



Community structure and habitat associations of fishes of the lower Tongue and Powder rivers
by Ryan Joseph Trenka

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish
& Wildlife Management

Montana State University

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Abstract:

The Yellowstone River is one of the nation's few remaining free-flowing rivers and contains some of the healthiest populations of several fish species of special concern (pallid sturgeon, blue sucker, Hybognathus spp., sturgeon chub, sicklefin chub and flathead chub). Much of the lower basin contains numerous irrigation diversions, but the effect of these diversions on the native fish community is poorly understood. As part of a larger effort to assess these effects, this study examined biotic and abiotic factors in the lower Tongue and Powder rivers, two major tributaries to the Yellowstone River in eastern Montana. Little is known about general distribution, abundance and life history of native fishes particularly sturgeon chub, flathead chub and Hybognathus spp. nor native game species such as sauger and shovelnose sturgeon which have substantially declined in these sections of the rivers. Fish populations and habitats of the Tongue and Powder rivers were inventoried to investigate longitudinal changes in fish communities and habitat. Additionally, relations between diel and seasonal use of major macrohabitats were examined. Twenty-five species representing 10 families were collected. The most abundant and species-rich family was Cyprinidae. Relatively unaltered habitat conditions in the Powder River supported a relatively unaltered fish community. Relative abundance of all non-game species has remained relatively stable compared to historical data. Populations of game fishes including sauger and shovelnose sturgeon have declined considerably. The Tongue River has been adversely affected by diversion dams and water withdrawals. Spring runoff, which triggers spawning activity, has been diminished by dam operation. Minnows used shallower, slower edge habitats in both rivers, areas extremely altered by modification of natural flow regime. In the Tongue River, the channel has become narrower and more uniform in depth, substrates have become larger and firm, aquatic vegetation has increased and turbidity levels have decreased when compared to the Powder River. This has resulted in decreased populations of benthic invertivores and increased numbers and species more adapted to sight feeding and fishes adapted to spawning over larger open substrate and plant material. Game fish population levels have declined here as well, pointing to possible basin wide problems.

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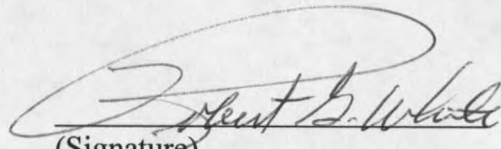
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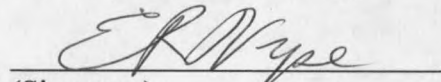
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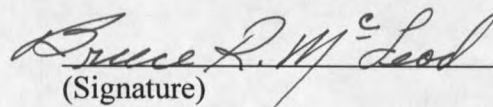
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ABSTRACT

The Yellowstone River is one of the nation's few remaining free-flowing rivers and contains some of the healthiest populations of several fish species of special concern (pallid sturgeon, blue sucker, *Hybognathus* spp., sturgeon chub, sicklefin chub and flathead chub). Much of the lower basin contains numerous irrigation diversions, but the effect of these diversions on the native fish community is poorly understood. As part of a larger effort to assess these effects, this study examined biotic and abiotic factors in the lower Tongue and Powder rivers, two major tributaries to the Yellowstone River in eastern Montana. Little is known about general distribution, abundance and life history of native fishes particularly sturgeon chub, flathead chub and *Hybognathus* spp. nor native game species such as sauger and shovelnose sturgeon which have substantially declined in these sections of the rivers. Fish populations and habitats of the Tongue and Powder rivers were inventoried to investigate longitudinal changes in fish communities and habitat. Additionally, relations between diel and seasonal use of major macrohabitats were examined. Twenty-five species representing 10 families were collected. The most abundant and species-rich family was Cyprinidae. Relatively unaltered habitat conditions in the Powder River supported a relatively unaltered fish community. Relative abundance of all non-game species has remained relatively stable compared to historical data. Populations of game fishes including sauger and shovelnose sturgeon have declined considerably. The Tongue River has been adversely affected by diversion dams and water withdrawals. Spring runoff, which triggers spawning activity, has been diminished by dam operation. Minnows used shallower, slower edge habitats in both rivers, areas extremely altered by modification of natural flow regime. In the Tongue River, the channel has become narrower and more uniform in depth, substrates have become larger and firm, aquatic vegetation has increased and turbidity levels have decreased when compared to the Powder River. This has resulted in decreased populations of benthic invertivores and increased numbers and species more adapted to sight feeding and fishes adapted to spawning over larger open substrate and plant material. Game fish population levels have declined here as well, pointing to possible basin wide problems.

INTRODUCTION

The Yellowstone River Basin contains many diversion dams and water intake structures. Many of these have been in place for decades and were constructed to provide water for irrigation. These diversions are known to prevent or impede the upstream movement of fish, and many fish are lost due to canal entrainment (Hesse 1987).

Declines of certain native fish populations in the Missouri River drainage have resulted in one being listed and others proposed for listing as threatened or endangered under both State and Federal laws. Currently only one species, the pallid sturgeon (*Scaphirhynchus albus*), is federally listed as endangered. An additional seven species (blue sucker, *Cycleptus elongatus*; western silvery minnow, *Hybognathus argyritus*; plains minnow, *Hybognathus placitus*; sturgeon chub, *Macrhybopsis gelida*; sicklefin chub, *Macrhybopsis meeki*; flathead chub, *Platygobio gracilis*; and paddlefish, *Polyodon spathula*) have been proposed or being considered for listing by the U.S. Fish and Wildlife Service (USFWS 1994).

While populations of many of these at-risk species appear healthy in the upper, less altered reaches of streams in the Missouri River Basin (White and Bramblett 1983), little is known about their abundance, distribution and habitat requirements, particularly when correlated with the effects of diversion structures.

Recognizing that irrigation intake structures may be contributing to the decline of native fish populations, the Bureau of Reclamation (BOR), Montana Fish Wildlife and Parks (MTFWP), and other State and Federal agencies initiated a study to examine major

diversion dams and large water intakes on the Yellowstone River system in Montana with the overall goals of minimizing migration restrictions for listed and candidate endangered species and certain game species, and for reducing entrainment and impingement of fish at water intakes. To meet these goals, knowledge of the distribution and habitat needs of native fishes is prerequisite. Since this information is generally lacking (Gould 1985), I examined the fish communities and their habitat associations in the lower Tongue and Powder rivers, tributaries to the lower Yellowstone River, with an overall goal of gaining critical information to assist BOR studies aimed at understanding and protecting Yellowstone River fishes in relation to irrigation diversion and intake systems as well as land and water development. I examined certain ecological attributes such as habitat associations, patterns of movement, and distribution to try to better understand the relationships between streams, their habitats, and their fish communities. The specific objectives of this study were: (1) to describe fish species composition and the relative abundance of those species in the lower Tongue and Powder rivers, (2) to describe diel and seasonal use of major macrohabitat types by the fish community, and (3) to describe the physical characteristics of the habitats used by the fish community.

STUDY AREA

The Tongue and Powder rivers are major tributaries to the lower Yellowstone River (Figures 1 and 2), which lies in the unglaciated Missouri River plateau. This area is primarily classified as one of the following geological land types; Northern Smooth High Plains, Northern Rolling High Plains, Pierre Shale Plains and Badlands, or Rolling Soft Shale Plains. Most of the lower Yellowstone basin is underlain by the Fort Union Coal Formation, a remnant of the Hell Creek Formation. The Fort Union Formation was formed 50-60 million years ago in a vast shallow lake. Extensive coal fields formed in this area of once large swamps and thick forests (Elser et al. 1977).

The dominant land use of the lower Yellowstone basin is agriculture, primarily irrigated cropland. In the lower basin the predominate riparian plant community is an extensive cottonwood-willow complex that hosts a diverse wildlife community, including numerous species of special concern in Montana. The lower Yellowstone River also supports a diverse and productive fishery, which is dependent upon adequate flows and good water quality (Elser et al. 1977). Historically, 46 species representing 12 families have been collected in the lower reaches of the Yellowstone (Phil Stewart, Montana Fish Wildlife and Parks, Miles City, Montana, personal communication, 1996). Several riverine species, including shovelnose sturgeon, channel catfish and sauger are known to utilize both the Tongue and Powder rivers, migrating long distances in the spring associated with spawning (Elser et al. 1977).

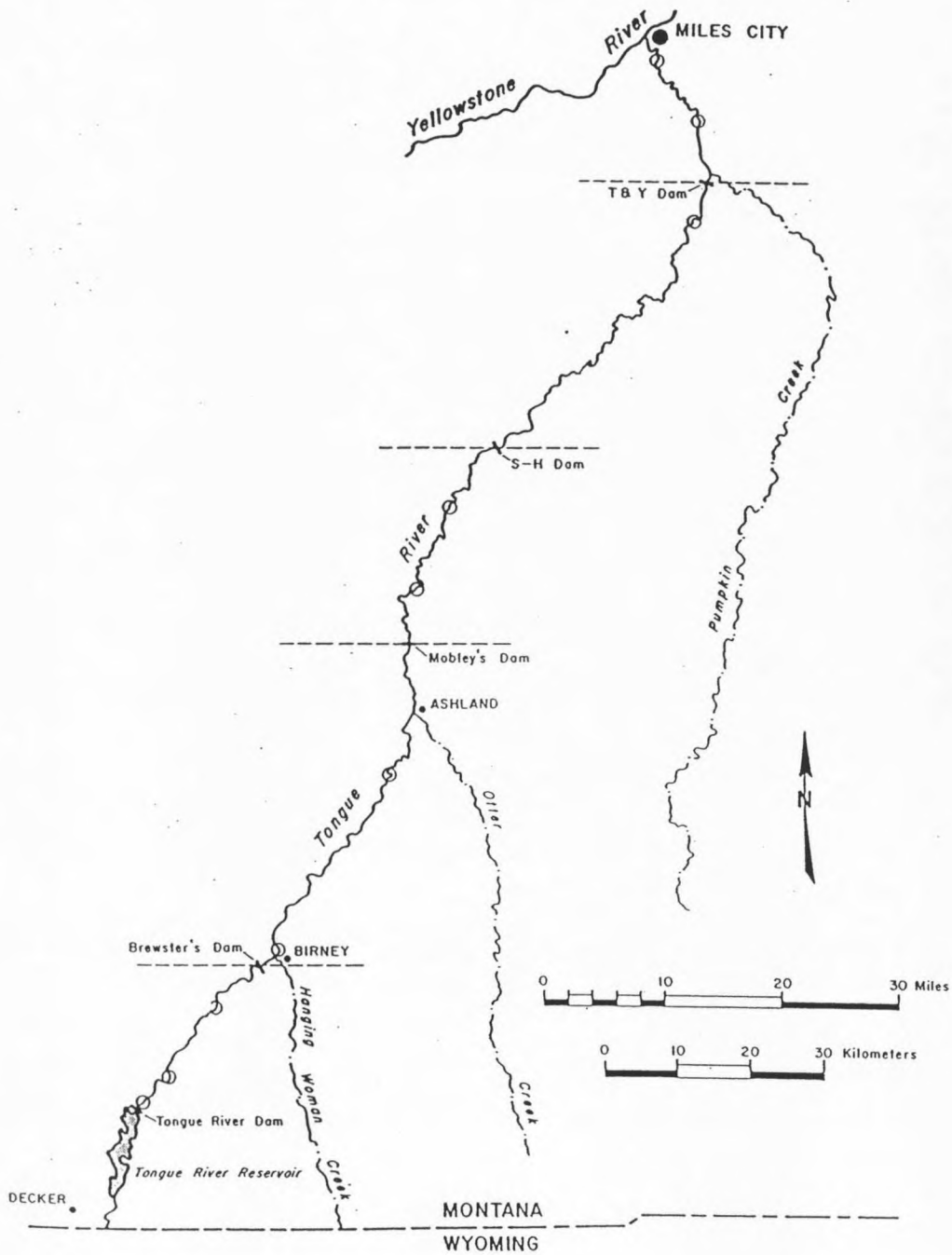


Figure 1. Map of the Tongue River, Montana. Specific study area is portion of Tongue River from T & Y dam to confluence with Yellowstone River, Montana.

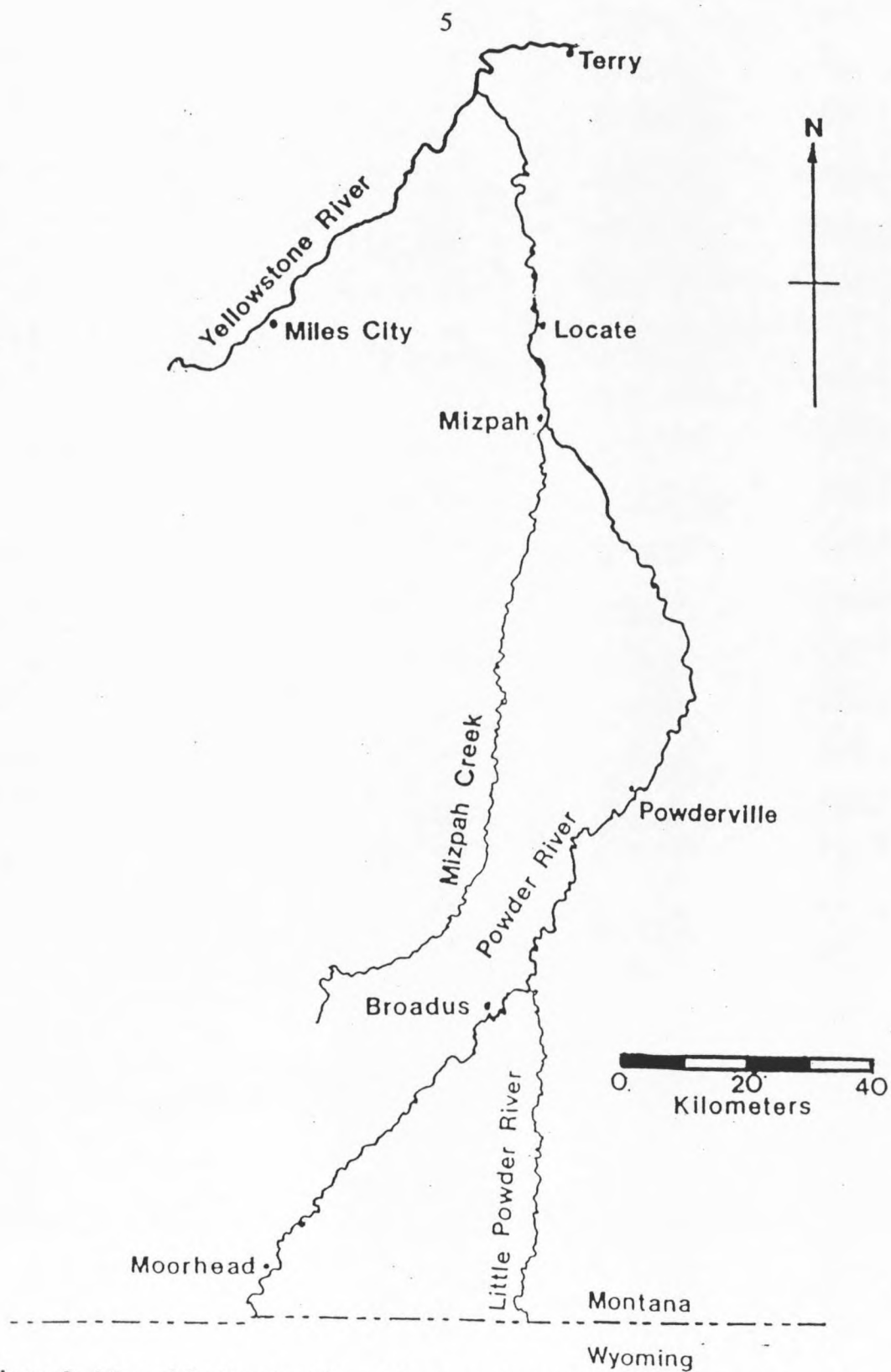


Figure 2. Map of the Powder River, Montana. Specific study area is portion of Powder River from Mizpah Creek to confluence with the Yellowstone River, Montana.

Tongue River

The Tongue River gets its name from an Indian word for a tree-covered limestone slab outlined by rock that resembles a bison tongue. The headwaters of the Tongue arise from the eastern side of the Bighorn Mountains in Wyoming and flow northeasterly through Wyoming and Montana to its confluence with the Yellowstone River at Miles City, Montana. Drainage area of the Tongue River basin is 13,932 km², with approximately 70% occurring in Montana. The total length of the Tongue River from the Montana-Wyoming border to its mouth is 337 km. Average annual discharge is 11.9 m³/s (Elser et al. 1977). Flow from the Tongue is generally less than six percent of the Yellowstone at their confluence, and peak discharge is bi-modal with its greatest flow usually occurring in March and another peak typically in June.

The Tongue River basin is comprised of narrow stream valleys, plateaus and gently rolling uplands. Relief is compromised in the lower reaches with less rugged conditions occurring nearer the confluence. Agriculture is the major land use in the basin with cattle ranching and irrigated or dry land farming dominating. Water quality of the Tongue is generally considered to be better than most other prairie streams of the Great Plains (Elser et al. 1977).

Flow of the Tongue River in Montana is regulated by a series of five dams, four of which are lowhead structures used to divert irrigation water. The first and largest is the Tongue River Dam located just inside the Montana border near Decker, Montana. The dam was built in 1940 as a storage facility and aids in flood control. It stores about

85 hm³ (8,512 ha-m) of water with a full pool area of 1,416 surface ha. (Elser et al. 1977).

My study area was in the lower 32.2 km of the Tongue River, from the T&Y diversion dam, located just upstream from the confluence of Pumpkin Creek, to the confluence of the Tongue and Yellowstone rivers (Figure 1). T&Y dam is the most downstream diversion on the river and the largest of the four lowhead diversions. The dam is 3 m high and 95 m long, spanning the entire river channel. It has a water right of 6.73 m³/s; therefore, during irrigation season instream flows above the dam are significantly higher than below the dam (Liston et al. 1994). Historically, this 32.2 km reach has been dominated by slow-water fish assemblages with migrant fish from the Yellowstone River using this reach when flows allow passage.

Powder River

The Powder River today is similar to what early pioneers encountered more than 100 years ago. Early settlers described it as a mile wide and an inch deep, too thin to plow and too thick to drink. The Powder River basin drains an area of approximately 34,318 km² in northeast Wyoming and southeast Montana. Over half of the drainage is in Wyoming and is bordered to the southwest by the Bighorn Mountains. The Powder River flows north to its confluence with the Yellowstone River near Terry, Montana. It is bounded on both sides by low divides and breaks that separate it from the Tongue River to the west and the Little Missouri, Belle Fourche, Cheyenne and the North Platte rivers to the east and south (Rehwinkle 1978). Although its origin is on the eastern slopes of

the Bighorn Mountains, it is generally classified as a Great Plains River (Rehwinkle 1978).

The Powder River, including the South Fork, is approximately 780 km long and is characterized by erratic flows and silt-laden bed load, resulting in a constantly shifting channel. It rarely develops pools and generally lacks aquatic and riparian vegetation. Annual discharge averages 17.6 m³/sec and is naturally saline with an average total dissolved solids of 1100 mg/L (Rehwinkle 1978). The yearly discharge pattern of the Powder is typical of a prairie stream, with spring runoff resulting in a bi-modal discharge pattern. A smaller discharge peak historically occurs around March, followed by a larger peak in June, receding to minimal flows in late summer.

The climate of the area varies altitudinally, with precipitation occurring primarily as snow at higher elevations. The plains section is arid with only 0.367 m of average annual precipitation. Air temperatures are similarly extreme, with summer highs exceeding 38 °C and winter lows commonly reaching -34 °C (Rehwinkle 1978).

Although water quality and quantity have naturally limited fish population diversity and abundance, the Powder River is an important spawning tributary for several species (Rehwinkel 1978). The river has been used extensively by migrant spawning populations of fish species including shovelnose sturgeon (*Scaphirhynchus platorynchus*), channel catfish (*Ictalurus punctatus*), and sauger (*Stizostedion canadense*). Additionally, it was formally documented as a spawning area for the pallid sturgeon (*Scaphirhynchus albus*), now an endangered species and currently absent from the area (Rehwinkle 1978).

My study area was the lower 72.1 km of the Powder River, from the mouth of Mizpah Creek to the confluence of the Powder and the Yellowstone river near Terry, Montana (Figure 2). This reach is characterized by an incised channel of approximately 6 to 30 m width (Rehwinkle 1978). Throughout this reach, the channel is either sinuous or irregularly meandering with prevailing midchannel bars and silt or sand as the dominant bed materials in low gradient areas and bedrock outcrops of limestone and sandstones dominant in higher gradient areas (Rehwinkle 1978).

METHODS

Macrohabitat Classification and Sample Site Selection

In the spring of 1997 the Tongue and Powder rivers were classified into five predominant fluvial macrohabitat types: main channel crossover, outside bend, inside bend, bar and secondary channel. This classification was a modification of the system developed by Sappington et al. (1996).

Main Channel Crossover

The main channel conveys the majority of the river discharge, and is defined as the thalweg of the river. Fish and habitat data were collected in the channel crossover area, which is the inflection point of the thalweg (ie., location where the thalweg crosses over from one concave side of the river to the next concave side).

Outside Bend

The outside bend was defined as the concave side of a river meander. In the Tongue River, outside bends were usually associated with rip-rap of some form. In the Powder River, outside bends were associated with eroding banks. Each outside bend was sampled between channel crossovers, while the lateral boundary was from the shore to the thalweg.

Inside Bend

An inside bend was the convex side of the river channel. Longitudinal and lateral boundaries were the same as outside bends. This macrohabitat was characterized by

point bars (ie., terrestrial/aquatic interface area of deposited sediment lying within the spatial boundaries of the inside bend).

Bar

A bar was areas above water but surrounded by stream flows, and were vegetated or non-vegetated. Bars are formed by deposition and because they are an active part of the flow geometry, they change in size, height, or location with flow conditions (Heede 1980). Most bars in the study area were mid-channel bars, a typical bed form for wide and shallow streams.

Secondary Channel

Secondary channel macrohabitats were flowing channels which carried less flow than the main channel. Their upstream and downstream ends were connected to the main channel permitting fish passage and water flow.

Macrohabitat types were identified and enumerated for both rivers using aerial photographs with ground truthing conducted and all channel changes noted. A systematic random sample was used to ensure that the sample was representative of all study reaches. Scheaffer et al. (1990) defined it as a sample obtained by randomly selecting one element from the first k elements in the frame and every k th element thereafter. Thus after a random start, macrohabitats were systematically sampled at a randomly selected interval throughout the study reaches. Certain sampling sites were eliminated if access was limited or sampling conditions were inefficient. In this case, I randomly chose to move upstream or downstream to the next nearest habitat unit.

