ECOLOGY OF FISHES IN THE LOWER MILK RIVER, MONTANA IN RELATION TO SPRING DISCHARGE

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AUTHORIZATION TO SUBMIT

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ABSTRACT

A water development project has been proposed that would divert water from the Milk River, an important main channel tributary to the upper Missouri River, Montana. During high spring flows, water would be diverted into an off-stream storage reservoir with up to 74 million m^3 capacity. The proposed project would further decrease the magnitude of the two-year flood and the frequency of other chance flooding. These proposed changes in the hydrograph and water quality were evaluated in this study for their potential effects on reproduction and life history of native fish species.

Larval fish were sampled from May to August in both 2002 and 2003 to describe differences among temporal and spatial distribution of the fish species spawning in the Milk River in relation to river discharge. Total larval fish density was 23 times higher in 2002 than in 2003. Fourteen taxa were found in 2002 and 9 taxa were found in 2003. In 2002, highest weekly larval fish density (4433 fish/100 m^3) immediately followed the peak discharge of 62 m^3/s on 15 June. Conversely in 2003 the highest weekly larval fish density (79 fish/100 m^3) also occurred in mid-June and did not immediately follow the peak in discharge of 70 m^3/s on 12 May. The observed difference in larval fish densities associated with differences in the duration and timing of the peak discharges in 2002 and 2003 supports the idea that the timing of the peak was important for the spawning of most native resident and migratory fish species.

The life history and ecology of the blue suckers (*Cycleptus elongatus*), a species of special concern, was also investigated. A total of 252 blue suckers was captured; 249 adult fish, three larval fish, and two age-0 juveniles. The ages (n=102) of the adult fish ranged from 10 to 37 years; maximum age greatly exceeded ages reported in other

studies. Fish in the Milk River population evidently grew slower, matured later, and lived longer than fish at lower latitudes. Females were longer and weighed more than males at a given age. The Von Bertalanffy growth equations for length were expressed as $L=752.9(1-e^{-0.1457t})$ for females and $L=695.1(1-e^{-0.1743t})$ for males. The Von Bertalanffy growth equations for weight were expressed as $W=3844.3[(1-e^{(-0.1412t)})^{2.8171}])$ for females and $W=2754.9[(1-e^{(-0.1604t)})^{2.8883}]$ for males. In 2002, 189 fish out of 222 adult fish caught were determined to be reproductively active; 93 females and 96 males. In 2003, one female fish out of 26 fish caught was determined to be reproductively active. Catches of adult blue suckers were highest during periods of high spring discharge as adults migrated into the Milk River to spawn during May and June.

Additional sampling was conducted from May to August 2002 and 2003 to investigate the importance of the lower Milk River for the spawning and rearing of native resident and Missouri River fish species. The ten most abundant species found were native migratory and resident fish species including the blue sucker (*Cycleptus elongatus*) and the flathead chub (*Hybopsis gracilis*), a watchlist species for Montana Natural Heritage Program. High catches of reproductively ready fish and species common in the Missouri River indicate that native migratory and resident fish species rely on the irregular seasonal discharge in the Milk River to spawn and rear. Age and growth analysis was conducted on channel catfish (*Ictalurus punctatus*), sauger (*Stizostedion canadense*), walleye (*Stizostedion vitreum*), northern pike (*Esox lucius*) and shovelnose sturgeon (*Scaphirhynchus platorynchus*). Channel catfish, sauger, walleye, and shovelnose sturgeon grew slower and lived longer than fish in lower latitudes. Overall, results of the two year study strongly indicate that the Milk River, with its quasi-natural hydrograph and high sediment loads, is an important spawning and early rearing habitat for native resident fish species as well as for migratory species from the highly flow-altered Missouri River segment into which it flows.

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INTRODUCTION

Tributaries play an integral role in the ecological functions of large river systems. Tributaries are an important source of water, sediments and nutrients to the main channel. Distinct physical and hydraulic habitat characteristics (e.g. substrates, depths, and velocities) in tributaries also provide important spawning and rearing conditions for fish species utilizing different portions of large rivers for their life cycles. As a result, in warmwater drainages, fish species composition in tributaries is typically more closely related to the composition in the main channel than to the composition in headwater streams (Osborne and Wiley 1992).

The Milk River is an important main channel tributary to the upper Missouri River, Montana. This long tributary (1,126 km) is an alluvial river with wide meandering banks, traversing northern Montana and the southern province of Alberta, Canada. The lower 188 rkm of continuous river below Vandalia Dam is characterized by incised channels with well-developed riparian zones and cobble riffles (Stash et. al 2001). This portion of the river supports a diversity of macrohabitats for several native fish species common to the Missouri River.

The warm turbid character of the lower Milk River contrasts sharply with conditions in the Missouri River at their confluence, 10 km below Fort Peck Dam. Downstream of the Dam, the Missouri River is cold (15° C, July) and clear (10 nephelometric turbidity units (NTU), July), as a result of hypolimnetic discharge from Fort Peck Dam and sediment trapping by the reservoir. In contrast, the Milk River retains some of the characteristics of the Missouri River prior to alteration; it is warmer (30° C, July) and more turbid (1000 NTU, July).

The Missouri River is 3,768 km long and drains approximately one-sixth of the United States. The river has undergone major alterations in the last 100 years. Between 1938 and 1963, six large reservoirs were constructed, including Fort Peck. The remaining riverine portions of the Missouri River have been channelized, straightened, widened, and deepened, resulting in alterations of the flow regime, physical habitat, and water quality of the river. Water temperature and turbidity have decreased and the substrate, especially important riffle spawning grounds, has become embedded (Pflieger and Grace 1987). Concurrently, the abundance and distribution of the native fishes has been reduced (Pflieger and Grace 1987; Hesse and Sheets 1993) .

Fort Peck Dam has also greatly altered Missouri River habitat downstream. Shields et al. (2000) reported that since the closure of Fort Peck Dam in 1937, the mean rates of erosion and sedimentation below the dam have decreased four-fold, resulting in reduced lateral migration of the channel for 200 km downstream of the dam. This reduced migration limits the ability of the river to create and maintain floodplains and backwater areas that are critical habitats for spawning and rearing of fish.

With these major habitat changes in the Missouri River, remnant habitat in tributaries such as the lower Milk River assumes critical importance in species survival. Stash et al. (2001) observed that three migratory species from the Missouri River, blue sucker (*Cycleptus elongatus*), shovelnose sturgeon (*Scaphirhynchus platorynchus*), and paddlefish (*Polyodon spathula*) were found only in the lower 188 rkm section of the Milk River below Vandalia Dam. Seven other native fish species, bigmouth buffalo (*Ictiobus cyprinellus*), channel catfish (*Ictalurus punctatus*), freshwater drum, goldeye (*Hiodon alosoides*), river carpsucker (*Carpiodes carpio*), shorthead redhorse (*Moxostoma *macrolepidotum*), and smallmouth buffalo (*Ictiobus bubalus*) were captured only in the lowermost 400 km of the Milk River. Most of these fish were captured below Vandalia Dam, and may have been migratory from the Missouri River.

In years of high spring flows, the Milk River exhibits characteristics much like a natural river in terms of increases in depth, velocity, and turbidity. However, there has been a 60 % decrease in the magnitude of the two-year flood and similar decreases in larger, less frequent flood events (Shields et. al 2000) as a result of seven impoundments on the river. The impoundments extend from 699 km to 188 km upstream of the confluence with the Missouri River and have been developed mainly for irrigation. These alterations to the Milk River have caused a reduction in high spring flows, and have in some instances created impassable barriers to fish. Such alterations may affect the spawning and rearing ability of the resident fish, as well as native migratory fish from the Missouri River, especially if the latter fish rely on the unpredictable spring flows of the Milk River for spawning. In view of the major habitat alterations on the Missouri River in the 20th century, such fish may be relying even more heavily on the Milk River for spawning and rearing habitat than in historical times.

A water development project has been proposed that would divert water from Milk River during high spring flows into an off-stream storage reservoir with up to 74 million m^3 capacity. The proposed project would further decrease the magnitude of the two-year flood and the frequency of other chance flooding. These proposed changes in the hydrograph and water quality were evaluated in this study for their potential effects on the reproduction and life history of native fish species. The goal of this study was to determine the importance of spring discharge in the lower Milk River for the spawning and rearing of native resident and Missouri River migratory fish species. Chapter one of this thesis examines the relationship between larval fish, as evidence of spawning success, and spring discharge. Chapter two examines the life history characteristics of the blue sucker, a species of special concern, in relation to spring discharge. Chapter three examines spawning, rearing, age, and growth of native resident and Missouri River fish species in relation to spring discharge.

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OVERVIEW OF THE MILK RIVER BASIN

The Milk River, named by Lewis and Clark for its milky-colored, turbid waters, is one of the largest tributaries to the upper Missouri River. It is 1,126 km in length and drains an area of approximately 57,839 km^2. From its headwaters in Glacier National Park, Montana, it flows northeastward, crossing into Canada for 348 km. It re-enters the United States in Hill County, Montana, and flows through most of the northeastern portion of the state to its confluence with the Missouri River immediately downstream of Fort Peck Dam.

The topography of the lower portion of the Milk River basin is heavily influenced by continental glaciers from the Pleistocene epoch (2,500,000 to 10,000 B.P.). The advance and recession of the continental glaciers left deposits of ground and terminal moraines and outwash channel deposits. Sand, silt, and clay of Recent alluvial deposits thinly cover older glacial deposits along the alluvium of the Milk River (Montana Department of Health and Environmental Sciences 1974).

In the past century the Milk River has become an important source of irrigation and municipal water. Approximately 558 km^2 of land are irrigated from the river, primarily for crops of alfalfa, native hay, oats, wheat, and barley (United States Bureau of Reclamation 1983; Simonds 1998). Twelve municipalities rely on water from the river for drinking water and sewage treatment. Most of the irrigation water comes from the Milk River Project, one of the first U.S. Bureau of Reclamation irrigation projects developed in 1902 (Simonds 1998). This project diverts and stores water with three storage dams, four diversion dams, and a pumping plant (Montana Department of Natural Resources and Conservation 1990).

STUDY AREA

The portion of the Milk River included in the study extends approximately 225 km upriver from the confluence of the Yellowstone River with the Missouri River, to 20 rkm above Vandalia Dam, the first major dam (Figure 2). The first 4.8 river kilometers of the Missouri River downstream of the Milk River were also included in the study area.

Sampling was conducted on the lower 188 rkm of the Milk River, below Vandalia Dam and in the first 4.8 rkm of the Missouri River downstream of the Milk River. Riffle and run habitats within the study area were sampled. Riffles were classified as areas with shallow, turbulent water passing through or over stones or gravel of a fairly uniform area. Runs were classified as areas with a depth of at least 0.9 m with slow to moderate current. Areas of slower moving water, pool-like in nature, were classified as runs. Four sampling locations were established on the Milk River and one sampling location was established on the Missouri River. At each location, three random sampling sites were established. Sampling for larval fishes (Chapter 1), blue sucker (Chapter 2), and all other adult fishes (Chapter 3) occurred at each of these sites over the period May to August, 2002 and 2003.

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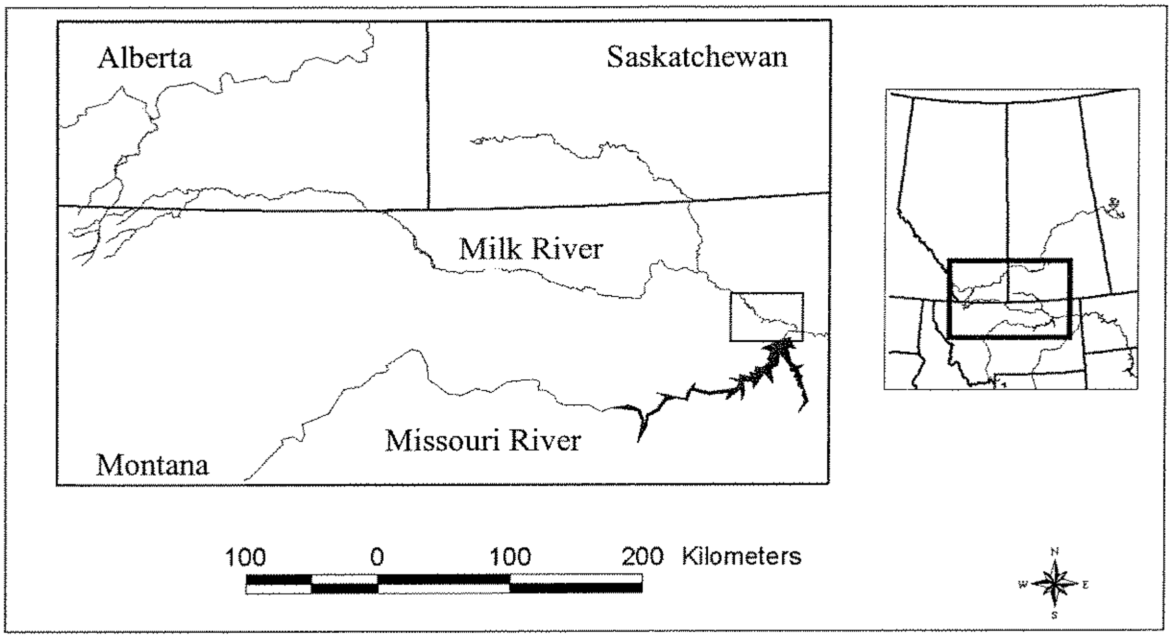

Figure 1. Milk River Basin.

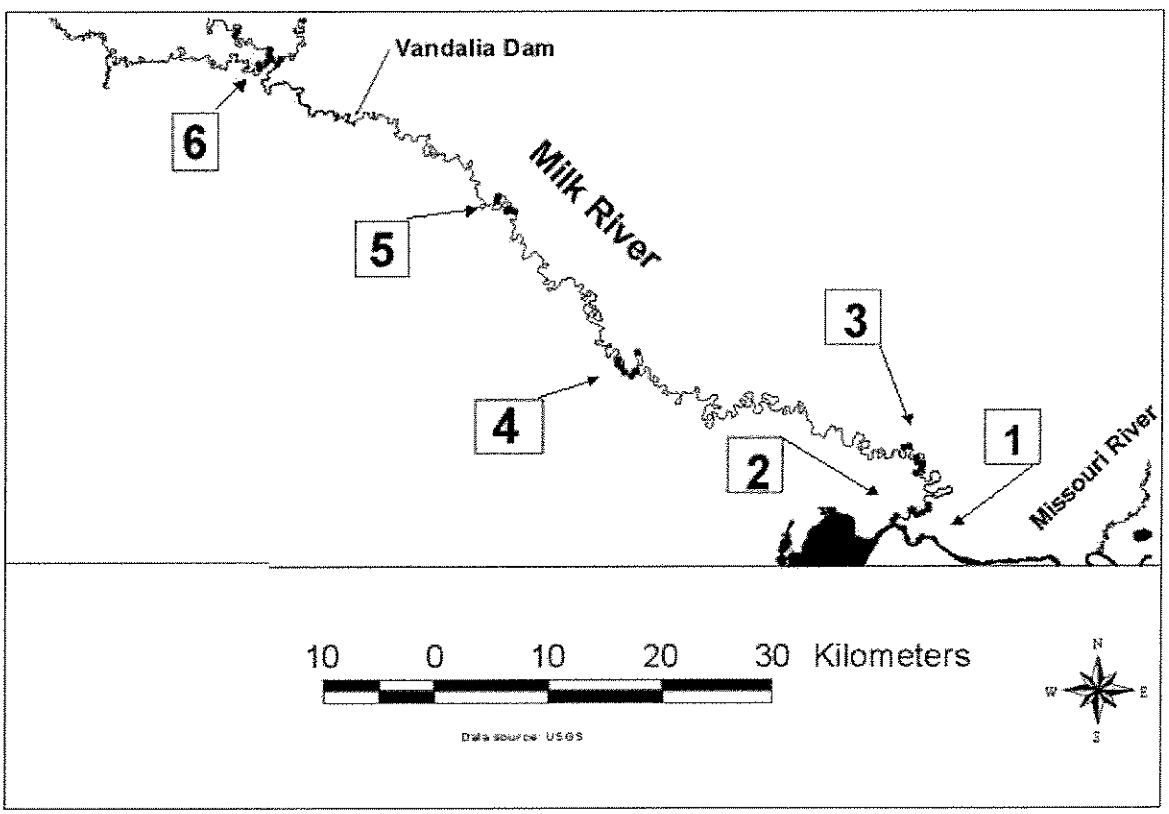

Figure 2. Lower Milk River study area, Montana.

CHAPTER 1. Larval fish distribution in the lower Milk River, Montana in relation to spring discharge

ABSTRACT

Larval fish were sampled from May to August of both 2002 and 2003 to describe differences among temporal and spatial distribution of the fish species spawning in the Milk River in relation to river discharge. Total larval fish density was 23 times higher in 2002 than in 2003. Fourteen taxa were found in 2002 and 9 taxa were found in 2003. In 2002, highest weekly larval fish density (4433 fish/100 m^3) immediately followed the peak discharge of 62 m^3/s on 15 June. Conversely in 2003 the highest weekly larval fish density (79 fish/100 m^3) also occurred in mid-June and did not immediately follow the peak in discharge of 70 m^3/s on 12 May. Major differences in larval fish densities associated with differences in the duration and timing of the peak discharges in 2002 and 2003 supports the idea that the timing of the peak was important for the spawning of native resident and migratory fish species.

INTRODUCTION

For many native riverine fishes, spawning is associated with an annual increase in spring discharge. Magnitude of discharge (Hynes 1970), duration of discharge (Koel and Sparks 2002), receding discharge (Robinson et al. 1998), floods (Matthews 1998), and associated increased turbidity (Fausch and Bestgen 1997) have all been implicated as important for reproduction of different large river species. Different species have evolved distinct responses to major predictable patterns of the hydrograph in large rivers.

For example, fishes such as the Centrarchidae rely on the firm substrate made available by newly flooded areas (Koel and Sparks 2002), whereas other species such as the freshwater drum *Aplodinotus grunniens* use the high discharge to carry their eggs and larvae to rearing areas (Koel and Sparks 2002), and others such as the fathead minnow (*Pimephales promelas*) wait until discharge decreases to spawn (Gale and Buynak 1982). As a result of these adaptations, spawning success for a given species can exhibit large annual variations with inter-annual and intra-annual variations in the discharge.

One method of assessing reproductive success of riverine fishes is to estimate relative abundance of larval fish. In the modified lower Missouri River, (Missouri) Brown and Coon (1984) found tributaries habitat critical for the early life stages of the fishes. In the Cahaba and Tallapoosa River, Alabama, Scheidegger and Bain (1995) found flow regulation limited abundance of larval fish in rearing habitat. In the Murray-Darling Basin, Australia, Humphries and Lake (2000) found that even with yearly variations in flow, most species spawned each year.

In the lower Milk River, Montana information on larval fish abundance and composition was collected from 1979 to 1981 on the first 10 km of the river above its confluence with the Missouri River (Gardner and Stewart 1987). However, little information is known on the abundance, composition, and reproductive success of larval fish in relation to spring discharge in the lower 197 km of the Milk River. The objective of this study was to investigate temporal and spatial distribution of larval fish in the lower Milk River in relation to river discharge.

METHODS

Larval fish samples were taken weekly during daylight hours (weather permitting) from mid-May to mid-Aug 2002 and 2003. The sampling effort began two weeks earlier in 2003 than in 2002, but ended at the same time.

Larval fish were sampled with 0.5 m x 1.8 m long conical nets (750 um Nitex mesh) with attached buckets and weighted with two 4.5 kg lead weights (Kelso and Rutherford 1996). A General Oceanics 230 OR flow meter was suspended in the mouth of the net to permit estimation of total water volume sampled (Kelso and Rutherford 1996). Two nets were placed on either side of the bow of the boat and released simultaneously into the water for ten min with the boat idling upstream. Samples were taken where the nets could be suspended in the water column without dredging bottom sediment. After each tow, the cod-end cups were removed and the water drained out. The contents were placed whirl-pak bags and a mixture of 10% formalin and Phloxene-B, a chemical dye, was added to stain the larval fish. The sample was then stored in an airtight container and returned to the laboratory.

In the laboratory, each sample was sorted and all larval fish were placed in a vial of 5% formalin. Prior to identification, a larval fish key was constructed for the species known to inhabit the Milk River. The key was constructed using information from Auer (1982), Holland-Bartels et al. (1990) Wallus et al. (1990) and Kay et al. (1994). Based on information in the key, larval fish were identified to the lowest taxonomic level possible, which was typically to genus.

Data analysis

Each sample of larval fish was converted into an estimate of total fish density per 100m^3 of water and the two samples from each tow were combined into one sample. The negative binomial generalized linear model (goodness of fit $\chi^2 = 1.2$) was used because the results of the preliminary analysis showed that the data were not distributed normally (McCullagh and Nedler1989; Power and Moser 1999; SAS Institute Inc. 1999; Agresti 2002). Two models were used to describe differences among temporal and spatial distribution of larval fish densities because there were too few parameters in a combined model with both year and week. Model one included year, location, and site and model two included weeks, location, sites, and turbidity. The results of the two separate models were dependent on each other. Calculations were performed using SAS (SAS Institute 1999).

To compare magnitude and duration of spring discharge (1 May to 15 August) among years 1940-2003, daily discharge measurements were obtained from the U.S. Geological Service gauging station (06174500) on the Milk River near Nashua, Montana. the year 2002 was chosen as an index. In 2002, the mean discharge from 9 June to 18 July, the period of high discharge (Figure 1) was 32 m^3/sec. For each year, the number of days from 1 May to 15 August above 32 m^3/sec was calculated. The frequency of days above 32 m^3/sec for each year was then plotted (Figure 2).

RESULTS

Estimated total larval fish density was 23 times higher in 2002 (9,218 fish/100 m^3) than in 2003 (390 fish/100 m^3) (Figure 3). Densities in locations 2, 3, and 5 were also significantly higher in 2002 than in 2003 (Figure 4). Locations 1 and 6 had low densities in both years. Larval fish density was significantly different between years and among locations (P=0.001), but not among sites at each location (P=0.736). Larval fish density was significantly different among weeks (P<0.001), turbidity (P=0.0052), and locations (P<0.001), but not among sites at each location (P=0.6225).

The difference in densities between 2002 and 2003 was associated with distinct differences in the timing and duration of the spring seasonal discharge patterns near Nashua, Montana between May and mid-August (Figure 1). In 2002, increased spring discharge lasted for 41 days, peaking at 62 m^3/s on 15 June and at 78 m^3/s on 28 June and returning to <10 m^3/s on 18 July. In 2003, increased spring discharge lasted for only 17 days, and occurred much earlier, peaking at 70 m^3/s on 12 May, and returning to <10 m^3/s on 28 May. The later peak in spring discharge in 2002 was associated with higher seasonal precipitation in 2002, whereas the peak in 2003 was associated with runoff from snow melt.

More taxa were found in 2002 (14) than in 2003 (9). Taxa identified at species level in 2002 included two species of concern, paddlefish (*Polyodon spathula*) and blue sucker (*Cycleptus elongatus*) as well as river carpsucker (*Carpiodes carpio*), shorthead redhorse (*Moxostoma macrolepidotum*), carp (*Cyprinus carpio*), goldeye (*Hiodon alosoides*), perch (*Perca flavescens*), freshwater drum (*Aplodinotus grunniens*), and lake whitefish (*Coregonus clupeaformis*) (Table 1). Taxa identified to genus included buffalo *Ictiobus* spp., *Catostomus* spp., and crappie *Pomoxis* spp. Taxa identified to family included Centrarchidae, other Catostomidae, and other Cyprinidae. In 2003, taxa identified to species included channel catfish (*Ictalurus punctatus*), river carpsucker, shorthead redhorse, carp, and freshwater drum. Taxa identified to genus included *Ictiobus spp.*, and *Catostomus* spp. Taxa identified to family included other Catostomidae and other Cyprinidae.

Larval fish taxa were categorized as carp, buffalo, river carpsucker, freshwater drum, other Cyprinidae (except carp), goldeye, shorthead redhorse, and all other fish. Location 2 had the highest larval fish densities of five taxa (buffalos, river carpsucker, freshwater drum, other Cyprinidae, and other fish; Figure 5). Location 1 had the highest density of shorthead redhorse, location 5 had the highest density of carp, and location 6 had the highest density of goldeye. All taxa except shorthead redhorse had significantly higher larval fish densities in 2002 than in 2003 (Figure 6).

A peak in weekly larval fish density of 4,433 fish/100 m^3 occurred in mid-June of 2002, where no comparable peak occurred in 2003 (Figure 7). Peak larval fish densities occurred soon after peak in discharge in 2002, but not in 2003 (Figures 1). The highest weekly larval fish density (4,433 fish/100 m^3) immediately followed the initial discharge peak on 15 June and the second highest weekly larval fish density (1,879/100 m3) immediately followed the second peak on 28 June (Figure 1). In 2003, the highest weekly larval fish density (79 fish/100m^3) occurred in mid-June and did not immediately follow the peak in discharge on 12 May (Figure 7).

In 2002, carp, buffalo, river carpsucker, and other fish densities peaked in mid-June (Figure 8). Goldeye, freshwater drum, and shorthead redhorse densities peaked in July. Density of other Cyprinidae peaked in late July.

DISCUSSION

The 23-fold higher density in 2002 than in 2003 was associated with distinct differences in seasonal discharge between the two years. In 2002, a longer duration of increased spring discharge occurred later in the spawning season than in 2003, whereas a shorter duration of increased spring discharge occurred early in the spawning season as a result of normal levels of seasonal snowpack (Figure 2). Similar patterns of discharge and fish reproductive success have been found elsewhere. For example, Schlosser (1985) found juvenile fish densities in Jordan Creek, Illinois 5.8 times greater in August in a year of above-normal discharge than in a year of stable, below-normal, discharge. For Great Plains rivers, the successful development and survival of larvae of some fish species is dependent on the ability of species to spawn with high discharge (Fausch and Bestgen 1997). For example, fish that spawn during the rising hydrograph release eggs that become semi-buoyant and are thus protected from abrasions with bottom substrate as they disperse downriver (Fausch and Bestgen 1997). Increased discharge also enhances dispersal of eggs and larvae into shallow water habitat for rearing. Peterson and Vanderkooy (1995), found that fish in Luxapalilia Creek, Mississippi used upstream riffle habitat to spawn and that the larval fish drifted downstream to areas with shallow water rearing habitat.

