Fish Assemblage Structure and Growth in the Lower Milk River, Montana in Relation to Environmental Conditions

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Abstract

With the major habitat alterations on the Missouri River in the 20th century, native fishes must rely more heavily on the larger, more natural, inflowing tributaries for spawning and rearing habitat. A two-year study was conducted to investigate the occurrence and abundance of fishes in the lower Milk River, Montana, which enters the Missouri River immediately below Fort Peck Dam. In sampling conducted from May to August in successive years (2002, 2003), the fish species assemblage included multiple species of special concern (blue sucker *Cycleptus elongatus*, paddlefish *Polydon spathula*, sauger *Sander canadense*) and multiple watch list species identified by the Montana Natural Heritage Program (burbot *Lota lota*, brassy minnow *Hybognathus hankinsoni*, plains minnow *Hybognathus placitus*). Relationships with environmental conditions and their interactions with temporal variables (month, year) were investigated for occurrence and total catch data. Models were generally similar for individual species with temperature and turbidity being the primary environmental conditions influencing fish occurrence and abundance. Age and growth analysis was conducted on channel catfish (*Ictalurus punctatus*), sauger, walleye (*Sander vitreus*), northern pike (*Esox lucius*) and shovelnose sturgeon (*Scaphirhynchus platorynchus*). Channel catfish, sauger, walleye and shovelnose sturgeon all grew slower and lived longer in the lower Milk River than populations at lower latitudes. In view of the lower Milk River's role as spawning and rearing habitat for native fishes and its history of alterations from upriver dams and irrigation withdrawals, more attention should be given to maintaining or improving existing habitat conditions, including adequate instream flows and turbidity.

Key words: Milk River, Missouri River, native species, environmental conditions, spawning, von Bertalanffy

Introduction

In the past century, large rivers worldwide have undergone extensive modifications, including damming, channelization and diversion, as part of diverse human development along watercourses (Hynes 1989). As flowing water habitats in main-stem rivers have undergone impoundment, hydrograph and temperature changes and suspended sediment reductions, major inflowing tributaries have assumed greater importance for providing the remaining spawning and rearing habitat for many native fishes formerly dominant in and reliant upon, large rivers (Benda et al. 2004; Moyle and Mount 2007).

On the upper Missouri River, major habitat changes over the past century, especially the construction of Fort Peck Dam, have greatly altered habitats for native

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fish species. Remnant habitat in tributaries such as the lower Milk River, which enters the Missouri River immediately below the dam, may assume much greater, or even critical, importance in species survival. The Milk River below its lowermost dam (Vandalia Dam, 188 rkm) has well-developed riparian zones, cobble riffles and an incised channel (Stash et al. 2001). That portion of the river provides a diversity of habitats used by several native fish species both common and of conservation concern in the Missouri River drainage. 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 in 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 in the lowermost 400 km of the Milk River (Stash et al. 2001). Most fish were captured below Vandalia Dam, which may indicate that the fish above the dam are isolated from fishes below the dam, which are mainly migratory fish from the Missouri River (Stash et al. 2001). These and other fishes may be relying more heavily on the lower Milk River for spawning and rearing habitat than prior to Missouri River alteration.

In years with high spring flows, the Milk River functions much like a natural, undammed river in terms of a range of physical habitat features, including depth, velocity, turbidity and temperature. The warm, turbid character of the lower Milk River differs sharply and abruptly from conditions in the Missouri River at their confluence. Downstream of Fort Peck Dam, the Missouri River is cold (15^{o}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^{o}C, July), more turbid (1000 NTU, July) and less altered.

However, in the past century the Milk River has experienced a 60 percent 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. The impoundments extend from 188 km to 699 km upstream of the confluence with the Missouri River and have been developed mainly for irrigation. The dams have resulted in a reduction in high spring flows and have created barriers to fish movement. 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 Missouri River fish rely on the seasonal flows of the Milk River for spawning.

As part of a broader interest in maintaining habitats for native species in the Missouri River, background information was needed on the fish of the lower Milk River as those fish may contribute to survival of main-stem Missouri River native fish fauna. This study was designed to provide information on the fish fauna of the lower river. The objectives of this study were to 1) evaluate occurrence, abundance (total catch), species richness and fish assemblage structure among sampling sites in relation to environmental conditions potentially influencing fish presence and abundance; and 2) evaluate age and growth of important recreational fishes in relation to adjacent populations of fish.

Study area

Lewis and Clark named the Milk River, one of the largest tributaries to the upper Missouri River, for its milky-colored, turbid waters. The Milk River main-stem is 1,126 river kilometers (rkm) in length and drains an area of approximately 59,857 km^2 (Milk River Watershed Council Canada 2013). From the headwaters in Glacier National Park, Montana, the Milk River flows northeast, crossing into Canada for approximately 275 km (Stash et al. 2001). The river re-enters the United States in Hill County, Montana and flows through most of the north central portion of the state to its confluence with the Missouri River immediately downstream of Fort Peck Dam (Fig. 1).

Continental glaciers from the Quarternary Period have greatly influenced the topography of the lower Milk River basin as it exists today. The advance and recession of the continental glaciers left deposits of ground and terminal moraines and outwash channel deposits (Alden 1932). 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).

