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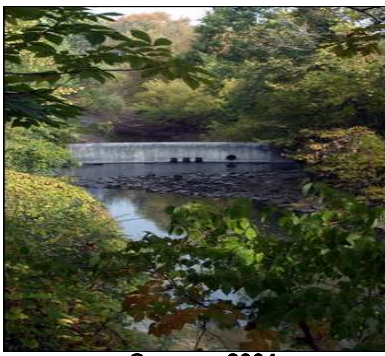
Impact of the Removal of the Secor Road Dam on the Fish Community Structure and Composition in the Ottawa River, Ohio.



Summer 2004

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submitted to

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Summary

Dams may impact the migration of fish and, consequently, the biological community as a whole. Such impacts are often cited to support dam removal but few studies have actually quantified fish community structure pre- and post-removal. Using an unreplicated BACI design, we contrasted the fish community up- and downstream from the last remaining dam in the Ottawa River (NW Ohio) by repeated block-seine sampling before (2003-04) and after (2008-09) dam removal. Up- and downstream QHEIs were comparable, as were DO, conductivity, pH, temperature and discharge at each sampling event. During 12 sampling events, a total 3,174 fish (belonging to 32 species) were identified, measured, assessed for condition and released. This included 408 juveniles (belonging to 8 species). Following dam removal, fish abundance, richness and diversity nearly doubled upstream while they remained unchanged in the downstream site. The index of similarity between the downstream and upstream sites increased from 0.45 to 0.72 following dam removal. The trophic composition upstream shifted from an omnivore-dominated assemblage to a 61% invertivore community with an average of 4% piscivores (measured by abundance). Catastomids (e.g., *Catostomus commersoni*), several sunfish (*Lepomis cyanellus, Lepomis macrochirus*), percids (*Perca flavescens*, *Percina caprodes*), cyprinids (*Cyprinella spiloptera*, *Luxilus chrysocephalus, Notropis atherinoides, Pimephales promelas*) and *Dorosoma cepedianum* gained access to upstream habitat or became much more abundant upstream after dam removal. *Semotilus atromaculatus*, not found downstream during the 2003-2004 sampling, was netted in three of the six samples downstream after dam removal. Starting in May of 2008, the exotic *Neogobius melanostomus* became abundant in the Ottawa making up 21% and 9% of the total catch downstream and upstream of the old dam site, respectively. Abundant juvenile fish upstream of the old dam site pointed to improved spawning success after dam removal. Before dam removal we netted an average of only 9 juvenile fish per sampling event (belonging to only two species) in the upstream location. Following dam removal, that number jumped to 46 juvenile fish belonging to seven species. Even though the Ottawa is generally considered degraded riverine habitat, we found abundant fish belonging to a total of 32 species. Despite its small size, the dam impacted the fish community in the Ottawa and, by extension, western Lake Erie.

Keywords: Dam removal, fish communities, migration, restoration, Ohio

Background

Dam removal or decommissioning continues to gain support as potential means for the restoration of rivers, wetlands, and coastal habitat (Evans *et al.* 2002; Doyle *et al.* 2003). The progressing deterioration of the majority of existing dams in the United States (NID 2006) and the associated liability and safety issues often provide added motivation to eliminate a dam (Pohl 2002). Although dam removals obliterate the originally intended function of the structure (e.g., water supply, recreation, flood control, hydropower, etc.) and demand careful consideration of issues such as downstream flood risk and transport of potentially contaminated sediments, such removals have a positive impact on stream ecosystems and restore a more natural flow regime to rivers (Heinz Center 2002). This, in turn, may contribute to improved biological diversity, restored fish passage, and re-established riffle/pool sequences (Poff *et al.* 1997; Bednarek 2001; Stanley and Doyle 2003; Aasani and Petit 2004).

Restoration of fish migration pathways and habitat for native fish are commonly cited as central reasons for the elimination of a dam. Barriers in rivers not only block the migration and distribution of fish (Kinsolving and Bain 1993; Bednarek 2001; Gregory *et al*. 2002; Katano *et al.* 2006), and therefore the biological community as a whole, they also change riverine habitat by disrupting temperature and dissolved oxygen regimes, altering sediment transport, and changing the dynamics of water level fluctuations (e.g., amplitude, frequency, timing). Furthermore, dams may also indirectly affect the fish community by modifying the food resources that are available to fish both upstream and downstream from the impoundment (Mérona *et al.* 2001, 2003). Separating the effect of dam removal on migration pathways from the effects on habitat recovery is quite complicated (Kareiva *et al.* 2000).

