	*Oncorhynchus gorbuscha*	Exotic	R	SC
Brook Trout	*Salvelinus fontinalis*	Native	A	AU;FB;GR;LB;MC;MO;OD;WI
Lake Trout	*Salvelinus namaycush*	Native	R	LB
Splake	Lake trout X Brook trout	Exotic Hybrid	U	LB
Lake Herring	*Coregonus artedi*	Native	R	MO; WI
Round Whitefish	*Prosopium cylindraceum*	Native	U	AU; LB; MO
PERCOPSIDAE				
Trout-perch	*Percopsis omiscomaycus*	Native	U	AU; LB; MC; MO; OD; WI
GADIDAE				
Burbot	*Lota lota*	Native	O	AU; LB; MC; MO; WI
GASTEROSTEIDAE				
Brook Stickleback	*Culaea inconstans*	Native	C	AU; FB; GR; MO; OD; WI
Ninespine Stickleback	*Pungitius pungitius*	Native	R	MO; WI
COTTIDAE[5]				
Mottled Sculpin	*Cottus bairdi*	Native	A	AU; FB; GR; MC; MO; OD; WI
Slimy Sculpin	*Cottus cognatus*	Native	A	AU; GR; MO; WI
CENTRARCHIDAE				
Smallmouth Bass	*Micropterus dolomieu*	Native	C	AU; FB; GR; LB; MC; MO; WI
Largemouth Bass	*Micropterus salmoides*	Native	C	AU; FB; GR; MO; WI
Pumpkinseed	*Lepomis gibbosus*	Native	A	AU; FB; GR; MC; MO; WI
Bluegill	*Lepomis macrochirus*	Native	A	AU; FB; GR; LB; MO; OD; WI
Rock Bass	*Ambloplites rupestris*	Native	C	AU;FB;GR;LB;MC;MO;OD;WI
Black Crappie	*Pomoxis nigromaculatus*	Native	A	AU; FB; MO; WI
PERCIDAE				
Walleye	*Stizostedion vitreum*	Native	C	AU; FB; LB; MC; MO; OD; WI
Yellow Perch	*Perca flavescens*	Native	A	AU;FB;GR;LB;MC;MO;OD;WI
Logperch	*Percina caprodes*	Native	O	AU; LB; MC; MO; OD; WI
Johnny Darter	*Etheostoma nigrum*	Native	C	AU; FB; GR; MC; MO; OD; WI
Iowa Darter	*Etheostoma exile*	Native	R	AU; FB; GR; MO; WI
Ruffe	*Gymnocephalus cernuus*	Exotic	C	LB; PR

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[1] A = abundant – species often collected in large numbers.
C = common – species often collected in moderate numbers.
O = occasional – species occasionally collected in moderate or small numbers.
U = uncommon – species infrequently collected in small numbers.
R = rare – species collected at rare intervals in very small numbers.

[2] AU – authors collections; CH – Churchill 1945; FB – WDNR Fisheries Management file data (Brule Area Office); GR – Greene 1935; LB – WDNR lamprey barrier trap 1986–1993; MO – Moore and Braem 1965; MC – McLain et al. 1965; PR – Pratt et al. 1992; OD – O'Donnell and Churchill 1954; SC – Scholl et al. 1984; SG – Schuldt and Goold 1980; US – USFWS data files (J. Heinrich, pers. comm.); WI – Wisconsin Fish Distribution Study (cited by Fago 1992).

[3] O'Donnell and Churchill (1954) reported the golden redhorse *(Moxostoma erythrurum)* to be common in the estuary; based on current distribution information this is likely to have been a misidentification– their specimens probably were shorthead redhorse or silver redhorse.

Main Areas of Distribution
not consistently reproducing in the Brule River system snce 1979; rarely strays from other waters
upper river and most of the tributaries
transient from Lake Superior into the lower river up to the lamprey barrier
transient from stocking programs elsewhere in Lake Superior
lowest mile of the lower river
lowest several miles of the lower river
lower river, becoming increasingly common towards the mouth
lower river below the lamprey barrier
scattered throughout the mainstem and most of the tributaries in weedy, slow-water areas
lowest mile of the lower river
entire mainstem but least common in cold, headwater areas; Trask, Blueberry, and Nebagamon creeks
colder tributaries and headwater areas; present but less common throughout most of the mainstem
lakes Nebagamon and Minnesuing; rarely reported from scattered mainstem and tributary areas
lakes Nebagamon and Minnesuing; rarely reported from scattered mainstem areas
lakes Nebagamon and Minnesuing; rarely reported from scattered mainstem and tributary areas
lakes Nebagamon and Minnesuing, and Nebagamon Creek; rarely reported from scattered mainstem areas
lakes Nebagamon and Minnesuing, and Nebagamon Creek; rarely reported from scattered mainstem areas
lakes Nebagamon and Minnesuing; rarely reported from scattered mainstem and tributary areas
lakes Nebagamon and Minnesuing; uncommonly reported from the lower river below the lamprey barrier
lakes Nebagamon and Minnesuing, and Nebagamon Creek; rarely reported from the lower river below the lamprey barrier
lower river up to the lamprey barrier
entire mainstem, Trask and Blueberry creeks, East Fork, West Fork, and Lake Minnesuing
lowest mile of the lower river, Blueberry Creek, and Lake Minnesuing
lower river below the lamprey barrier; most common in the estuary

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[4] In the early 1900s, some specimens of grass pickerel *(Esox americanus)* were reported from Lake Nebagamon (Fago 1992). These reports were probably erroneous because Lake Nebagamon is well outside of the known range of this species, and in early years northern pike were sometimes referred to as grass pickerel and walleye were often called pickerel. It is possible that true grass pickerel were introduced into Lake Nebagamon, but that a viable population failed to become established.

[5] There appear to be overlapping distributions of mottled and slimy sculpins throughout the mainstem and in the tributaries, with mottled sculpins predominating in the mainstem and the warmer tributaries and slimy sculpins predominating in the colder tributaries. Although the limited data collected are consistent with this pattern, the conclusion is tentative because separation of these species in the field is difficult and specimens from relatively few sites were examined in the laboratory.

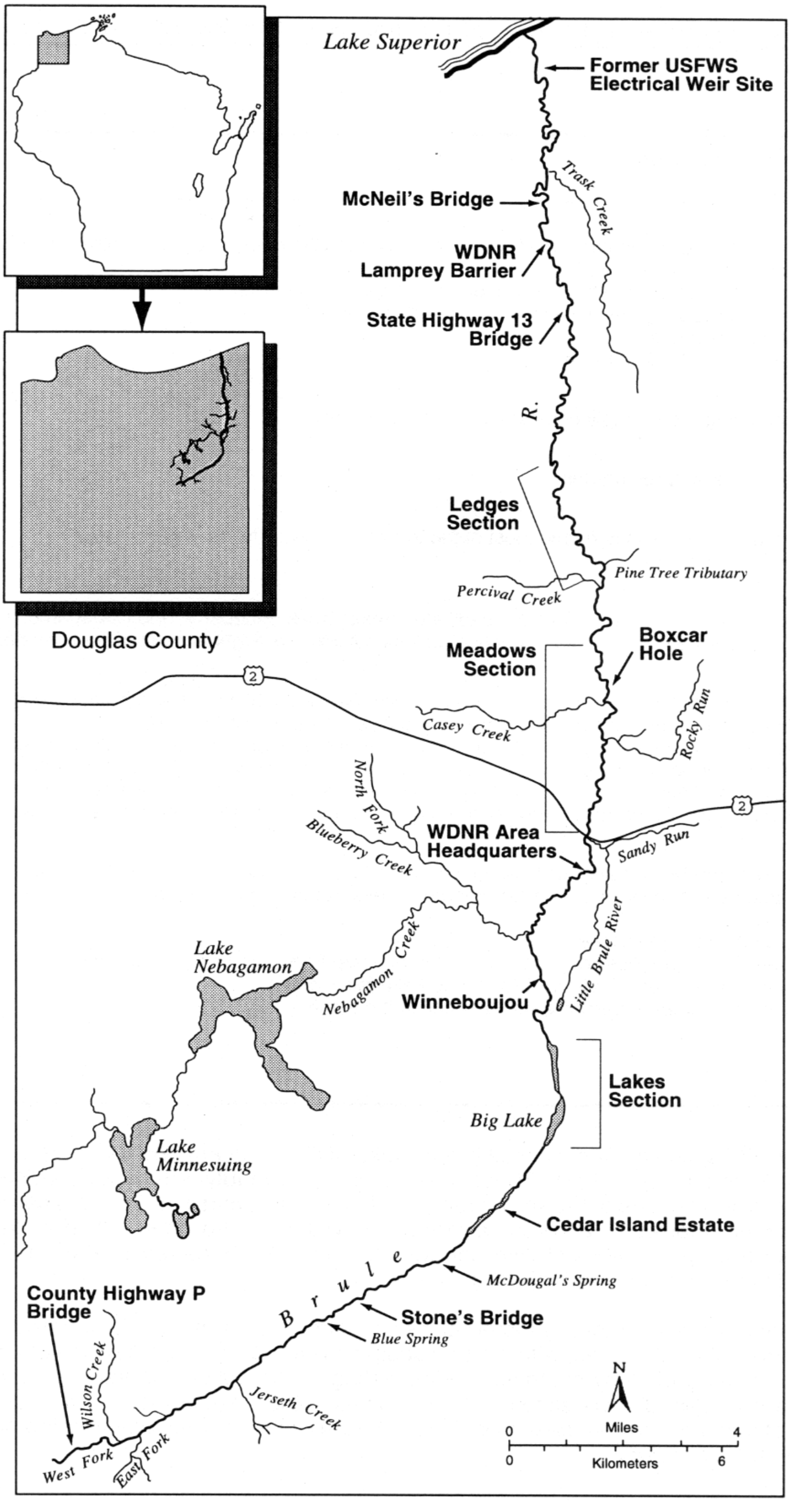

Fig. 1. Map of the Bois Brule River study area including major tributaries

cooler in summer and warmer in winter than most streams its size (both characteristics are most evident in the upper reaches). The lower river flows through a region of red clay that contributes high runoff and associated turbidity and siltation to this section during pluvial periods. A longitudinal gradient of water temperature consists of less thermal moderation as the river proceeds to its mouth. In winter, the lower river is heavily ice-covered, and during warm summers, water temperature in the lowest section is marginal for salmonids. Patterns of spring flow and water temperature probably existed historically much as they do today. The physical and chemical characteristics of the river system are summarized in Table 2; more detailed descriptions of the geology and topography of the watershed (Bean and Thomson 1944; Dickas and Tychsen 1969), the forest cover types within the Brule Valley (Fassett 1944; Thomson 1945), and the chemical aspects of the river system (Bahnick et al. 1969) are also available.