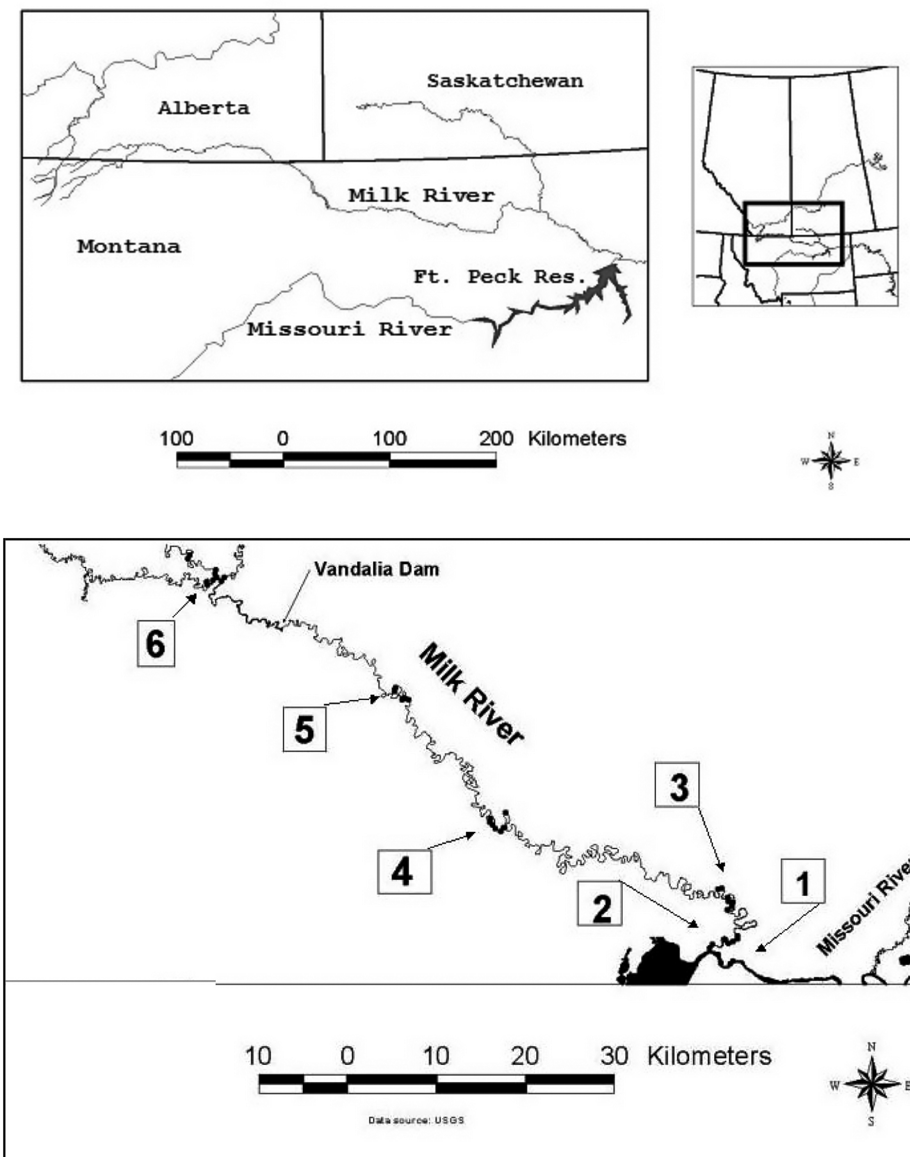

Figure 1. Map of the lower Milk River study area showing the specific sampling locations.

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 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 systems. 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 (one in our study area) and a pumping plant (Montana Department of Natural Resources and Conservation 1990).

The portion of the Milk River included in the study extends from the confluence of the Milk River with the Missouri River, to 20 rkm above Vandalia Dam, the first major diversion dam (Fig. 1). The first 4.8 rkm of the Missouri River downstream of the Milk River were also included in the study area, making a total study area of 212.8 rkm. The lower Milk River has been previously identified as having a warmwater and coolwater fish species assemblage (Stash et al. 2001).

Methods

Fish Collection

Sampling was conducted in two years, 2002 (Year 1) and 2003 (Year 2) at locations along the entire study area. Riffle and run habitats within the study area were sampled. Riffles were classified as areas with shallow, turbulent water passing through or over cobble 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 pools. Five 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.

Sites were repeatedly sampled with five gears: sinking gill nets, floating gill nets, trammel nets, hoop nets and bag seines, to increase the probability of sampling species present in each location. Each gear was deployed at least three times per site on the lower Milk River from mid-May to mid-August in both sampling years. 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 bar measure mesh. Floating gill nets were 150 m in length, by 1.8 m high, with 7.6 cm bar measure 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 2.5 cm bar measure mesh. 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 the net with a 5 mm ace mesh and a "many ends" mud lead line attached.

Most fish were identified to species in the field except members of the genus *Hybognathus* which were grouped and recorded together. Fish were weighed (g) and total length was recorded (mm) for all species, except sturgeon, where fork length was used and paddlefish, where body length from eye to fork of caudal fin was used (Ruelle and Hudson 1977). Relative weights (*Wr*) were calculated for the common recreational game fish. Fulton's condition factor (*K*; Ricker 1975) was calculated as an additional metric of condition and was the only condition metric for two species with no standard weight (W_s) equation. The presence of mature fish with milt or roe was sought as evidence of spawning activity. Sampled fish were checked manually; if roe or milt was detected after gentle pressure was applied to the abdomen, the fish was recorded as gravid.

We did not attempt to calibrate for gear differences in catchability by species, although we knew they existed. We compared total catches to assess abundance of fish consolidated across sampling gears.

We were, however, interested in assessing the influence of abiotic factors on fish use and total catch. Occurrence and abundance for each species was analyzed using environmental conditions as covariates in multiple regression models.

Turbidity at each site was measured in NTU's using a Hach model 2100P (Hach Corp., Loveland, CO). Depth and temperature were also measured during sampling. Daily discharge measurements were available from the U.S. Geological Service gauging stations (06174500; 06172310) on the Milk River near Nashua and Tampico Road, Montana. Flows were averaged for the sampling day and two days prior under the assumption that current stream flow may be only partially causative of species presence and a recent average stream flow would potentially provide more information on conditions fish cue on in a sampling location.

Age and Growth

Hard structures were collected for age and growth analysis for five common recreational fish species: channel catfish, walleye (*Sander vitreus*), shovelnose sturgeon, sauger (*Sander canadensis*) and northern pike (*Esox lucius*). The structures selected for use in age determination were based on previous studies documenting the utility of a particular structure. Random samples of pectoral fin rays were collected from channel catfish (Starkey and Scarnecchia 1999) with lengths ≥ 300 mm. Lead pelvic and dorsal fin rays were collected from all sauger and walleye (Borkholder and Edwards 2001). Cleithra were opportunistically collected from all incidental mortalities of northern pike (Casselman 1974). Pectoral fin rays were collected from shovelnose sturgeon (Everett et al. 2003; Koch et al. 2008).

