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SHORT COMMUNICATION

EFFECTS OF DAM REMOVAL ON BROOK TROUT IN A WISCONSIN STREAM

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ABSTRACT

Dams create barriers to fish migration and dispersal in drainage basins, and the removal of dams is often viewed as a means of increasing habitat availability and restoring migratory routes of several fish species. However, these barriers can also isolate and protect native taxa from aggressive downstream invaders. We examined fish community composition two years prior to and two years after the removal of a pair of low-head dams from Boulder Creek, Wisconsin, U.S.A. in 2003 to determine if removal of these potential barriers affected the resident population of native brook trout (*Salvelinus fontinalis*). Despite the presence of other taxa in the downstream reaches, and in other similar streams adjacent to the Boulder Creek (including the brown trout, *Salmo trutta*), no new species had colonized the Boulder Creek in the two years following dam removal. The adults catch per unit effort (CPUE) was lower and the young-of-the-year catch per unit effort (YOY CPUE) was higher in 2005 than in 2001 in all reaches, but the magnitude of these changes was substantially larger in the two dam-affected sample reaches relative to an upstream reference reach, indicating a localized effect of the removal. Total length of the adults and the YOY and the adult body condition did not vary between years or among reaches. Thus, despite changes in numbers of adults and the YOYs in some sections of the stream, the lack of new fish species invading Boulder Creek and the limited extent of population change in brook trout indicate that dam removal had a minor effect on these native salmonids in the first two years of the post-removal. Copyright © 2007 John Wiley & Sons, Ltd.

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INTRODUCTION

Resource managers are faced with myriad and often conflicting challenges and limited scientific information in their efforts to maintain productive, sustainable fish populations. A notable example of one such conflicting challenge involves the management of aging dams. Increasingly, removal is being considered for dams with compromised structural integrity and which are no longer financially viable. Environmental benefits are often cited in support of removal (Stanley and Doyle, 2003), as these structures fundamentally alter upstream and downstream habitats and create barriers to fish migration. Short and long distance movements in both upstream and downstream directions are common in many fish species, including those that are not considered truly migratory. These movements are often associated with the searches for suitable reproductive, feeding or overwintering habitat and may occur over daily, seasonal or annual time scales (e.g. see Moyle and Cech, 2004). Thus, once a dam is removed, the upstream migrations and changes in upstream community composition can occur quickly (Kanehl *et al*., 1997; Catalano *et al*., In press). However, arguments in favour of greater connectivity within drainages present an

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interesting counterpoint to growing concerns about increasing ichthyofaunal homogenization (Rahel, 2000; Olden *et al*., 2004; Schade and Bonar, 2005). Native and introduced salmonids provide an excellent example of this problem, as the popularity of trout fishing has led to extensive introduction and stocking of several species outside of their native ranges. In several cases, introduced (or invading) species may displace resident salmonids (e.g. Fausch and White, 1981; Donald and Alger, 1993). One suggested means of protecting native salmonids is the construction or maintenance of barriers (dams) to isolate streams with self-sustaining resident populations (Novinger and Rahel, 2003). Similar strategies have been promoted to restrict invasion of a variety of taxa including lampreys (Lavis *et al*., 2003) and crayfish (Kerby *et al*., 2005). In short, a key challenge presented by removing a dam involves the potential conflict associated with opening the door to downstream taxa- some of which are desired in upstream reaches, but others of which are not.

This brief communication reports the results of fish surveys conducted two years prior and two years following the removal of two low-head dams from Boulder Creek, a second-order coldwater stream in Wisconsin. While most coldwater streams in the state are populated by brown trout (*Salmo trutta*), native populations of brook trout (*Salvelinus fontinalis*) persist in a subset of streams throughout the state. Prior to dam removal, brook trout were present in Boulder Creek, and concerns were raised that removal of the dam might permit invasion by brown trout, which were present in the adjacent drainage (Rowley Creek; Figure 1) and had been collected during winter months in the Baraboo River, the larger system into which both Boulder and Rowley creeks flow (M. Catalano unpublished data). Our objective was to determine if the removal of these dams allowed the invasion of brown trout or affected the resident brook trout population.

