F-15-6

Distribution, Relative Abundance, and Habitat Associations of Milk River Fishes Related to Irrigation Diversion Dams

Final Report

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Sean Stash and Robert G. White
USGS Cooperative Fishery Research Unit
Montana State University

Dave Fuller
Montana Fish, Wildlife and Parks
Fort Peck, Montana

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ABSTRACT

The structure and habitat associations of the stream fish assemblage in the Milk River are poorly understood. As the demand for water increases, changes from current water management practices are imminent and will likely further impact fish assemblages in the Milk River. Our study collected baseline data on the distribution, relative abundance, and habitat associations of Milk River fishes related to irrigation diversion dams. These structures can alter the natural hydrograph, increase or decrease natural water temperatures, homogenize macrohabitat structure by reducing multiple, braided channels to a single incised channel, reduce sediment transport, sever connectivity with the flood plain, and reduce ecological connectivity between upstream and downstream reaches. We collected 10,995 fish representing 41 species and 13 families. Twenty eight species are native to the Milk River basin, 13 species are introduced, 12 species are classified as game fish, and 4 species are Montana Species of Special Concern (blue sucker, paddlefish, pearl dace, and sauger). Longitudinal distribution of species tended to increase in a downstream direction with 10 species collected in the upper-most section and 29 species collected in the lower-most section. The Morista-Horn community similarity index indicated fragmented fish communities between the free flowing section 8 and adjacent section 7 as well as between section 2 and adjacent section 1, which retains its connectivity with the Missouri River. Whereas coarse substrate is rare in the Milk River, macrohabitats (Riffles and Tailwater Zones) with greater percentages of gravel and cobble tended to have greater species richness, diversity, and fish captured per gear deployment. Mean percentage of coarse substrate, mean depth, and diversity of macrohabitats tended to increase downstream. Mean percentage of fines and mean water velocities tended to decrease downstream. Developing fish passage at Vandalia Diversion Dam would reconnect native migratory fishes of the Missouri River with an additional 251 km of the Milk River and benefit the fishery.

INTRODUCTION

The importance of the Milk River in providing irrigation and municipal water supplies for north-central Montana is well established (Bureau of Reclamation (BOR) 1977, 1984, 1989, 1990; Fish and Wildlife Service 1983, 1984, 1988; Montana Department of Natural Resources and Conservation 1977; Montana Water Resources Board 1967). However, limited information is available on abundance, distribution, and habitat characteristics of the resident and migratory fishes in the Milk River, especially related to effects of dams and diversion structures.

Little has been published describing the pre-settlement conditions of the Milk River. Since the 1880s, the Milk River Basin has provided water for agricultural communities (BOR 1990). The first known diversion dam on the river was built in the 1890s (Simonds 1998). Diversion dams (Elser et al. 1977; Hesse and Sheets 1993; Helfrich 1999) as well as channelization (Gorman and Karr 1978; Portt et al. 1986), siltation (Berkman and Rabeni 1987; Matthews 1988), and flow modifications (Bain et al. 1988; Travnichek et al. 1995) may negatively affect habitat diversity, fish production, and community composition. Expansion of land use and all of these perturbations have occurred on the Milk River and with increasing demands for water, further impacts to the fish assemblage in the Milk River are expected.

Information based on entire fish assemblages, distributional patterns, and habitat associations is increasingly being used as a basis for formulating improved stream management practices (Tonn et al. 1983; Meffe and Sheldon 1988; Peterson and Rabeni

1995); therefore, a community-level investigation is necessary to best understand and preserve stream resource values (Orth 1987; Miller et al. 1988).

The purpose of this study was to develop baseline data on the population structure, distribution, and habitat use of fishes in the Milk River using standardized methods. The project involved a combined effort between the Montana Fish, Wildlife and Parks (MFWP), U.S. Geological Survey (USGS) Cooperative Fishery Research Unit, and the U.S. Bureau of Reclamation (BOR). Information generated will allow for future evaluations and assessment of potential impacts to the fish community structure in the Milk River. These evaluations provide support for federal actions involving repairs to and construction of project facilities, contract renewals, additional diversions, and instream flows. The specific objectives of this study were to: (1) document fish species and relative abundance in the Milk River from the eastern crossing of the Canada-Montana border downstream to the confluence with the Missouri River, (2) describe fish assemblages associated with different habitats, and (3) examine the potential effects of diversion structures on longitudinal distribution patterns.

STUDY AREA

The Milk River is one of the longest tributaries (1,127 km) of the Missouri River. From its headwaters at the eastern edge of Glacier National Park, the river flows 72.5 km northeast before crossing the Canadian border. The system flows 275.3 km through Alberta, Canada, before re-entering Montana. After reentry, the river meanders 784.3 km to its confluence with the Missouri River near Nashua, Montana. Total drainage area is about 57,839 km^2.

Since initiation of the Milk River Project in 1916, the natural flow of the Milk River has been supplemented with water from the St. Mary River drainage through the 47-km St. Mary Canal. The canal originates at the St. Mary Diversion Dam, 1.2 km downstream from Lower St. Mary Lake, and discharges water into the North Fork Milk River. The canal was designed to carry up to 24.1 m^3/s (850 cfs).

A short distance (85 km) after the Milk River re-enters Montana from Canada, its flow is contained and regulated by Fresno Dam. The 2,170-ha Fresno Reservoir, 23.5 km west of Havre, Montana, serves as the primary irrigation storage structure for the Milk River Project (BOR and Montana Department of Natural Resources and Conservation (DNRC) 1984). Since the completion of the dam in 1939, the highest recorded discharge was 185.5 m^3/s (6550 cfs) on April 2, 1952. A discharge of 0 m^3/s has occurred in 23 different years. In 1999, maximum discharge was 32.7 m^3/s (1155 cfs) on July 28, and the minimum was 1.1 m^3/s (39 cfs) recorded on November 15.

Currently, the Milk River Project consists of three major storage dams (Lake Sherburne, Fresno, and Nelson), five diversion dams (Swift Current, St. Mary, Paradise, Dodson, and Vandalia), 322 km of canals, 353 km of laterals, 472 km of drains, and 42,530 irrigated hectares. Two other privately owned diversion dams, Fort Belknap Irrigation Diversion Dam and Fort Belknap Reservation Diversion Dam, are also located on the Milk River below Fresno Reservoir. This network also provides irrigation water for an additional 10,009 ha served by contract and private pumpers (R. DeVore, BOR, Billings, personal communication). Principal crops produced are alfalfa, native hay, oats, wheat, barley, and sugar beets (BOR 1983). Other uses of Project water include municipal supplies, recreation, and allotments for fish and wildlife (BOR and DNRC 1984).

Our study area was the section of the Milk River between the eastern crossing of the Canadian-Montana border downstream to the confluence with the Missouri River (Figure 1). Elevations range from 811.2 m at the eastern border crossing to 618.5 m at the confluence with the Missouri River, a gradient change of 0.26 m/km.

The upper section (section 8), from the eastern border crossing down to Fresno Reservoir, has an appearance different from that of the rest of the study area. Even though natural flows in this reach are influenced by supplemental water from the St. Mary Canal, this is likely the most pristine section of the study area. Characteristics include a poorly developed riparian zone lacking any substantial woody vegetation, highly fluctuating flows, and extremely high turbidity. The river channel is mostly shallow and highly braided. Diversion dams do not exist within or above this reach on the Milk River proper.

From Fresno Dam down to Vandalia Diversion Dam, a distance of 512 km, the river is fragmented by four diversion dams and one municipal water weir (Figure 1), all of which block upstream fish movement at normal flows. The Fort Belknap Irrigation Diversion Dam may allow upstream fish passage at high flows. Cobble and riprap placed across the bottom and along the banks directly below these structures provide a unique habitat of faster, broken water.

Flows between Fresno Dam and Vandalia Diversion Dam are more stable and turbidity is less than above Fresno Reservoir. The river is confined to a single, incised channel with highly erosive, vertical banks and a moderately developed riparian area. Substrate is still dominated by sand and silt with very few areas of gravel and cobble. Deeper habitat is more common, but well-developed riffle habitat is almost nonexistent. Instream structure is rare and mostly limited to woody debris. The lower-most section from Vandalia Diversion Dam down to the confluence with the Missouri River (117 km) is the only stretch of the Milk River that is accessible to migratory fishes from the Missouri River.

After irrigation begins in the basin, usually by mid May, flow in the two lower sections (Juneberg Bridge and Nashua) declines quickly while water volume at all upriver sites is increasing (Figure 2). Water is held back at every diversion dam upstream of Vandalia Diversion Dam to help meet the water demands throughout the growing season.

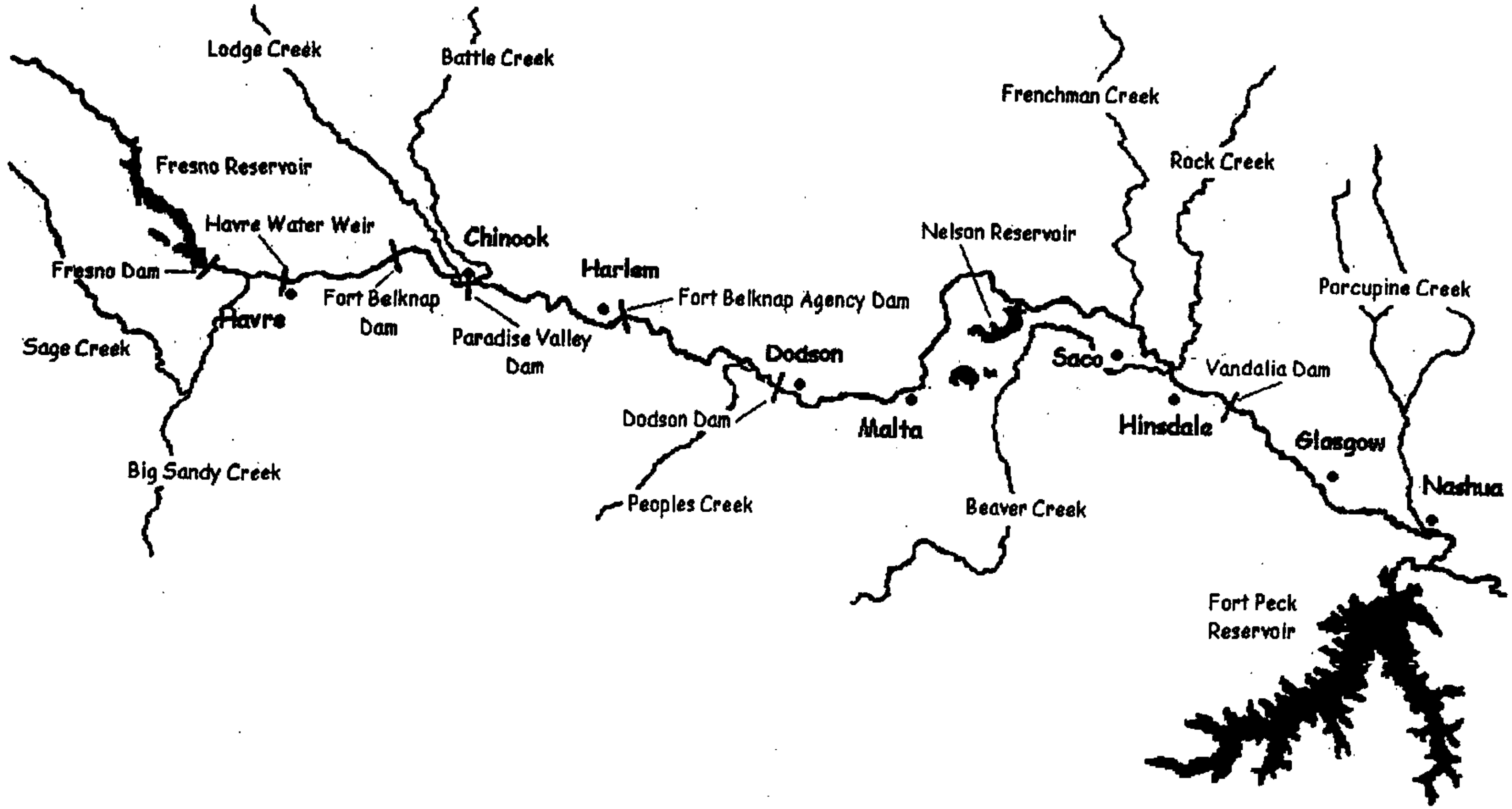

Figure 1. Milk River study area in northcentral Montana.

The r.ver below Vandalia Diversion Dam is a single, incised channel with well-developed riparian stands. Deeper habitat is available and well-developed cobble riffles are more common than at upriver locations. Instream structure consists of a moderate amount of fallen trees and car bodies.

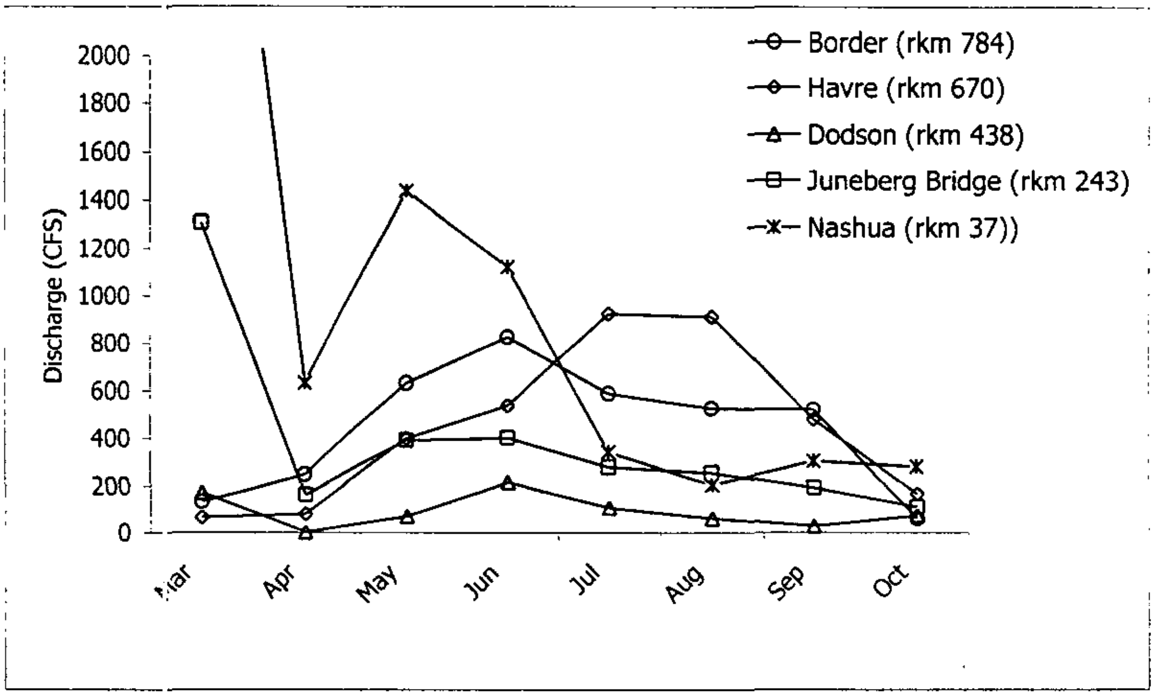

Figure 2. Mean monthly discharge of the Milk River at five USGS gauging stations, Montana (USGS 1999).

METHODS

During the 2 year study (1999 – 2000) lotic habitats within the Milk River were sampled to collect baseline data on the population structure, distribution, and habitat use of Milk River fishes. Standardized sampling methods and habitat classification were used to allow future monitoring of the fish community and population structure in the river. Sampling techniques were similar to the Long Term Resource Monitoring Program (1995) of the National Biological Service and the Missouri River Benthic Fishes Consortium (1998) because these procedures are based on commonly accepted methods. Slight modifications to these methods were needed to accommodate for limited manpower, access, and stream size.

Sampling Sites

The Milk River study area, from the eastern international crossing to the mouth, was divided into eight sections based on man-made structures (e.g., dams, diversions, and water weirs) that are impassible to upstream fish movement. The uppermost section (section 8), from the international crossing downstream to Fresno Reservoir, is free flowing and was divided into two segments. Sections 1 and 2 were divided into four segments each, to better represent the sampling effort for these longer sections of river and increase the probability of capturing all species that might occupy these stream reaches. River sections are defined as follows:

Section	Description
1	Missouri River to Vandalia Diversion Dam River Mile 0 – 117 (km 0 – 187.2)
2	Vandalia Diversion Dam to Dodson Diversion Dam River Mile 117 – 274 (km 187.2 – 438.4)
3	Dodson Diversion Dam to Fort Belknap Reservation Diversion Dam River Mile 274 – 333 (km 438.4 – 532.8)
4	Fort Belknap Reservation Dam to Paradise Valley Diversion Dam River Mile 333 – 374 (km 532.8 – 598.4)
5	Paradise Valley Diversion Dam to Fort Belknap (Lohman) Diversion Dam River Mile 374 – 393 (km 598.4 – 628.8)
6	Fort Belknap (Lohman) Diversion Dam to Havre Water Weir River Mile 393 – 419 (km 628.8 – 670.4)
7	Havre Water Weir to Fresno Dam River Mile 419 – 437 (km 670.4 – 699.2)
8	Fresno Reservoir to eastern crossing of Canada-Montana border River Mile 437 – 490 (km 699.2 – 784.3)

Limited legal access and physical conditions that impeded boat launching and travel necessitated a non-random selection of sample sites. Because of apparent homogeneity of the physical characteristics of the Milk River, we assumed that most existing forms of habitat could be reached within a half-hour boat ride both upstream and downstream of the access point. This concept was applied to reasonably manage available time. Latitude and longitude of each macrohabitat sampled are presented in Appendix A.

Habitat Classification and Measurements

The range of habitats in the Milk River was selected based on the macrohabitat classifications in the Missouri River Benthic Fishes Consortium (1998). These consisted of both natural and man-made physical features that potentially provide a variety of conditions for the fish communities. These habitats are defined as follows:

Main Channel Cross-Over (CHXO) - The main channel carries the majority of the river discharge and is defined as the thalweg of the river. The channel crossover area is defined as the inflection point of the thalweg (i.e., location where the thalweg crosses over from one concave side of the river to the other concave side) and carries the greatest volume of water.

Outside Bend (OSB) - the concave side of a river bend. In the Milk River, this is commonly associated with steep, continually eroding banks.

Inside Bend (ISB) – the convex side of a river bend. This was characterized by shallow sandbars not exceeding 1.2 m in depth.

Riffle (RIF) – a shallow area of the channel composed of cobble or rubble substrate that causes the water surface to become broken and turbulent. These areas are very rare in the Milk River above Dodson Diversion Dam.

Tailwater Zones (TWZ) – the area immediately downstream of a dam or water weir. For this study these habitats were associated with the man-made structures that form the boundaries for each study section and prohibit any further upstream fish movement.

Secondary Channel Non-Connected (SCN) – these are side channels that are blocked at one end by dry land such that water velocities are essentially 0.0 m/s. Fish movement into and out of this habitat is permitted only through the end connected to the main river channel.

Tributary Mouth (TRM) – the area where smaller streams enter the Milk River. These tributaries must be at least 6.1 m wide and deep enough to allow boat passage for a distance of 45 m upstream.