Fish and Habitat Sampling

Macrohabitats were sampled using three techniques. Pulsed direct-current electrofishing was used to sample fish in outside bend macrohabitats in 1997 and the spring of 1998. Electrofishing was discontinued after the pre-runoff period in 1998 because consistently high turbidity reduced visibility, making netting inefficient.

Electrofishing was conducted using a single boom suspended system mounted on a 4.3 m aluminum flat bottom boat with a 15 hp outboard motor. Electric current was generated using a Honda 5000 watt generator and converted into pulsed direct current via a Coffelt VVP-15 electrofishing unit. The distance covered while electrofishing was estimated using a Rangematic 1200 rangefinder and recorded.

Seining was used in inside bends, secondary channels, and bar macrohabitats. Seining was an effective method for collecting small fish in shallow macrohabitats (inside bends, bars and secondary channels) where the net wall extended from the surface to the bottom. Seining is most effective for nearshore residents or species that concentrate near shore seasonally or on a diel basis (Kelso and Rutherford 1996). Water depth in these habitats was too shallow to operate the boat, and electrofishing was not a viable technique. A net haul was the standard unit of effort (number of fish/seine haul) (Sappington et al. 1996). I compared bag seine and beach seine efficiency early in the 1997 field season and determined that the standard beach seine was more applicable in the sand and silt conditions encountered frequently. The beach seine used for sampling

was 10.7 m long and 1.8 m high with 5 mm mesh and had a 29.5 kg lead line and a top float line. To deploy the seine, one end was anchored on shore by a technician while the other end was pulled upstream to full extension along the shoreline. Once the net was extended, the net was then pulled in a 180-degree arc around the anchored pivot.

Main channel crossover macrohabitats were sampled by drifting multifilament experimental mesh gill nets. Nets used on the Tongue River were 15.2 m in length and 1.8 m high while nets used on the Powder River were 30.4 m long and 1.8 m high. They contained four panels of equal length with mesh sizes of 1.9 cm, 3.8 cm, 5.1 cm, and 7.6 cm, respectively. Nets were drifted 100-200 m, estimated using a Rangematic 1200 rangefinder. If the net became snagged and required substantial effort to retrieve, and/or the net folded around a snag, the drift was eliminated from the sample. All sampling techniques were standardized using the protocol of Sappington et al. (1996), modified to accommodate the smaller scale of the Tongue and Powder rivers.

To describe fish species composition and longitudinal distribution, a systematic random sample was employed to ensure representative sampling of the entire study reach of both rivers. Sampling took place in the base flow period (Aug 1-Sept 10) when fish movement was likely to be minimal. In both rivers, at least three of each macrohabitat type were sampled in the study area to examine the longitudinal distribution and composition of the resident fish community.

To describe seasonal and diel use of major macrohabitat types by the fish community, three ecologically important time periods were chosen for sampling:

- 1) Pre-runoff: This typically occurs in April and May when water temperatures are

warming, water flows are increasing, and the majority of fish in these systems are spawning or are in pre-spawn stage. Sampling occurred between 4/15-5/15.

2) Post-runoff: This typically occurs in July when water temperatures are high and flow is decreasing. During this period fish are moving toward or are concentrated at feeding areas, some exhibit post-spawning migration patterns (Buckley and Kynard 1985).

Sampling occurred between 7/1-7/31.

3) Base flow: This typically occurs in August or September when flows are relatively stable or slowly decreasing. Fish are typically in or moving to their wintering habitats.

Sampling occurred between 8/1-9/10.

To examine the seasonal use of macrohabitats by the fish community, I systematically sampled at least three of each macrohabitat type in the Tongue and the Powder rivers, during each of the three sampling periods described above. To examine the diel use of macrohabitats by the fish community, I sampled these habitats on a 24 h cycle, excluding main channel crossover due to the safety concerns of drifting nets at night. During the 1997 diel sampling period, at least one of the other four habitats was sampled during late summer periods. In the 1998 field season, I was able to sample at least one inside bend, bar, and secondary channel during pre-runoff and again in late summer periods. The macrohabitat site randomly selected for diel sampling was sampled four times throughout a 24-h period: noon, sunset, midnight, and sunrise. Sampling started approximately one half hour before each designated time and ended approximately one half hour after that time. Location of diel sampling was not completely random because certain areas were extremely difficult to sample at night. It was also necessary to

select sampling sites in close proximity to each other to maximize sampling efforts and minimize the safety concerns of night work.

To describe the physical characteristics of the macrohabitats used by the fish community, 10 physical parameters were measured at each sampling site in conjunction with fish collection to identify macrohabitat associations. Depth and velocity was measured using a standard top-set wading rod and a Marsh-McBirney meter. Depth was measured to the nearest 0.1 m and velocity to the nearest 0.1 m/s at 0.6 water depth to represent mean column velocity. During seining, depth and velocity were taken at 25% and 75% of full extension along a transect perpendicular to the center of the arc anchored onshore. After each electrofishing run and gill net drift, depth and velocity were measured mid-channel at 25% and 75% of the length of the run. Air and water temperature (°C) were measured at each sampling site using a hand-held thermometer. Turbidity was measured using a Secchi disk. At each site the disk was lowered into the water, and the depth at which it disappeared was recorded to the nearest centimeter. Conductivity was measured at each site using a hand-held Hanna DIST WP3 conductivity meter. Location was recorded at each site using a Magellan NAV 5000 GPS unit and comparing that with U.S. Geological Survey topographical maps with 1:24000 scale. Flow and river stage were reported using USGS provisional flow data at station 06308500-- Tongue River at Miles City, Montana, and station 06326500--Powder River near Locate, Montana. Weather information was also noted by visual observation, and recorded.

Dominant substrate was determined by visual observation or feeling substrate diameter at each depth and velocity measurement location and assigned a corresponding number (Table 1).

Table 1. Criteria used to classify substrate sizes in Tongue and Powder rivers (modified from Platts et al. 1983)

Substrate Type	Size (mm)	Code
Silt	<1	5
Sand	1 to 4	4
Gravel	4.8 to 76	3
Cobble	76.1 to 304	2
Boulder	>305	1
Bedrock		0

All fish sampled that were >40 mm in total length were identified, enumerated, weighed to the nearest 1 g, and measured to the nearest 1 mm. In samples that contained more than 50 individuals of one species, 50 were randomly selected for weighing and measuring, the remaining portions of that catch were counted and recorded. Specimens not identifiable in the field were preserved and identified later at Montana State University-Bozeman.

Data analysis

Statistical analyses were conducted using the Statistical Analysis System (SAS 1998). A Tukey Studentized Range multiple comparison test was used to test for

differences among habitats. Analysis of variance and Tukey's multiple comparison test were used to examine differences in flathead chub proportion within diel sampling periods (dawn, noon, dusk, and midnight). Bars, inside bends, and secondary channels were analyzed while outside bends were deleted from analysis due to small sample size. A Ryan-Einot-Gabriel-Welsch Multiple Range Test (REGWQ) was used to examine differences in proportion of seasonal catch of flathead chub among macrohabitats. Proportions (p) were transformed by taking the arcsin $\sqrt{p}$ to approximate normality (Zar 1996).

RESULTS

A total of 3,484 individuals representing 21 species in 8 families were collected in the Tongue River (Table 2). Five species were non-native to Montana (Brown 1971). The most abundant and species-rich family was Cyprinidae. Flathead chub was the most common species collected in the Tongue River, making up 55.2% of total catch, followed by *Hybognathus spp*, emerald shiner, longnose dace, and goldeye.

A total of 2,315 individuals representing 19 species in 9 families were collected in the Powder River (Table 3). Three species were non-native to Montana (Brown 1971). The most abundant and species-rich family was Cyprinidae. Flathead chub was the most common species collected in the Powder River, making up 77.41% of total catch, followed by *Hybognathus spp*, longnose dace, goldeye, and channel catfish.

Tongue and Powder River Fish Assemblages

Flathead chub In my survey the flathead chub was the most abundant species in the Tongue and Powder rivers. A total of 1,924 were collected in the Tongue River representing 55.2% of catch, and 1,792 were collected in the Powder River, representing 77.4% of total catch.

The flathead chub was widely but unevenly distributed in the Tongue River, occurring throughout the entire study area, but 37% of total catch occurred between river

Table 2. Fish species composition, occurrence, and abundance from the Tongue River, Montana, May-September 1997 and 1998.

Common name	Scientific name	Number	Relative abundance (%)
Flathead chub	<i>Platygobio gracilis</i>	1924	55.20%
<i>Hybognathus</i> sp.		560	16.07%
Emerald shiner	<i>Notropis atherinoides</i>	234	6.71%
Longnose dace	<i>Rhinichthys cataractae</i>	167	4.79%
Goldeye	<i>Hiodon alosoides</i>	107	3.07%
Channel catfish	<i>Ictalurus punctatus</i>	110	3.16%
Shorthead redhorse	<i>Moxostoma macrolepidotum</i>	127	3.64%
River carpsucker	<i>Carpoides carpio</i>	80	2.30%
Longnose sucker	<i>Catostomus catostomus</i>	66	1.89%
Carp ^a	<i>Cyprinus carpio</i>	42	1.21%
Stonecat	<i>Noturus flavus</i>	24	0.69%
Fathead minnow	<i>Pimephales promelas</i>	23	0.66%
Shovelnose sturgeon	<i>Scaphirhynchus platyrhynchus</i>	2	0.06%
Walleye ^a	<i>Stizostedion vitreum</i>	5	0.14%
Smallmouth bass ^a	<i>Micropterus dolomieu</i>	5	0.14%
Sauger	<i>Stizostedion canadense</i>	3	0.09%
Burbot	<i>Lota lota</i>	1	0.03%
Blue sucker	<i>Cycleptus elongatus</i>	1	0.03%
Black bullhead ^a	<i>Ameiurus melas</i>	1	0.03%
Smallmouth buffalo	<i>Ictiobus bubalus</i>	1	0.03%
Black crappie ^a	<i>Pomoxis nigromaculatus</i>	1	0.03%

^a Non-native species

Table 3. Fish species composition, occurrence, and abundance from the Powder River, Montana, May-September 1997 and 1998.

Common name	Scientific name	Number	Relative abundance (%)
Flathead chub	<i>Platygobio gracilis</i>	1792	77.41%
<i>Hybognathus</i> sp.		176	5.05%
Longnose dace	<i>Rhinichthys cataractae</i>	48	1.38%
Goldeye	<i>Hiodon alosoides</i>	100	2.87%
Channel catfish	<i>Ictalurus punctatus</i>	79	2.27%
Shorthead redhorse	<i>Moxostoma macrolepidotum</i>	6	0.17%
River carpsucker	<i>Carpoides carpio</i>	17	0.49%
Longnose sucker	<i>Catostomus catostomus</i>	2	0.06%
Sturgeon chub	<i>Macrhybopsis gelida</i>	60	1.72%
Carp ^a	<i>Cyprinus carpio</i>	9	0.26%
Stonecat	<i>Noturus flavus</i>	5	0.14%
Shovelnose sturgeon	<i>Scaphirhynchus platyrhynchus</i>	10	0.29%
Sauger	<i>Stizostedion canadense</i>	1	0.03%
Bigmouth buffalo	<i>Ictiobus cyprinellus</i>	3	0.09%
Burbot	<i>Lota lota</i>	2	0.06%
Blue sucker	<i>Cycleptus elongatus</i>	1	0.03%
Plains killifish ^a	<i>Fundulus zebrinus</i>	2	0.06%
Black bullhead ^a	<i>Ameiurus melas</i>	1	0.03%
Freshwater drum	<i>Aplodinotus grunniens</i>	1	0.03%

^a Non-native species

km 4.5-6 (Figure 3). Flathead chub abundance showed a significant weak negative correlation with increased distance from the mouth (river km) $R^2 = -0.204$, $P = 0.038$, $n = 104$). Abundance patterns, distribution, and exact location of collection indicated that the flathead chub has somewhat specific habitat requirements. Flathead chub abundance was greatest in shallow macrohabitats, with 81.8% of catch occurring in bar and inside bend habitats (Figure 4). Most flathead chubs (83.9%) were captured where water depth was between 0.2-0.59 m, and 59.4 % were captured where water velocities were between 0.2-0.59 m/s (Figure 5).

Flathead chubs were widely and evenly distributed in the Powder River. The largest numbers were collected at river km 1.1, where 7.5% of total catch occurred (Figure 6). As in the Tongue River, abundance patterns, distribution, and exact location of collection indicated that the flathead chub has somewhat specific habitat requirements. Ninetyeight percent of flathead chubs were collected from inside bends, bar, and secondary channel habitats (Figure 7). Abundance was greatest at shallow, moderately swift habitats, with 81.5% of catch occurring at depths between 0-0.39 m, and 96% occurring in areas with velocities between 0.2-0.79 m/s (Figure 5).

Hybognathus spp. This group of similar species (western silvery minnow, plains minnow, brassy minnow), that are difficult to identify from each other without dissection, are all native to Montana. As a group, *Hybognathus spp.* were second in abundance of species collected in the Tongue River. A total of 560 was collected representing 16.1% of catch in the Tongue River. *Hybognathus spp.* were found throughout the study area of the Tongue River but were unevenly distributed.

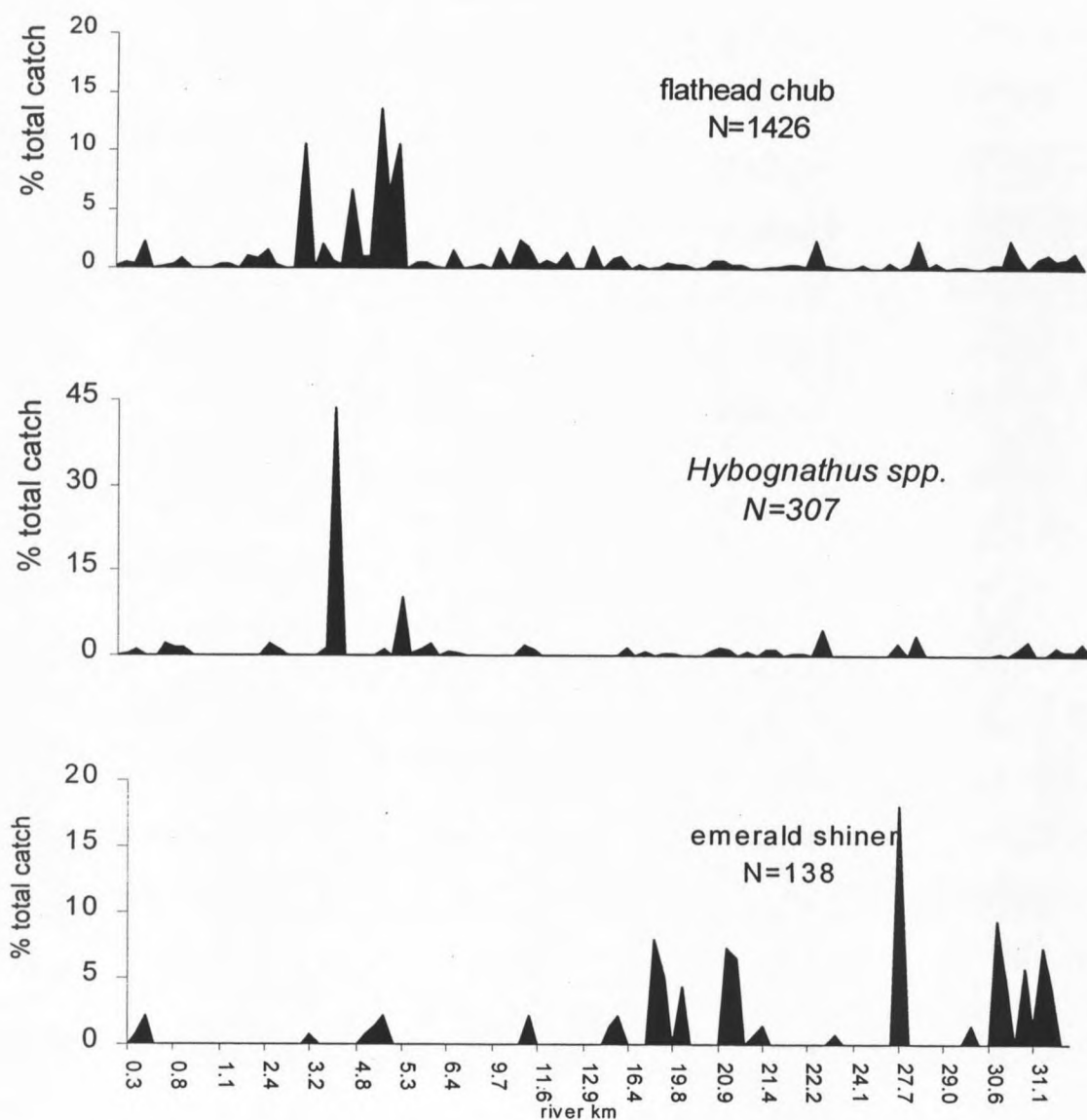


Figure 3. Longitudinal distribution and relative abundance of fishes of the Tongue River, Montana, April-August 1997-1998.

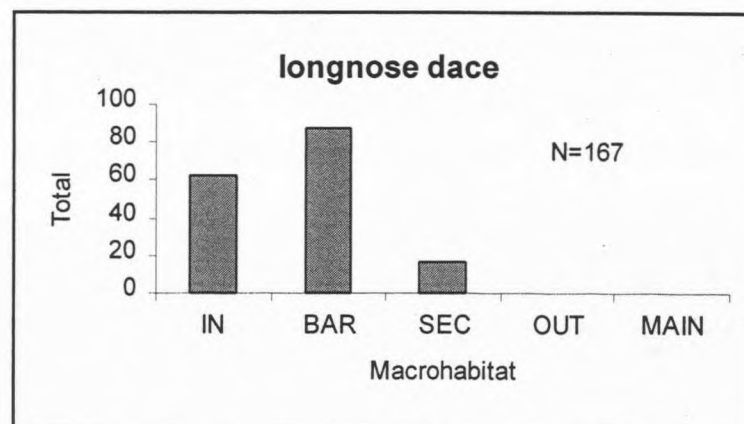
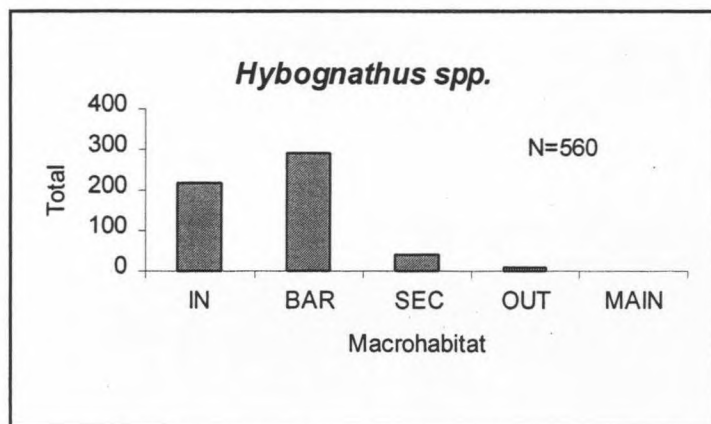
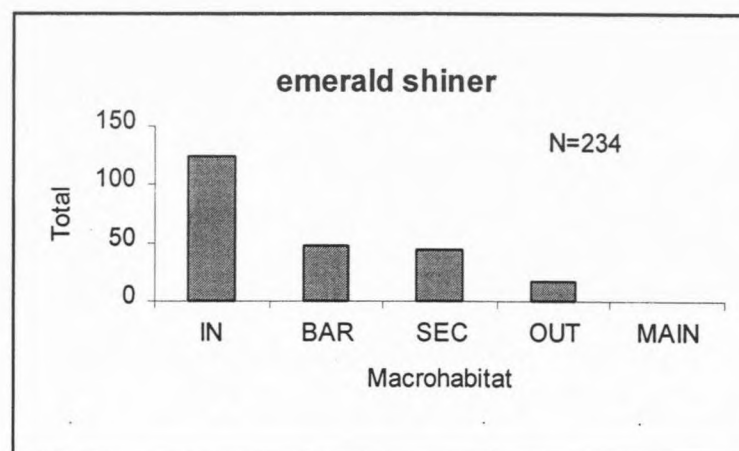
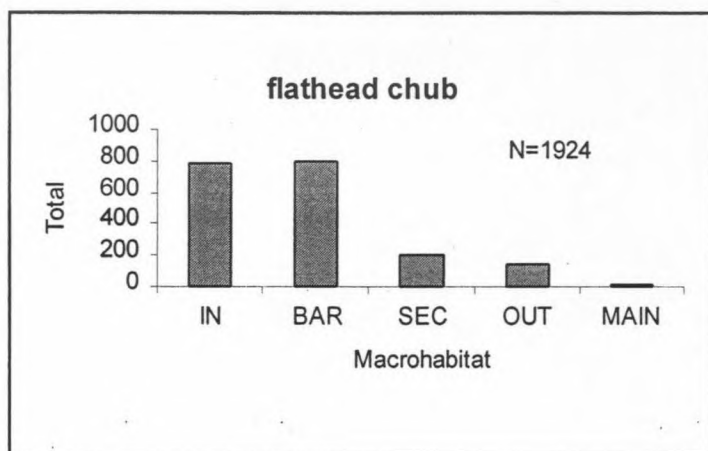


Figure 4. Frequency of use of the five macrohabitat types (inside bends, bars, secondary channel, outside bends, and main channel) by selected fishes from Tongue River, Montana, collections 1997-1998.