The relationship between increases in discharge and spawning activity on the Milk River is also supported by other research on Milk River adult fish. Observed movements of Missouri River adult migratory fish species into the Milk River overlapped with changes in the hydrograph in 2002 and 2003. Most catches of adult blue sucker, shovelnose sturgeon, and paddlefish in the Milk River occurred after the initial rise of the hydrograph in early June, 2002 (Bednarski and Scarnecchia 2003). In another concurrent study on the Missouri and Milk Rivers, fifteen radio-tagged blue suckers and one shovelnose sturgeon entered the Milk River on the rising limb of the hydrograph in early May, 2003. All of the blue suckers exited on the descending limb of the hydrograph (D. Fuller, Montana Department of Fish, Wildlife, and Parks, Personal Communication, 2004).

The major differences in larval fish densities in relation to differences in the timing of the peak discharges in 2002 and 2003 supports the idea that the timing of the peak, and not just any rise at any time, was important for the spawning of native resident and migratory fish species. The greatest weekly larval fish density for 2003 did not coincide with the peak in spring discharge, but occurred later, at the same time as the maximum larval fish density in 2002. The importance of discharge timing was also noted in an earlier study (1979–1982) on the Milk River by Gardner and Stewart (1987). In their 4-year study of the lower most 10 km reach, two of the four years (1979 and 1982) had average to above-average levels of spring discharge and two years (1980 and 1981) had below-average levels of spring discharge (Figure 9). The first and fourth year (1979, 1982) had more days above 32 m^3/s than 2002 (Figure 2), but the peak in 1979 was in early May whereas the peaks in 1982 and 2002 were in mid-June. In general, the timing of the increased spring discharge influenced the annual abundance of larval fish; the number of larval fish per sample was 41.3 in 1979 and 228.8 in 1982. Between 7 June and 7 July the discharge level exceeded 32 m^3/s for only two days in 1979, whereas the increased discharge exceed 32 m^3/s for 18 days in 1982, and 16 days in 2002 (Figure 10).

Other investigations have also concluded that changes in the timing of increased spring discharge affect the abundance, composition and assemblage of native riverine fishes (Ward and Stanford 1989).

The higher abundance of many larval fishes associated with high discharge in June may be the result of evolved responses to typical discharge patterns of Great Plains rivers. At the latitude of the lower Milk River most native fish species spawn late May to early August. In such a situation, the more predictable rising hydrograph from yearly snow melt may trigger movement of spawners in preparation for the later rise in discharge produced by seasonal precipitation. In the lower Milk River study area, the month of June has the highest seasonal rainfall with 21.5% of the yearly total precipitation (Western Regional Climate Center 2001). Prior to flow regulation, the Milk River spring hydrograph most likely had two distinct peaks, the first from mountain and highland snow melt and the second from seasonal precipitation (Figure 11), which would follow the pattern of a natural hydrograph for rivers in the Great Plains. Prior to regulation, the Missouri River also generally had two peaks in spring discharge, the first typically in April from snow melt and the second typically in June from seasonal rainfall (Pflieger and Grace 1987). The earlier peak may be more beneficial for earlier spawning species such as sauger, which are known to spawn in the Milk River (Gardner and Stewart 1987), but spawn too early to be sampled in this study. A later peak provides good spawning conditions for other species, such as the goldeye and freshwater drum as observed in 2002 with its greater species richness than in 2003.

In Great Plains rivers, where annual quantity and timing of discharge vary greatly, the wide array of species present with different life histories may thus result in conditions favorable to one species in one year, and another species the next. This naturally variable flow regime can support diverse assemblages of native species (Cross and Moss 1987; Pflieger and Grace 1987; Matthews 1988). For regulated reaches, it therefore may be critical to maintain variable annual flow regimes for a diverse native species assemblage (Bowen et al. 1998). In Alabama, Scheidegger and Bain (1995) observed that the total catch of larval fish was more than three times greater in the unregulated Cahaba River than in a flow-regulated Tallapoosa River. They found that flow regulation negatively impacted larval fish habitat and diversity of native river fish. In years, such as 2002, where the Milk River exhibits remnant features of a Great Plains river with unpredictable increased flows, it continues to provide critical spawning habitat. In contrast to the clear, cold hypolimentic water releases at Fort Peck Dam on the Missouri River, the lower Milk River has been recognized as an important spawning and rearing habitat for the regulated Missouri River (Gardner and Stewart 1987).

Results from this two-year study suggest that spawning success, as indicated by larval fish densities, are influenced by the timing and duration of spring discharge. If so, further reductions in spring discharge would negatively affect resident and native migratory fish species spawning in the Milk River. Additional research is needed on the timing, amount, and duration of spring discharge necessary to maintain spawning populations of native migratory and resident fish species.

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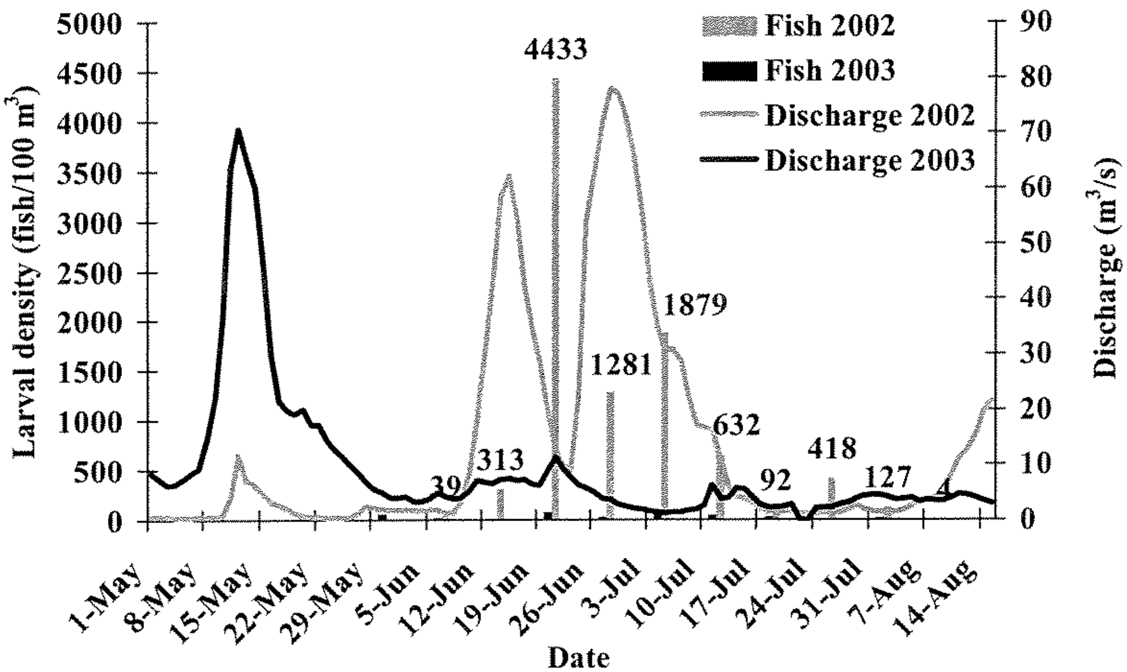


Figure 1. Weekly larval fish/100m^3 (Fish) and mean daily discharge for the lower Milk River from the USGS gauging station (06174500) near Nashua, Montana, 2002 and 2003. Values are weekly larval fish densities for 2002.

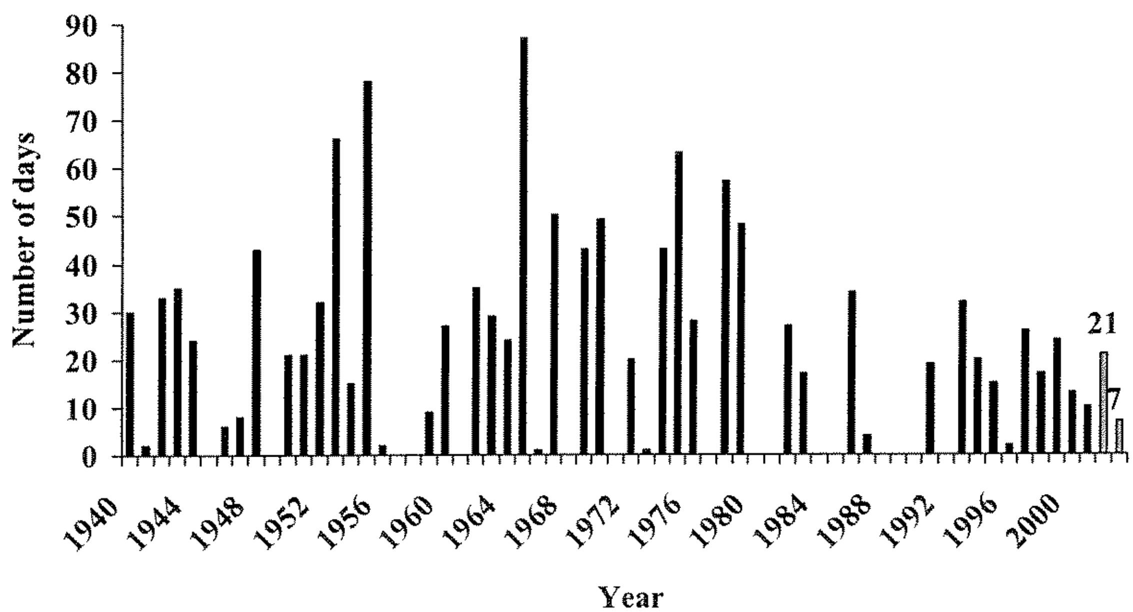


Figure 2. The number of days above the mean discharge rate 32 m^3/s, May-August 1940-2003 for the lower Milk River from the USGS gauging station (06174500) near Nashua, Montana.

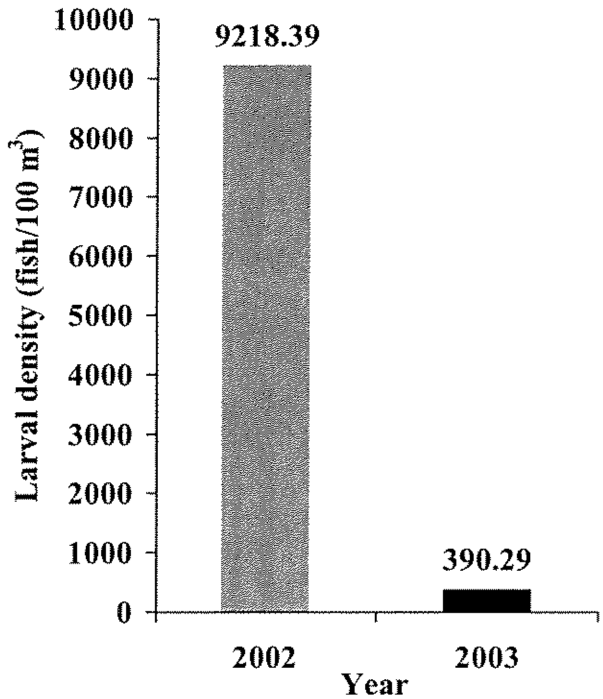


Figure 3. Total larval fish density/100m^3, 2002 and 2003.

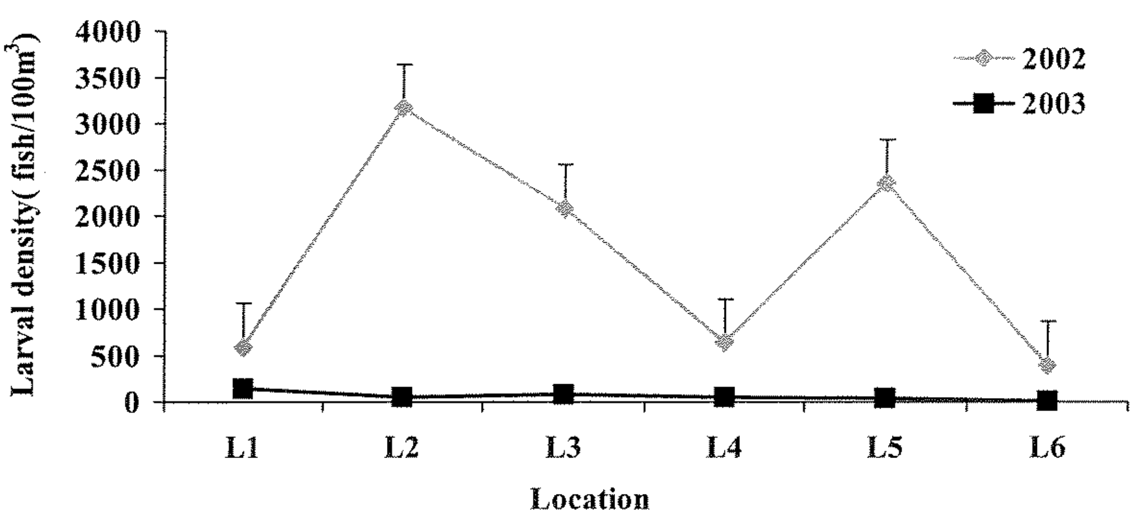
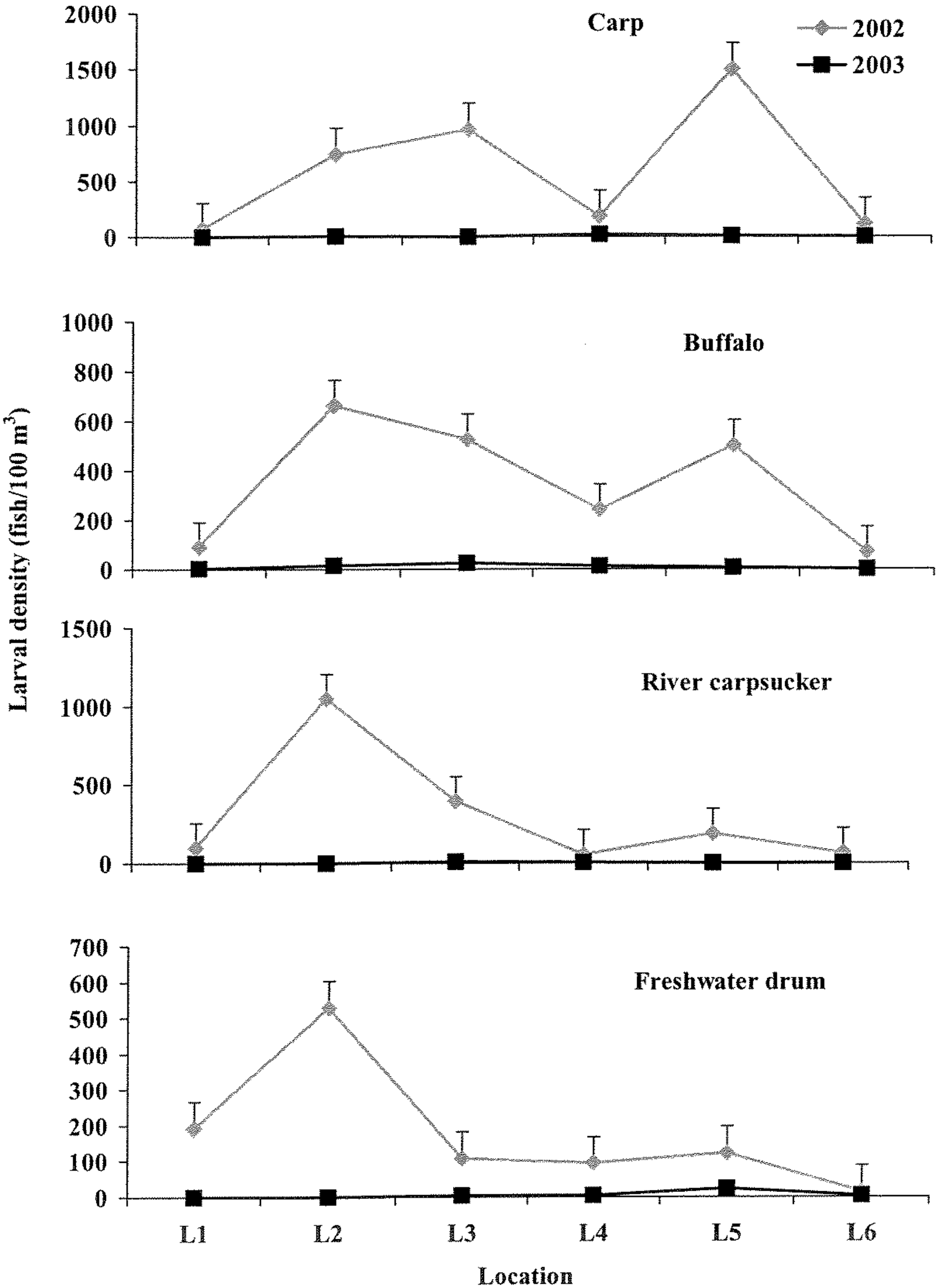


Figure 4. Larval fish densities at sampling locations along the lower Milk River, 2002 and 2003. L1-L6 represents the furthest downstream sampling location to the most upstream location.

Table1. Family, genus, and common name of taxa of larval fish identified in the lower Milk River. An x denotes fish taxa captured in 2002 and/or 2003.

Family	Common name	Genus/species	2002	2003
Polyodontidae	paddlefish	*Polyodon spathula*	x	
	crappie	Pomoxis		
Catostomidae	sucker		x	x
	blue sucker	*Cycleptus elongatus*	x	
	river carpsucker	*Carpiodes carpio*	x	x
	shorthead redhorse	*Moxostoma macrolepidotum*	x	x
	buffalo	*Ictiobus spp.*	x	x
	sucker	*Catostomus* spp.	x	x
Cyprinidae	minnow		x	x
	carp	Cyprinus carpio	x	x
Hiodontidae	goldeyes	*Hiodon alosoides*	x	
Percidae	yellow perch	*Perca flavescens*	x	
Sciaenidae	freshwater drum	Aplodinotus grunniens	x	x
Salmonidae-Coregoninae	lake whitefish	*Coregonus clupeaformis*	x	
Ictaluridae	channel catfish	*Ictalurus punctatus*		x


Carp
2002
2003
2000
1500
1000
500
0
Buffalo
1000
800
600
400
200
0
River carpsucker
1500
1000
500
0
Freshwater drum
700
600
500
400
300
200
100
0
L1
L2
L3
L4
L5
L6
Location
Larval density (fish/100 m3)

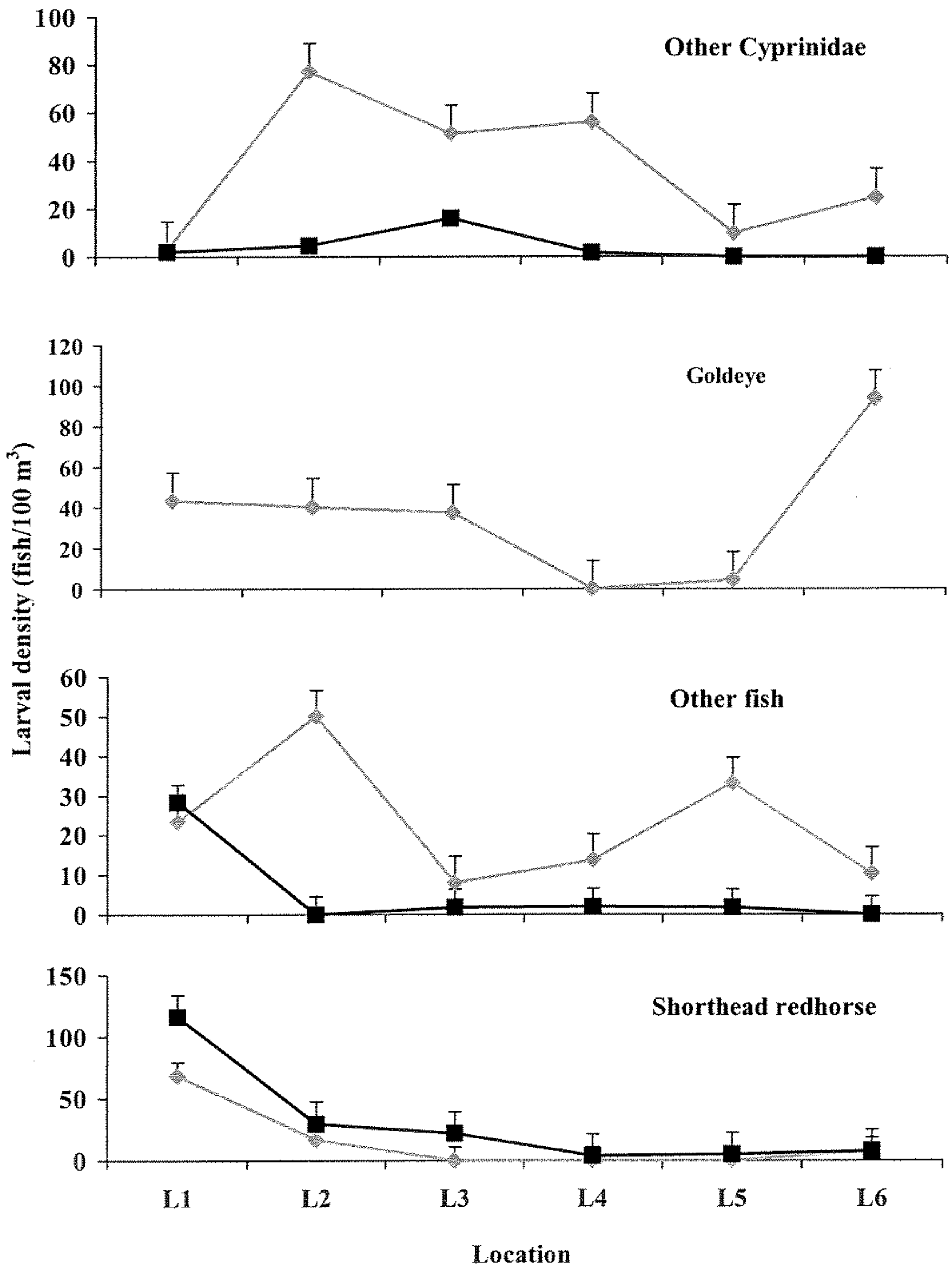


Figure 5. Larval fish densities by taxa at sampling locations along the lower Milk River, 2002 and 2003.

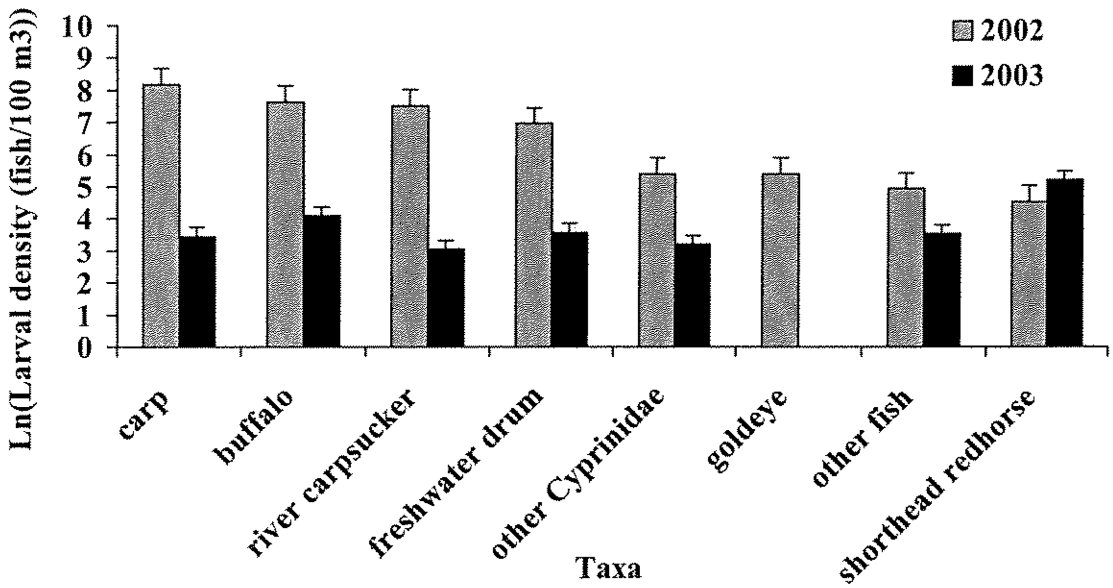


Figure 6. Natural log of total fish densities of selected taxa for 2002 and 2003.