Attempts were made to sample each representative macrohabitat in each section, but not all categories were found in every section. A summary of the number of macrohabitats sampled in each section is provided in Appendix A. Additionally, because some macrohabitats were more common, and therefore sampled more often than others, a standardized index of the number of individuals captured per gear deployment in each of the macrohabitat types was calculated. By dividing the total number of individuals captured in each macrohabitat by the total number of gear deployments in that macrohabitat, a simple fish:gear deployment ratio was generated.

Site-specific habitat measurements, which were believed to be most relevant to fish populations, were recorded in conjunction with fish collections. These habitat measurements included water temperature, depth, velocity, turbidity, conductivity, and substrate. Protocols for measurements were based on the standard operating procedures developed by the Missouri River Benthic Fishes Consortium (1998). Substrate was subjectively classified as percent fines (sand and silt), gravel, or cobble. Turbidity measurements were taken with a Secchi disk in sections 3 – 8 and a turbidity meter in sections 1 and 2. Therefore, only readings from sections 3 – 8 were compared. Readings were recorded as the depth (cm) into the water column at which the black and white disk was no longer visible.

We compared depth, velocity, turbidity, and substrate composition within each of the four common macrohabitat types (Channel Crossovers, Inside Bends, Outside Bends, and Tailwater Zones) between each study section to determine if habitat complexity increases in a downstream manner in the Milk River. Additionally, because longitudinal increases in trophic structure and species richness have been attributed to longitudinal increases in habitat complexity (Schlosser 1982; Patton and Hubert 1993) or moderation of environmental conditions and increased living space (Rahel and Hubert 1991; Degerman and Sers 1992), substrate composition, mean depth, and mean velocity were further examined to determine the potential significance of these variables on the total species richness, mean species richness, diversity, and fish per gear deployment in Tailwater Zone macrohabitats.

Fish Collections

To evaluate community structure and distribution, fish were collected using a variety of sampling gears that were most effective on the greatest diversity of fish in the habitats available. An initial sampling season was used to test equipment and assess its effectiveness on fish in the Milk River. A description of fish collecting equipment and how and where it was used follows.

Bag Seine – 10.7 m long by 1.8 m deep; 1.8 m x 1.8 m x 1.8 m bag at center of net; 5 mm Ace mesh; "many ends" mudline attached to entire length at the bottom. Seining was used to sample inside bends, riffles, and secondary channels. Two seine hauls were used at each habitat site if there was enough area to avoid overlap. Sampling started at the downstream-most point. To deploy the seine, one end was anchored at the shoreline while the other end was stretched upstream and parallel to the shoreline. The upstream end of the net was then pulled into the water with a pivoting motion until the net was stretched out perpendicular to shore and then both ends were pulled downstream to a predetermined point. If snagging occurred, the haul was abandoned and another nearby site was selected. Distance of each haul was recorded to determine sampled area.

Electrofishing – Coffelt Mark 10 CPS backpack shocker, pulsed DC-60 cps, and a 14-foot Jon boat equipped with a Coffelt VVP 15 rectifying unit, a Honda 5000EX generator, and other necessary apparatus to conduct electrofishing from a boat. Backpack electrofishing was used to sample the Tailwater Zone habitats in Sections 3 – 7 whereas boat electrofishing was used to sample the Tailwater Zone habitats in Sections 1 and 2. Sampling of the Tailwater Zone started at a determined downstream point and progressed upstream until the dam or weir prevented further progress. Length of habitat sampled and the amount of shock-time (seconds) were recorded to standardize the effort. Further, because boat electrofishing was so versatile, it was used in nearly all other macrohabitat types. Sampling in each habitat started at a determined upstream point and progressed downstream. The boat was then turned around and an upstream pass of the same habitat was used to complete the sample. Length of habitat sampled and amount of shock-time were recorded.

Gill Nets – 15 m and 30 m sinking nets; 1.8 m high; divided horizontally into four equal segments of 1.9 cm, 3.8 cm, 5.0 cm, and 7.6 cm mesh size. These nets were used to sample Tailwater Zone habitats in sections 3 – 7, the main river where areas of very slow current could be found, and tributary mouths. Typical deployment strategy in deeper water involved staking one end of the net near the shoreline with a fence post while pulling the other end out into the water channel, perpendicular to the shoreline, and securing with heavy weights and a float. Because of the differing sizes of mesh, a coin was tossed to determine which end of the net would be staked near the shoreline to maintain randomness. Start-times and end-times were recorded for each effort and all nets were fished at least 12 h.

Hoop Nets – 1.1 m diameter hoops; 2.5 cm and 5.0 cm mesh size. This gear was used in Outside Bend, Inside Bend, and Main Channel Cross-Over habitats. In order to be fished effectively, water had to be at least 1.0 m deep and velocities had to be fast enough to keep the hoops standing on edge. Hoop nets were set by tossing a hoop net anchor, with 4 to 5 m of rope attached, off the bow of the boat. After the anchor was secure in the substrate, the hoop net was attached to the rope and fed off the bow as the boat drifted downstream. Once the hoop net was stretched, it was released and allowed to sink to the bottom. An additional buoy line was also attached to the anchor to help locate and retrieve the nets. Nets were fished for a minimum of 12 h. Both baited and unbaited nets were used to determine the best capture method.

Trammel Nets – 23 m: 2.5 cm inner mesh and 15.2 cm outer mesh. These nets were used to sample areas with velocities greater than 0.4 m/s. Each sample consisted of at least a 75 m drift while recording both start and finish times. To deploy the net, one member of the crew waded across the channel with one end of the net while the other member anchored the other end. Once the net was stretched, both members walked downstream at an even pace with the flow while holding on to each end of the net. When finished with the drift, one of the crew made a downstream arc to end on the same side as the other member and the net was pulled ashore. This sampling technique was used in only Sections 1 and 2 because of the difficulties of frequent snagging in all other sections. All sampling locations were documented with a Magellan NAV 5000 GPS unit to ensure sample sites could be located again for future community monitoring.

Fish collected were identified to species, enumerated, weighed, and measured. Because of the difficulties associated with larval fish identification, only fish greater than 30 mm were identified. Each fish was weighed to the nearest 0.1 g using an Ohaus CT1200 electronic balance. Fish that exceeded 1200 g were weighed to the nearest 25 g using a Yamato Accu-Weigh SM-40PK dial scale. Total length of each fish was measured to the nearest millimeter. Appendix B provides a summary of the size distribution of the species captured during this study. Any specimens that could not be readily identified in the field were preserved using a 10% solution of formalin and brought back to the lab for identification.

If a large number of individuals of one species was present in a sample, a subsample of 25 was randomly selected. Any additional fish of that species were enumerated to record the total number of fish in the collection.

Data Analysis

We determined the presence (richness) and proportion (relative abundance) of fish species for each macrohabitat type (all sections combined) and for each section. The relationship between macrohabitat and species richness, as well as study section and species richness, was examined using one-way Analysis of Variance (ANOVA) with a critical value (P) of 0.05. When significant differences were detected, Tukey's Studentized Range test was used to determine where specific differences occurred. To determine if differences in depth, velocity, and substrate existed between sections, data were $\log_{10}(x+1)$ transformed to better fit normality assumptions and compared using one-way ANOVA. Again, Tukey's test was used to determine where differences occurred.

The fish community was further described using Shannon's diversity index, $H' = -\sum p_i \log_2 p_i$, where p_i is the proportion of the *i*th species in the sample, and the Morista-Horn community similarity index, $I_{mh} = [2 * \sum(an_i bn_i)]/[(da + db)\ aN * bN]$, where aN is the number of individuals in site A; bN, the number of individuals in site B; an_i, number of individuals of the *i*th species in site A; bn_i, the number of individuals of the *i*th species in site B; $da = \sum an_i^2/aN^2$; and $db = \sum bn_i^2/bN^2$. These indices were used to evaluate spatial changes in fish assemblage composition in relation to barrier dams and stream gradient. Because these indices are not statistics, critical values are not associated with them. In considering similarity indices such as Morista-Horn, no absolute value exists to indicate if two adjacent fish assemblages are distinct or similar. It derives values from zero, indicating no community similarity, to one, indicating total similarity, and takes into account both taxa richness and abundance; it is highly sensitive to the abundance of the most abundant taxa (Wolda 1981). We followed suggestions of other researchers who considered Morista-Horn similarity values of about 0.67 to be indicative of high faunal similarity and values of about 0.33 and lower to represent distinct communities (Moyle and Vondracek 1985; Ross et al. 1985; Matthews et al. 1988; Travnichek et al. 1995).

We used principal components analysis to identify fish species assemblages related to the longitudinal structure of the eight study sections. Principal component analysis efficiently summarizes community data into a simpler form and assists in defining existing patterns. The data were arranged in a species presence and proportion by study section correlation matrix with species relative abundances transformed to an octave scale as suggested by Gauch (1982). This transformation was performed to reduce the effects of the most abundant species. Species that were represented by less than 1% of the total catch were excluded from the analysis to simplify interpretation of results. Gradients of community change were identified from the resulting plot that places species on either side of the axis based on principal component loadings for each species.

To further assist in the interpretation of the resulting principal components plot, Pearson's correlations were examined between the first two principal components and mean physical habitat variables for each section as well as total species richness and total number of individuals.

RESULTS

Fish Community

A total of 10,995 fish, representing 41 species, was collected from the Milk River between the confluence with the Missouri River upstream to the eastern Canada-Montana border crossing from April – June and September – October, 1999 and 2000. The 41 species belong to 13 families of fishes including Acipenseridae (sturgeons, 1 species), Polydontidae (paddlefishes, 1 species), Hiodontidae (mooneyes, 1 species), Cyprinidae (minnows, 12 species), Catostomidae (suckers, 8 species), Ictaluridae (catfishes, 3 species), Esocidae (pikes, 1 species), Salmonidae (trouts, 3 species), Gadidae (codfishes, 1 species), Gasterosteidae (sticklebacks, 1 species), Centrarchidae (sunfishes, 4 species), Percidae (perches, 4 species), and Sciaenidae (drums, 1 species) (Table 1). Twenty eight of these species are native to Montana (Holton and Johnson 1996) and represented 69.9% of the total collection. The remaining 30.1% of the fish captured consisted of 13 species not native to Montana. Twelve species are designated game fish by Montana statutes (Holton and Johnson 1996). Four species, blue sucker, paddlefish, pearl dace, and sauger are Montana Fishes of Special Concern (Hunter 1997; K. McDonald, MFWP, Helena, personal communication), and two species, flathead chub and western silvery minnow are on the Montana Natural Heritage Program watch list (Roedel 1999).

Table 1. Fish species collected in the Milk River, Montana, April-June and September-October, 1999 and 2000.

Family / Species		Native / Introduced	Special Status
Cyprinidae			
Lake chub	*Couesius plumbeus*	Native	
Common carp	*Cyprinus carpio*	Introduced	
Hybognathus spp.	*Hybognathus spp.*	Native	Watch List
Brassy minnow	*Hybognathus hankinsoni*	Native	
Pearl dace	*Margariscus margarita*	Native	Special Concern
Emerald shiner	*Notropis atherinoides*	Native	
Spottail shiner	*Notropis hudsonius*	Introduced	
Northern redbelly dace	*Phoxinus eos*	Native	
Fathead minnow	*Pimephales promelas*	Native	
Flathead chub	*Platygobio gracilis*	Native	Watch List
Longnose dace	*Rhinichthys cataractae*	Native	
Creek chub	*Semotilus atromaculatus*	Native	
Catastomidae			
River carpsucker	*Carpiodes carpio*	Native	
Longnose sucker	*Catostomus catastomus*	Native	
White sucker	*Catostomus commersoni*	Native	
Mountain sucker	*Catostomus platyrhynchus*	Native	
Blue sucker	*Cycleptus elongates*	Native	Special Concern
Smallmouth buffalo	*Ictiobus bubalus*	Native	
Bigmouth buffalo	*Ictiobus cyprinellus*	Native	
Shorthead redhorse	*Moxostoma macrolepidotum*	Native	
Centrarchidae			
Bluegill	*Lepomis macrochirus*	Introduced	
Smallmouth bass	*Micropterus dolomieu*	Introduced	
White crappie	*Pomoxis annularis*	Introduced	
Black crappie	*Pomoxis nigromaculatus*	Introduced	
Percidae			
Iowa darter	*Etheostoma exile*	Native	
Yellow perch	*Perca flavescens*	Introduced	
Sauger	*Stizostedion canadense*	Native	Special Concern
Walleye	*Stizostedion vitreum*	Introduced	
Ictaluridae			
Black bullhead	*Ameiurus melas*	Introduced	
Channel catfish	*Ictalurus punctatus*	Native	
Stonecat	*Noturus flavus*	Native	
Salmonidae			
Lake whitefish	*Coregonus clupeaformis*	Introduced	
Rainbow trout	*Oncorhynchus mykiss*	Introduced	
Brown trout	*Salmo trutta*	Introduced	

Table 1. Continued.

Family / Species		Native / Introduced	Special Status
Acipenseridae			
Shovelnose sturgeon	*Scaphirhynchus platorynchus*	Native	
Polyodontidae			
Paddlefish	*Polyodon spathula*	Native	Special Concern
Hiodontidae			
Goldeye	*Hiodon alosoides*	Native	
Esocidae			
Northern pike	*Esox lucius*	Introduced	
Gadidae			
Burbot	*Lota lota*	Native	
Gasterosteidae			
Brook stickleback	*Culaea inconstans*	Native	
Sciaenidae			
Freshwater drum	*Aplodinotus grunniens*	Native	

The eight study sections (except section 3) in this 784 km segment of the Milk River followed a distributional pattern of species richness common to lotic ecosystems. The total number of species tended to increase progressively downstream. In section 8, the uppermost study section, we collected 10 species whereas the greatest total species richness was found in section 1 with 29 species (Table 2). Mean species richness was significantly different (ANOVA, $P < .001$) between the study sections. Section 2 had the greatest mean richness with a value of 4.1 ± SE 0.30, followed by section 1 (4.0 ± 0.30), section 4 (3.6 ± 0.46), section 5 (3.0 ± 0.41), section 7 (2.2 ± 0.36), section 8 (1.9 ± 0.15), section 6 (1.8 ± 0.35), and section 3 (1.2 ± 0.24) (Figure 3).

Table 2. Fish species and numbers collected in sections 1 – 8 of the Milk River, spring and fall, 1999 and 2000. Species arranged to reflect an additive pattern, from upstream to downstream, in the fish assemblage.

	(upstream)			Section			(downstream)			
Species	8	7	6	5	4	3	2	1	Total	% Total
Burbot	6	7			1			2	16	0.15
Sauger	28	10	2	11	17			73	141	1.28
Lake chub	2	1	6	8	14	28			59	0.54
Stonecat	13	1		12	3	1	3	123	156	1.42
Longnose sucker	32	115	23	56	20	2		9	257	2.34
Flathead chub	954	2	38	153	245	6	57	430	1885	17.14
Hybognathus spp.	64	1	11	2	1	1	8	326	414	3.77
Northern pike	1	23	19	28	67	19	59	11	227	2.06
Spottail shiner	5	169	275	16	79	3	1434	14	1995	18.14
White sucker	3	186	53	113	39	2	79	82	557	5.07
Rainbow trout		18							18	0.16
Brown trout		23	2						25	0.23
Black bullhead		2	11	6				1	20	0.18
Lake whitefish		30	4	5	3			8	50	0.45
Pearl dace		1		1	14	14			30	0.27
Longnose dace		31	72	71	145		19	12	350	3.18
Emerald shiner		27	16	8	9	2	673	236	971	8.83
Fathead minnow		7	2	375	143	14	157	129	827	7.52
Walleye		36	13	6	43	11	72	20	201	1.83
Yellow perch		66	19	72	69	24	109	2	361	3.28
Common carp			7	17	111	73	93	66	367	3.34
Brassy minnow			6			1			7	0.06
Mountain sucker			1	1					2	0.02
Northern redbelly dace				1	3				4	0.04
Brook stickleback					4				4	0.04
Iowa darter					2				2	0.02
Smallmouth bass					1		13	3	17	0.15
Black crappie					1		9	1	11	0.10
Bluegill							5		5	0.05
Creek chub							9		9	0.08
White crappie							16		16	0.15
Bigmouth buffalo							4	9	13	0.12
Channel catfish							27	120	147	1.34
Freshwater drum							14	71	85	0.77
Goldeye							78	351	429	3.90
River carpsucker							49	293	342	3.11
Shorthead redhorse							232	234	466	4.24
Smallmouth buffalo							21	26	47	0.43
Blue sucker								23	23	0.21
Paddlefish								1	1	0.01
Shovelnose sturgeon								438	438	3.98
Total Individuals	1108	756	580	962	1034	201	3240	3114	10995	
Total Species	10	20	19	20	23	15	24	29	41	

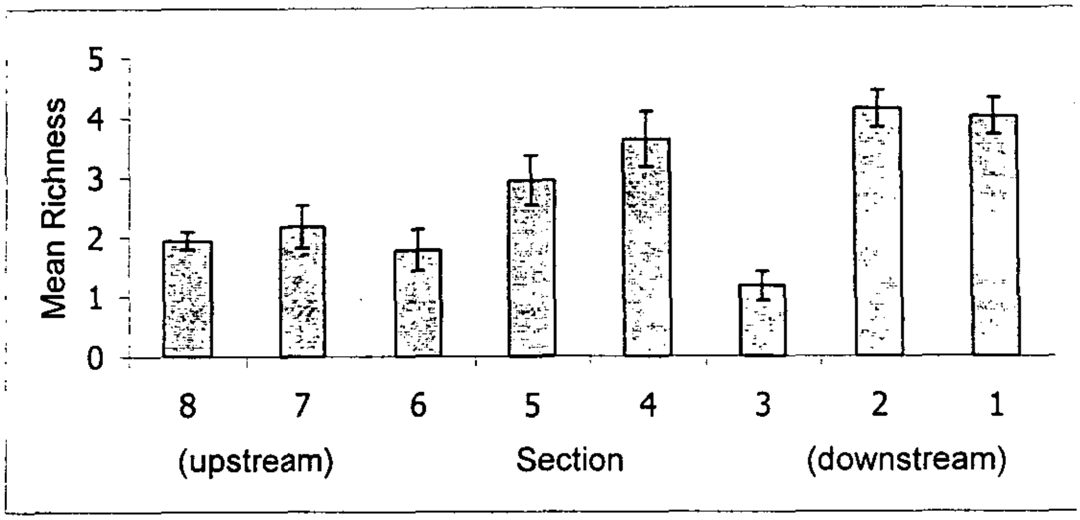

Figure 3. Mean species richness (± 1 SE) for the eight study sections of the Milk River, Montana, 1999 and 2000..

The 12 species of Cyprinidae and 8 species of Catostomidae numerically dominated our collections with 62.9% (n = 6918) and 15.5% (n = 1707), respectively, of the total catch. Four other families each represented greater than two percent of the total catch. These included Percidae (6.4%, n = 705), Acipenseridae (4.0%, n = 438), Hiodontidae (3.9%, n = 429), and Ictaluridae (2.9%, n = 323). Cyprinids, catostomids, percids, and ictalurids were represented in all eight study sections. Hiodontidae were found only in sections 1 and 2 while Acipenseridae were collected only from section 1. The relatively large percentage of shovelnose sturgeon (Acipenseridae) can probably be attributed to intensive sampling efforts in section 1 during the spring of 1999.

