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LARVAL FISH CATCHES IN THE LOWER MILK RIVER, MONTANA IN RELATION TO TIMING AND MAGNITUDE OF SPRING DISCHARGE

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ABSTRACT

Larval fishes were sampled in the Milk River, Missouri River drainage, Montana from May to August 2002, 2003 and 2004 to describe temporal spawning distribution in relation to spring discharge. Total larval catch-per-unit-effort (CPUE) in 2002 (28.9 fish/100 m^3) was an estimated 29 times greater than in 2003 (0.99 fish/100 m^3) and 16 times greater than in 2004 (1.78 fish/100 m^3). In 2003 and 2004 more than one third of the total catch occurred before 12 June whereas in 2002, only 5% of the total catch occurred before 12 June. Marked differences in larval species composition were also observed between years, suggesting that a later peak in discharge may benefit some species and an earlier peak others. In 2002, when flows peaked later (at 77 $m^3 s^{-1}$), common carp *Cyprinus carpio* represented 37% of the total larval catch. Common carp were proportionally less abundant in 2003 (7.2%) and 2004 (1.4%) than in 2002. In 2004, when flows peaked (at 163 $m^3 s^{-1}$) 32 days earlier than in 2002 but only 15 days earlier than in 2003 (at 73 $m^3 s^{-1}$), shorthead redhorse *Moxostoma macrolepidotum* and suckers *Catostomus sp*. were the numerically dominant taxa. These results indicate that the timing, not necessarily the magnitude, of peak spring discharge may influence spawning success in the lower Milk River, as indicated by larval fish catches. Copyright © 2008 John Wiley & Sons, Ltd.

KEY WORDS: larval; Milk River; Missouri River; regulated; spawning; Great Plains; discharge

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INTRODUCTION

For many 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 turbidity (Fausch and Bestgen, 1997) have all been implicated as important for the reproduction of a wide range of species. Different species have evolved different responses in spawning activity in relation to the flood pulse. For example, freshwater drum *Aplodinotus grunniens* rely on high discharge to carry eggs and larvae to rearing areas (Koel and Sparks, 2002), while other species such as fathead minnow *Pimephales promelas* delay spawning until discharges decrease (Gale and Buynak, 1982). As a result of these adaptations, spawning success for a given species can exhibit large annual variation with inter-annual and intra-annual variation in discharge.

In regulated large-river systems, tributaries often provide important seasonal increases in discharge, and 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, monitoring the reproductive success of fishes spawning in tributaries of large rivers can provide insight on the ecological role of seasonal discharge patterns in these tributaries.

The Milk River is an important main channel tributary to the upper Missouri River, Montana (Figure 1). 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

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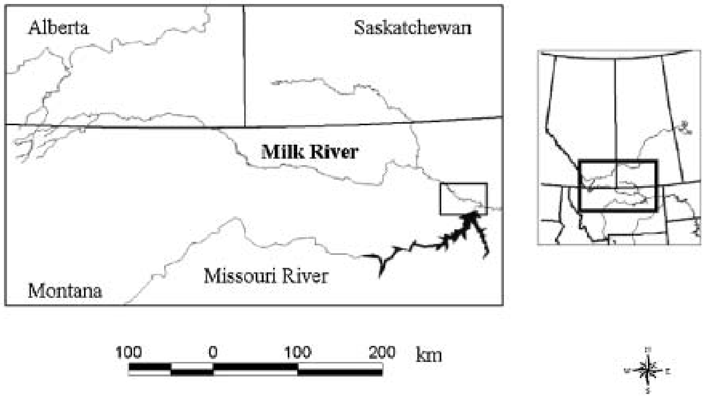

Figure 1. Map of the lower Milk River, Montana, USA

(10 nephelometric turbidity units (NTU), July) as a result of hypolimnetic discharge and sediment trapping by the reservoir. However, there has been a 60% decrease in the magnitude of the 2-year flood in the Milk River and similar decreases in low frequency, high intensity flood events because of seven irrigation impoundments (Shields *et al*., 2000).