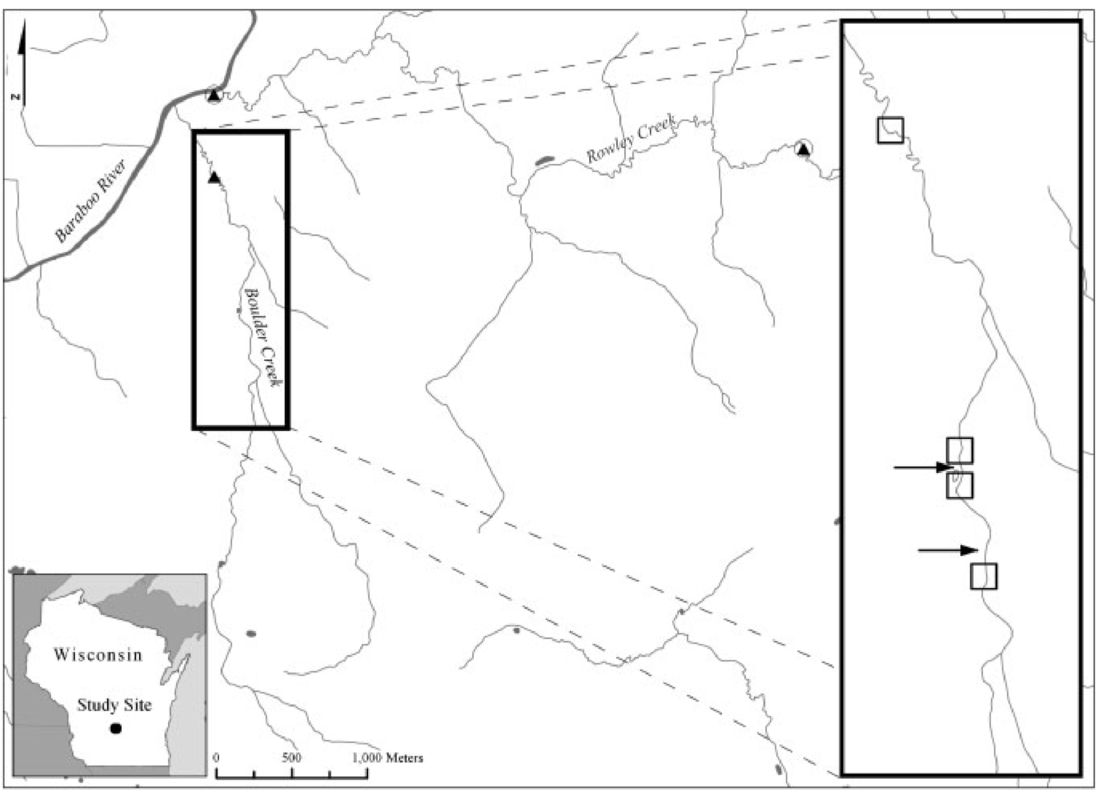

Figure 1. Map of the Boulder Creek region and the second order Boulder Creek mainstem (right inset) indicating sites of prior brown trout (circles) and brook trout (triangles) collection (WDNR 2006) in adjacent streams. In the inset of the Boulder Creek mainstem, arrows indicate location of dams prior to their removal and boxes show fish sampling reaches (site 1 = most downstream; site 4 = most upstream site)

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METHODS

Study site

The Boulder Creek drainage in south-central Wisconsin consists of two perennial first order tributaries (1.5-2 km in length) that merge to form a 1.6-km 2nd-order stream that flows into the 5th-order Baraboo River (Figure 1). The watershed is one of several headwater systems in the area that drain into the Baraboo River and support populations of coldwater taxa such as brook trout, brown trout and brook stickleback (*Culaea inconstans*). Other fishes collected in adjacent streams include creek chub (*Semotilus atromaculatus*), central mudminnows (*Umbra limi*), brassy minnow (*Hybognathus hankinsoni*), blacknose dace (*Rhinichthys obtusus*) and white sucker (*Catostomus commersonii*) (WDNR, 2006). Annual water temperatures monitored in a riffle during 2003–2004 varied from 0.5–25°C, and a mean summertime (June–August) temperature of 17.8°C (Orr *et al*., 2006).