Only five species were found in all eight study sections. These include flathead chub, *Hybognathus* spp., northern pike, spottail shiner, and white sucker. However, only one northern pike was found in section 8 and only one *Hybognathus* spp. was found in each of sections 3, 4, and 7. Flathead chub decreased from its greatest relative abundance in section 8 (n = 954, 86%) to its least relative abundance in adjacent section 7 (n = 2, 0.3%). The most common species encountered was the introduced spottail shiner (n = 1995), accounting for 18.1% of the total collection followed by four native species including flathead chub (17.1%, n = 1885), emerald shiner (8.8%, n = 971), fathead minnow (7.5%, n = 827), and white sucker (5.1%, n = 557). Nine species were exclusive to a particular study section including brook stickleback (section 4), bluegill (section 2), blue sucker (section 1), creek chub (section 2), Iowa darter (section 4), rainbow trout (section 7), paddlefish (section 1), shovelnose sturgeon (section 1), and white crappie (section 2). Twenty two of the 41 species encountered each made up less than one percent of the total catch (Table 2).

Of the game fish in the Milk River contributing more than one percent of the total catch, shovelnose sturgeon was the most common species collected followed by yellow perch, northern pike, walleye, channel catfish, and sauger. Shovelnose sturgeon accounted for 4.0% of the total collection with 438 individuals and was only collected in section 1. No shovelnose sturgeon were captured in the fall. Yellow perch accounted for 3.3% of the total collection with 361 individuals. This species was found in each of sections 1 – 7, however, only two individuals were captured in section 1. Northern pike (n = 227, 2.1%) was the only game fish species found in each of the eight study sections. Walleye (n = 201, 1.8%) were collected from each of sections 1 – 7. Channel catfish (n = 147, 1.3%) were collected in only sections 1 and 2 even though restocking efforts by MFWP have occurred in sections 3, 4, 5, 6, and 7 (K. Gilge, MFWP, Havre, personal communication). Sauger accounted for 1.3% of the total catch with 141 individuals.

This species was captured in six of the eight sections; 72% were captured in sections 1 and 8. These two sections are distinct from the other study sections because they are not bounded at both ends by irrigation dams. Section 1 retains its connectivity with the Missouri River while section 8 has no dams above it to block upstream fish movements.

Four Species of Special Concern were collected during our sampling efforts. Twenty three blue suckers and one paddlefish were found exclusively in section 1. Additionally, these two species were collected only in the spring and mostly over Riffle macrohabitats. Sauger, the most recently added species to the list, were found in sections 1, 4, 5, 6, 7, and 8. Pearl dace were collected in sections 3, 4, 5, and 7, although only one individual was found in each of sections 5 and 7. Fourteen were captured in each of sections 3 and 4 and all of these 28 were captured in the Tailwater Zone macrohabitat, directly below irrigation dams.

The longitudinal position of each study section (1 – 8) was a fairly accurate indicator of species diversity (H') in the Milk River (Figure 4). The trend was similar to that of species richness with downstream diversity generally greater than upstream sections, inferring some effect of longitudinal position. However, the relationship was affected by the diversity values generated in sections 2 and 3. The section 3 index (H' = 2.14) was probably not reflective of actual diversity in this reach because of sampling difficulties. The relatively low index value (H' = 2.81) for section 2 reflects the prevalence of two species in this reach. Combined, spottail shiner (n = 1434) and emerald shiner (n = 673) accounted for 65.0% of the total collection for this section.

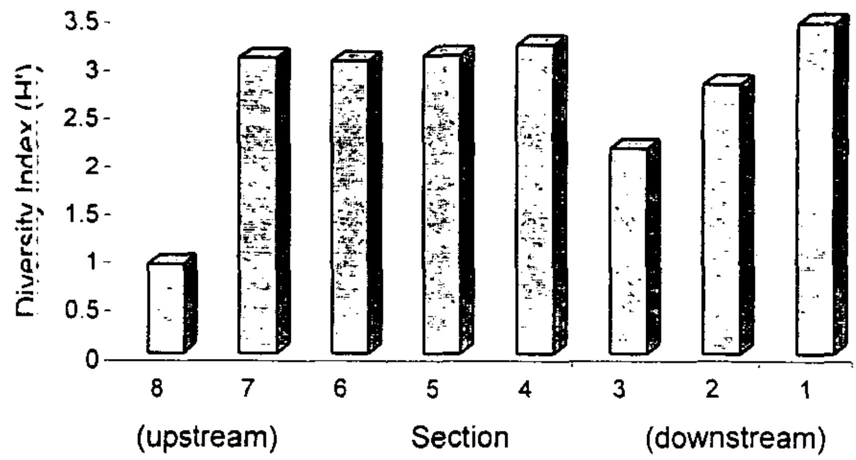

Figure 4. Fish species diversity values (H') for the eight study sections of the Milk River, Montana, 1999 and 2000.

The percentage of nonnative fish in each section ranged from 1% in section 8 to 65% in section 3 (Figure 5). Section 6 had the second greatest number of nonnative fish (60%) followed by section 2 (56%), section 7 (49%), section 4 (36%), section 5 (16%), and section 1 (4%). The percentage of nonnative species ranged from 20% in section 8 to 42% in section 6 (Figure 6). Section 7 had the second greatest percentage of nonnative species (40%) followed by section 2 (38%), section 5 (35%), section 4 (35%), section 3 (33%), and section 1(31%).

Morista-Horn similarity index values for all adjacent sections ranged from 0.02 – 0.80 (Figure 7). Three pairs of adjacent study sections had similarity index values lower than 0.33. The low similarity value between sections 2 and 3 (I_{mh} = 0.07) can probably be attributed to the poor representation of the fish community due to sampling difficulties in section 3. The pattern most evident is the distinction between sections 8 and 7 (I_{mh} = 0.02) and sections 2 and 1 (I_{mh} = 0.21) (Figure 7). Sections 1 and 8 are the only study sections bounded by only one irrigation dam allowing relatively unrestricted movement. Comparisons of these two sections with their adjacent bounded sections indicated low similarity between each of their fish communities, which may be suggestive of fragmentation. Further, all comparisons of bounded sections (excluding comparisons of sections 3 and 2) resulted in similarity values greater than 0.33, indicating greater similarity among these fish assemblages.

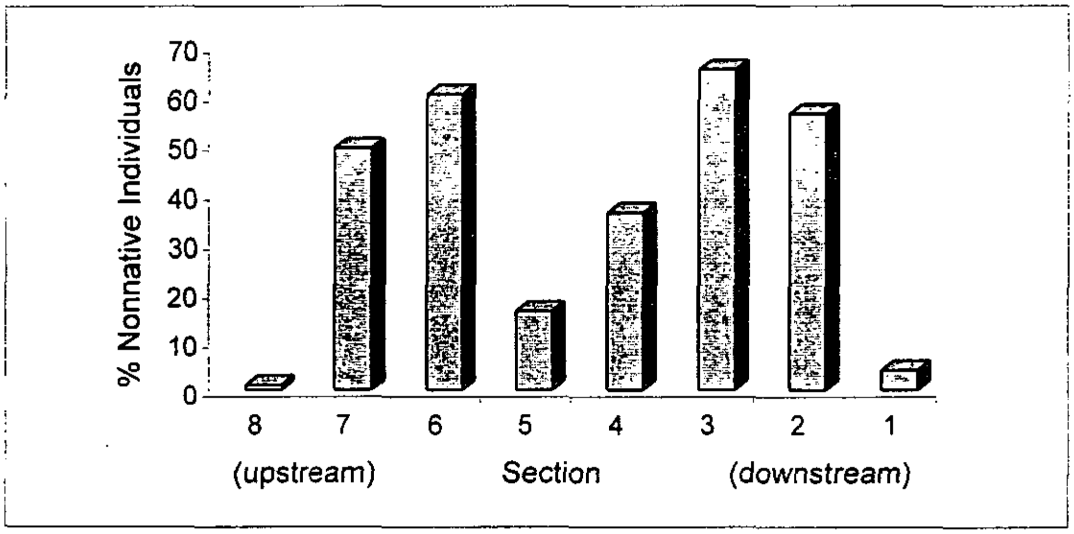

Figure 5. The percentage of nonnative fish captured in study sections 1- 8 of the Milk River, Montana, 1999 and 2000.

Fish were collected from each of the seven macrohabitat types of the Milk River. However, Riffles, Secondary Channels Non-connected, and Tributary Mouths were located and sampled only in sections 1 and 2. Total species richness was greatest in Tailwater Zones, which accounted for 34 species, followed by Main Channel Crossovers (29 species), Riffles (28 species), Outside Bends (27 species), Inside Bends (22 species), Tributary Mouths (22 species), and Secondary Channels Non-connected (5 species)

(Table 3). Because only one Secondary Channel Non-connected fitting our description was located and sampled, this macrohabitat type was excluded from analysis.

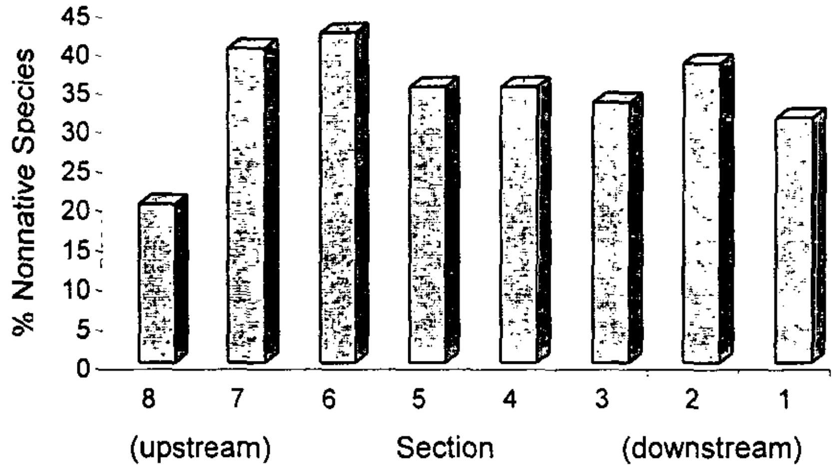

Figure 6. The percentage of nonnative species captured in study sections 1 – 8 of the Milk River, Montana, 1999 and 2000.

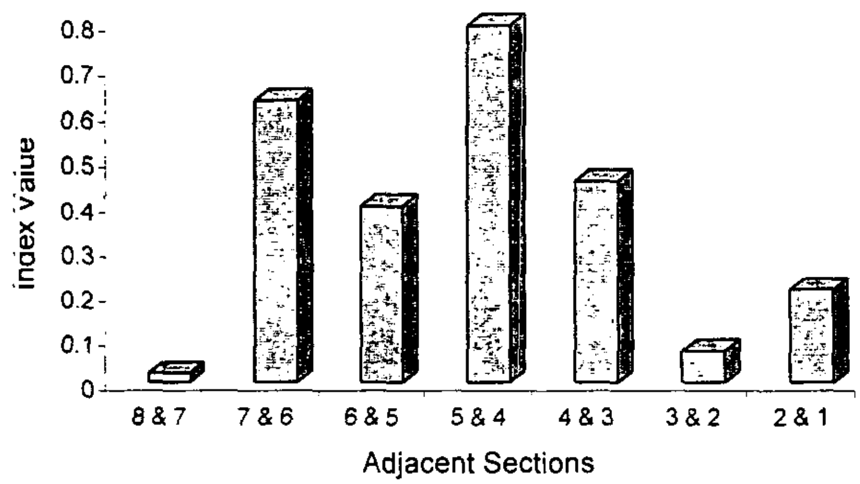

Figure 7. Morista-Horn community similarity index for comparisons of adjacent fish assemblages in the eight study sections of the Milk River, Montana, 1999 and 2000.

Table 3. Fish species and numbers collected by macrohabitat type in sections 1 – 8 of the Milk River, Montana, 1999 and 2000.

Family / Species	Macrohabitat						
	CHXO	ISB	OSB	RIF	SCN	TRM	TWZ
<u>Cyprinidae</u>							
Lake chub	2	3	1				53
Common carp	88	13	146	44		13	63
Hybognathus spp.	16	222	11	116	10		39
Brassy minnow							7
Pearl dace	1		1				28
Emerald shiner	186	239	70	229	30	202	15
Spottail shiner	20	156	1038	313		1	467
Northern redbelly dace							4
Fathead minnow	38	159	14	83	51	3	479
Flathead chub	152	1029	146	423			135
Longnose dace	1	3		29			317
Creek chub				4	5		
<u>Catastomidae</u>							
River carpsucker	33	90	27	165	3	14	10
Longnose sucker	53	20	51			9	124
White sucker	98	28	147	125		13	146
Mountain sucker							2
Blue sucker				19		4	
Smallmouth buffalo	7		2	22		16	
Bigmouth buffalo	1		2	1		4	5
Shorthead redhorse	83	5	38	276		11	53
<u>Centrarchidae</u>							
Bluegill	1			4			
Smallmouth bass	2	1	3	7			4
White crappie	1	10		1		4	
Black crappie		6	1			3	1
<u>Percidae</u>							
Iowa darter							2
Yellow perch	53	65	95	5		25	118
Sauger	26	20	25	34		23	13
Walleye	26	6	23	11		47	88
<u>Ictaluridae</u>							
Black bullhead	5		11	1			3
Channel catfish	34	3	22	72		6	10
Stonecat	10		3	125			18
<u>Salmonidae</u>							
Lake whitefish	5		5				40
Rainbow trout							18
Brown trout							25

Table 3. Continued

Family/Species	CHXO	ISB	OSB	RIF	SCN	TRM	TWZ
Acipenseridae							
Shovelnose sturgeon				406		32	
Polyodontidae							
Paddlefish				1			
Hiodontidae							
Goldeye	58	2	55	206		75	33
Esocidae							
Northern pike	34	10	36	7		22	118
Gadidae							
Burbot	5		2			2	7
Gasterosteidae							
Brook stickleback							2
Sciaenidae							
Freshwater drum	13	54	5	6		1	6
Total individuals	1052	2144	1980	2735	99	530	2455
% Total	9.6%	19.5%	18.0%	24.9%	0.9%	4.8%	22.3%
Total species	29	22	27	28	5	22	34

CHXO (Main Channel Crossover), ISB (Inside Bend), OSB (Outside Bend), RIF (Riffle), SCN (Secondary Channel Non-connected), TRM (Tributary Mouth), TWZ (Tailwater Zone)

The highest ratio of fish captured per gear deployment occurred in Tailwater Zone macrohabitats (35:1) (Table 4). This was followed by Riffles (24:1), Inside Bends (23:1), Tributary Mouths (18:1), Outside Bends (17:1), and Channel Crossovers (9:1).

Table 4. Fish captured per gear deployment for the six macrohabitat types in the Milk River, Montana, 1999 and 2000.

Habitat	# of Fish	# of Gear Deployments	Ratio
Channel Crossovers	1054	120	9:1
Inside Bends	2122	92	23:1
Outside Bends	1974	114	17:1
Riffles	2755	115	24:1
Tributary Mouths	527	29	18:1
Tailwater Zones	2515	72	35:1

Seven species were found exclusively in Tailwater Zone macrohabitats. These included rainbow trout, brown trout, brassy minnow, mountain sucker, northern redbelly dace, brook stickleback, and Iowa darter. The only other species exclusive to a particular macrohabitat was one paddlefish caught in Riffle macrohabitat. The greatest number of individuals captured for 18 different species occurred in Tailwater Zones while the greatest number of 12 other species was collected in Riffles. In addition, Tailwater Zones harbored the greatest number of nonnative species (11) and the second greatest relative abundance of nonnative individuals (38.5%). Outside Bends yielded the greatest relative abundance of nonnative individuals with 68.6% of the total catch in this particular macrohabitat. However, this is due to a single electrofishing effort in section 2 which captured 1018 spottail shiners.

Tributary Mouth macrohabitats had the greatest mean richness with 6.2 ($\pm$ SE 0.42) followed by Tailwater Zones (5.2 $\pm$ SE 0.46), Riffles (4.8 $\pm$ SE 0.38), Inside Bends (2.7 $\pm$ SE 0.21), Channel Crossovers (2.4 $\pm$ SE 0.24), and Outside Bends (2.2 $\pm$ SE 0.19) (Figure 8). Mean richness was significantly different between macrohabitats (ANOVA $P < 0.001$). Results from a Tukey's Studentized Range test indicated mean richness was not significantly different between Tributary Mouths, Tailwater Zones, and Riffles as well as between Inside Bends, Outside Bends, and Channel Crossovers. However, these two groups were significantly different from each other.

Shannon's diversity index for the fish community of each macrohabitat type did not follow the same order as the mean species richness. Channel Crossovers, which had the second lowest mean species richness, had the most diverse fish community with a value of 3.91 followed by Tailwater Zones (H' = 3.79), Riffles (H' = 3.74), Tributary Mouths (H' = 3.23), Outside Bends (H' = 2.76), and Inside Bends (H' = 2.68).

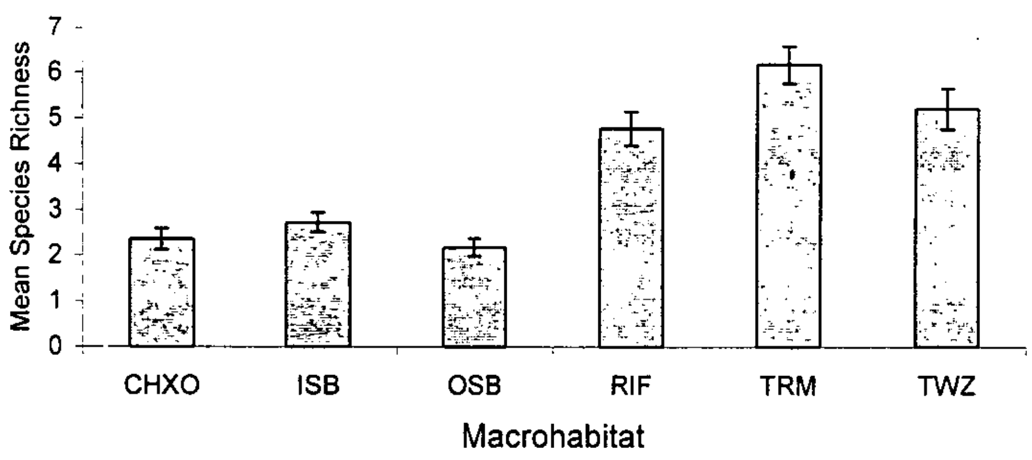

Figure 8. Mean species richness (± 1 SE) for six macrohabitat types of the Milk River, Montana, 1999 and 2000. See pages 11 and 12 for macrohabitat description.

Physical Habitat Variables

The dominant substrate in the Milk River is fines (sand and silt). Comparisons between the four common macrohabitat types (Channel Crossovers, Inside Bends, Outside Bends, and Tailwater Zones) indicated very small proportions of gravel and cobble contributed to the total substrate composition, except in Tailwater Zones (Figures 9, 10, 11, and 12). Substrate composition did not differ significantly between Channel Crossovers, Inside Bends, and Outside Bends. Tailwater Zones differed significantly in substrate composition ($P < 0.05$) from the other three common macrohabitat types and had the lowest mean percentage of fines (53.4% ± SE 5.31), greatest mean percentage of gravel (16.1% ± SE 2.68). and greatest mean percentage of cobble (28.4% ± SE 4.11). While significant amounts of fines still exist in most of the Tailwater Zones, turbulent water released from the irrigation dams during the irrigation season, in combination with placement of larger substrate (riprap and larger cobble) to prevent erosion, act to substantially change the substrate composition from fines to a more heterogeneous mix.