A water development project has been proposed that would divert water from the Milk River during high spring flows into an off-stream storage reservoir with up to a 74 millions m^3 capacity. The proposed project would further decrease the magnitude of the 2-year flood and the frequency of other chance flooding. The potential impacts of this proposed water development project are not adequately understood. The objective of this study was to investigate temporal and spatial distribution of larval fish in relation to different annual spring discharges to assess the effects of further flow regulation on the reproductive success of fishes in the lower Milk River.

STUDY AREA

The Milk River is one of the largest tributaries to the upper Missouri River at 1126 km in length and 57 839 km^2 in drainage area. The river irrigates approximately 558 km^2 of land, primarily in crops of alfalfa, native hay, oats, wheat and barley (United States Bureau of Reclamation, 1983; Simonds, 1998). Twelve municipalities rely on the river for drinking water and sewage treatment. Most of the water comes from the Milk River Project, a U.S. Bureau of Reclamation irrigation project developed in 1902. This project diverts and stores water with three storage dams, four diversion dams and a pumping plant (Simonds, 1998).

The portion of the Milk River included in this study extends approximately 225 km upriver from the confluence of the Milk River with the Missouri River, to 37 km above Vandalia Dam. The study area also included the first 4.8 km of the Missouri River downstream of the Milk River. The Missouri River immediately below its confluence with the Milk River was characterized by turbulent, cold (May–July, mean 13.0°C), clear, deepwater habitat. The Milk River from its mouth to 25 km below Vandalia Dam had slow, warm (May–July, mean 17.0°C), turbid, shallow-water habitat with incised channels and riffles. The Milk River from Vandalia Dam 37 km upstream had slow, warm (May–July, mean 16.0°C), deepwater habitat.

METHODS

Larval fish samples were taken weekly during daylight hours from mid-May to mid-August 2002, 2003 and 2004. Larval fish were sampled with $0.5 \times 1.8\,m^2$ conical nets (750 μm Nitex mesh) with attached buckets and weighted with two 4.5 kg lead weights. A General Oceanics 230 OR flow metre was suspended in the mouth of the net to permit estimation of total water volume sampled. Two nets sampled on either side of the bow of the boat simultaneously for 10 min. Nets were towed upstream at a rate of 1–2 $km\,h^{-1}$ without dredging bottom sediment.

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This active sampling approach was used to compensate for a possible lack of larval drift during low flow periods. After each tow, the cod-end cups were removed and the water drained out. The contents were preserved in 10% formalin and Phloxene-B, a chemical dye, was added to stain larval fishes.

Identification of larval fishes was performed using a key based on information from Auer (1982), Holland-Bartels *et al*. (1990) Wallus *et al*. (1990) and Kay *et al*. (1994). Each fish was enumerated and assigned a taxonomic classification (typically genus or species). Eggs were enumerated but not identified. A U.S. Geological Survey gauging station on the Milk River near Nashua, Montana provided daily discharge measurements ($m^3 s^{-1}$). A portable turbidimeter and thermometer provided site-specific measurements of water temperatures (°C) and turbidity (NTU).

Larval fishes were placed into groups based on relative abundance and taxonomic categories. Groups included common carp *Cyprinus carpio*, other Cyprinidae, buffalos *Ictiobus sp*., river carpsucker *Carpoides carpio*, shorthead redhorse *Moxostoma macrolepidotum*, goldeye *Hiodon alosoides* and freshwater drum *Aplodinotus grunniens.* Less common fishes were placed into a mixed category (Table I). We standardized group catches to the number of larvae per 100 m^3 of filtered water (CPUE). Extrapolation of CPUE to fish per 100 m^3 was used because average individual net-tow volume of all 3 years was approximately 70 m^3. Reproductive patterns of each group were assessed in relation to the timing and magnitude of peak discharge in each year.