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

The fin ray sections were cut with a low speed saw (Buehler, Lake Bluff, IL) 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 rays as possible to create a smooth edge. Each additional cut resulting in a thin section was viewed under a microscope attached to an Optical Pattern Recognition System (OPRS; BioSonics Inc., Seattle, WA) to determine if adjustments needed to be made during the cutting process to improve the resolution of the section. Whole cleithra or four fin ray sections were placed on a glass slide using clear fingernail polish and viewed under the OPRS.

Annuli were enumerated to determine age. No validation of age was possible, each ring was assumed to be an annulus. 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 used to get a consensus age between both readers.

Lengths at age of capture were used to develop von Bertalanffy growth curves for each species. Total length was used for all species except shovelnose sturgeon where fork length was used. The von Bertalanffy growth equations were expressed as $L = L_{\infty} \times (1-e^{-kt})$ for length (mm), where L is the length of the fish (mm) at age t, L_{∞} is the theoretical size limit and k is the curvature parameter. Because of a shortage of small, likely 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 (SAS Institute Inc., Cary, NC).

Statistical Analysis

Some data were missing from the overall dataset. Data imputations were performed for habitat variables of temperature (6.57% missing), turbidity (8.02% missing) and depth (19.71% missing). Temperature was imputed using a parametric bootstrapping algorithm in the MICE package (van Buuren and Groothuis-Oudshoorn 2011) of R statistical programming language (R Core Team 2016). Depth and turbidity were imputed using a random forest algorithm (Doove et al. 2014) and all imputed data was checked manually for congruence to the underlying dataset.

Variables flow and turbidity were log10 transformed to meet assumptions of normality. Differences in species richness between sampling location and sampling gear were compared using a Kruskal-Wallis Rank Sum Test (Higgins 2004; Smith et al. 2015) with a Holm correction used to account for multiple comparisons of location and gears. Location averaged habitat variables (depth, turbidity, etc.) were also compared using the same method to analyze habitat characteristics among sampling locations.

Fish assemblage relationships were investigated for total catch using non-metric multidimensional scaling (NMDS). NMDS is a robust ordination technique that has been used to assess species assemblage relationships (Smith et al. 2015; Watkins et al. 2015). Ordination fit was evaluated by stress values with stress of less than 20.0 indicating good fit (McCune and Grace 2002). Fish assemblage was investigated using pooled total catch data from each location. Differences in assemblage structure were investigated with permutational multivariate analysis of variance (PERMANOVA) and significant vectors were fit to the NMDS with rotational vector fitting for total catch data.

Species-specific Models

In addition to investigations of species richness, habitat associations and fish assemblage structure, species-specific relationships with abiotic factors were investigated for presence/absence and total catch data with multiple regression models. Generalized linear models were used to identify abiotic factors most associated with occurrence and total catch of selected fish species. Sampling was conducted between 20 May and 11 August for both years and interactions between environmental conditions and time were investigated in candidate models. Sampling from 20 May to 30 June (Month 1) and 1 July to 11 August (Month 2), in addition to Year 1 and Year 2, were used in interactions with abiotic predictor variables to account for any temporal variability.

A binomial error distribution and logit link function were used for presence/absence models. An over-dispersion (variance > mean) parameter ($\hat{c}$) was calculated for global models for all species and used as an indication of data structure. Models with $\hat{c}$ over 1 were considered over-dispersed and Schwarz's Bayesian Information Criterion (Schwarz 1978; BIC) was used for model selection. The distribution for total catch models was selected by creating global models (models with the most parameters) for each species using Poisson and negative binomial error distributions and zero-inflated versions of both and BIC was used to rank the models with different distributional assumptions. The negative binomial distribution had the lowest BIC value for all species and was used for subsequent modeling of total catch data. Model fit was evaluated by using Spearman's rank correlations (ρ) between actual and predicted values of the response variable for each model considered plausible (Holbrook et al. 2016).

Prior to model fit, habitat characteristics were investigated for multicollinearity using Spearman's correlation coefficients to identify correlations between all pairs of habitat variables. *A priori* correlation of $|\rho| \geq 0.70$ would be considered highly correlated and variables would not be used together in candidate models. No highly correlated variable pairs were found.

The candidate occurrence and total catch models consisted of 7-13 *a priori* models for each species. An information-theoretic approach was used to select the most parsimonious model among the candidate model set for each species (Burnham and Anderson 2002). Candidate models were ranked using BIC values and models with ΔBIC values of ≤ 2 were considered equally parsimonious and retained for interpretation. Results were not considered for species caught only in seines and for rare species because models did not seem meaningful and often did not converge. Models explaining use by environmental conditions and temporal interactions were developed for bigmouth buffalo, blue sucker, common carp (*Cyprinus carpio*), channel catfish, goldeye, river carpsucker, sauger, shorthead redhorse, shovelnose sturgeon, smallmouth buffalo and walleye.

Results

In all, 8,910 fish, representing 29 species, were captured; 4,953 (56%) in Year 1 (2002) and 3,957 (44%) in Year 2 (2003). For trammel nets, hoop nets and bag seines the percentage of fish caught was higher in Year 1 than in Year 2 and for stationary gill nets the percentage of fish caught was lower in Year 1 than Year 2. The ten most abundant species overall were native to the Milk and Missouri rivers (Table 1). Three of the native species, blue sucker, sauger and paddlefish are Montana species of special concern. Another native species, burbot (*Lota lota*), is a watch list species for Montana Natural Heritage Program, as are two members of the genus *Hybognathus*, the plains minnow (*Hybognathus placitus*) and brassy minnow (*Hybognathus hankinsoni*). There were also many non-native fishes caught (8 species), but generally as small percentages of fishes in a particular location or with a particular gear (Table 1).