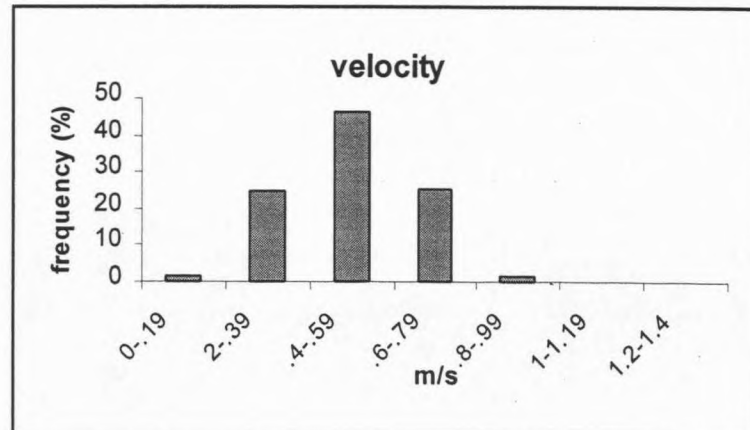
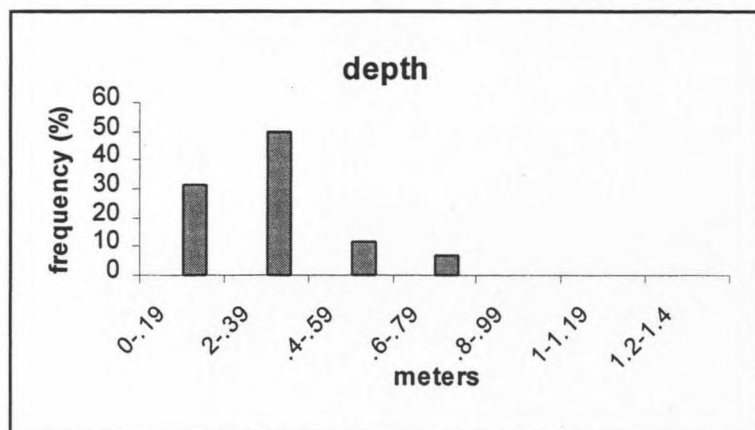
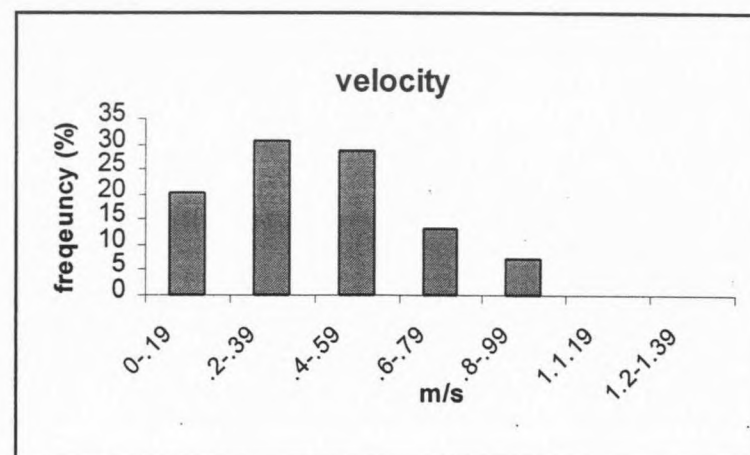
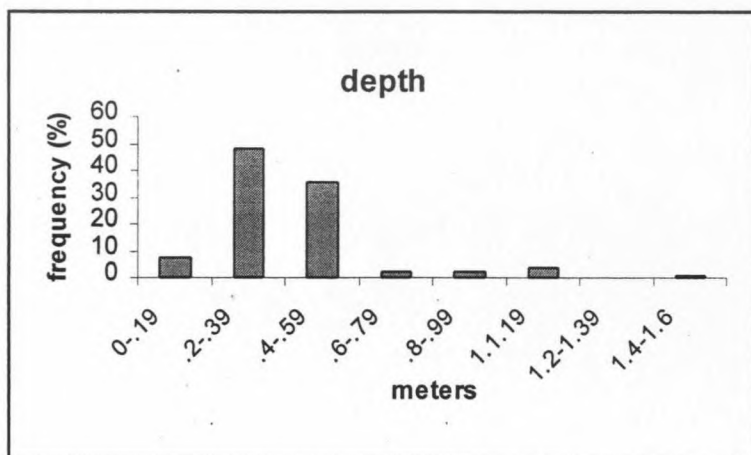


Figure 5. Frequency of occurrence of flathead chub in various depth, and velocity intervals from Tongue (upper) (N=1924) and Powder River (lower) (N=1790) collections.

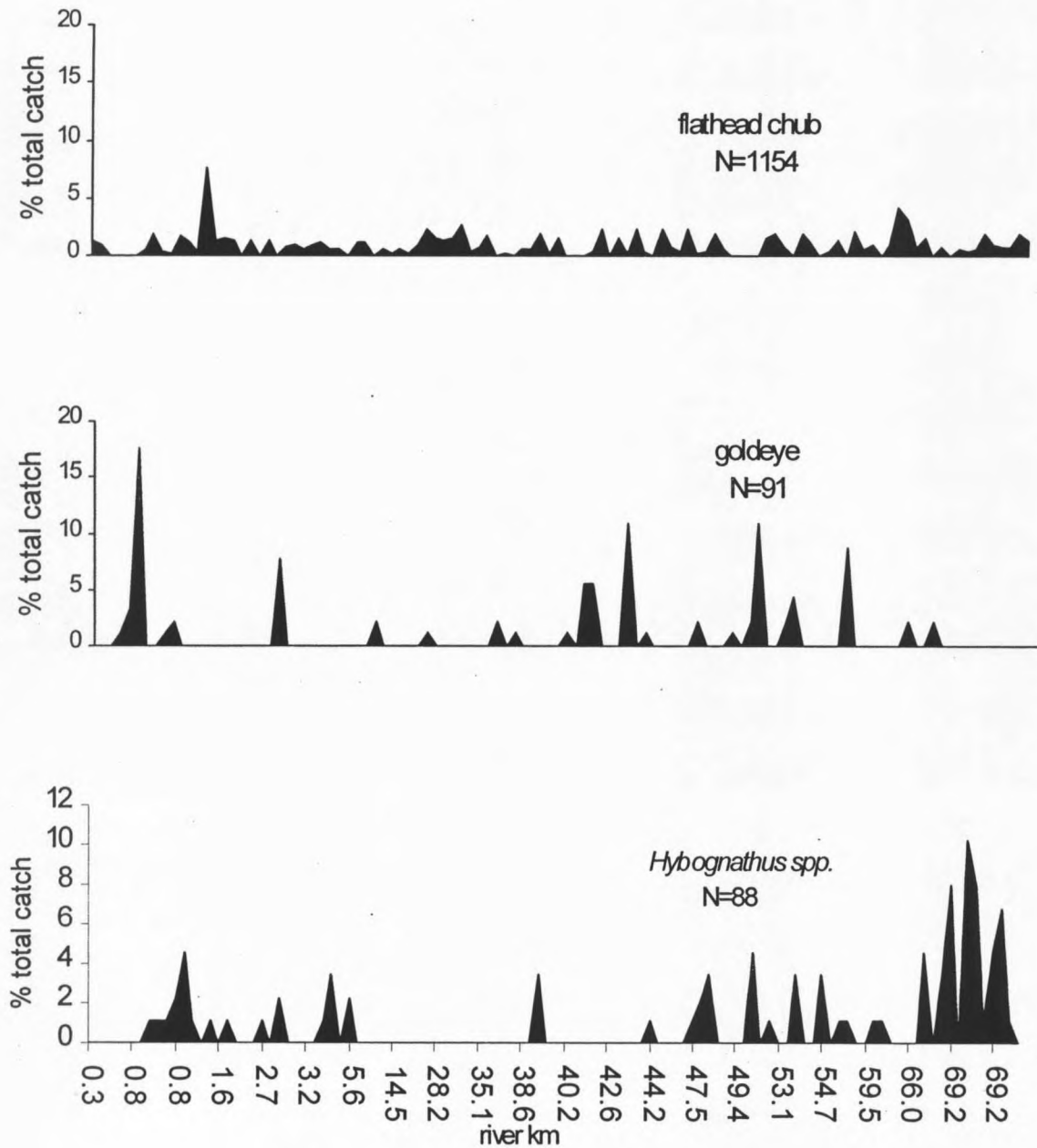


Figure 6. Longitudinal distribution and relative abundance of fishes of the Powder River, Montana, April-August 1997-1998.

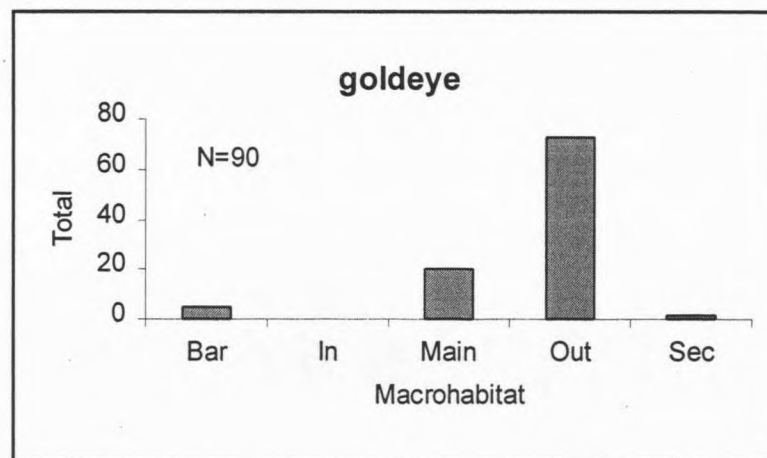
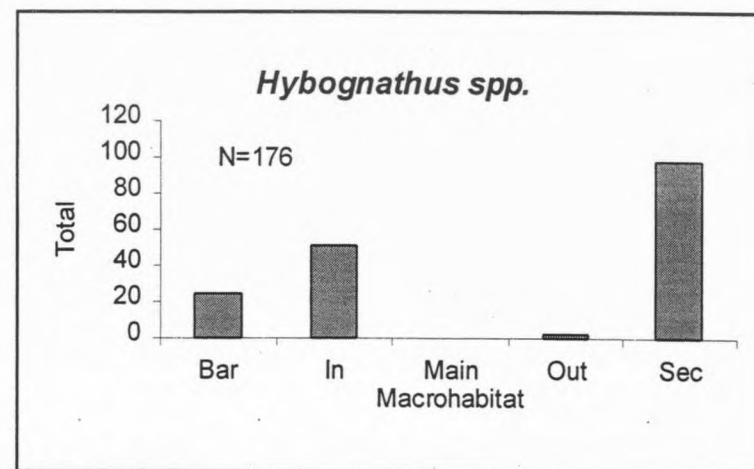
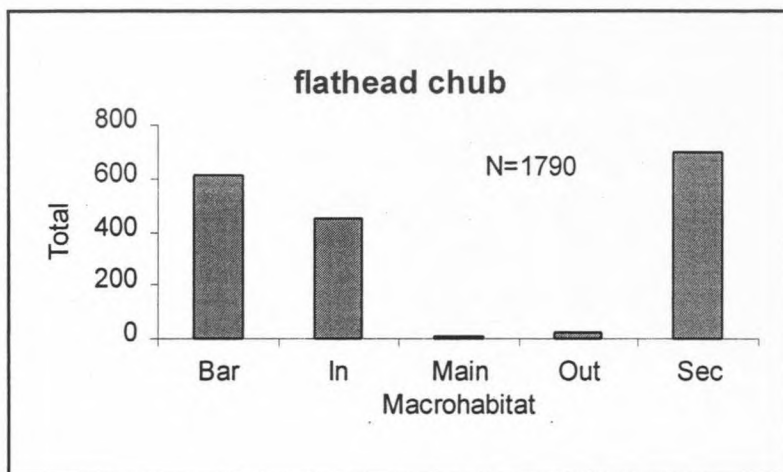


Figure 7. Frequency of use of the five macrohabitat types (inside bends, bars, secondary channel, outside bends, and main channel) by selected fishes from Powder River, Montana, collections 1997-1998.

A significant number (44.9%) of total catch occurred between river km 3.5-4.5 (Figure 3). *Hybognathus spp.* abundance showed no correlation to distance from the mouth.

Abundance patterns, distribution, and exact location of collection indicated that *Hybognathus spp.* has somewhat specific habitat requirements. Abundance was greatest in shallow water macrohabitats, with 90.9% of catch occurring in bar and inside bend habitats (Figure 4). Most (86.9%) *Hybognathus spp.* were collected in water with depths of 0.2-0.69 m and 98.1% were collected in water with velocities of 0.2-0.69 m/s (Figure 8).

Hybognathus spp. were found unevenly distributed throughout the study area of the Powder River. Abundance was greatest in the upper 1/3 of the study area, with 71.6% occurring above river km 47 (Figure 6). Abundance showed a significant, although weak, correlation with increased distance from the mouth $R^2 = 0.288$, $P = 0.0026$, $n = 108$). Collection patterns indicated that *Hybognathus spp.* has specific habitat associations, with 98.9% occurring at inside bends, bars, and secondary channels (Figure 7). Abundance was greatest in shallow, moderately swift areas (89.2% occurred in depths between 0-0.39, 83.6% in velocities between 0.2-0.59 m/s) (Figure 8).

Emerald shiner I found the emerald shiner to be the third most abundant species in the Tongue River. A total of 234 were collected, representing 6.7% of catch in the Tongue River. The emerald shiner had a disjunct distribution in the Tongue River, with 85.8% of catch occurring upstream of river km 20 (Figure 3) and scattered abundance occurring throughout the lower portion of the study area. Emerald shiner abundance exhibited a

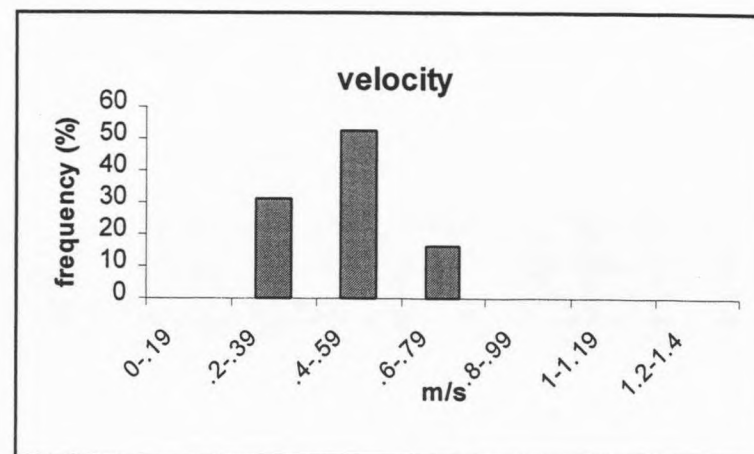
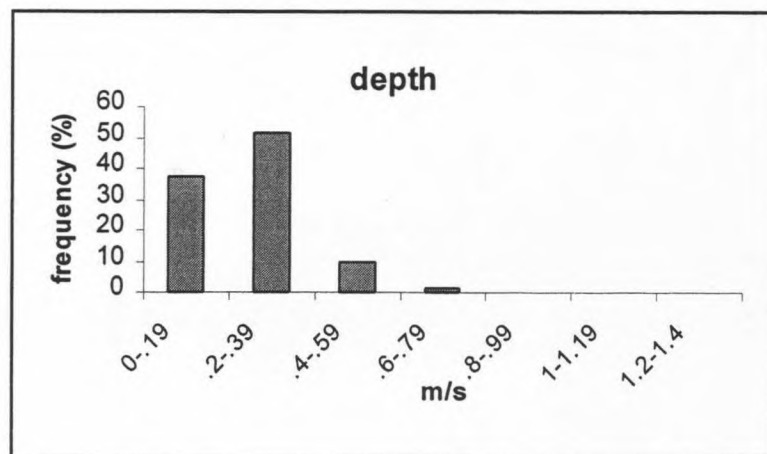
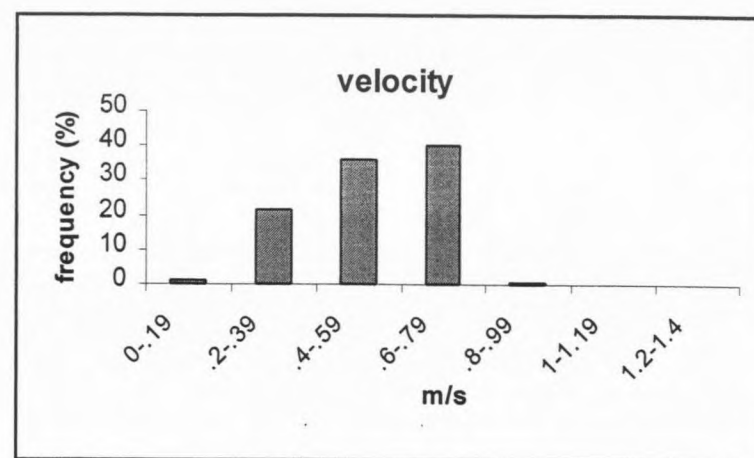
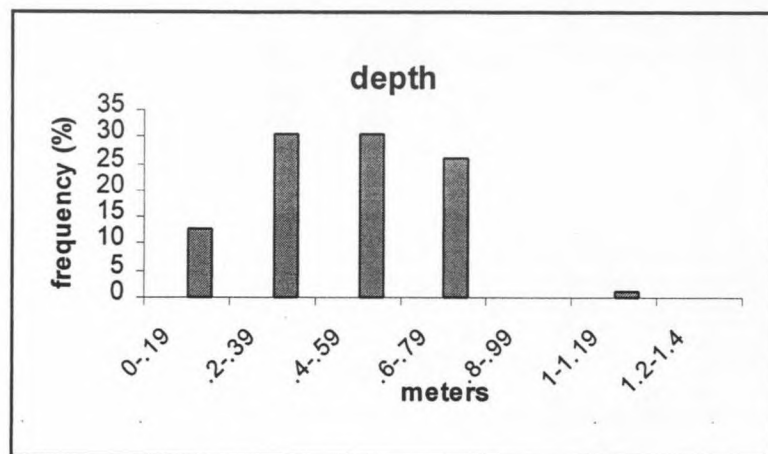


Figure 8. Frequency of occurrence of *Hybognathus* spp. in various depth, and velocity intervals from the Tongue (upper) (N=560) and Powder River (lower) (N=176) collections.

weak but significant positive correlation with distance from the mouth $R^2 = 0.314$, $P = 0.0012$, $n = 104$). Emerald shiners were specific in habitat association, with 73.5% of emerald shiners collected in bar and inside bend habitats (Figure 4). Abundance was greatest in shallow water habitats, with 91% of total catch associated with habitats with depths between 0.2-0.59 m, while 77% were associated with habitats with water velocities between 0.2-0.59 m/s (Figure 9). No emerald shiners were collected in the Powder River.

Longnose dace A total of 167 longnose dace were collected, representing 4.8% of catch in the Tongue River. Longnose dace were found throughout the study area of the Tongue River although unevenly distributed. Abundance was greatest in the lower portion of the study area with 52.7% of catch occurring below river km 5 (Figure 10). Longnose dace were captured exclusively in shallow water habitats (100% were collected at bar, inside bend, and secondary channel habitats) (Figure 4). Longnose dace were specific in habitat associations as 98.8% were collected in areas with water depths between 0-0.59 m, and 70.6% were collected in areas with water velocities between 0.2-0.59 m/s (Figure 11).

The longnose dace were found throughout the study area of the Powder River with the greatest abundance collected at river km 70 where 20.5% of catch occurred (Figure 12). Longnose dace abundance was associated with shallow habitats as 100% were found at inside bends, bars, and secondary channels (98.7% in depths between 0-0.59 m) (Figure 11). Abundance was greatest in moderately swift current as 70.6% were collected in areas with velocities between 0.2-0.59 m/s (Figure 11).

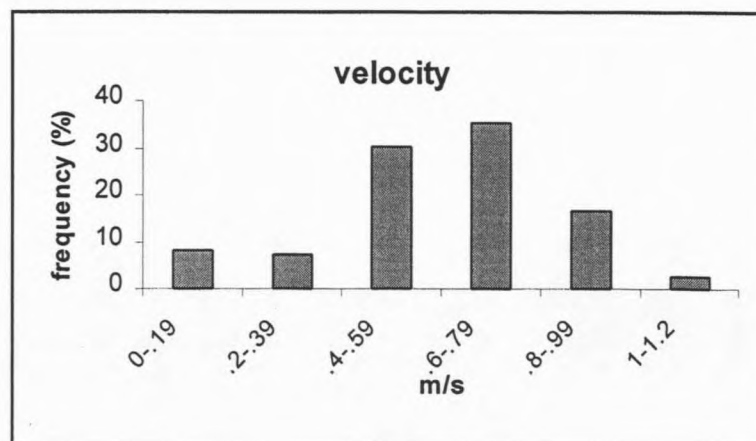
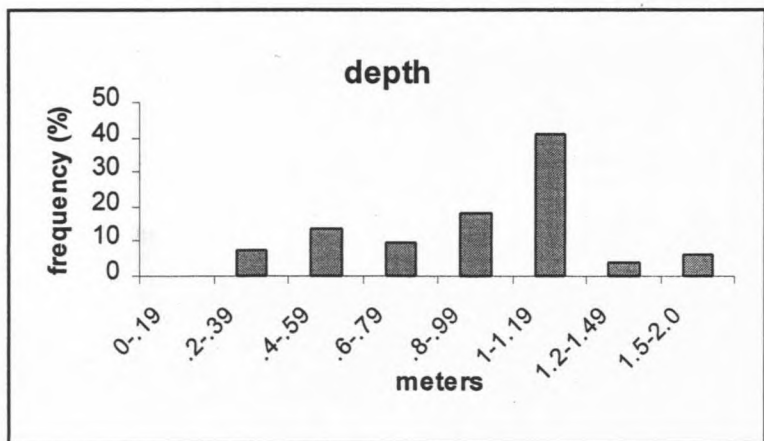
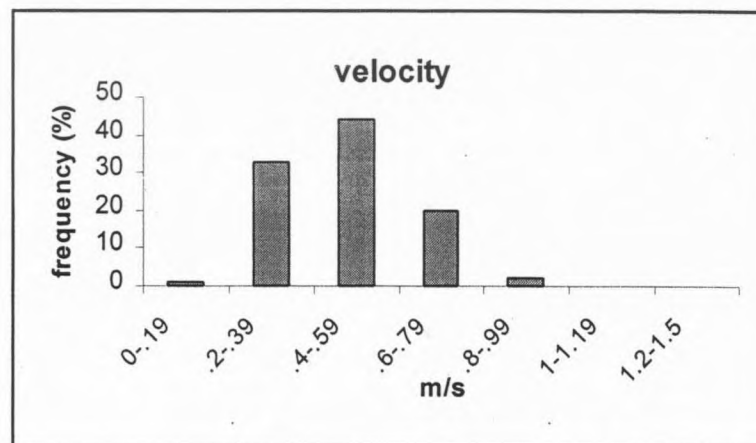
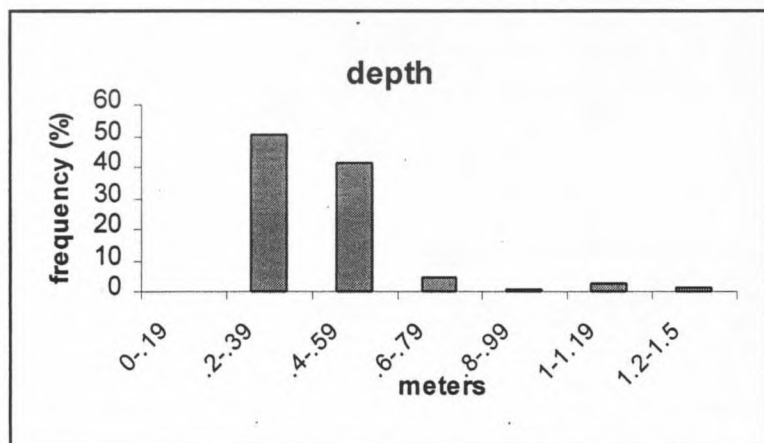


Figure 9. Frequency of occurrence of emerald shiner (upper) (N=234) and shorthead redhorse (lower) (N=125) in various depth, and velocity intervals from Tongue River collections.