RESULTS

Estimated total larval fish density was 29 times greater in 2002 (28.9 fish/100 m^3) than in 2003 (0.99 fish/100 m^3) and 16 times greater than in 2004 (1.78 fish/100 m^3). The differences in densities among years were associated with distinct differences in the spring discharge patterns of the Milk River (Figure 2). In 2002, spring discharge peaked latest, at 78 $m^3 s^{-1}$ on 28 June and returned to $<10\, m^3 s^{-1}$ on 18 July. In 2003, spring discharge peaked earliest, at 70 $m^3 s^{-1}$ on 12 May, and returned to $<10\, m^3 s^{-1}$ on 28 May. In 2004, spring discharge peaked at 163 $m^3 s^{-1}$ on 28 May and returned to $<10\, m^3 s^{-1}$ on 23 June. The later peak in spring discharge in 2002 was associated with higher seasonal precipitation in June, whereas the peaks in 2003 and 2004 were associated with runoff from snow melt.

In 2002, the year with the latest peak discharge (June), only 5% of the total catch occurred before 12 June. In 2003 and 2004, when discharge peaked in May, more than one-third of the total catch occurred before 12 June. The highest weekly larval fish density (118 fish/100 m^3 on 18 June 2002) followed the initial discharge peak on 15 June and the second highest weekly larval fish density (63/100 m^3 on 3 July 2002) followed the second peak on 28 June. In neither 2003 nor 2004 (when flows peaked in May) did larval abundance approach the magnitude of 2002 (Figure 3). In 2003, the highest weekly larval fish density (2.13 fish/100 m^3) occurred in mid-June, more than a month after the peak in discharge on 12 May. In 2004, the highest weekly larval fish density (4.3 fish/100 m^3) occurred on 18 May, 10 days before peak discharge on 28 May.

Table I. Relative abundance of larval fishes identified from the lower Milk River, Montana 2002–2004

Taxon	2002	2003	2004
	Number (per cent)		
Buffalos	1865 (23.2)	34 (13.6)	18 (8.5)
Common carp	3000 (37.3)	18 (7.2)	3 (1.4)
Cyprinidae	187 (2.3)	15 (6.0)	11 (5.2)
Freshwater drum	991 (12.3)	22 (8.8)	9 (4.3)
Goldeye	204 (2.5)	0 (0)	11 (5.2)
River carpsucker	1594 (19.8)	13 (5.2)	18 (8.5)
Shorthead redhorse	87 (1.0)	124 (49.6)	47 (22.3)
Others	116 (1.4)	24 (9.6)	94 (44.5)

The cyprinid category excludes common carp. *Catostomus sp.* numerically dominated the other category in 2004.