Catches by species differed by year. Most of the blue suckers (88%) and shovelnose sturgeon (84%) were sampled in Year 1. In contrast, most walleye (88%), shorthead redhorse (76%) and sauger (61%) were sampled in Year 2. Most other species were sampled in similar proportions between years. Gravid fish of 11 different species, indicating reproductive readiness, were sampled in nearly equal proportion between hoop and gill nets, mainly during May and June. Gravid fish were generally caught at locations farther upstream, with location 5 having the highest number of gravid fish sampled (mainly shovelnose sturgeon).

Location 2 (Fig. 1) had the highest number of fish sampled and location 1 on the Missouri River, downstream of the confluence of the Milk and Missouri River and location 6 above Vandalia Dam, had the lowest number of fish sampled. Habitat characteristics were not significantly different between locations ($\chi^2 = 23$; 23 df; $P = 0.46$) suggesting fairly homogenous conditions in the lower Milk River. Species richness was significantly different between locations ($\chi^2 = 15.2081$; 5 df; $P = 0.01$) with significant pairwise differences between location 6 and locations 2 ($P = 0.03$) and 3 ($P = 0.01$).

Species richness was significantly different among gears ($\chi^2 = 28.507$; 4 df; $P < 0.01$) with significant pairwise differences between floating gill nets and hoop nets, siene and sinking gill nets ($P < 0.01$). Some species, in particular small minnows (*Cyprinidae*), were only caught with the small-meshed seine. These catches included fathead minnow ($n = 736$), longnose dace ($n = 65$), emerald shiner ($n = 1523$) and spottail shiner ($n = 16$). Overall, seine catches were greater later in the year (July and August). Four other species sampled by only one gear were caught in very low numbers ($n < 7$; Table 1).

The timing and duration of the spring seasonal discharge patterns over the period May to mid-August differed between Years 1 and 2. In Year 1, 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 before dropping to < 10 m^3/s on 18 July. In Year 2, increased spring discharge lasted for only 17 days and occurred much earlier, peaking at 70 m^3/s on 12 May and before dropping to < 10 m^3/s on 28 May. The later peak in spring discharge in Year 1 was associated with higher rainfall in late spring,

Table 1. Percentage catch for each location or gear type. N = native fish, S = species of special concern and I = non-native species (Holton and Johnson 2003). DTN = drifting trammel net, FGN = floating gill net, SGN = sinking gill net. Species are abbreviated as follows black bullhead (BKBH), bigmouth buffalo (BMBF), burbot (BRBT), blue sucker (BUSK), common carp (CARP), channel catfish (CNCF), white crappie (CRPE), emerald shiner (ERSN), flathead chub (FHCB), fathead minnow (FHMW), freshwater drum (FWDM), goldeye (GDEY), *Hybognathus* (HBNS), longnose dace (LNDC), longnose sucker (LNSK), northern pike (NTPK), paddlefish (PDFH), rainbow trout (RBTT), river carpsucker (RVCS), sauger (SGER), shorthead redhorse (SHRH), smallmouth buffalo (SMBF), smallmouth bass (SMBS), shovelnose sturgeon (SNSG), stonecat (STCT), spottail shiner (STSN), walleye (WLYE), white sucker (WTSK) and yellow perch (YWPH).

		Location						Gear				
Species	**Status**	**1**	**2**	**3**	**4**	**5**	**6**	**DTN**	**FGN**	**HOOP**	**SEINE**	**SGN**
BKBH	I	0.00	0.00	0.05	0.12	0.00	0.00	0.00	0.00	0.08	0.00	0.04
BMBF	N	0.31	0.13	0.16	0.48	0.16	0.00	0.84	0.00	0.17	0.11	0.07
BRBT	S	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00
BUSK	S	4.66	7.18	1.15	0.00	0.00	0.00	3.77	59.46	10.44	0.02	3.00
CARP	I	0.93	2.53	3.24	3.26	0.81	4.36	11.11	0.00	0.76	2.18	1.68
CNCF	N	5.59	14.46	20.24	28.38	26.09	12.59	14.88	0.00	45.03	2.50	22.23
CRPE	I	0.00	0.03	0.00	0.48	0.00	1.21	0.00	0.00	0.08	0.11	0.14
ERSN	N	30.43	6.41	15.74	7.61	9.98	0.00	0.00	0.00	0.00	34.27	0.00
FHCB	S	6.21	11.13	10.75	0.48	1.45	0.00	0.21	0.00	0.25	18.74	0.36
FHMW	N	1.24	3.41	5.98	14.49	5.48	0.00	0.00	0.00	0.00	16.56	0.00
FWDM	N	0.00	0.10	0.22	0.60	0.00	1.69	0.00	0.00	0.08	0.14	0.43
GDEY	N	8.39	10.99	11.41	9.66	18.36	29.54	19.92	8.11	3.11	0.79	25.08
HBNS	S	6.21	4.59	2.08	3.86	0.48	0.00	0.00	0.00	0.00	8.39	0.00
LNDC	N	0.62	1.15	1.04	0.12	0.81	0.00	0.00	0.00	0.00	1.46	0.00
LNSK	N	0.31	0.10	0.00	0.00	0.16	0.00	0.21	0.00	0.08	0.09	0.00
NTPK	I	0.00	0.40	0.38	1.21	1.45	2.66	0.00	0.00	0.25	0.00	1.64
PDFH	S	0.62	0.03	0.00	0.00	0.00	0.00	0.42	2.70	0.00	0.00	0.00
RBTT	I	1.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00

Table 1. continued next page

Table 1. continued

Species	Status	Location 1	2	3	4	5	6	Gear DTN	FGN	HOOP	SEINE	SGN
RVCS	N	8.39	20.80	8.78	10.27	5.15	17.68	22.22	24.32	22.39	5.47	19.55
SGER	N	3.42	3.24	2.74	1.45	0.97	0.00	3.98	0.00	1.85	0.41	4.14
SHRH	N	12.42	5.87	8.72	8.45	20.77	12.35	5.24	0.00	10.02	5.49	11.56
SMBF	N	0.31	4.11	3.62	7.25	4.83	5.57	5.45	0.00	4.63	1.19	4.78
SMBS	I	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.08	0.05	0.04
SNSG	N	4.66	1.58	2.80	0.00	0.00	0.00	10.48	5.41	0.08	0.00	2.21
STCT	N	0.00	0.07	0.22	0.36	0.00	0.00	0.00	0.00	0.08	0.09	0.14
STSN	I	0.31	0.24	0.16	0.24	0.48	0.00	0.00	0.00	0.00	0.36	0.00
WLYE	I	0.00	0.30	0.27	0.97	1.29	11.38	0.00	0.00	0.25	0.00	2.64
WTSK	N	3.42	1.11	0.11	0.24	0.48	0.00	1.26	0.00	0.17	1.44	0.04
YWPH	I	0.00	0.00	0.00	0.00	0.48	0.97	0.00	0.00	0.00	0.00	0.21

whereas the peak in Year 2 was associated with snowmelt runoff.