History of Human Activity Within the Brule River Watershed as Related to the Fish Community

The Brule River is renowned for its relatively undisturbed natural setting, and indeed it has weathered human encroachment with less disturbance than most large streams in Wisconsin. Nonetheless, changes to its physical setting have occurred during the last century that may have affected the fish community. Early accounts of explorers' journeys up the Brule River mention the presence of one hundred or more beaver *(Castor canadensis)* dams that had to be broken through (Marshall 1954). Locations of these dams are not given, but they were probably most abundant in the upper river above the Cedar Island estate area (Fig. 1). Beaver were heavily trapped in 1803–04, and the dams were subsequently removed by the military to facilitate use of the river as a water route between the Great Lakes and the Mississippi River prior to the development of a military road network (Marshall 1954). These dams may have hindered brook trout movement to spawning areas (Marshall 1954), and accounts reporting excellent trout fishing are commonly found only after removal of most dams in about 1830 (O'Donnell 1944; Marshall 1954; Jerrard 1956).

Aboriginal fish harvest from the Brule River for centuries had undoubtedly been modest; recent research indicates that the Chippewa who settled along the southern littoral of Lake Superior did not rely on fish for their primary subsistence (Kaups 1984). Access to the river for European settlers prior to about 1850 was by water along Lake Superior, mostly from the city of Superior (Marshall 1954). Travel upriver was time-consuming and arduous, and the bark canoes used required skillful handling and frequent repair from damage caused by striking rocks. Hence, the brunt of early fishing probably took place near the mouth of the river. The first record of fish caught from the Brule River comes from the journal of Michel Curot who set two gill nets near the mouth of the river in 1804 and caught eight unidentified fish (Wisconsin Historical Society 1911).

Increased angling pressure on other sections of river began when overland access improved following the cutting of a crude wagon trail from St. Paul to Bayfield in 1850 (Marshall 1954). This trail passed through the town of Gordon (then called Amik), and an early road cut from Gordon to the Brule River about two miles south of Cedar Island soon followed (Marshall 1954). As early as 1855, canoes and Mackinaw boats complete with crews for fishing were advertised for hire in the

Table 2. Mean physical and chemical characteristics of the lower Brule River[1], the upper Brule River[2], and 14 tributaries for which reliable fish distribution information exists (compiled from data collected by the authors, from Fisheries Management files [Brule Area and Superior Offices], or from Sather and Johannes 1973; n/a means no data available).

Mainstem Section Or Tributary	*Mean Width (ft)*	*Mean Depth (inches)*	*Estimated Normal Discharge (ft^3/s)*	*Mean Gradient (ft/mile)*	*pH*	*MPA (ppm)*	*Specific Conductance @ 77°F (umhos)*	*Approximate Maximum Summer Water Temperature (°F)*
Lower River	66	30	221	13	7.7	66	119	high 70’s
Upper River[3]	54	30	97	6	7.5	45	106	high 60’s
Trask Creek	7	6	2	55	7.6	123	237	at least mid 70’s
Casey Creek	10	7	1	40	7.0	49	106	at least mid 70’s
Percival Creek	4	2	<0.5	111	7.3	100	213	n/a
Pine Tree tributary	3	4	<0.5	264	n/a	n/a	n/a	n/a
Rocky Run	10	7	2	90	7.5	105	142	low 60’s
Sandy Run	7	6	7	47	7.4	99	161	low 60’s
Little Brule River	17	10	12	20	7.3	66	91	mid 60’s
Nebagamon Creek	21	10	20	20	7.1	41	91	high 70’s
Minnesuing Creek	20	10	3	2	7.3	45	98	at least high 70’s
Blueberry Creek	11	10	5	29	6.4	26	70	low 70’s
Jerseth Creek	5	4	1	71	7.2	43	84	high 50’s
Wilson Creek	4	5	2	50	7.0	36	80	mid 60’s
West Fork	15	6	2	5	7.3	66	134	low 70’s
East Fork	15	14	4	23	7.3	42	83	high 50’s

[1] Lower river refers to the stretch of river from U. S. Highway 2 north to Lake Superior

[2] Upper river refers to the stretch of river from U. S. Highway 2 south to the confluence of the East and West forks

[3] excluding Big Lake

Superior newspaper *(Superior Chronicle,* August 28, 1855). A fishing excursion on the Brule River in 1862 was reported to have caught “a lot of trout weighing from four to five pounds each” *(Superior Chronicle,* August 23, 1862).

The period from 1870 through 1890 is noteworthy in the history of the Brule River because means of transportation for reaching the river improved dramatically, the countryside around the river was rapidly “filling up with immigrants” (Marshall 1954), and recreational use of the river steadily increased from that time on (Holbrook 1949; Marshall 1954). In 1870, the Bayfield trail was cut from Superior to Bayfield, and it quickly became an important artery (Marshall 1954; Jerrard 1956). Near the Brule River the Bayfield trail followed the Copper Range and crossed the river about two miles south of the present County Highway FF bridge. At first, this trail was usable by wagon only in winter until it was improved in 1876. During the early 1870s, Alexander McDougall caught bushels of trout through the ice from the Cedar Island spring ponds and shipped them by dogsled to the Bayfield trail, then by horse team to markets in Duluth (Marshall 1954). Several articles in the *Superior Times* during the mid-1870s indicated that angling parties were making fine sport catches from the river. During the 1880s another wagon trail was cut from the town of Solon Springs (then called White Birch) to the Blue Spring area of the upper river just south of Stone’s Bridge. Access to the river was eased further by the development of a railway system. The Northern Pacific rail line from Duluth to Ashland was laid in 1883; this train crossed the river at the newly established town of Brule (Marshall 1954). In 1892, the laying of the Duluth and South Shore Railroad crossed the river at Station Rapids just south of the present County Highway B bridge (Marshall 1954). By 1884, Joe Lucius was operating a guiding service for anglers on the river, and by 1900, the river had been “well discovered by anglers” (Marshall 1954). Roads in the Brule area were first passable by automobile in 1914.

Much of the virgin timber within the Brule River valley was clear-cut beginning in the early 1890s; this activity ushered in a new era of human perturbation and development in the region (Jerrard 1956). Two logging dams (also called splash dams), one near the mouth of the river and the other about two miles north of the town of Brule (near the present Boxcar Hole), were built to facilitate movement of logs downriver (Marshall 1954; Jerrard 1956). These dams, although thought to be short-term, appear to have blocked the migration route of coaster brook trout at critical times and contributed to decline of the fishery (O’Donnell 1944). Also significant was damage caused to the streambed and shoreline areas when the dams were breached and large numbers of logs were run swiftly downstream (Marshall 1954). The extent of siltation, erosion, and subsequent flooding caused by timber cutting in riparian areas is uncertain but likely was substantial. Clearly, the logging dams and lumbering operations negatively affected the fishing, and fishing improved when these activities were terminated (O’Donnell 1944; Jerrard 1956). The late 1800s and early 1900s also saw increasing human activities regarding agriculture, road construction, and delivery of utilities within the watershed; the extent to which these activities may have harmed the fish populations is unknown.

The written record of human dwellings in the Brule River Valley begins with a Chippewa village at the mouth of the river during the late-1850s that exported large quantities of Lake Superior fish by sailing sloop (Marshall 1954). At about the same time, several commercial fishers of European descent also maintained their fishing stations there, and exported large quantities of whitefish (*Coregonus clupeaformis*), siscowet (a “fat” morph of lake trout, *Salvelinus namaycush*), and lake trout *(Superior Chronicle,* May 1, 1859; also *Superior Times,* July 15, 1875). In 1880, Samuel Budgett established the town of Clevedon at the same location, but this community persisted for only about five years. Land on the present Cedar Island Estate was purchased in 1877 by two Minnesota men for the purpose of using the series of spring ponds on the property to commercially raise brook trout (*Superior Times,* January 27, 1877). In the late 1870s Frank Bowman built a cabin on this property (Marshall 1954). During the early 1880s, Henry Clay Pierce added to the now extensive Cedar Island Estate, and the first of the Winneboujou Club cabins were built. These were the first of the long-term dwellings that sprang up along the banks of the Brule River during the 1880s (Marshall 1954; The Winneboujou Club 1990). By the early 1900s, most of the permanent dwellings that now exist along the upper river had been completed. On the entire length of river, about four dozen permanent dwellings can now be found; this number is slowly shrinking as properties become available for public ownership through the state’s land acquisition program.

In 1905, Pierce created a large fish hatchery at Cedar Island by blocking off the extensive system of interconnected spring ponds from the river; this action greatly reduced the amount of spawning area for the upper river brook trout population. These spring ponds had gravel bottoms with areas of upwelling ground water that provided excellent spawning habitat. Early accounts (summarized by O’Donnell 1944) affirm that these spring ponds were the primary spawning grounds of the original brook trout population. A major decline in the brook trout fishing apparently started about 1910, about five years after this spawning area was separated from the river proper (Jerrard 1956). Early reports by WDNR fishery workers (O’Donnell 1944; O’Donnell and Churchill 1954) recognized the tremendous spawning potential represented by the Cedar Island spring ponds and recommended state acquisition of the ponds to make them accessible once again as natural spawning grounds.

The State of Wisconsin built a fish hatchery on the Little Brule River, at about its midpoint (Fig. 1), in 1928. Still operating, this hatchery has always been used to meet statewide demands for domestic salmonids. It uses the entire flow of the Little Brule River for its water supply and creates a complete barrier to upstream fish movement. Run-of-the-river fish hatcheries like the ones on the Little Brule River and at Cedar Island, in addition to the positive effect of producing fish, have the potential to affect ecosystem health in negative ways as well. They can cause localized habitat destruction by their placement, downstream water pollution by their operation, and present a risk for disease outbreaks that can spread to adjacent wild populations. Although they have reduced critical habitats, there is no evidence to suggest that either hatchery within the Brule River system has negatively affected ecosystem health through disease outbreaks or substantial pollution.

The Brule River ecosystem is subject to considerable recreational activity apart from fishing, the byproducts of which could conceivably impact the fish community. Recreational canoe and kayak use is seasonally heavy, averaging about 13,000 people annually over the last ten years on the upper river alone, and use on the lower river is probably similar in magnitude (C. Zosel, WDNR, pers. comm.). The relatively pristine setting of the upper river, having two stretches exceeding eight miles in length without road crossings, provides a rare canoeing experience. Litter resulting inadvertently from spills is substantial given the volume of boat traffic. Tubing was a popular activity on the Brule River before it was banned in 1981 because of conflicts between tubers and other river users, and a myriad of other concerns. Issues of crowding and potential conflicts between anglers and recreational canoers have frequently surfaced and may ultimately need to be addressed by managers through some sort of usage allotment system as increases in both activities continue. Campgrounds on the middle and lower sections of river also draw numbers of recreationists into the watershed.

Ecological Investigations on the Brule River Watershed

While the Brule River has received fame as a quality trout stream, its history has been interspersed with perceived declines in fishing quality (Schneberger and Hasler 1944). Consequently, the river has been the focus of many studies to preserve and restore the fishery. These efforts have compiled a wealth of information about physical, chemical, and biological aspects of the river.