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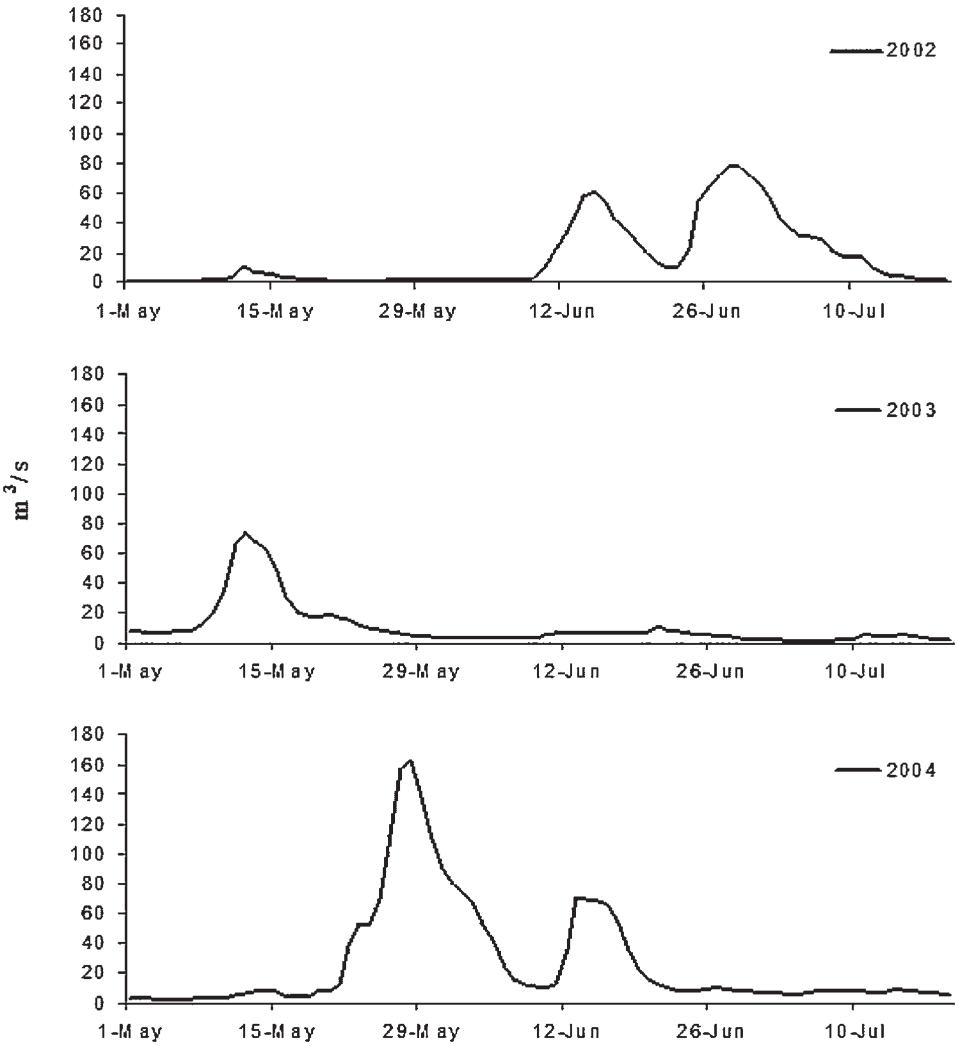

Figure 2. Spring discharge for the lower Milk River near Nashua, Montana during 2002–2004

More taxa were also found in 2002 (14) than in 2003 (9) or 2004 (12; Table I). Taxa identified at species level in 2002 included two species of concern, paddlefish *Polyodon spathula* and blue sucker *Cycleptus elongatus*. Neither of these species was collected in 2003 or 2004.

Differences in the contribution of dominant taxa were also evident among years. Of the 8044 total fish caught in 2002, common carp ($N = 3000$; 37.3%) and *Ictiobus sp*. ($N = 1865$; 23.2%) accounted for nearly two-thirds of the catch. Total catches in 2003 (250 fish) and 2004 (211 fish) were more than an order of magnitude lower. In 2003, shorthead redhorse ($N = 124$; 49.6%) was the dominant taxon. In 2004, shorthead redhorse ($N = 47$; 22.3%) and *Catostomus sp*. ($N = 37$; 17.5%) were the dominant taxa. Shorthead redhorse showed a lower relative abundance in 2002 (1.0% of total catch) than in 2003 or 2004.

Differences in the timing of peak abundance of taxa were observed among years. In 2002, carp, buffalo and river carpsucker densities peaked in mid-June. Densities of goldeye, freshwater drum, shorthead redhorse and other Cyprinidae (i.e. excluding carp) peaked in late July. In 2003, buffalo and river carpsucker densities peaked in late May, but at much lower numbers than in 2002. Carp densities peaked in mid-June and Cyprinidae (excluding carp) and freshwater drum densities peaked in early July. No larval goldeye were captured in 2003 but goldeye were