Trends in our fish collections suggest that many Milk River fishes tend to be associated with greater amounts of coarse substrate. Tailwater Zone macrohabitats had the greatest total species richness (34 species), the greatest number of individuals captured per gear deployment (35:1), the second largest mean species occurrence (5.2, SE ± 0.46), and the second largest diversity value (H' = 3.79). In addition, Riffle macrohabitats, which also had greater proportions of coarse substrate but were very rare in the upper six study sections (sections 3 – 8), had the second greatest number of individuals captured per gear deployment (24:1) and was third greatest in total species richness (28), mean richness (4.8 ± SE 0.38), and diversity (H' = 3.74). Riffles also differed significantly in substrate composition ($P < 0.05$) from Channel Crossovers, Inside Bends, and Outside Bends.

While Tailwater Zones ranked high in total species richness, mean species richness, diversity, and fish per gear deployment ratio, the depths and velocities associated with this macrohabitat exhibited few significant differences from the other macrohabitat types. Tailwater Zone mean depth (1.19 m ± SE 0.16) was significantly different from only Outside Bends, which had the greatest mean depth (1.47 m ± SE 0.06), and Inside Bends, which were shallowest (0.50 m ± SE 0.02). Mean velocity in

Tailwater Zones (0.18 m/s ± SE 0.02) was second lowest of all six macrohabitats but differed significantly from only Riffles, which had the greatest mean velocity (0.57 m/s ± SE 0.06), and Tributary Mouths, which had the smallest mean velocity (0.00 m/s ± SE 0.0).

Very few significant differences in mean depth occurred along the gradient for each of the four common macrohabitats. When significant differences did occur, they were usually a contrast between a macrohabitat from section 8, above Fresno Reservoir, and one or more from the lower seven sections. In Outside Bends, the general trend was an increase in depth along the gradient (Figure 10). However, significant differences ($P < 0.014$) only occurred between section 8 (mean 1.14 m ± SE 0.10) and sections 4 (mean 1.78 m ± SE 0.15) and 6 (mean 1.71 m ± SE 0.13). Inside Bend depths also tended to increase in a downstream direction (Figure 11) with significant differences ($P < 0.001$) occurring only between section 8 (mean 0.40 m ± SE 0.02) and sections 1 (mean 0.71 m ± SE 0.05) and 2 (mean 0.59 ± SE 0.06) as well as between section 1 and sections 4 (mean 0.44 ± SE 0.03) and 5 (mean 0.48 ± SE 0.03). Mean depth for Channel Crossovers tended to increase from section 8 to section 3, but then decreased in sections 2 and 1 (Figure 12). The only significant difference ($P < 0.021$) occurred between section 8, the shallowest (mean 1.00 m ± SE 0.08), and section 3, the deepest (mean 1.84 m ± SE 0.24). Tailwater Zone depths actually decreased in a downstream direction but no significant differences between sections occurred (Figure 9).

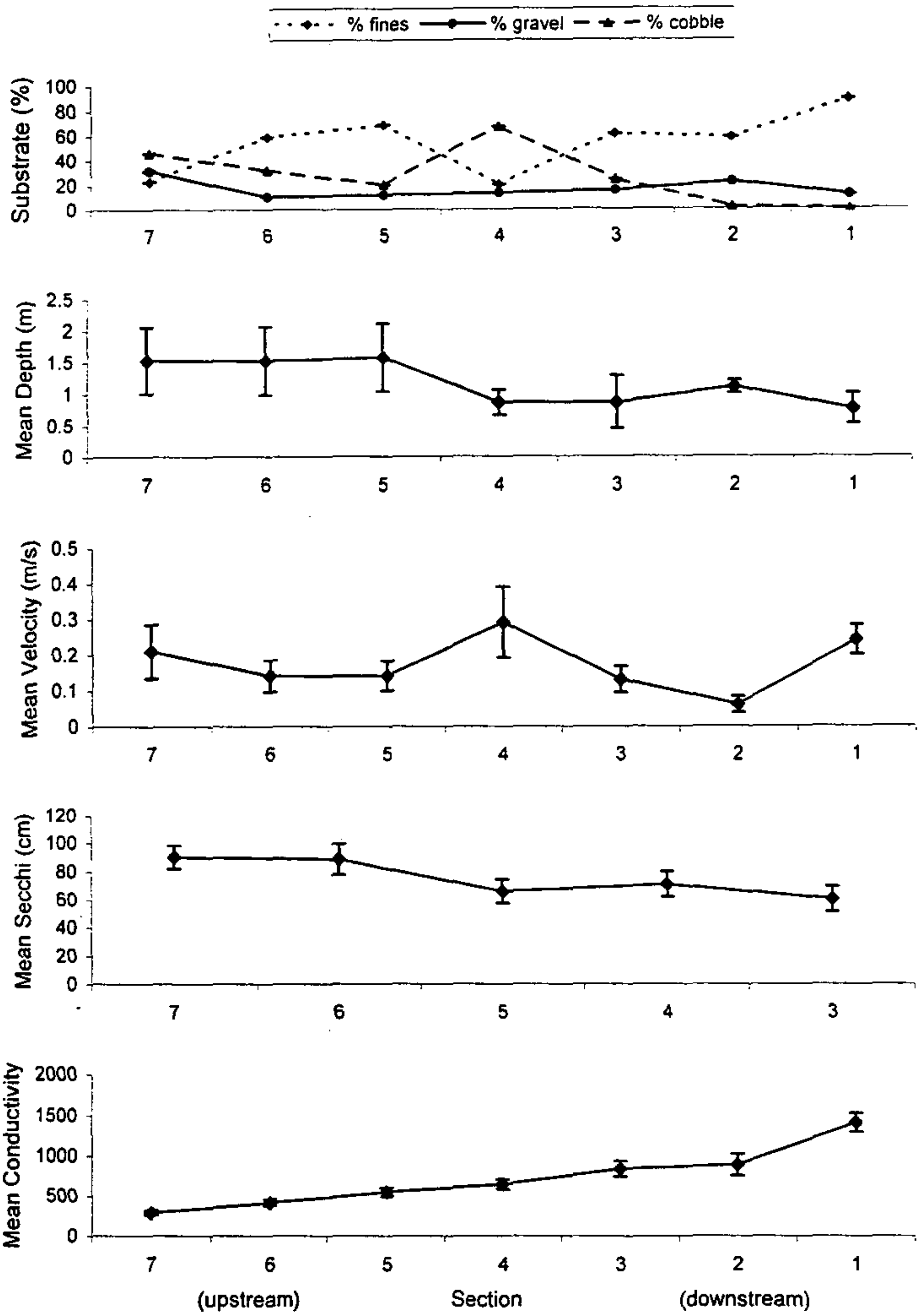

Figure 9. Longitudinal profile of mean habitat characteristics (± 1 SE) for Tailwater Zone macrohabitats in the Milk River, Montana.

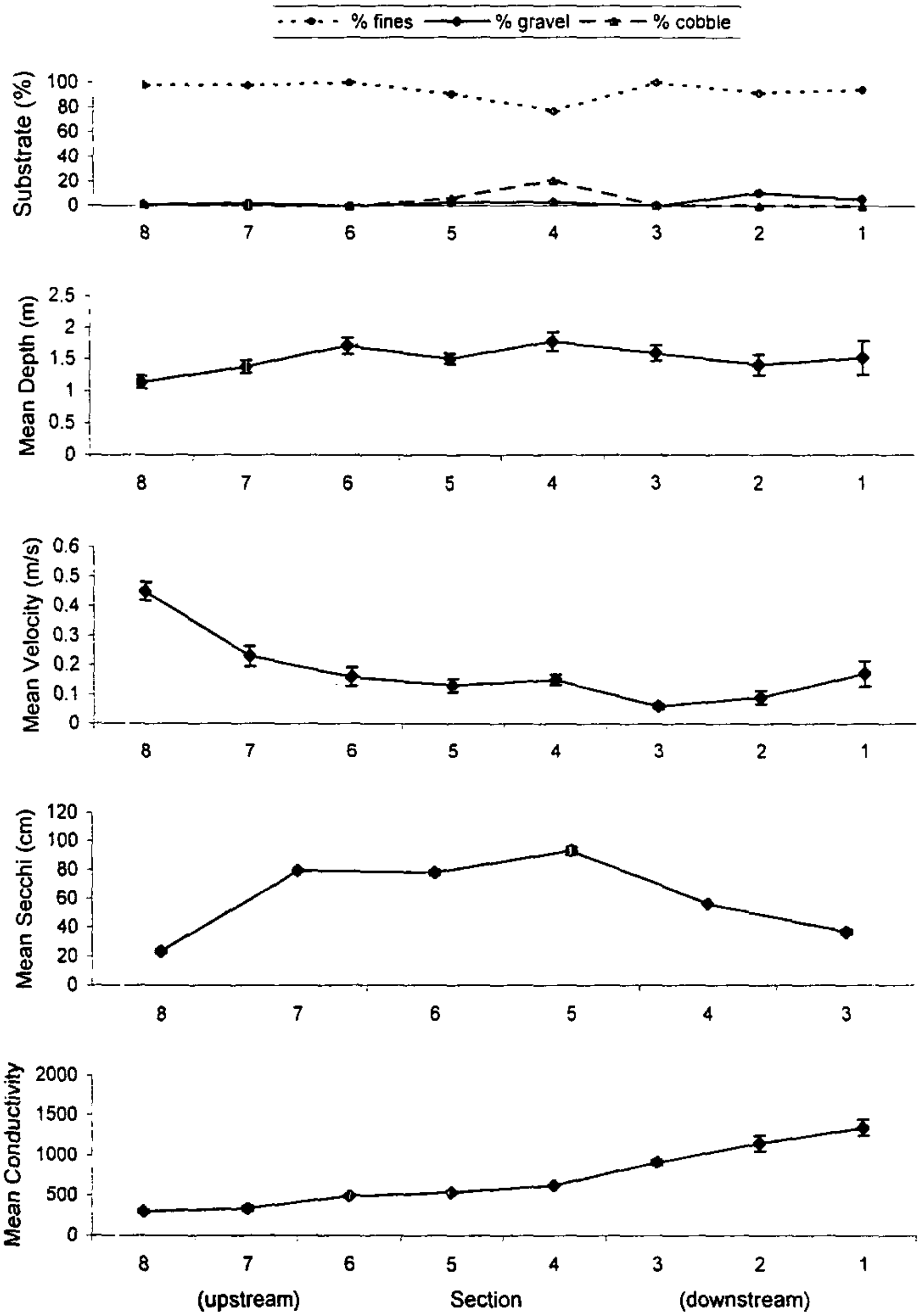

Figure 10. Longitudinal profile of mean habitat characteristics (± 1 SE) for Outside Bend macrohabitats in the Milk River, Montana.

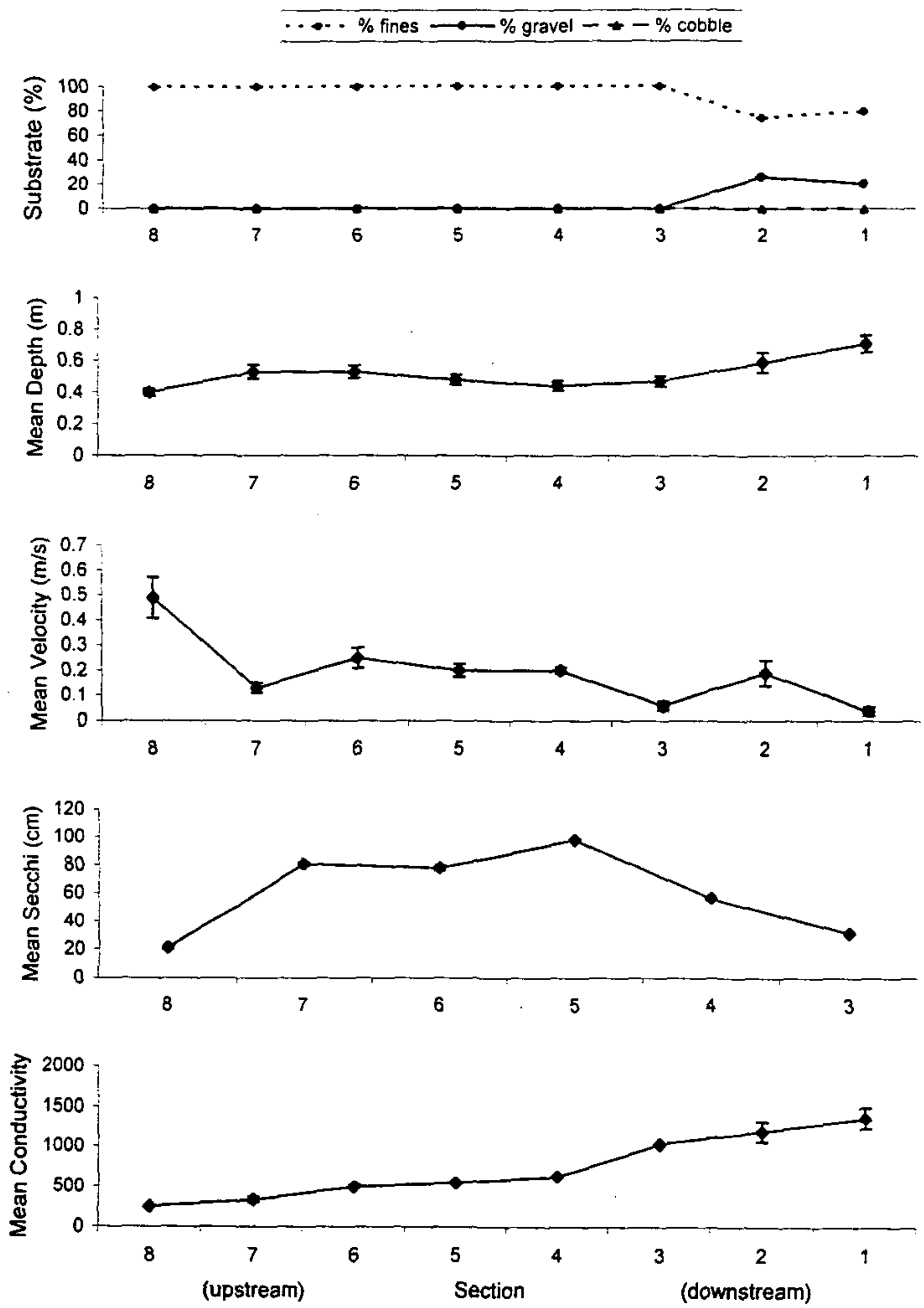

Figure 11. Longitudinal profile of mean habitat characteristics (± 1 SE) for Inside Bend macrohabitats in the Milk River, Montana.

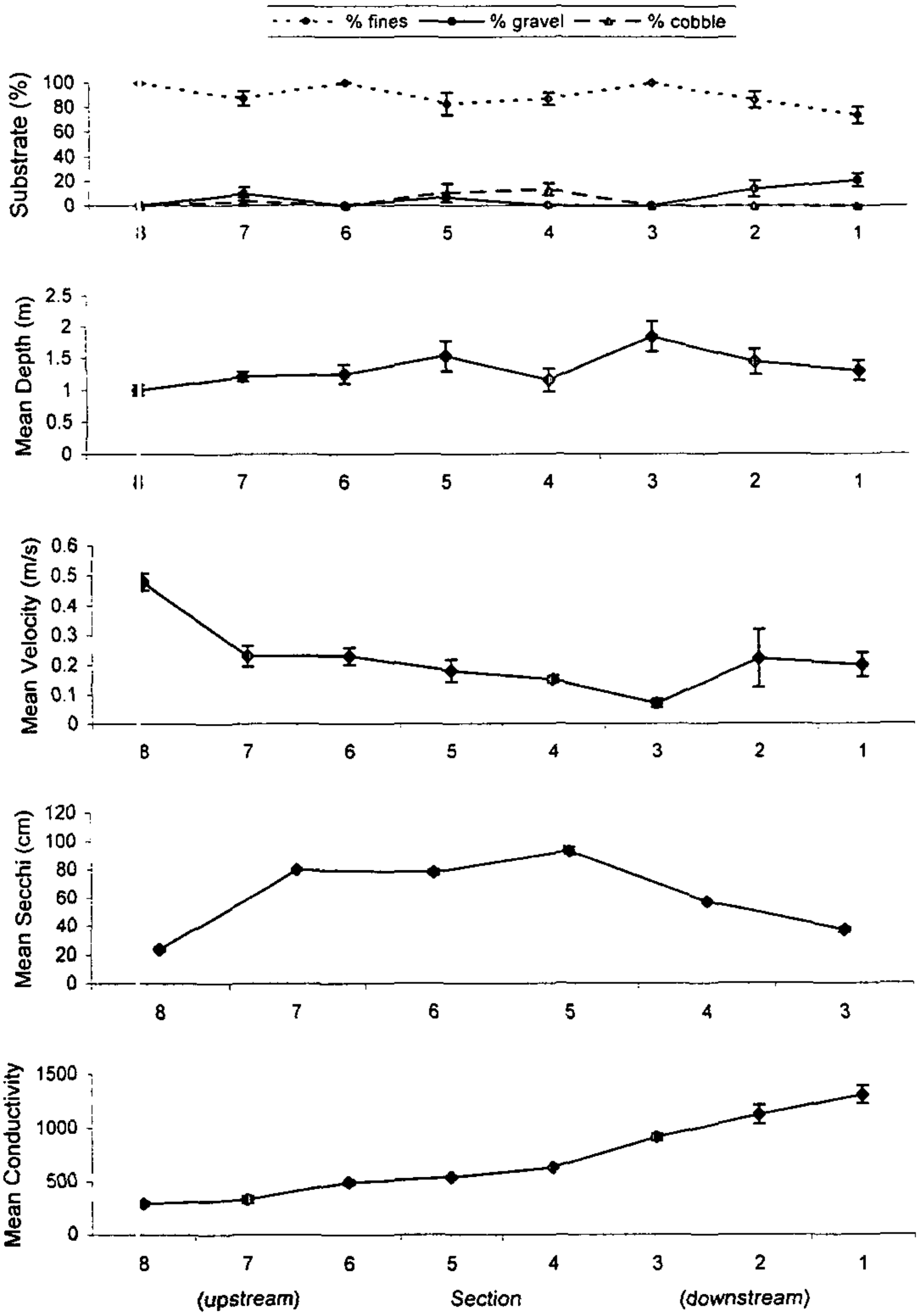

Figure 12. Longitudinal profile of mean habitat characteristics (± 1 SE) for Channel Crossover macrohabitats in the Milk River, Montana.

Mean velocities in Outside Bends, Inside Bends, and Channel Crossovers tended to decrease down the gradient to as far as section 3 and then increase slightly in sections 2 and 1 (Figures 10, 11, and 12). Similar to mean depths, most significant differences occurred between the quicker water velocities of section 8 and the velocities from sections 1 through 7. For Outside Bends, mean velocity was greatest for section 8 (0.45 m/s $\pm$ SE 0.03) which differed significantly ($P < 0.001$) from Outside Bends of the seven downstream sections. Additionally, mean velocities from section 7 Outside Bends (0.23 m/s $\pm$ SE 0.03) differed significantly from those of sections 3 (0.06 m/s $\pm$ SE 0.01) and 2 (0.09 $\pm$ SE 0.02). Inside Bends also exhibited greatest mean velocities in section 8 (0.49 m/s $\pm$ SE 0.08) with significant differences ($P < .001$) resulting between this section and each of the lower sections (1 – 7). Mean velocities of Inside Bends from section 1 (0.04 m/s $\pm$ SE 0.02) and section 6 (0.25 m/s $\pm$ SE 0.04) were the only other significantly different velocities. Mean water velocities for Channel Crossovers were greatest in section 8 (0.48 m/s $\pm$ SE 0.03) with the only significant differences ($P < 0.001$) occurring between this section and each of the lower seven sections. While Tailwater Zones exhibited a more erratic pattern in mean velocities, no significant differences occurred between sections (Figure 9).