In the early 1940s, the Brule River and its watershed were subjected to one of the most exhaustive interdisciplinary studies ever done on a Wisconsin stream. The intent was to evaluate the physical, biological, and chemical characteristics of the watershed so that an efficient and well-balanced management plan could be developed by the WDNR (then the Wisconsin Conservation Department, WCC). Eleven technical papers were subsequently published in the *Transactions of the Wisconsin Academy of Sciences, Arts and Letters;* these were later reissued as one collection (Wisconsin Conservation Department 1954). Topics covered included: topography and geology of the Lake Superior basin (Bean and Thomson 1944); vegetation of the watershed (Fassett 1944; Thomson 1945); a history of fishing (O’Donnell 1944); a survey of the aquatic plants and bank flora (Thomson 1944); parasites found on fishes (Fischthal 1945); results of a four-year creel census (O’Donnell 1945); bottom sediments (Evans 1945); biology of the northern brook lamprey, *Ichthyomyzon fossor* (Churchill 1945); and physical, chemical, and biological attributes of the river as habitat for trout (O’Donnell and Churchill 1954). In 1946, a brief summary of fishery recommendations emerged which constituted the first WDNR management plan for the river. Recommendations included stocking guidelines, public acquisition of the Cedar Island spring ponds, an extended autumn season on the lower river, initiation of creel and trout population surveys, and several riparian protection and erosion control measures.

Early efforts by the WDNR to sample fishes using weirs occurred at Stone’s Bridge and near the WDNR Ranger Station in 1943 (O’Donnell and Churchill 1954) and again at Stone’s Bridge in 1958–60 (Fallis and Niemuth 1962). During 1961–64, intensive investigations of the anadromous brown trout and steelhead populations by the WDNR (Niemuth 1967, 1970) provided the first substantial data set from which management applications could be drawn. Field work included operation of fish weirs with two-way traps during much of the open-water seasons, electrofishing sampling of some mainstem reaches using mark/recapture techniques to obtain population estimates, and documenting upper river spawning sites. The weir locations were initially below Winneboujou and later just north of U.S. Highway 2. A similar investigation was repeated in 1978–79 (Scholl et al. 1984). This study also included electrofishing surveys of several Brule River tributaries. From 1957 to 1979 the U.S. Fish and Wildlife Service (USFWS) operated an electrical weir one mile above the mouth of the river in an effort to control spawning of sea lamprey. However, in the later years of its use, the TFM (3-tri-fluoromethyl-4-nitrophenol) lampricide program had been developed, and this weir served primarily to monitor the effectiveness of chemical control. Some data on anadromous salmonid populations were obtained from the operation of this weir (Scholl et al. 1984); however, its operation caused an increased incidence of spinal deformities to the salmonid populations as the downstream-migrating smolts passed through the electric field (Devore and Eaton 1983) and may have contributed to mortality of adult spawners as well. Unfortunately, reliable quantitative information about the salmonid populations was difficult to obtain from any of the fish weirs because of malfunctions caused by high water or vandalism during portions of virtually every operating season.

Studies by two University of Wisconsin–Madison graduate students also added to knowledge about Brule River trout. Hunt (1965) studied the importance of surface-drift insects in the trout diet, and Salli (1962, 1974) reported on the early life history of trout species in the lakes sector[3] (Fig. 1).

Efforts to assess the sport fishery were made in 1936, 1940, and in 1943–44 (O’Donnell 1945); in 1948–49 (Brasch 1950); in 1954 (Daly 1954); in 1962–64 (Niemuth 1970); in 1973 (Swanson 1974); in 1978–79 (Scholl et al. 1984); and in 1984, 1986, 1990, and 1992 (this report). Some of these were partial surveys with limited objectives, while others were intended to be comprehensive surveys of the river’s mainstem. However, the size of the river, difficulty of access to some areas, and multiple uses by the public (which can render car and canoe counts unreliable as indicators of pressure), have created difficulties in obtaining reliable estimates of total angling pressure and harvest. Furthermore, comparisons among surveys are difficult because of changing open seasons, daily bag limits, size limits, stocking policies, and survey techniques over time. Results show that angling pressure on the upper river has remained fairly stable during recent years, but pressure has decreased on the lower river since the late 1970s (Table 3). On the upper river, catch rates have increased in recent years, while harvest has declined because of more restrictive regulations and an increased tendency by fly-fishers to voluntary release their catch (Table 3). On the lower river, catch rates have remained fairly stable or declined, while harvest of steelhead and brown trout have declined substantially (Table 3).

The WDNR Bureau of Research initiated a two-year pilot research study in 1983, which was followed by a long-term research initiative (1986–93). Both were carried out jointly with the WDNR Bureau of Fisheries Management. Topics addressed during this research, and the reporting status of the studies, are described in Table 4. This cooperative effort, in conjunction with direction supplied by the Brule River Committee, has contributed to improved management of the Brule River ecosystem.

History of the Fish Community

At least 63 fish species, including 11 exotic species plus one cultured hybrid, have been collected from the Brule River system (Table 1). Important shifts in the fish

Community from the historical condition have unquestionably occurred. These shifts appear to be primarily related to establishment of exotic species (additions of exotics or reductions in populations of native species attributable to sea lamprey control), although the loss of coaster brook trout could be attributed to over-exploitation or blockage of migration routes. Many species have not experienced demonstrable changes in their populations over the last 50 years, suggesting little (if any) change in habitat conditions. These conclusions were reached through a comparison of the fish fauna of 1987–91 with that described from surveys done during the mid-1940s (O'Donnell and Churchill 1954). However, the comparison is valid only for common species because of differences in equipment, survey techniques, and survey effort between the two time periods. Early surveys were less intensive than surveys done from 1987–91, and early electrofishing gear was less efficient. Hence, we have assumed that uncommon species not reported by O'Donnell and Churchill (1954) were missed by their sampling (as opposed to not being present).

Among the lampreys (Petromyzontidae) the differences between time periods are striking, with two species of native lampreys suffering from greatly reduced distributions and population densities. Northern brook lamprey were abundant in the 1940s (Churchill 1945), but we found no specimens during electrofishing surveys in the Brule River system in recent years. Silver lamprey *(Ichthyomyzon unicuspis)* were once plentiful in the lower river (McLain et al. 1965), but only a few specimens were found there in the 1970s (Schuldt and Goold 1980). The only silver lamprey we have seen in the Brule River was a specimen attached to a migratory brown trout that could have originated elsewhere. Using specialized gear and techniques developed for sampling lampreys, USFWS personnel have collected three adult northern brook lampreys from one mainstem area and Minnesuing Creek over the last thirty years (J. Heinrich, USFWS, pers. comm.). They have also collected moderate numbers of ammocoetes of *Ichthyomyzon* from Minnesuing Creek and the upper section of Nebagamon Creek, as well as small numbers of specimens from scattered mainstem areas. These specimens could be northern brook lamprey, silver lamprey, or some combination of the two. (It is not presently possible to identify *Ichthyomyzon* ammocoetes to species.) These species were seriously impacted by lampricide treatments aimed at controlling the sea lamprey (Table 1 – see also section on the sea lamprey and the effects of control efforts). Sea lamprey are now common downstream of the barrier/fishway, but were not yet established in the 1940s.

The most common minnow species (Cyprinidae) do not appear to have changed in either relative abundances or distributions since the 1940s. A number of occasional, uncommon, or rare species reported here (Table 1) were not reported by O'Donnell and Churchill (1954), but this difference is attributed to less efficient sampling during the 1940s. Shifts in population distributions of two less-common minnow species may have occurred. The northern redbelly dace (*Phoxinus eos*) occurred in the upper part of the mainstem in the 1940s, but in 1987–91 was confined to the lower river and tributaries. Similarly, the common shiner (*Luxilus cornutus*) was found in deeper sections of the upper river in the 1940s, but we found it only in the lower river below the barrier/fishway.

Among the salmonids no major changes in distributions of brook trout or steelhead

Table 3. Angling pressure, catch, and harvest statistics for upper and lower sections meaningful comparisons). Steelhead throughout the river system and brown trout from marily of anadromous adults, whereas the < 13" categories are primarily stream-resi- (reported in the "all brown trout" category only).

	Lower River				
Category	*1973*	*1978–79*	*1984*	*1986*	*1990*
Angling Pressure					
Trips per Mile	n/a	1,440	1,183	887	739
Hours per Mile	n/a	5,314	4,365	3,274	2,726
Total Hours	n/a	132,847	109,122	81,856	68,140
Catch per Hour					
Brook Trout	n/a	n/a	0.007	0.009	0.002
Steelhead (≥ 13")	n/a	n/a	n/a	0.030	n/a
Steelhead (< 13")	n/a	n/a	n/a	0.037	n/a
Steelhead (all)	n/a	n/a	0.098	0.067	0.100
Brown Trout (≥ 13")	n/a	n/a	n/a	0.007	n/a
Brown Trout (< 13")	n/a	n/a	n/a	0.013	n/a
Brown Trout (all)	n/a	n/a	0.015	0.020	0.004
Pacific Salmon	n/a	n/a	0.001	0.005	0.002
All Species	n/a	n/a	0.121	0.101	0.108
Harvest per Hour					
Brook Trout	n/a	n/a	0.004	0.007	0.002
Steelhead (≥ 13")	n/a	0.056	0.033	0.019	n/a
Steelhead (< 13")	n/a	0.027	0.002	0.007	n/a
Steelhead (all)	n/a	0.083	0.035	0.026	0.032
Brown Trout (≥ 13")	n/a	0.003	0.002	0.004	n/a
Brown Trout (< 13")	n/a	0.004	0.008	0.003	n/a
Brown Trout (all)	n/a	0.007	0.010	0.007	0.001
Pacific Salmon	n/a	n/a	0.001	0.005	0.002
All Species	n/a	n/a	0.050	0.045	0.037
Harvest per Mile					
Brook Trout	1.8	n/a	15.5	21.4	4.8
Steelhead (≥ 13")	189.0	299.6	143.5	63.8	n/a
Steelhead (< 13")	89.0	141.0	10.0	22.7	n/a
Steelhead (all)	278.0	440.6	153.5	86.5	86.4
Brown Trout (≥ 13")	16.5	17.7	9.7	14.7	n/a
Brown Trout (< 13")	8.4	19.7	36.6	9.4	n/a
Brown Trout (all)	24.9	37.4	46.3	24.1	4.1
Pacific Salmon	4.2	n/a	4.2	17.7	4.6
All Species	308.9	n/a	219.5	149.7	99.9

[1] See section on regulations for daily bag and size limits in effect during each survey year; sampling periods for the surveys included the entire regular open seasons on the upper river in 1973, 1984, 1986, and 1992, and the regular open seasons plus extended early and late seasons on the lower river in 1973, 1984, 1986. In 1990 the survey period on the lower river coincided with the spring and autumn anadromous salmonid runs and was not extended through the summer; also sampled was the time interval 1 July 1978–30 June 1979 during the regular and extended seasons on the upper and lower sections of river.