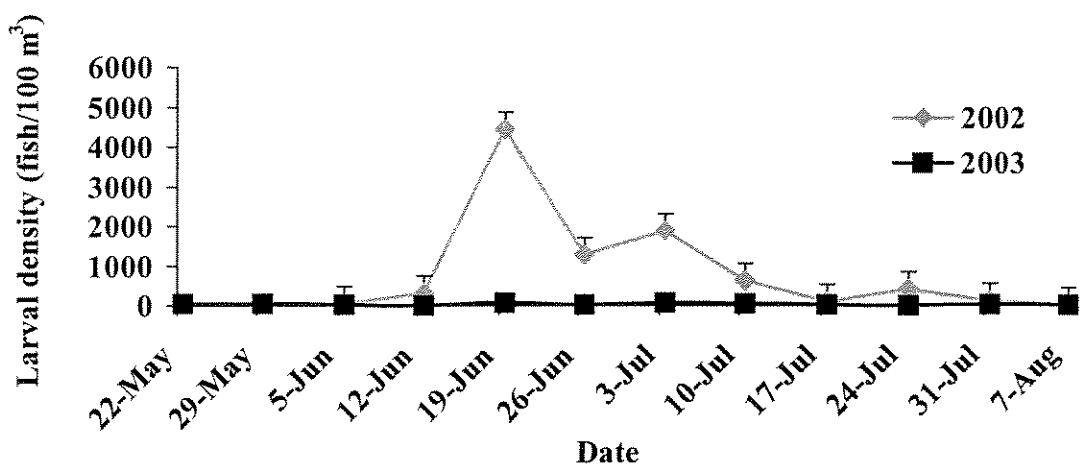
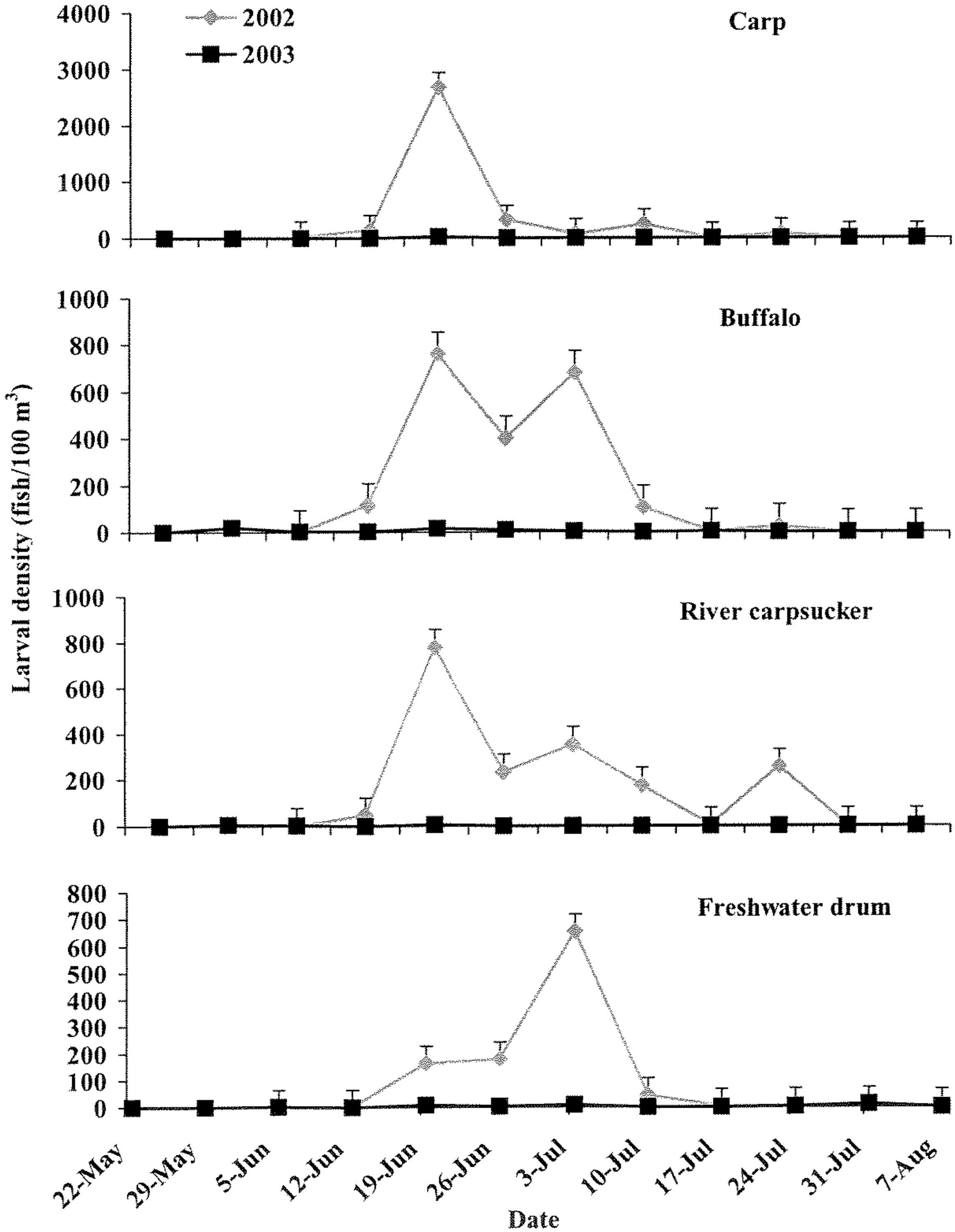


Figure 7. The total weekly larval fish density for 2002 and 2003.


2002
2003
Carp
4000
3000
2000
1000
0
Buffalo
1000
800
600
400
200
0
River carpsucker
1000
800
600
400
200
0
Freshwater drum
800
700
600
500
400
300
200
100
0
Larval density (fish/100 m³)
22-May
29-May
5-Jun
12-Jun
19-Jun
26-Jun
3-Jul
10-Jul
17-Jul
24-Jul
31-Jul
7-Aug
Date

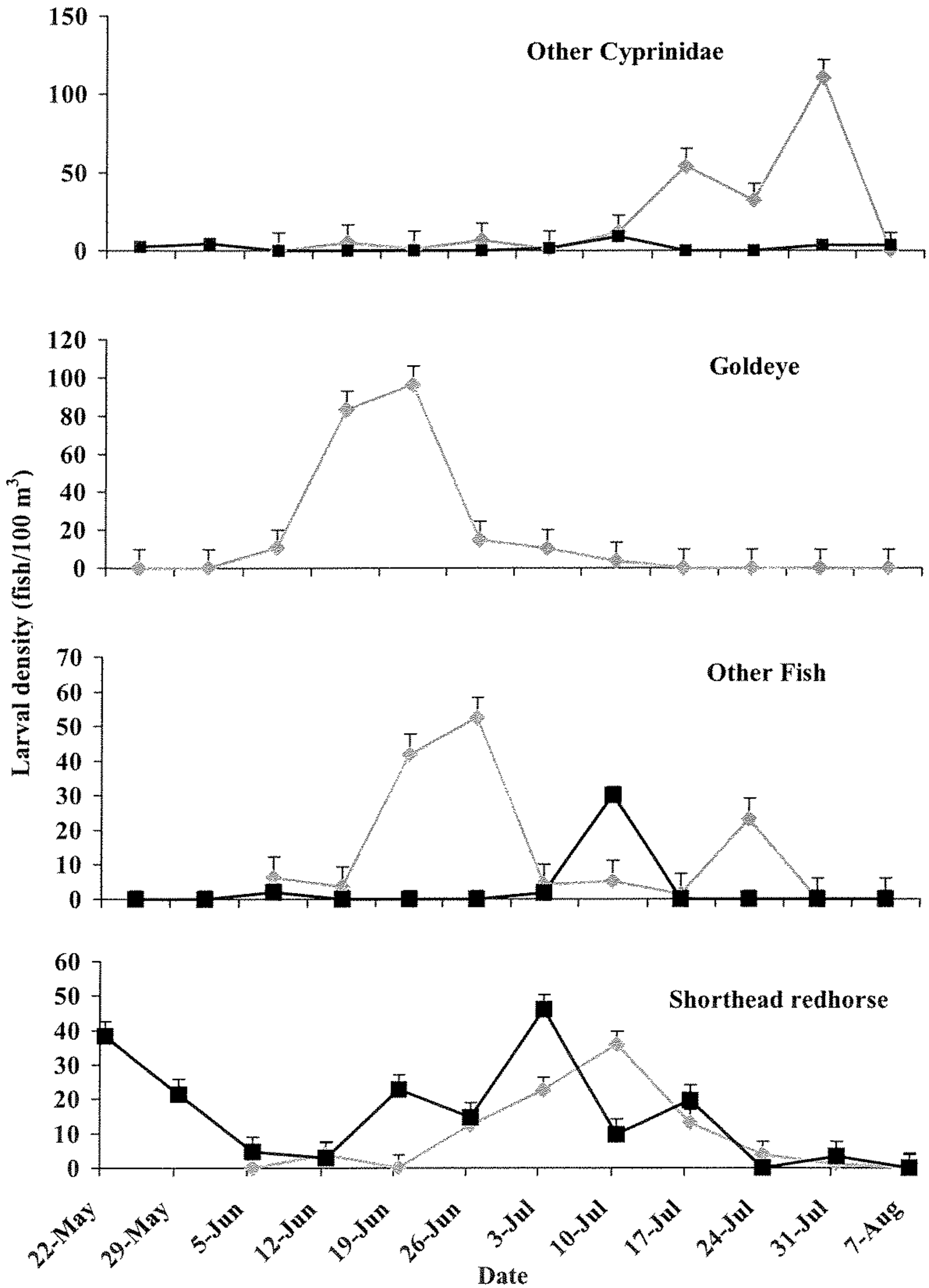


Figure 8. Weekly larval fish densities by taxa 2002 and 2003.

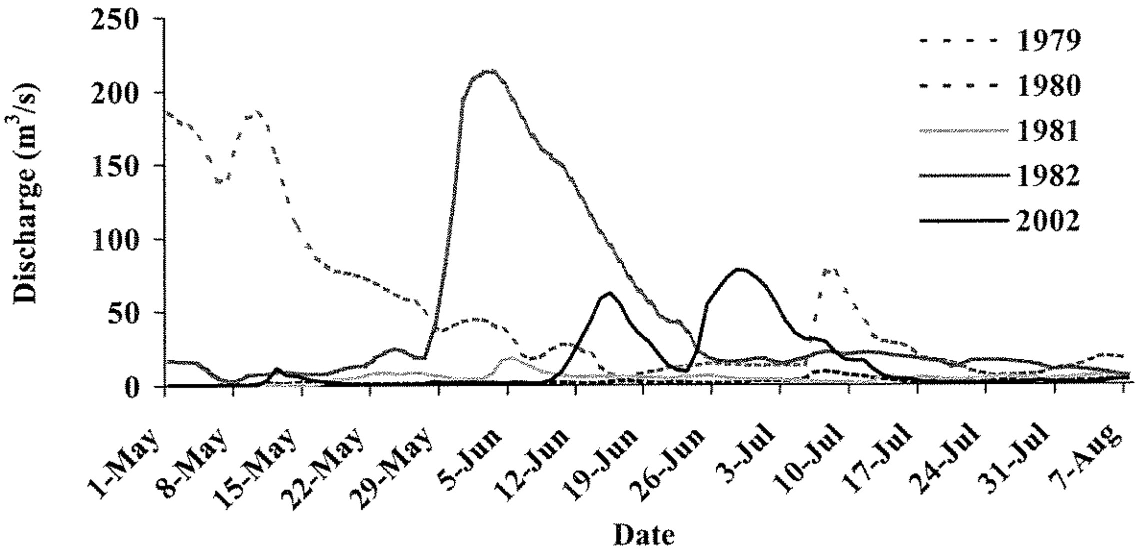


Figure 9. Mean daily discharge for the lower Milk River 1979 to 1982 and 2002 from the USGS gauging station (06174500) near Nashua, Montana.

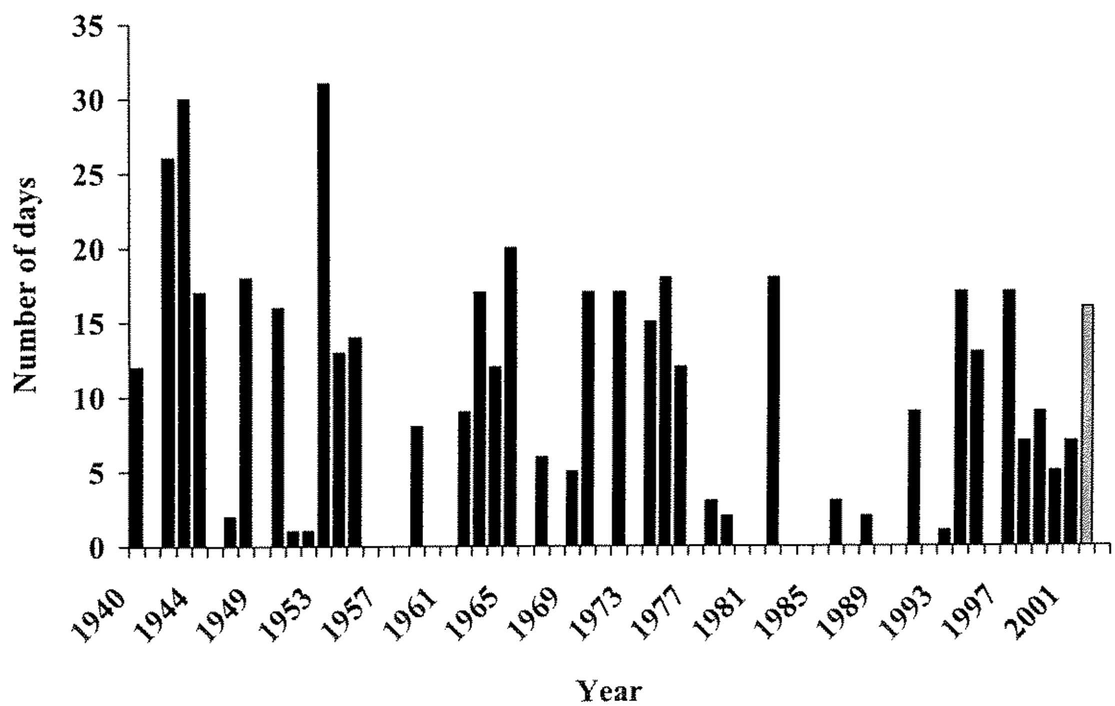


Figure 10. The number of days above the mean discharge rate 32 m^3/s, in June 1940-2003 for the lower Milk River from the USGS gauging station (06174500) near Nashua, Montana.

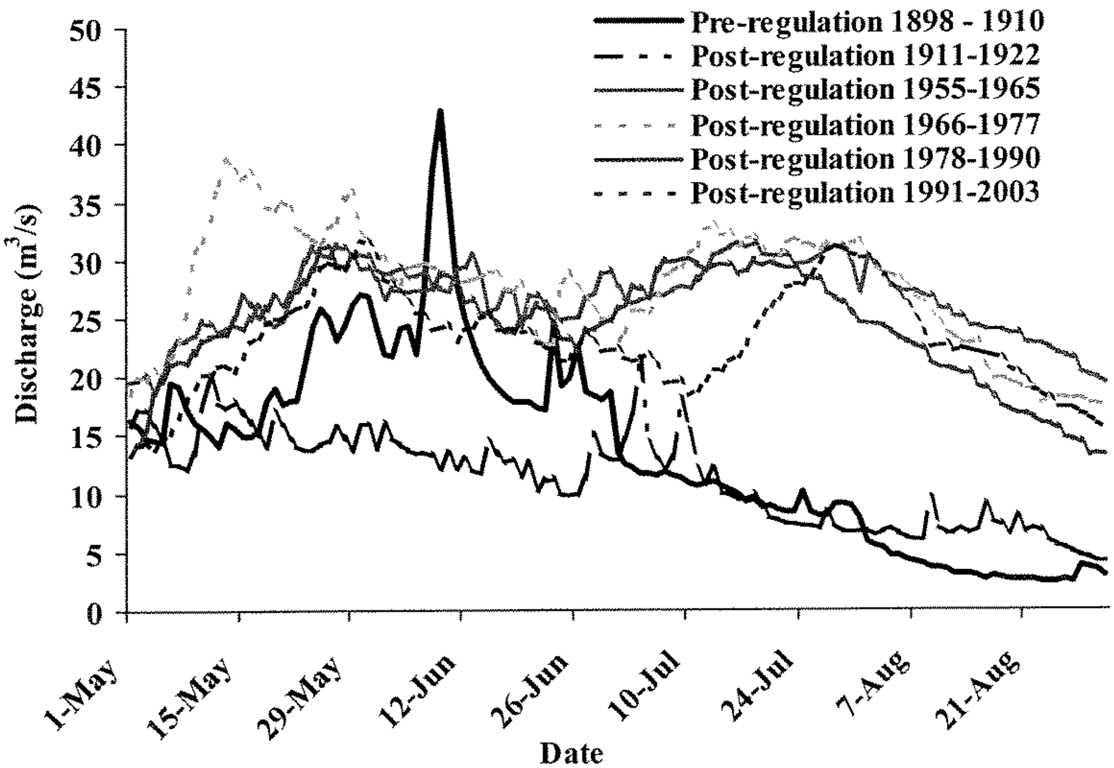


Figure 11. Average mean daily discharge for the Milk River pre-regulation (1898 to 1910) and ten to twelve year averages post-regulation (1911 to 1922 and 1955 to 2003) from the USGS gauging station (06140500) near Havre, Montana.

CHAPTER 2. Life history characteristics of the blue sucker in the lower Milk River, Montana

ABSTRACT

The life history and ecology of the blue suckers (*Cycleptus elongatus*) in the Lower Milk River, Montana were investigated. A total of 253 blue suckers was captured; 249 adult fish, three larval fish, and two age-0 juveniles. The ages (n=102) of the adult fish ranged from 10 to 37 years; maximum age greatly exceeded ages reported in other studies. Fish in the Milk River population evidently grew slower, matured later, and lived longer than fish at lower latitudes. Females were longer and weighed more then males at a given age. The Von Bertalanffy growth equations for length were expressed as $L=752.9(1-e^{-0.1457t})$ for females and $L=695.1(1-e^{-0.1743t})$ for males. The Von Bertalanffy growth equations for weight were expressed as $W=3844.3[(1-e^{(-0.1412t)})^{2.8171}])$ for females and $W=2754.9[(1-e^{(-0.1604t)})^{2.8883}]$ for males. In 2002, 189 fish out of 222 adult fish caught were specifically determined to be reproductively active; 93 females and 96 males. In 2003, one female fish out of 26 fish caught was determined to be reproductively active. Catches of adult blue suckers were highest during periods of high spring discharge as adults migrated into the Milk River to spawn during May and June.

INTRODUCTION

The blue sucker, *Cycleptus elongatus,* is a large cypriniform fish (family Catostomidae) of large river habitats in the Mississippi, Missouri, Pearl, and Rio Grande River drainages (Pflieger 1975; Becker 1983). Although, the species is widespread from

Montana east to Wisconsin and Pennsylvania and south to Alabama and Mexico, it is considered to be rare throughout much of its range (Becker 1983, Elstad and Werdon 1993, Pflieger 1975). It once supported commercial fishing on the Mississippi River (Coker 1930; Becker 1983), but in recent decades it has declined in abundance because of habitat loss associated with construction of dams and other modifications of large river systems (Hesse et al. 1989; Pflieger 1975; Becker 1983; Moss et al. 1983)

In 1989, the American Fisheries Society listed the blue sucker as a species of special concern in 23 states in the United States and three states in Mexico (Williams et al. 1989) and in 1993 it became a Federal Category 2 species, a candidate for threatened or endangered species status (Elstad and Werdon 1993). In the state of Montana, the northwestern portion of their range in the upper Missouri River and tributaries, they are listed as a species of special concern (Holton and Johnson 2003).

Many aspects of the blue sucker life history are poorly known. Information has been elusive because the species typically occupies deep swift water in the main channel (Pflieger 1975), where many conventional sampling methods are not always effective (Moss et al. 1983). Most available information has been on adult fish; juveniles have seldom been captured (Beal 1967; Christenson 1974; Hand and Jackson 2003; Deiterman and Barry 1995; and Morey and Berry 2003).

It is believed that blue suckers migrate prior to spawning to riffles in large turbid tributaries such as the Milk River in the upper Missouri River. The lower 188 km of continuous river, below Vandalia Dam, to the confluence of the Missouri River is characterized by incised channels with well-developed riparian zones and cobble riffles (Stash et al. 2001). Blue suckers have been documented in the lower Milk River as sexually mature adults (Fuller 2002; Stash et al. 2001) and as larval fish (Gardner and Stewart 1987) during the spring and early summer. Age-0 juveniles have been captured in the Missouri River just below the confluence of the Milk and Missouri rivers (Fuller 2000). More information on life history and ecology would improve management capability and clarify the importance of the Milk River for this fish.

The goal of this study was to investigate the life history and ecology of the blue sucker in the lower Milk River, Montana. The specific objectives of this study were to: 1) assess age and growth 2) assess the relationship between spring flows in the Milk River and the year class strength and 3) characterize the spawning in the Milk River in relation to river discharge.

METHODS

Adult Fish Collection

Fish were sampled with a five gears, stationary gill nets, floating gill nets, trammel nets, hoop nets, and bag seines in order to effectively sample the range of species and habitats present (Table 1). Each gear was deployed at least three times per site on the lower Milk River from mid-May to mid-August 2002 and 2003. Stationary gill nets and hoop nets were set overnight. Stationary sinking gill nets were 30 m long by 1.8 m high, and were divided into four equal panels of 1.9 cm, 3.8 cm, 5 cm, and 7.6 cm mesh sizes. Floating gill nets were 150 m in length, by 1.8 m high, with 7.6 cm mesh. Trammel nets were 22.9 m in length with a 2.5 cm inner mesh and a 15.2 cm outer mesh. Hoop nets were 1 m in diameter with a mesh size 2.5 cm. Bag seines were of two sizes: 10.7 m long by 1.8 m tall and 7.6 m long by 1.8 m tall. Both seines had a 1.8m x 1.8m base at the center of net with a 5 mm ace mesh and a "many ends" mud lead line attached. Further details of sampling methods are outlined in Bednarski and Scarnecchia (2003).

Blue suckers were measured to total length to the nearest mm and weighed to the nearest g. The condition factor was expressed as $K=W(10^5)/L^3$, where W=weight and L=length. An analysis of variance (ANOVA) procedure and Tukeys means were used to statistically compare the lengths, weights, and condition factors among females, males, and fish of unknown sex. The presence of mature fish with milt/roe was sought as evidence of spawning activity. The fish sampled were checked externally for maturation. If roe or milt was detectable after gentle pressure was applied to the abdomen, the fish was recorded as ready to spawn.

Age analysis

For age analysis, diagonal pliers were used to cut the first pectoral fin ray as close to the point of articulation as possible (Sappington et al. 1998). Although other studies on the blue sucker have used scales for age determination (Hand and Jackson 2003; Moss and Anderson 1983; Berg 1981; Rupprecht and Jahn 1980) pectoral fin rays were chosen for age analysis because scales are known to underestimate the age of catostomids (Beamish and McFarland 1987). The methods for determining the age from pectoral fin rays followed DeVries and Frie (1996) as modified by to Dingman (2001). Fins were first soaked in distilled water for least 2 h to moisten the attached flesh to facilitate its removal from the fins. The first lead fin ray was glued to a labeled, wooden craft stick, fin ray parallel to the stick, using clear epoxy with the end nearest point of articulation closest to end of the stick. The glued fins were allowed to dry for 24 h before cutting.

Thin sections were cut with a Buehler Isomet Speed Sectioning saw equipped with a 10 cm diameter x 0.3 mm thick diamond-edged wafer blade. The first cut was as close to the proximal end of the fin as possible to create a smooth edge. Four sections were placed on a glass slide and mounted permanently using clear fingernail polish. Sections were viewed under a microscope attached to a Biosonics Optical Pattern Recognition System (OPRS). Annual rings were counted to determine age. No validation of age was possible; one clear ring was assumed to be developed each year. If the sections were not readable a second series of cuts was attempted. Two people (a primary and secondary reader) independently aged sections from each fish. If the disagreement for fish aged between 5 to 10 were within one year, fish aged 11 to 15 were within +/- two years, and fish aged 16 and over were within +/- three years, the age determined by the primary reader was assigned. All other disagreements on the age were determined by a second pair of independent readings. If there was still disagreement after two paired readings, a third reading was made with both people present.

Lengths and weights at age were used to estimate Von Bertalanffy growth curves (Moreau 1987). Separate growth curves were estimated for females and males. Von Bertalanffy growth equations were expressed as $TL=L_{\infty}(1-e^{-kt})$ for total length (mm) and $W=W_{\infty}[(1-e^{-kt})^{b}]$ for weight, where TL is the total length of the fish (mm) at age t, W is the weight (g) of a fish at age t, L_{∞} and W_{∞} are the theoretical limiting size, k is the curvature parameter, and b is the exponent of the length/weight relationship. Because of a shortage of small, young fish the initial condition parameter was set at zero and a two-parameter model was fit. Estimates for Von Bertalanffy growth parameters were calculated in SAS (1999). A log-likelihood ratio test was used to test for differences between female and male growth rates (Kimura 1980).

In order to evaluate if river discharge in spring and year class strength were correlated, estimated ages of fish (n=152) were assigned to a brood year. Catches of blue suckers by age were assumed to be indicative of brood year strengths. Catches were ranked by brood year. Daily discharge measurements were obtained from the U.S. Geological Service gauging station (06174500) on the Milk River near Nashua, Montana. Flows for each year were then ranked based on the number of days in May as well as the number of days in June that flows exceeded 27 m^3/s. The estimated number of fish by brood year from the age determination was plotted against the frequency of days above the May and June mean discharge rate (27 m^3/s) separately for May and June 1964 to 1992. The relationship between catches and flows was evaluated with Spearman's Rank Correlation (Higgins 2004). The same analysis was also conducted using three-year running averages of both ranked catches and ranked flows. By smoothing the ranked catches and ranked flows, data from slightly mis-aged fish might still be useful in assessing any patterns between brood year strengths and flows. For these analyses, only the years 1972 to 1992 were used, based on the assumption that fish from brood years 1972 to 1992 were fully recruited, and that in the absence of a fishery, their lifespan would commonly reach 30 years.

Larval Fish Collection

The second type of evidence sought for assessing the importance of the Milk River for spawning was the presence of larval fish. Larval fish samples were taken weekly from mid-May to mid-Aug 2002 and 2003, during daylight hours. Weather related problems prevented the sampling of some locations in some weeks in 2002. Larval sampling began two weeks earlier in 2003 than in 2002, but ended at the same time. Larval fish were sampled with 0.5 m x 1.8 m long conical nets (750 um Nitex mesh) with attached buckets and weighted with two 4.5 kg lead weights (Kelso and Rutherford 1996). A General Oceanics 230 OR flow meter was suspended in the mouth of the net to permit estimation of total water volume sampled (Kelso and Rutherford 1996). Two nets were placed on either side of the bow of the boat and released simultaneously into the water for ten min with the boat idling upstream. After each tow, the cod-end cups were removed and the water drained out. The contents were placed whirl-pak bags in 10% formalin. Phloxene-B, a chemical dye was added to stain to improve visibility of larval fish and to expedite sorting. In the laboratory, each sample was rinsed and sorted. Larval fish were identified to the species level using a key developed by Kay et al. (1994).

RESULTS

Fish abundance

A total of 253 blue suckers was caught, 225 fish in 2002 and 28 in 2003 (Table 2). By gear, 124 fish were caught in hoop nets, 84 fish in stationary gill nets, 22 fish in floating gill nets, and 18 fish in trammel nets. One juvenile (age-0) was caught in a bag seine, and one juvenile (age-0) and three larval fish were caught in larval nets. Based on extrusion of sex products when handled, in 2002, 189 fish out of 225 fish caught were determined to be reproductively active, 93 females and 96 males. In 2003, one female fish out of 27 fish caught was determined to be reproductively active (Table 2).