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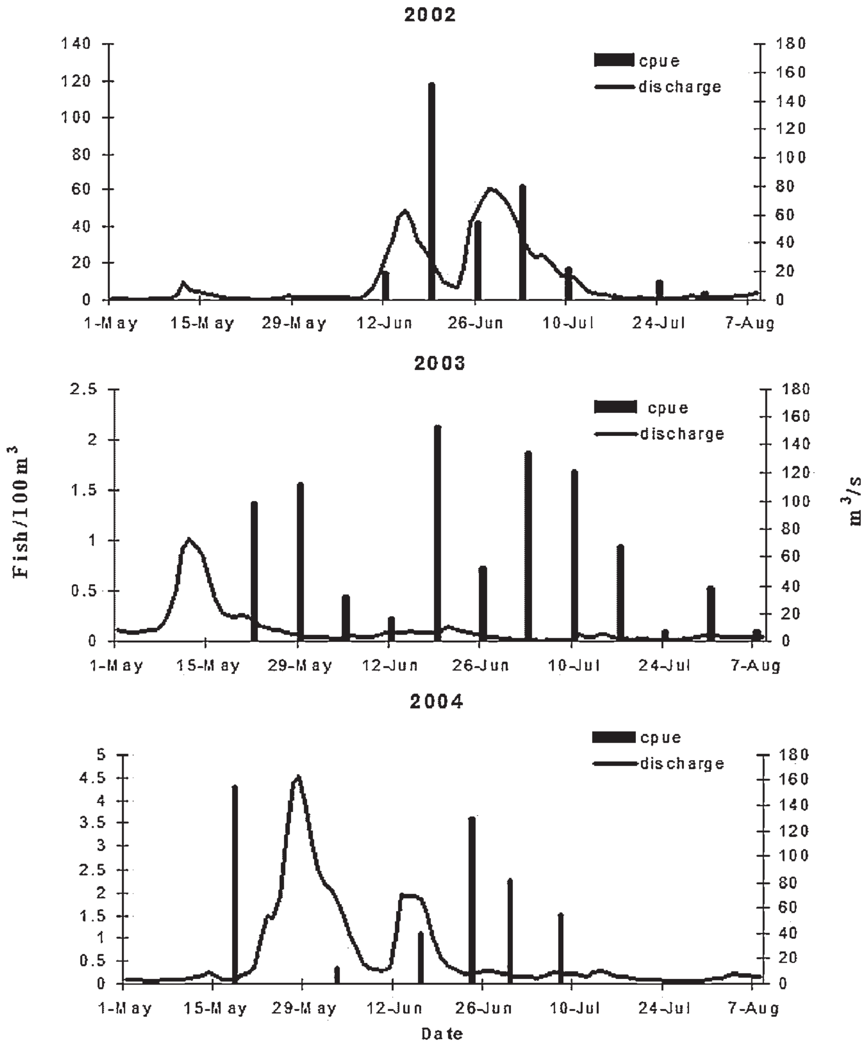

Figure 3. Total weekly larval fish catch-per-unit-effort in the lower Milk River, Montana in relation to spring discharge during 2002–2004

captured in 2002 ($N = 204$) and 2004 ($N = 11$). In 2004, shorthead redhorse densities peaked in mid-May. River carpsucker and buffalo densities peaked in early and mid-June, respectively. Cyprinidae (including carp) and goldeye densities peaked in late June. Freshwater drum densities peaked in early July.

DISCUSSION

Total larval fish abundance was 29 times greater in 2002 (28.9 fish/100 m^3) than in 2003 (0.99 fish/100 m^3) and 16 times greater than in 2004 (1.78 fish/100 m^3). Such inter-annual variability in reproductive success of riverine fishes has been observed elsewhere. Humphries *et al*. (2002) reported that total larval fish abundance in the Campaspe River, Australia differed by as much as two orders of magnitude among breeding seasons. Johnston *et al*. (1995) estimated that total annual larval drift in the Valley River, Canada ranged from 14 000 to >93 million among 7 study years. Smith *et al*. (2005) found that recruitment of smallmouth bass *Micropterus dolomieu* in rivers of Virginia, USA differed by as much as an order of magnitude among years.