Two low-head dams were situated approximately 1.0 and 1.2 km upstream of the confluence, and represent the only structural barriers between the upper reaches of the stream and the Baraboo River. The relatively diminutive upstream dam consisted of a simple 1-m concrete wall across the channel. Channel morphology was not conspicuously affected by this structure however, as there was no distinct impoundment pool, channel widening, or difference in sediment composition. The lower dam was a 2.5 m high, ca. 15 m wide concrete structure that had originally created a wide pond in the stream. Most of the impoundment had filled with sediment over the estimated 50 years since its construction, although a small pool persisted at the downstream end of the impoundment. A total of 38 m of the stream immediately upstream of the structure was considered to be dam-influenced due to the reduced channel slope, open canopy and sandy sediment composition.

Both dams were removed on 9 July 2003. The channel within the former downstream impoundment was rapidly converted to a highly incised, narrow (ca. 1 m), shallow (mean depth = 12 cm) riffle. Fine reservoir sediments were transported downstream and filled the plunge pool below the dam, but bed sediment composition returned to pre-removal conditions within a year. Incision also occurred at the smaller upstream dam site, affecting 19 m of the channel. A detailed description of the physical changes caused by the dam removals is provided by Orr et al. (2006). Changes to nutrient dynamics, macroinvertebrates and algal biomass following the dam removal were relatively small and short-lived (Orr *et al*., 2006; Rogers *et al*., In review).

Fish sampling

Fish populations were surveyed in three reaches of the 2nd order channel on July 2001 and September 2005 to determine the species composition and population structure of fishes in Boulder Creek before and after the dam removal. Reach selection was intended to detect potential responses to physical changes caused by the larger dam and its removal, as well as to the removal of migration barriers. We sampled a reach immediately downstream of the lower dam (Reach 2), a dam-affected reach immediately upstream of this same larger dam (Reach 3) and a 'reference' reach upstream of both dams (Reach 4, Table I, Figure 1). An additional downstream site (Reach 1) was also sampled in 2001 (ca. 600 m below the dam), but was not sampled in 2005 due to lack of landowner permission.

Table I. Reaches surveyed for fishes in Boulder Creek in 2001 and 2005. Sites are listed from downstream to upstream

Reach	Location	Length (m)	Habitat characteristics
1	Approximately 750 m downstream from dams	100	Free-flowing, mixed sand and gravel; sampled in 2001 only
2	Directly downstream from the lower dam (length constrained by property boundary)	60	Free-flowing, mixed sand, gravel cobble riffle + 10-m tailwater pool below dam prior to the removal; mixed sand, gravel cobble riffle after removal
3	Immediately upstream of the lower dam	35	Sandy low-gradient run ending in a pool at the dam face prior to the removal; incised high-gradient shallow riffle after the removal with sand, gravel and small cobble
4	50 m upstream from upper dam	100	Free flowing riffle; mixed sand, gravel cobble substrate; not affected by dam removal

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While 100 m is suggested as an appropriate reach length needed to obtain a representative sample of species (Lyons, 1992), two of our three reaches were shorter because of access restrictions (Reach 2) and the decision to focus specifically on habitat affected by the presence and removal of the dam (Reach 3). Thus, this sampling design may have reduced our ability to detect all species and/or provide estimates of the variability of fish responses to removal both because of the shortened length of Reaches 2 and 3, and because the replicate reach types did not exist.

We followed standardized sampling methods developed by the Wisconsin Department of Natural Resources (Lyons *et al*., 1996), with the exception of reach lengths as noted above. Fish were collected by two netters accompanying a third individual making one upstream pass through each reach with a backpack electrofisher that produced 300 V of pulsed direct current at a pulse rate of 50 Hz and a pulse width of 2 ms. To account for differences in sampling effort between the years and the reaches, all counts were standardized by sampling time and expressed as catch per unit effort (CPUE). Fish were identified, counted, measured for total length (mm) and weighed (g). Trout were separated into the young-of-the-year (YOY) and Age-1+ (adult) categories, based on clear breaks in size-frequency distributions in both years. Differences in the total lengths for the YOY and the adults were assessed using a 2-way ANOVA on log-10 transformed data. Adult trout were measured and weighed individually whereas the YOY were measured individually then weighed in aggregate. In 2001, only half of the adults (31 of 62) in Reach 2 were measured and weighed. We calculated the body condition as Fulton's Index of relative weight for adults: $K = W/L^3$ and compared condition among reaches and years using a 2-way ANOVA.