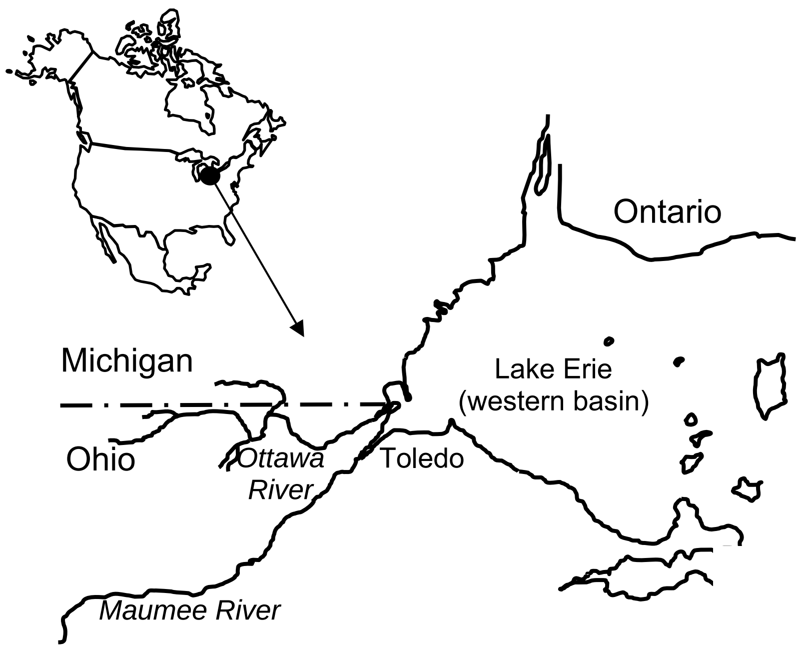
Notwithstanding the significance of these impacts on ichthyofauna, few papers have been published on the response of fish communities to dam removal. The usefulness of dam removal as a restoration technique is more based on anecdotal evidence of fish migration past former dam sites than on a quantitative assessment pre- and post removal (Doyle *et al.* 2005). In the Great Lakes region, Kanehl *et al.* (1997) quantified the response of fish communities to the removal of a dam on the Milwaukee River. They documented a reduction in exotic common carp (*Cyprinus carpio*) and an increase in smallmouth bass (*Micropterus dolomieu*) post dam removal and showed that these changes were due to altered habitat conditions rather than blocked migration pathways.

The scarcity of studies in the Great Lakes basin on the effect of undamming rivers on fish is remarkable given the importance of fisheries and spawning habitat in this region. In addition to many non-game species, migratory species that are of commercial and recreational interest, including yellow perch (*Perca flavescens*), northern pike (*Esox lucius*), walleye (*Stizostedion vitreum)*, lake sturgeon (*Acipenser fulvescens*) and bluegill (*Lepomis machrochirus*) are clearly impacted by dams. Further, dams may influence the distribution of other biota such as freshwater unionid mussels, a group of organisms of special concern in the Great Lakes region. Some fish may serve as hosts for semi-parasitic mussel larvae and the lack of mussels upstream from the dams has been linked to interruption of fish migration (Watters 1996). Finally, some 60% of the 632 dams listed for northern Ohio alone are currently in hazardous condition due to lack of maintenance or old age (Roberts *et al.* 2007) and are likely candidates for removal. That fact by itself makes research on the effects of dam removal particularly urgent.

Our objective was to contrast the structure and composition of the fish community in the Ottawa River (NW Ohio) upstream and downstream from its only remaining dam before and after its removal in November of 2007. We predicted that (1) upstream and downstream fish communities would differ before the dam removal, (2) this difference would disappear following dam removal so that both communities would resemble the downstream community before the dam was taken out, and (3) upstream habitat would be accessed by fish for spawning and nursery after dam removal.

Methods

The Ottawa River drains a 446 km^2 low-gradient basin in northwestern Ohio and discharges into western Lake Erie near Toledo, Ohio (Figure 1). At base flow the river discharge is negligible; during high stage condition (particularly during the spring), however, discharge commonly exceeds 40 m^3/sec and may exceed 90 m^3/sec as measured at The University of Toledo U.S. Geological Survey station. (# 04177000) located at river kilometer (RK) 17.8.