Fish Size

Females ranged in length from 634 mm to 806 mm (mean length 722 mm; SE=42 mm) and weighed between 2,100 g and 4,700 g (mean weight 3,302 g; SE=603 g) (Figure 1). The length-weight relationship for females was expressed as $\log_{10}W=-3.66+2.51 \log_{10}L$ ($r^2=0.62$). Males ranged in length from 532 mm to 754 mm (mean length 661 mm; SE=49 mm) and weighed between 800 g and 3,600 g (mean weight 2,267 g; SE=583 g). The length-weight relationship for males was expressed as $\log_{10}W= -4.81+2.89 \log_{10}L$ ($r^2=0.70$). Unknowns ranged in length from 531 mm to 805 mm (mean length 681 mm; SE=103 mm) with weighed between 1,200 g and 4,200 g (mean weight 2,618 g; SE=811 g). The length-weight relationship for unknowns was expressed as $\log_{10}W= -5.3+3.07 \log_{10}L$ ($r^2=0.87$). Lengths and weights were significantly different among females, males, and unknowns ($P<0.05$). Mean condition factors were 0.87 (SE=0.1) for females, 0.79 (SE=0.1) for males, and 0.80 (SE=0.08) for unknowns. Female condition factor was significantly different from males and unknown ($P<0.05$), but males and unknowns were not significantly different ($P>0.05$).

Age and growth

Ages were assigned to 102 fish; 53 females and 49 males. Fin sections typically had the same general pattern of putative annual marks. Females ranged in age from 14 to 37 years, males ranged in age from 10 to 33 years, and unknowns ranged in age from 11 to 33 years (Figure 2). The first eight to ten annuli were widely spaced and then the annuli were tightly packed (Illustrations 1-4).

Females were longer than males at a given age (Figure 3). The Von Bertalanffy growth equations for length were expressed as $L=752.9(1-e^{-0.1457t})$ for females and $L=695.1(1-e^{-0.1743t})$ for males.

The curvature parameter, k, was not significantly different between females and males ($\chi^2=1.77$; 2 df; $P>0.05$). Asymptotic length, L_∞ for females and males was significantly different ($\chi^2=26.35$; 2 df; $P<0.05$). The Von Bertalanffy growth equations for length, with the same fitted k, were expressed as $L=743.1\ (1-e^{-0.1608t})$ for females and $L=702.8\ (1-e^{-0.1608t})$ for males.

Females weighed more than the males at a given age (Figure 4). The Von Bertalanffy growth equation for weight were expressed as $W=3844.3[(1-e^{(-0.1412t)})^{2.8171}]$ for females and $W=2754.9[(1-e^{(-0.1604t)})^{2.8883}]$ for males.

The weight growth curvature parameter, k, was not significantly different between females and males ($\chi^2=1.77$, 2 df, $P>0.05$). Asymptotic weight, W_∞ for females and males was significantly different ($\chi^2=31.30$, 2 df, $P<0.05$). The Von Bertalanffy growth equations for weight, with the same fitted k, were expressed as $W=3844.3[(1-e^{(-0.1604t)})^{3.2587}]$ for females and $W=2819.2[(1-e^{(-0.1551t)})^{3.2587}]$ for males. The Von Bertalanffy growth equations indicated that an age 22 female was 722 mm and 3379 g and that an age 22 male was 667 mm and 2528 g.

Discharge

The timing and duration of the spring seasonal discharge patterns near Nashua, Montana differed greatly between 2002 and 2003 for the period May to mid-August (Figure 5). Increased spring discharge lasted for 41 days in 2002, increasing on 9 June, peaking at 62 m^3/s on 15 June, then dropping and peaking again at 78 m^3/s on 28 June and returning to base flows on 18 July. Increased spring discharge lasted for 17 days in 2003 increasing on 6 May, peaking at 70 m^3/s on 12 May, and returning to base flows on 28 May. The later peak in spring discharge in 2002 resulted from seasonal precipitation whereas the peak in 2003 resulted from snowmelt.

Discharge and catches

Higher catches of adult blue suckers occurred in 2002, the year with higher spring discharge than in 2003, the year with lower spring discharge (Figure 6). On the rising limb of the hydrograph on 10 June 2002, 120 adult fish were caught in two hoop nets. In 2003, in contrast only 26 adult fish were captured, also in mid-June. The three larval blue suckers captured in 2002 were caught on the descending limb of the hydrograph. One larval fish was caught in 21 June and two were caught on 28 June. The two juvenile blue suckers captured in 2003 were caught two months after the peak in discharge. One juvenile was caught on 15 July and the other on 16 July.

Year class strength and discharge

Assuming that the age analysis represented the true brood year, no relationship was evident between year class strength and seasonal discharge (Figure 7). There was no correlation between brood years and May (r= 0.1, p=0.6431, df=21) or June (r=0.13, p=0.6431, df=21) discharge (Figure 8). Also there was no correlation between the running averages of brood years and May (r=0.48, p=0.2685, df=7) or June (r=0.15 p=0.7556, df=7) discharge (Figure 9).

DISCUSSION

Age and growth

The estimated ages of the blue suckers in the Milk River (females 14–37, males 10-33) were much greater than fish the reported in other locations. Maximum ages determined from scales were 10 in the Neosho River, Kansas (Moss et al. 1983), 13 in the Yazoo River, Alabama (Hand and Jackson 2003), and 17 in the Missouri River, Montana (Berg 1981). The differences in age between this study and others may result in part from the use of pectoral fin rays rather than scales for aging. Although previous age studies on the blue suckers have used scales to determine age, Rupprecht and Jahn (1980) compared scales and pectoral fins rays and found age discrepancies of up to three years greater in pectoral fin rays after the age of seven. The age determination method of blue suckers for this study has not been validated, but photographs from fin ray sections show the apparent longevity of these fish (Illustrations 1-4), especially the differences between the smaller, presumably young fish (Illustration 1) and the larger, presumably older fish (Illustration 4).

This general pattern of early growth in the first decade followed by slow growth afterward for many years is similar to that observed in paddlefish *Polyodon spathula* (Scarnecchia et al. 1996) and shovelnose sturgeon *Scaphirhynchus platorynchus* (Everett et al. 2003) in the upper Missouri River system. The older ages of mature females (minimum age-14) to the younger ages of mature males (minimum age-10) is also consistent with the paddlefish and shovelnose sturgeon, evidently females mature later than males and as a result reach larger sizes than the males. This pattern has been well documented for both the paddlefish and sturgeon (Scarnecchia et al. 1996; Everett et al. 2003).

A second possible cause of the older fish in the study than elsewhere maybe the tendency for fish at higher latitudes to grow slower, mature later, and live longer than fish at lower latitudes (Nikolsky 1963). This pattern has also been observed in growth and maximum age of channel catfish *Ictalurus punctatus* in the Yellowstone River compared to stocks further south (Starkey and Scarnecchia 1999).

If ages of blue sucker in all of the studies are accurate Milk River blue suckers are taking longer to reach a given length and weight, and also delaying maturation and living longer than fish in other populations. In the Neosho River, Kansas reproductively ready mature males 507 mm were as young as age-3 (Moss et al. 1983) and in the Mississippi River, Iowa reproductively ready males 503 mm were as young as age-4 (Rupprecht and Jahn 1980) whereas fish at similar lengths in the Milk River were age-10. The blue suckers in the lower Milk River are thus slower growing, longer-lived and later maturing than in lower latitudes. Because of this slower growth and later maturation, blue suckers in the Milk River may be less resilient; once depleted, they would take longer to recover.

The long life span may also explain why so few young blue suckers have been found in the Upper Missouri River over the past three decades (Gardner and Stewart 1987; Fuller 2000, 2002). Reproduction may be very scant and irregular and the stock may persist because of the long life span of its members once they have been recruited. If reproduction occurs at low levels over several years each decade, strong year class peaks would not manifest themselves in analysis of brood years (Figure 6). Conversely, if reproduction occurs only rarely each decade, strong year class peaks may exist, but may not be exactly detectable in an analysis of brood years if age determination is not sufficiently accurate.

Timing

The timing and size distribution of the blue suckers caught were indicative of a migratory run of adult fish associated with high spring discharge. Several types of evidence support this interpretation. First, in 2002, more than half of the fish were captured on the increasing limb of the hydrograph (Figure 5). Of the 177 known reproductively active fish caught in 2002, 174 were caught between 20 May 2002 and 18 June 2002, which coincided with the period of high discharge. In contrast, few fish were captured when there was a low, stable hydrograph in 2002 and 2003. Secondly, the size distribution for 247 adult fish caught (531 mm and 806 mm) was consistent with sizes of fish caught in previous sampling conducted on the Milk River (Gardner and Stewart 1987; Fuller 2000 and 2002; and Stash et al. 2001). Third, a high fraction of fish was caught in just two hoop nets, which indicates that they were traveling together. Evidence of group movements also comes from telemetry. In 2003, the Montana Department of

Fish Wildlife and Parks tracked the movements of fifteen blue suckers radio-tagged in the Missouri River into the Milk River around 7 May on the rising limb of the hydrograph. All the fish exited on the descending limb of the hydrograph about 15 May, and within a week of exiting the Milk River 12 of the fish traveled more than 350 km, two traveled more than 414 km, and one traveled 545 km up the Yellowstone River (D. Fuller, Montana Department of Fish, Wildlife, and Parks, Personal Communication 2004). The absence of smaller sized fish (i.e. 100 mm to 500 mm), the seasonal trends in catches of adults, and the movements of radio-tagged fish suggest that adult blue suckers migrate in groups into the Milk River during the spring. The presence of milt and roe indicates that also indicated that they were ready to spawn.

This pattern of migratory spawning behavior associated with high spring discharge is common in many riverine species. In the James River, South Dakota, spawning blue suckers were found associated with average to above average flow and no blue suckers were found in a year with below average flow (Morey and Barry 2003). Modde and Irving (1998) found that the spawning migration of the razorback suckers *Xyrauchen texanus* in the middle Green River, Utah was similarly influenced the by increases discharge and temperature. This pattern has also been noted for other sucker species including the quillback *Carpiodes cyprinus* (Parker and Franzin 1991) and white sucker *Catostomus commersoni* (Barton 1980).

Movement of reproductively active adults into the Milk River during the increased hydrograph was followed by evidence of successful spawning. Larval fish were captured on the descending limb of the hydrograph (2002) in mid to late June and the age-0 juvenile fish were captured two months after the peak in the hydrograph (2003).

Brown (1989) found 41 yolk sac larvae three days after a peak in the hydrograph in the Lamine River, Missouri and Moss et al. (1983) found age-0 juvenile fish 100 mm long by midsummer in the Neosho River, Kansas.

Despite the indication that more blue suckers were present for spawning in 2002, when flows were higher for longer periods, than 2003, when flows were lower, no correlation was found between brood year strengths (as indicated by catches) and either May or June flows. Running averages of catches and flows also yielded no positive relationships. Several reasons may account for the lack of positive relationships. First, catches may not actually represent brood year strength. Secondly, age determination is only approximate, and mis-aged fish may make the detection of a relationship difficult. Thirdly, the relationship between brood year strength and flows may not be adequately expressed by the flow index used (i.e. the rank of the number of days with flows above 27 m^3/s). For a more reliable brood year analysis to be calculated, validated brood year strength data should be used, age determination should also be validated, and more information should be obtained on how migration and spawning of blue suckers are influenced by flows. Until then it is not possible to either conclude or dismiss the hypothesis that flows and brood year strengths are correlated.

Results from this two-year study indicate that reproductively active adult blue suckers make spawning migrations into the Milk River during periods of increased spring discharge. A water development project has been proposed that would divert water from Milk River during high spring flows into an off-stream storage reservoir with up to 74 million m^3 capacity decreasing the magnitude of increased spring flows. Because it is thought that reduced velocities caused by dam construction could be responsible for the decline the abundance of the blue sucker species (Pflieger 1975) timing their spawning with increases in spring discharge could be essential for reproduction. Any further changes made to the already greatly altered Missouri River-Milk River hydrosystem could further impede the spawning and reproductive ability of this species.

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Table 1. Habitats where specific fishing gears were used to collect blue suckers in the Milk River.

	Run		Riffle	
Gear	Low flow	High flow	Low flow	High flow
Stationary gill net	x			
Trammel net	x	x		x
Hoop net	x	x		
Bag seine			x	
Electrofishing	x	x		x
Floating gill net				x
Larval fish net	x	x		

Table 2. Total catches of blue suckers by gear type, sex, and reproductive status in the lower Milk River 2002 and 2003.

	2002				2003				
		Ripe				Ripe			Grand
Gear	Unknown	Female	Male	Total	Unknown	Female	Male	Total	Total
Hoop	12	59	53	124					124
Stationary gill	17	17	27	61	22	1		23	84
Floating gill		11	11	22					22
Trammel	4	6	5	15	3			3	18
Seine					1			1	1
Larval	3			3	1			1	4
Total	36	93	96	225	27	1		28	253

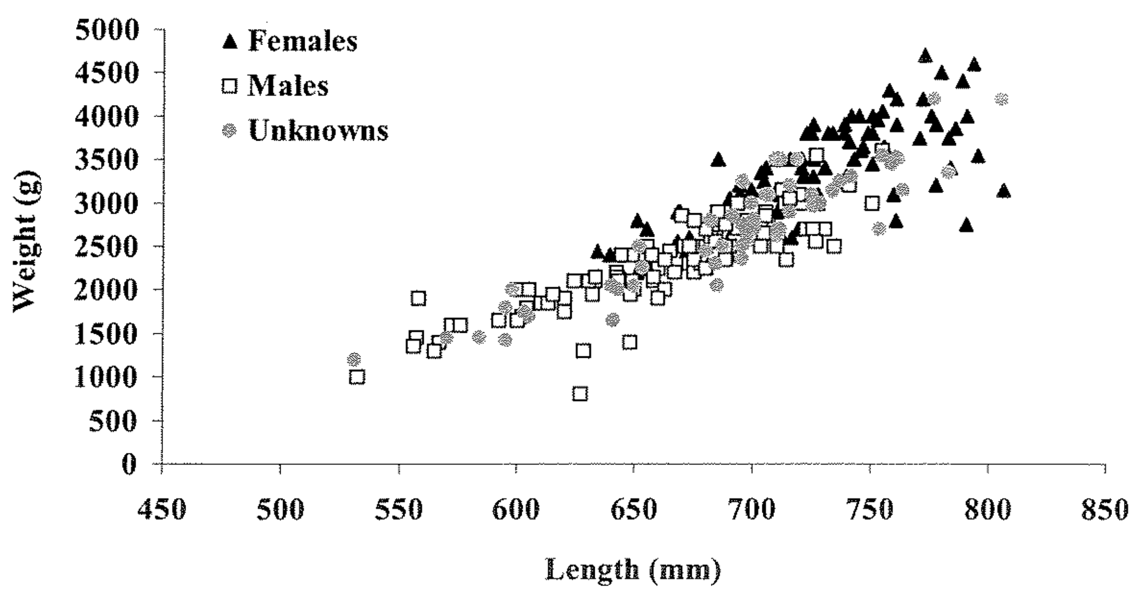

Figure 1. Weight length relationship for females, males, and unknowns.

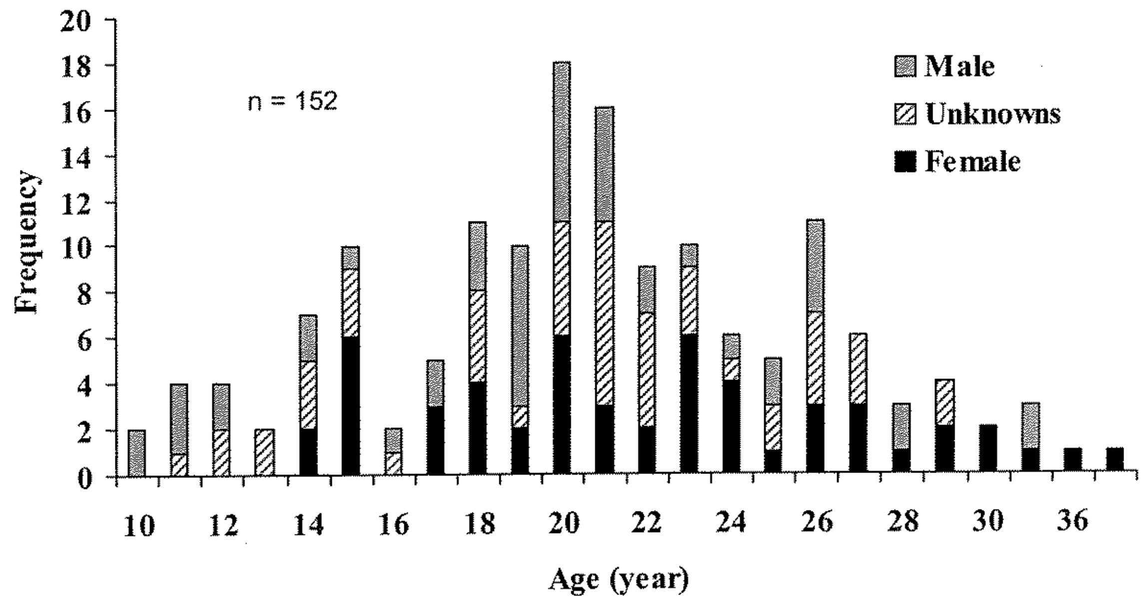

Figure 2. Age frequency distribution of blue sucker and the contribution of females, males, and unknowns to each age in the lower Milk River study, 2002 and 2003.

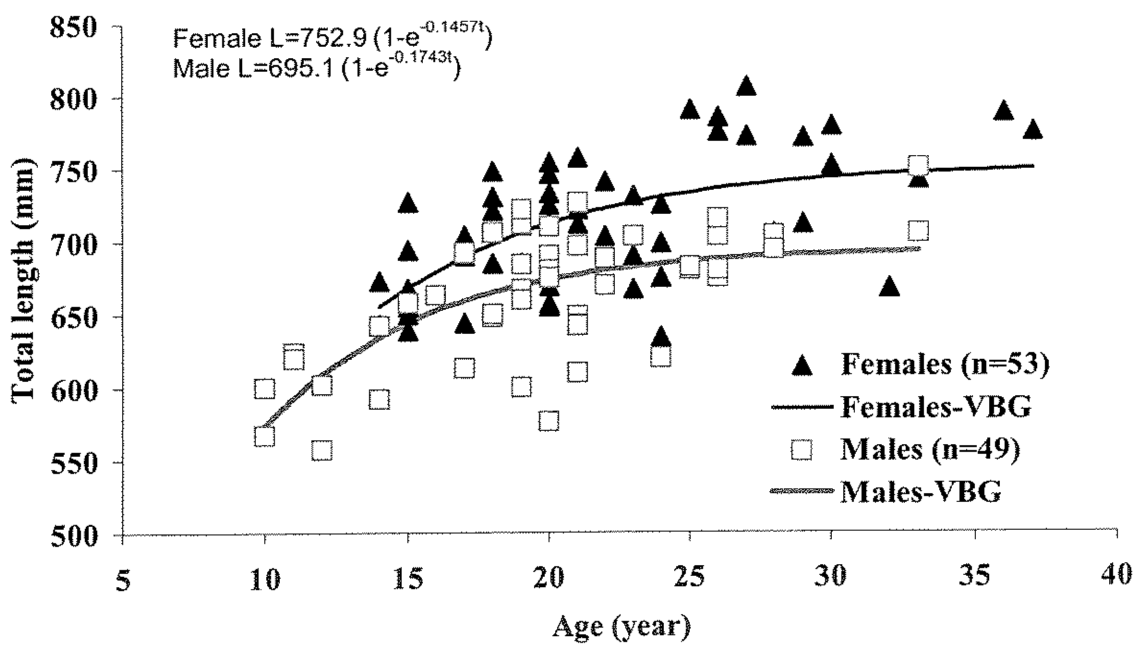

Figure 3. Length at age and the Von Bertalanffy growth curve for the blue suckers in the Milk River.

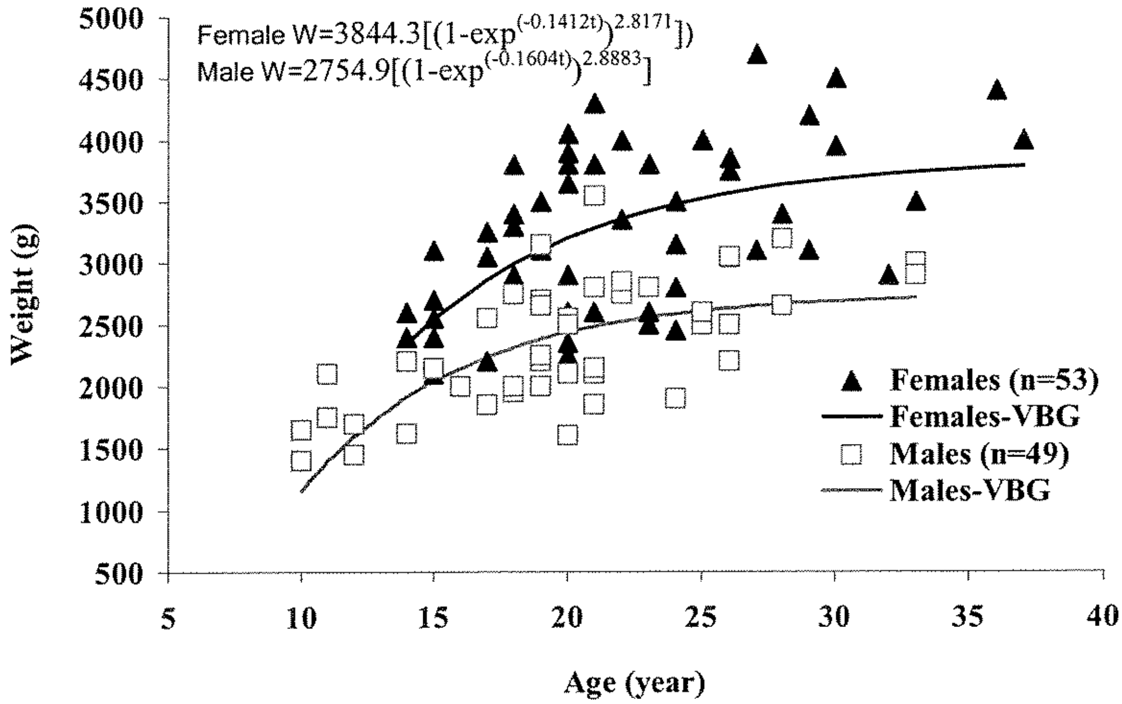

Figure 4. Weight at age and the Von Bertalanffy growth curve for the blue sucker in the Milk River.

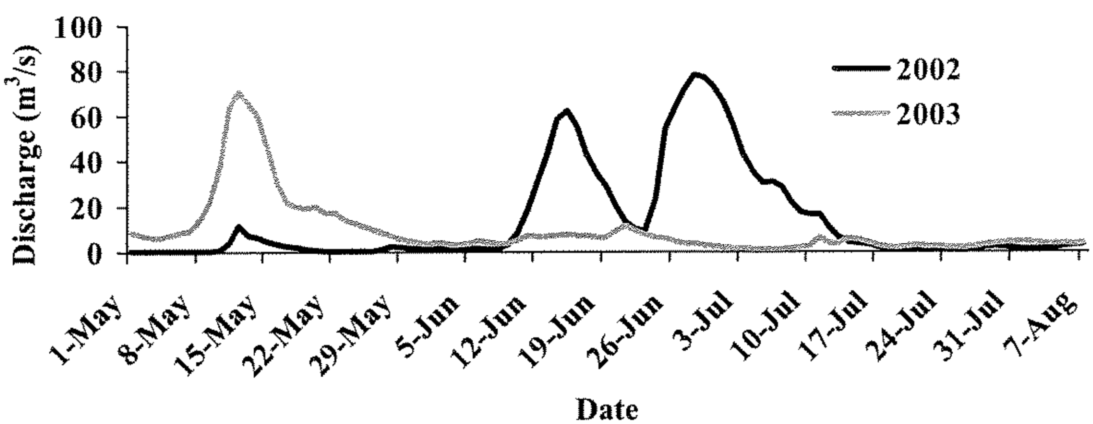

Figure 5. The discharge at the U.S.G.S. gauging station (06174500) near Nashua, Montana 2002 and 2003.

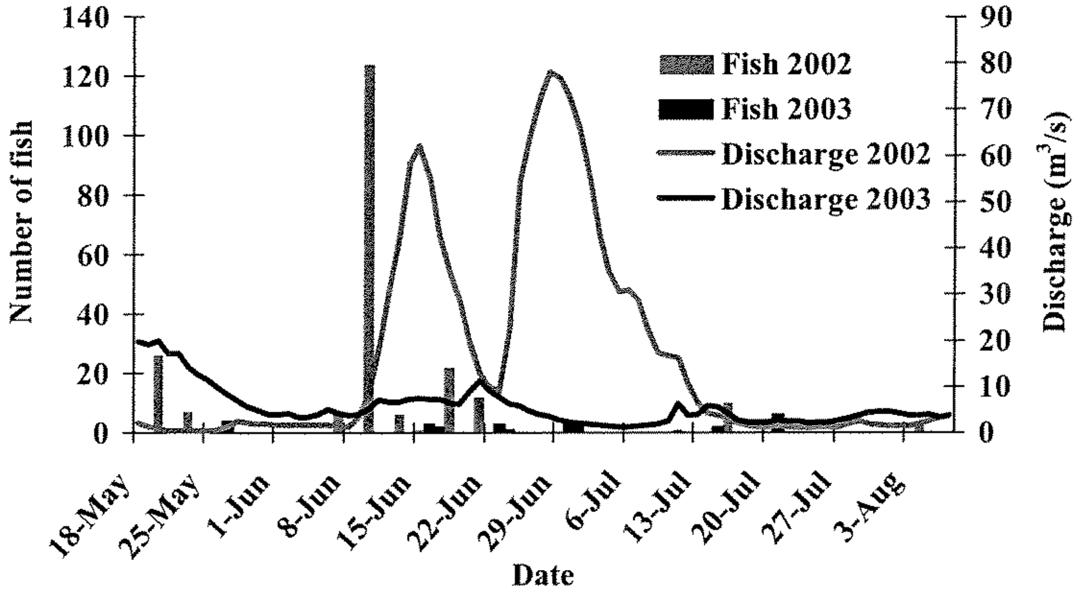

Figure 6. The distribution of blue suckers caught in the lower Milk River study and the mean daily discharge from the U.S.G.S. gauging station (06174500) near Nashua, Montana, 2002 and 2003.