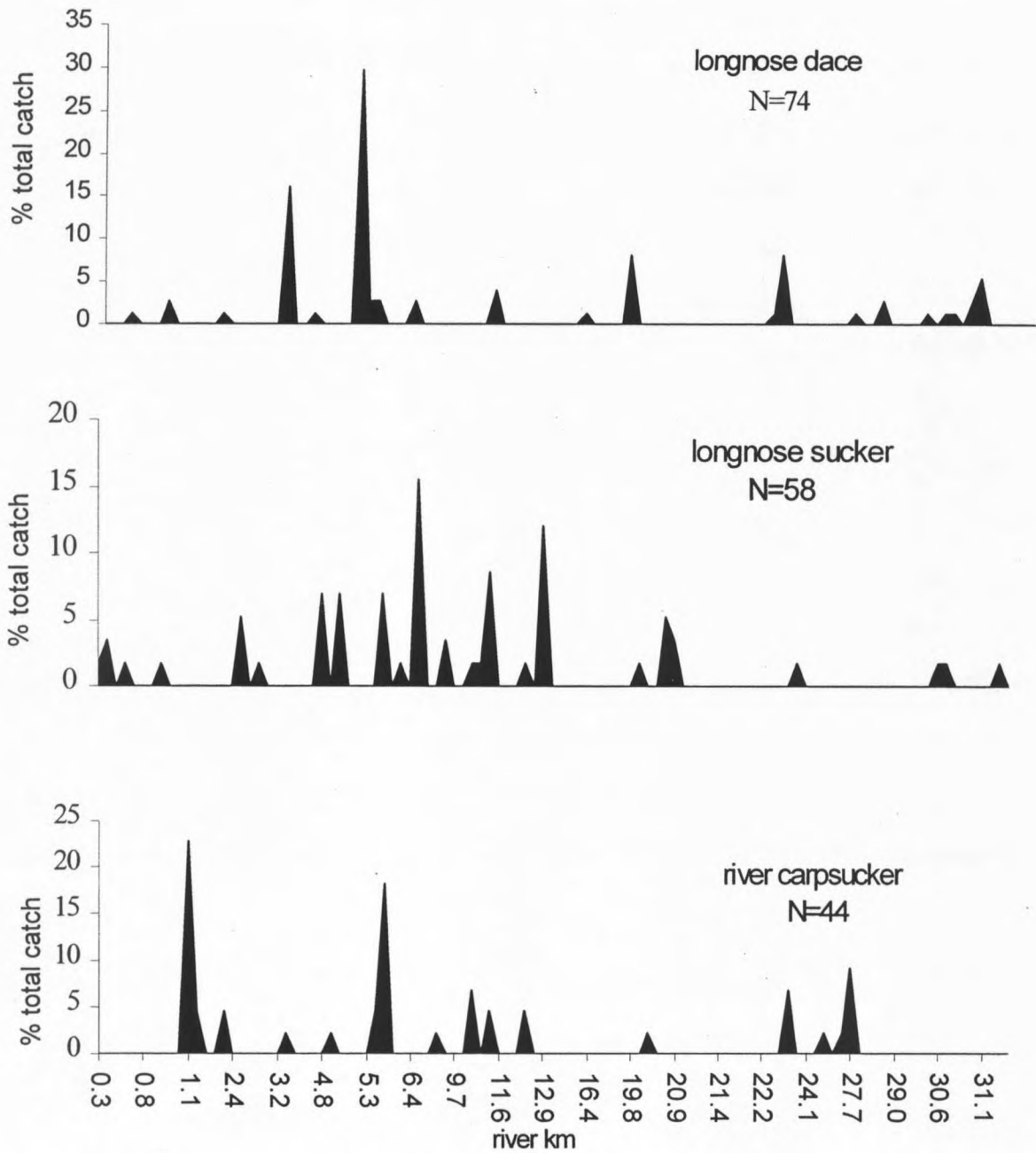


Figure 10. Longitudinal distribution and relative abundance of fishes of the Tongue River, Montana, April-August 1997-1998.

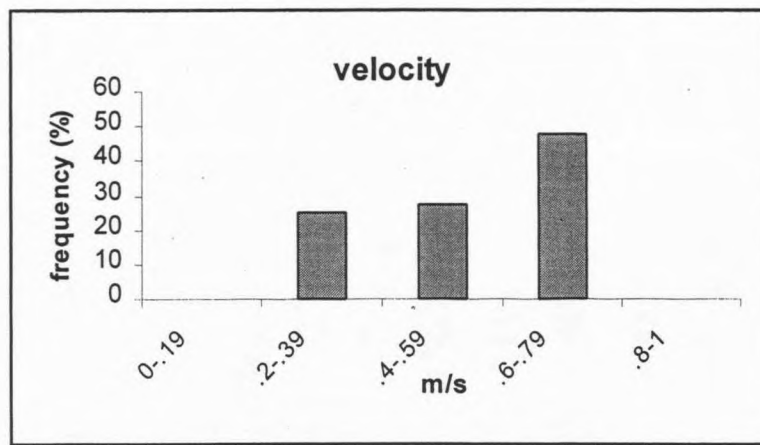
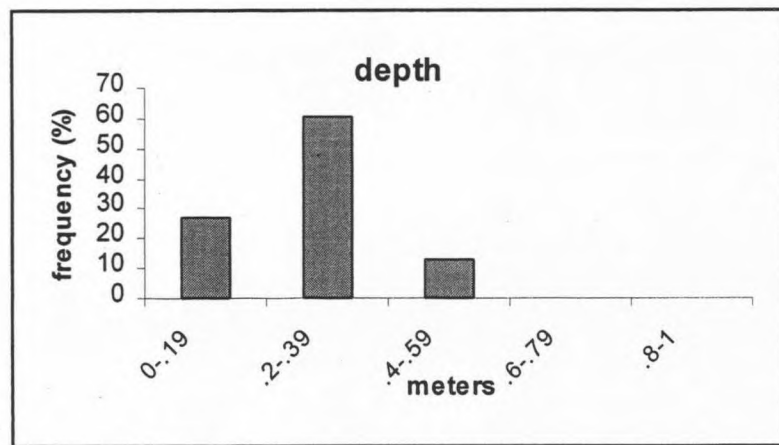
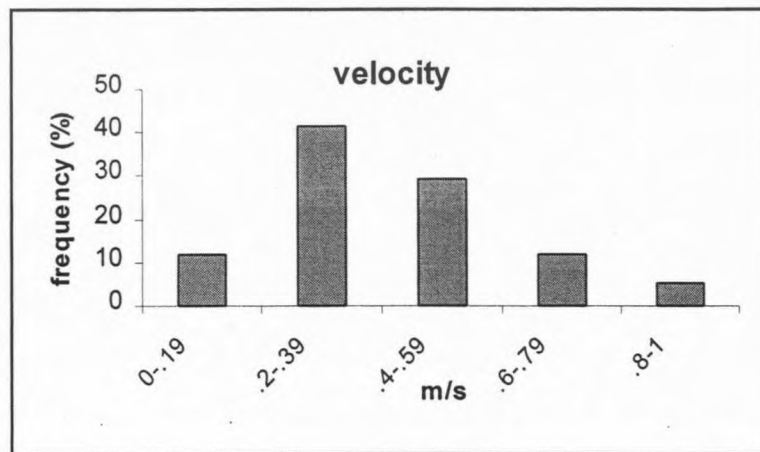
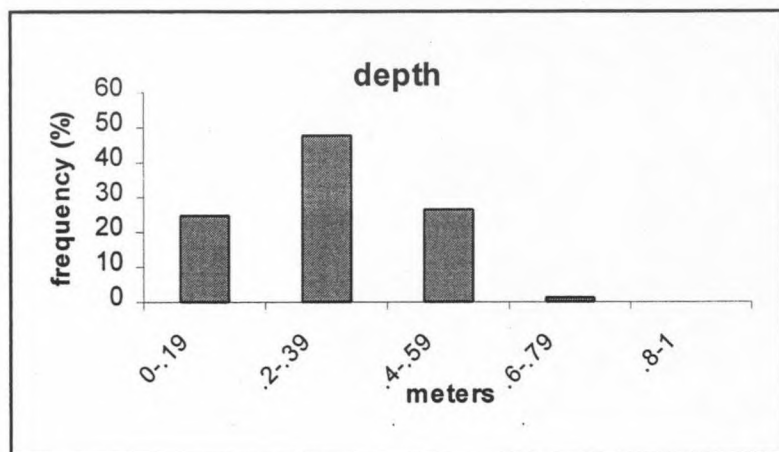


Figure 11. Frequency of occurrence of longnose dace in various depth, and velocity intervals from Tongue (upper) (N=167) and Powder River (lower) (N=48) collections.

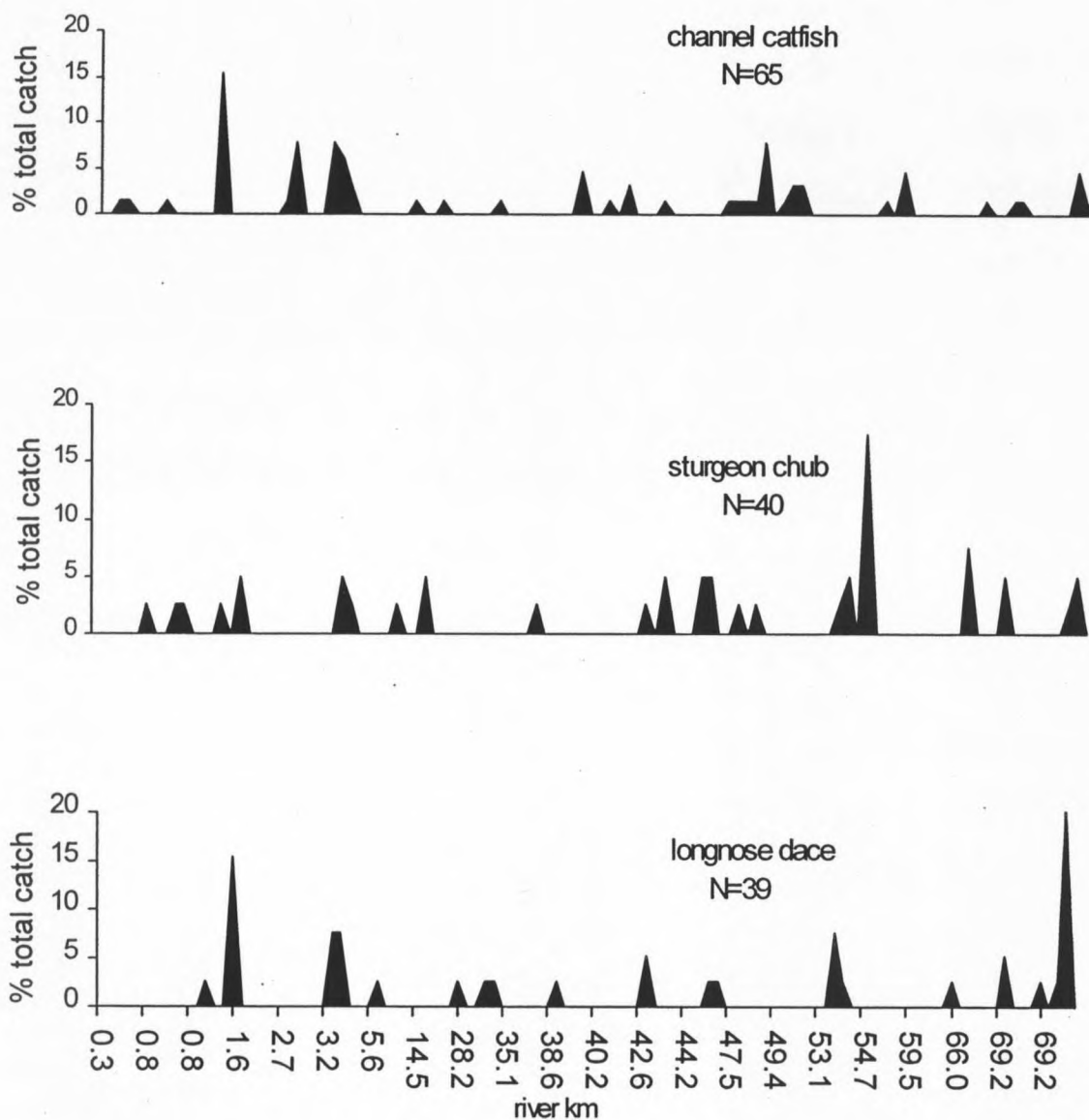


Figure 12. Longitudinal distribution and relative abundance of fishes of the Powder River, Montana, April-August 1997-1998.

Shorthead redhorse In my survey, 127 shorthead redhorse were collected making them the fifth most abundant species in the Tongue River, representing 3.6% of total catch.

Shorthead redhorse were found throughout the study area of the Tongue River.

Abundance was distributed somewhat evenly through the reach, with the greatest abundance occurring at river km 11, where 17% of shorthead redhorse were collected (Figure 13). Shorthead redhorse preferred deep, swift habitats in the Tongue River with 90.7% collected in outside bend habitats, 69% collected in areas with water depths between 0.75-0.99 m, and 76% collected in water with velocities between 0.5-0.99 m/s (Figure 9).

Shorthead redhorse abundance was very limited in the Powder River. Only six were collected making up 0.26% of total catch. These individuals were all collected in close proximity to the mouth and were probably a seasonal migrant. Because of the small number collected in the Powder River, no habitat association analysis was done.

Channel catfish A total of 110 channel catfish were collected in the Tongue River comprising 3.2% of total catch. Populations of channel catfish were found evenly distributed longitudinally throughout the study area of the Tongue River (Figure 13). I found abundance to be somewhat similar in all macrohabitats (bar=20.9%, inside bends=12.7%, main channel=25.5%, outside bends=33.6%) except secondary channels where only 7.3% of channel catfish were collected (Figure 14). Channel catfish utilized a range of water depths (37% in depths between 0.4-0.59 m, 17% in depths between 1.0-1.19 m) and 73.4% were found in moderate-swift current velocities between 0.4-0.79 m/s (Figure 15).

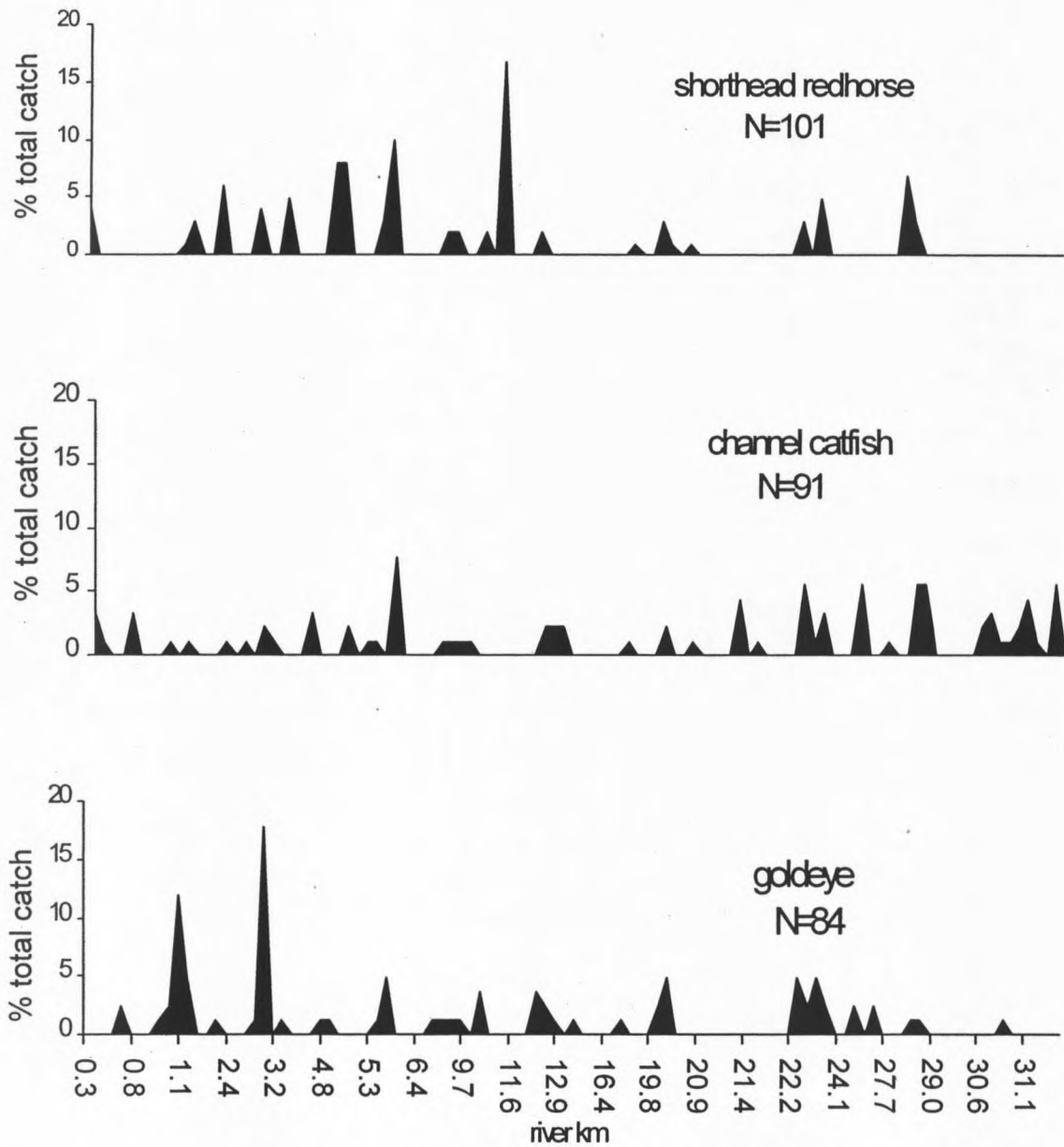


Figure 13. Longitudinal distribution and relative abundance of fishes of the Tongue River, Montana, April-August 1997-1998.

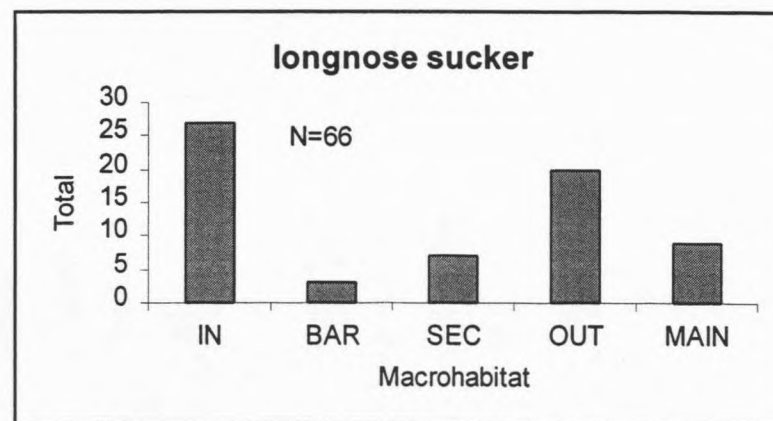
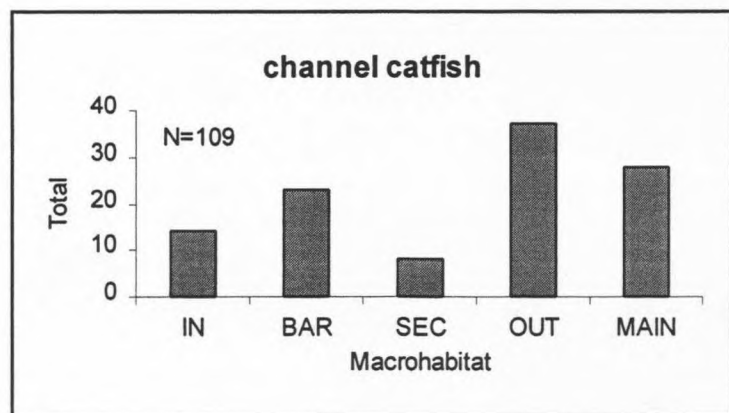
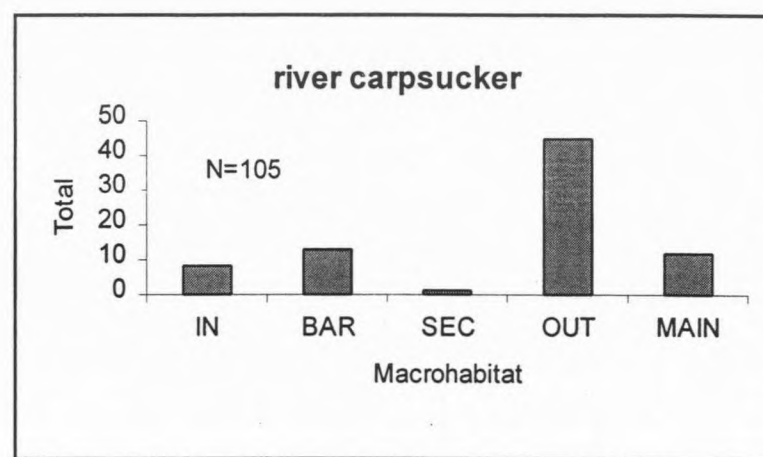
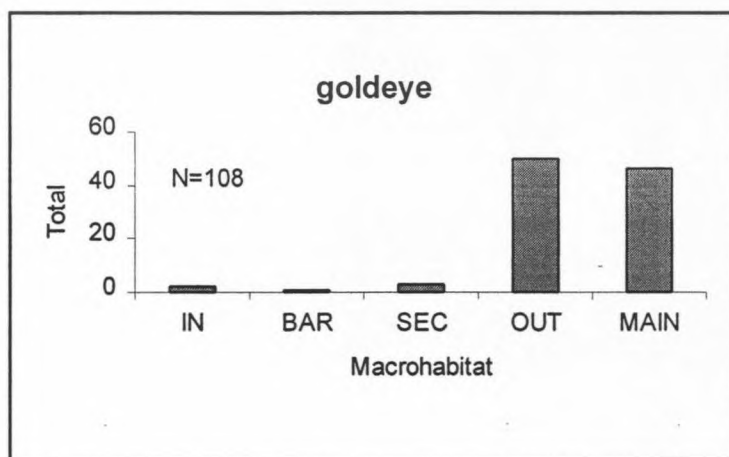


Figure 14. Frequency of use of the five macrohabitat types (inside bends, bars, secondary channel, outside bends, and main channel) by selected fishes from Tongue River, Montana, collections 1997-1998.