of the Bois Brule River since 19731 (n/a = data not available or insufficient to provide the lower river are reported in two categories; the ≥13″ categories are comprised pri- dent or juvenile anadromous forms. This distinction is invalid for upper river brown trout

Upper River				
1973	*1978–79*	*1984*	*1986*	*1992*
n/a	284	436	297	310
n/a	1,354	2,081	1,414	1,482
n/a	17,599	27,054	20,108	19,271
n/a	n/a	0.208	0.296	0.650
n/a	n/a	n/a	0.004	0.018
n/a	n/a	n/a	0.195	0.190
n/a	n/a	0.097	0.199	0.208
—	—	—	—	—
—	—	—	—	—
n/a	n/a	0.057	0.067	0.149
n/a	n/a	0.002	0.007	0.021
n/a	n/a	0.364	0.568	1.028
n/a	n/a	0.105	0.095	0.059
n/a	0.014	0.001	0.001	0.006
n/a	0.026	0.028	0.021	0.001
n/a	0.040	0.029	0.022	0.007
—	—	—	—	—
—	—	—	—	—
n/a	0.043	0.032	0.037	0.022
n/a	n/a	0	0.005	0.002
n/a	n/a	0.166	0.159	0.090
73.6	n/a	218.7	147.2	88.2
4.1	19.5	2.0	1.4	8.8
148.8	34.5	58.8	32.6	0.8
152.9	54.0	60.8	34.0	9.6
—	—	—	—	—
—	—	—	—	—
66.9	58.6	66.1	56.8	33.2
0	n/a	0	7.2	2.3
293.4	n/a	345.6	245.2	133.3

Table 4. Topics addressed during the 1984—93 research initiative

Topic	*Reporting Status*
A bibliography of fishery-related references	DuBois 1989
Fecundity of steelhead from western Lake Superior	DuBois et al. 1989
Annual monitoring of adult anadromous salmonid run sizes, age structure, and migration timing using a fish trap at the lamprey barrier	file data in the WDNR Superior Office (D. Pratt contact) will be formally reported at a later date
Investigation of density, biomass, age and growth, and species composition of stream-resident and juvenile anadromous salmonids within discrete habitat zones	DuBois et al. in press
Sampling wild salmonid smelts	DuBois et al. 1991; other reports in preparation
Experiment to determine the effectiveness of planting hatchery-reared steelhead smolts of Brule River origin	file data in the WDNR Superior Office (D. Pratt contact), file report forthcoming
Evaluation of recent and historical habitat improvement efforts	DuBois and Schram 1993; this report summarizes all efforts to date
creel surveys done in 1984, 1986, 1990, and 1992	unpublished file report in preparation; this report
Status of the aquatic insect community	DuBois 1993; DuBois and Rackouski 1992
The effects of lampricide treatments on the salmonids and their aquatic invertebrate food source	DuBois and Plaster 1993; DuBois and Blust 1994

between time periods were apparent. Brown trout were reported to be most abundant in the lower half of the river system in the 1940s (O'Donnell and Churchill 1954); however, based on the habitat needs and present distribution of this species we doubt this observation was accurately recorded. More recently, brown trout have been most common in the middle and upper reaches of the river. Populations of Pacific salmon have become established only since the early 1970s. Among the Esocidae, the northern pike (*Esox lucius*) was reported as being moderately common in some upper river areas (O'Donnell and Churchill 1954), whereas we encountered them only rarely from 1987–91. However, we did not effectively sample the areas having the best habitat conditions for northern pike (the lakes section[3]). The reasons for these apparent population shifts are unknown, but do not seem to be habitat-related.

Exotic species have changed the complexion of the fish community of the Brule River in major ways. Exotic salmonids have diversified the predator complex and, consequently, the angling opportunities. These salmonids gained access either through deliberate introductions to the river itself (brown trout, steelhead) or to other Lake Superior areas (Atlantic salmon [*Salmo salar*], chinook salmon, coho salmon, pink salmon [*Oncorhynchus gorbuscha*]). Other species gained access to the river unintentionally through a variety of avenues including the opening of the St. Lawrence Seaway via the Welland Canal (sea lamprey, American eel [*Anguilla rostrata*]), population expansion from introductions to connecting waters of the Great Lakes (rainbow smelt [*Osmerus mordax*], common carp [*Cyprinus carpio*]), or from the release of ballast water from transoceanic vessels in the Duluth/Superior harbor (ruffe [*Gymnocephalus cernuus*], Pratt et al. 1992). The establishment of exotic species in the Brule River has had mixed effects that have sometimes been difficult to assess, with some additions regarded positively (the salmonids), but others causing concern. For example, the sea lamprey has been the focus of expensive control efforts in Lake Superior tributaries for over thirty years, and the ruffe, while viewed as a limited threat to the Brule River ecosystem, may ultimately warrant control efforts in some areas of Lake Superior.

Of 52 native species, only 21 (40%) are primary riverine species with viable populations in lotic areas. The remainder are species that either are primarily found in the lentic habitats of Lakes Nebagamon and Minnesuing, are residents of Lake Superior that occasionally move into the lowest section of the lower river, or are locally rare forms that stray into the river. The longnose gar (*Lepisosteus osseus*), collected once from the river (Table 1), is at the northern periphery of its range in Lake Superior. Lake sturgeon (*Acipenser fulvescens*) have not been reported from the Brule River, but may have entered it historically since they are present in western Lake Superior and are known from nearby rivers. Arctic grayling (*Thymallus arcticus*) were not mentioned in any of the early accounts about the Brule River, but a population (now extinct) existed in Michigan waters of Lakes Superior, Michigan and. Huron (Scott and Crossman 1973). Therefore, Arctic grayling could have strayed into the Brule River, and they are mentioned along with brook trout in regulations pertaining to the river in the early 1890s.

Because the salmonids and the sea lamprey have received the majority of research and management attention, their life histories and interactions in the Brule River ecosystem are described in more detail in the remainder of this section.

Brook Trout

Reports of tremendous fishing for brook trout in the Brule River abound, particularly for the period 1830–1900 (O’Donnell 1944; Holbrook 1949; Marshall 1954). Historical records of angling catches can be unreliable, and must therefore be interpreted cautiously, but the consistency of the early angling records pertaining to brook trout is impressive (summarized by O’Donnell 1944). For example, a U.S. Infantry Lieutenant wrote in 1831 that “the river is exceedingly clear and cold and is filled with thousands of real mountain brook trout.” And in 1846, a geologist charting the region in the interest of mining companies wrote, “It surpasses all other streams in its brook trout, some of them, ... weighing ten pounds. Its waters colder and clearer, if possible than any other river.”

The only salmonid native to the Brule River, brook trout sometimes grew to a large size with reports of 6- to 10-pound fish not uncommon (O’Donnell 1944). That a part of the original brook trout population was of the coaster variety is virtually certain (O’Donnell 1944). This conclusion is consistent with historical information about the life history of brook trout in other Lake Superior tributaries (Bullen 1988). Coasters appear to have been common along the south shore of Lake Superior during the 1800s (Shiras 1935), and the Brule River may have been a major producer.

However, by the 1870s evidence of public concern about overharvest of brook trout in the region was beginning to surface. A quote from the *Superior Times* (February 24, 1876) is illustrative: “while our legislature is devoting time and money to the propagation of fish within the state it is a pity they do not stop the wholesale slaughter of brook trout through the ice in the Lake Superior counties.” By the early 1890s, the Brule River brook trout fishery had begun to decline (O’Donnell 1944). Excessive angling catches undoubtedly occurred frequently during the late 1800s and early 1900s as regulation of recreational angling was very liberal with no daily bag in effect until 1905 (see section on regulation of the fishery). This history of substantial and at times excessive harvest has continued to the present as increases in angling pressure have accompanied increasing harvest restrictions. Hence, over-exploitation is a major factor implicated in the reduction of the brook trout population.

Lumber interests started cutting the virgin timber in the Brule Valley in 1892, and the logging dams they built allegedly damaged the coaster population by blocking their migration route at critical times (O’Donnell 1944). A law was on the books at that time requiring a fishway at any dam or obstruction on the Brule River (Chapter 251, Laws of 1891). Unfortunately, noncompliance was rife, and a 1906 article (quoted by O’Donnell 1944) explicitly states that there were no fishways at the logging dams on the Brule River. Siltation associated with poor forestry practices likely also contributed to the decline of the fishery (Holbrook 1949; Marshall 1954). Interspecific competition with heavily stocked brown trout and rainbow trout during the 1920s and 1930s may have also negatively affected the brook trout population. Coaster brook trout were apparently extirpated from the river by the mid-1940s, with the latest reliable record being of a 24-inch fish observed spawning in the upper river in 1944 (O’Donnell and Churchill 1954).

Efforts to bolster the sagging brook trout fishery included supplemental stocking of domestic strains, which began in 1894 and continued steadily for over 80 years, and introductions of exotic species (early plantings summarized by O’Donnell 1945). Stocking of brook trout was terminated in 1979 because of emerging evidence from the fisheries literature, now even more firmly established, that stocking domestic strains of trout on top of healthy wild populations often has more negative than positive effects (White 1989; Goodman 1990). This represented a major change in management policy which may have contributed to some recent recovery of the brook trout population.

Early records about the strains of brook trout stocked in the Brule River are sketchy, and undocumented plantings by wealthy private citizens or citizen groups may have occurred. Domestic brook trout strains, which have been systematically selected from fast-growing, early-maturing brood stocks, can have a significant reproductive advantage over wild fish. Gene flow from these strains may have altered, to an unknown degree, the genetic structure of the original brook trout population, which was uniquely adapted to the physical setting of the river.