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The initiation of the annual flood pulse and the magnitude of spring discharge have been suggested as explanations for inter-annual variation in reproductive success of fishes in other lowland rivers (Humphries *et al*., 2002; Propst and Gido, 2004). In our study, the year with greatest larval abundance (2002) had a peak discharge level (77 $m^3 s^{-1}$) that was less than the year with intermediate larval abundance (2004; 163 $m^3 s^{-1}$) and similar to the year with lowest larval abundance (2003; 73 $m^3 s^{-1}$). These results suggest that other factors, such as timing, and not solely the magnitude of peak discharge, may be associated with the annual abundance of larval fishes in the Milk River.

The marked differences in species composition observed among years, where *Ictiobus sp*., common carp and river carpsucker were most abundant in 2002, suggest that a later peak in discharge may benefit some species and an earlier peak others. These differences were most pronounced for common carp where in 2002 carp represented 37% ($N = 3000$) of the total catch but were proportionally less abundant in 2003 (7.2%; $N = 18$) and 2004 (1.4%; $N = 3$). In 2002, the majority (87%) of carp were captured during the 3-week period of highest spring discharge. Mean water temperature for all sample locations combined was 20.3°C during this period. In 2003, the majority (77%) of carp were captured during a 1-week period in mid-June when mean water temperature for all locations combined was 21.7°C. However, this occurred 5 weeks after peak discharge for the year. Peak discharge in 2003 was associated with colder (14.3°C) mean water temperatures. These results are consistent with other studies that have suggested that common carp and closely related species may reproduce most effectively when high spring discharge coincides with warm (17–22°C) water temperatures (McCrimmon, 1968; Panek, 1987; Schrank *et al*., 2001).

In contrast to common carp, the native catostomid shorthead redhorse had a higher relative abundance in 2003 (22%; $N = 47$) and 2004 (49%; 124) than in 2002 (1%; $N = 87$). At the latitude of the lower Milk River, most native fish species spawn during late May to early August. In such a situation, the more predictable rising hydrograph from yearly snowmelt 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 average seasonal rainfall (mean, 6.2 cm). June precipitation in 2002 was above average (7.5 cm) while 2003 (5.2 cm) and 2004 (6.0 cm) exhibited below or near normal June rainfall (Western Regional Climate Center, 2001).

Despite differences in precipitation patterns and flow regimes among years, native catostomids appeared to be able to partition their spawning over a greater time period than most of the other fishes sampled. However, CPUE values for native catostomids were much higher in 2002 than in the other sample years although they represented a greater proportion of the catch in 2003 and 2004. The greater proportional abundance of these fishes in 2003 and 2004 was likely biased by the lack of a significant carp spawn in these years. Therefore, a later peak discharge also appeared to promote better native catostomid reproduction.

The differences in species composition observed in our study among years may also be associated with diel drift patterns or other sampling biases. For example, Gale and Mohr (1978) reported a day/night drift ratio of 1:3.8 for larval fishes in the Susquehanna River. Muth and Schmulbach (1984) reported that larval ictalurids and catostomids were nocturnal drifters in the James River, South Dakota but that freshwater drum were diurnal drifters. Gallagher and Conner (1983) found that larval shad *Dorosoma sp*. in the lower Mississippi River were more likely to be in the upper water column during the day but that freshwater drum were more abundant in the middle of the water column during day. Thus, if the intent is to quantify total larval abundance, sampling methods must be designed to select for certain species under a set of given conditions. The intent of the current study was not to generate total drift estimates of select species but to provide comparable trend data on relative abundance of larval fishes among years. Thus, species-specific drift patterns likely had negligible effects on the interpretation of our results.