Blue sucker and shovelnose sturgeon catches also differed greatly between years. In Year 1, two hoop nets caught 124 blue suckers at location 2 on 10 June, before the first discharge peak. Fifty shovelnose sturgeon were caught in one stationary gill net at location 3 on 17 June, between the two discharge peaks. In the following year, in which peak flows occurred earlier and only one peak occurred, blue suckers and shovelnose sturgeon were not captured during the peak in discharge. Total catches for these two species were also lower than in the previous year.

The NDMS ordination characterized differences in fish assemblage structure by location. The NMDS for total catch data, which indicated species associations with location and habitat vectors, showed strong associations for catches with low totals and locations at the periphery of the study area. For instance, longnose sucker, rainbow trout, paddlefish and black bullheads were associated with location 1 below the confluence of the Milk River with the Missouri River and black crappie and yellow perch were associated with location 6, the only location above Vandalia Dam (Fig. 2). Species with higher catch numbers clustered around locations in the middle of the ordination plot and appeared to be associated with locations in the middle of our sampling area: location 2 (blue sucker, bigmouth buffalo, shovelnose sturgeon and white sucker), location 3 (emerald shiner, longnose dace) and location 4 (sauger, walleye, river carpsucker and smallmouth buffalo) (Fig. 2).

In models explaining environmental conditions and temporal interactions for individual species, results for occurrence (Table 2)

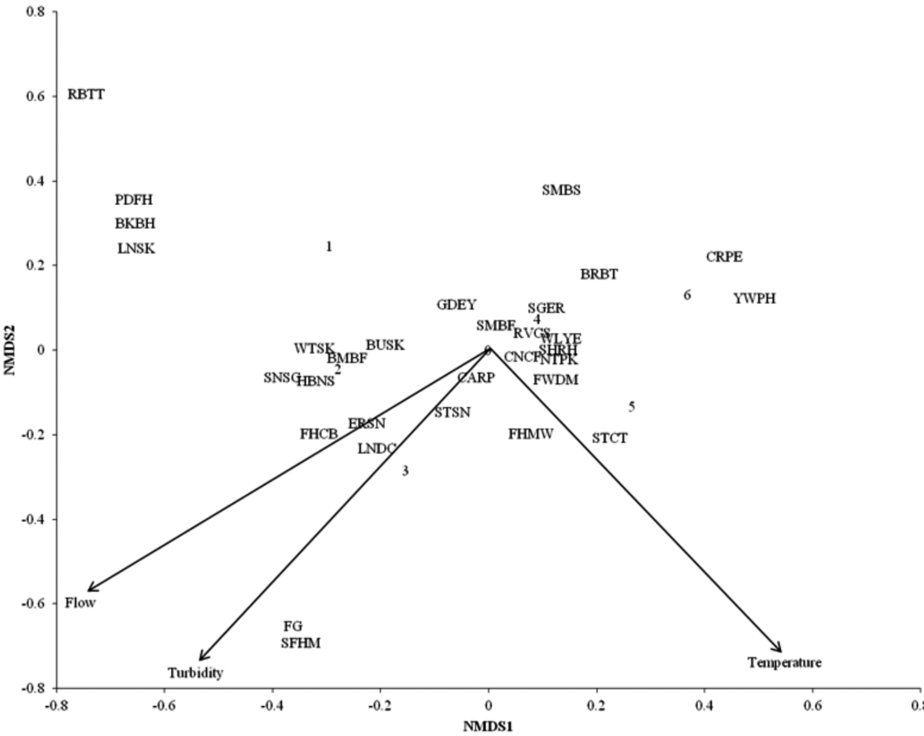

Figure 2. Nonmetric multidimensional scaling ordination (stress = 0.8) of the fish assemblage structure using total catch data from six sites in the Milk and Missouri Rivers. Significant (P ≤ 0.05) habitat vectors are included and sites are delineated by number, but 0 delineates the origin, not a site. Reference Table 1 for species codes.

and total catch (Table 3) were very similar for most species. Blue sucker, common carp, channel catfish, goldeye, shorthead redhorse, shovelnose sturgeon, smallmouth buffalo and walleye all had models of almost equal parsimony for both occurrence and abundance with the same explanatory variables (Tables 2 and 3). River carpsucker and sauger were the only species to have no explanatory variables in common between parsimonious models for occurrence and abundance (Tables 2 and 3). Blue sucker, common carp and shorthead redhorse were all significantly positively associated with turbidity while walleye were significantly negatively associated with turbidity. Shorthead redhorse occurrence was also significantly positively associated with a turbidity and Year 2 interaction. Channel catfish and smallmouth buffalo were positively associated with temperature, as was the abundance of river carpsucker and sauger. Shovelnose sturgeon were positively associated with flow, while goldeye were significantly negatively associated with the flow by Month 2 (July/August) interaction.

Age and Growth

In all, 508 fish were aged in this study: 189 channel catfish, 28 northern pike, 146 sauger, 72 shovelnose sturgeon and 73 walleye (Table 4). Mean lengths at age were calculated for aged fish and varied from 330 mm at age 5 to 615 mm at age 21 for channel catfish, from 287 mm at age 2 to 542 mm at age 13 for sauger, from 271 mm at age 2 to 725 mm at age 16 for walleye, from 386 mm at age 2 to 810 mm at age 10 for northern pike and from 538 mm at age 8 to 637 mm at age 22 for shovelnose sturgeon. Length weight equations and von Bertalanffy growth models were developed

Table 2. Occurrence models using logistic regression for important native and recreational species of the lower Milk River. Model selection criteria and c-hat (**ĉ**) are reported. **ĉ** gives an idea of overdispursion in the underlying dataset with values ≤ 1 indicating no overdispursion.