The present brook trout population is largely confined to the upper (southern) half of the river and most of the tributaries (Fig. 2) where ice-free conditions for long stretches during winter provide evidence of abundant spring flow. They exist sympatrically with populations of exotic

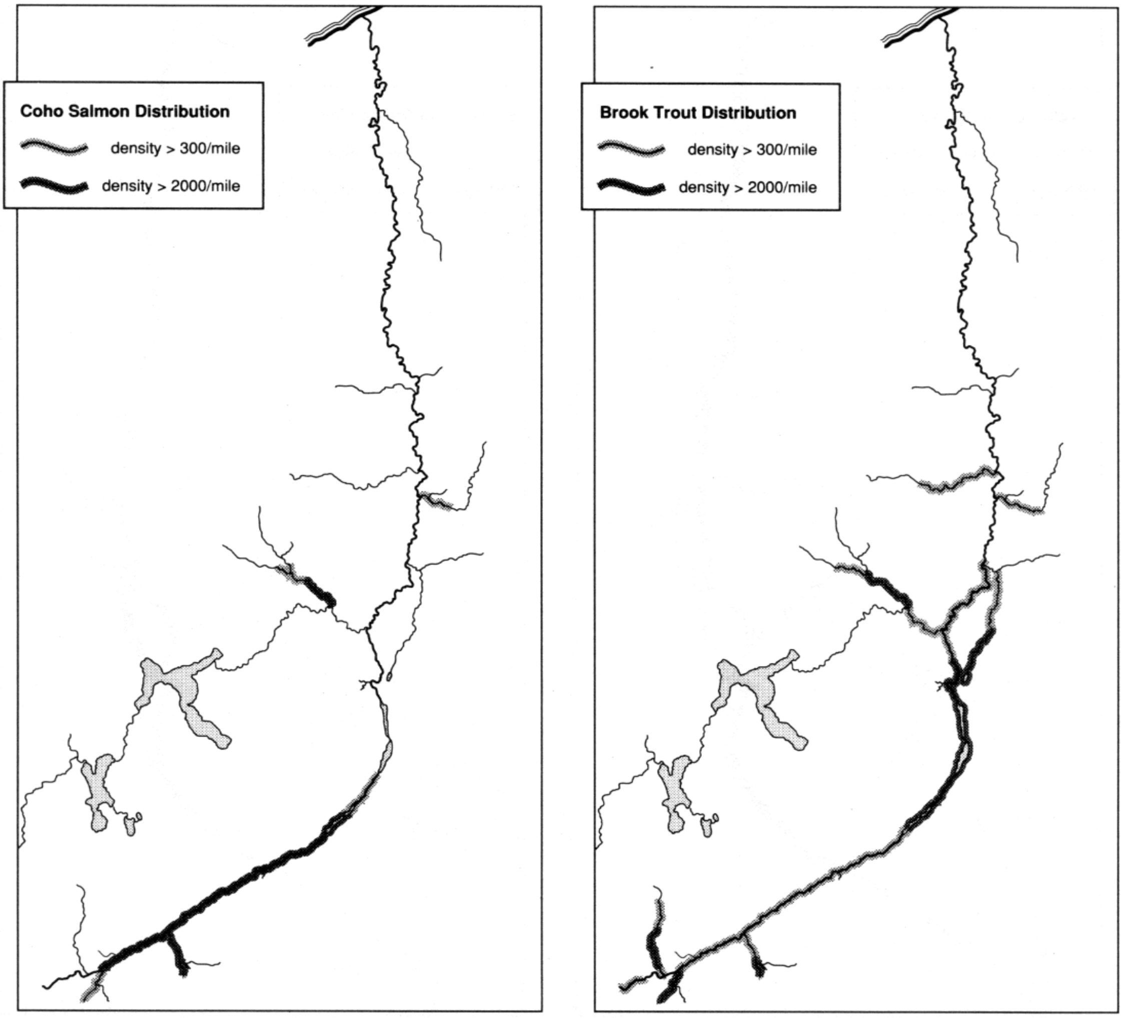

Fig. 2. Present distribution of juvenile coho salmon and brook trout of all age classes in the Bois Brule River system showing areas of highest population density

salmonids in sufficient numbers and sizes to provide acceptable fishing. The Brule River contains the largest population of brook trout of all Wisconsin streams draining into Lake Superior. However, they are the least abundant of the three primary salmonid species in the Brule River system (DuBois et al. in press). Brook trout spawn in slower-flow areas, often near springs where small-sized gravel and the upwelling ground water conditions they require are suitable. Spawning areas in the Brule River have not been well documented, but are probably scattered widely throughout the upper river and several tributaries in spring pond areas and other areas of reduced flow. Spawning likely could be enhanced by dredging spring pond areas adjacent to the main channel along the upper river (Carline 1980).

Steelhead

Steelhead were first introduced to the Brule River in 1892 (O'Donnell 1944), and stocking of a variety of Pacific Coast strains continued periodically through 1981 (see

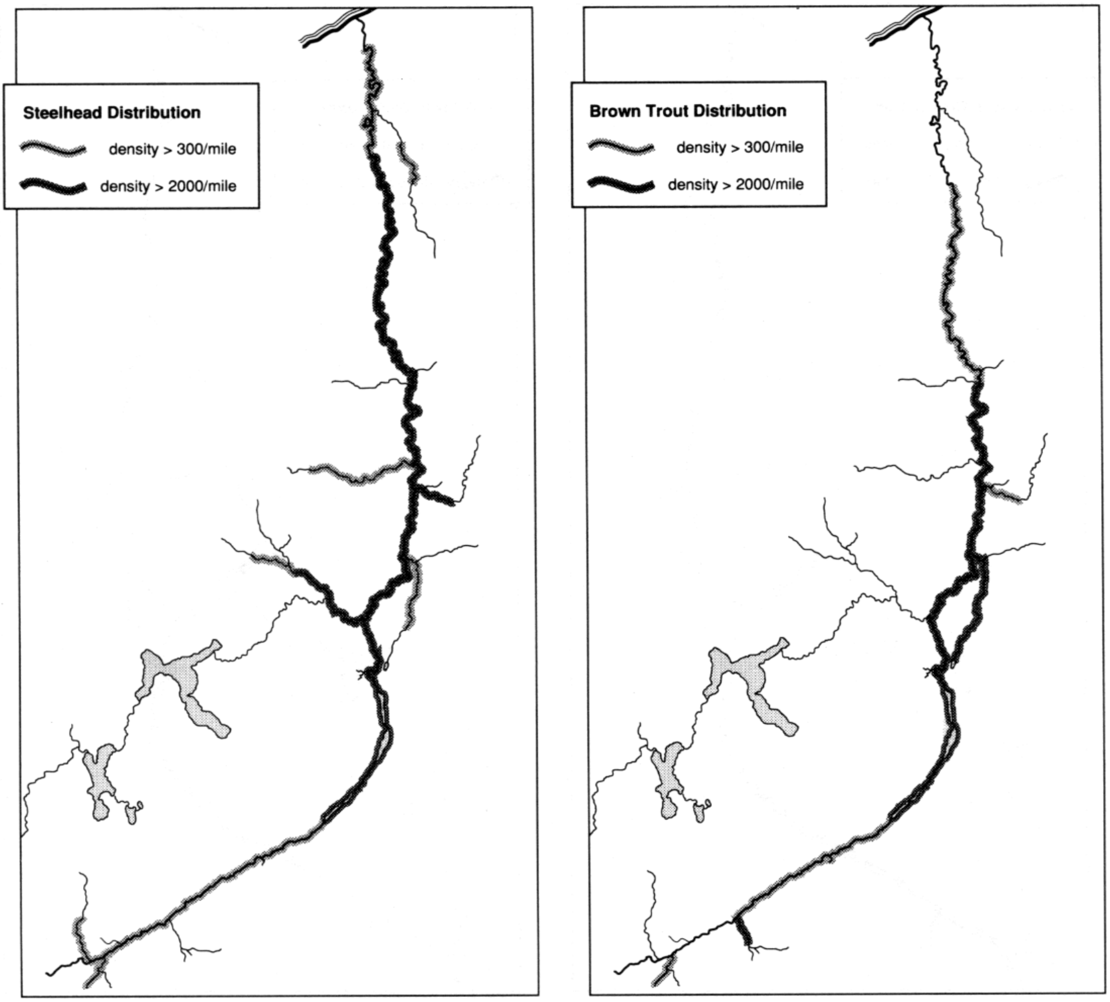

Fig 3. Present distribution of juvenile steelhead and brown trout of all age classes in the Bois Brule River system showing areas of highest population density

MacCrimmon and Gots 1972, and Krueger and May 1987a). Steelhead have become the most abundant salmonid in the river system (DuBois et al. in press). This species has a strong migratory tendency, and it appears that the entire Brule River population is anadromous, although this apparently was not the case originally (O'Donnell 1944). Steelhead inhabit most of the river system as juveniles (Fig. 3), but descend into Lake Superior as smolts after one, two (usually), or three summers in the river. Once in the lake, these fish grow to a large size and then return to the river to spawn after one, two, or three more years. Upon reaching maturity they spawn annually (Swanson 1985), with a few spawning every other year (Seelbach 1993).

About 15 major spawning areas used by steelhead were identified by O'Donnell and Churchill (1954) and Niemuth (1967, 1970) in riffle areas between Stone's Bridge and Winneboujou. Spawning in the lower river is even more significant, but it is more diffi-

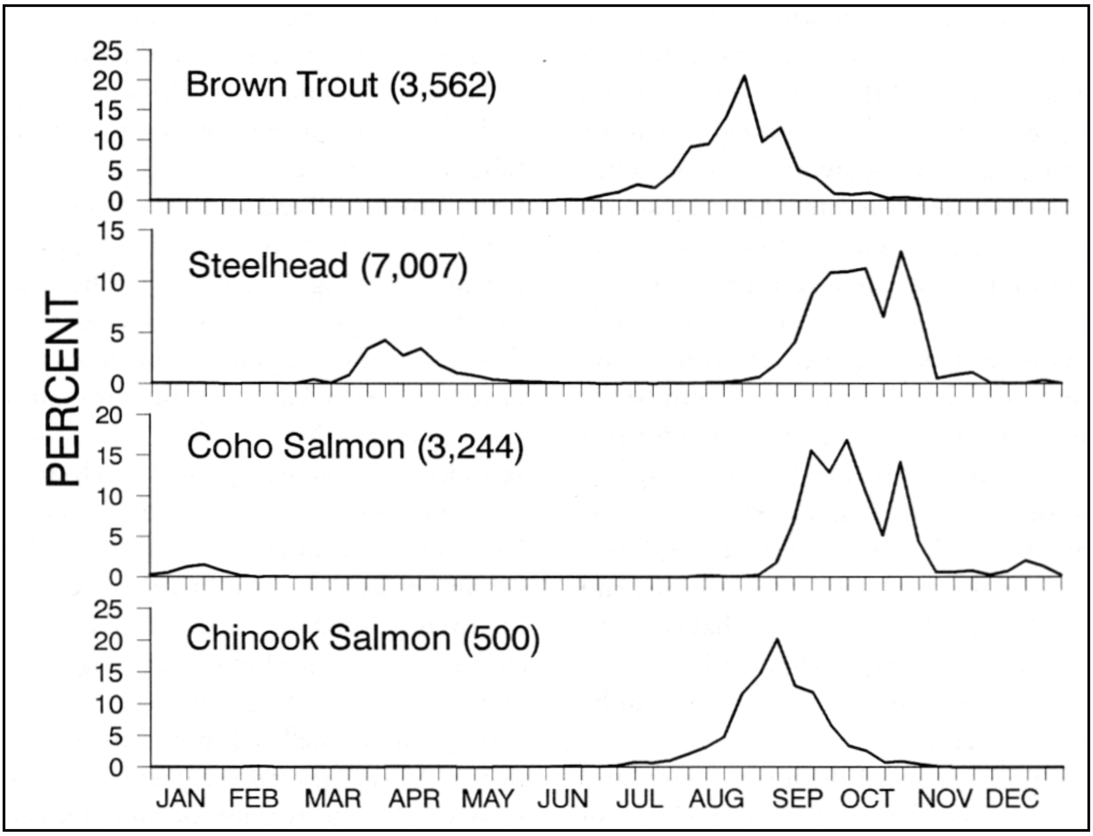

Fig. 4. Five-year (1989–93) mean weekly distribution of anadromous salmonids ascending the Bois Brule River on annual spawning runs (mean number per year for each species during 1989–93 in parentheses)

cult to document the specific locations used and hatching success because of higher turbidity and deeper water. Year-class strength of juvenile steelhead has been stable in the upper river, but highly variable in the lower river (DuBois et al. in press). This variation has apparently resulted largely from environmental factors and may not be closely related to numbers of spawning adults. The lower river is less stable than the upper river in terms of both its flow and temperature regimes. We speculate that a critical factor associated with year-class strength in the lower river pertains to spring flooding, which may have a devastating effect on eggs and newly hatched fry (Seegrist and Gard 1972). The limited data available suggest that when there is little flooding in the spring when the young-of-the-year are small (less than about 2 inches), survival is high. Also, during warm springs, growth is faster, allowing young fish to grow more quickly through the critical “window of time” when they are vulnerable to spring flooding.