RESULTS

The 2001 Boulder Creek fish community was dominated by brook trout, with only four individuals from different taxa (1 central mudminnow, *Umbra limi* and 2 brook sticklebacks, *Culaea inconstans* from site 1 and 1 green sunfish, *Lepomis cyanellus,* collected at site 2). In 2005, all individuals collected were brook trout. CPUE for the YOY was greater in all reaches in 2005 than in 2001, with the greatest increase occurring in Reach 3 (Figure 2). In contrast to the YOY, more adults were captured per unit effort prior to removal relative to the post-removal survey. The decline was particularly large in the most downstream reach (Reach 2). Prior to removal, several adults were captured in the plunge pool at the base of the lower dam's spillway, but this pool filled with sediments from the impoundment after removal. Differences between pre and post CPUE for both adults and the YOY were smallest in the most upstream reach (Reach 4).

The YOY lengths were not significantly different among reaches ($F = 1.212$, $p > 0.10$) or years ($F = 0.738$, $p > 0.10$ and no reach *x* year interaction, $F = 1.691$, $p > 0.10$), although average lengths were always slightly higher and the range of individual lengths was greater in 2005 relative to 2001 (Figure 3). Similarly, the average lengths

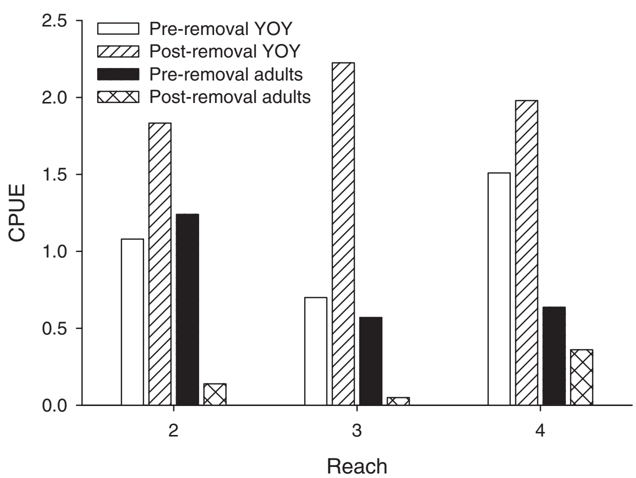

Figure 2. Catch per unit effort (CPUE) of young-of-the-year (YOY) and adults in study reaches of Boulder Creek in 2001 prior to the removal of the two dams, and after dam removal in 2005

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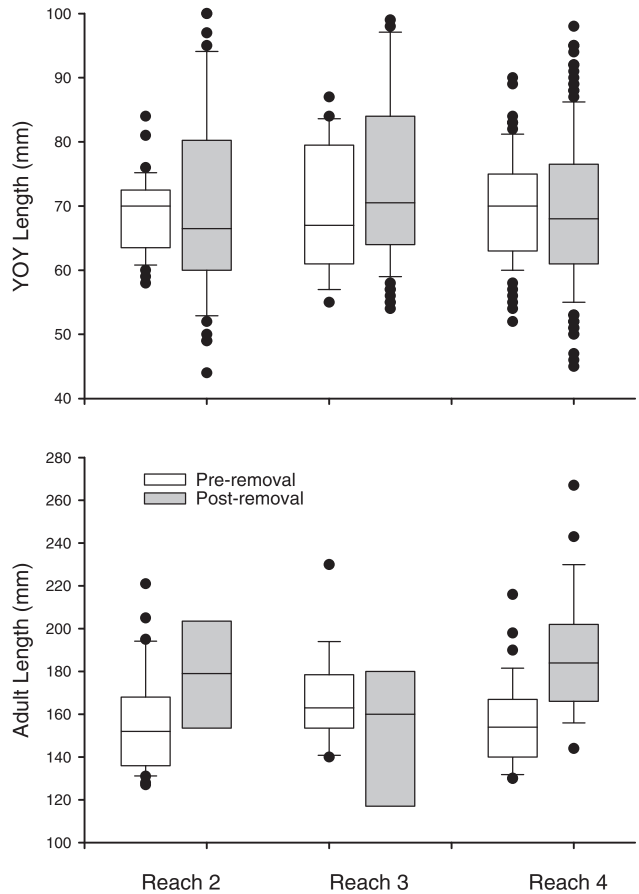