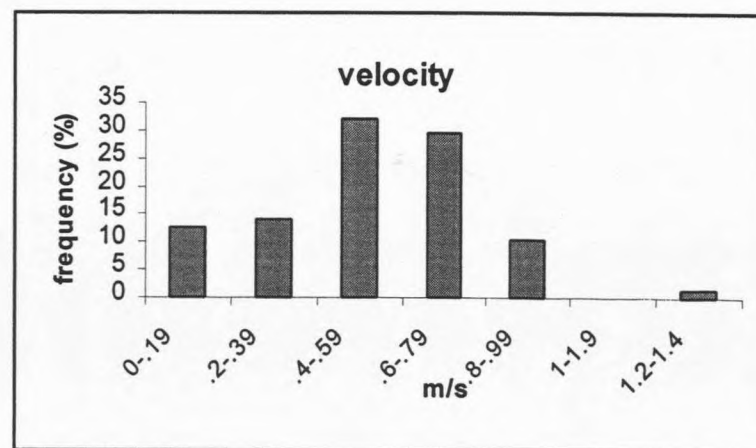
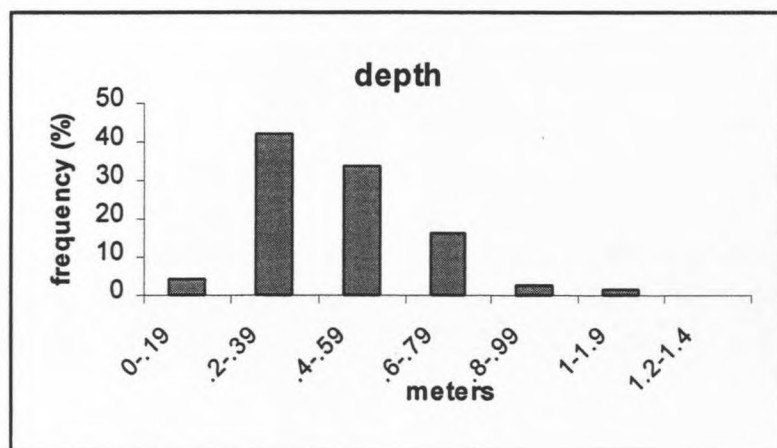
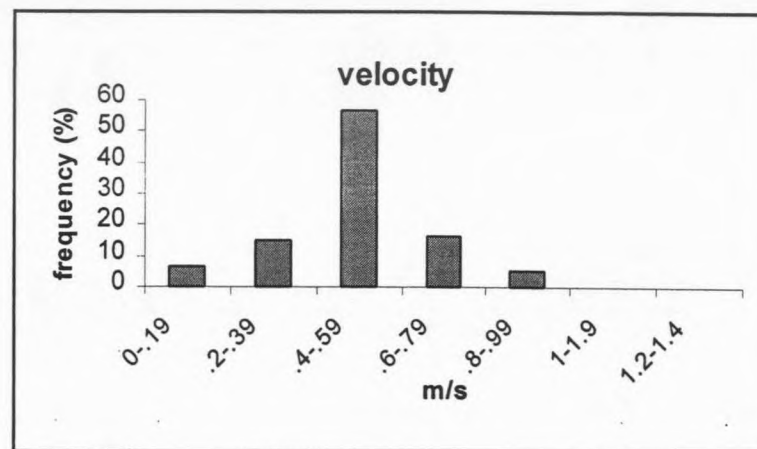
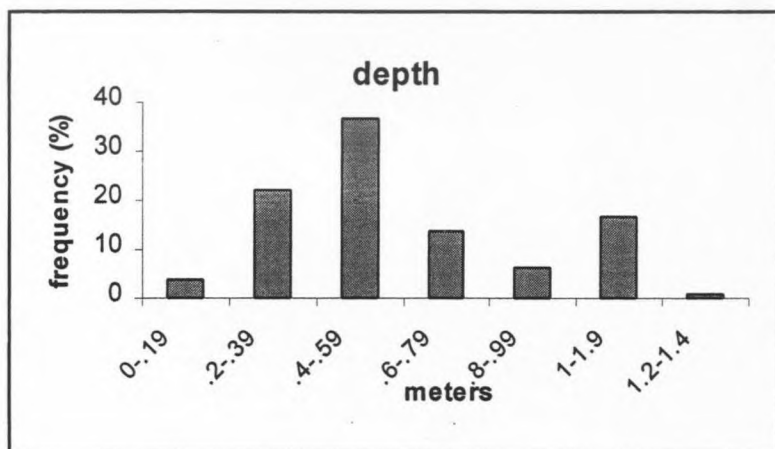


Figure 15. Frequency of occurrence of channel catfish in various depth, and velocity intervals from Tongue (upper) (N=109) and Powder River (lower) (N=78) collections.

Channel catfish were commonly captured in the Powder River. Seventy nine were collected, representing 3.4% of total catch. Channel catfish were distributed throughout the study area of the Powder River, with the greatest abundance occurring at river km 1.1 where 15.4% of catch was collected (Figure 12). Abundance was distributed across all macrohabitat types (bar=35.4%, inside bends=32.9%, main channel=10.1%, outside bends=13.9%, secondary channels=7.6%) (Figure 16). Channel catfish utilized a range of water depths (87.2% in depths between 0.4-1.0 m) and were most commonly found in swift current (71.9% in velocities between 0.6-1.2 m/s) (Figure 15).

Goldeye A total of 109 goldeye were collected in the Tongue River, making up 3.1% of total catch. Goldeye were widely but unevenly distributed in the Tongue River, with 52.4 % of total catch occurring between the mouth and river km 6. Although a weak negative correlation was found between abundance and distance from the mouth it was not significant at the $\alpha = 0.05$ significance level ($R^2 = -0.171$, $P = 0.081$) (Figure 13).

Goldeye were found in all macrohabitats but 88.9% of total catch occurred in main channel and outside bend habitats (Figure 14). This species utilized areas of deep water (35.2% in depths between 1-1.2 m) and areas with swift current (90.8% in velocities between 0.4-0.99 m/s) (Figure 17).

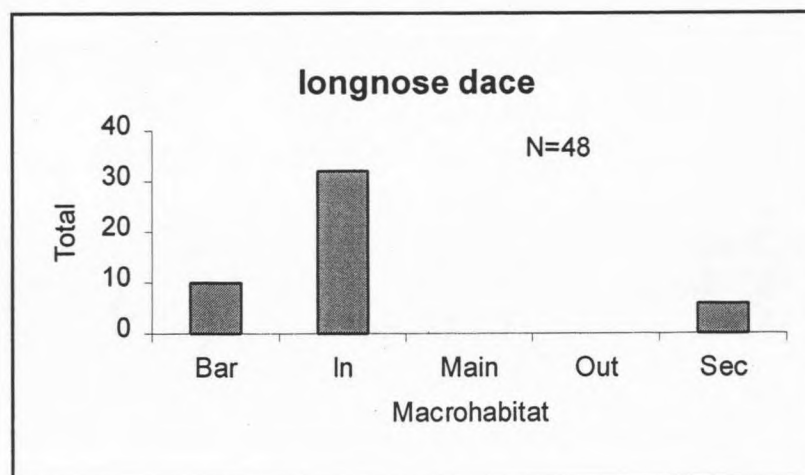
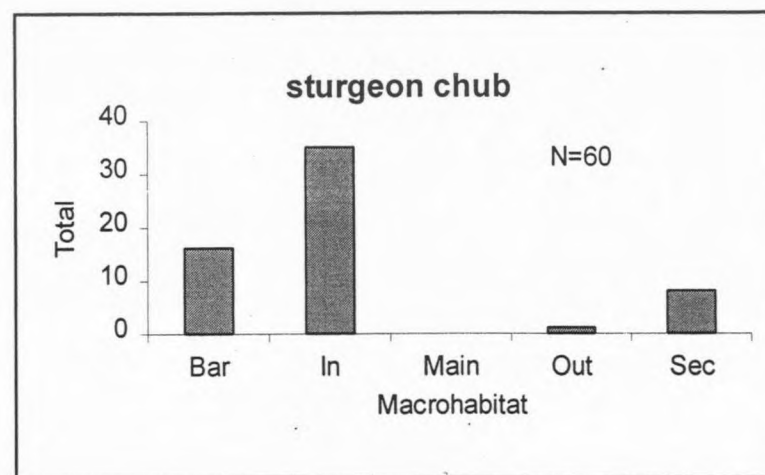
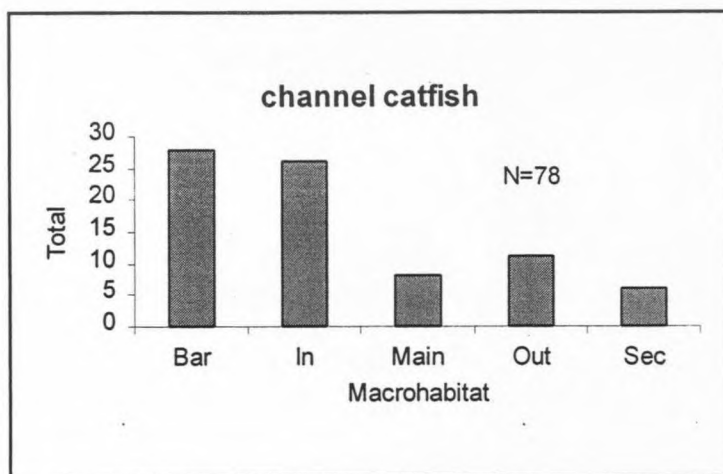


Figure 16. Frequency of use of the five macrohabitat types (inside bends, bars, secondary channel, outside bends, and main channel) by selected fishes from Powder River, Montana, collections 1997-1998.

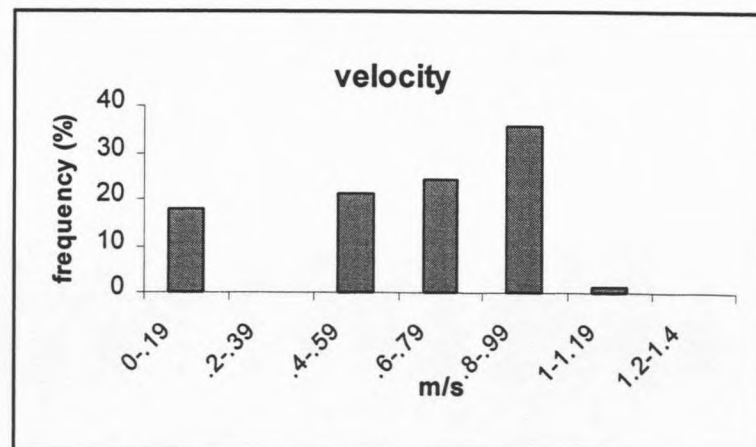
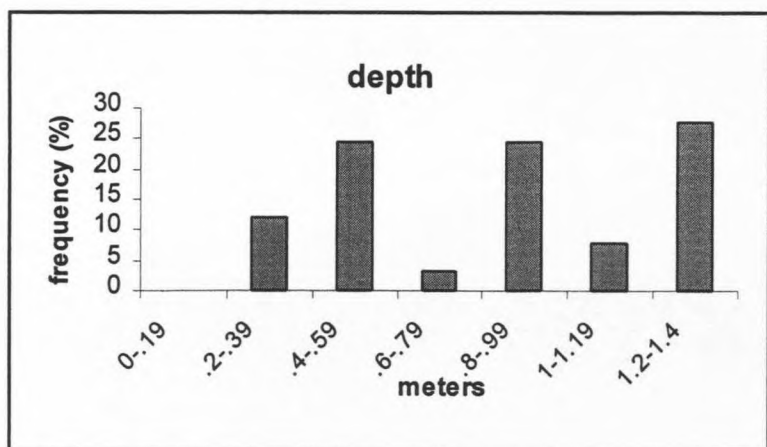
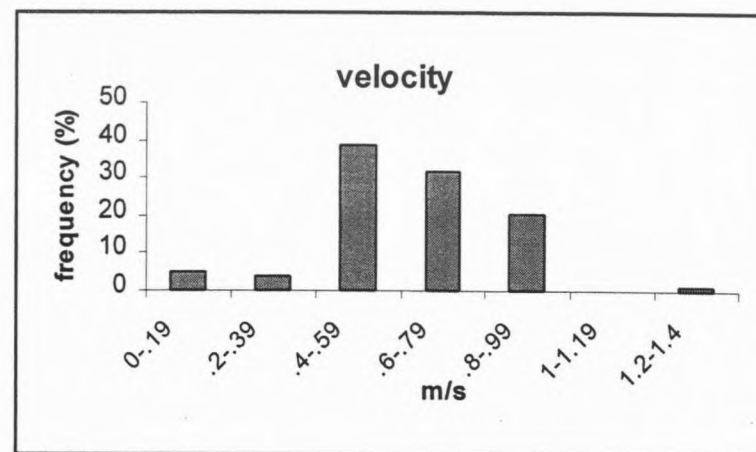
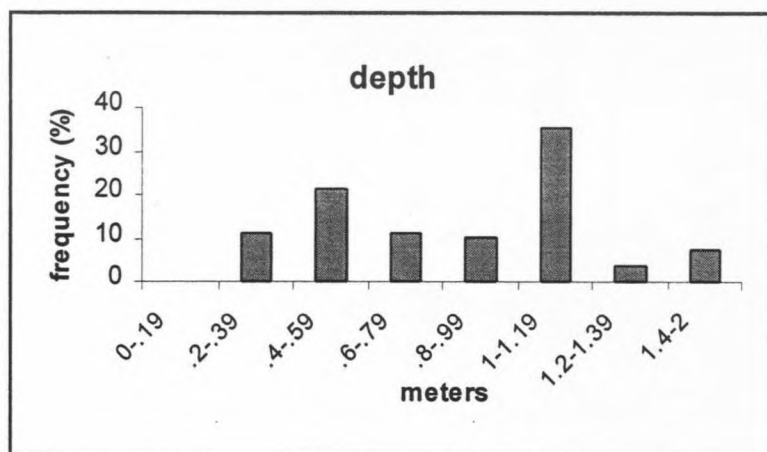


Figure 17. Frequency of occurrence of goldeye in various depth, and velocity intervals from Tongue (upper) (N=108) and Powder River (lower) (N=90) collections.

Goldeye were locally abundant in the Powder River. One hundred were collected, representing 4.3% of total catch. Populations of goldeye were found evenly distributed throughout the study area with the largest abundance collected at river km 1 where 17.6% of total catch occurred (Figure 7). Goldeye occurred primarily in deep water habitats (93% occurred at main channels and outside bends) (Figure 7). Goldeye utilized a wide range of depths and velocities in the Powder River (100% in depths between 0.2-1.4 m, and 100% in velocities between 0-1.2 m/s) (Figure 17).

River carpsucker Eighty one river carpsuckers were collected in the Tongue River, comprising 2.3% of catch. The river carpsucker was found throughout the study area with an uneven distribution pattern, with 77.3% collected between the mouth and river km 12 (Figure 10). River carpsuckers were commonly found in all macrohabitats (bars 16.5%, inside bends 10.1%, main channels 15.2%, and outside bends 57%) except secondary channels where only 1.3% of total catch occurred (Figure 14). Abundance patterns, distribution, and exact location of collection (Figure 18) indicated that the river carpsucker is somewhat of a habitat generalist, utilizing a range of depths and velocities (57% occurred in depths between 0-0.59 m, and 87.2% occurred in velocities between 0.2-0.99 m/s). Abundance of the river carpsucker was limited in the Powder River. Only 17 were sampled, comprising 0.73% of total catch. Distribution was also limited in the Powder River as 71.4% of catch occurred before river km 2.

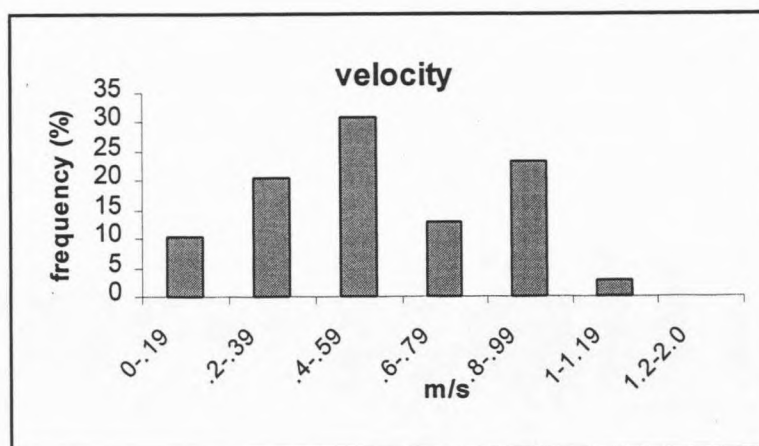
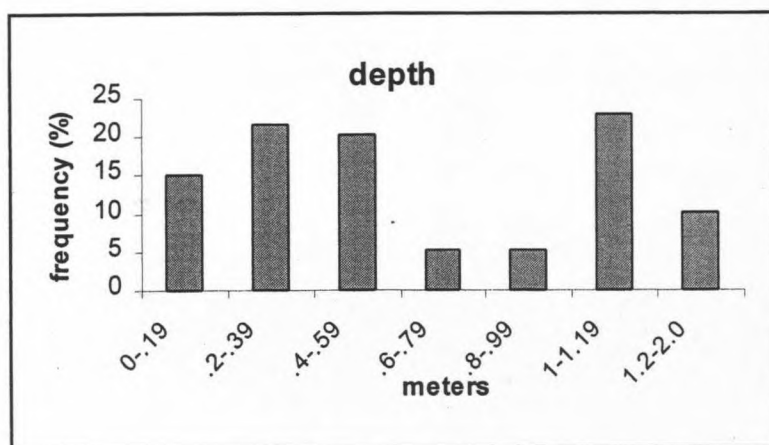
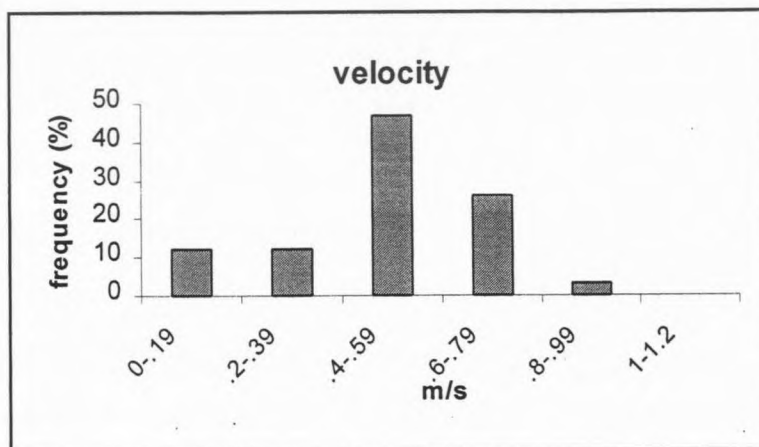
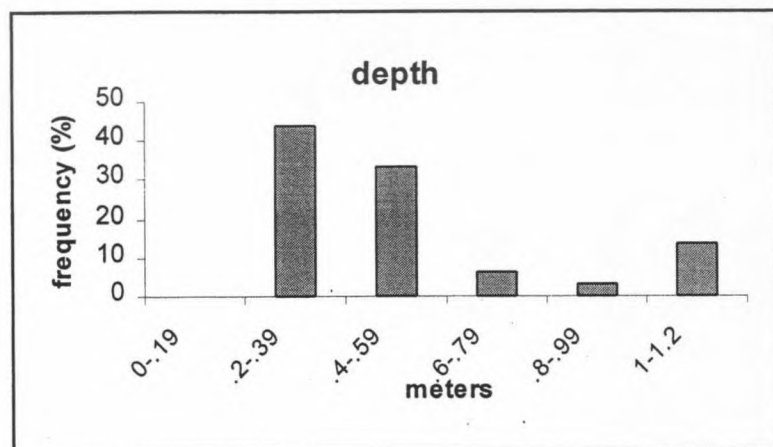


Figure 18. Frequency of occurrence of longnose sucker (upper) (N=66) and river carpsucker (lower) (N=79) in various depth, and velocity intervals from Tongue River collections.

Longnose sucker In my survey, 66 longnose suckers were collected in the Tongue and Powder river making it uncommon, only constituting 1.9% of total catch. The relatively few longnose suckers collected were widely but unevenly distributed in the Tongue River, with 82.8% between the mouth and river km 13. Although a weak negative correlation was found between abundance and distance from the mouth, it was not significant at the $\alpha=0.05$ level ($R^2 = -0.18$, $P= 0.066$ $n=104$). Longnose suckers were found in all macrohabitats, with the greatest abundance occurring at inside bends (40.9% of total catch) and outside bends (30.3%) (Figure 14). In the Tongue River, longnose suckers were associated with moderate depth and moderate current with 77.3% collected in areas with depths between 0.2-0.59 m, and 73.7% in areas with velocities between 0.4-0.79 m/s (Figure 18). Because of the small number of longnose suckers collected in the Powder River ($N=2$), no distribution or habitat association could be made.

Sturgeon chub I found no sturgeon chubs in the Tongue River, contrary to Elser et al. (1977) who found the species to be common. In contrast, the sturgeon chub was the fifth most abundant species we sampled in the Powder River. Sixty one sturgeon chubs were collected, representing 2.6% of total catch in the Powder River.

Sturgeon chubs were found throughout the 70 km study area that extended upstream from the confluence of the Powder River and the Yellowstone River, with somewhat of an even distribution pattern. The largest abundance occurred near river km 54 where 17.5% of total catch occurred. However, no correlation was found between sturgeon chub abundance and distance from the mouth (Figure 12). Abundance patterns, distribution, and exact location of collection indicated that sturgeon chubs were specific

in habitat requirements. Abundance was greatest in shallow water habitats, with 98.3% collected at bar, inside bend, and secondary channel habitats (Figure 16). Sturgeon chubs were associated with shallow, moderately swift current (66.7% were collected in areas with depths between 0.2-0.39 m, and 75% were collected in areas with velocities between 0.4-0.79 m/s) (Figure 19).

Abundance of Other Species

In addition to the most abundant species, 12 other taxa in the Tongue River and 9 other taxa in the Powder River were also collected. Taxa collected included numerous specimens of game species including sauger (N=4), smallmouth bass (N=5), shovelnose sturgeon (N=12), and walleye (N=5). Complete taxa list, distribution, and relative abundance is described in Table 3.