Though all steelhead spawning apparently occurs in the spring (some autumn spawning is possible but unlikely), two distinct migration patterns have emerged: a larger autumn run of fish ascends the river from September through December and overwinters in deeper holes throughout the mainstem of the river, and a smaller spring run begins to ascend the river in February or early March and continues through May (Fig. 4). A study to investigate the possible genetic distinctness of these runs did not show significant differences (Krueger and May 1987a). It is therefore probable that the autumn and spring spawning runs are actually one extended run interrupted by a temperature-related cessation of migration cues during winter. The large autumn run on the Brule River is unique among Wisconsin's tributaries to Lake Superior, the others having substantial spring runs and only small autumn runs (if any). The reason(s) for this difference among streams is not clearly understood, but the availability of suitable overwinter holding areas in the Brule River, the relative seasonal stability of its flow, and the moderated thermal regime that contributes to its becoming ice-free earlier in the spring than most other streams, may all be important factors.

Evidence mounted during the early and mid-1980s that the steelhead population of the Brule River had declined disturbingly since the late 1970s and may now be at only a small fraction of its former abundance. For example, the estimated steelhead harvest during 1978–79 (about 7,000) was roughly similar in magnitude to the estimates of the entire run sizes in recent years (Fig. 4). Other tributaries along Wisconsin's Lake Superior shoreline showed a similar pattern of declining runs since the 1970s suggesting that the western Lake Superior steelhead stocks were collectively declining and may have been approaching a collapse (B. Swanson, WDNR, pers. comm.). Causes of this decline (which unfortunately coincided with a year-round open season on the Brule River during 1983–85) were unknown, but overharvest in Lake Superior as well as in the streams was strongly suspected.

In response to this perceived threat to the steelhead stocks, the WDNR enacted more restrictive size and bag limit regulations in 1989, and embarked on a limited-term steelhead stocking experiment for the Brule River to bolster its population. The stocking plan called for an annual egg-take operation (about 100,000 eggs annually) from wild Brule River steelhead and subsequently raising these juveniles to smolt size (approaching or exceeding 7½ inches). The goal of the stocking program was to release 50,000 functional smolts at various locations on the lower river each May until the program was no longer needed. Anglers have also responded by practicing more catch-and-release angling for steelhead on a voluntary basis (D. Pratt, unpubl. data). In 1993, the minimum legal size was further increased to 26 inches to allow maiden spawners to spawn at least once before entering the harvest (see section on regulations for complete description of steelhead sport harvest restrictions). At least several years will be required to assess the effectiveness of these measures. The wisest course of action for steelhead is to manage with conservative regulations; however, highly variable year-class strength related to environmental factors outside of management control will lead to large variations in annual angling quality, regardless of best management practices. Additional descriptive aspects of the Brule River steelhead population have been reported by Niemuth (1970) and Scholl et al. (1984).

Brown Trout

Brown trout were introduced to the Brule River by the WCC in 1920 (O'Donnell 1945). However, they may have already become established in the river from stockings elsewhere in the Lake Superior basin (Krueger and May 1987b). Many domestic strains of brown trout were undoubtedly stocked before stocking of this species was terminated in 1974. A selfsustaining population of brown trout developed early on, and they are now common throughout much of the river system (Fig. 3).

Two ecologically distinct groups of autumn-spawning brown trout coexist: a stream-resident component provides a challenging upper-river fishery and an anadromous (lake-run) component exhibits a life history strategy similar to steelhead. Anadromous brown trout spawning runs begin in July, peak in August, and extend into October (Fig. 4). Juveniles reside in the river for one (usually), two, or rarely three years before smolting in the spring or autumn. They then usually spend two years in the lake before returning to the river to spawn at age three or four. Although spawning need not result in the death of brown trout in an obligatory sense, as is the case with Pacific salmon, repeat spawning is relatively uncommon, and high natural mortality appears to be associated with spawning.

Brown trout sampled from western Lake Superior tributaries were found to differ genetically among drainages, between anadromous and stream-resident life histories, and among locations within the Brule River drainage (Krueger and May 1987b). Anadromous brown trout provide a rare trophy fishery, but have been generally less popular than steelhead because they are often harder to catch. Additionally, they are susceptible to mortality from furunculosis, caused by the bacterium *Aeromonas salmonicida*. Some fish carry the disease without symptoms, but outbreaks of furunculosis have sometimes reached epidemic proportions in the Brule River. Although furunculosis was observed prior to intensive weir study (Niemuth 1967), stress associated with handling large numbers of brown trout at weirs may have aggravated the prevalence of the disease. Warm river temperatures in August when most anadromous brown trout ascend the river have also been implicated in activating symptoms.

Resident and anadromous brown trout spawn in many of the same mainstem areas used by steelhead, but are more spatially restricted than steelhead in the lower river and the tributaries. This restriction may be related to the difficulty posed for overwintering eggs by anchor ice in the less-thermally-moderated lower river and by typically lower water levels in the tributaries during their autumn-spawning period. Information on size and age structures and other descriptive aspects of the anadromous brown trout stocks have been reported by Niemuth (1967) and Scholl et al. (1984).

Pacific Salmon

Three species of Pacific salmon have been found in the Brule River in recent years; all are strays from stockings by neighboring states and the Province of Ontario. Their sudden appearance serves as a reminder that the Brule River is not an isolated system, but rather, is intimately tied to the ecology of the surrounding region. Scott and Crossman (1973) described the life histories of Pacific salmon in the Great Lakes, and Scholl et al. (1984) provided early information about the population characteristics of these autumn-spawning species in the Brule River.

First documented in the Brule River in 1973, coho salmon have established a viable though widely fluctuating population. Their life history strategy involves one year of stream residency for juveniles, outmigration as smolts in May, and growth in the lake for one or two years before returning to the stream to spawn and die. Adults have contributed significantly to the sport catch in recent years. Coho salmon have so far shown a three-year cycle of abundance in the order of a small-run year, an intermediate year, and a large-run year. Numbers of spawners and the resulting young are strongly correlated. Spawning runs have peaked in mid to late September, but substantial movement has occurred throughout autumn and extended into winter (Fig. 4). Coho salmon spawn successfully throughout the upper river and tributaries, favoring smaller riffles near headwater areas (Fig. 2). Juveniles fare well in the slow, deep, alder-choked sections of the upper river south of Stone's Bridge; because these areas are extensive, the Brule River will likely remain a strong coho salmon producer.

Establishment of a viable chinook salmon population has developed more slowly than that of the coho salmon, although the first adults were also documented in 1973. During the late 1970s and early 1980s, small numbers of juveniles were found only in Blueberry and Nebagamon creeks and in mainstem riffles close to the confluence with Nebagamon Creek (Fig. 1). Since 1988, chinook salmon have spawned over a slightly wider range of locations, although still centered in the same general area. Year-class strength has also shown modest increases (DuBois et al. in press). Chinook salmon in the Brule River smolt mostly as young-of-the-year in May and June, with the remainder smolting during autumn or the following April/May. After smolting, chinook salmon spend up to five years in the lake (four years is most common) before returning to the river to spawn. Spawning runs, which have peaked from mid-August through September (Fig. 4), have contained modest numbers of spawners; the extent to which their population size or distribution may change is unknown.

Pink salmon have also been found in the Brule River, although not in appreciable numbers since 1979 (Scholl et al. 1984). Their potential for establishment in the Brule River appears limited.

The Sea Lamprey and Effects of Control Programs on Other Fishes

Sea lamprey were introduced to the upper Great Lakes through the opening of the Welland Canal and were first reported in Lake Superior in 1938 (Becker 1983). Although early records of their spawning in the Brule River are sketchy, they had developed a viable population in western Lake Superior by the mid-1950s. Primary spawning areas in the Brule River are not well known but likely included both mainstem and tributary riffles near silt beds for ammocoete habitat. Sea lampreys quickly caused serious damage to the salmonid populations of Lake Superior (National Research Council of Canada 1985). The Brule River was one of the largest tributary producers of sea lampreys in the Lake Superior basin, yielding approximately one-third of the entire catch from Lake Superior streams (McLain et al. 1965). Beginning in the mid-1950s, control programs initiated by the USFWS began to dramatically reduce sea lamprey recruitment to Lake Superior by disrupting their spawning and larval phases through use of mechanical weirs, electrical weirs, and later, selective lampricide treatments (Smith and Tibbles 1980). In the Brule River, sea lamprey control has included an electrical weir one mile upstream from the mouth of the river from 1957 through 1979, selective lampricide treatments using TFM at three-year intervals in the entire mainstem and throughout most of the tributaries from 1959 through 1986, and a mechanical barrier used in conjunction with chemical treatment only below the barrier since 1986.

Although TFM treatments of the Brule River successfully reduced sea lamprey recruitment, deleterious effects on some nontarget organisms were observed, and the monetary cost of treatments was high

(Gilderhus and Johnson 1980). Concern about these negative aspects led to the construction in 1984 of a sea lamprey barrier, located about seven miles upstream from the mouth of the river (Fig. 1). Initially, a low-head dam with jumping pools to allow migratory salmonids to pass upriver was built. However, this structure did not pass salmonids during all water conditions, and plans for remodeling were formulated. A reconstruction, including an effective fishway, was begun in 1985 and completed in March of 1986. The fishway included a viewing window which has proven to be a valuable research tool to obtain data on salmonid run numbers and other population statistics. This barrier system functions via use of a low-head dam with an overhanging metal lip within the fishway of a height surmountable by leaping salmonids but insurmountable to sea lampreys. The primary barrier which crosses the entire width of the river is higher than the fishway barrier and is impassable by all sea lampreys and most migratory salmonids. During autumn when no sea lamprey movement occurs, the fishway barrier is removed, allowing free upstream access to all fish species. The USFWS will periodically monitor the entire river and tributaries for presence of ammocoetes to determine any need for further treatment of upriver areas. Because the barrier appears to stop all sea lamprey movement, routine TFM treatments will now be made only downstream of it. Sections of the Brule River above the sea lamprey barrier were last treated in 1986 to kill ammocoetes produced before its completion.