The characteristics of the flood pulse in 1 year may favour one group of species whereas a different timing or magnitude of another flood pulse may favour a different group of species (Welcomme, 1986). That a range of times of peak discharge may favour early, mid- or late spawning riverine species is consistent with the diversity of life histories and spawning times observed in the Milk River. In the Milk River from 1939 to 2004, more than 60% of the peak spring discharges occurred during the months of March or April whereas only 17% occurred during the month of June (Figure 4). The late date of peak discharge observed in 2002 (28 June) thus did not represent a common Milk River flood pulse. Our sampling period, which began in May, thus did not adequately quantify the larval abundance of earlier spawning fishes such as sauger *Sander canadensis* (Nelson, 1968). Our results nevertheless supported the idea that a later peak discharge, even if not a common occurrence, was associated with higher overall reproductive success of Milk River fishes.

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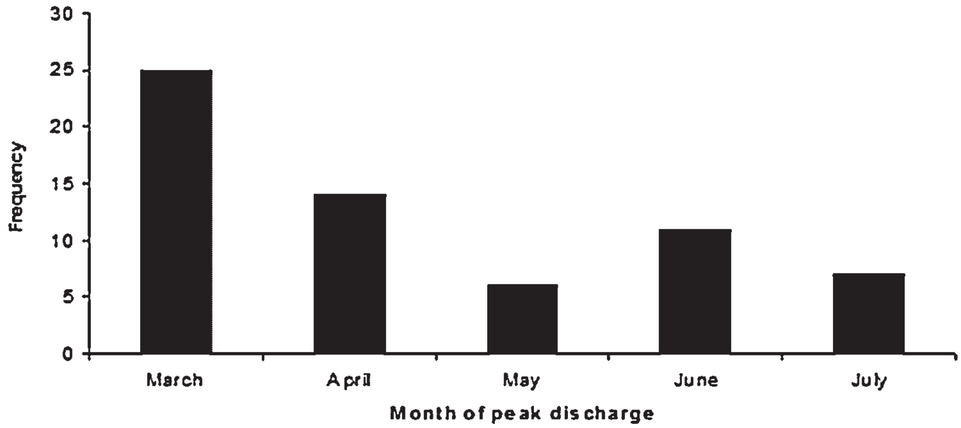

Figure 4. Frequency of occurrence of peak discharge by month (April–July) for the Milk River near Nashua, Montana, USA, 1939–2004

The reach of the lower Milk River below Vandalia Dam to its confluence with the Missouri River appears to provide better spawning conditions than do the more regulated river reaches sampled in this study. Moreover, the timing of spring discharge influences spawning success, as indicated by total larval fish densities. Further flow regulation, especially water withdrawals in mid-June through mid-July, may have a deleterious effect on fish reproduction in the Milk River. Further research is needed on the timing, magnitude and duration of spring discharge necessary to maintain spawning populations of native and game fish species. In addition, quantitative description of spawning habitat in the lower Milk River below Vandalia Dam would provide useful information for future research.

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ERRATUM

Erratum: Larval Fish Catches in the Lower Milk River, Montana in Relation to Timing and Magnitude of Spring Discharge. J. Bednarski, S.E. Miller, D.L. Scarnecchia. River Research and Applications. Published online 25 March 2008 at www.interscience.wiley.com DOI:10.1002/rra1098

The author has since identified that the current wording in certain sections in the article contradicts scientific evidence. Please find below the corrected text.

Page 1 Abstract line 23 should read:
These results indicate that the timing, not solely the magnitude, of peak spring discharge may influence spawning success in the lower Milk River, as indicated by larval fish catches.

Page 3 line 16 should read:
Expression of CPUE to fish per 100 m^3 was used because average individual net-tow volume of all 3 years was approximately 70 m^3.

Page 7 lines 18 and 19 should read:
The reaches of the lower Milk River below Vandalia Dam sampled in this study appear to provide better spawning conditions than do the reaches sampled above the dam.