Species	Model	BIC	ΔBIC	-Log(l)	ĉ	Weight
Blue Sucker	+LogTurb,-LogTurb:Month2	139.6	0.00	-62.41	0.97	0.48
	+Temp,-Temp:Month1	141.0	1.41	-63.12	0.97	0.24
Common Carp	+LogTurb	177.0	0.00	-83.57	1.21	0.78
Channel Catfish	+Temp	156.0	0.00	-73.06	1.06	0.77
Goldeye	+LogTurb	197.9	0.00	-94.04	1.40	0.23
	-LogFlow	198.0	0.10	-94.09	1.40	0.22
	+Depth	198.3	0.39	-94.23	1.40	0.19
	-Temp	198.4	0.52	-94.29	1.40	0.18
	-LogFlow,-LogFlow:Month2	199.3	1.42	-94.29	1.40	0.12
River Carpsucker	+LogTurb	190.9	0.00	-90.53	1.36	0.53
Sauger	+LogTurb	190.3	0.00	-90.23	1.34	0.66
Shorthead Redhorse	+LogTurb,+LogTurb:Year2	187.8	0.00	-86.50	1.40	0.91
Shovelnose Sturgeon	+LogFlow	90.5	0.00	-40.31	0.52	0.84
Smallmouth Buffalo	+Temp	190.8	0.00	-90.46	1.33	0.81
Walleye	+Temp,+Temp:Year2	133.5	0.00	-59.38	0.88	0.40
	-LogTurb	134.9	1.35	-62.52	0.88	0.20

for all species used in age and growth analyses and are summarized in Table 4.

The overall pattern of *W*r shows Milk River fishes had low condition on average, with the possible exception of northern pike and river carpsucker (Table 5). The average *Wr* of smallmouth buffalo (74) was the lowest of all species analyzed. The *K* values were variable due to the differences in body type of species sampled. The two species without *Wr* equations, blue sucker and goldeye, had condition factors less than 1 (Table 5).

Discussion

The ten most abundant species caught in our sampling were all native to the Milk and Missouri rivers, which indicates the Milk River provides important habitat for a variety of native species. One of the ten species, the blue sucker, is a Montana species of special concern; another species, the flathead chub, is much reduced throughout its range (Rahel and Thel 2004). As the largest tributary to the Missouri River between Fort Peck Dam and the confluence of the Yellowstone River (375 rkm), the high incidence of native fish fauna in the Milk River has important conservation implications. The Missouri River fauna below mainstem dams, including Fort Peck, has changed from species uniquely adapted for life in turbid waters with fluctuating flows and temperatures such as flathead chub and blue

Table 3. Total catch models using negative binomial regression for important native and recreational fish of the lower Milk River. Model selection criteria are reported as a way to assess model fit and support relative to other candidate models.

Species	**Model**	**BIC**	**ΔBIC**	**-Log(*l*)**	**ρ**	**Weight**
Blue Sucker	+LogTurb,-LogTurb:Month2	269.9	0.00	-138.61	0.32	0.65
Common Carp	+LogTurb	380.7	0.00	-182.97	0.25	0.89
Channel Catfish	+Temp	884.6	0.00	-434.94	0.30	0.61
	+Temp,+LogTurb,+Depth,-LogFlow	885.7	1.04	-428.08	0.37	0.36
Goldeye	-LogFlow,-LogFlow:Month1	649.4	0.00	-314.87	0.19	0.59
River Carpsucker	+Temp,-Temp:Month2	773.0	0.00	-376.64	0.31	0.93
Sauger	+Temp,-Temp:Month2	428.2	0.00	-204.27	0.28	0.93
Shorthead Redhorse	+LogTurb,+LogTurb:Year2	652.2	0.00	-316.24	0.36	0.62
	-Temp,+Temp:Year2	653.4	1.27	-316.87	0.35	0.33
Shovelnose Sturgeon	+LogFlow	175.8	0.00	-80.53	0.33	0.92
Smallmouth Buffalo	+Depth	529.4	0.00	-257.30	0.13	0.27
	+Temp,-Temp:Month2	529.6	0.22	-254.95	0.23	0.24
	+Temp	529.9	0.55	-257.58	0.21	0.21
	-LogFlow	531.2	1.80	-258.21	-0.01	0.11
	-LogTurb	531.3	1.92	-258.26	-0.14	0.10
Walleye	-LogTurb	206.3	0.00	-95.75	0.21	0.90

sucker to pelagic planktivores and sight-feeding predators such as emerald shiners and walleye (Pflieger and Grace 1987; Rabeni 1996; Everett et al. 2004). Milk River habitat for native species has thus assumed greater importance than before Missouri River main channel alterations.

The significantly lower species richness in location 6, above Vandalia Dam, than locations 2 and 3, is consistent with results of Stash et al. (2001). Species richness was greater further downstream in the Milk River and there were differences above and below Vandalia Dam (Stash et al. 2001). The main factor associated with this difference in our study and that of Stash et al. (2001) is the diversion dam, which acts as a barrier to fish movement in all flows (Stash et al. 2001). Barriers impeding dispersal have been shown to be detrimental to other Great Plains systems and fishes (Cross et al. 1985; Bestgen and Platania 1990, 1991; Winston et al. 1991; Fausch and Bestgen 1997; Luttrell et al. 1999; Matthews and Marsh-Matthews 2007). There can be successful re-colonization of habitat by native fishes if fish passage is provided (McKoy 2013) but special considerations must be made for certain species that resist passage (e.g., shovelnose sturgeon; White and Mefford 2002). Our results emphasize the need to provide fish passage at such dams whenever possible to assist spawning success of native species.

Table 4. Age and growth results showing the species aged (reference Table 1 for species codes) and total numbers used in age and growth analysis. Fish sizes, ages and both length weight equations and von Bertalanffy growth equations were calculated for age and growth analysis.