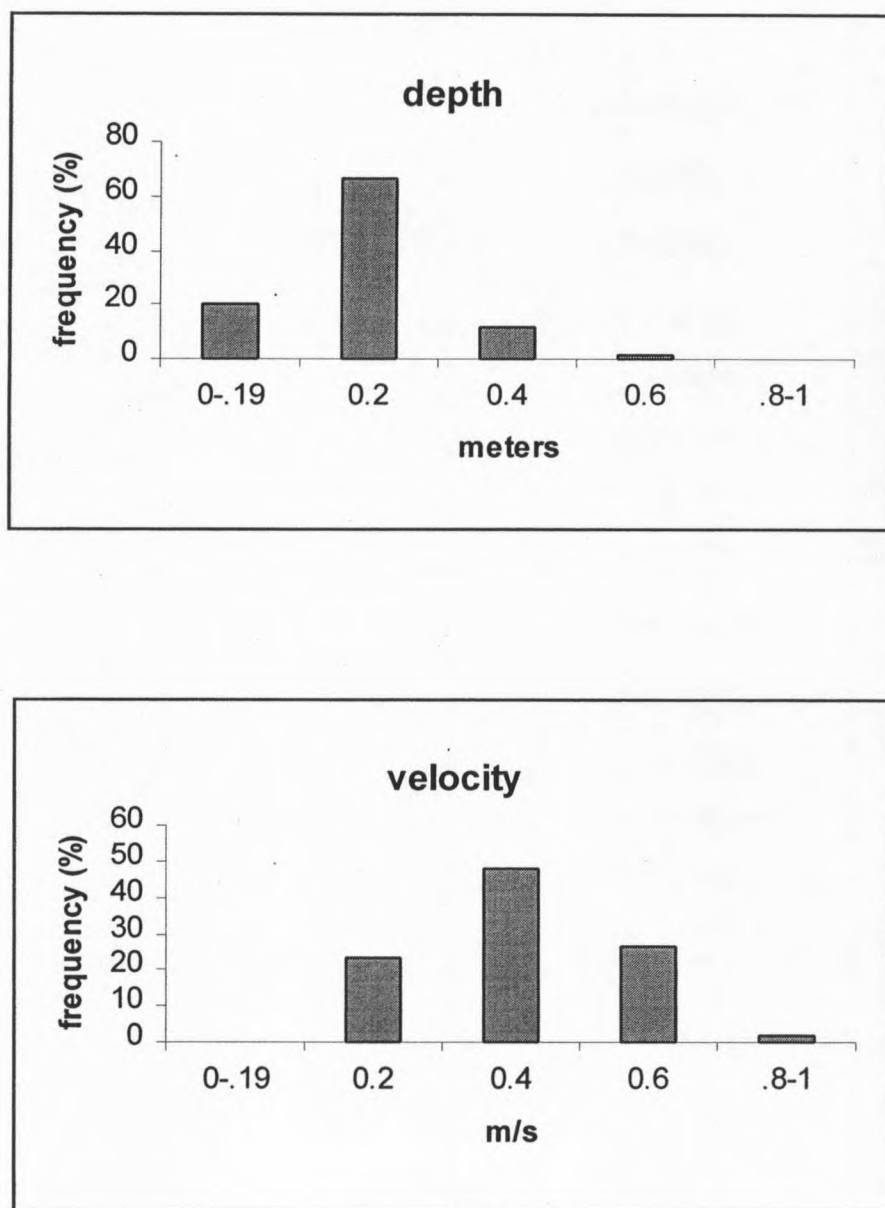


Figure 19. Frequency of occurrence of sturgeon chub in various depth and velocity intervals from the Powder River, Montana, collections (N=61).

Physical Habitat Variables

Seasonal patterns of flow in the Tongue River differed considerably between 1997 and 1998 (Figure 20). During the study period in 1997 (April 15 - September 15) discharge in the Tongue River at Miles City gauging station 06308500 ranged from 329 cfs ($9.32 \text{ m}^3/\text{s}$) on September 13, to a maximum discharge of 2,790 cfs ($79 \text{ m}^3/\text{s}$) on June 20. In 1998, discharge during the study period ranged from 52 cfs ($1.47 \text{ m}^3/\text{s}$) on May 30, and again on July 25, to a maximum discharge of 857 cfs ($24.28 \text{ m}^3/\text{s}$) on June 28, less than a third of maximum discharge in 1997. During both periods of low flow in 1998, there was no flow over T&Y diversion dam. The 1997 hydrograph had three distinct peaks over the six month field season compared to only two in 1998.

Discharge in the Powder River had a very similar pattern to the Tongue River and also contrasted sharply between 1997 and 1998 (Figure 21). During the study period in 1997 (April 15 - September 15) discharge at the Locate gauging station 06326500 ranged from 3,900 cfs ($110.44 \text{ m}^3/\text{s}$) on June 12 to 305 cfs ($8.64 \text{ m}^3/\text{s}$) on July 22, and down to 261 cfs ($7.39 \text{ m}^3/\text{s}$) on the last day of the field season (September 15). During the study period in 1998 (April 15 - September 15) discharge ranged from 1,820 cfs ($51.54 \text{ m}^3/\text{s}$) on July 6-7, less than half the 1997 maximum, to minimum flow of 46 cfs ($1.30 \text{ m}^3/\text{s}$) three weeks later on July 29. The 1997 hydrograph had four distinct peaks in the six month field season as compared with only three in 1998.

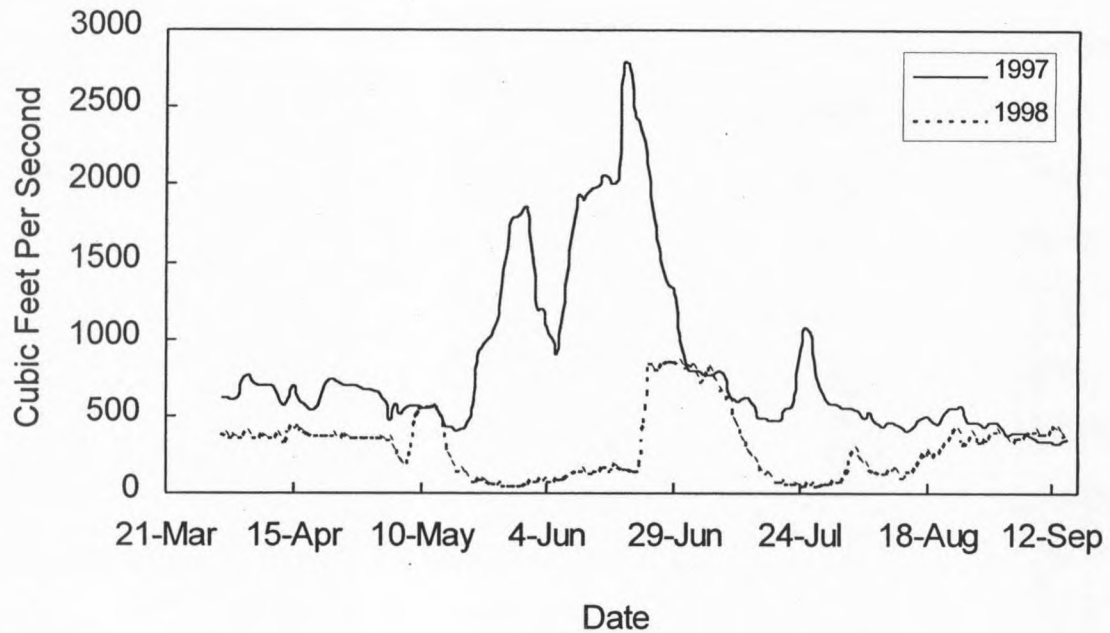


Figure 20. Average daily discharge of the Tongue River measured at the Miles City gauging station during the study period April-September, 1997 and 1998. (U.S. Geological Survey 1998).

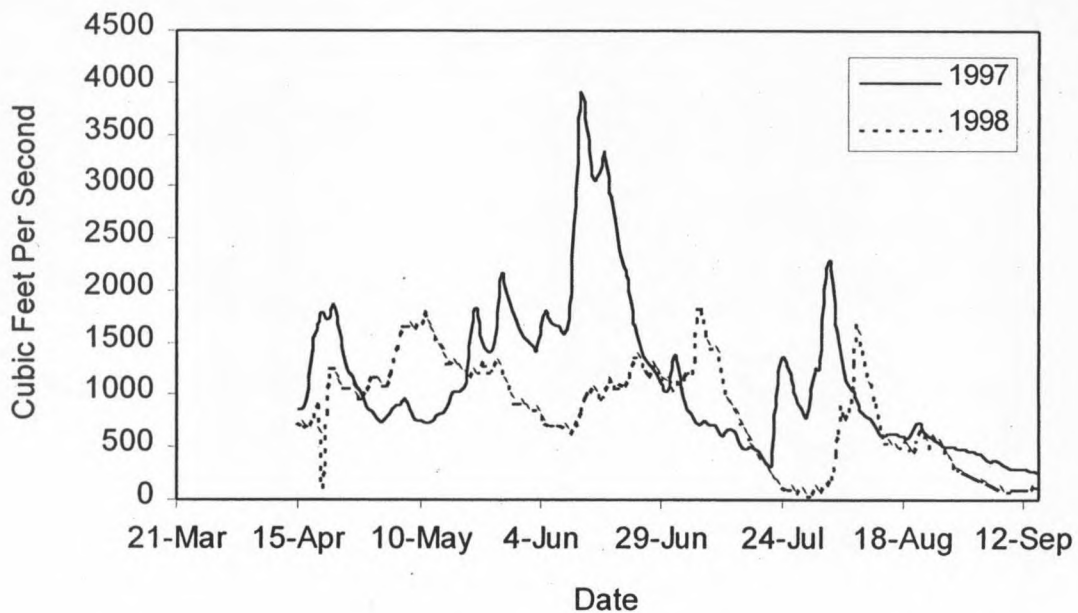


Figure 21. Average daily discharge of the Powder River measured at the Locate gauging station during the study period, April-September, 1997 and 1998. (U.S. Geological Survey 1998).

I measured substrate, depth, velocity, turbidity, conductivity, and water temperature at 103 macrohabitat sites in the Tongue River and 108 sites in the Powder River (excluding diel sampling) (Tables 4 and 5). Gravel was the most abundant substrate (79.0%) in the Tongue River, followed by sand (11.9%), and rubble (7.7%). Sand made up 75.0% of the substrate in the Powder River, followed by gravel (20.3%), and silt and rubble each comprised 2.0%. Macrohabitats were compared for differences between rivers. Significant differences were found in all five macrohabitats (main $P=0.0001$, inside bends $P=0.0001$, outside bends $P=0.005$, bars $P=0.0001$, secondary channels $P=0.0001$).

Mean water depth in all macrohabitat types (except main channel crossovers) examined was greater in the Tongue River than the Powder River. Mean water depth at inside bends was significantly different ($P=0.003$) in the Tongue River than the Powder River. Mean water depth in the Tongue River was 0.374 m (0.1-0.9) (Table 6) compared to 0.305 m (0.04-0.66) in the Powder River (Table 7). Mean depth at bars in the Tongue River was 0.361 (0.12-0.9) (Table 6) compared to 0.326 m (0.08-0.72) in the Powder River (Table 7) although the differences were not significant ($P=0.80$). Mean water depth of secondary channels was significantly different (0.0001) in the Tongue River when compared to the Powder River. Mean depth at secondary channels in the Tongue River was 0.374 m (0.17-0.64) (Table 6) compared to 0.255 m (0.04-0.53) in the Powder River (Table 7).

Table 4. A summary of the number of sites sampled for each macrohabitat type in the Tongue and Powder rivers, Montana, in 1997 and 1998 during pre-runoff, post-runoff and late-summer sampling periods.

Habitat type	1997		1998	
	Tongue	Powder	Tongue	Powder
Inside bend	12	14	12	12
Bar	12	14	12	12
Secondary	8	12	11	12
Outside bend	13	11	4	3
Main channel	10	9	9	9

Table 5. A summary of the number of sites sampled for each macrohabitat type in the Tongue and Powder rivers, Montana, 1997 and 1998 during pre-runoff, post-runoff and late-summer sampling periods.

Habitat type	Tongue			Powder		
	Pre	Post	Late	Pre	Post	Late
Inside bend	7	6	11	6	7	13
Bar	6	6	12	7	8	11
Secondary	5	6	8	6	7	11
Outside bend	9	4	4	7	3	4
Main channel	6	6	7	6	6	6

Table 6. Mean depths (m) and standard deviations (in parentheses) during Pre-runoff (Pre), Post-runoff (Post), and Late-summer (Late) in the Tongue River, 1997-1998. IN= inside bends; BAR= bars; SEC= secondary channels; OUT= outside bends; MAIN= main channels.

Habitat	Year	Season		
		Pre	Post	Late
IN	1997	0.40 (0.16)	0.44 (0.18)	0.49 (0.14)
	1998	0.39 (0.11)	0.26 (0.08)	0.28 (0.04)
BAR	1997	0.35 (0.24)	0.38 (0.17)	0.45 (0.14)
	1998	0.28 (0.03)	0.34 (0.05)	0.36 (0.23)
SEC	1997	0.42 (0.13)	0.37 (0.09)	0.52 (0.05)
	1998	0.31 (0.11)	0.31 (0.07)	0.31 (0.03)
OUT	1997	1.33 (0.43)	1.03 (0.09)	0.92 (0.19)
	1998	0.74 (0.16)	--	--
MAIN	1997	0.92 (0.34)	0.52 (0.15)	0.60 (0.15)
	1998	0.44 (0.11)	0.47 (0.05)	0.45 (0.01)

Table 7. Mean depths (m) and standard deviation (in parentheses) during Pre-runoff (Pre), Post-runoff (Post), and Late-summer (Late) in the Powder River, 1997-1998. IN= inside bends; BAR= bars; SEC= secondary channels; OUT= outside bends.

Habitat	Year	Season		
		Pre	Post	Late
IN	1997	0.29 (0.03)	0.26 (0.17)	0.40 (0.15)
	1998	0.31 (0.07)	0.24 (0.49)	0.32 (0.07)
BAR	1997	0.37 (0.10)	0.23 (0.10)	0.47 (0.15)
	1998	0.33 (0.08)	0.30 (0.08)	0.26 (0.09)
SEC	1997	0.16 (0.10)	0.22 (0.10)	0.34 (0.09)
	1998	0.32 (0.19)	0.29 (0.05)	0.20 (0.08)
OUT	1997	1.21 (0.14)	0.78 (0.15)	0.77 (0.17)
	1998	0.68 (0.23)	--	--
MAIN	1997	0.98 (0.21)	0.61 (0.22)	0.70 (0.22)
	1998	0.58 (0.11)	0.38 (0.04)	0.56 (0.02)

Mean depth at outside bends in the Tongue River was 1.005 m (0.5-1.52) (Table 6) compared to 0.859 m (0.53-1.37) in the Powder River (Table 7), although the differences were not significant ($P=0.16$). Mean depth at main channel crossovers was 0.566 m (0.33-1.13) in the Tongue River (Table 6) compared to 0.633 m (0.34-1.21) in the Powder River (Table 7), but the differences were not significant ($P=0.38$).

Mean water velocities at all macrohabitats (except secondary channels) was higher in the Powder River than the Tongue River. Mean water velocity at inside bends was significantly different ($P=0.03$) in the Tongue River compared to the Powder River. Mean water velocity at inside bends was 0.482 m/s (0.05-0.92 m/s) in the Tongue River (Table 8) compared to 0.515 m/s (0.11-0.85 m/s) in the Powder River (Table 9). Mean velocity at bars was 0.427 m/s (-0.31-0.67 m/s) in the Tongue River (Table 8) compared to 0.522 m/s (0.11-0.85 m/s) in the Powder River (Table 9), but the differences were not significant ($P=0.26$). Mean water velocity at secondary channels was significantly different ($P=0.0002$) in the Tongue River compared to the Powder River. Mean velocity at secondary channels was 0.573 m/s (0.17-0.98 m/s) in the Tongue River (Table 8) compared to 0.456 m (0.24-0.69 m/s) in the Powder River (Table 9). Mean water velocity at outside bends was significantly different ($P=0.01$) in the Tongue River compared to the Powder River. Mean velocity at outside bends was 0.578 m/s (0.15-1.3 m/s) in the Tongue River (Table 8) compared to 0.688 m/s (0.1-1.1 m/s) in the Powder

Table 8. Mean velocity measurements (m/s) and standard deviations (in parentheses) during Pre-runoff, Post-runoff, and Late-summer sampling periods in the Tongue River 1997 and 1998. IN= inside bends; BAR= bars; SEC= secondary channels; OUT= outside bends.

Habitat	Year	Season		
		Pre	Post	Late
IN	97	0.71 (0.24)	0.32 (0.27)	0.55 (0.06)
	98	0.44 (0.07)	0.44 (0.15)	0.44 (0.05)
BAR	97	0.19 (0.42)	0.44 (0.15)	0.55 (0.092)
	98	0.42 (0.22)	0.51 (0.04)	0.46 (0.12)
SEC	97	0.84 (0.19)	0.45 (0.22)	0.70 (0.13)
	98	0.45 (0.25)	0.49 (0.11)	0.50 (0.07)
OUT	97	0.85 (0.28)	0.57 (0.11)	0.60 (0.05)
	98	0.28 (0.09)	--	--
MAIN	97	0.80 (0.10)	0.56 (0.15)	0.60 (0.14)
	98	0.45 (0.04)	0.47 (0.02)	0.47 (0.03)

Table 9. Mean velocity measurements (m/s) and standard deviations (in parentheses) during Pre-runoff, Post-runoff, and Late-summer sampling periods in the Powder River 1997 and 1998. IN= inside bends; BAR= bars; SEC= secondary channels; OUT= outside bends.

Habitat	Year	Season		
		Pre	Post	Late
IN	97	0.57 (0.03)	0.42 (0.22)	0.73 (0.12)
	98	0.47 (0.20)	0.41 (0.03)	0.49 (0.04)
BAR	97	0.69 (0.14)	0.41 (0.10)	0.67 (0.14)
	98	0.40 (0.20)	0.46 (0.09)	0.51 (0.14)
SEC	97	0.39 (0.03)	0.46 (0.17)	0.60 (0.08)
	98	0.40 (0.07)	0.44 (0.08)	0.45 (0.09)
OUT	97	0.63 (0.30)	0.75 (0.22)	0.85 (0.25)
	98	0.51 (0.38)	--	--
MAIN	97	1.09 (0.15)	0.70 (0.06)	0.83 (0.14)
	98	0.94 (0.28)	0.55 (0.08)	0.75 (0.04)

River (Table 9). Mean velocity at main channel crossovers was 0.560 m/s (0.44-0.92) in the Tongue River (Table 8) compared to 0.81 m/s (0.49-1.25) in the Powder River (Table 9), although the differences were not significant ($P=0.18$).

The Powder River was always more turbid than the Tongue River. Mean Secchi measurements were significantly different between the two rivers in every sampling season ($P<0.0001$). Mean Secchi measurements of all macrohabitats during pre-runoff was 26.0 cm in the Tongue River compared to 2.7 cm in the Powder River. Mean Secchi measurements during post-runoff was 26.5 cm in the Tongue River compared to 6.5 cm in the Powder River. Mean Secchi measurements during late summer sampling was 20.7 cm in the Tongue River compared to 2.9 cm in the Powder River (Tables 10 & 11).

Mean conductivity ($\mu\text{S}/\text{cm}$) was significantly different between the Tongue and Powder rivers during all sampling seasons ($P<0.0001$). Mean conductivity at all macrohabitats in the pre-runoff sampling period in the Tongue River was 585 $\mu\text{S}/\text{cm}$ compared to 1,048 $\mu\text{S}/\text{cm}$ in the Powder River. Mean conductivity during the post-runoff sampling period in the Tongue River was 414 $\mu\text{S}/\text{cm}$ compared to 1,055 $\mu\text{S}/\text{cm}$ in the Powder River. Mean conductivity during the late summer sampling period in the Tongue River was 505 $\mu\text{S}/\text{cm}$ compared to 1030 $\mu\text{S}/\text{cm}$ in the Powder River.

Mean water temperature was higher in the Tongue River during pre-runoff and post-runoff, while temperatures were higher in the Powder River during late summer sampling, although no differences were found to be significant. Mean water temperature ($^{\circ}\text{C}$) of all macrohabitats in the pre-runoff sampling period was 18.1 $^{\circ}\text{C}$ (12-25 $^{\circ}\text{C}$) in the Tongue River compared to 18.0 $^{\circ}\text{C}$ (9-25 $^{\circ}\text{C}$) in the Powder River. Mean water

Table 10. Mean Secchi disk measurements (cm) and standard deviations (in parentheses) during Pre-runoff, Post-runoff, and Late-summer sampling periods in the Tongue River 1997 and 1998. IN= inside bends; BAR= bars; SEC= secondary channels; OUT= outside bends.

Habitat	Season			
	Year	Pre	Post	Late
IN	97	8.2 (2.0)	13.1 (3.7)	24.9 (7.7)
	98	48.0 (6.1)	44.0 (10.4)	13.2 (3.4)
BAR	97	8.9 (2.2)	12.6 (4.5)	27.0 (2.9)
	98	4.5 (4.6)	42.3 (9.2)	13.2 (3.4)
SEC	97	1.0 (0.2)	11.1 (0.5)	28.4 (0.7)
	98	4.3 (7.0)	44.0 (10.4)	12.3 (2.9)
OUT	97	5.3 (5.9)	14.5 (3.0)	25.8 (5.3)
	98	3.9 (10.5)	--	--
MAIN	97	8.3 (6.8)	13.4 (3.7)	26.6 (11.5)
	98	4.4 (8.0)	44.0 (11.3)	15.3 (3.8)

Table 11. Mean Secchi disk measurements (cm) and standard deviations (in parentheses) during Pre-runoff, Post-runoff, and Late-summer sampling periods in the Powder River 1997 and 1998. IN= inside bends; BAR= bars; SEC= secondary channels; OUT= outside bends.

Habitat	Season			
	Year	Pre	Post	Late
IN	97	3.0 (1.7)	7.7 (2.8)	2.8 (1.7)
	98	2.4 (0.5)	4.5 (2.2)	3.0 (0.6)
BAR	97	2.9 (1.6)	8.1 (3.5)	3.1 (1.6)
	98	2.4 (0.4)	4.7 (1.4)	2.8 (0.3)
SEC	97	3.0 (1.4)	7.8 (4.0)	3.0 (1.8)
	98	2.5 (0.6)	4.5 (1.9)	3.0 (1.4)
OUT	97	4.0 (0.3)	7.9 (3.0)	2.5 (1.7)
	98	2.5 (0.5)	--	--
MAIN	97	2.5 (1.1)	8.5 (4.0)	2.8 (1.9)
	98	2.4 (0.5)	4.6 (2.3)	2.9 (0.1)

temperature during the post-runoff sampling period was 28.0 °C (23-33 °C) in the Tongue River compared to 27.4 °C (23-31 °C) in the Powder River. Mean water temperature during the late summer sampling period was 24.2 °C (21-27 °C) in the Tongue River compared to 26.0 °C (23-30 °C) in the Powder River.