All species of lampreys are highly sensitive to TFM, and populations of three species of endemic lampreys have been greatly reduced or eliminated from treated streams within the Lake Superior basin (Schuldt and Goold 1980). In the Brule River, the silver lamprey and the northern brook lamprey were once abundant, and their populations have been greatly reduced by repeated treatments (Table 1). It is not known if silver lamprey were historically indigenous to sections of the Brule River above the sea lamprey barrier.

Other groups of aquatic organisms are affected to different degrees by TFM. Lampricide treatments usually have substantial negative effects on a relatively few forms of invertebrate life (Gilderhus and Johnson 1980; Dermott and Spence 1984; MacMahon et al. 1987), and they do not usually have severe direct effects on salmonid populations (Dahl and McDonald 1980). Secondary effects on salmonids due to a reduced invertebrate food supply also are unlikely to be severe (Merna 1985; DuBois and Blust 1994). However, other families of fishes, particularly ictalurids (catfishes) and catostomids (suckers), are quite sensitive to TFM. Stonecats (*Noturus flavus*) in the lower Brule River and in other western Lake Superior tributaries were so severely affected by TFM treatments that it was initially feared that they might have been eliminated from Lake Superior (Dahl and McDonald 1980). Fortunately, untreated refugia apparently existed for a portion of the stonecat population. Populations of other fishes indigenous to the Brule River may have been reduced because of TFM treatments. Dahl and McDonald (1980) provide a thorough discussion of the known effects of sea lamprey control on non-target fishes in the Great Lakes.

Control of sea lamprey spawning in the Brule River will remain an important fisheries management priority. Although research on alternative methods of sea lamprey control is ongoing, mechanical barriers and chemical treatments remain the most successful of the practical options.

Habitat Management

The history of the Brule River is dotted with numerous efforts to preserve the integrity of the physical habitat, enhance habitat for salmonids, and stabilize riparian areas. These efforts fall into five categories: (1) preservation of riparian areas, (2) in-stream habitat enhancements, (3) beaver control and dam removal, (4) bank stabilization in red clay areas subject to slippage, and (5) dredging projects.

Preservation Efforts

A major factor in the preservation of the Brule River ecosystem has been the protection afforded by state stewardship acquisition of land bordering the river. The Brule River State Forest was established in 1907 when Frederick Weyerhauser deeded 4,320 acres to the state. Land acquisition since has added to that total as funds have allowed. In 1959, the boundaries of the Brule Forest were extended to include the entire Brule River corridor. Presently about 40,000 acres of land are under state ownership, which represents about 80% of the total acreage within the boundary of the Brule River State Forest and includes about 50% of the river frontage (C. Zosel, WDNR, pers. comm.).

Another major factor contributing to preservation of the Brule River ecosystem has been the excellent stewardship practiced by private riparian landowners over many years (Holbrook 1949). Brule River Preservation, Inc., is a public nonprofit corporation including over 20 landowners from the upper river dedicated to preserving the Brule River and fostering sound ecological management for its use. The Nature Conservancy (TNC), an international organization dedicated to preserving unique natural areas, has a Conservation Easement Grant Program in effect on much of the upper river between Blue Spring and the WDNR Brule Area Headquarters (Fig. 1). This program features agreements between individual landowners and TNC whereby the landowners voluntarily restrict certain rights of use and development on their lands in perpetuity in order to ensure that these lands are protected against unwise commercial development and ecological degradation.

In-Stream Habitat Enhancement

The WDNR has been at the forefront nationally in the development of in-stream habitat enhancement techniques for salmonids. Consequently, much is now known about the identification of environmental deficiencies and the application of appropriate structural remedies to Wisconsin’s streams (White and Brynildson 1967; Hunt 1988, 1993). Techniques used in the Brule River have included wing deflectors and bank covers, debrushing and installation of brush bundles, and removal of downed trees and other debris. Unfortunately, most of these efforts were undertaken before knowledge about effective techniques had been refined. A project of “stream improvement” was started in 1936 using Works Progress Administration labor. A total of 286 structures were installed in the river including deflectors, bank covers, and other stream enhancement devices, many of dubious value for creating trout habitat (O’Donnell 1944; Holbrook 1949; Marshall 1954). This effort appears to have been focused on making the river easier to canoe (O’Donnell 1944). Some of these structures still exist, either complete or as remnants, below County Highway P, below Stone’s Bridge, in the Winneboujou area, and near the WDNR Area Headquarters. Additionally, the Civilian Conservation Corps installed structures, planted willows, and “clean[ed] out large amounts of down trees and other materials" at about the same time (O'Donnell 1944, p.29). The beneficial role of large, downed timber in shaping stream morphology and creating salmonid habitat has only been realized in recent decades (Harmon et al. 1986; Bisson et al. 1987). Current thinking now favors adding large woody debris to the stream to compensate for wood removed by earlier enhancement efforts or lost for other reasons[4]. During the 1960s, a series of rock deflectors was installed below the State Highway 13 bridge by the Brule River Sportsmen's Club, Inc. Also in the 1960s, the Douglas County Fish and Game League (under cooperative agreement with the WDNR) constructed rock wing deflectors in several lower river locations to provide cover for salmonids and deflect current away from red clay banks. No follow-up evaluations were made of any of these early efforts.

Habitat enhancement efforts by the WDNR within the Brule River watershed since the l960s have focused on riparian debrushing and installation of brush bundles on inside bends in some tributary areas choked with speckled alders (*Alnus rugosa*). Riparian debrushing lets sunlight into the stream for aquatic plant growth and encourages physical improvements in the stream channel, while brush bundles provide cover for trout fry and accelerate a favorable channel-constriction process (Hunt 1979). Such efforts on the East and West forks of the Brule River appear to have improved trout habitat, but were not evaluated to document their impact on trout populations. During 1978–91, a project on the Little Brule River below the state trout hatchery to remove all beaver dams and riparian alders and install brush bundles was conducted and evaluated (DuBois and Schram 1993). Natural reproduction in both treatment and control sections improved during the post-treatment period. However, numbers of legal-size brown trout declined markedly in both treatment and control sections following treatment, a result that could have been due to increased fishing pressure brought on by publicity surrounding the project, the improved fishability of the debrushed stream segment, or movement of large brown trout out of the stream.

Beaver Control and Dam Removal

Effects of beaver dams on trout habitat have generally been regarded as negative in Wisconsin although they are considered beneficial in small, high-gradient streams. Negative effects are most likely to occur on streams of low-to-moderate gradient where dams may contribute to warming of water, hinder salmonid movement and spawning, cause silting-in of gravel areas important for producing insects, and produce poor channel characteristics (summarized by Avery 1983). Traditionally, beaver have been regulated by trapping because of the value of their fur. For example, heavy trapping of beaver on the Brule River in 1803–04 drastically reduced their numbers (Marshall 1954). However, beavers are prolific, and animals from surrounding areas tend to recolonize trapped-out areas, creating an unceasing cycle. Furthermore, intensity of trapping effort fluctuates because of unstable fur prices. Recent low fur prices and excellent habitat have resulted in a large beaver population in northern Wisconsin. The Brule River and tributaries have been on various special extended beaver trapping seasons since the early 1960s, including a liberal open season since the mid-1980s. The Brule River watershed was included in a WDNR beaver subsidy program from 1986–88 that provided a financial incentive for trappers to control populations in designated areas. Since then, a trapper from the Animal Plant Health Inspection Service of the U.S.

Department of Agriculture has worked under WDNR direction to remove beaver from within the Brule River watershed and other salmonid tributaries to Lake Superior.

Beaver dams on the Brule River generally occur only in the upper river above Stone's Bridge and in several tributary areas. Although historically these were probably also the areas of heaviest beaver activity, dams may have occurred further downstream as well. Numerous recent excursions to remove beaver dams from the upper Brule River have been made by WDNR workers, members of area sports clubs, and other citizens, but results have been short-lived, especially if beaver were not also removed. A recent habitat development project on the Little Brule River evaluated the effects of beaver dam removal and riparian debrushing on the physical conditions of the stream channel and on the salmonid populations (DuBois and Schram 1993). Although physical changes in channel morphometry following these manipulations were impressive, salmonid population responses were mixed, and the beneficial aspects could not be attributed solely to dam removal.

Bank Stabilization

The clay soils in the Brule River watershed appear to be geologically young and undergoing a high rate of natural erosion. When Europeans settled in this area, their lumbering, road construction, and agricultural activities removed the established mixed-conifer forest cover type and altered drainage patterns in ways that accelerated this pattern of erosion. Present-day activities, although more carefully controlled, continue to aggravate the erosion process.

Erosion of the red clay soils of the lower Brule River Valley has the potential to negatively affect salmonid populations. The potentially most damaging effect is from sedimentation, which can inhibit aquatic invertebrate life and reduce salmonid spawning success by causing high egg and larval mortality. In extreme cases, turbidity can also reduce feeding success of visually feeding salmonids and inhibit proper gill function (Berg and Northcote 1985). However, turbidity is probably not an important limiting factor for salmonids in the lower Brule River because other tributaries to Lake Superior in Wisconsin are known to have longer-term turbidity episodes yet have contained robust salmonid populations in recent decades.

A red clay interagency committee was formed of state and federal agencies in 1955 to investigate land-use problems on the red clay soils of northwestern Wisconsin. The goals of this committee were to determine the causes of red clay sedimentation in area lakes and streams and to study means of erosion and sedimentation control. Experimental work to reduce clay erosion was done on the Brule River in a few areas using gabions and riprap to stabilize bank slippage. Some successes were achieved in areas of less extreme slippage, but the efforts were expensive and the results obtrusive in a natural setting. Various mulchings and plantings were also tried in localized areas. State forest management goals now call for specialized timber management in steeply sloped red clay areas, with the long-range objective of returning the area to mixed-conifer forest. This plan may eventually lead to reduced bank erosion and slippage, but decades will be required to assess the results.

Dredging Projects

Dredging of spring ponds in Wisconsin can benefit brook trout spawning (Carline 1980), but indiscriminate dredging of streams can produce harmful physical changes such as degradation of the streambed (headcutting) and bank erosion (Kanehl and Lyons 1992). Several dredging projects have been carried out on the Brule River with the goal of enhancing trout habitat by creating deeper pools and exposing gravel substrates for spawning and increased invertebrate production. In the late 1920s, the WDNR dredged the east side of Big Lake. Blue Spring and a short stretch of river above Stone’s Bridge were dredged by a private interest in the late 1960s. These projects were never evaluated to document benefits that may have accrued. In 1967, Douglas County and the Douglas County Fish and Game League tried to deepen and straighten the mouth of the Brule River by dredging. The attempt was futile, however, as the river quickly reverted back to its original form.