Species	*n* (aged)	Age		Length (mm)			Weight (g)			Length Weight Equation	von Bertalanffy Growth Equation
		Min	Max	Mean (SE)	Min	Max	Mean (SE)	Min	Max		
CNCF	739(189)	5	21	397(101)	20	740	608(543)	0.1	4200	$\log_{10}W=2.9966\log_{10}L-5.1065$ ($r^2=0.97$)	$L=631.5(1-e^{(-0.1249t)})$
SGER	157(146)	2	13	326(63)	220	543	294(207)	50	1330	$\log_{10}W=2.86\log_{10}L-4.79$ ($r^2=0.81$)	$L= 427(1-e^{(-0.335t)})$
WLYE	82(73)	2	16	418(139	196	867	820(945)	50	4400	$\log_{10}W=2.761\log_{10}L-4.47$ ($r^2=0.87$)	$L=649.7(1-e^{(-0.196t)})$
NTPK	59(28)	2	10	634(158)	326	926	1832(1135)	250	4300	$\log_{10}W=2.70\log_{10}L-4.38$ ($r^2=0.87$)	$L=864(1-e^{(-0..2717t)})$
SNSG	114(72)	8	22	620(65)	465	805	997(391)	300	2650	$\log_{10}W=3.38\log_{10}L-6.47$ ($r^2=0.89$)	$L=733.7(1-e^{(-0.1341t)})$

The presence of many gravid fish during spring flows is consistent with other studies (Geen et al. 1965; Cross 1967; Curry and Spacie 1984; Walters et al. 2014). Those authors have concluded that the fish may be keying in on elements of the hydrograph for preferable environmental conditions for spawning, as would be expected for Great Plains fishes (Fausch and Bestgen 1997). Our study supports this conclusion. In the lower Milk River study area, the month of June has the highest seasonal rainfall with 21.5 percent of the yearly total precipitation (Western Regional Climate Center 2001). The typical Milk River spring hydrograph most likely had two distinct peaks, the first from mountain and highland snow melt and the second from spring rainfall or late season snow, which would correspond to the natural pattern in the hydrograph for Great Plains rivers. 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, for example, goldeye moved upstream into Crazy Women Creek and deposited eggs; the eggs then drifted and hatched downstream in the Powder River (Smith and Hubert 1989). In the current 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 Year 1, 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, 222 blue suckers (63%), 9 paddlefish (100%) and 108 shovelnose sturgeon (62%) were caught. The higher catches during this period is indicative of increased use and movement during high flows as fish migrate upriver in preparation for spawning. In addition, a higher percentage of juvenile fish were sampled at downstream locations, in contrast

Table 5. Fish condition metrics for species with standard weight equations or important native species with large total catch.

Species (n)	W_r Citation	Mean Wr (SE)	Mean K (SE)	Length (mm)		
				Mean	Min	Max
Bigmouth Buffalo (8)	Bister et al. 2000	85 (4)	1.55 (0.08)	641.9	492	784
Blue Sucker (241)	--	--	0.82 (0.01)	692	531	806
Common Carp (86)	Bister et al. 2000	87 (1.4)	1.23 (0.02)	494.8	250	730
Channel Catfish (828)	Brown et al. 1995	86 (1)	0.79 (0.01)	398.4	78	740
Freshwater Drum (12)	Blackwell et al. 1995	99 (6)	1.28 (0.08)	404.4	332	460
Goldeye (398)	--	--	0.92 (0.03)	295.2	145	438
Northern Pike (40)	Anderson and Neumann 1996	101 (14)	0.68 (0.09)	677.6	326	906
River Carpsucker (577)	Bister et al. 2000	101 (1)	1.4 (0.01)	470.5	195	690
Sauger (152)	Anderson and Neumann 1996	79 (2)	0.75 (0.02)	326.6	220	543
Shorthead Redhorse (297)	Bister et al. 2000	99 (4)	1.14 (0.05)	366.8	120	565
Smallmouth Buffalo (195)	Bister et al. 2000	74 (1)	1.39 (0.01)	548.1	354	710
Shovelnose Sturgeon (112)	Quist et al. 1998	91 (1)	0.39 (0.01)	619.2	465	805
Walleye (68)	Murphy et al. 1990	84 (4)	0.87 (0.04)	435.6	210	867
White Sucker (9)	Bister et al. 2000	88 (6)	1.08 (0.08)	398	152	527

to many gravid adult fish sampled at location 5. Gravid fish at upstream locations indicates use of the Milk River for spawning, similar to other studies (Peterson and VanderKooy 1995; Walters et al. 2014) that found adults using upstream riffle habitat to spawn, enabling larval fish to drift downstream into suitable rearing habitats.

The modeling of occurrence and abundance provided insights on what environmental conditions influence use of the Milk River by many native and nonnative species. Temperature and turbidity were identified as the most important variables for predicting occurrence and relative abundance of most species. The environmental conditions explained the occurrence and relative abundance of many fishes, similar to results in other locations (Geen et al. 1965; Cross 1967; Curry and Spacie 1984; Walters et al. 2014). The modeling data suggest native species key on aspects of the natural hydrograph to complete portions of their life history. Care must be taken to ensure that additional habitat is not lost due to anthropogenic disturbances of the Milk River.

Age and growth analysis on several fish species, including channel catfish, sauger, walleye, northern pike and shovelnose sturgeon indicates that many of the fish are slower growing and longer lived than commonly found elsewhere. The maximum age estimated for channel catfish in our study was 21y, compared to the maximum age from the

Missouri River, Montana of 18y (Berg 1981) and 24y in the Red River, North Dakota (Hegrenes 1992). Channel catfish ages in southern latitudes have rarely been reported to exceed 10y (Carlander 1969). The size of channel catfish was also similar to those reported for other populations across their distribution 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 reported by Hubert (1999), in contrast, was strongly related to the latitude; fish in southern latitudes matured earlier than fish in northern latitudes.