Figure 3. Box plots of young-of-the-year (YOY) (top panel) and adult (bottom panel) total lengths in each study reach of Boulder Creek before and after dam removal. The horizontal line within each box denotes the median length, lower and upper box boundaries represent the 25th and 75th percentiles, upper and lower error bars show the 90th and 10th percentiles, and dots represent outliers

were consistently, but not significantly higher in 2005 for Age 1+ individuals ($F = 0.585$, $p > 0.10$), and no differences existed among the reaches ($F = 0.484$, $p > 0.10$, and no reach *x* year interaction, $F = 2.122$, $p > 0.10$). Finally, no significant independent or interactive effects of year and reach were detected for adult body condition (*K*) ($p > 0.20$ for all effects; results not shown).

DISCUSSION

Boulder Creek supported a substantial population of brook trout, both before and after the removal of two low-head dams. Size structure in 2001 and 2005 differed slightly, with the presence of more adults when the dams were in place and with the presence of more YOYs after the removal in all reaches. We observed no significant changes in adult body condition or in total length of either the adults or the YOY. The non-significant trend of greater total lengths in all reaches after dam removal likely reflected the later sampling date, and consequent additional growth in 2005 relative to 2001.

The magnitude of the adult declines and the YOY increases in CPUE were substantially larger in the two dam-affected reaches (Reach 2 immediately below the large dam and Reach 3 upstream of the dam) relative to Reach 4, indicating an effect of the dam removal on brook trout. Prior to removal, several adults were collected in the plunge pool below the dam in Reach 2 and the remaining pool section of the impoundment in Reach 3, but not

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surprisingly, similar collections were not made in 2005 after these deeper habitats had been destroyed by sediment transport and deposition. We cannot determine if these declines were due to mortality or dispersal to other areas of the stream, but these changes emphasize a negative response to the habitat changes caused by the dam removal. While physical changes caused by the removal adversely affected adults, the opposite was true for the YOY as the largest between-year changes were again observed in the two dam-affected reaches. Presumably, the habitat conversions that made these reaches less suitable for adults made them more suitable, or at least more available, to juveniles. High downstream catches in Reach 2 also indicate that the YOY were not seriously affected by the continued movement of reservoir sediments into the reach that continued for at least a year after the removal (Orr *et al*., 2006), even though early life history stages of *S. fontinalis* are susceptible to sedimentation (Curry and MacNeill, 2004).

With respect to species composition, despite the existence of a downstream pool of colonists in both the lower reaches of the Boulder Creek and the Baraboo River, and the presence of brown trout (and other taxa) in both Rowley Creek and the Baraboo River (Figure 1), new species have yet to move into Boulder Creek following the dam removal. This before-after comparison illustrates the simple point that removal of a barrier does not automatically trigger invasions and changes in upstream fish community structure. Absence of new species moving into Boulder Creek two years after the dam removal indicate that the habitat characteristics of this creek are more suitable to brook trout than brown trout or other taxa, but this suitability does not negate the point that barrier removal alone does not inevitably lead to changes in fish community structure.

In conclusion, we observed a mixture of brook trout changes associated with the removal of the Boulder Creek dams. Given the nature of our sampling regime, we cannot exclude the possibility that these changes reflected normal spatial and temporal variation in the creek, but the amplified responses in the reaches immediately upstream and downstream of the dam provided good support for a removal effect. Although the removals appeared to have a negative effect on the adults, on a more basic level we noted that two years after the removals, the brook trout population in the Boulder Creek has remained in place, has not been supplanted by other taxa, and has a large juvenile population indicative of ongoing recruitment. In turn, these observations suggested that, thus far, the adverse effects of the removal on brook trout have been relatively small.

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