Regulation of the Fishery

Restrictions on fishing on the Brule River have usually followed the regular statewide trout and salmon regulations, with various extended special seasons on the lower river. In the early 1900s the four northern counties bordering Lake Superior were sometimes subjected to different open seasons on trout than the rest of the state. The many changes occurring over the history of regulation in open season dates, daily bag limits, and minimum sizes are described below in chronological order.

Open Seasons

Regular Season. The first restriction on trout fishing enacted in Wisconsin was a reduction in the length of the statewide open season from 12 months to 8 months in 1858. In 1878, the open season was further reduced to 5 months. From 1891 through 1898 the open season on the Brule River was greatly reduced to just 26 days in August (Chapter 138, Laws of 1891). Reasons for this restriction were not stated, but we note its concurrence with the era of intensive logging and use of logging dams to transport logs downriver en masse; release of these dams would have created serious hazards for anglers downstream. The length of the open season has varied since, but has usually been between 4 and 5 months. The season opener has varied between mid-April and mid-May; the closing date for the regular season has also been variable, occurring sometime between August 20 and September 30.

Special Extended Seasons. Various extended seasons have been enacted for the lower river between U.S. Highway 2 and Lake Superior to allow increased angling opportunities during anadromous salmonid spawning runs. These seasons have included a special early season, starting in spring sometime prior to the regular season and running to the regular season opener, and a special late season, starting in autumn after the regular open season and extending for various periods of time. Season extensions began in 1935 with a special early season starting on May 1 (at that time the regular season opener was on May 15). The starting day for the special early season has since varied, but has most often been the Saturday nearest April 1. Special regulations for the autumn season began in 1954 with an extension through November 15 and a further extension to December 31 in 1974. In 1983, a year-round open season was created from U.S. Highway 2 to Lake Superior to spread out fishing pressure and create additional angling opportunities. This year-round season was rescinded after the 1985 season because of public dissatisfaction and indications of excessive harvest. Present season extensions run from the Saturday nearest April 1 through November 15.

Daily Bag and Minimum Size Restrictions Prior to 1989

There was no statewide restriction on the daily bag for trout until 1905 when it was set at not more than 10 pounds. In 1909, the daily bag was changed to 45 trout; it was subsequently reduced to 35 trout in 1917, 25 trout in 1923, 15 trout in 1929, and 10 trout in 1949. From 1949 to 1989 the daily bag during the regular season remained at ten trout or salmon, sometimes with the stipulation that only five of those could be steelhead, or steelhead and brown trout in aggregate. Daily bag limits for the Brule River during the special extended seasons were more restrictive than during the regular seasons. From 1962 to 1989, the daily bag during the extended seasons was five trout or salmon in aggregate, with the stipulation for 16 of those years that only two of the five could be steelhead.

The first size limit enacted for trout in Wisconsin was a 6-inch minimum in 1905. In 1915 the statewide minimum length was increased to 7 inches; it was set back to 6 inches again in 1950, where it remained until 1989. The special extended seasons have been subject to higher minimum lengths, beginning with a 13-inch minimum for the late season in 1954. In 1970, the minimum length limit during the early and late seasons was reduced to 10 inches, where it remained until 1989.

Recent Changes in Daily Bag and Minimum Size Limits

Although anglers were increasingly practicing voluntary catch-and-release during the 1980s (Table 3), by 1989 it became apparent that additional restrictions on harvest of both adult spawners and presmolts of steelhead and brown trout were necessary to protect the fishery. Excessive harvest was strongly implicated in the declining numbers of spawning steelhead. Concern had also mounted that harvest of large, resident brown trout may have been dangerously high, especially during a popular, early-summer mayfly hatch (*Hexagenia limbata*) when trout are particularly vulnerable. An additional concern surfaced that harvest of presmolt steelhead and brown trout 6 to 10 inches in length may have been substantially reducing run sizes of adult spawners. Studies had shown smolt size to be positively correlated with survival to the maiden spawner stage (e.g. Ward and Slaney 1988), and that if steelhead survived their presmolt winter, they had an excellent chance to grow to trophy size (Seelbach 1987). Hence, larger presmolts were valuable and required protection from harvest.

New regulations in 1989 for the entire open season therefore included a reduced daily bag limit of five salmonids in total of which only one could be a steelhead 12 inches or larger and only two could be brown trout larger than 15 inches. Minimum sizes were increased to 10 inches on brown trout and 12 inches on steelhead and Pacific salmon to protect anadromous presmolts. The minimum size limit on brook trout was also increased to 8 inches to allow more fish to grow into a desirable size range. In 1993, the minimum size limit on steelhead was further increased to 26 inches for the Brule River and all other Wisconsin tributaries to Lake Superior to ensure that young adults would have the opportunity to spawn at least once before entering into the harvest. More time is needed to determine the extent to which these changes may have benefited the fishery.

Concurrent with the decline in the Brule River steelhead run in the mid and late

1980s were indications of reduced steelhead runs in other Wisconsin tributaries to Lake Superior (B. Swanson, WDNR, pers. comm.). Increasing harvest of steelhead in Lake Superior by anglers in charter and private boats was suspected of contributing substantially to this disturbing decline of steelhead in western Lake Superior. Hence, in 1990, regulations for the Wisconsin waters of Lake Superior were changed to allow daily harvest of only one steelhead over 28 inches in length.

Other Restrictions on Fishing

Gear restriction proposals for reducing harvest and post-release mortality of salmonids in sections of the upper river have periodically been voiced. However, the only gear restriction ever enacted was for “fly fishing only” for the stretch of river from Stone’s Bridge to Winneboujou in 1938 in response to a petition by landowners. This restriction was rescinded shortly thereafter, following a storm of public protest that may have been politically generated (Holbrook 1949).

Other restrictions include no fishing from 1/2 hour after sunset to 1/2 hour before sunrise during the extended seasons on the lower river, and the establishment of small refuge areas closed to fishing where migrating fish tended to congregate and illegal snagging was known to have occurred (below the sea lamprey barrier, the Boxcar Hole and the Skid Mays area within the Ledges section[5]).

Voluntary catch-and-release is being practiced with increasing frequency, especially on the upper river, as the angling community re-evaluates the value it places on wild salmonids. Brule River Preservation, Inc., the Brule River Sportsmen’s Club, Inc., and Trout Unlimited of Wisconsin have undertaken a collaborative signage project on the upper river that suggests the practice of voluntary catch-and-release to preserve good fishing. These types of voluntary initiatives have been shown to effectively shape angler behavior because many anglers are influenced by the ethics of their peers. Also, anglers are concerned about the future of their sport and typically respond well to education.

Management Implications

1. Continue the focus on riparian protection. A strong posture by the WDNR and private interests on protecting riparian areas has existed for decades and should continue. A healthy riparian zone is instrumental for maintaining water quality and instream habitat diversity, which are in turn critical for the continuing support of a diverse array of coldwater life. The state should continue its policy of land acquisition within State Forest boundaries from willing sellers where feasible. An enduring focus on cooperative ecosystem stewardship by riparian landowners, the Brule River Preservation, Inc., the Brule River Sportsmen’s Club, Inc., and a broad range of WDNR functions will remain invaluable.

2. Focus for instream habitat maintenance and enhancement. Habitat maintenance and enhancement considerations for the river system should include beaver control and dam removal to maintain an unimpeded migration route, dredging of spring pond areas to increase brook trout spawning potential (however, dredging of the mainstem is not recommended), and addition of downed conifers, rootwads, and other forms of large woody debris throughout the system to compensate for wood removed since the late 1800s. Existing instream habitat improvement structures that seem to have been useful should be refurbished. Public acquisition of any part of the Cedar Island spring pond area to be again made accessible for wild brook trout spawning should be a high priority if that property becomes available; a substantial boost to the brook trout population would likely result given the apparent paucity of spawning areas for that species elsewhere throughout the upper river.

3. Continue the trend for increasingly restrictive angling regulations. Increasingly restrictive regulations have contributed to a brighter future for the salmonid fisheries, especially since over-exploitation was identified as one of their major threats. This trend should be maintained, and gear restrictions for sections of the upper river should be considered pending determination of the effects of the 1989 regulatory changes on the salmonid populations.

4. Further monitoring of the stream biota. The recent establishment of numerous exotic species serves to remind us that the Brule River is part of a larger ecosystem that will remain continually at risk from distant occurrences. Given the climate of uncertainty under which the system must be managed, there will be a need for periodic monitoring of the fish and aquatic insect communities to test for impacts of exotic animals on native species. Additionally, an abbreviated sampling schedule of the quantitative investigations into salmonid population dynamics initiated during the last decade should continue, as much as economically feasible, to ensure benefits to future fisheries management.

5. Continue the research focus. Many indications from the public including the admirable work of the Brule River Committee and the committee’s strong support of the research efforts of the last decade suggest that status quo management of this river system is not acceptable. The public has a right to expect state-of-the-art management on a resource as valuable as the Brule River. Resource management policies have come under increased scrutiny from special interest groups and this trend will likely continue. Continuing research will be needed to satisfy the demand for sound management.

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Endnotes

[1] Coaster brook trout apparently exhibited an anadromous life history strategy similar to that of the anadromous brown trout. Little scientific information on coaster brook trout in Great Lakes tributaries is available because most populations were extirpated before scientific data were collected. Bullen (1988) describes a remnant population in a Lake Superior tributary.

[2] Upper river refers to the river reach from U.S. Highway 2 south (upstream) to the con-

fluence of the East and West forks. Lower river refers to the river reach from U. S. Highway 2 north (downstream) to Lake Superior. Upper or above always refers to an upstream direction; lower or below always refers to a downstream direction. Mainstem refers to the main thread of the Brule River proper without the tributaries.

[3] The lakes section is composed of four wide-spreads of the Brule River (Sucker, Big, Lucius, and Spring lakes) located just south of the river's midsection (Fig. 1).

[4]There is likely much less large woody debris in the Brule River (and other rivers and streams in northern Wisconsin) than there was historically for several reasons in addition to the removal efforts of early fisheries workers. Woody debris has been systematically removed from our rivers and streams for more than a century to maintain open channels for human navigation, and during the intensive logging era of the late 1800s removal efforts were intensified to maintain smooth channels for the downriver transport of logs. Additionally, the clear-cutting of our northern forests at that time (which included steamside areas) temporarily interrupted the continual natural process of dying streamside trees falling into waterways.

[5] The ledges section is the reach of river having maximum gradient where it crosses the Copper Range (Fig. 1). The river descends 80 ft in 2¼ miles at that point (Bean and Thompson 1944).

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