The age distribution of the sauger (Braaten and Guy 2002) and northern pike (Wolfert and Miller 1978) in the Milk River was consistent with other populations at similar latitudes. The maximum age of walleye in the Milk River (16 y) is greater than reported for other populations in northern latitudes. The maximum age was 10 y in the Missouri River, Montana (Berg 1981) and 12 y in the Mississippi River, Wisconsin (Becker 1983). The average life expectancy is typically 5–7 y in southern latitudes and 12–15 y in northern latitudes (Colby and Nepszy 1981).

The mean length-at-age for shovelnose sturgeon in the Milk River (465–805 mm) was similar to results reported in the Missouri River, downstream of Ft. Peck dam to the confluence of the Yellowstone River (472–732 mm; Gardner and Stewart 1987), but lower than the populations in the Yellowstone River, Montana (202–996 mm; Everett et al. 2003) and the Missouri River, Montana (566–914 mm; Berg 1981) upstream of Fort Peck Dam. The sturgeon in the Milk River grew significantly slower than fish in the Yellowstone River; the curvature parameter, k, was significantly lower for the Milk River ($\chi^2 = 35.65$; 2 df; $P < 0.001$) as was the asymptotic length, $L\infty$ ($\chi^2 = 357.51$; 2 df; $P < 0.001$) compared to the Yellowstone River. One sampled fish was a male that was not yet reproductively ready and was estimated to be age 8. Shovelnose sturgeon typically reach sexual maturity about age 5 for males and age 7 for females (Hurley and Nickun 1984). Gardner and Stewart (1987) and Quist et al. (2002) reported the fish inhabiting the lower Missouri River below Ft. Peck Dam to be slower growing than fish from the Missouri River above Fort Peck reservoir. The mean differences in length-at-age 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 Yellowstone River, with mean monthly water temperature 7°C warmer during summer, grew faster than shovelnose sturgeon in the Missouri River below Garrison Dam. The Yellowstone River is less extensively altered than most other large rivers, with only six low head diversion dams (Helfrich et al. 1999). 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). A study on the movements of pallid and shovelnose sturgeon in the Yellowstone and Missouri River (Bramblett and White 2001) found that shovelnose sturgeon mostly occupy the Yellowstone River, avoiding impounded areas, whereas pallid sturgeon made seasonal migrations into the Missouri River. We expect shovelnose sturgeon found in the Milk River spend much of their time in the main channel of the Missouri River and less time in the Yellowstone River. Observed differences in shovelnose sturgeon age and growth between rivers thus may have more ecological significance than if the fish moved widely between rivers.

Overall, the length-at-age and maximum age of most species in this study was consistent with other populations in northern latitudes and fish generally grew slower and lived longer than populations farther south, similar to the results of Bratten and Guy (2002). It is also consistent with the higher metabolic and more rapid movement through life stages commonly associated with various fish species with warmer waters (Scarnecchia et al. 2011).

The later maturation and longer lifespan of native species in the Milk River may also make them more vulnerable to short term environmental stochasticity. Population depletions could take longer to recover in the Milk River than in populations with faster growth and earlier maturity.

Results of this study indicate that the Milk River probably provides important spawning habitat for shovelnose sturgeon, blue suckers and other species. The sturgeon, which typically occupies large turbid rivers with high current velocities (Carlson et al. 1985), is only sampled in the Milk River during high spring flows (Fuller 2000 and 2002). No shovelnose sturgeon have been sampled in in the Milk River during fall sampling (Fuller 2000 and 2002; Stash 2001). In spring, however, many gravid males (running milt; 31) and a single gravid female (ovulated eggs) were captured during our sampling. Other females, however, may have had mature eggs that were not yet ovulated and thus not expelled upon handling.

Similarly, the large number of blue suckers in spring provides strong evidence of the importance of the Milk River as spawning habitat. Although they are generally known as an inhabitant of the Mississippi and Missouri rivers (e.g., Rupprecht and Jahn 1980), blue suckers are well-known to be highly migratory (Neely et al. 2009) and are also known to spawn in mid-sized, turbid tributaries, such as the Neosho River, a tributary of the Arkansas River (Moss et al. 1983) the Grand River in North-central Missouri (Vokoun et al. 2003) and the James and Big Sioux rivers in South Dakota (Morey and Berry (2003). In some cases, they are known in rivers only from spawning specimens (e.g., Vokoun et al. 2003). Several pieces of evidence support the idea that blue suckers sampled in this study were on a spawning migration, including the most effective sampling on the increasing hydrograph, the aggregated nature of the fish and catches and the presence of running milt and developed roe (Bednarski 2004; Bednarski and Scarnecchia 2006).

The occurrence and abundance of native fish in the Milk River, in contrast to the altered fish fauna in the Missouri River, is likely a result of the Milk River retaining more attributes of a natural Great Plains river. The Milk River retains many natural characteristics for 188 rkm below Vandalia Dam, compared to the clear, cold, highly regulated, channelized Missouri River into which it flows. The mouth of the Milk River is 200 rkm upstream of the confluence of the Missouri and Yellowstone Rivers where there are more natural floodplains and backwater habitats (Shields et al. 2000), which are critical habitat for spawning and rearing of native fish. The Milk River has remained turbid and warm with irregular flows and acts as a refuge for native fish in this section of the Missouri River system (Everett et al. 2004). Efforts are needed to ensure that habitat is not further degraded by additional modifications or irrigation withdrawals. Additionally, large reaches of riverine habitat need to be preserved to improve current conditions and allow for the environmental conditions needed by riverine species to carry out their life histories.

Acknowledgements

B. Dennis, J. Braatne, J. Firehammer and R. Long provided technical and statistical assistance. We also thank B. Parker, D. Henry and K. Hell for field and laboratory assistance. Additional technical assistance was kindly provided by P. Braaten, D. Fuller, M. Ruggles, F. McDonald, M. Baxter, J. Remis, B. J. Erickson. An earlier version of this manuscript was improved by the comments of two anonymous reviewers. Funding was provided by Montana Fish, Wildlife and Parks and the U.S. Bureau of Reclamation.

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Received 07 July 2016
Accepted 11 October 2016