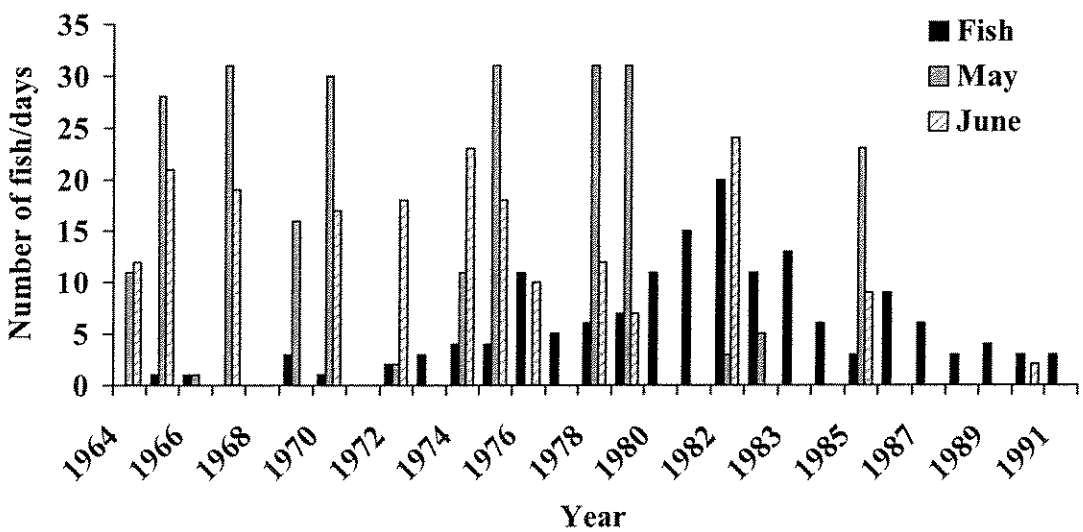

Figure 7. The estimated number of blue suckers by brood year and the number days above the mean discharge rate 27 m^3/s, May and June 1964-1992 for the Milk River from the USGS gauging station (06174500) near Nashua, Montana.

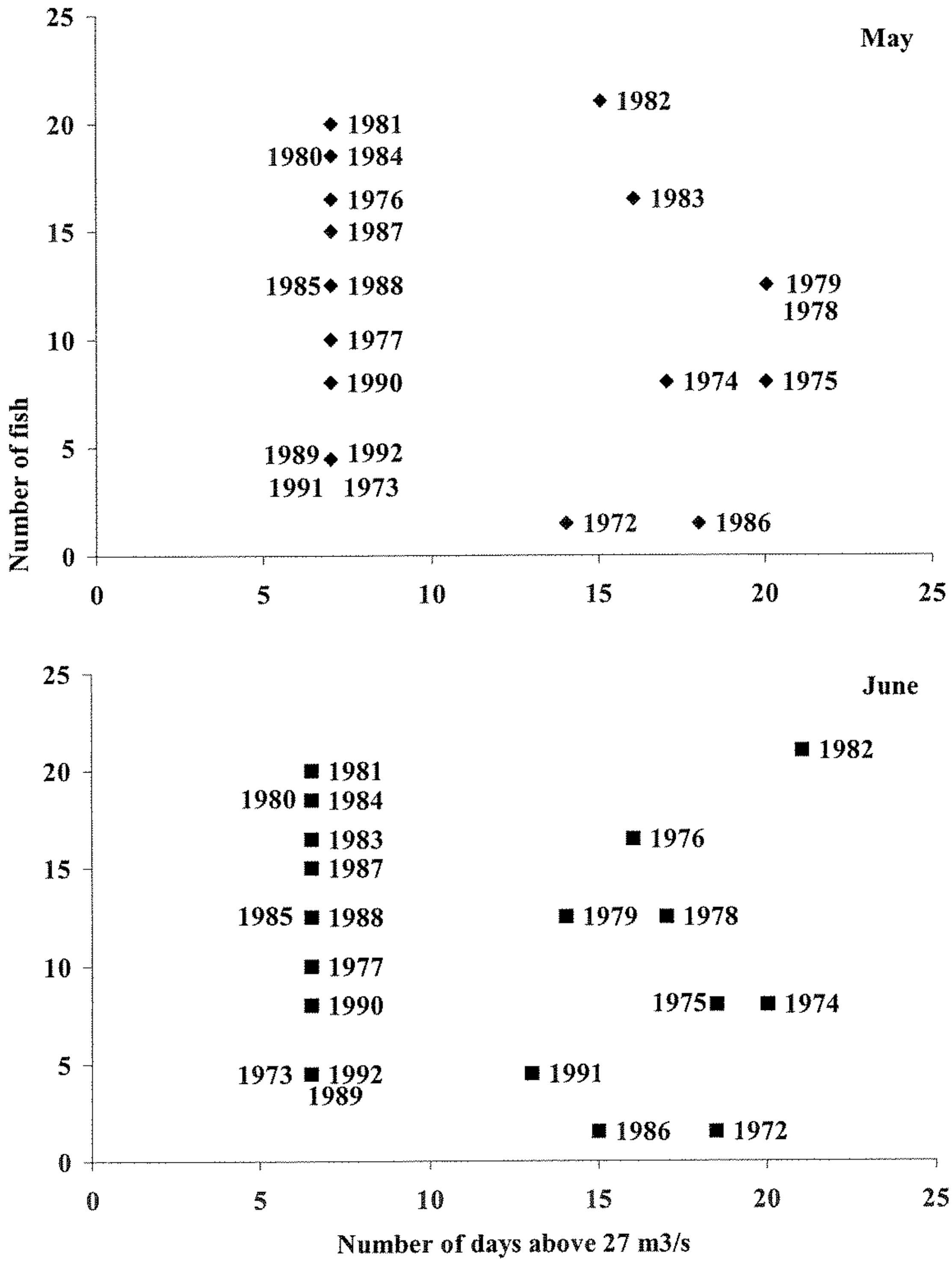

Figure 8. The rank of the number of fish and rank of the number of days above 27 m^3/s discharge for the Milk River from the USGS gauging station (06174500) near Nashua, Montana.

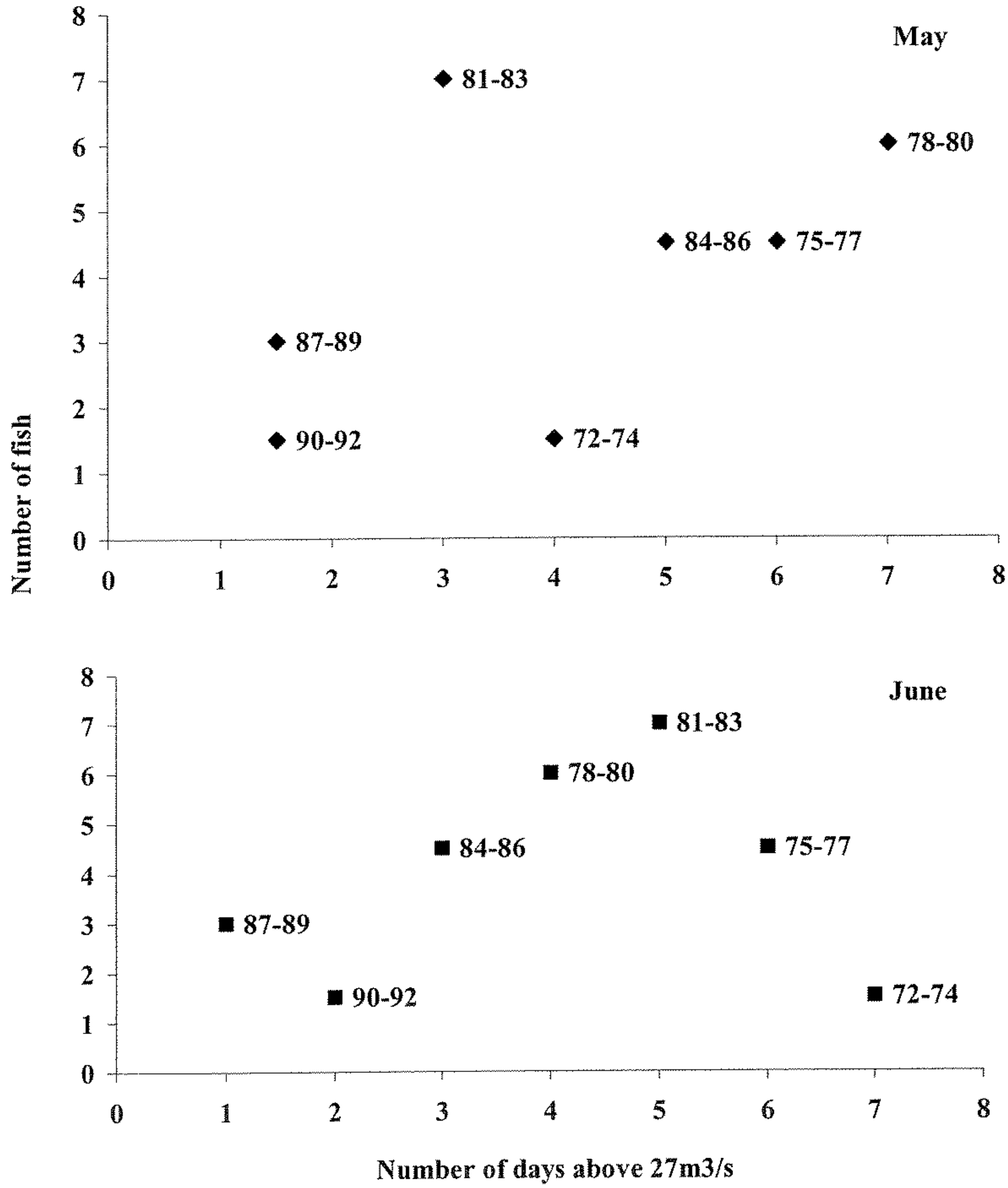

Figure 9. The running average of the rank of the number of fish and rank of the number of days above 27 m^3/s discharge for the Milk River from the USGS gauging station (06174500) near Nashua, Montana.

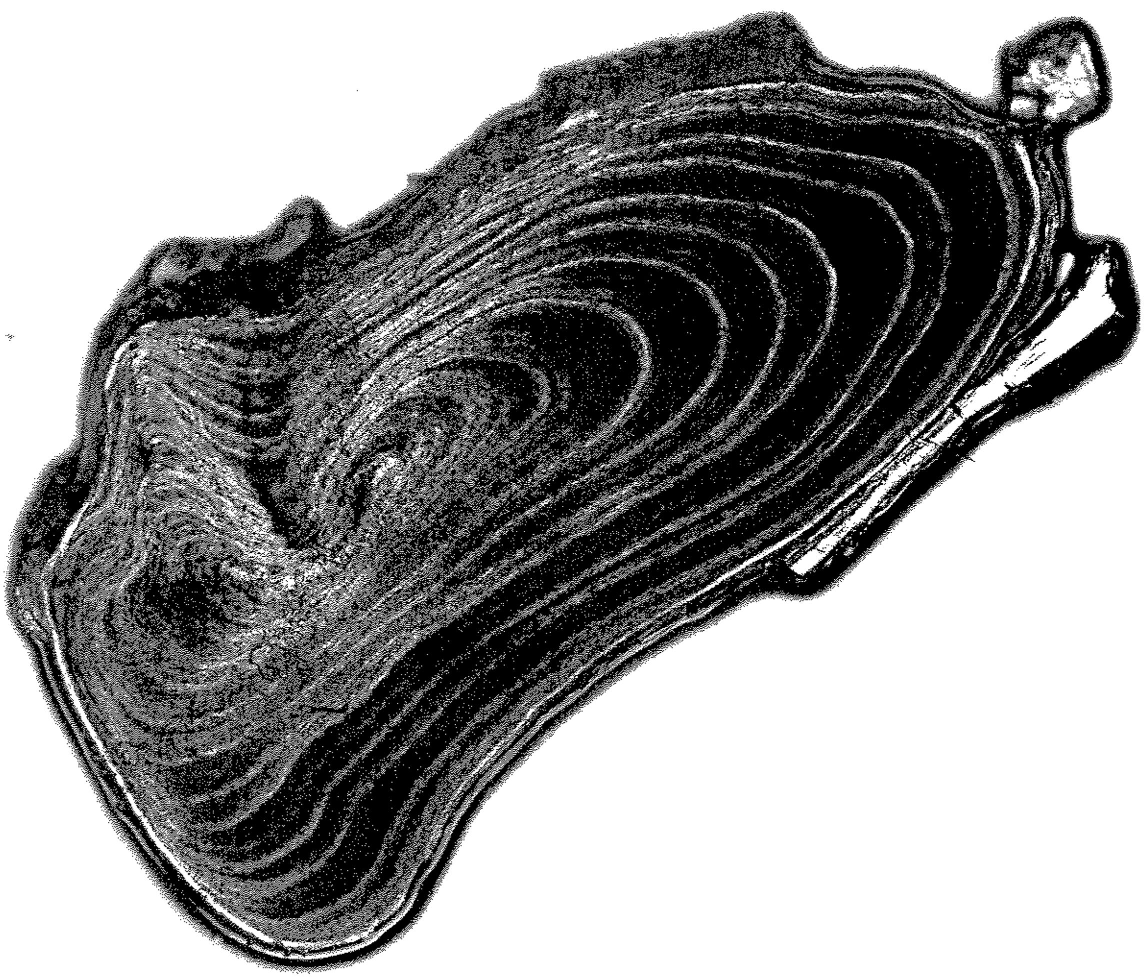

Illustration 1. The lead pectoral fin ray section of a blue sucker, 603 mm and 1,750 g, in the Milk River, Montana. Age estimated at 13.

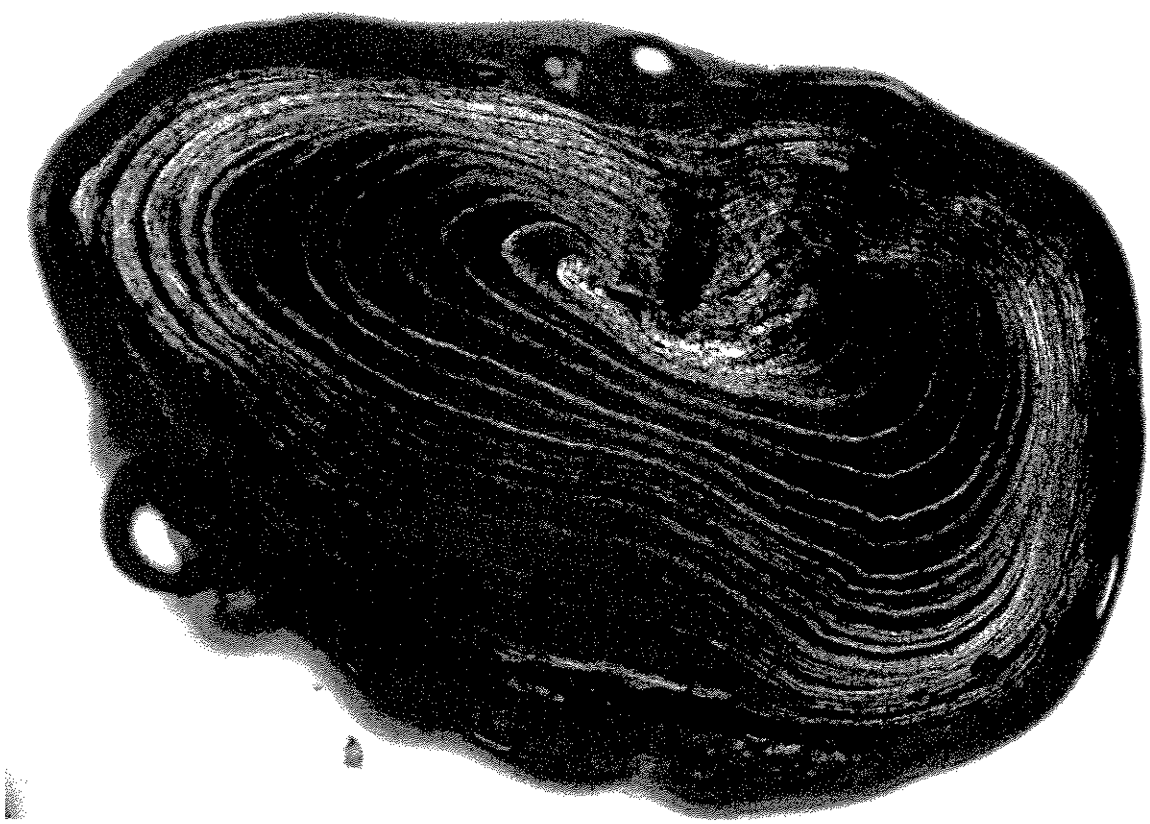

Illustration 2. The lead pectoral fin ray section of a female blue sucker, 690 mm and 3,050 g in the Milk River, Montana. Age estimated at 17.

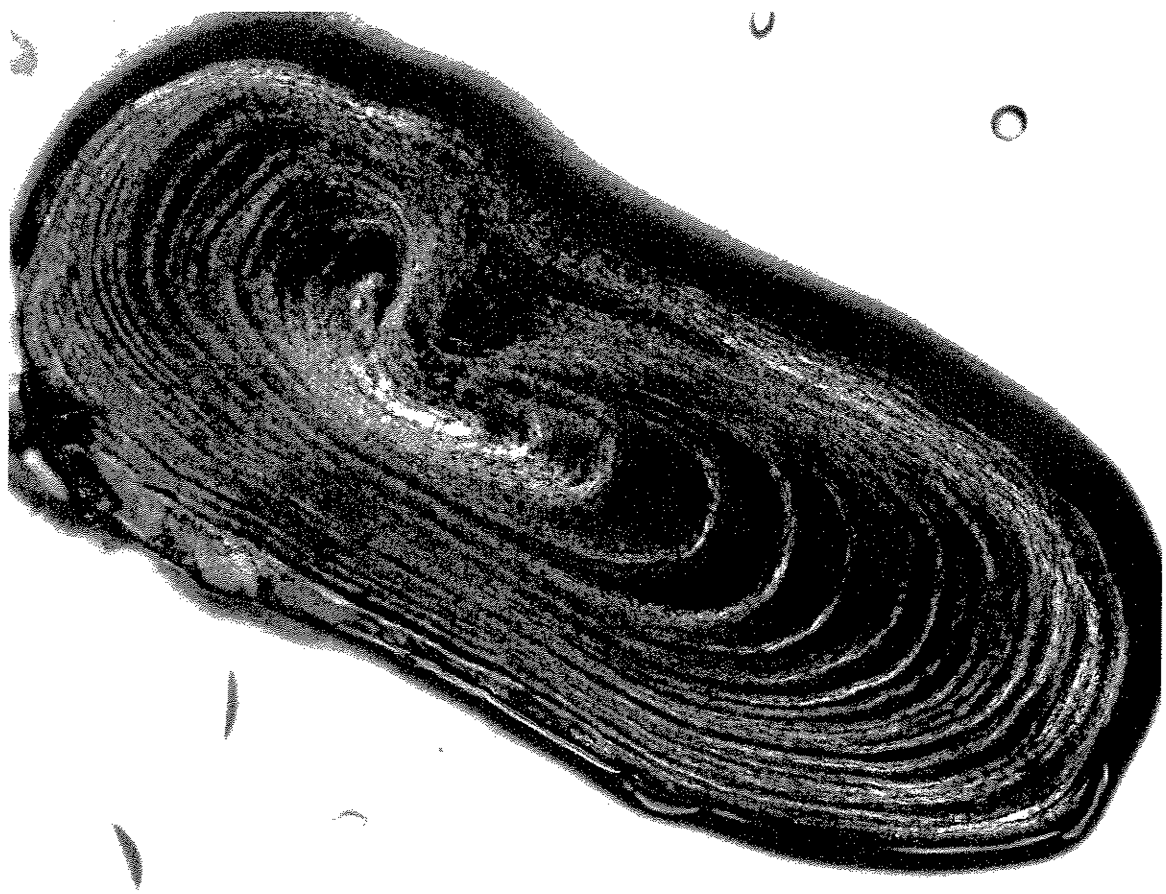

Illustration 3. The lead pectoral fin ray section of a male blue sucker, 630 mm and 2,100 g in the Milk River, Montana. Age estimated at 20.

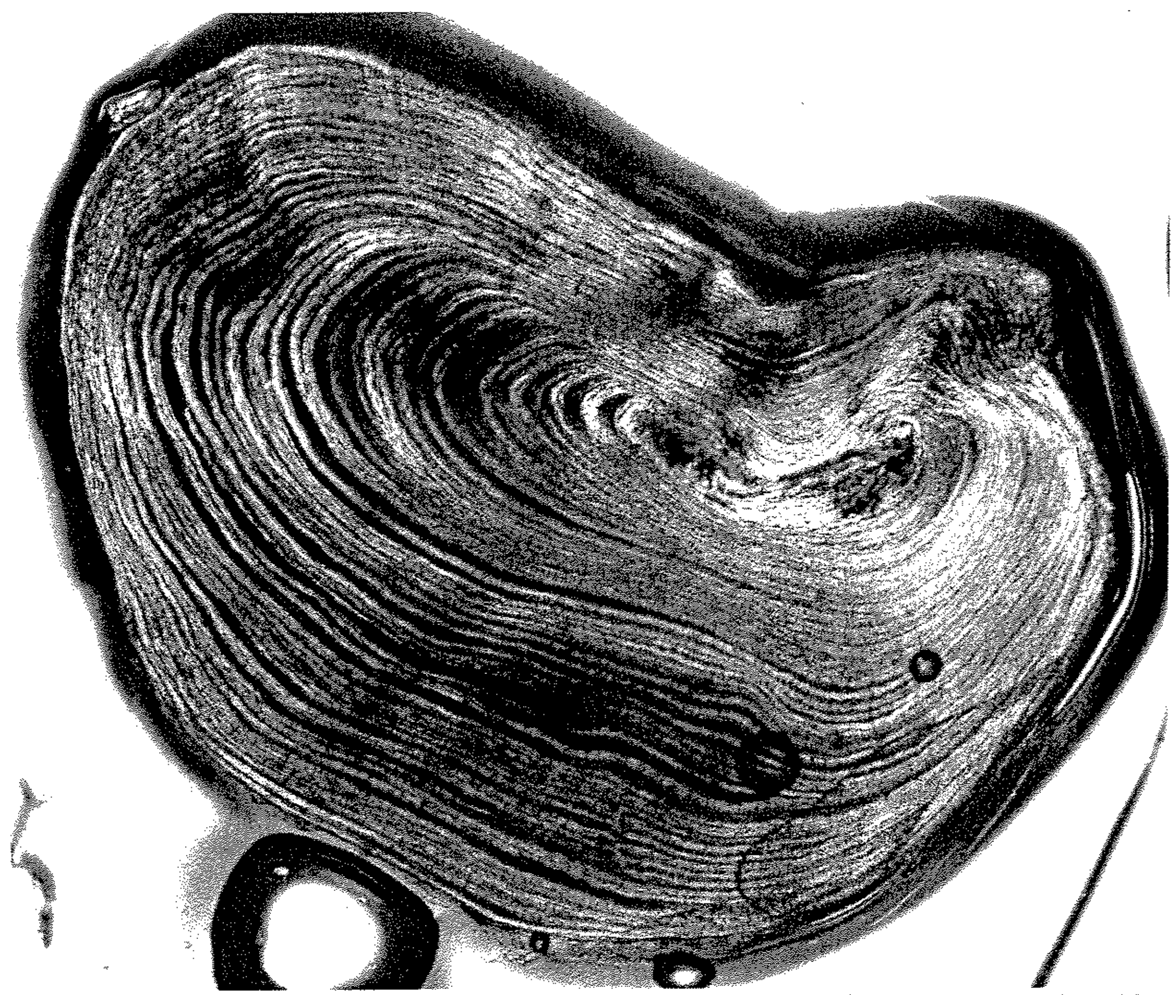

Illustration 4. The lead pectoral fin ray section of a male blue sucker, 750 mm and 3,000 g in the Milk River, Montana. Age estimated at 33.

CHAPTER 3. Fishes of the lower Milk River, Montana

ABSTRACT

Sampling was conducted from May to August in both 2002 and 2003 to investigate the importance of the lower Milk River for spawning and rearing of native resident and Missouri River fish species. The ten most abundant fish species found in the study included the blue sucker (*Cycleptus elongatus*), a species of special concern, and the flathead chub (*Hybopsis gracilis*), a watchlist species for Montana Natural Heritage Program. High catches of reproductively active fish and species common in the Missouri River indicate that native migratory and resident fish species rely on the irregular seasonal discharge in the Milk River to spawn and rear. Age and growth analysis was conducted on channel catfish (*Ictalurus punctatus*), sauger (*Stizostedion canadense*), walleye (*Stizostedion vitreum*), northern pike (*Esox lucius*) and shovelnose sturgeon (*Scaphirhynchus platorynchus*). Channel catfish, sauger, walleye, and shovelnose sturgeon all grew more slowly and lived longer in the lower Milk River than fish of those species in lower latitudes.

INTRODUCTION

The Milk River is an important main channel tributary to the upper Missouri River, Montana. The lower 188 rkm of continuous river below Vandalia Dam is characterized by incised channels with well-developed riparian zones and cobble riffles (Stash et al. 2001). This portion of the river supports a diversity of macrohabitats for several native fish species common to the Missouri River.

The warm turbid character of the lower Milk River contrasts sharply with conditions in the Missouri River at their confluence. Downstream of Fort Peck Dam, the Missouri River is cold (15° C, July) and clear (10 nephelometric turbidity units (NTU), July), as a result of hypolimnetic discharge from Fort Peck Dam and sediment trapping by the reservoir. In contrast, the Milk River retains some of the characteristics of the Missouri River prior to alteration; it is warmer (30° C, July), more turbid (1000 NTU, July) and less altered.