Turbidity did not differ significantly between macrohabitats within a section. Therefore, comparisons were made between each of the study sections (3 – 8) along the gradient. Turbidity decreased from section 8 to section 5 and then increased in sections 4 and 3, respectively (Figures 10, 11, and 12). Mean turbidity in section 8 was 23.2 cm $\pm$ SE 0.77, significantly less ($P < 0.001$) than in sections 3 – 7. The only section comparisons that were not significant were between section 7 (mean 81.5 cm ± SE 1.42) and sections 5 (mean 79.7 cm ± SE 1.93) and 5 (mean 91.3 cm ± SE 2.14).

In Channel Crossover macrohabitats, the smallest mean percentage of fines was 73.8% (± SE 6.57) in section 1. This was significantly different ($P < 0.001$) from Channel Crossovers in sections 3 (100%), 6 (100%), and 8 (99.8%). Section 1 had the greatest mean percentage of gravel (21.3% ± SE 5.41) for Channel Crossovers and was significantly different ($P < 0.001$) from sections 3, 4, and 6, where no gravel was found, and section 8 (0.20%). Percent cobble composition in Channel Crossovers was greatest in section 4 (13.2% ± SE 5.09). This value differed significantly ($P < 0.001$) from those of sections 1, 2, 3, 6, and 8, where no cobble was recorded.

Fines dominated Inside Bend macrohabitats as well. In sections 3 – 8, substrate composition was 100% fines. This differed significantly ($P < 0.001$) from sections 1 (79.4% ± SE 11.3) and 2 (74.1% ± SE 10.9). Gravel composition for Inside Bends was greatest in section 2 (25.9% ± SE 10.9) followed by section 1 (20.6% ± SE 11.3). No cobble substrate was recorded for Inside Bends.

The mean percentage of fines in Outside Bends was greater than 90% for all sections except section 4 (76.7% ± SE 4.10). This value differed significantly ($P < 0.001$) from all others. Gravel composition did not differ significantly ($P \leq 0.139$) between sections. Mean cobble composition of Outside Bends was greatest in section 4 (20.4% ± SE 3.41), differing significantly ($P < 0.001$) from all other sections.

Principal Components Analysis

The first two principal components accounted for a combined 45% of the variation in fish assemblage structure in the Milk River. Based on site scores from the principal components analysis of the species-by-site data matrix, the first axis (PC 1) reflects changes in community structure primarily due to location along the stream gradient. All sites from sections 1 and 2 received positive scores along this axis. Sites in section 3 weighted fairly evenly and sites from upstream sections 4 – 8 had negative scores along the axis (Figure 13).

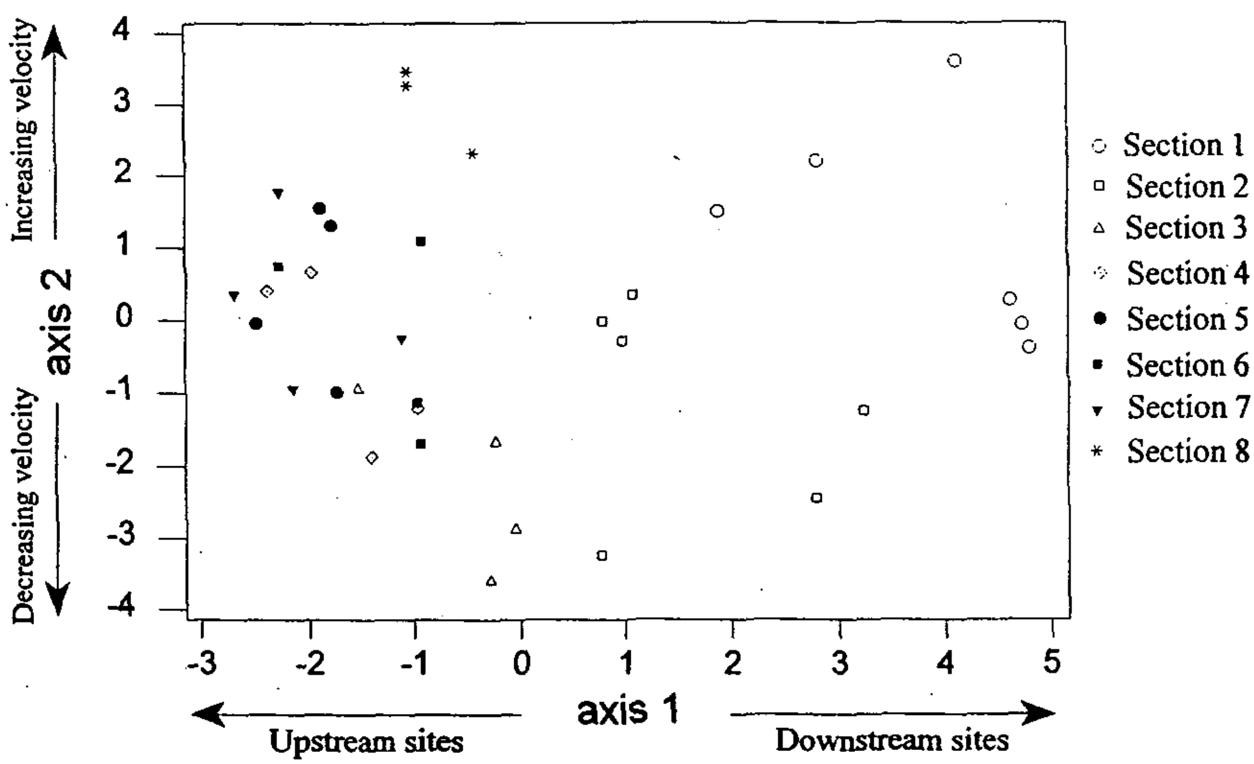

Figure 13. Principal component ordination on the first two principal components of sample sites from sections 1 – 8 of the Milk River, Montana.

Component loadings for the first axis, which indicate the relative importance of each variable (species abundance), contrasted species common to the lower study sections (positive scores) with those more common in the upper reaches (negative scores) (Table 5). This is reflected by the numerical dominance of species found exclusively or predominately in these lower two sections including goldeye (+ 0.40), channel catfish (+ 0.39), river carpsucker (+ 0.38), shorthead redhorse (+ 0.38), emerald shiner (+ 0.22), *Hybognathus* spp. (+ 0.18), and shovelnose sturgeon (+ 0.17). Species strongly associated with the upper reaches included longnose sucker (- 0.30), white sucker (-0.22), spottail shiner (- 0.21), yellow perch (- 0.17), and flathead chub (- 0.17). The remaining seven species from PC 1 are taxa with component loadings closer to a value of zero, indicative of a fairly even distribution throughout the eight sections or greater relative abundances in the middle reaches.

Interpretation of the second axis (PC 2) was aided by calculating Pearson's correlations between the first two principal components and percent coarse substrate (gravel and cobble), mean water depth, mean water velocity, total species richness, and total number of individuals (Table 6). Principal component 2 was strongly and positively correlated ($r = 0.62$, $P < 0.001$) to mean water velocity as well as moderately and positively correlated ($r = 0.42$, $P < 0.05$) with total number of individuals. Therefore, this suggests that positive site scores on the second axis (PC 2) indicate sample sites with faster water velocities while larger positive component loadings on the fish species (Table 5) are indicative of taxa commonly collected in relatively faster water.

Table 5. Principal component loadings defining the first two principal components of the data set based on the octave transformed species abundances.

Species	PC 1	PC 2
Common carp	0.112	-0.408
Channel catfish	0.394	0.008
Emerald shiner	0.216	-0.131
Flathead chub	-0.171	0.349
Fathead minnow	-0.076	0.030
Goldeye	0.396	0.063
Hybognathus spp.	0.178	0.272
Longnose dace	-0.146	0.127
Longnose sucker	-0.301	0.129
Northern pike	-0.114	-0.388
River carpsucker	0.380	0.047
Sauger	-0.021	0.295
Shorthead redhorse	0.376	0.020
Shovelnose sturgeon	0.167	0.220
Stonecat	0.012	0.296
Spottail shiner	-0.210	0.103
Walleye	0.033	-0.321
White sucker	-0.217	0.036
Yellow perch	-0.174	-0.304
Eigenvalue	5.17	3.31
Percent of variance	27.2	17.4
Cumulative percent	27.2	44.6

Table 6. Correlations between the first two principal components, percent coarse substrate, mean depth, mean velocity, total species richness, and total number of individuals for study sections 1 – 8 of the Milk River, Montana, 1999 and 2000. Significance levels are indicated as ns for P > 0.05, * for P < 0.05, and ** for P < 0.01.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) PC I	---	ns	ns	ns	ns	ns	ns
(2) PC II	.00	---	ns	ns	**	ns	*
(3) % Coarse Substrate	.01	.19	---	ns	ns	**	**
(4) Depth	.04	-.29	.02	---	ns	ns	ns
(5) Velocity	-.02	.62	.33	-.21	---	ns	*
(6) Total number of species	.32	.21	.77	.10	.17	---	**
(7) Total number of individuals	.28	.42	.61	-.10	.49	.59	---

All of the sampling sites representing section 8 and the majority of sampling sites representing section 1 were located on the positive side of axis 2 (Figure 13). As mentioned previously, section 8 had the greatest mean water velocity (0.47 m/s) of all sections while section 1 (0.26 m/s) had the second greatest mean water velocity. Conversely, all sampling sites representing section 3 are located on the negative side of axis 2. Section 3 had the lowest mean water velocity of all sections with a value of 0.08 m/s.

Flathead chub (+ 0.35), stonecat (+ 0.30), sauger (+ 0.30), *Hybognathus* spp. (+ 0.27), and shovelnose sturgeon (+ 0.22) were moderately weighted on the positive scale of axis 2 (faster water velocities) (Table 5 (PC 2)). Indeed, these species were more commonly collected in macrohabitats with faster mean water velocities. Stonecat, sauger, and shovelnose sturgeon collections were numerically dominant in Riffle macrohabitats (Table 3), which had the greatest mean water velocity (0.57 m/s) of all macrohabitats. Flathead chub and *Hybognathus* spp. collections were numerically dominant in Inside Bends (Table 3),which had the second greatest mean velocity (0.25 m/s).

Common carp (- 0.41), northern pike (- 0.39), walleye (- 0.32), and yellow perch (- 0.30) had the greatest negative loadings from PC 2 indicating greater abundances in slower waters. While most carp were collected from Outside Bend macrohabitats (Table 3), which had the third lowest mean water velocity (0.20 m/s), northern pike, walleye, and yellow perch abundance was greatest in Tailwater Zone macrohabitats (Table 3) which had the second lowest mean velocity (0.18 m/s).

Additional Collection Efforts

In addition to our standardized sampling protocol, supplemental collection efforts were conducted during the 1999 and 2000 season. These efforts consisted of fishing a gill net across the entire width of the river and bag seining in the Tailwater Zone of section 1. Because these techniques were not part of our study design, the data collected was not included in any of the totals or data analysis performed for this study. However, because a large number of fish were captured, we felt it should be noted.

The reservoir behind Vandalia Diversion Dam was drawn down after the irrigation season to perform repairs on the dam during each year of our study. This caused severe siltation in the Tailwater Zone directly below the dam and significantly decreased the mean depth of this macrohabitat. Maximum depth was approximately 0.7 m.

Because these conditions caused difficulties with our standardized sampling techniques for Tailwater Zone macrohabitats, bag seining was used to collect fish. In September 2000, 2,288 fish were captured in two seine hauls at this location. These fish consisted primarily of *Hybognathus* spp. (2,044), emerald shiner (120), and young of the year smallmouth buffalo and channel catfish. In addition, a significant fish kill was observed at the time of the sampling. Hundreds of dead fish were counted including common carp, freshwater drum, goldeye, shorthead redhorse, smallmouth bass, walleye, channel catfish, northern pike, and smallmouth buffalo.

A mark-recapture project, as well as genetic screening, was also conducted during the course of this study. A total of 982 fish were tagged in sections 1 and 2. A list identifying these fish and their capture location can be obtained from the Montana Fish, Wildlife and Parks office in Fort Peck, Montana. Additionally, tissue samples were taken from sauger collected during the primary study. Four of the 52 sauger tissue samples indicated hybridization with walleye. A complete report of this electrophoretic screening can be obtained from the Montana Fish, Wildlife and Parks office in Fort Peck, Montana.

DISCUSSION

Unregulated rivers of the Great Plains region are typically dynamic systems with low gradients, highly fluctuating flows, high turbidities, multiple channels, and unstable bottoms consisting of sand and silt (Cross and Moss 1987; Berry et al. 1996; Hubert 1996). The construction of dams and reservoirs can dramatically change the physical characteristics of these rivers, reducing natural biodiversity and production by obstructing ecological connectivity between upstream and downstream reaches (Gehrke et al. 1995; Hesse et al. 1996; Stanford et al. 1996).

Agriculture dominates the Milk River watershed, and land use practices, as well as water resource management, have undoubtedly affected the native fish community by adding silt and nutrients, altering stream flow patterns, and blocking upstream fish movement with dams. Densities and distribution of the native fish species have likely been altered since the first permanent structure, Dodson Diversion Dam, was built in 1910.

The Milk River fish community is one of the least studied assemblages in Montana. The most extensive investigation was performed by Montana Fish, Wildlife, and Parks personnel who sampled Milk River fishes from the eastern international border downstream to the confluence with the Missouri River in 1986 (Needham and Gilge 1987). This report included a compilation of all past records of fish collections in the Milk River in addition to the 1986 collections. Previous data was located and summarized exclusively from Montana Fish, Wildlife and Parks department files.

Whereas the primary purpose of their study was to provide an index of species richness, sampling techniques were not standardized; consequently, relative abundance and habitat associations were not estimated. Alvord (1955) cataloged the waters of the Milk River Project area; however, information on the fish community was vague and mostly based on reports from anglers.

Altered Hydrograph

Flow regulation probably has the greatest interactive effects on a stream fish community. Hydrology has a significant influence on the temporal and spatial stability of habitat characteristics within a lotic ecosystem, which in turn has a significant influence on the fish community structure (Schlosser 1985; Bain et al. 1988; Bramblett and Fausch 1991; Braaten and Berry 1997). Within a stream, features such as channel morphology, floodplain connectivity, and instream structure are created and maintained by a wide range of flows (Stanford et al. 1996; Poff et al. 1997). It has been suggested that standing stock abundances can decline by as much as 98% when floodplain and main channel connectivity are severed (Karr and Schlosser 1978).

Because the Milk River is a highly regulated system, it rarely experiences extreme seasonal variation in discharge (Figure 14). The unregulated Powder River, with a similar sized drainage basin, has two discharge spikes in the spring and early summer as well as another smaller spike in the late fall (Figure 14). The regulated Milk River hydrograph exhibits a small spike in the spring followed by a higher sustained discharge during the irrigation season (mid May through mid October) and then flows decline to 0.7 – 1.2 m^3/s (25 – 40 cfs) during fall and winter.

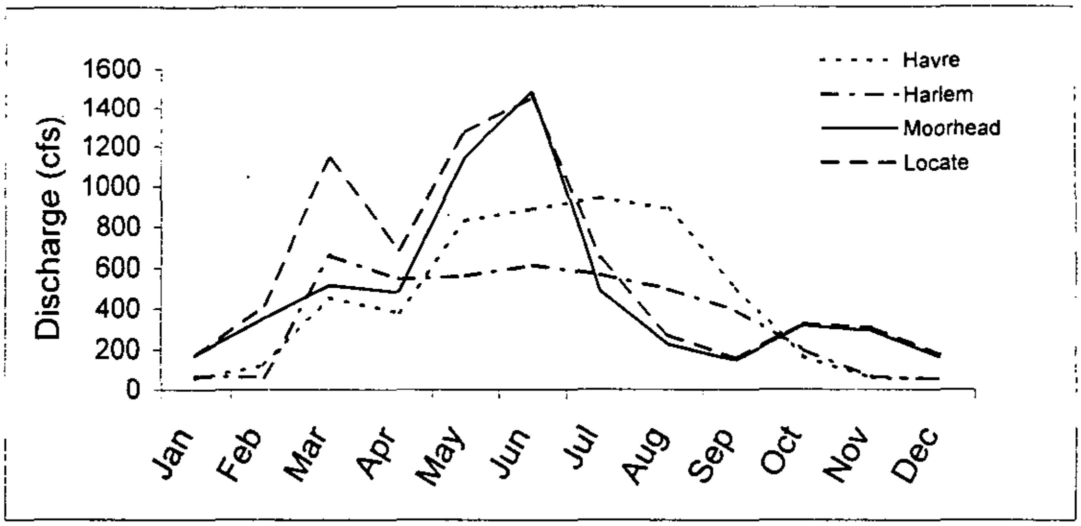

Figure 14. Seasonal discharge comparisons of the regulated Milk River, MT (Havre and Harlem), and the unregulated Powder River, MT (Moorhead and Locate). Values are based on the monthly means for the period of 1989 – 1999.

Whereas the Havre gauging station (section 6, river km 670.4) and the Harlem gauging station (section 3, river km 532.8) on the Milk River do not exhibit pronounced natural seasonal fluctuations in discharge, the Juneberg gauge (section 2, river km 243.2) and the Nashua gauge (section 1, river km 36.8) on the Milk River reveal distinct spikes of discharge in early spring (Figure 2). These spikes occur as the result of spring run-off transported to the Milk through several significant tributaries including Beaver Creek, Frenchman Creek, and Rock Creek (section 2), and Porcupine Creek (section 1) (Figure 1).

By altering the discharge in the Milk River and reducing seasonal variation, dams may be desynchronizing environmental cycles and thus reproductive cycles of the native fish. Many of these fish rely on seasonal peaks in discharge, especially in the spring, as a cue to initiate reproductive behavior. Increasing departure from the natural discharge regime reduces the reproductive success and recruitment of native species (Stanford et al. 1996), while the establishment and proliferation of nonnative species whose reproductive cycles are not cued by seasonal discharge cycles are favored (Li et al. 1987).

The distribution of native and nonnative species in the Milk River closely follows this association (Figures 5 and 6). While section 8 is influenced by diversions from the St. Mary's Canal, it remains the least regulated section in the study area and harbors the lowest percentage of nonnative species as well as the lowest numbers of nonnative fish. Abundance of nonnative fish increases significantly below Fresno Reservoir in the highly regulated sections 2 – 7. Section 1, while still highly regulated, deviates from these trends, likely due to greater seasonal discharge amplitude and connectivity with the Missouri River and its native migratory species. Most shovelnose sturgeon were captured several days after a large pulse of water moved through this section in the spring of 1999.