Habitat characteristics (depth and velocity) at sampling sites were analyzed for differences between macrohabitats. There were significant differences in mean depth among the five macrohabitat types in the Tongue River (ANOVA, $P=0.0001$). Outside bend mean depths were significantly different from the other four macrohabitats as was main channel crossovers (Tukey's Studentized Range Test). However, inside bends, bars, and secondary channels were similar but significantly different from outside bends and main channel crossovers (Table 12). There were also similar significant differences in mean depths among the five macrohabitat types in the Powder River (ANOVA $P=0.0001$). Tukey's Studentized Range Test results indicated that outside bends and main channel crossovers were unique and significantly different from the other four habitat types while inside bends, bars, and secondary channels were all similar (Table 13).

There were significant differences in mean velocity among the five macrohabitat types in the Tongue River (ANOVA, $P=0.0002$). Outside bends, main channel crossovers, secondary channels, and inside bends were all similar while inside bends and bars were similar and bars were significantly different from the remaining four habitat types (Tukey's Studentized Range Test) (Table 14). Significant differences were also found in mean velocity in the Powder River (ANOVA, $P=0.0001$) (Table 15).

Table 12. Tukey's Studentized Range Test for variability in depth among macrohabitat types in the Tongue River, Montana, 1997-1998. Corresponding letters indicates similarity.

Grouping	Tongue River	
	N	Habitat
A	25	Outside
BB	18	Main
CCC	23	Secondary
CCC	40	Inside
CCC	36	Bar

Table 13. Tukey's Studentized Range Test for variability in depth among macrohabitat types in the Powder River, Montana, 1997-1998. Corresponding letters indicates similarity.

Grouping	Powder River	
	N	Habitat
A	17	Outside
BB	18	Main
CCC	34	Secondary
CCC	38	Inside
CCC	40	Bar

Table 14. Tukey's Studentized Range Test for variability in velocity among macrohabitat types in the Tongue River, Montana, 1997-1998. Corresponding letters indicates similarity.

Grouping	Tongue River	
	N	Habitat
A	25	Outside
A	18	Main
A	23	Secondary
A BB	40	Inside
BB	36	Bar

Table 15. Tukey's Studentized Range Test for variability in velocity among macrohabitat types in the Powder River, Montana, 1997-1998. Corresponding letters indicates similarity.

Grouping	Powder River	
	N	Habitat
A	17	Outside
A	18	Main
BB	34	Secondary
BB	38	Inside
BB	40	Bar

Main channel crossovers and outside bends were similar to each other and significantly different from inside bends, bars, and secondary channels which were not significantly different.

Diel and Seasonal Sampling

In the Tongue and Powder rivers the most common species were collected during diel and seasonal sampling. Proportions of all species other than flathead chub were too low for reliable analysis. For diel sampling, the proportion of fish collected that was flathead chubs during each of the four sampling periods was compared during analysis (Figure 22). For seasonal sampling, the proportion of catch that was flathead chubs during each sampling season was compared (Figure 23).

Diel Sampling

In the Tongue River, diel habitat use by flathead chubs in shallow water habitats was variable (Figure 22). The proportion of flathead chubs in the total catch collected in the three shallow water habitats (inside bends, bars, and secondary channels) was greatest at dawn (0.58), followed by midnight (0.5), dusk (0.49), and noon (0.41). Differences were not significant between time periods (ANOVA $P=0.21$).

In the Powder River, diel habitat use by flathead chubs in shallow water habitats was also variable (Figure 22). The proportion of flathead chubs in the total catch collected in the three shallow water habitats (inside bends, bars, and secondary channels) was greatest at midnight (0.88), followed by dawn (0.86), dusk (0.81), and noon (0.81). Differences were not significant between time periods.

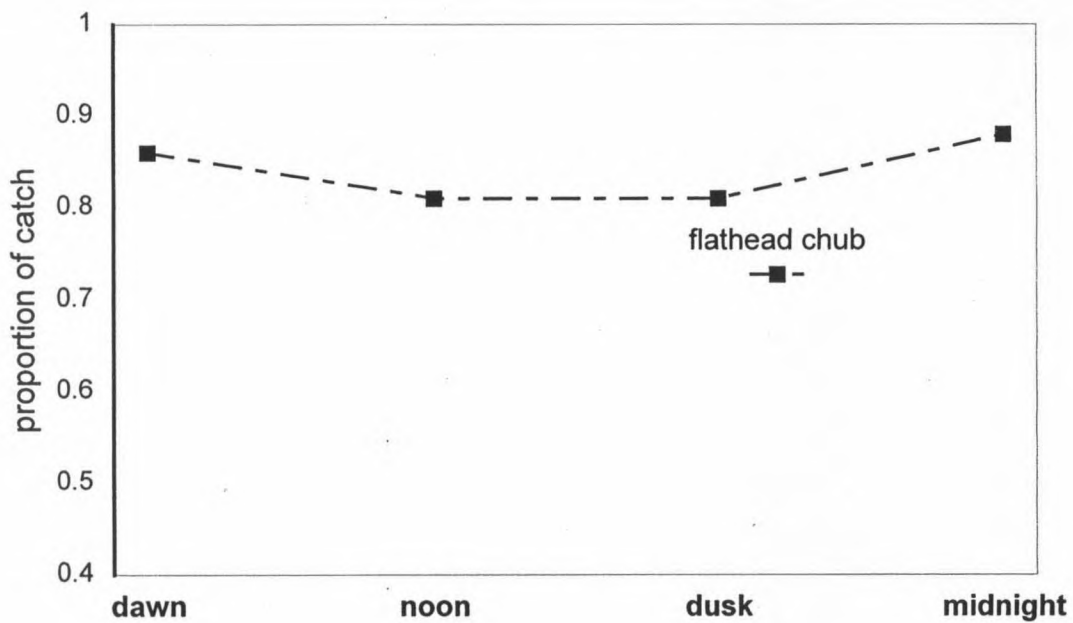
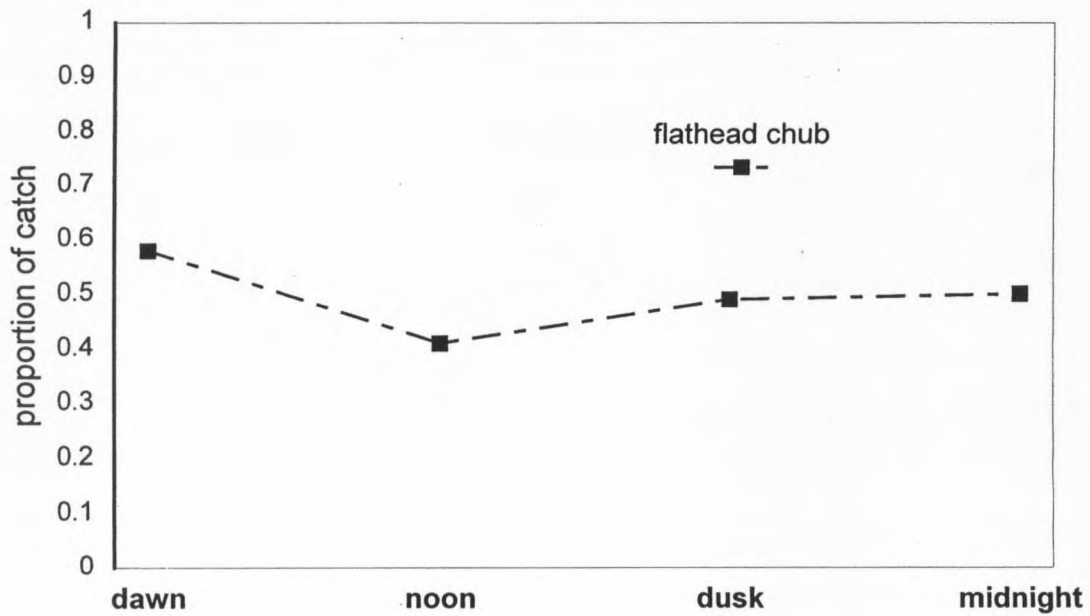


Figure 22. Diel habitat use by flathead chubs in shallow water habitats (inside bends, bars, and secondary channels) in the Tongue River (top) and the Powder River (bottom), Montana, 1997-1998.

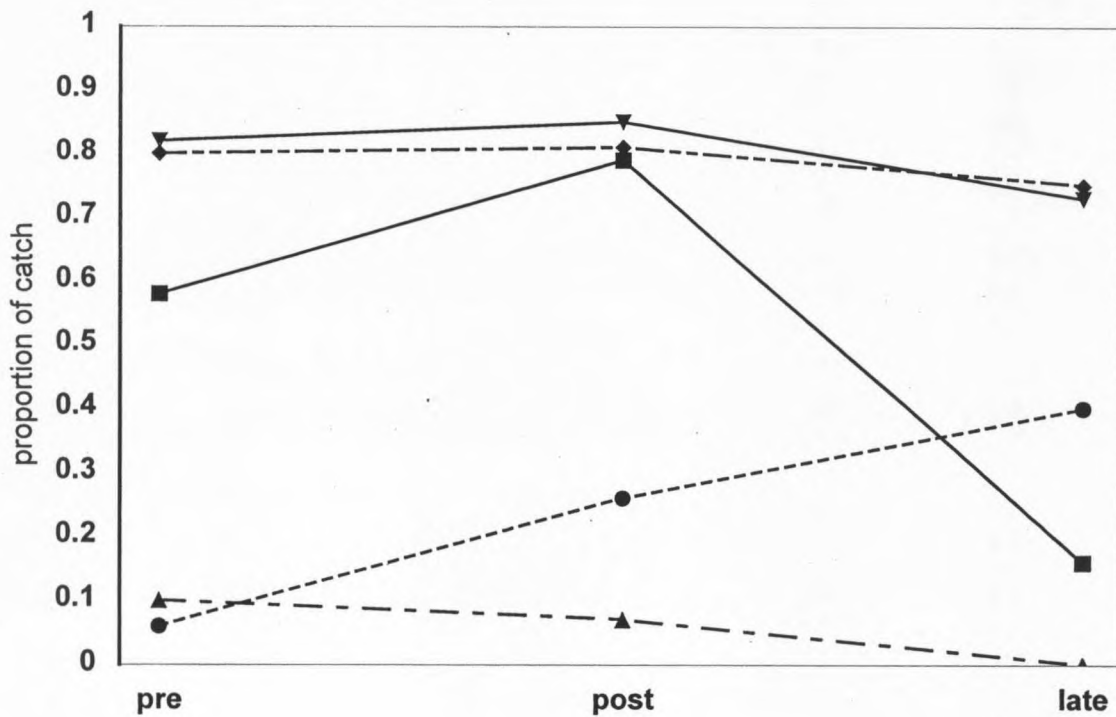
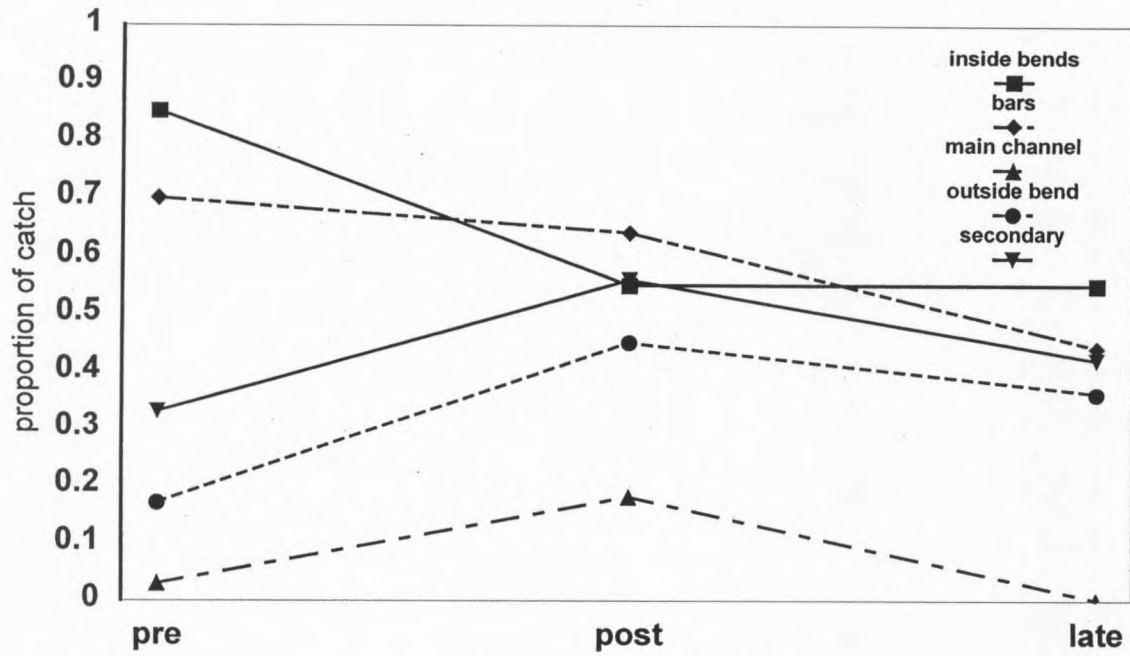


Figure 23. Seasonal use (pre-runoff, post-runoff, and late summer) of macrohabitats by flathead chubs in the Tongue River (top) and the Powder River (bottom), Montana, 1997-1998.

Seasonal Sampling

Flathead chub use of macrohabitats in the Tongue River throughout the year (pre-runoff, post-runoff, and late summer) was variable (Figure 23). No significant differences were found in proportion of flathead catch between macrohabitats across seasons. Macrohabitats were also pooled in each sampling season for analysis and no significant differences were found in proportion of flathead catch. Flathead chub use of macrohabitats in the Powder River throughout the year (pre-runoff, post-runoff, and late summer) was also variable (Figure 23). No significant differences in proportion were found among each macrohabitat between seasons. When macrohabitats were pooled in each sampling season, flathead chub abundance varied significantly between sampling seasons (ANOVA $P = 0.05$). REGWQ grouping indicated post-runoff proportion (0.89) and late summer (0.83) differed significantly from pre-runoff (0.76).

DISCUSSION

The results of this study indicated that the most common species in the Tongue and Powder rivers were: flathead chub, *Hybognathus spp.*, emerald shiner, longnose dace, shorthead redhorse, channel catfish, goldeye, river carpsucker, longnose sucker and sturgeon chub, accounting for 96.8% of all specimens in the Tongue River and 98.5% in the Powder River. A general description of the natural life history and habitats of these species are as follows.

Flathead chub The flathead chub is native to Montana and is one of the most common species collected in the Missouri and Yellowstone drainages of Montana. It was first collected here by the Railroad Surveys (1853-1855) in the Milk and Yellowstone rivers (Brown 1971). Flathead chub populations have dramatically declined in much of their range and are considered a species of special concern in many areas of the lower Missouri River drainage, although the flathead chub is common to abundant in the Missouri mainstem, its tributaries and in the Yellowstone River and its tributaries in Montana (Brown 1971) .

Like many other small non-game fish, life history information is incomplete and fragmented. Gould (1985) stated " The basic information available on food habits, age and growth, and fecundity of the flathead chub is fragmentary and inadequate. Information on the seasonal movements and habitat usage, spawning behavior,

embryology, and interaction with other fish species appears to be nonexistent".

The flathead chub is highly adapted to inhabit large, turbid, highly alkaline rivers and streams with sand and gravel substrate (Gould 1985). The flathead chub is an invertivore, feeding primarily on aquatic and terrestrial insects throughout the water column (Simon 1999). Its reproductive strategy is largely unknown. Flathead chubs presumably spawn in June or July when optimum water temperatures occur, since ripe females have been collected in June and spent females have been examined from collections taken in August (Brown 1971).

Hybognathus spp. This group of similar species (western silvery minnow, plains minnow, brassy minnow), that are difficult to identify from each other without dissection, are all native to Montana. They are widely distributed in Montana with the first recorded collection by the railroad surveys (1853-1855) in the Poplar River and O'Fallon Creek (Brown 1971). They have been abundant in collections in the lower Yellowstone and Missouri rivers, although recent declines in parts of their historical range have prompted concern about their status as species of special concern.

All three species are highly adapted to live in large, semi-turbid waters with sand and gravel substrate (Brown 1971). They have been described as planktivore/detritivore, eating bottom ooze, zooplankton and other algae (Simon 1999). *Hybognathus spp.* presumably spawn in early summer, as adults in breeding condition have been collected in Missouri and Arkansas in June (Pflieger 1975). *Hybognathus* are classified as an obligate plant spawner or phytophil. Breeding females have adhesive eggs envelopes that stick to submerged live or dead plants (Simon 1999).

Emerald shiner The emerald shiner is a native cyprinid in Montana and was first collected from the Poplar River in 1892 (Bergstedt 1999). It is locally abundant at the present time in the Missouri River below Great Falls and in the Yellowstone River below the mouth of the Bighorn River (Brown 1971). It has been described as the most abundant minnow in the Missouri and Mississippi rivers (Pflieger 1975).

The emerald shiner characteristically inhabits open channels of larger streams and their impoundments (Pflieger 1975). They are pelagic and generally found near the surface in schools. They tolerate a wide range of turbidity and bottom types and are usually found where there is noticeable current (Brown 1971). The emerald shiner is a planktivore, consuming microcrustaceans, midge larvae, and some algae (Simon 1999). Its reproductive strategy is that of a pelagophil, broadcast spawning numerous buoyant eggs into the water column.

Longnose dace The longnose dace is native to Montana and abundant in every river system in Montana except the Flathead River above Kerr Dam. The species was first collected in 1892 in the Missouri River near Craig (Brown 1971). We found the longnose dace to be the fourth most abundant species in the Tongue River.

Brown (1971) described the habitat of the longnose dace as "so varied it is hard to describe." It has been found in clear, fast-flowing streams as well as in turbid intermittent streams in eastern Montana. They are also frequently found in inshore waters of lakes. The longnose dace is a benthic invertivore eating both adult and immature stages of aquatic insects (Simon 1999). In reproductive strategy they are classified as a

lithopelagophil, spawning over rock and gravel. Their embryos are initially adhesive and then become pelagic (Simon 1999).

Shorthead redhorse The shorthead redhorse is native to Montana and common in the Missouri, Yellowstone and Little Missouri river drainages. The first known collection was in 1892 in the Poplar River (Brown 1971).

The shorthead redhorse inhabits a diversity of stream types but appears to be most abundant in moderately large rivers having a predominance of gravelly or rocky bottoms and permanent strong flow (Pflieger 1975). The shorthead redhorse is a benthic invertivore feeding on a variety of immature forms of aquatic insects. It is a lithophil broadcast spawner, utilizing rock and gravel substrate, and having benthic larvae that hide beneath stones (Simon 1999).

Channel catfish The channel catfish is native to Montana and was first collected by the Lewis and Clark expedition of 1803-1806 (Brown 1971). They are locally abundant throughout the Missouri River below Great Falls and in the Yellowstone River as far upstream as Pryor Creek (Brown 1971).

Channel catfish occur in a variety of habitats, but is especially characteristic of larger streams and their tributaries as well as ponds and lowland lakes (Pflieger 1975). The feeding guild of the channel catfish is classified as an invertivore/carnivore, feeding on an array on invertebrates and fishes. Its reproductive strategy is classified as a speleophil spawner. These are fish that utilize natural holes and cavities to nest in and also guard their nest and young.

Goldeye The goldeye is native to Montana with the earliest record for Montana dating from the Lewis and Clark expedition 1803-1806, in the Missouri River near the mouth of the Marias River. It is locally abundant in the Missouri River drainage below Morony Dam and in the Yellowstone River drainage below Pine Creek (Brown 1971).

The goldeye is most often found in the open waters of large rivers where it frequents areas with swift current as well as quiet pools. It can also often be found in pools of associated tributaries (Pflieger 1975). The goldeye appears to be tolerant of high turbidities and does not invade cool mountain streams for any distance (Brown 1971).

The goldeye is an invertivore, feeding on aquatic insects in drift and on the surface (Simon 1999). It is a rock and gravel spawner, or lithopelagophil, with eggs that are initially adhesive that soon turn to pelagic free embryos (Simon 1999).

River carpsucker The river carpsucker has a native range that includes Montana, in which it was first collected in the Milk River in 1853-1855 (Brown 1971). It is locally abundant at lower elevations in the Missouri and Yellowstone river systems (Brown 1971).

The preferred habitat of the river carpsucker is the quiet silt/sand-bottomed pools, backwaters, and oxbows of large streams having little gradient. It also occurs in the deeper pools of smaller prairie streams and is often found in impoundments. It appears to prefer waters that are turbid much of the time (Pflieger 1975). The river carpsucker is a benthic planktivore/detrivore, feeding on periphyton and small planktonic plants and animals (Simon 1999). The river carpsucker is classified as a rock and gravel spawner or

a lithopelagophil. Their embryos are initially adhesive and soon become buoyant and pelagic (Simon 1999).

Longnose sucker The longnose sucker has a native range that includes Montana, with the first collection dating back to the Lewis and Clark Expedition (1803-1806). The current distribution of the longnose sucker in Montana includes all major drainages on both sides of the continental divide (Brown 1971).

The habitat of the longnose sucker appears to be quite varied. They are most common in clear cold streams and lakes but are frequently collected in drainages where temperatures are moderately warm and turbidities are high (Brown 1971; Pflieger 1975). The longnose sucker is an invertivore, feeding primarily benthically on aquatic insects and plants. It is a rock and gravel spawner, or lithopelagophil, with embryos initially adhesive and then becoming buoyant and pelagic (Simon 1999).

Sturgeon chub The sturgeon chub has a native range that includes Montana. The first Montana collections were taken from the Milk River by the railroad surveys (1853-1855). Sturgeon chub has not been found in the Milk River since early times and is now found only in collections in the Missouri River (Grisak 1996) and lower Yellowstone River and its tributaries (Brown 1971). The sturgeon chub is highly adapted to inhabit large, turbid, highly alkaline rivers and streams with sand and gravel substrate (Gould 1985). The sturgeon chub is an invertivore, feeding primarily benthically on aquatic insects and plants (Simon 1999). Its reproductive strategy is largely unknown.

Community Structure

The goals of community ecology are to record the patterns that occur in nature and to explain those patterns (Schlosser 1987). Schlosser goes on to state that any advances in this field will come as a result of syntheses that reconcile opposing perspectives. Recently, in aquatic biology, many differing views have been presented regarding the relative importance of physical versus biological processes in regulating stream-fish communities. These differences in perspective reflect the complexity of natural communities (Schlosser 1987).

Hiram and Judith (1987) found that biotic interactions such as predation, competition, mutualism, parasitism, and disease are often important in shaping communities, especially in stable and predictable environments. In contrast, the ability to disperse, colonize and be habitat generalists may be a predominant factor in streams subject to harsh recurrent disturbances such as the Tongue and Powder rivers. Hiram and Judith (1987) found that stream fish communities that were trophically simple, were regulated by competition rather than predation, and more importantly, were regulated by the morphological characteristics of their biota. Based on these findings, biological patterns are largely adjusted and maintained by physical patterns. Thus, a need exists for a broad framework that places streams, their habitats, and their fish communities into a pattern of relationships. My study aimed to aid in this attempt and to more specifically identify the linkages that may help provide the conceptual basis for habitat-based fish

population models that are needed to predict the effects of habitat changes on fish populations.