With the major habitat changes in the Missouri River over the past century, remnant habitat in tributaries such as the lower Milk River may assume critical importance in species survival. Stash et al. (2001) observed that three migratory species from the Missouri River, blue sucker (*Cycleptus elongatus*), shovelnose sturgeon (*Scaphirhynchus platorynchus*), and paddlefish (*Polyodon spathula*) were found only in the lower 193 km section of the Milk River below Vandalia Dam. Seven other native fish species, bigmouth buffalo (*Ictiobus cyprinellus*), channel catfish (*Ictalurus punctatus*), freshwater drum (*Aplodinotus grunniens*), goldeye (*Hiodon alosoides*), river carpsucker (*Carpiodes carpio*), shorthead redhorse (*Moxostoma macrolepidotum*), and smallmouth buffalo (*Ictiobus bubalus*) were captured only in the lowermost 400 km of the Milk River. Most of these fish captured were below Vandalia Dam, which may indicate that the fish above the dam are smaller, isolated populations, and the fishes below the dam are mainly Missouri River migratory fish.

In years the Milk River has high spring flows, the river operates like a natural river in terms of physical habitat features such as increased depth, increased velocity, and increased turbidity. However, there has been a 60 % decrease in the magnitude of the two-year flood and similar decreases in larger, less frequent flood events (Shields et al. 2000) as a result of seven impoundments on the river. The impoundments extend from 699 km to 187 km upstream of the confluence with the Missouri River and have been developed mainly for irrigation. These alterations to the Milk River have caused a reduction in high spring flows, and have created barriers to fish migrations. Such alterations may affect the spawning and rearing ability of the resident fish, as well as native migratory fish from the Missouri River, especially if the latter fish rely on the irregular flows of the Milk River for spawning. In view of the major habitat alterations on the Missouri River in the 20th century, such fish may be relying even more heavily on the Milk River for spawning and rearing habitat than in historical times.

A water development project has been proposed that would divert water from Milk River during high spring flows into an off-stream storage reservoir with up to 74 million m^3 capacity. The proposed project would further decrease the magnitude of the two-year flood and the frequency of other chance flooding. These proposed changes in the hydrograph and water quality were evaluated for their potential effects on reproduction and life history of native fish species. The goal of this study was to determine the importance of the lower Milk River for the spawning and rearing of native resident and Missouri River migratory fish species. The specific objectives of this study were to: 1) estimate relative abundance and species composition of fish among sampling sites in relation to seasonal discharge 2) characterize the spawning of the fish species in the lower Milk River in relation to spring discharge and concurrent habitat conditions and 3) examine age and growth of selected fish species.

METHODS

Fish Collection

Fish were sampled with a five gears, stationary gill nets, floating gill nets, trammel nets, hoop nets, and bag seines in order to effectively sample the range of species and habitats present. Each gear was deployed at least three times per site on the lower Milk River from mid-May to mid-August 2002 and 2003. Stationary gill nets and hoop nets were set overnight. Stationary sinking gill nets were 30 m long by 1.8 m high, and were divided into four equal panels of 1.9 cm, 3.8 cm, 5 cm, and 7.6 cm mesh sizes. Floating gill nets were 150 m in length, by 1.8 m high, with 7.6 cm mesh. Trammel nets were 22.9 m in length with a 2.5 cm inner mesh and a 15.2 cm outer mesh. Hoop nets were 1 m in diameter with a mesh size 2.5 cm. Bag seines were of two sizes: 10.7 m long by 1.8 m tall and 7.6 m long by 1.8 m tall. Both seines had a 1.8m x 1.8m base at the center of net with a 5 mm ace mesh and a "many ends" mud lead line attached.

Fish were identified to species in the field. Total length to the nearest mm was recorded for all species, except for sturgeon, where fork length was used, and paddlefish, where body length from eye to fork of caudal fin was used (Ruelle and Hudson 1977). Fish were weighed to the nearest g. The condition factor was expressed as $K=W(10^5)/L^3$, where W=weight and L=length. The presence of mature fish with milt/roe was sought as evidence of spawning activity. The fish sampled were checked externally, if roe or milt was detectable after gentle pressure was applied to the abdomen, the fish was recorded as ready to spawn.

Species composition by location and ripe fish per gear was analyzed using homogeneity of proportions (Cody and Smith 1997, SAS Institute Inc. 1999, and Agresti 2001).

Gonad analysis

Gonad samples were collected from incidental mortalities of shovelnose sturgeon. Determination of gender and the stage of gonadal development was based on Bruch et al. (2001) and confirmed by J. Cloud at the Reproductive Biology Laboratory, University of Idaho.

Histology

The gonadal tissues were analyzed in the histology laboratory at the Holm Research Center, Department of Food Science and Toxicology, University of Idaho. Formalin fixed tissues were trimmed into pieces and embedded into paraffin blocks. A rotary microtome was used to make 8 μm section of tissue that were floated onto a glass slide and air-dried overnight. Afterward, the tissues sections were stained with an H and E (Harris' Hematoxylin and Eosin) staining protocol. A glass cover slip was adhered to the tissue on the slide with mounting media and then air dried before microscopic investigation.

Age structure collection

Hard structures for age analysis were collected from five species based on their importance to the recreational fishery (channel catfish, walleye (*Stizostedion vitreum*), shovelnose sturgeon and northern pike (*Esox lucius*)) or on their scarcity and sensitivity status (sauger (*Stizostedion canadense*)). The structures selected for use in age determination were based on previous studies documenting the usefulness of a particular structure. Random samples of pectoral fin rays were collected from channel catfish (Starkey and Scarnecchia 1999) ranging in length from 300 mm and greater. Lead pelvic and dorsal fin rays were collected from all sauger and walleye caught (Borkholder and Edwards 2001). Cleithra were taken from northern pike that suffered from incidental mortalities (Casselman 1974). Pectoral fin rays were collected from shovelnose sturgeon (Everett et al. 2003).

Age analysis

The methods for determining the age from fins followed DeVries and Frie (1996) as modified in the lab according to Dingman (2001). The fins were glued to a labeled, wooden craft stick, fin rays parallel to the stick, using clear epoxy with the end nearest point of articulation closest to end of the stick. The glued fins were allowed to dry for 24 h before cutting.

The fin sections were cut with a Buehler Isomet Speed Sectioning saw equipped with a 10 cm diameter by 0.3 mm thick diamond-edge blade. The first cut was made as close to the end of the fin as possible to create a smooth edge. Each additional cut resulting in a thin section was viewed under a microscope attached to a Biosonic Optical Pattern Recognition System (OPRS) to determine if adjustments needed to be made during the cutting process to improve the resolution of the section. Four sections were placed on a glass slide using clear fingernail polish.

The sections on the slide were viewed under the OPRS equipment. Annual rings counted to determine age. No validation of age was possible, one clear ring was assumed to be developed each year. If the sections were not readable a second series of cuts was attempted. Two people (a primary and secondary reader) independently aged sections from each fish. If the disagreement for fish aged between 5 to 10 were within one year, fish aged 11 to 15 were within +/- two years, and fish aged 16 and over were within +/- three years, the age determined by the primary reader was assigned. All other disagreements on the age were determined by a second independent reading. If there was still disagreement after two paired readings, a third reading was made with both people present.

Lengths at age were used to estimate Von Bertalanffy growth curves. Separate growth curves were estimated for each species used in the age analysis. Total length was used for all species except shovelnose sturgeon where fork length was used. Von Bertalanffy growth equation was expressed as $L=L_{\infty}(1-e^{-kt})$ for length (mm), where L is the length of the fish (mm) at age t, L_{∞} is the theoretical limiting size, and k is the curvature parameter. Because of a shortage of small, young fish ages the initial condition parameter was set at zero and a two-parameter model was fit. Estimates for Von Bertalanffy growth parameters were calculated in SAS (SAS Institute Inc.1999).

In addition, the growth rates of shovelnose sturgeon in the Milk River were compared to growth rates of fish from the Yellowstone River sampled in 1991 to 1993, 1995, and 1996 Everett (2003). These fish all occupy the same continuous segment of the Missouri River, between Fort Peck Dam and Lake Sakakawea. Comparisons were made using a log likelihood ratio test (Kimura 1980).

Habitat measurements

Turbidity at each site was measured in nephelometric turbidity units (NTU) using a Hach model 2100P. Daily discharge measurements were available at the U.S. Geological Service gauging station (06174500) on the Milk River near Nashua, Montana.

RESULTS

A total of 7962 fish was captured; 4,652 (58%) in 2002 and 3,337 (42%) in 2003. The total abundance of fish captured was significantly different among years and gear types (χ^2=166.75; 3 df; P<0.001). For trammel nets, hoop nets, and bag seines, the percentage of the fish caught was higher in 2002 than in 2003 and for stationary gill nets the percentage of fish caught was higher in 2003 than 2002 (Figure 1).

A total of 29 species was captured (Table 1), of which 21 species were native and 8 were nonnative. Three of the native species, blue sucker, sauger, and paddlefish, were species of special concern. Another of the native species, flathead chub (*Hybopsis gracilis*), was a watch list species for Montana Natural Heritage Program.

Overall, the ten most abundant species captured were all species native to the Milk and Missouri rivers. The species by percentage of catch were emerald shiner (*Notropis atherinoides*) 16%, channel catfish 15%, river carpsucker 13%, goldeye 11%, flathead chub 10%, fathead minnow (*Pimephales promelas*) 8%, shorthead redhorse 8%, *Hybognathus* 4%, smallmouth buffalo 4%, and blue sucker 3% (Figure 2).

Net catches

The proportion of fish species captured with drift trammel nets, hoop nets, and stationary gill nets was significantly different between years (χ^2=271; 22 df; P<0.001). Fifty-four percent of the fish were caught in 2002 and 45% in 2003. The differences in species composition between years differed according to species (Figure 3). More than 88% of the blue sucker and shovelnose sturgeon were captured in 2002, whereas only about 55% of carp (*Cyprinus carpio*), channel catfish, goldeye, smallmouth buffalo and northern pike were captured that year. In 2003, more than 50% of river carpsucker and walleye and more than 60% of sauger and shorthead redhorse were captured.

The composition of fish species captured with drift trammel nets, hoop nets, and stationary gill nets (combined) was significantly different among locations (χ^2=1304.91; 45 df; P<0.001). Location 2, the first sampling area above the confluence of the Milk and Missouri Rivers, had the highest percentage of fish caught with nets and location 1 on the Missouri River, downstream of the confluence of the Milk and Missouri River, had the lowest percentage of fish caught with nets (Figure 4). Location 2 had the highest percentages of channel catfish (33%), goldeye (33%), river carpsuckers (65%), smallmouth buffalo (45%), blue sucker (85%), and sauger (52%). Location 3 had the highest percentage of shovelnose sturgeon (57%). Location 5 had the highest percentage of shorthead redhorse (29%), and location 6 had the highest percentages of walleye (61%) and carp (33%).

Seines

The percentages of fish species captured with seines were significantly different between years (χ^2=454; 22 df; P<0.001). Sixty-two percent of the fish were captured in 2002 and 38 % in 2003. More than half of the channel catfish, longnose dace (*Rhinichthys cataractae*), flathead chub, fathead minnow, *Hybognathus*, river carp sucker, and white sucker (*Catostomus commersoni*) were captured in 2002 (Figure 5), where as more than half of the shorthead redhorse and carp were captured in 2003. Overall, July had the highest percent of fish caught in seines, followed by August, June, and May.

The percent of fish species captured in seines was significantly different among locations (χ^2=2451; 88 df; P<0.001). Locations 2 and 3 had the highest percentages of fish. Location 1 on the Missouri River and location 5, the farthest upstream section below Vandalia Dam, had the lowest percentages of fish (Figure 6). Location 2 had the highest percentages of flathead chub (66%), *Hybognathus* (72%), longnose dace (56%), and white sucker (82%). Location 3 had the highest percent of carp (41%), emerald shiner (57%), and shorthead redhorse (36%). Location 4 had the highest percent of channel catfish (50%), and river carpsucker (69%).

Discharge

The timing and duration of the spring seasonal discharge patterns near Nashua, Montana differed between May to mid-August, 2002 and 2003 (Figure 7). In 2002, increased spring discharge lasted for 41 days, peaking at 62 m^3/s on 15 June and at 78 m^3/s on 28 June and returning to <10 m^3/s on 18 July. In 2003, increased spring discharge lasted for only 17 days, and occurred much earlier, peaking at 70 m^3/s on 12 May, and returning to <10 m^3/s on 28 May. The later peak in spring discharge in 2002 was associated with higher seasonal precipitation, whereas the peak in 2003 was associated with runoff from of snowmelt.

Presence of select fishes in relation to discharge

The aggregate number of blue suckers, shovelnose sturgeon, and paddlefish, three important large river species, caught in the lower Milk and Missouri River, was highest during the high flow period, (late spring and early summer; Figure 8). In all, 339 fish of these species were caught in 2002 and 34 fish in 2003. On 10 June, 2002, before the first discharge peak, two hoop nets caught 124 blue suckers at location 2. In one stationary gill net on 17 June 2002, between the two discharge peaks, 50 shovelnose sturgeon were caught at location 3. Eight of the nine observed paddlefish were sampled between 29 June 2002 and 1 July 2002, the time of maximum discharge. In 2003, the smaller numbers of important large river fish captured were not distinctly associated with any peaks in discharge.

Ripe fish

Presence of ripe fish was detected in 11 fish species caught with hoop nets and stationary gill nets (Table 2). Of the ripe fish, 48% were captured in hoop nets and 52% were captured in stationary gill nets. The percentages of ripe fish were significantly different between 2002 and 2003 (χ^2=91.81; 1 df; P<0.001). The percent of ripe fish was also significantly different between months (χ^2=181; 3 df; P < 0.001). June had the highest percent of ripe fish (60%), followed by May (29%), July (11%), and August (1%) (Table 2). The detection of ripe fish was significantly different among locations (χ^2=1191; 4 df; P<0.001). Location 2 had 68% of the ripe fish in the total catch and location 5, the first downstream section below Vandalia Dam, had 19% of the ripe fish in the total catch (Table 3).

Shovelnose sturgeon gonad samples

Gonad samples of 36 shovelnose sturgeon, 4 females and 32 males, were examined for the stage of development. One female was reproductively ready and three female were in the early stages of oocyte development and would not be ready to spawn for at least one year. Thirty-one of the males had completed spermatozoa and were ready to produce milt during the spawning season. An age-8 male was immature and was just beginning testicular development.

Age and growth analysis

Channel catfish ranged in length from 20 mm to 740 mm with a mean length of 397 mm (SE=101 mm; n=739) and weighed between 0.1 g and 4,200 g with a mean weight of 608 g (SE=543 g; n=739). The length-weight relationship for channel catfish was expressed as $\log_{10}W=2.9966 \log_{10}L-5.1065$ (r^2=0.97). The mean condition factor ($K=W(10^5)/L^3$) was 0.78 (SE=0.18). Random samples of 189 fish were used in the age determination analysis. Ages ranged from 5 to 21 years (Figure 9). Mean lengths at age ranged from 330 mm at age 5 to 615 mm at age 21. The Von Bertalanffy growth equation was $L=631.5(1-e^{(-0.1249t)})$ (Figure 10).

Sauger ranged in length from 220 mm to 543 mm with a mean length of 326 mm (SE=63 mm; n=157) and weighed between 50 g and 1,330 g with a mean weight of 294 g (SE=207 g; n=157). The length-weight relationship was $\log_{10}W=2.86\ \log_{10}L–4.79$ (r^2=0.81). The mean condition factor ($K=W(10^5)/L^3$) was 0.76 (SE=0.25). One hundred and forty-six sauger were assigned ages, which ranged from 2 to 13 years (Figure 11). Mean fork length at age ranged from 287 mm at age 2 to 742 mm at age 13. The Von Bertalanffy equation was $L= 427(1-e^{(-0.335t)})$ (Figure 12).

Walleye ranged in length from 196 mm to 867 mm with a mean length of 418 mm (SE=139 mm; n=82) and weighted between 50 g and 4,400 g with a mean weight of 820 g (SE=945 g; n=82). The length-weight relationship was $\log_{10}W=2.761\ \log_{10}L–4.47$ (r^2=0.87). The mean condition factor ($K=W(10^5)/L^3$) was 0.88 (SE=0.31). Seventy-three walleye were assigned ages, which ranged from 2 to 16 years (Figure 13). Mean lengths at age were 271 mm at age 2 to 725 mm at age 16. The Von Bertalanffy equation was $L=649.7(1-e^{(-0.196t)})$ (Figure 14).

Northern pike ranged in length from 326 mm to 926 mm with a mean length of 634 mm (SE=158 mm; n=59) and weighted between 250 g and 4,300 g with a mean weight of 1,832 g (SE=1135 g; n=59). The length-weight relationship was $\log_{10}W=2.70\log_{10}L–4.38$ (r^2=0.87). The mean condition factor ($K=W(10^5)/L^3$) was 0.68 (SE=0.48). Twenty-eight northern pike were assigned ages, which ranged in from 2 to 10 years (Figure 15). Mean lengths at age were 386 mm at age 2 to 810 mm at age 10. The Von Bertalanffy equation was $L=864(1-e^{(-0..2717t)})$ (Figure 16).

Shovelnose sturgeon ranged in length from 465 mm to 805 mm with a mean length of 620 mm (SE=65 mm; n=114) and weighed between 300 g and 2,650 g with a mean weight of 997 g (SE=391 g; n=114). The length-weight relationship was $\log_{10}W=3.38\log_{10}L-6.47$ ($r^2=0.89$). The mean condition factor ($K=W(10^5)/L^3$) was 0.39 (SE=0.05). Seventy-two shovelnose sturgeon were assigned ages, which ranged from 9 to 22 years (Figure 17). Mean lengths at age were 538 mm at age 8 to 637 mm at age 22. The Von Bertalanffy equation was $L=733.7(1-e^{(-0.1341t)})$ (Figure 18).

Shovelnose sturgeon in the Milk River grew significantly slower than fish in the Yellowstone River (Figure 18). The Von Bertalanffy growth equation was expressed as $L=733.7(1-e^{-0.1341t})$ for the Milk River and $L=809.3(1-e^{-0.2053t})$ for the Yellowstone River (Figure 18). Curvature parameter, k, was significantly less for the Milk River ($\chi^2=35.65$; 2 df; P<0.001) as was the asymptotic length, L_∞ ($\chi^2=357.51$; 2 df; P<0.001).

DISCUSSION

Species occurrence

The occurrence of the ten most abundant species caught all being native to the Milk and Missouri rivers indicates that the Milk River provides important habitat for a variety of native species. One of the ten species, the blue sucker, is a species of special concern, and another, the flathead chub is a Montana Natural Heritage watchlist species. As the largest tributary to the Missouri River between, Fort Peck Dam and the confluence of the Yellowstone River (375 rkm), the high composition of native fauna found is significant because the main channel Missouri River fauna in the area has changed from species uniquely adapted for life in turbid waters with fluctuating flows and temperatures such as flathead chub and blue sucker to pelagic planktivores and sight-feeding predators such as emerald shiners and walleye (Pflieger and Grace 1987; Rabeni 1996).

The abundance of native fish in the Milk River in contrast to the major changes in the fish fauna in the Missouri River may result from the Milk River retaining more attributes of a natural Great Plains river. The lower Milk River has 188 rkm of continuous river that meets the channelized Missouri River 200 rkm upstream of natural floodplains and backwater habitats (Shields et al. 2000) that are critical habitat for spawning and rearing of fish. The Milk River has remained turbid and warm with irregular flows.

Evidence of Spawning

A higher percentage of age-0 and juvenile fish were found at downstream locations than at upstream locations. Conversely a higher percent of reproductively ready adult fish where found at upstream locations. Peterson and Vanderkooy (1995) found that fish in Luxapalilia Creek, Mississippi used upstream riffle habitat to spawn and that the larval fish drifted downstream to areas with shallow water rearing habitat. In this study, a high percentage of reproductively ready fish such as the shovelnose sturgeon found at location 3 (rkm20) and the high percent of ripe fish at location 5 (100rkm) supports the idea that fish move upstream in the Milk River for the purpose of spawning.

The percent of reproductively ready fish was highest in June followed by May and July, which suggests that fish spawn during the increased hydrograph. In the lower Milk River study area, the month of June has the highest seasonal rainfall with 21.5 % of the yearly total precipitation (Western Regional Climate Center 2001). Prior to flow regulation, the Milk River spring hydrograph most likely had two distinct peaks, the first from mountain and highland snow melt and the second from seasonal precipitation, which would follow the pattern of a natural rise in the hydrograph for rivers in the Great Plains (Figure 19).

Upstream movement of pre-spawning fish with the increasing hydrograph is a common strategy of native Great Plains fishes (Fausch and Bestgen 1997). For example eggs are deposited in the water column upstream during high flows to protect them from abrasion with the fine, silty substrates (Fausch and Bestgen 1997). After the larvae hatch they can drift with the current towards suitable rearing habitat. In Wyoming, goldeye moved upstream into Crazy Women Creek and deposited eggs; the eggs then drifted and hatched downstream into the Powder River (Smith and Hubert 1989). In this study, many of the Missouri River migratory fish were captured in the Milk River during the period of high discharge in June. In the late spring and early summer of 2002, there were two peaks in discharge (14 June and 28 June). For example, during the period of high discharge from 10 June to 13 July, 63% of the 222 blue suckers, 100% of the nine paddlefish caught, and 62% of the 108 shovelnose sturgeon were caught. The higher catches during this period may be indicative of increased fish movements and vulnerability to capture as they migrate upriver in preparation for spawning.

Results from this study suggest that the lower Milk River provides 187 rkm of continuous critical river habitat to many native migratory and resident fish species. These fish are spawning in association with the increased spring and early summer discharge.

Age and growth analysis

Channel catfish-- The length-at-age and maximum age of channel catfish found in this study was consistent with other populations in northern latitudes (Figure 20). The maximum age determined for fish was 18 in the wild and scenic Missouri River, Montana (Berg 1981) and 24 in the Red River, North Dakota (Hegrenes 1992), whereas fish in more southerly latitudes have rarely been reported to exceed 10 years (Carlander 1969).

The size of channel catfish, however, was similar to those reported for other populations through out its range in the United States (Carlander 1969). In an assessment of 102 channel catfish age and growth studies, Hubert (1999) found no differences in regional size patterns. In the Red River, North Dakota, Hegrenes (1992) found size and not age to be important in determining maturation. The age of maturity, in contrast, reported by Hubert (1999) was strongly related to the latitude; fish in the southern latitudes matured earlier than fish in the northern latitudes (Hubert 1999). This supports the idea that the fish in the Milk River are growing slower and maturing later than fish in more southerly latitudes.

Sauger--The age distribution of the sauger population in the Milk River was consistent with other populations in northern latitudes (Figure 21). In the Missouri River, Braaten and Guy (2002) found that fish in more northern latitudes also grew slower and lived longer than fish in more southern latitudes.

Walleye--The maximum age of the walleye in the Milk River is greater (16 years) than reported in other populations in northern latitudes. The maximum age determined was 10 in the wild and scenic Missouri River, Montana (Berg 1981), and 12 in the Mississippi River, Wisconsin (Becker 1983). The mean age that walleye mature in Mississippi River, Wisconsin was found to be 4.6 years for males and 7.8 years for females (Becker 1983). The average life expectancy is typically 5-7 in southern latitudes and 12–15 in northern latitudes (Colby and Nepszy 1981). In addition to living longer, the age of maturity is related to the latitude; fish in the southern latitude have been reported to mature earlier than fish in the northern latitude (Colby and Nepszy 1981).

Northern pike--The mean length at age for the northern pike population in the Milk River is consistent with other locations. In general, northern pike mature by age 2 or 3 (Becker 1983).

Shovelnose sturgeon--The mean length at age for shovelnose sturgeon in the Milk River (range 465-805 mm) was similar to those reported in the Missouri River, downstream of Ft. Peck dam to the confluence of the Yellowstone River (Gardner and Stewart 1987; mean range 472- 732 mm), but lower than the populations in the Yellowstone River, Montana (range 202-996 mm; Everett et al. 2003) and the wild and scenic Missouri River, Montana (mean range 566-914 mm; Berg 1981) upstream of Fort Peck Dam (Figure 22). Gardner and Stewart (1987) and Quist et al. (2002) considered the fish inhabiting the lower Missouri River below Ft. Peck Dam to be slower growing than those from the wild and scenic Missouri River. The mean differences in age-at-length among river segments may be related to the cold-water releases at Fort Peck Dam. Everett et al. (2003) found that shovelnose sturgeon in the slightly altered Yellowstone River, with mean monthly water temperature 7° C warmer during the peak growing season, grew faster than fish in a highly altered Missouri River below Garrison Dam. The Yellowstone River, the longest free flowing river (with no mainstem dams) remaining in the continuous United States, is less extensively altered than most other large rivers, with only six low head diversion dams on the main channel (Helfrich et al. 1999). The wild and scenic Missouri River at 333 km is last major free flowing section in the Missouri River (Berg 1981) whereas the lower Missouri River at cold, clear, highly-altered section immediately downstream of Ft. Peck Dam. Although, fish captured in the Milk River have also been captured in the Yellowstone River (D. Fuller Montana Department of Fish, Wildlife, and Parks, Personal Communication 2004) a study on the movements of pallid and shovelnose sturgeon in the Yellowstone and Missouri River (Bramblett and White 2001) found the shovelnose to mostly occupy the Yellowstone River, avoiding impounded areas, whereas the pallid sturgeon made seasonal migrations into the Missouri River. Shovelnose sturgeon found in the Milk River thus would be expected to spend much of their time in the main channel of the Missouri River and less time in the Yellowstone River.

Shovelnose sturgeon in the Milk River not only grew more slowly than other populations in the region, they also matured later. In this study, an eight-year-old male was in the beginning stages of testicular development. Shovelnose sturgeon typically reach sexual maturity about age-5 for males and age-7 for females (Hurley and Nickun 1984).