Physical Habitat Variables

The physical habitat characteristics of lotic ecosystems are important factors influencing fish community composition (Gorman and Karr 1978; Schlosser 1982; Moyle and Vondracek 1985; Bain et al. 1988; Aadland 1993). Water depth, water velocity, and substrate composition are some of the more important variables defining the distribution, abundance, and richness of these fish assemblages. Based on the River Continuum

Concept (Vannote et al. 1980) for unregulated streams, predicted downstream longitudinal changes of these habitat variables include increased depth, increased flow velocity, and a decrease in substrate size. Overall, this contributes to increased habitat complexity of downstream reaches that often results in more complex trophic structure and species richness (Schlosser 1982; Degerman and Sers 1992; Patton and Hubert 1993).

While the River Continuum Concept integrates physical changes from headwaters to the mouths of streams, our study area focused on a segment of the Milk River well downstream of its headwaters in the mountains and foothills of the northern Rocky Mountains. However, because our study area encompassed the lower 784 km of the river, we would anticipate seeing gradual changes in depth, velocity, and substrate composition.

Depth of Outside Bends, Inside Bends, and Channel Crossovers gradually increased in a downstream direction (Figures 10, 11, and 12). Tailwater Zone macrohabitats decreased in depth along the gradient (Figure 9). While the first three macrohabitats occur naturally and tend to follow expected trends along the longitudinal gradient, Tailwater Zones result from man-made altercations to the continuity of the river. The decrease in depth of this macrohabitat along the gradient may be related to decreased water volume at each consecutive downstream dam due to cumulative water withdrawals. Smaller volumes of water will be less erosive to macrohabitats directly below dams. However, depth was not significantly correlated to either total number of species or total number of fish in the Milk River (Table 6).

Water velocity in Outside Bends, Inside Bends, and Channel Crossovers decreased in a downstream direction (Figures 10, 11, and 12); opposite of expectations for longitudinal patterns in unregulated lotic environments (Townsend 1980). Again, the multitude of upstream water withdrawals and insignificant tributary influence after spring runoff may leave less water to affect velocities in the downstream reaches of the Milk River. Velocity was not correlated with total number of fish species but was correlated with number of individuals ($r = 0.49$, $P < 0.05$) (Table 6).

While it is not unusual for a prairie stream's substrate to be composed primarily of fines (sand and silt), there was an increase of coarse substrate in Outside Bend, Inside Bend, and Channel Crossover macrohabitats in downstream sections 1 and 2 of the Milk River (Figures 10, 11, and 12). It is apparent that these sections experience a significantly greater discharge than the other study sections in the early spring (Figure 2). These discharges may be great enough to more effectively carry sand and silt downstream and leave a greater amount of coarse substrate exposed.

Substrate composition in Tailwater Zone habitats was a more heterogeneous mix of fines and coarse material compared to other habitat types (Figure 9). While the coarse substrate in this macrohabitat is largely unnatural, it appears to provide a unique and beneficial habitat to many fish species. For species requiring coarse substrate to spawn or for cover, Tailwater Zones are one of the few places in the river that will meet their needs. The percentage of coarse substrate had the strongest positive correlation with total number of species ($r = 0.79$, $P < 0.001$) and total number of individuals ($r = 0.61$, $P < 0.001$) (Table 6).

Water Temperature

Fresno Reservoir is the only significant impoundment on the main stem of the Milk River and it is not particularly large. The reservoir had an original capacity of 129,062 acre/ft but a sediment survey from 1999 revealed a current capacity of 93,000 acre/ft (S. Guenthner, BOR, Billings, personal communication). Releases from Fresno Dam are cool enough to sustain a put-and-take rainbow trout and brown trout fishery that is restricted to the first 500 m downstream. Only two brown trout were located elsewhere on the river. No young of the year trout were collected in the 2 years of sampling indicating that spawning and recruitment success of these species is doubtful.

Because Fresno Reservoir and the other major water storage reservoirs associated with the Milk River system allow for greater flows during the warmer summer months, water temperatures are probably cooler than would occur naturally if dams were not present on the Milk River. This would tend to benefit nonnative taxa that may not tolerate higher temperature extremes. However, every species collected in the cooler Fresno tailwater, except rainbow trout, was collected at other locations throughout the study area.

Macrohabitats

Before European settlers discovered the Milk River Basin in the mid 1800's, the Milk River, as with other unregulated prairie streams, undoubtedly controlled its own character as a dynamic system. As dams were constructed on the Milk River, the characteristics of the downstream channel morphology and macrohabitats were altered. In other regulated prairie rivers (Cross and Moss 1987; Patton and Hubert 1993; Berry et al. 1996; Hesse et al. 1996), reservoirs act as sediment traps, dams reduce water velocities, and downstream reaches are often reduced from multiple, braided channels to a single incised channel. In addition, side channels, islands, and backwaters can be significantly reduced or completely eliminated.

Our findings on the Milk River are consistent with these observations. The channel characteristics associated with section 8, which is above Fresno Reservoir and remains unaltered from the effects of dams, feature a moderate flood plain with a poorly developed riparian zone, high turbidity, shifting sand and silt substrate, and moderate channel braiding. Riffles with coarse substrates were not located in this study section.

As the river becomes regulated below Fresno Reservoir, sections 3 - 7 acquire the characteristics of a single incised channel with a moderately developed riparian zone. Side channel and backwater macrohabitats are rare. Instream structure, while still very limited, exists in the form of downed cottonwoods or old automobiles once used as bank stabilization. Tributaries are present in these sections; however, they are highly seasonal and their contribution to the fish community was not investigated.

Contrary to many regulated systems, reaches between each of the dams do not appear to be sediment starved, as downstream riffles created by coarse substrates were not located. However, these reaches are incised and due to the geology of the area, there may be little or no rock underlying the sand and silt substrate. Other than the Tailwater Zone, sand and silt dominate the substrate composition.

Sections 1 and 2, the downstream-most sections, appear to yield greater macrohabitat heterogeneity. While still a predominately single incised channel, riffles created by coarse substrates are more common and tributaries with perennial flows add to the diversity of macrohabitats available to the fish community. This increased habitat diversity appears to be significant to the fish community in the Milk River.

The possible loss of backwater and side channel macrohabitats due to flow regulation below Fresno Reservoir could be negatively impacting the fish community in the Milk River. However, it is not known if these macrohabitats existed before regulation. O'Shea et al. (1990) and Patton and Hubert (1993) report that backwater macrohabitats had greater species richness and diversity compared to side channel and main channel macrohabitats. Backwaters provide an area off the main channel where species can rest, escape predation, spawn, and rear. Further, studies by Schlosser (1987), Lobb and Orth (1991), and Patton and Hubert (1993) suggest that side channels are also important to smaller warmwater stream fishes.

Instream Barriers

Fresno Dam, Havre Water Weir, and four of the five irrigation diversion dams are constructed in a way that prevents further upstream migration of the fishes in the Milk River. These structures range in height from 5 m to 33.6 m and are not equipped with any type of fish passage facilities. The fifth diversion structure, Fort Belknap Diversion Dam located near Lohman, Montana (river km 628.8), may permit passage during extremely high flows. By severing the continuity of the Milk River, these structures can potentially create fragmented fish communities and greatly increase the risk of local extinctions without the possibility of natural recolonization. However, because fish can pass over these structures in a downstream direction, recruitment from upstream sites is possible.

The possibility of fragmented fish communities occurred primarily between sections bounded by barriers and those permitting greater unrestricted movement (adjacent sections 1 and 2 and adjacent sections 7 and 8), whereas adjacent sections that are bounded by dams at both the upstream and downstream demarcation had the greatest similarities in the study area. The most probable explanation for the low similarity value between sections 8 and 7 is species richness. The significant increase in species richness in section 7 is due to nonnative species found downstream of Fresno Reservoir that were not collected above the reservoir. These two sections had the lowest similarity value and the greatest difference in species richness between all pairs of adjacent sections in the study area.

A structural barrier does not exist above Fresno Reservoir in section 8. However, only two nonnative species (northern pike and spottail shiner) were collected in section 8 in 2 years of sampling. Rainbow trout, brown trout, black crappie, kokanee, yellow perch, emerald shiner, smallmouth bass, largemouth bass, spottail shiner, and walleye have been stocked in Fresno Reservoir since 1946 (K. Gilge, MFWP, Havre, personal communication). Only the emerald shiner is native to the system. Because walleye, northern pike, and yellow perch are primarily sight feeders and were numerically dominant at sites with slower water velocities, the higher turbidity and faster water velocities of section 8 may be acting as a barrier to upstream colonization by these nonnative taxa.

Differences between sections 1 and 2 were subtler. Section 1 (29 species) had only five more species than section 2 (24 species). However, eight species collected in section 1 were not collected in section 2 and three species found in section 2 were not collected in section 1. Also contributing to the distinction between the two sections were the abundances of the most numerous species from each section. Shovelnose sturgeon (n = 438) was the most commonly captured species in section 1. No shovelnose sturgeon were captured in section 2. Spottail shiner was the most abundant species collected in section 2 (n = 1434) while only 14 spottail shiners were captured in section 1.

Vandalia Diversion Dam, the first structural barrier upstream from the confluence with the Missouri River, had an important influence on the fish community. Three migratory species from the Missouri River, blue sucker, paddlefish, and shovelnose sturgeon, were captured exclusively in section 1. Additionally, bigmouth buffalo, channel catfish, freshwater drum, goldeye, river carpsucker, shorthead redhorse, and smallmouth buffalo were captured only in sections 1 and 2. However, the numbers of fish captured in section 1 for each of these species, except shorthead redhorse and smallmouth buffalo, were far greater than the numbers captured in section 2 (Table 2). This may suggest that these taxa are primarily migratory species from the Missouri River with much smaller, isolated populations above Vandalia Diversion Dam. The numbers of shorthead redhorse and smallmouth buffalo were fairly even between the two sections.

Fish Community Assessment

Even though the Milk River has numerous physical barriers that prevent upstream fish passage, longitudinal distribution was characterized by the addition of species rather than species replacement. Upstream fish passage barriers such as low-head dams are rarely barriers to downstream fish movements. The gradual downstream increase of warmwater species in our study, except in section 3, probably reflects downstream movement as well as a trend of increased macrohabitat diversity and moderated environmental conditions in a downstream direction. Similar patterns have been reported by Gorman and Karr (1978), Evans and Noble (1979), Schlosser (1982), and Barfoot and White (1999). The aberration in section 3 was likely due to sampling bias. The depth and substrate characteristics made seining inefficient, increased depth (mean of 1.47m was greater than all other sections) may have reduced electrofishing efficiency, and reduced water velocities (mean of 0.08m/s was less than all other sections) may have hindered effectiveness of hoop nets, which rely on water velocity to deploy properly.

Changes in the fish community will be difficult to compare. Comparisons of our data with those of a 1986 study (Needham and Gilge 1987) shows that both studies found fish communities typical of prairie streams of this general latitude as described by Rahel and Hubert (1991). The majority of fish belonged to either the minnow (Cyprinidae) or sucker (Catostomidae) families. In 1986, 34 species were collected, 10 of them nonnative. In 1999 and 2000 we collected all of these and an additional 7 species. This may be attributed to the differences in sampling techniques and timing or it may involve an actual increase or decrease in species relative abundance. Distribution of sauger and burbot was more restricted in our study. This could be due to sampling bias or population decline. Sampling bias seems unlikely since our sampling efforts were more intensive and we used a greater variety of gears than the 1986 study.

One evident alteration to the Milk River fish assemblage from pre-dam conditions is the introduction of nonnative species, primarily as a result of stocking efforts occurring in Fresno Reservoir. Most introduced fishes have some undesirable effect on native fish assemblages. Impacts can include habitat use alterations of native species, introduction and spread of diseases and parasites, hybridization with native species, trophic alterations, and spatial distribution modifications (Taylor et al. 1984). However, the degree to which nonnative species affects the native fish community depends greatly on the physical harshness of the environment to which they were introduced (Peckarsky 1983; Bramblett and Fausch 1991; Pearsons et al. 1992). Minckly and Meffe (1987) suggest that native species in unregulated streams can withstand natural physical extremes of the lotic ecosystem much better than introduced species. Conversely, when a dynamic lotic environment is regulated, the moderated conditions often result in the proliferation of introduced species (Holden 1979; Minckly and Meffe 1987; Allan 1995). Because the native fish community is currently subjected to flow regulation and the presence of nonnative species, it appears that a complex of both physical and biological processes are acting to structure the fish assemblage in the Milk River.

Project Limitations

Attempts were made to standardize the sampling effort between each of the sections during this study. However, because two independent crews were sampling two different areas of the river, some variation in effort occurred. Sampling gears also added bias to this study. Whereas several types of gear are needed to best sample a variety of macrohabitats, each gear is biased to the size of the fish it will capture and its efficiency depending on the macrohabitat where it is used. To increase the efficiency of our sampling efforts, the same types of gear were not always used in each of the different macrohabitats. Therefore, we cannot be certain that the fish assemblage described for each macrohabitat is completely representative.

CONCLUSION AND MANAGEMENT IMPLICATIONS

Over time, the cumulative effects of regulated flows, impassible barriers, and numerous unscreened irrigation diversions have almost certainly altered distribution, abundance, species richness, and size structure of Milk River fishes. As the demand for water continues to increase, it is likely that further changes will occur.

To date, three Indian reservations and Canada have not claimed their full Milk River water rights. Because their water rights are senior, additional water claimed in the future would be at the cost of the junior water rights holders (farmers and municipalities). In light of this, several proposals have been made to increase storage and efficiency of water use. These include upgrading irrigation methods, enlarging Fresno Reservoir, building reservoirs on Milk River tributaries, and transferring water from the Missouri River.

The Milk River provides habitat for 28 fish species native to Montana, including four Montana Species of Special Concern and two species on the Montana Natural Heritage Program watch list. Future water development should take into account potential impacts on habitat needs and community structure of these Milk River fishes. Because of the fragmenting effect existing barriers have on the fish community, further perturbations could greatly increase the potential of local extinction without the possibility of natural recolonization.

Perhaps the Milk River's most important contribution to the area's fishery resource is its alliance with the Missouri River. While much of Missouri River has lost its ability to function as a natural lotic ecosystem (Hesse and Sheets 1993; Schmulbach and Braaten 1996), major tributaries such as the Milk River provide critical spawning and rearing habitat for migratory and resident fishes.

Our results provide evidence that the Milk River is important to the Missouri River fish community. Several native species of the Missouri River, including bigmouth buffalo, blue sucker, channel catfish, freshwater drum, goldeye, paddlefish, river carpsucker, sauger, shorthead redhorse, smallmouth buffalo, and shovelnose sturgeon move into the warmer, turbid waters of the Milk River to spawn and rear. Since several of these species have remnant populations above Vandalia Diversion Dam, necessary habitat conditions must occur there. Therefore, Vandalia Diversion Dam provides an excellent opportunity to develop a fish bypass system that would reconnect native species to an additional 251 km of potentially important habitat in the Milk River. Such a facility could revitalize the fish community structure and lead to the recovery of numerically depressed populations above Vandalia Diversion Dam. In addition, the use of screening technology on the numerous irrigation diversions would significantly decrease losses of Milk River fish, especially young of the year, during periods of substantial water withdrawals (May – October).

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APPENDIX A

SAMPLE LOCATIONS AND EFFORT

Table 7. Summary of sampling locations and effort for study sections 1 – 8 of the Milk River, Montana, 1999 and 2000.

Sect	Date	Location(GPS)	Macrohab[a]	Gear[b]	Duration(min)	Distance(m)
8	990929	NONE	CHXO	EF	10	300
8	990929	NONE	CHXO	EF	9	250
8	991011	48.58.38 110.25.26	CHXO	EF	4	100
8	000924	48.58.09 110.24.38	CHXO	EF	3.1	100
8	000924	48.57.99 110.24.22	CHXO	EF	4.3	100
8	000924	48.58.02 110.23.52	CHXO	EF	4.9	200
8	990923	48.59.16 110.25.76	CHXO	HOOP	1324	
8	990923	48.57.98 110.23.71	CHXO	HOOP	965	
8	990923	48.58.13 110.24.15	CHXO	HOOP	1004	
8	000923	48.58.76 110.25.21	CHXO	HOOP	1260	
8	000923	48.58.98 110.25.34	CHXO	HOOP	1210	
8	000923	48.58.90 110.25.90	CHXO	HOOP	1110	
8	990929	48.58.70 110.25.26	ISB	BS		10
8	000924	48.58.07 110.26.01	ISB	BS		20
8	990929	48.58.70 110.25.26	ISB	BS		10
8	000924	48.58.07 110.26.01	ISB	BS		20
8	990929	48.58.77 110.25.64	ISB	BS		40
8	000924	48.58.82 110.25.80	ISB	BS		20
8	990929	48.58.77 110.25.64	ISB	BS		20
8	000924	48.58.82 110.25.80	ISB	BS		20
8	990930	48.57.82 110.23.97	ISB	BS		20
8	000924	48.58.89 110.25.31	ISB	BS		20
8	990930	48.57.82 110.23.97	ISB	BS		20
8	000924	48.58.89 110.25.31	ISB	BS		20
8	990929	NONE	OSB	EF	8	250
8	990929	NONE	OSB	EF	9	300
8	991011	48.58.38 110.25.26	OSB	EF	7	200
8	000924	48.58.36 110.25.15	OSB	EF	6	200
8	000924	48.58.02 110.23.44	OSB	EF	3.2	100
8	000924	48.57.69 110.23.34	OSB	EF	3	175
8	990928	48.58.18 110.24.56	OSB	HOOP	1475	
8	990928	48.58.98 110.25.40	OSB	HOOP	1417	
8	990928	48.59.13 110.26.11	OSB	HOOP	1423	
8	000923	48.59.13 110.25.56	OSB	HOOP	1190	
8	000923	48.58.98 110.25.41	OSB	HOOP	1165	
8	000923	48.58.99 110.26.10	OSB	HOOP	1050	
8	991011	48.47.09 110.08.47	CHXO	EF	8	200
8	991011	48.47.36 110.08.55	CHXO	EF	8	200
8	991011	48.47.63 110.08.34	CHXO	EF	5	160
8	000920	48.47.58 110.08.32	CHXO	EF	4	100
8	000920	48.47.45 110.08.50	CHXO	EF	7.6	175

Table 7. Continued

Sect	Date	Location(GPS)	Macrohab[a]	Gear[b]	Duration(min)	Distance(m)
8	000920	48.47.02 110.08.48	CHXO	EF	3.8	80
8	991001	48.49.03 110.08.83	CHXO	HOOP	1126	
8	991001	48.48.16 110.08.10	CHXO	HOOP	1128	
8	000920	48.48.75 110.08.28	CHXO	HOOP	3000	
8	000920	48.48.51 110.08.27	CHXO	HOOP	3005	
8	000920	48.48.88 110.08.41	CHXO	HOOP	2959	
8	990930	48.49.01 110.08.75	ISB	BS		25
8	000920	48.49.04 110.08.82	ISB	BS		20
8	990930	48.49.01 110.08.75	ISB	BS		25
8	000920	48.49.04 110.08.82	ISB	BS		20
8	990930	48.48.35 110.08.44	ISB	BS		25
8	000920	48.48.73 110.08.27	ISB	BS		20
8	990930	48.48.35 110.08.44	ISB	BS		25
8	000920	48.48.73 110.08.27	ISB	BS		20
8	990930	48.47.36 110.08.58	ISB	BS		25
8	000920	48.48.38 110.08.44	ISB	BS		20
8	990930	48.47.36 110.08.58	ISB	BS		15
8	000920	48.48.38 110.08.44	ISB	BS		20
8	991011	48.47.27 110.08.60	OSB	EF	10	300
8	991011	48.47.51 110.08.43	OSB	EF	5	150
8	991011	48.47.63 110.08.19	OSB	EF	6	200
8	000920	48.47.70 110.08.06	OSB	EF	6.7	175
8	000920	48.47.24 110.08.58	OSB	EF	3.7	175
8	000920	48.46.88 110.08.27	OSB	EF	3.9	175
8	990930	48.47.40 110.08.52	OSB	HOOP	1047	
8	991001	48.48.50 110.08.27	OSB	HOOP	1123	
8	000920	48.48.75 110.08.26	OSB	HOOP	3009	
8	000920	48.49.08 110.08.92	OSB	HOOP	2935	
8	000920	48.49.24 110.08.88	OSB	HOOP	2920	
7	991012	NONE	CHXO	EF	9	20
7	991012	NONE	CHXO	EF	9	150
7	991012	48.34.33 109.45.21	CHXO	EF	9	300
7	000927	NONE	CHXO	EF	2	50
7	000927	48.35.74 109.56.04	CHXO	EF	1.8	50
7	000927	48.35.85 109.55.51	CHXO	EF	2.7	60
7	991012	48.34.28 109.46.00	CHXO	HOOP	1245	
7	991012	48.34.78 109.46.25	CHXO	HOOP	1256	
7	991012	48.34.59 109.46.00	CHXO	HOOP	1252	
7	000927	48.35.81 109.55.83	CHXO	HOOP	1310	
7	000927	48.35.96 109.56.15	CHXO	HOOP	1435	
7	000927	48.35.96 109.56.22	CHXO	HOOP	1395	
7	991013	48.34.51 109.45.25	ISB	BS		25

Table 7. Continued.