Studies of the relationship between habitat structure and community diversity were first pioneered by R.H. MacArthur who demonstrated bird diversity increased as complexity of vegetation increased (MacArthur and MacArthur 1961). Later, the same principles were used in mammalian biology and more recently in aquatic environments (Gorman and Karr 1978). Researchers, including Cross and Moss (1987) have suggested that the only way to maintain biotic diversity on riverine corridors is to preserve the many unique habitats. An understanding of fish-habitat relationships in streams has been a major concern of fisheries biologists. By identifying habitat conditions that limit standing stocks, biologists can focus management efforts on specific protection, enhancement, and mitigation practices to improve habitat conditions (Bozek and Rahel 1991). This will ultimately help in understanding the complex, cumulative effects of changing land use on stream habitats and biological communities (Frissell et al. 1986). Without the many dimensions of a riverine system, river structure and function is degraded and many species that evolved within the uniqueness of each system cannot survive.

Most recent studies investigating the habitat needs of warmwater fish have concentrated on single species in small to medium streams (Lobb and Orth 1991). A larger scale, community-level perspective is needed to protect stream resources. For example, Gorman and Karr (1978) found that fishes in select Indiana and Panama streams tended to specialize on specific habitat types. Secondly, the fish community

characteristics of a segment of a stream are determined by the complexity of habitats. They concluded the paper by directing future studies toward detailing the relationships of habitat structure and water quality parameters to species distributions and community structure in fishes. This would aid in the development of theories relating habitat to fish community structure.

The relative importance of processes related to both physical disturbance and biological interactions is strongly influenced by habitat heterogeneity, frequency and intensity of physical disturbances, and life history attributes (Schlosser 1987) of the community. The response of western Great Plains stream fishes to disturbances is unknown because little is known about their life histories (Fausch and Bramblett 1991). I examined ecological attributes such as habitat associations, patterns of movement, and distribution that may help better understand the relationships between streams, their habitats, and their fish community.

The Tongue and Powder rivers are often subject to frequent disturbances and fluctuating flows characteristic of western Great Plains streams (Fausch and Bramblett 1991). Past fisheries studies of the Tongue and Powder rivers showed species dominance by cyprinids, that are predominantly small, vagile, and early maturing. These streams have contained very few large aquatic carnivorous predators (Rewinkle 1978; Elser et al. 1977). This follows predictions for characteristics of species inhabiting western Great Plains rivers exposed to frequent disturbances (Fausch and Bramblett 1991, Schlosser 1996).

The Tongue and Powder rivers provide a rare comparison of riverine systems.

The Powder River represents a relatively unaltered river system with extreme environmental conditions, consequently it has a fish community that is uniquely adapted to such environmental conditions. The Tongue River is a drastically different situation. Historically, it was probably similar in habitat structure and in fish community composition to the Powder River (Hubert 1996). But the construction of the Tongue River Dam and four downstream low-head diversion dams for irrigation withdrawals have dramatically changed the habitat structure. With the physical differences the Tongue and Powder rivers also support different fish communities.

Relatively unaltered habitat conditions in the Powder River has resulted in a persistence of a fish community for at least 22 years since Rehwinkle's survey (1978). Rehwinkle (1978) collected 16 species in summer and fall sampling, all native fish except the common carp. I collected 18 species, all native except the common carp and the plains killifish, which was not previously collected. Relative abundances of all species remained relatively similar. In both studies, flathead chub was the most abundant species, comprising 92.2% of total catch in Rehwinkle's survey (1978), compared to 77.4% of total catch in my study. Sturgeon chub was common in both studies comprising 0.04% of catch in the earlier study, 2.6% of total catch in this study. The only major change in abundance was in sauger and shovelnose sturgeon. Rehwinkle (1978) sampled 470 sauger in the spring of 1977 and 1978 between March 18 and May 18. Sauger and shovelnose sturgeon migrate into the Powder River to spawn (Rehwinkle 1978). I did not sample as early in the spring and this may explain why I collected only four sauger. The

same explanation may apply for the apparent decline of shovelnose sturgeon, in which I only collected 12 shovelnose sturgeon while Rehwinkle (1978) collected 434 in the spring of 1976 and 1977.

Due to naturally high saline levels, the Powder River's utility for irrigation is limited, resulting in an undeveloped riparian area and floodplain. Thus historical riverine structure and function is relatively intact including extremely high turbidity levels, unstable bottom substrate, variation in flow, a shallow and highly braided meandering channel lacking pools, and large variation in seasonal temperatures. This lack of development has been advantageous for native fishes that are highly adapted morphologically and behaviorally to plains rivers. These adaptations include small eyes and optic lobes, well-developed cutaneous sense organs and facial lobes of the brain, thickened integument, crowded or embedded scales, benthic habit, and, in some instances, enlarged lateral line canals (Cross and Moss 1987). Native fish species of the Powder River have evolved life history strategies that have allowed them to survive in extreme environmental conditions (Hubert 1993). Any water development that would alter historical discharge patterns, reduce turbidity levels, block migratory corridors, modify sediment transport, or change water quality would change its characteristics and alter the native fish community.

In contrast, the lower Tongue River has been drastically altered both biologically and physically by the construction of dams and water withdrawals. A major influence has been alteration of historical discharge patterns. Discharge patterns for the two study years show the Tongue River had one less distinct peak in flow than the Powder River.

In both years the diminished peak was early in the spring when water managers are attempting to fill Tongue River Reservoir. This time period directly coincides with flows that trigger spawning activity of most species of this system including sauger, shovelnose sturgeon, and channel catfish (Hubert 1996). Peaks in discharge were smaller in magnitude when compared to the Powder River and low flow discharge was considerably smaller and more prolonged in the Tongue than the Powder. In at least two instances of low flow periods on the Tongue River, no water was coming over T&Y diversion dam, isolating fish in shallow, groundwater fed pools where they were susceptible to elevated water temperatures and terrestrial predators.

Alterations of the Tongue River's historical structure and function can be seen biologically as well. Elser et al. (1977) collected 20 fish species in 1974 and 1975 in the same study area, and I collected 21 species. In contrast to Elser et al. (1977), I collected no sturgeon chub, paddlefish, or pumpkinseed sunfish, but collected five species that were absent in their collections: emerald shiner, *Hybognathus* spp, fathead minnow, black crappie, and the smallmouth buffalo. Some distinct changes have occurred among the most abundant species in each study. Both studies found the flathead chub to be the most abundant species. I found the flathead chub comprised 55.2% of catch while Elser et al. (1977) found they comprised 20.8% of their catch. The second and third most abundant species in my study were *Hybognathus* spp. (16.1%) and the emerald shiner (6.7%). These species were not collected in the 1977 study. Elser et al. (1977) found shorthead redhorse (17.0%), sauger (14.2%), carp (13.2%), and goldeye (7.5%) were the next most abundant species in their sampling. Abundances of these fishes in my samples were

3.6%, < 0.05%, < 1%, and 3.1% of total catch in the Tongue River, respectively.

Sturgeon chub were routinely collected by Elser et al. (1977) in fall sampling, comprising 2.0% of catch, but none were sampled during my study.

Elser et al. (1977) estimated that about 3,700 sauger moved into the Tongue River to spawn in the spring of 1976. They reported the optimum spawning temperatures were from 9.3° C to 12.5° C. I sampled later in the spring than they did and may have missed the spawning migration. I sampled when spring water temperatures ranged from 12° C to 25° C and were mostly higher than their reported "optimum" temperatures. Despite the overlap, I found sauger abundance to be extremely low representing less than 0.05% of catch. Similar trends were seen in collections of shovelnose sturgeon. Elser et al. (1977) reported estimates between 400-500 sturgeon/km present in the lower Tongue River during 1975 and 1976 with reported optimum spawning temperatures between 16.9° C and 21.5° C. Despite sampling during "optimum" periods, using similar gears, I collected only two sturgeon.

Species shifts observed in the Tongue River may also be seen in shifts in community trophic composition. Without the river's naturally occurring extreme annual fluctuations in discharge, the river channel has become narrower and more uniform in depth. Substrates have become larger and firm, rather than loose and continuously shifting. Turbidity levels have decreased, favoring fishes more adapted to sight feeding. Fishes like the flathead chub, smallmouth bass, and of the black crappie have all increased in numbers, and the size of bottom substrate has increased from predominately shifting sand to gravel. These are all factors that have possibly contributed to the

apparent local extinction of the sturgeon chub and reduced numbers of longnose dace, shorthead redhorse, and shovelnose sturgeon. Increased riparian vegetation and clearer waters now favor populations of herbivores, detritivores, and planktivores with the addition of four new species to the lower Tongue River (black bullhead, fathead minnow, emerald shiner, and *Hybognathus spp.*). Abundances of lithopelagophils, or fishes that are obligate substrate spawners (sturgeon, walleye, sauger, river carpsucker, goldeye, blue sucker, longnose dace, and burbot), have all decreased. However, abundances of pelagophils fishes that utilize any open substrate (emerald shiner) and phytophils fishes that are obligate plant spawners (*Hybognathus spp.*) have become dominant species of the system.

Complicating the evaluation of impacts to the fish community is the fact that little is available about the spawning strategies of many of the native species. No information exists on the strategies used by the flathead chub or the sturgeon chub, both species of special concern. Some of the fish of these systems, perhaps most, spawn pelagically during floods whenever the first abrupt increase in flow occurs (Cross and Moss 1987). Strong flows suspend buoyant eggs, protecting them from molar action of sand moving continuously along the riverbed, and floods maximize available habitat and food supplies for the developing young as organic materials are washed in and concentrated as floods recede. This trait of pelagic spawning would result in downstream displacement of eggs and embryos. This displacement coupled with the presence of diversion dams may result in depleted populations of fish. My findings follow trends in Great Plains systems where researchers like Cross and Moss (1987) have reported the

dominant species of the turbid-river community persisted longer, but many declined precipitously from 1950-80 following impoundment of nearly all rivers of the region. The native riverine fauna was largely replaced by sight-feeding planktivores and piscivores adapted to clear moderate flow. Reduction in turbidity levels now favors fishes more adapted to sight feeding. Flathead chub, smallmouth bass, and the black crappie have all increased in numbers in the Tongue River. Plains species (i.e. pallid sturgeon, sturgeon chub, flathead chub, blue sucker, western silvery minnow, and plains minnow) that were common 30 years ago in the lower Yellowstone and Missouri rivers are now found to be threatened in much of their native range.

Populations of aquatic invertebrates also seem to be following similar patterns. Samples taken by Gustafson in the Powder River have yielded a complete taxa list indicative of a "very healthy great plains system", with very sensitive and rare taxa collected frequently (personal communication). In contrast, Gustafson has observed only remnant populations of historical taxa in the Tongue River (Gustafson personnel communication). In the lower Tongue River Gustafson found only tolerant species thriving and sensitive species absent or in very low abundances.

Channel shape defines fish habitat. Fewer fish reside in the center of thalweg because of high velocity and high sediment transport rates (Hesse and Sheets 1993). Diversities of depths, discharges, and substrates associated with natural channel shape provide niches adjacent to the thalweg, which allows river organisms to adapt to life in a moving column of water (Bain et al. 1988).

Studies in small warmwater streams reveal that physical habitat structure, mainly

depth and current velocity, influences species composition and species diversity (Lobb and Orth 1991). The coexistence of some species and high community diversity frequently depend on habitat heterogeneity caused by environmental disturbances, but large-scale or frequent anthropogenic disturbances may impose habitat homogeneity (Bain and Finn 1988). In both the Tongue and Powder rivers, the highest densities of fish were found along shoreline habitats. We saw that the dominant species (cyprinid spp.) extensively utilized shallow water habitats, most with depths between 0.2-0.5 m. Other species like shorthead redhorse, channel catfish, and goldeye extensively used deeper outside bend habitats with depths usually between 0.75-1.2 m. It should be noted that there is the potential for exaggerated results because of bias due to sampling gears (e.g. seining is bias to smaller fish, electrofishing and gill nets bias toward larger fish).

Stream margin habitats in channels of large streams are particularly important to smaller fishes (Leonard and Orth 1988). Channel borders, side channels and the associated slack water areas optimize the use of total river area by riverine organisms (Hesse and Sheets 1993). Shoreline and other shallow areas are the habitats most affected by flow modifications, and inhabitants of these shallow, slow-water stream margins are the most negatively affected by flow modifications (Leonard and Orth 1988).

Altered discharge regimes and its affects, convert the offset V-shaped natural channel into a U-shaped channel. The natural channel offers a much wider range of depths and velocities at all discharge rates than does the U-shaped channel (Hesse and Sheets 1993). Without the functional availability of shallow, slow shoreline areas, the stream environment becomes one general type of usable habitat, dominated by the few

habitat generalist and those species using midstream-type habitats (Bain et al. 1988).

With the alteration of historical flow patterns in the Tongue River, stream margin habitats are being lost and riverine organisms that utilize these areas are declining in abundance as well.

In warmwater stream environments in general, there is little information available on the diel movements by a fish community across habitats. I examined diel habitat associations by the fish community through 24 h periods. Only flathead chubs were abundant enough in samples to reliably analyze diel habitat use. In both the Tongue and Powder rivers, flathead chubs had similar patterns of abundance in shallow water habitats (inside bends, bars, and secondary channels) throughout the day. Flathead chubs were relatively abundant in all the dominant habitats, suggesting they are habitat generalists. This supports most recent studies of relations between habitats and fish assemblages that have identified a generalist habitat guild (Lobb and Orth 1991, Leonard and Orth 1988). High overlap in habitat use among the fishes may indicate that space or food is not a limiting resource, presumably because populations are rarely large enough to use all available space. Although not statistically significant, I did find that the abundance of predaceous species peaked during dusk or at night in shallow water habitats (midnight in the Tongue River and dusk in the Powder River). These results suggest that riverine predators move into shallow water habitats with reduced light, avoiding possible terrestrial predators, and most likely feeding on the abundance of smaller fishes in shallower water.

Tributaries to the Yellowstone River like the Tongue and Powder rivers provide spawning and nursery habitat for riverine fishes and support unique fish assemblages (Hubert 1996). Elser et al. (1977) collected four species (burbot, paddlefish, shovelnose sturgeon, and blue sucker) only during spring collections. They estimated there were 417 sturgeon/ km, 3,796 sauger, and "sizeable numbers" of channel catfish using the Tongue River as a spawning tributary in the spring. Rehwinkle (1978) also found substantial migrant populations of sauger, shovelnose sturgeon, channel catfish, and to a lesser extent, paddlefish using the Powder River during spring. Although my sampling schedule did not directly coincide with the previous studies, there was overlap of collection periods. My study indicates an apparent disappearance of these migration runs and may be cause for concern and for the serious evaluation of land-water use practices of the lower Yellowstone Basin. Seasonal movement of riverine fishes into tributaries like the Tongue and Powder rivers may be essential to the continued maintenance of many species including, shovelnose sturgeon, sauger, goldeye, river carpsucker, shorthead redhorse, and channel catfish (Hubert 1993).

MANAGEMENT IMPLICATIONS

The Tongue and Powder rivers provide an opportunity to compare and contrast a modified vs. a relatively unmodified prairie stream. The Powder River fish community represents a more natural community characteristic of free-flowing Great Plains rivers. Most similar rivers have been drastically modified by land and water development and do not sustain the habitat or the diverse fish community the Powder River currently contains. Any future management practices should remain focused on the preservation of existing habitats to maintain the abundance of native species. This can be accomplished by protecting the system from forms of development that would alter historical flow regimes, reduce turbidity levels, change water quality, modify sediment transport, or block migratory routes for riverine fishes .

Many changes have occurred in the Tongue River that coincide with anthropogenic modifications. In contrast to the Powder River, the Tongue River has been drastically influenced by dams, water withdrawal, and introduced species. Previous studies showed at least seven species including goldeye, shovelnose sturgeon, paddlefish, and sturgeon chub are now restricted to waters below the most downstream diversion dam, and my study suggests that the sturgeon chub and the paddlefish may now be absent (Elser et al. 1977) . Elser et al. (1977) found large migratory runs of sauger, shovelnose sturgeon, and channel catfish utilizing the Tongue Rivers, and again, my study may indicate these runs are depleted and may be in jeopardy. In the Tongue River, flows have become less varied, substantial riparian vegetation has developed, stabilizing banks and reducing

turbidity. These effects have been accompanied by possible shifts in the species assemblage. Encroaching vegetation, clearer water, and fewer gravel bars provides poor habitat for turbid-water adapted fishes such as the sturgeon chub, but is good habitat for sight feeders like the emerald shiner and *Hybognathus* spp.

The results of this study have important implications for current fish managers and future development plans in arid regions of the west. As the demand for water increases, it is likely that land and water uses will change and adversely affect fish communities. Future fisheries management plans should take into account, as well as better understand the habitat needs and natural life history traits of native fishes in weighing the pros and cons of past and future development.

REFERENCES CITED

- Bain, M. B., J. T. Finn, and H. E. Booke. 1988. Streamflow regulation and fish community structure. *Ecology* 69: 382-392.
- Bozek, M. A., and F. J. Rahel. 1991. Assessing habitat requirements of young Colorado River cutthroat trout by the use of macrohabitat and microhabitat analysis. *Transactions of the American Fisheries Society* 120: 571-581.
- Brown, C. F. D. 1971. *Fishes of Montana*. Big Sky Books, Bozeman.
- Buckely, J., and B. Kynard. 1985. Yearly movements of shortnose sturgeons in the Connecticut River. *Transactions of the American Fisheries Society* 114: 813-820.
- Cross, F. B., and R. E. Moss. 1987. Historic changes in fish communities and aquatic habitats in plains streams of Kansas. Pages 155-165 in W. J. Matthews and D. C. Community and Evolutionary Ecology of North American Stream Fishes. Norman, Oklahoma.
- Elser, A. A., R. C. McFarland, and D. Schwehr. 1977. The effect of altered stream flow on fish of the Yellowstone and Tongue rivers, Montana. *Montana Fish Wildlife and Parks Technical Report* 8.
- Fausch, K. D., and R. G. Bramblett. 1991. Disturbance and fish communities in intermittent tributaries of a western great plains river. *Copeia* 3: 659-674.
- Frissell, C. A., W. J. Liss, C. E. Warren, and M. D. Hurley. 1986. A hierarchal framework for stream habitat classification: viewing streams in a watershed context. *Environmental Management* 10: 199-214.
- Gorman, and J. R. Karr. 1978. Habitat structure and stream fish communities. *Ecology* 59: 507-515.
- Gould, W. 1985. Aspects of the biology of the flathead chub (*Hybopsis gracilis*) In Montana. *Great Basin Naturalist* 45: 332-336.
- Grisak, G. G. 1996. The status and distribution of the sicklefin chub in the middle Missouri River, Montana. M.S. Thesis, Montana State University-Bozeman, Bozeman.
- Heede, B. H. 1980. Stream dynamics: an overview for land managers. General Technical Report RM-72, Rocky Mountain Forest and Range Experiment Station, U.S. Forest Service, Fort Collins, Colorado.

- Hesse, L. W. 1993. The Missouri River hydrosystem. *Fisheries* 18: 5-14.
- 1987. Taming the wild Missouri River: what has it cost?. *Fisheries* 12: 2-8.
- Hiram, W. L., and L. L. Judith. 1996. Fish community composition. Pages 391-408 *in* R. F. Hauer and G. A. Lambert, editors. *Methods in Stream Ecology*. San Diego, California.
- Hubert, W. A. 1996 . The Powder River: a relatively pristine stream on the great plains. Pages 387-395 *in* L. W. Hesse, C. B Stalnaker, N. G. Benson, J. R. Zuboy, editors. *Proceedings of the Symposium on Restoration Planning for the Mississippi River Ecosystem*. Fort Collins, Colorado.
- Kelso, W. E., and D. A. Rutherford. 1996. Collection, preservation, and identification of fish eggs and larvae. Pages 255-302 *in* B. R. Murphy and D. W. Willis, editors. *Fisheries Techniques Second Edition*, American Fisheries Society, Bethesda, Maryland.
- Leonnard, P. M., and D. J. Orth. 1988. Use of habitat guilds of fishes to determine instream flow requirements. *North American Journal of Fisheries Management* 8: 399-409.
- Liston, C., P. Johnson, B. Mefford, and D. Robinson. 1994. Fish passage and protection considerations for the Tongue River, Montana, in association with the Tongue River Dam Rehabilitation Project. Bureau of Reclamation, draft.
- Lobb, D. M., and D. J Orth. 1991. Habitat use by an assemblage of fish in a warmwater stream. *Transactions of the American Fisheries Society* 120: 65-78.
- MacArthur, R. H., J. W. MacArthur. 1961. On bird species diversity. *Ecology* 42: 594-598.
- Pflieger, W. L. 1975. The fishes of Missouri. Missouri Department of Conservation, Columbia.
- Rehwinkle, B. J. 1978. Powder River aquatic ecology project. final report, Montana Fish Wildlife and Parks, Helena.
- Sappington, L. C., D. J. Dieterman, and D. L. Galat. 1996. Missouri River benthic fish consortium 1996 standard operating procedures to evaluate the population structures and habitat use of benthic fishes along the Missouri River. Midwest Science Center, Columbia, MO.

- SAS. 1998. Statistical Analysis System. Release 7.0 SAS Institute Inc. SAS Circle, Box 8000, Cary, NC 27513.
- Scheaffer, R. L., W. Mendehall, and L. Ott. 1990. Elementary survey sampling, 4th edition. Boston, Massachusetts.
- Schlosser, I. J. 1987. A conceptual framework for fish communities in small warmwater streams. Pages 17-59 *in* W. J. Matthews and D. C. Heins, editors. Community and Evolutionary Ecology of North American Stream Fishes. Norman, Oklahoma.
- Simon, T. P. 1999. Assessment of Balon's reproductive guilds with application to Midwestern North American freshwater fishes. *in* T. P. Simon eds. Assessing the sustainability and biological integrity of water resources using fish communities. CRC Press, Washington D.C.
- USFWS. 1994b. Endangered and threatened wildlife and plants; animal candidate review for listing as endangered or threatened species; Proposed rule. Dept. Interior, Fish and Wildlife Service. Federal Register, 50 CFR Part 17. 50(219): 58982-59028.
- White, R. G., and R. G. Bramblett. 1993. The Yellowstone River: Its fish and fisheries. *in* L. W. Hesse, C. B. Stalnaker, N. G. Benson and J. R. Zuboy eds. Restoration Planning for the the Rivers of the Mississippi River Ecosystem. National Biological Survey Report 19, Washington D.C.
- Zar, J. H. 1996. Biostatistical analysis. Simon and Schuster, Upper Saddle River, New Jersey.

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