Although, there is no direct evidence (e.g. eggs and larvae) from this study or other studies (D. Fuller, Montana Department of Fish, Wildlife, and Parks, Personal communication, 2004) that the shovelnose sturgeon spawn in the Milk River, it is probable that they enter the river to spawn. Because the shovelnose sturgeon typically occupy large turbid rivers with high current velocities (Carlson et al. 1985) fish are usually found in the Milk River during high spring flows (Fuller 2000 and 2002; Figure 8) and no fish have been caught in fall (Fuller 2000 and 2002; Stash 2001). The 36 gonad samples analyzed found 31 reproductively active mature males, 1 immature male, 1 reproductively active female, and 3 females that were not reproductively active.

Age summary--Age and growth analysis on the selected fish species including, channel catfish, sauger, walleye, northern pike, and shovelnose sturgeon has indicated that many of the fish are slower growing, longer lived populations, than commonly found elsewhere. The later maturation and longer lifespan characteristic of native Milk River species may make them more vulnerable to short term, environmental influences such as water regulation. Similarly, it would take longer to rebuild depleted stocks of these species on the Milk River than elsewhere.

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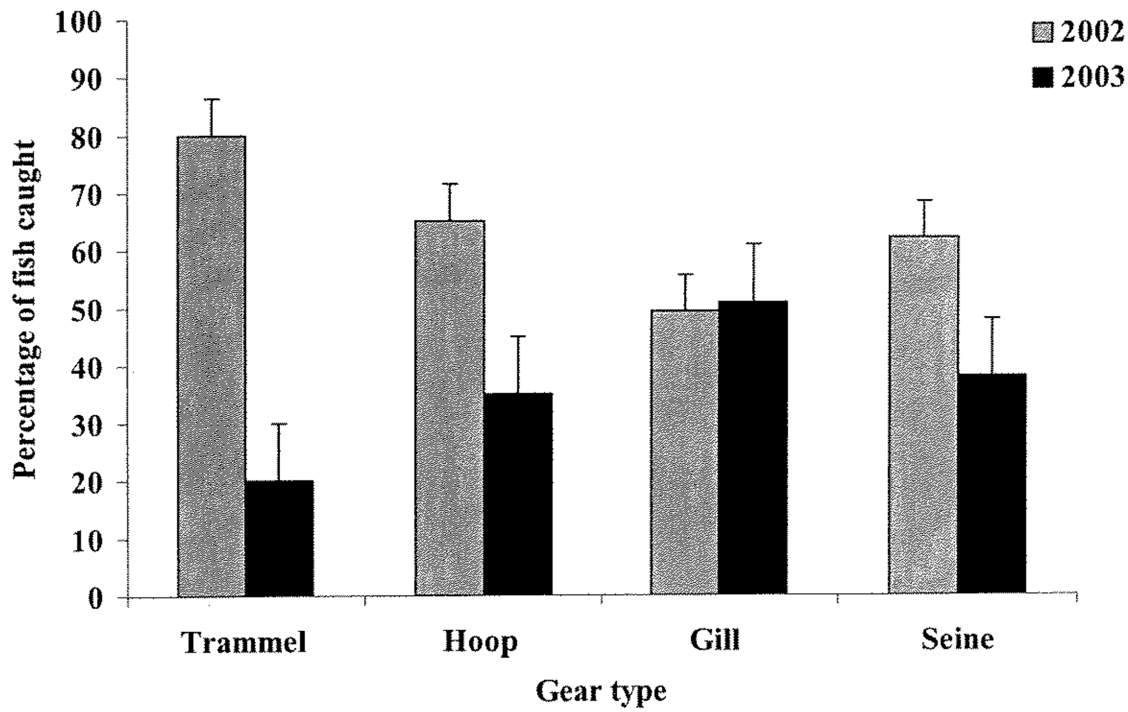

Figure 1. The percentage of total fish caught catch with seines, drift trammel nets, hoop nets, and stationary gill nets on the Milk and Missouri rivers 2002 and 2003.

Table 1. The fishes caught with trammel nets, hoop nets, bag seines, and stationary gill nets in the Milk and Missouri rivers, Montana 2002 and 2003. N=native fish, S=Species of Special Concern, and I=non-native species (Holton and Johnson 2003).

Species	Scientific Name	Status	Gear			
			Trammel	Hoop	Seine	Gill
Bigmouth buffalo	*Ictiobus cyprinellus*	N	x	x	x	x
Black bullhead	*Ameiurus melas*	I		x		x
Burbot	*Lota lota*	N		x		
Blue sucker	*Cycleptus elongatus*	S	x	x	x	x
Common carp	*Cyprinus carpio*	I	x	x	x	x
Channel catfish	*Ictalurus punctatus*	N	x	x	x	x
Emerald shiner	*Notropis atherinoides*	N			x	
Flathead chub	*Hybopsis gracilis*	S		x	x	x
Fathead minnow	*Pimephales promelas*	N			x	
Freshwater drum	*Aplodinotus grunniens*	N		x	x	x
Goldeye	*Hiodon alosoides*	N	x	x	x	x
Hybognathus sp.	*Hybognathus* sp.	N			x	
Longnose dace	*Rhinichthys cataractae*	N			x	
Longnose sucker	*Catostomus catostomus*	N	x	x	x	
Northern pike	*Esox lucius*	N		x		x
Paddlefish	*Polyodon spathula*	S	x			
Rainbow trout	*Oncorhynchus mykiss*	I			x	
River carpsucker	*Carpiodes carpio*	N	x	x	x	x
Sauger	*Stizostedion canadense*	S	x	x	x	x
Shorthead redhorse	*Moxostoma macrolepidotum*	N	x	x	x	x
Smallmouth buffalo	*Ictiobus bubalus*	N	x	x	x	x
Smallmouth bass	*Micropterus dolomieui*	I		x		x
Shovelnose sturgeon	*Scaphirhynchus platorynchus*	N	x	x		x
Stonecat	*Noturus flavus*	N		x	x	x
Spottail shiner	*Notropis hudsonius*	I			x	
Walleye	*Stizostedion vitreum*	I		x		x
White Crappie	*Pomoxis annularis*	I		x	x	x
White sucker	*Catostomus commersoni*	N	x	x	x	x
Yellow perch	*Perca flavescens*	I			x	x
Unknown					x	

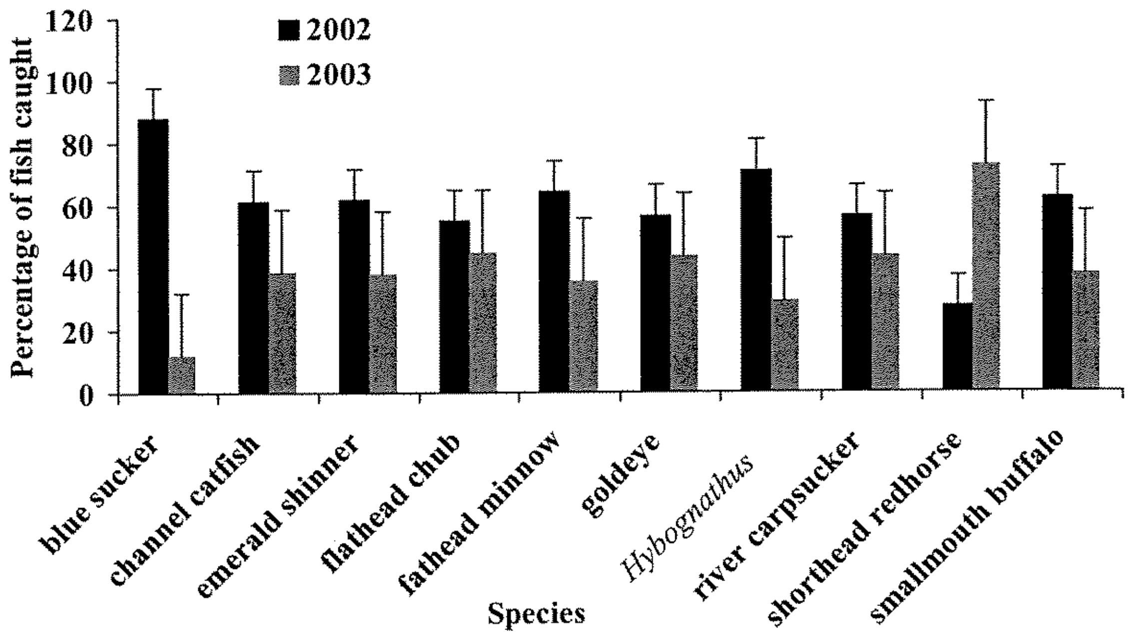

Figure 2. The proportions of the total catch of ten most abundant fish species caught in 2002 versus 2003 on the Milk and Missouri rivers, Montana.

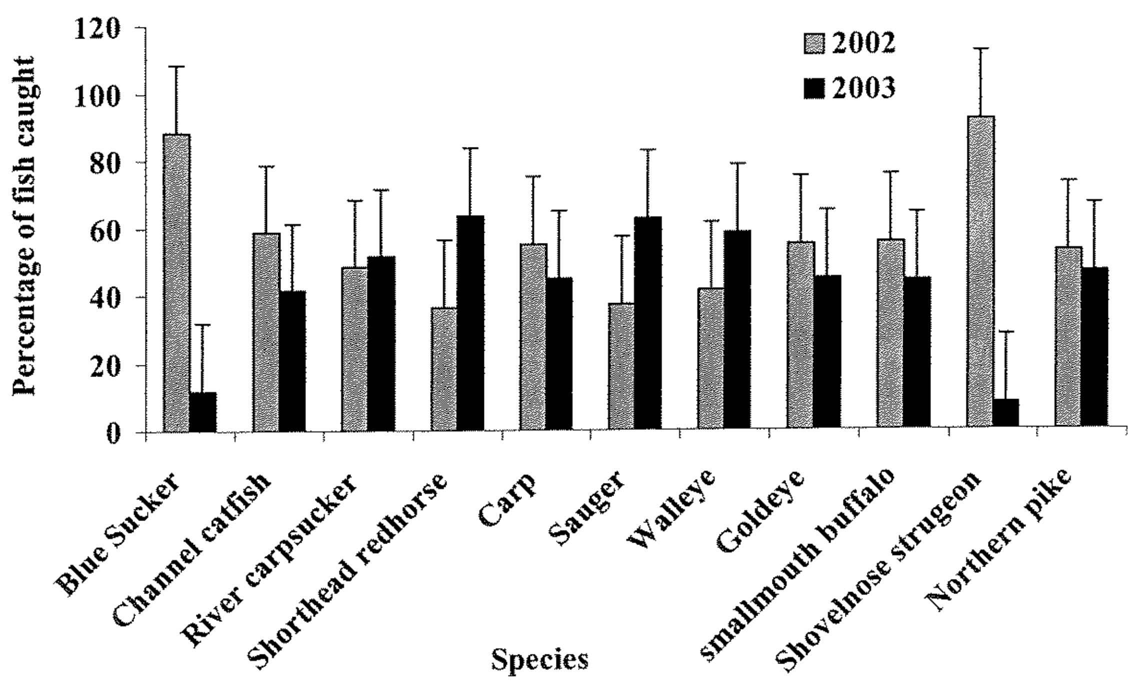

Figure 3. The proportions of the total catch of ten most abundant fish species caught in 2002 versus 2003 with drift trammel nets, hoop nets, and stationary gill nets on the Milk and Missouri rivers, Montana.

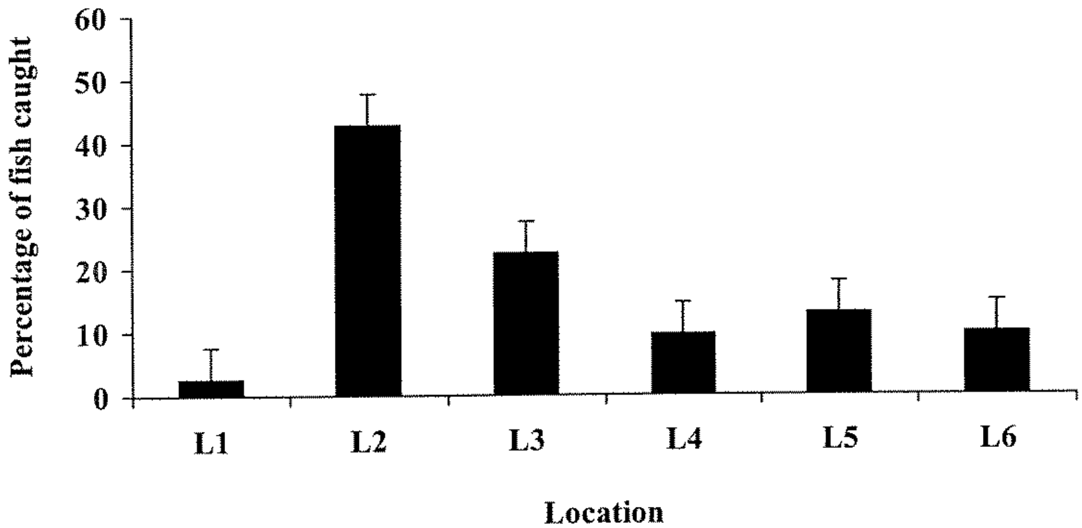

Figure 4. The proportion of fish per sample location caught with seines, drift trammel nets, hoop nets, and stationary gill nets on the Milk and Missouri rivers, Montana 2002 and 2003. L1-L6 represents the furthest downstream sampling location to the most upstream location.

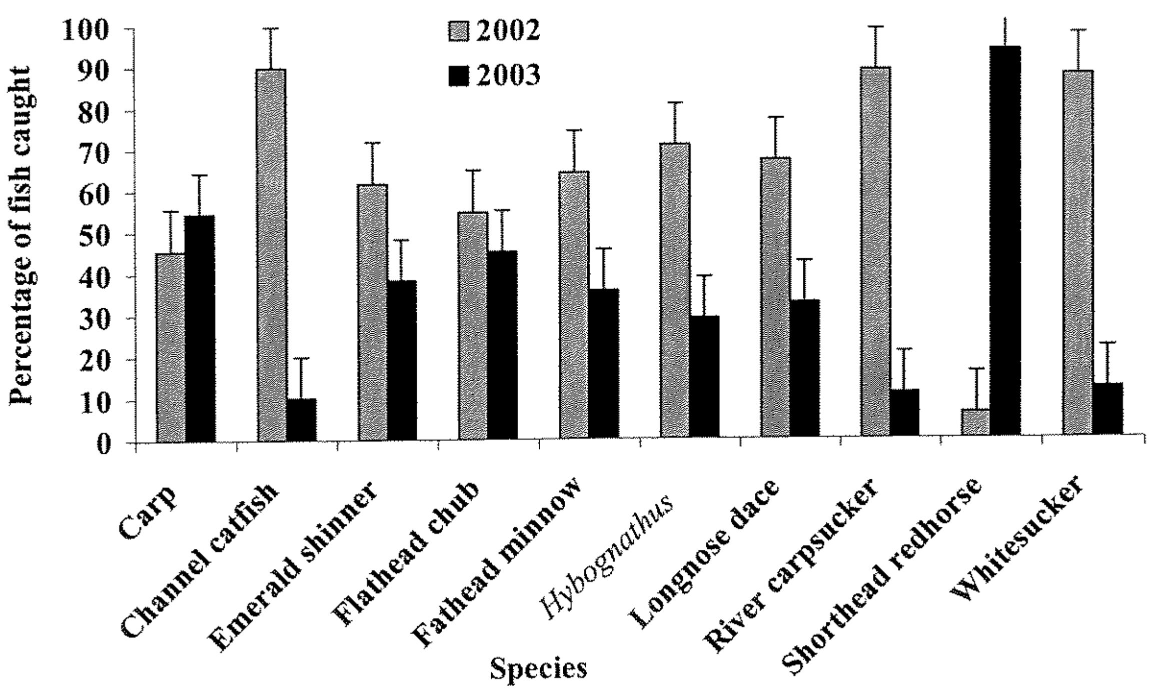

Figure 5. The proportions of the total catch of ten most abundant fish species caught in 2002 versus 2003 with seines on the Milk and Missouri rivers, Montana.

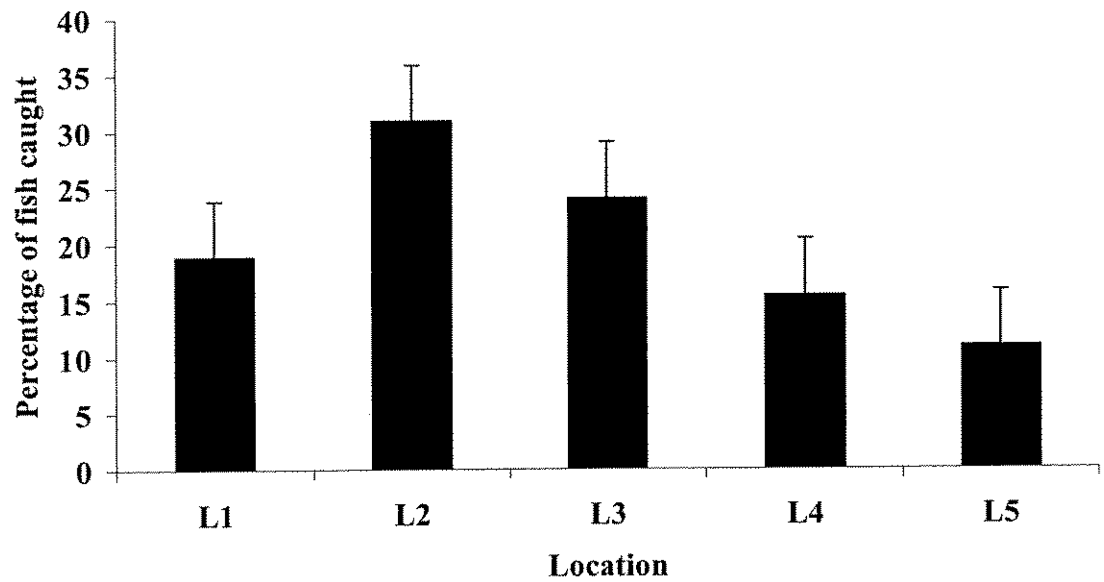

Figure 6. The proportion of fish per sample location caught with seines on the Milk and Missouri rivers, Montana 2002 and 2003. L1-L5 represents the furthest downstream sampling location to the most upstream location.

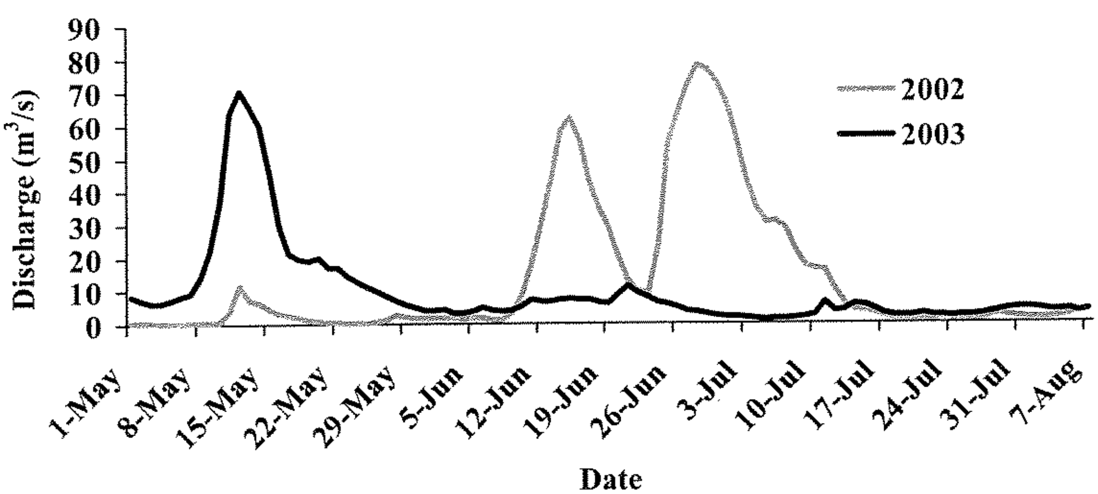

Figure 7. The discharge at the U.S.G.S. gauging station (06174500) near Nashua, Montana 2002 and 2003.

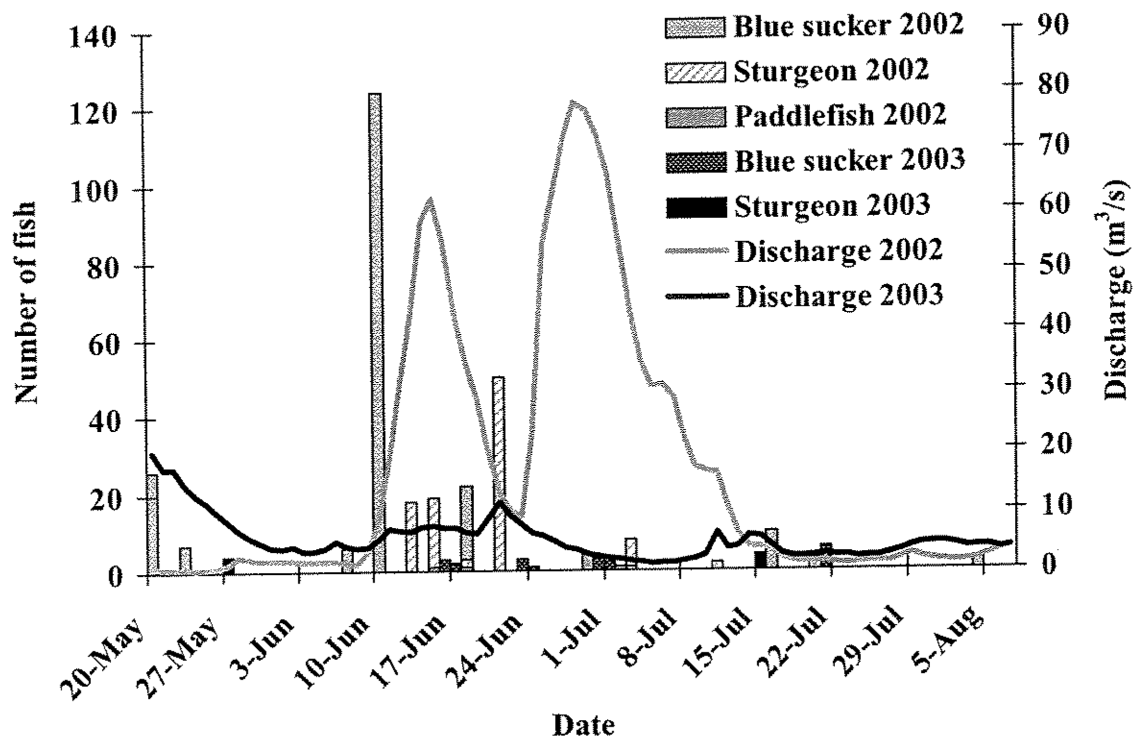

Figure 8. The distribution of blue sucker, shovelnose sturgeon, and paddlefish caught in the lower Milk and Missouri rivers, Montana and the discharge at the U.S.G.S. gauging station (06174500) near Nashua, Montana 2002 and 2003.

Table 2. Percent of ripe and unripe fish caught with hoop nets and stationary gill nets in the Milk and Missouri rivers, Montana 2002 and 2003 and the percent for each month.

		Year			Month				
Sex	Percent	2002	2003	Total	May	Jun	Jul	Aug	Total
Ripe	Frequency	265	74	339	97	203	36	3	339
	Percent of total	8	2	11	3	6	1	0	11
	Percent of row	78	22		29	60	11	1	
	Percent of column	15	5		18	17	3	2	
Unripe	Frequency	1458	1416	2874	457	980	1305	132	2874
	Percent of total	45	44	89	14	31	41	4	89
	Percent of row	51	49		16	34	45	5	
	Percent of column	85	95		82	83	97	98	
Total	Frequency	1723	1490	3213	554	1183	1341	135	3213
	Percent of total	54	46	100	17	37	42	4	100

Table 3. Percent of ripe and unripe fish caught per location in the Milk and Missouri rivers, Montana.

		Location						
Sex	Percent	L1	L2	L3	L4	L5	L6	Total
Ripe	Frequency	0	230	34	3	66	6	339
	Percent of total	0	7	1	0	2	0	11
	Percent of row	0	68	10	1	19	2	
	Percent of column	0	16	5	1	16	2	
Unripe	Frequency	21	1182	714	315	354	288	2874
	Percent of total	1	37	22	10	11	9	89
	Percent of row	1	41	25	11	12	10	
	Percent of column	100	84	95	99	84	98	
Total	Frequency	21	1412	748	318	420	294	3213
	Percent of total	1	44	23	10	13	9	100

Figure 9. Age frequency of 189 channel catfish in the lower Milk River, Montana.

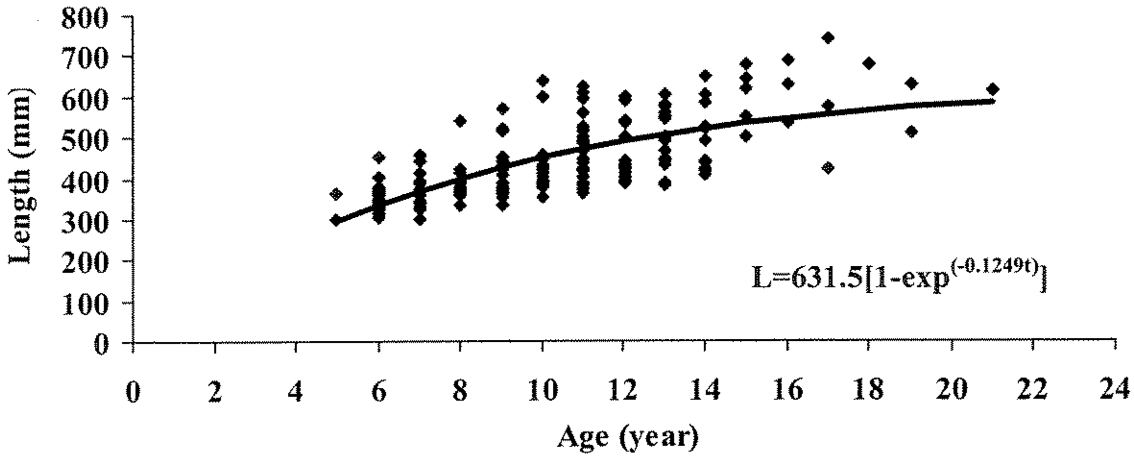

Figure 10. The Von Bertalanffy growth curve of channel catfish (n=189).