Sect	Date	Location(GPS)	Macrohab[a]	Gear[b]	Duration(min)	Distance(m)
7	000928	48.35.72 109.55.68	ISB	BS		20
7	991013	48.34.51 109.45.25	ISB	BS		30
7	000928	48.35.72 109.55.68	ISB	BS		20
7	991013	48.34.39 109.45.37	ISB	BS		30
7	000928	48.35.80 109.55.77	ISB	BS		20
7	991013	48.34.39 109.45.37	ISB	BS		30
7	000928	48.35.80 109.55.77	ISB	BS		20
7	991013	48.34.37 109.46.22	ISB	BS		30
7	000928	48.35.88 109.55.84	ISB	BS		20
7	991013	48.34.37 109.46.22	ISB	BS		30
7	000928	48.35.88 109.55.84	ISB	BS		20
7	991012	NONE	OSB	EF	9	250
7	991012	48.34.22 109.45.09	OSB	EF	12	350
7	991012	48.34.47 109.45.13	OSB	EF	10	220
7	000927	48.35.83 109.55.82	OSB	EF	1.8	70
7	000927	48.35.81 109.54.88	OSB	EF	2.7	75
7	000927	48.35.90 109.55.69	OSB	EF	3.5	150
7	991012	48.34.41 109.46.03	OSB	HOOP	1249	
7	991012	48.34.85 109.45.80	OSB	HOOP	1258	
7	991012	48.34.38 109.46.33	OSB	HOOP	1258	
7	000927	48.35.90 109.55.83	OSB	HOOP	1300	
7	000927	48.35.73 109.55.64	OSB	HOOP	1320	
7	000927	48.35.67 109.56.05	OSB	HOOP	1345	
7	990401	48.35.99 109.56.30	TWZ	EF	12	
7	990401	48.35.99 109.56.30	TWZ	EF	20	
7	990423	48.35.99 109.56.30	TWZ	E-FISHPACK	7.1	
7	990509	48.35.99 109.56.30	TWZ	E-FISHPACK	7.6	
7	991018	48.29.25 109.56.30	TWZ	E-FISHPACK	12	60
7	000422	48.29.25 109.56.30	TWZ	E-FISHPACK	13.7	60
7	000505	48.29.25 109.56.30	TWZ	E-FISHPACK	5.1	60
7	000928	48.29.25 109.56.30	TWZ	E-FISHPACK	14.3	100
7	991018	48.29.25 109.56.30	TWZ	GN 100FT	1174	
7	000422	48.29.25 109.56.30	TWZ	GN 100FT	805	
7	000927	48.29.25 109.56.30	TWZ	GN 100FT	945	
7	990423	48.35.99 109.56.30	TWZ	TN		180 arc
7	990509	48.35.99 109.56.30	TWZ	TN		180 arc
6	991014	48.35.84 109.24.42	CHXO	EF	13	400
6	991014	48.35.83 109.25.13	CHXO	EF	6.5	220
6	991014	48.35.61 109.25.65	CHXO	EF	8	300
6	000923	48.35.76 109.25.34	CHXO	EF	3.5	100
6	000923	48.35.82 109.25.06	CHXO	EF	5.3	100
6	000923	48.35.85 109.24.80	CHXO	EF	3.5	125

Table 7. Continued.

Sect	Date	Location(GPS)		Macrohab[a]	Gear[b]	Duration(min)	Distance(m)
6	991013	48.36.11	109.24.35	CHXO	HOOP	1320	
6	991013	48.35.80	109.25.18	CHXO	HOOP	1270	
6	991013	48.35.66	109.25.77	CHXO	HOOP	1235	
6	000922	48.35.94	109.24.73	CHXO	HOOP	1380	
6	000922	48.35.93	109.24.53	CHXO	HOOP	1365	
6	000922	48.35.87	109.24.91	CHXO	HOOP	1270	
6	991014	48.35.75	109.25.16	ISB	BS		30
6	000922	48.35.71	109.25.47	ISB	BS		20
6	991014	48.35.75	109.25.16	ISB	BS		25
6	000922	48.35.71	109.25.47	ISB	BS		20
6	991014	48.35.66	109.25.78	ISB	BS		25
6	000922	48.35.84	109.24.70	ISB	BS		20
6	991014	48.35.66	109.25.78	ISB	BS		20
6	000922	48.35.84	109.24.70	ISB	BS		20
6	991014	48.35.83	109.25.63	ISB	BS		30
6	000922	48.35.91	109.24.66	ISB	BS		20
6	991014	48.35.83	109.25.63	ISB	BS		25
6	000922	48.35.91	109.24.66	ISB	BS		20
6	991014	48.35.94	109.24.62	OSB	EF	7.5	250
6	991014	48.35.75	109.25.50	OSB	EF	7	300
6	991014	48.35.43	109.25.65	OSB	EF	5.8	350
6	000923	48.35.72	110.25.51	OSB	EF	5.6	175
6	000923	48.35.94	109.24.49	OSB	EF	2.7	75
6	000923	48.36.11	109.24.36	OSB	EF	6.7	100
6	991013	48.35.87	109.24.93	OSB	HOOP	1284	
6	991013	48.35.73	109.25.54	OSB	HOOP	1258	
6	991013	48.35.80	109.25.59	OSB	HOOP	1215	
6	000922	48.36.09	109.24.57	OSB	HOOP	1418	
6	000922	48.36.05	109.24.46	OSB	HOOP	1398	
6	000922	48.35.91	109.24.40	OSB	HOOP	1305	
6	990403	48.33.67	109.41.94	TWZ	E-FISHPACK	13.1	
6	991018	48.33.67	109.41.94	TWZ	E-FISHPACK	10	30
6	000422	48.33.67	109.41.94	TWZ	E-FISHPACK	13.2	50
6	000505	48.33.67	109.41.94	TWZ	E-FISHPACK	14.8	50
6	000928	48.33.67	109.41.94	TWZ	E-FISHPACK	12.9	100
6	991018	48.33.67	109.41.94	TWZ	GN 100FT	1190	
6	000422	48.33.67	109.41.94	TWZ	GN 100FT	920	
6	000927	48.33.67	109.41.94	TWZ	GN 100FT	1205	
6	990403	48.33.67	109.41.94	TWZ	TN		180 arc
5	991015	48.35.50	109.21.73	CHXO	EF	15	175
5	991015	48.35.52	109.21.48	CHXO	EF	6.7	200
5	991015	48.35.71	109.22.36	CHXO	EF	8.3	200

Table 7. Continued.

Sect	Date	Location(GPS)		Macrohab[a]	Gear[b]	Duration(min)	Distance(m)
5	000915	48.35.84	109.21.85	CHXO	EF	9.3	150
5	000915	48.35.60	109.21.80	CHXO	EF	10.3	150
5	000915	48.35.44	109.21.40	CHXO	EF	7.2	125
5	991015	48.35.49	109.21.47	CHXO	HOOP	1418	
5	991015	48.35.47	109.21.65	CHXO	HOOP	1438	
5	991015	NONE		CHXO	HOOP	1403	
5	000914	48.35.84	109.22.04	CHXO	HOOP	1445	
5	000914	48.35.72	109.22.04	CHXO	HOOP	1406	
5	000914	48.35.82	109.22.10	CHXO	HOOP	1388	
5	991016	48.35.93	109.21.97	ISB	BS		25
5	000914	48.35.78	109.22.31	ISB	BS		10
5	991016	48.35.93	109.21.97	ISB	BS		25
5	000914	48.35.78	109.22.31	ISB	BS		20
5	991016	48.35.47	109.21.69	ISB	BS		30
5	000914	48.35.71	109.22.10	ISB	BS		15
5	991016	48.35.47	109.21.69	ISB	BS		25
5	000914	48.35.71	109.22.10	ISB	BS		20
5	991016	48.35.88	109.22.37	ISB	BS		15
5	000914	48.35.79	109.21.94	ISB	BS		20
5	991016	48.35.88	109.22.37	ISB	BS		20
5	000914	48.35.79	109.21.94	ISB	BS		20
5	991015	48.35.90	109.22.26	OSB	EF	6.7	150
5	991015	48.35.82	109.22.73	OSB	EF	10.3	250
5	991015	48.35.99	109.23.66	OSB	EF	13	150
5	000915	48.35.72	109.21.78	OSB	EF	4.4	75
5	000915	48.35.00	109.21.51	OSB	EF	4.6	75
5	000915	48.35.47	109.21.34	OSB	EF	3.9	50
5	991015	48.35.47	109.21.31	OSB	HOOP	1401	
5	991015	48.35.94	109.22.00	OSB	HOOP	1413	
5	991015	48.35.75	109.21.92	OSB	HOOP	1445	
5	000914	48.35.80	109.21.96	OSB	HOOP	1420	
5	000914	48.35.91	109.22.34	OSB	HOOP	1368	
5	000914	48.35.77	109.22.26	OSB	HOOP	1350	
5	990402	48.36.09	109.24.17	TWZ	E-FISHPACK	12.9	
5	990423	48.36.09	109.24.17	TWZ	E-FISHPACK	6.3	
5	990508	48.36.09	109.24.17	TWZ	E-FISHPACK	5.6	
5	991018	48.36.09	109.24.17	TWZ	E-FISHPACK	10	40
5	000423	48.36.09	109.24.17	TWZ	E-FISHPACK	12.3	50
5	000505	48.36.09	109.24.17	TWZ	E-FISHPACK	4.3	50
5	000923	48.36.09	109.24.17	TWZ	E-FISHPACK	8.7	50
5	991018	48.36.09	109.24.17	TWZ	GN 100FT	1266	
5	000422	48.36.09	109.24.17	TWZ	GN 100FT	1011	

Table 7. Continued.

Sect	Date	Location(GPS)		Macrohab[a]	Gear[b]	Duration(min)	Distance(m)
5	000922	48.36.09	109.24.17	TWZ	GN 100FT	940	
5	990402	48.36.09	109.24.17	TWZ	TN		180 arc
5	990423	48.36.09	109.24.17	TWZ	TN		180 arc
5	990508	48.36.09	109.24.17	TWZ	TN		180 arc
4	991017	48.34.08	109.10.90	CHXO	EF	10	200
4	991017	48.34.15	109.10.82	CHXO	EF	10	200
4	991017	48.33.99	109.09.89	CHXO	EF	9	140
4	000913	48.34.20	109.10.56	CHXO	EF	6.5	200
4	000913	48.33.96	109.09.84	CHXO	EF	7.8	150
4	000913	48.34.07	109.11.01	CHXO	EF	2.9	50
4	991016	48.34.16	109.10.79	CHXO	HOOP	1344	
4	991016	48.34.11	109.10.02	CHXO	HOOP	1367	
4	000913	48.34.07	109.11.01	CHXO	HOOP	1208	
4	000913	48.34.12	109.10.94	CHXO	HOOP	1190	
4	000913	48.33.96	109.10.19	CHXO	HOOP	1110	
4	991016	48.33.85	109.09.30	ISB	BS		20
4	000914	48.34.20	109.10.39	ISB	BS		20
4	991016	48.33.85	109.09.30	ISB	BS		20
4	000914	48.34.20	109.10.39	ISB	BS		20
4	991016	48.34.20	109.10.40	ISB	BS		25
4	000914	48.34.05	109.10.47	ISB	BS		10
4	991016	48.34.20	109.10.40	ISB	BS		25
4	000914	48.34.05	109.10.47	ISB	BS		10
4	991016	48.34.11	109.10.02	ISB	BS		20
4	000914	48.33.99	109.10.19	ISB	BS		10
4	991016	48.34.11	109.10.02	ISB	BS		15
4	000914	48.33.99	109.10.19	ISB	BS		20
4	991017	48.34.03	109.10.45	OSB	EF	6.3	75
4	991017	48.34.28	109.10.39	OSB	EF	8	150
4	991017	48.33.99	109.10.14	OSB	EF	9	110
4	000913	48.34.18	109.10.38	OSB	EF	8.5	175
4	000913	48.34.00	109.10.19	OSB	EF	4.9	75
4	000913	48.33.96	109.10.19	OSB	EF	4.2	75
4	991016	48.33.95	109.10.20	OSB	HOOP	1293	
4	991016	48.34.22	109.10.50	OSB	HOOP	1327	
4	991016	48.34.01	109.10.47	OSB	HOOP	1309	
4	000913	48.34.23	109.10.40	OSB	HOOP	1155	
4	000913	48.34.05	109.10.48	OSB	HOOP	1139	
4	000913	48.34.00	109.10.19	OSB	HOOP	1122	
4	991017	48.34.23	109.10.48	TRM	EF	6	120
4	990403	48.33.95	109.11.24	TWZ	E-FISHPACK	15	
4	990423	48.33.95	109.11.24	TWZ	E-FISHPACK	4.4	

Table 7. Continued.

Sect	Date	Location(GPS)		Macrohab[a]	Gear[b]	Duration(min)	Distance(m)
4	990509	48.33.95	109.11.24	TWZ	E-FISHPACK	8.1	
4	991018	48.33.95	109.11.24	TWZ	E-FISHPACK	12	60
4	000423	48.33.95	109.11.24	TWZ	E-FISHPACK	11.1	70
4	000505	48.33.95	109.11.24	TWZ	E-FISHPACK	11	70
4	000921	48.33.95	109.11.24	TWZ	E-FISHPACK	14.2	100
4	991018	48.33.95	109.11.24	TWZ	GN 50FT	1325	
4	000422	48.33.95	109.11.24	TWZ	GN 50FT	1207	
4	000921	48.33.95	109.11.24	TWZ	GN 50FT	1141	
4	990403	48.33.95	109.11.24	TWZ	TN		180 arc
4	990423	48.33.95	109.11.24	TWZ	TN		180 arc
3	991026	48.25.34	108.20.72	CHXO	EF	5.9	150
3	991026	48.25.66	108.21.00	CHXO	EF	7.5	175
3	991026	48.25.84	108.21.08	CHXO	EF	6.5	150
3	000912	48.25.37	108.20.80	CHXO	EF	3.9	150
3	000912	48.25.77	108.21.63	CHXO	EF	4.2	100
3	000912	48.26.33	108.21.68	CHXO	EF	3.2	100
3	991025	48.25.43	108.20.34	CHXO	HOOP	1371	
3	991025	48.25.66	108.21.00	CHXO	HOOP	1374	
3	991025	48.25.71	108.21.16	CHXO	HOOP	1379	
3	000912	48.26.05	108.21.95	CHXO	HOOP	1229	
3	000912	48.26.33	108.21.69	CHXO	HOOP	1228	
3	000912	48.26.45	108.21.98	CHXO	HOOP	1228	
3	991026	48.25.95	108.21.16	ISB	EF	6.9	125
3	991026	48.25.56	108.20.20	ISB	EF	6.7	150
3	991026	48.25.25	108.19.63	ISB	EF	6.5	150
3	991026	48.25.69	108.20.76	OSB	EF	7.7	200
3	991026	48.25.76	108.21.37	OSB	EF	7.3	175
3	991026	48.25.98	108.21.31	OSB	EF	7.4	200
3	000912	48.25.65	108.21.61	OSB	EF	7.3	200
3	000912	48.25.75	108.20.90	OSB	EF	13.2	250
3	000912	48.26.29	108.21.48	OSB	EF	7	200
3	991025	48.25.56	108.20.08	OSB	HOOP	1370	
3	991025	48.25.34	108.20.35	OSB	HOOP	1370	
3	991025	48.25.00	108.21.12	OSB	HOOP	1376	
3	000912	48.25.76	108.21.45	OSB	HOOP	1247	
3	000912	48.25.89	108.21.76	OSB	HOOP	1237	
3	000912	48.25.85	108.21.89	OSB	HOOP	1234	
3	990403	48.29.25	108.45.90	TWZ	E-FISHPACK	9.7	
3	990424	48.29.25	108.45.91	TWZ	E-FISHPACK	5	
3	990509	48.29.25	108.45.94	TWZ	E-FISHPACK	6.4	
3	991025	48.29.25	108.45.89	TWZ	E-FISHPACK	5	50
3	000422	48.29.24	108.45.88	TWZ	E-FISHPACK	14.9	50

Table 7. Continued.

Sect	Date	Location(GPS)		Macrohab[a]	Gear[b]	Duration(min)	Distance(m)
3	000505	48.29.24	108.45.88	TWZ	E-FISHPACK	11.9	50
3	000921	48.29.24	108.45.88	TWZ	E-FISHPACK	9	50
3	991025	48.29.25	108.45.89	TWZ	GN 100FT	900	
3	990403	48.29.25	108.45.89	TWZ	TN		180 arc
3	990424	48.29.25	108.45.92	TWZ	TN		180 arc
3	990424	48.29.25	108.45.93	TWZ	TN		180 arc
2	10/6/99	482510	10704959	CHXO	EF	10	350
2	10/6/99	482510	10704959	CHXO	EF	10	350
2	6/17/99	482506	1070417	CHXO	EF	15	400
2	6/17/99	482704	1070884	CHXO	EF	10	400
2	10/25/00	4823573	10748897	CHXO	EF	15	500
2	10/19/99	4830950	10714154	CHXO	EF	10	400
2	10/20/00	4830582	10713546	CHXO	EF	10	350
2	10/21/99	4823143	10748649	CHXO	EF	10	350
2	10/21/99	4823727	10748993	CHXO	EF	10	200
2	10/18/00	4825190	10704839	CHXO	EF	10	350
2	11/9/99	4824450	10818031	CHXO	EF	10	400
2	10/25/00	482455	10818363	CHXO	HOOP	1200	
2	10/6/99	482502	10704962	CHXO	HOOP	1450	
2	10/24/00	4823573	10748897	CHXO	HOOP	1410	
2	10/18/99	4830904	10714321	CHXO	HOOP	1010	
2	10/19/00	4830624	10713242	CHXO	HOOP	1130	
2	10/20/99	4823793	10749033	CHXO	HOOP	1649	
2	10/17/00	4825011	10704928	CHXO	HOOP	990	
2	10/26/99	4824511	10818273	CHXO	HOOP	1440	
2	10/18/99	4830635	10713642	CHXO	GN	1370	
2	10/26/00	482457	10818370	ISB	BS		20
2	10/7/99	4824920	10704916	ISB	BS		6
2	10/7/99	4824920	10704916	ISB	BS		6
2	10/24/00	4822809	10748891	ISB	BS		15
2	10/24/00	4822886	10748770	ISB	BS		30
2	10/19/00	4830457	10713070	ISB	BS		30
2	10/20/99	4822751	10749104	ISB	BS		10
2	10/17/00	4825156	10704153	ISB	BS		30
2	10/17/00	4825156	10704153	ISB	BS		30
2	10/26/99	4824450	10818031	ISB	BS		15
2	10/26/99	4824328	10818868	ISB	BS		30
2	10/25/00	4823560	10748756	ISB	EF	15	400
2	10/19/99	4830793	10713785	ISB	EF	5	
2	10/20/00	4830919	10714148	ISB	EF	15	500
2	10/21/99	4823612	10748166	ISB	EF	10	350
2	10/18/00	4825264	10704483	ISB	EF	10	350

Table 7. Continued.