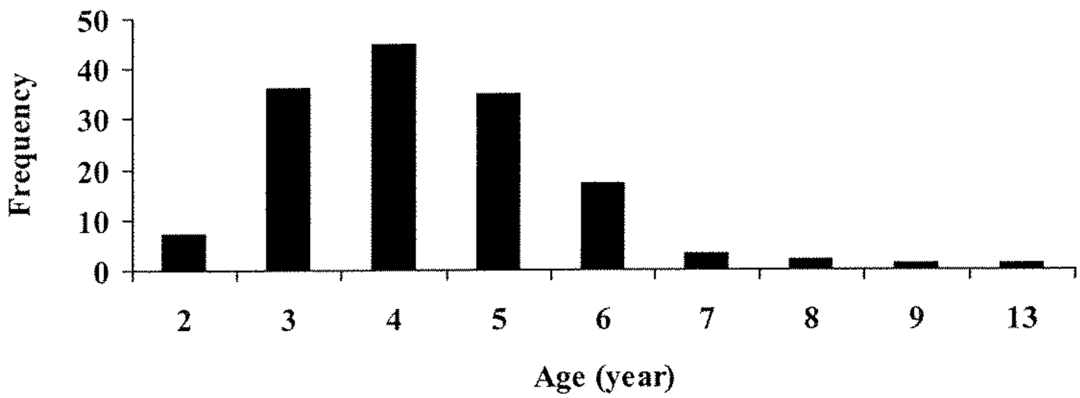

Figure 11. Age frequency of 146 sauger in the lower Milk River, Montana.

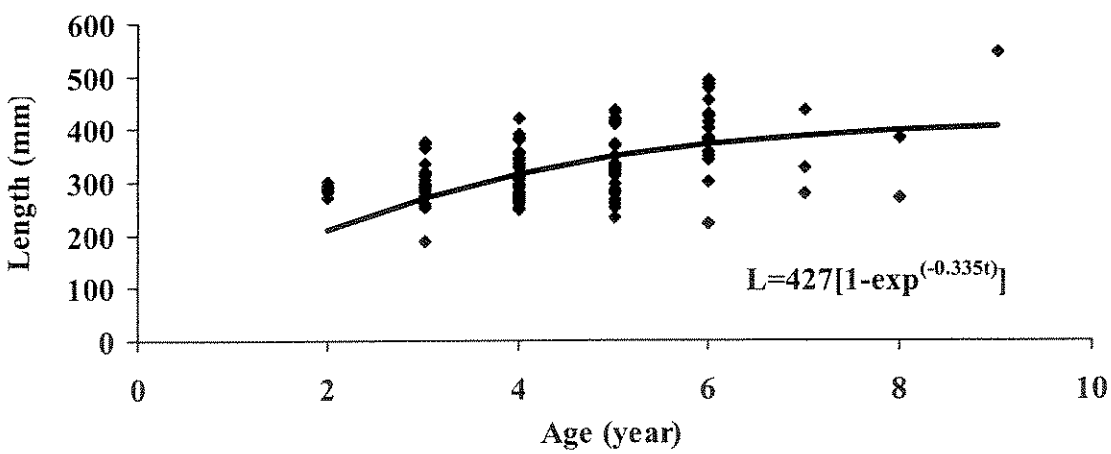

Figure 12. The Von Bertalanffy growth curve of sauger (n=146).

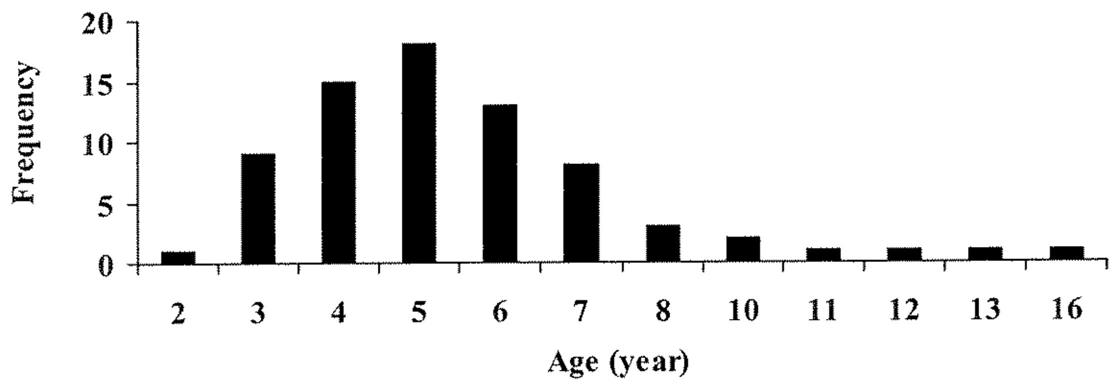

Figure 13. Age frequency of 73 walleye in the lower Milk River, Montana.

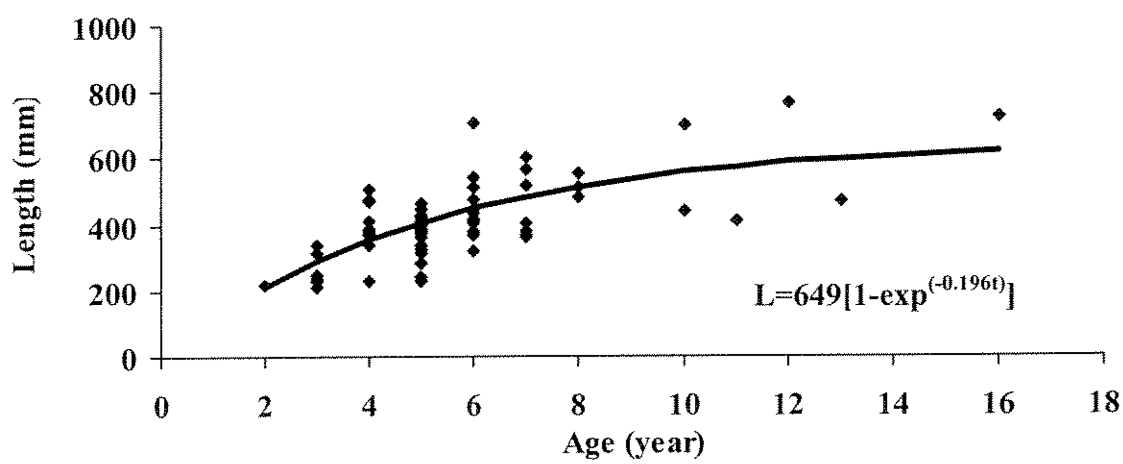

Figure 14. The Von Bertalanffy growth curve of walleye (n=73).

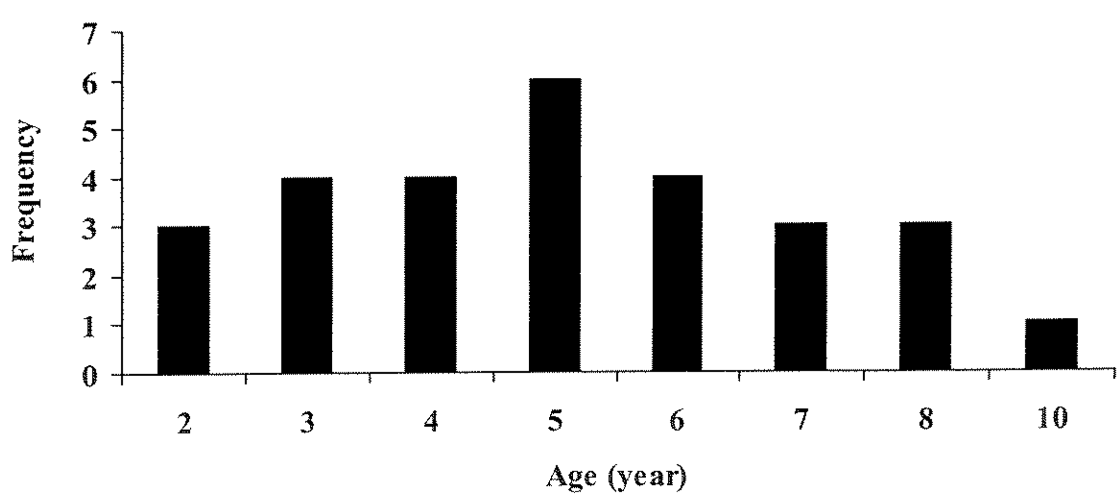

Figure 15. Age frequency of 28 northern pike in the lower Milk River, Montana.

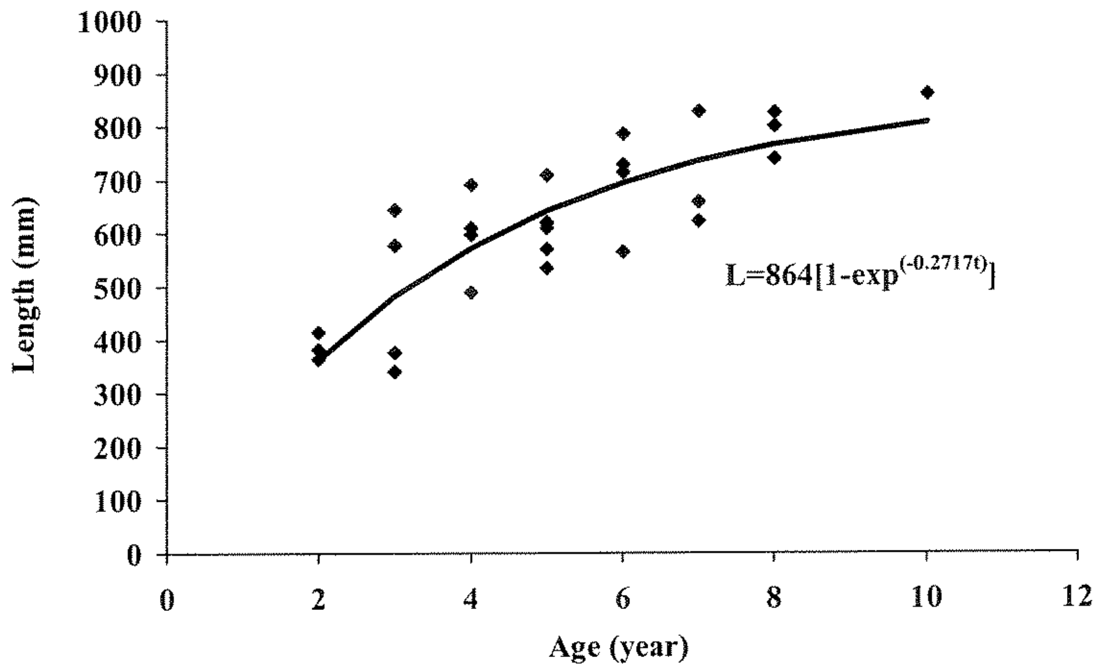

Figure 16 . The Von Bertalanffy growth curve of northern pike (n=28).

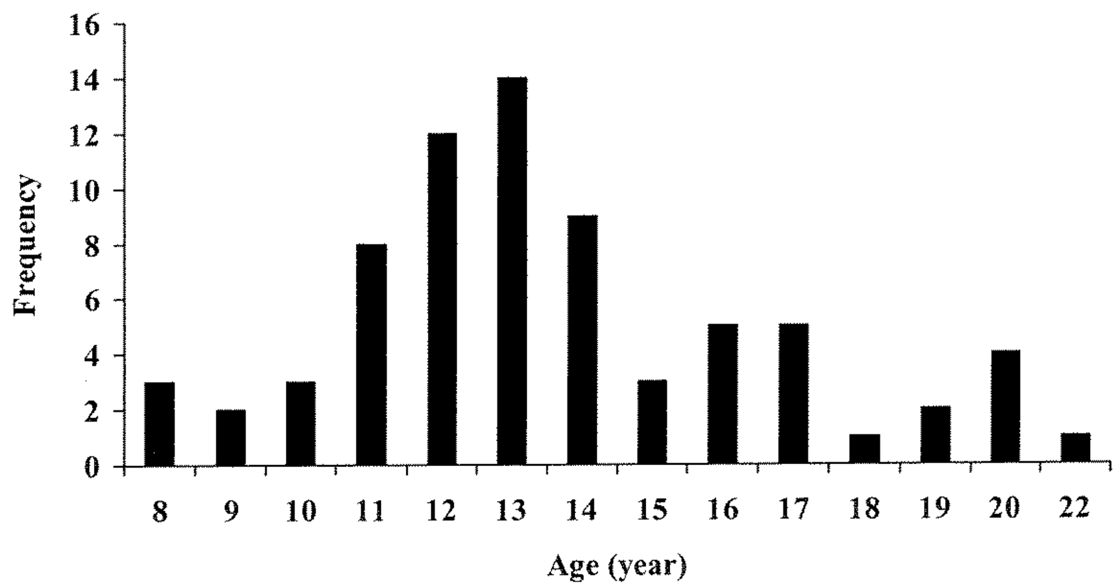

Figure 17. Age frequency of 72 shovelnose sturgeon in the lower Milk River, Montana.

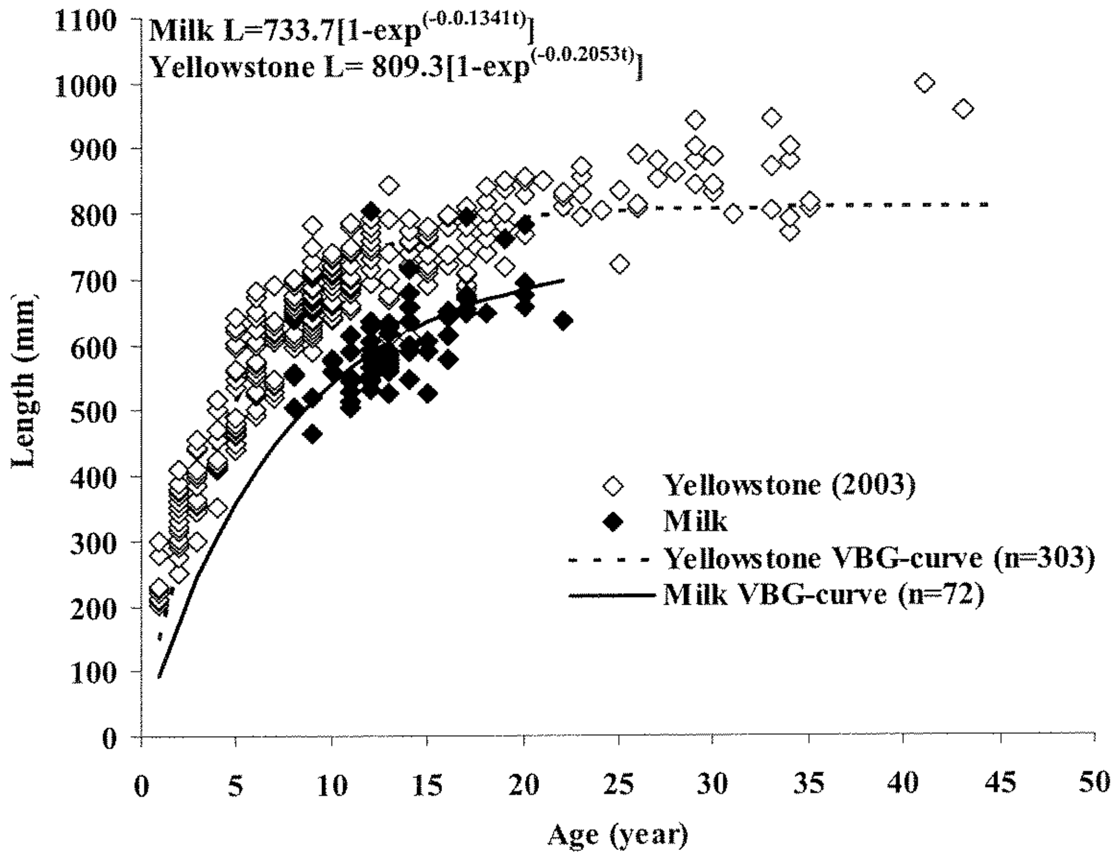

Figure 18. Von Bertalanffy growth curves of shovelnose sturgeon from the Milk and the Yellowstone rivers, Montana (Everett et al. 2003).

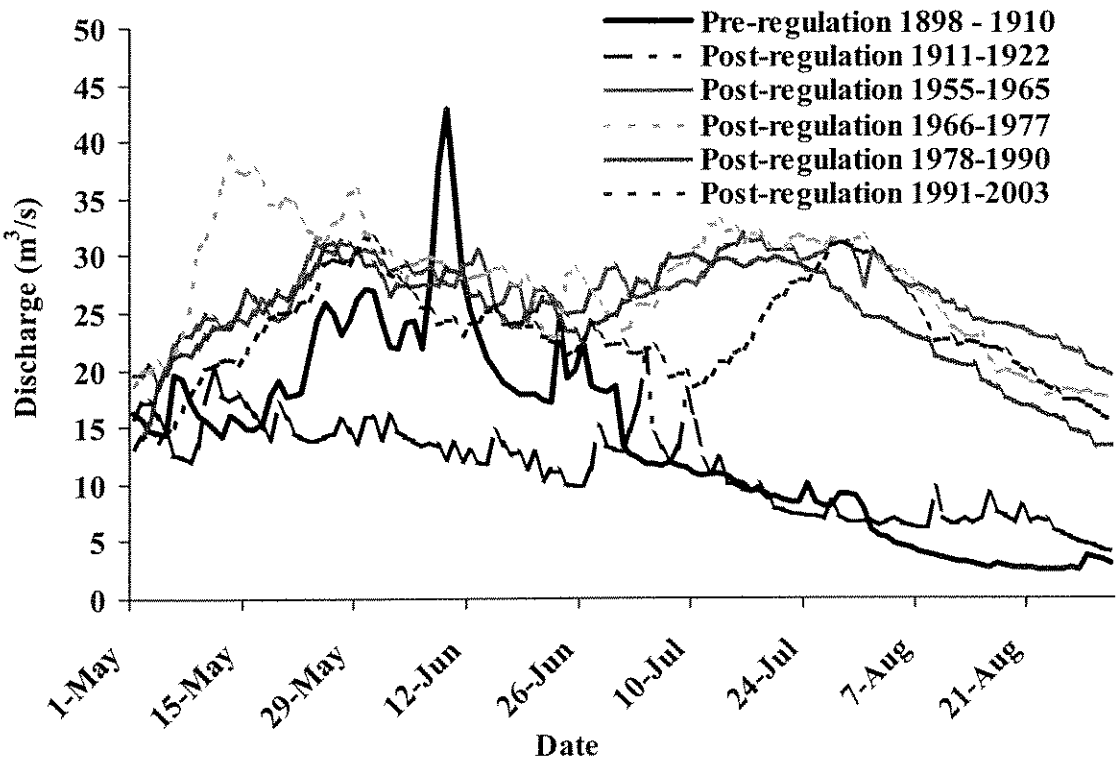

Figure 19. Average mean daily discharge for the Milk River pre-regulation (1898 to 1910) and ten to twelve year averages post-regulation (1911 to 1922 and 1955 to 2003) from the USGS gauging station (06140500) near Havre, Montana.

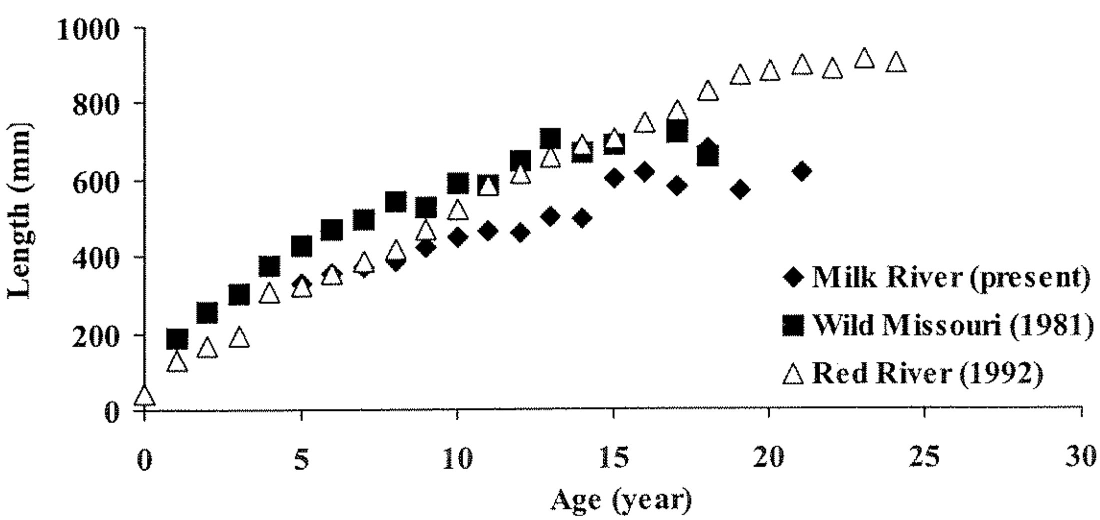

Figure 20. Mean length at age for channel catfish from the Milk River, Montana, Red River, North Dakota (Hegrenes 1987), and the wild and scenic Missouri River, Montana (Berg 1981).

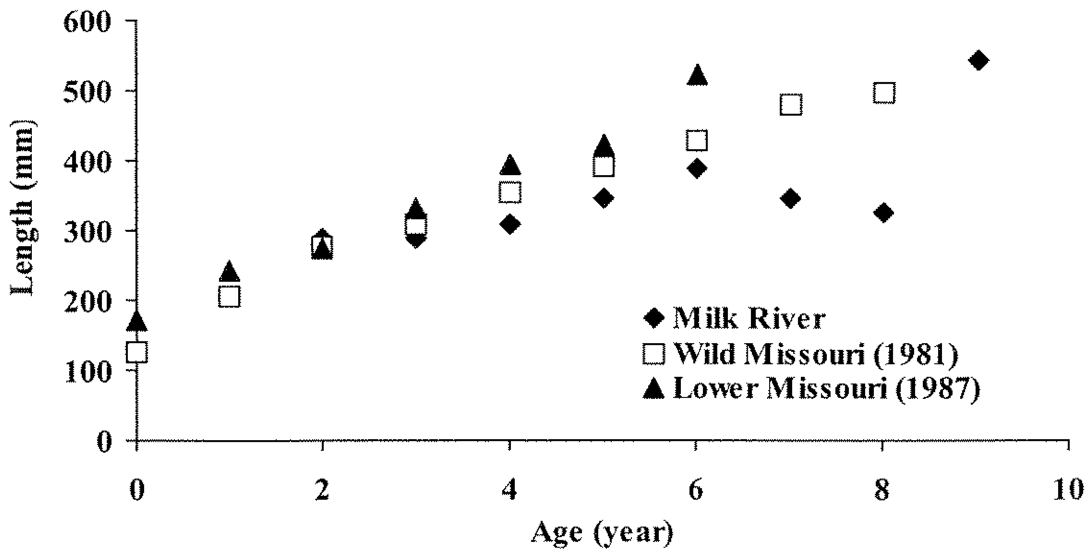

Figure 21. Mean length at age for sauger from the Milk River, Montana, wild and scenic Missouri River, Montana (Berg 1981), and the lower Missouri River, Montana (Gardner and Stewart 1987).

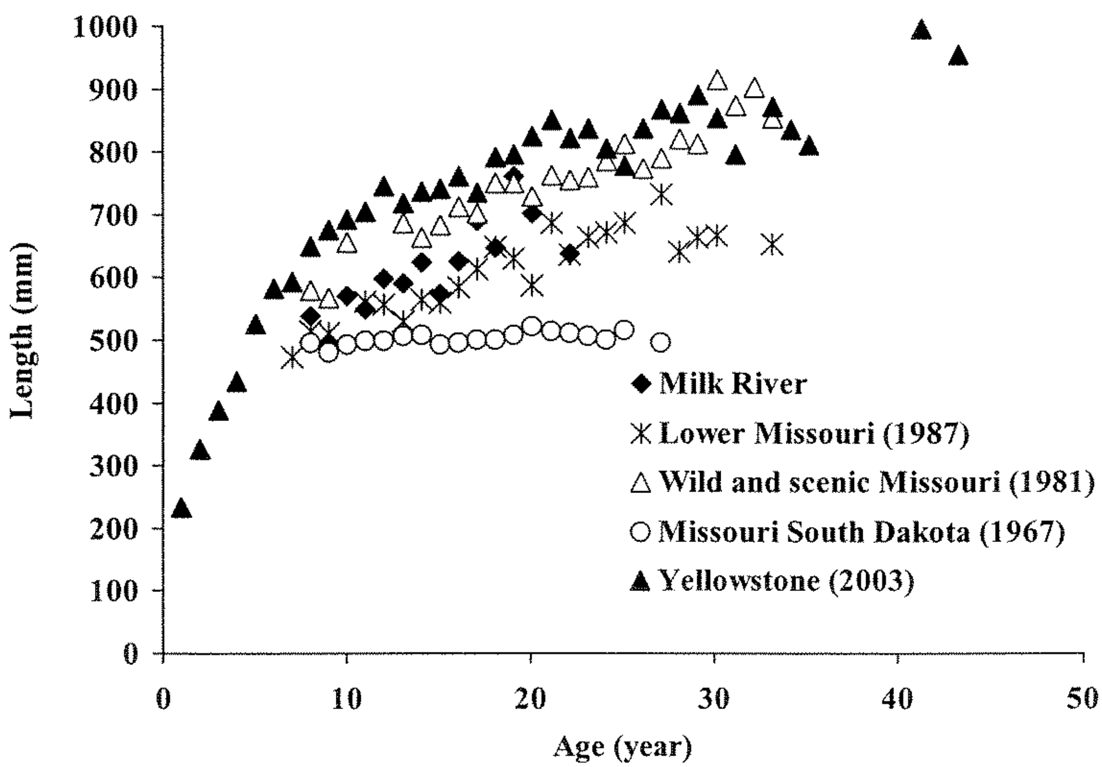

Figure 22. Mean length at age for shovelnose sturgeon from the Milk River, Montana, lower Missouri River, Montana (Gardner and Stewart 1987), the wild and scenic Missouri River, Montana (Berg 1981), Missouri River, South Dakota (Zweiacker 1967), and the Yellowstone River (Everett et al. 2003).