Sect	Date	Location (GPS)		Macrohab[a]	Gear[b]	Duration(min)	Distance(m)
2	10/6/99	4825251	10704460	OSB	EF	10	350
2	10/25/00	4822886	10748770	OSB	EF	15	550
2	10/19/99	4830622	10713257	OSB	EF	10	350
2	10/20/00	4830537	10713113	OSB	EF	10	400
2	10/21/99	4823524	10748704	OSB	EF	15	400
2	10/18/00	4825001	10704915	OSB	EF	10	350
2	11/9/99	4824531	10818273	OSB	EF	10	300
2	10/25/00	4824554	10818366	OSB	HOOP	1200	
2	10/6/99	4824976	10704910	OSB	HOOP	1455	
2	10/24/00	4823581	10749143	OSB	HOOP	1410	
2	10/18/99	4830945	10713945	OSB	HOOP	1456	
2	10/19/00	4830926	10713937	OSB	HOOP	1130	
2	10/20/99	4823628	10749191	OSB	HOOP	1660	
2	10/17/00	4824900	10704968	OSB	HOOP	990	
2	10/26/99	4824531	10818335	OSB	HOOP	1440	
2	10/26/00	4824644	10818420	RIF	BS		40
2	10/24/00	4823027	10748741	RIF	BS		30
2	10/24/00	4822809	10748891	RIF	BS		30
2	10/18/99	4830458	10713033	RIF	BS		125
2	10/18/99	4830458	10713033	RIF	BS		30
2	10/20/99	4822874	10748738	RIF	BS		10
2	10/20/99	4822768	10748932	RIF	BS		100
2	10/20/99	4822775	10748916	RIF	BS		50
2	10/20/00	4830457	10713070	RIF	BS		30
2	10/19/00	4830457	10713070	RIF	BS		25
2	10/26/99	4824644	10818465	RIF	BS		50
2	6/17/99	482712	1070865	RIF	DTN		150
2	6/17/99	482713	1070862	RIF	DTN		50
2	10/18/99	4830458	10713033	RIF	DTN		125
2	10/20/99	4823069	10748739	RIF	DTN		200
2	10/19/00	4830457	10713070	RIF	DTN		50
2	10/26/99	4824644	10818465	RIF	DTN		100
2	6/17/99	482712	1070865	RIF	EF	10	75
2	10/19/99	4830508	10712964	RIF	EF	15	400
2	10/25/00	4823895	10748727	RIF	EF	10	300
2	10/19/99	4830811	10714450	RIF	EF	10	350
2	10/21/99	4822818	10748927	RIF	EF	5	250
2	10/21/99	4822828	10748853	RIF	EF	10	150
2	10/20/00	4830796	10714485	RIF	EF	12	250
2	11/9/99	4824644	10818465	RIF	EF	5	300
2	10/13/99	4830458	10713033	SCN	BS		3
2	10/6/99	4825002	10704156	TRM	EF	10	

Table 7. Continued.

Sect	Date	Location (GPS)		Macrohab[a]	Gear[b]	Duration(min)	Distance(m)
2	10/6/99	4825002	10704156	TRM	EF	10	
2	10/6/99	4824996	10705505	TRM	EF	10	
2	10/6/99	4824996	10705505	TRM	EF	10	
2	6/17/99	482613	1070233	TRM	EF	5	50
2	6/17/99	482506	1070415	TRM	EF	25	400
2	10/18/00	4824877	10705453	TRM	EF	10	300
2	10/18/00	4825054	10704159	TRM	EF	10	400
2	10/6/99	4824969	10705540	TRM	GN	1460	
2	10/6/99	4825002	10704156	TRM	GN	1186	
2	6/17/99	482506	1070416	TRM	GN	300	
2	10/17/00	4825006	10705514	TRM	GN	1050	
2	10/17/00	4825027	10704176	TRM	GN	990	
2	10/26/00	4824700	10818547	TWZ	EF	10	250
2	11/9/99	4824700	10818547	TWZ	EF	10	300
2	11/9/99	4824700	10818547	TWZ	EF	10	300
2	10/25/00	4824700	10818547	TWZ	GN	960	
2	10/26/99	4824700	10818547	TWZ	GN	1250	
1	9/29/99	4803917	10617371	CHXO	EF	11	200
1	9/29/99	4803886	10617473	CHXO	EF	5	150
1	10/13/00	4810603	10638957	CHXO	EF	10	300
1	10/13/00	4810524	10638082	CHXO	EF	10	400
1	10/1/99	4806007	10617046	CHXO	EF	10	300
1	10/10/00	4806610	10617332	CHXO	EF	10	400
1	10/10/00	4806031	10618033	CHXO	EF	10	400
1	10/5/99	4818441	10648697	CHXO	EF	15	
1	10/5/99	4818425	10649024	CHXO	EF	10	
1	10/5/00	4803832	10617304	CHXO	EF	10	350
1	10/5/00	4803957	10617360	CHXO	EF	10	300
1	10/8/99	4822389	10658514	CHXO	EF	10	500
1	10/16/00	4822826	10657785	CHXO	HOOP	1200	
1	9/28/99	4803865	10617469	CHXO	HOOP	1474	
1	10/12/00	4811275	10639907	CHXO	HOOP	1020	
1	9/30/99	4806086	10617162	CHXO	HOOP	1335	
1	10/10/00	4806931	10618502	CHXO	HOOP	1440	
1	10/4/99	4818519	10648677	CHXO	HOOP	1290	
1	10/5/00	4803975	10617295	CHXO	HOOP	1260	
1	10/7/99	4822821	10657641	CHXO	HOOP	1300	
1	9/29/99	4804046	10617812	CHXO	GN	1350	
1	9/28/99	4803882	10617560	ISB	BS		10
1	10/12/00	4811700	10640155	ISB	BS		20
1	9/30/99	4805842	10617280	ISB	BS		8
1	9/30/99	4805869	10617137	ISB	BS		8

Table 7. Continued.

Sect	Date	Location (GPS)		Macrohab[a]	Gear[b]	Duration(min)	Distance(m)
1	10/11/00	4806769	10617504	ISB	BS		30
1	10/11/00	4806793	10618400	ISB	BS		40
1	10/5/00	4804160	10616673	ISB	BS		50
1	10/5/00	4803839	10617666	ISB	BS		40
1	10/13/00	4811460	10637938	ISB	EF	10	400
1	10/13/00	4810967	10637775	ISB	EF	10	350
1	10/13/00	4810314	10638525	ISB	EF	10	350
1	10/10/00	4806769	10617504	ISB	EF	10	350
1	10/10/00	4806793	10618400	ISB	EF	10	400
1	10/5/99	4818486	10648359	ISB	EF	7	300
1	10/5/00			ISB	EF	10	300
1	10/5/00	4804013	10617781	ISB	EF	10	300
1	10/8/99	4822703	10657335	ISB	EF	10	450
1	9/29/99	4803862	10617748	OSB	EF	10	450
1	10/13/00	4810524	10638082	OSB	EF	8	300
1	10/13/00	4811100	10637793	OSB	EF	10	400
1	10/1/99	4805846	10617339	OSB	EF	10	480
1	10/10/00	4806594	10617068	OSB	EF	10	350
1	10/10/00	4806931	10618502	OSB	EF	10	400
1	10/5/99	4818394	10648444	OSB	EF	8	300
1	10/5/00	4803920	10617810	OSB	EF	10	350
1	10/5/00	4804214	10616646	OSB	EF	10	350
1	10/8/99	4822389	10657872	OSB	EF	16	175
1	10/16/00	4822827	10657899	OSB	HOOP	1290	
1	9/28/99	4803855	10617733	OSB	HOOP	1392	
1	10/12/00	4811683	10639479	OSB	HOOP	990	
1	10/10/00	4806667	10618376	OSB	HOOP	1490	
1	10/4/99	4818583	10648482	OSB	HOOP	1340	
1	10/5/00	4804149	10616653	OSB	HOOP	1260	
1	10/5/00	4804149	10616653	OSB	HOOP	1260	
1	10/7/99	4822839	1065872	OSB	HOOP	1330	
1	9/28/99	4804472	10616901	RIF	BS		20
1	9/28/99	4804228	10616621	RIF	BS		25
1	6/10/99	480423	1061669	RIF	BS		10
1	6/10/99	480423	1061669	RIF	BS		10
1	7/14/99	480422	1061666	RIF	BS		10
1	8/19/99	480454	1061699	RIF	BS		10
1	9/30/99	4806086	10617162	RIF	BS		40
1	10/4/99	4818426	10648842	RIF	BS		10
1	10/5/00	4804213	10616642	RIF	BS		60
1	9/28/99	4804228	10616621	RIF	DTN		100
1	9/28/99	4804701	10617002	RIF	DTN		100

Table 7. Continued.

Sect	Date	Location (GPS)		Macrohab[a]	Gear[b]	Duration(min)	Distance(m)
1	5/24/99	480451	1061691	RIF	DTN		50
1	5/24/99	480451	1061691	RIF	DTN		100
1	5/24/99	480451	1061691	RIF	DTN		100
1	5/25/99	480451	1061693	RIF	DTN		100
1	5/25/99	480462	1061699	RIF	DTN		100
1	5/25/99	480451	1061693	RIF	DTN		100
1	5/25/99	480419	1061664	RIF	DTN		50
1	5/27/99	480462	1061705	RIF	DTN		150
1	5/27/99	480462	1061705	RIF	DTN		150
1	5/28/99	480418	1061659	RIF	DTN		50
1	5/28/99	480418	1061659	RIF	DTN		50
1	6/7/99	480418	1061659	RIF	DTN		75
1	6/7/99	480407	1061669	RIF	DTN		150
1	6/10/99	480425	1061665	RIF	DTN		100
1	6/15/99	480389	1061744	RIF	DTN		100
1	6/15/99	480423	1061669	RIF	DTN		100
1	6/15/99	480451	1061693	RIF	DTN		100
1	6/15/99	480460	1061704	RIF	DTN		100
1	6/16/99	480423	1061669	RIF	DTN		100
1	6/16/99	480423	1061669	RIF	DTN		100
1	7/14/99	480422	1061666	RIF	DTN		150
1	8/19/99	480476	1061702	RIF	DTN		50
1	8/19/99	480414	1061665	RIF	DTN		75
1	8/30/99	480414	1061665	RIF	DTN		75
1	8/30/99	480414	1061665	RIF	DTN		75
1	5/25/99	480419	1061669	RIF	DTN		75
1	5/25/99	480419	1061669	RIF	DTN		75
1	5/26/99	480419	1061669	RIF	DTN		75
1	5/27/99	480419	1061669	RIF	DTN		75
1	5/27/99	4805000	10616678	RIF	DTN		100
1	5/27/99	480419	1061669	RIF	DTN		75
1	5/27/99	480419	1061669	RIF	DTN		75
1	5/27/99	480419	1061669	RIF	DTN		75
1	6/2/99	480419	1061669	RIF	DTN		75
1	6/2/99	480419	1061669	RIF	DTN		75
1	6/2/99	480419	1061669	RIF	DTN		75
1	6/2/99	480419	1061669	RIF	DTN		75
1	6/2/99	480419	1061669	RIF	DTN		75
1	6/14/99	480423	1061670	RIF	DTN		100
1	6/16/99	480423	1061670	RIF	DTN		100
1	6/16/99	480423	1061670	RIF	DTN		100
1	9/30/99	4806086	10617162	RIF	DTN		60

Table 7. Continued.

Sect	Date	Location (GPS)		Macrohab[a]	Gear[b]	Duration(min)	Distance(m)
1	5/26/99	480776	1062172	RIF	DTN		150
1	5/26/99	480776	1062172	RIF	DTN		50
1	5/26/99	480776	1062172	RIF	DTN		25
1	5/26/99	480776	1062172	RIF	DTN		25
1	5/26/99	480776	1062172	RIF	DTN		50
1	5/26/99	480663	1062019	RIF	DTN		20
1	5/26/99	480663	1062019	RIF	DTN		150
1	5/26/99	480656	1061975	RIF	DTN		200
1	5/26/99	480656	1061975	RIF	DTN		200
1	5/26/99	480656	1061975	RIF	DTN		300
1	5/27/99	480500	1061670	RIF	DTN		150
1	5/27/99	480500	1061670	RIF	DTN		150
1	6/10/99	480496	1061662	RIF	DTN		150
1	6/10/99	480579	1061762	RIF	DTN		100
1	6/10/99	480656	1061958	RIF	DTN		150
1	6/10/99	480785	1062303	RIF	DTN		200
1	6/15/99	480500	1061679	RIF	DTN		150
1	10/4/99	4818426	10648842	RIF	DTN		250
1	10/4/99	4818487	10648895	RIF	DTN		200
1	10/5/00	4804215	10616644	RIF	DTN		150
1	9/29/99	4804185	10616691	RIF	EF	5	125
1	9/29/99	4804811	10616895	RIF	EF	10	350
1	9/29/99	4804394	10616752	RIF	EF	10	200
1	4/27/99	480419	1061664	RIF	EF	10	400
1	10/1/99	4806705	10619323	RIF	EF	10	400
1	10/1/99	4805905	10617610	RIF	EF	10	200
1	10/5/99	4818460	10648770	RIF	EF	5	350
1	10/10/00	4806636	10618713	RIF	EF	10	250
1	10/5/99	4818552	10648716	SCN	EF	1	5
1	5/28/99	480334	1061899	TRM	DTN		300
1	5/28/99	480334	1061899	TRM	DTN		300
1	5/28/99	480333	1061894	TRM	DTN		200
1	5/28/99	480328	1061881	TRM	DTN		100
1	5/28/99	480328	1061881	TRM	DTN		100
1	5/28/99	480331	1061896	TRM	DTN		50
1	5/28/99	480331	1061896	TRM	DTN		50
1	6/7/99	480333	1061895	TRM	DTN		250
1	6/7/99	480333	1061895	TRM	DTN		250
1	6/15/99	480329	1061884	TRM	DTN		75
1	7/14/99	480330	1061898	TRM	DTN		150
1	6/2/99	480331	1061896	TRM	DTN		75
1	6/2/99	480331	1061896	TRM	DTN		75

Table 7. Continued.

Sect	Date	Location (GPS)		Macrohab[a]	Gear[b]	Duration(min)	Distance(m)
1	6/2/99	480331	1061896	TRM	DTN		75
1	5/26/99	480703	1062020	TRM	DTN		20
1	10/17/00	4822405	10658476	TWZ	EF	10	200
1	10/17/00	4822468	10658181	TWZ	EF	5	150
1	10/17/00	4822741	10657873	TWZ	EF	10	450
1	10/17/00	4822691	10657570	TWZ	EF	10	450
1	10/17/00	4822623	10657253	TWZ	EF	10	450
1	10/8/99	4822389	10658514	TWZ	EF	15	
1	10/7/99	4822389	10658514	TWZ	GN	1130	

[a] CHXO (Channel Crossover), ISB (Inside Bend), OSB (Outside Bend), RIF (Riffle), SCN (Secondary Channel Nonconnected), TRM (Tributary Mouth), TWZ (Tailwater Zone)

[b] BS (Bag Seine), DTN (Drifting Trammel Net), EF (Electrofishing from boat), E-Fishingpack (Electrofishing with a backpack shocker), GN (Gill Net), Hoop (Hoop Net), TN (Trammel Net used like a Bag Seine)

APPENDIX B

SPECIES SIZE DISTRIBUTION

Table 8. Size distribution for fish species captured in the Milk River, Montana, 1999 and 2000.

Species	Number measured	Average Length (mm)	Length Range (mm)	Average Weight (g)	Weight Range (g)
Black bullhead	19	171.2	40-230	89.6	1-179
Black crappie	14	92.7	39-338	61.8	0.8-725
Brook stickleback	4	53.0	46-58	1.2	0.9-1.4
Bluegill	4	38.8	26-48	1.3	0.2-2.4
Bigmouth buffalo	13	399.7	255-616	1406.0	290-3625
Brown trout	25	292.2	126-528	477.1	11.7-2375
Burbot	13	336.2	125-660	504.5	13.3-1800
Brassy minnow	7	65.3	45-89	2.9	1.3-5.1
Common carp	241	447.9	32-709	1607.3	0.8-5000
Creek chub	10	53.7	24-83	2.0	0.1-5.3
Channel catfish	171	353.4	46-748	639.6	1.4-4200
Emerald shiner	570	57.0	20-102	1.8	0.1-8.3
Flathead chub	1003	96.1	28-272	12.1	0.2-192
Fathead minnow	390	48.3	23-74	1.3	0.2-4.3
Freshwater drum	85	154.2	46-648	241.5	0.8-2750
Goldeye	560	257.3	72-407	198.8	3.1-768
Hybognathus spp.	283	78.2	31-151	6.6	0.3-31.8
Iowa darter	3	54.0	52-57	1.3	1.1-1.5
Lake chub	59	63.5	38-114	3.6	0.5-18.8
Lake whitefish	65	382.3	146-521	698.4	21.5-1650
Longnose dace	232	54.4	31-120	1.9	0.2-15.8
Longnose sucker	244	270.1	46-521	391.6	1.2-1425
Mountain sucker	2	61.5	61-62	2.2	2.2-2.2
Northern redbelly dace	3	58.7	49-74	2.2	1.4-3.8
Northern pike	244	524.2	184-1110	1305.0	39.5-8200
Pearl dace	30	63.8	37-114	3.1	0.3-14.7
Rainbow trout	18	291.1	124-333	385.1	20.4-538.7
River carpsucker	228	245.2	17-567	537.3	0.1-2150
Sauger	109	251.5	96-555	219.3	5.4-1675
Shorthead redhorse	471	302.5	48-657	361.3	1.5-1800
Smallmouth buffalo	79	391.2	40-673	1507.7	0.8-4450
Smallmouth bass	20	159.2	70-380	134	7.7-846
Stonecat	38	166.2	45-253	64.7	1.2-213
Spottail shiner	447	64.7	27-107	2.8	0.1-12.6
Walleye	230	340.5	55-748	554.9	1.7-4700
White crappie	15	67.9	41-150	4.9	1.0-33.0
White sucker	435	238.8	34-464	320.1	0.3-1400
Yellow perch	319	105.9	50-250	24.2	0.9-250