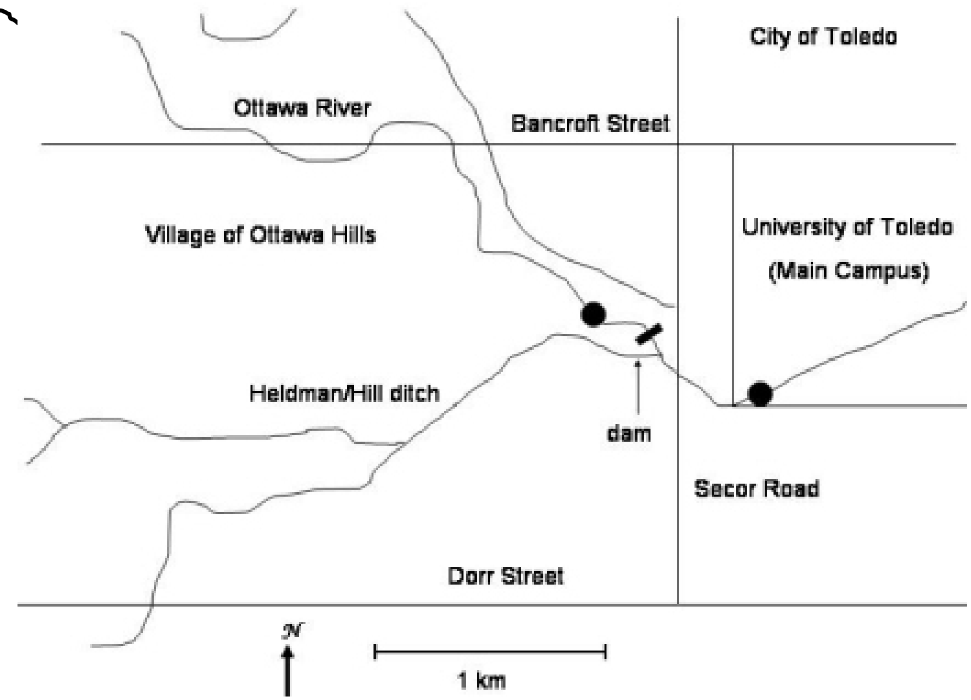


Figure 1. Northwest Ohio and southeastern Michigan with the study site on the Ottawa River (Toledo) highlighted. The Secor Road Dam is indicated by a heavy line (bottom right). Each study site (lower right) is shown with a closed circle.

The upper portion of the watershed is largely agricultural. Further downstream, the river flows through mostly urban and suburban regions, while the lower basin (below river kilometer, RK-12) is dominated by intense urban and industrial land-use. The dam is located immediately West of Secor Road at RK-18.3 and is the last remaining barrier of any significance in the river. It was constructed in the 1960s and replaced a 1920s structure originally built to create a local pond. The dam is ca. 17m long, rises 2.5m above streambed and has three circular sluice gates installed at the bottom of the dam (each approximately 0.2 m^2 in size) that can be closed with flap gates. Wings constructed from steel bulkheads extend both upstream and downstream of the dam on both banks of the river, and rise 0.5 m above the weir. These walls effectively eliminate water from pooling around the dam at all but extremely high stages. The dam is owned by the Village of Ottawa Hills. The two sites chosen for this project are situated approximately 150 m downstream and upstream of the Secor Road dam (Lat. 41º39′27″/Long. 83º37′13″ and Lat. 41º39′33″/Long. 83º37′23″, respectively). In 2005, following a feasibility study (Gottgens *et al.* 2004) and consultation with the dam owner (Village of Ottawa Hills) and village residents, removal of the dam was approved.

Using an unreplicated BACI design (Before-After-Control-Impacted), we contrasted fish communities up- and downstream from the Secor Road dam in the Ottawa by repeated block-seine sampling six times before (2003-04) and six times after (2008-09) dam removal. All seining was done at low water levels between April and October each year, using an Ohio Division of Wildlife permit (11-182). We used seines that were 9.2, 4.6 and 2.5m in length, and 1.8, 1.2 and 1.2m high, respectively. Mesh size was 6mm for the large seine (which was also equipped with a 1.8m wide bag), and 3mm for the two smaller ones. Our team was careful to apply the same sampling methods throughout the entire study period. Fishes were identified to species in the field in accordance with identification characteristics in Trautman (1981). When needed, fish (juvenile fish in particular) were photographed to double-check their identity with taxonomic keys. Relevant habitat conditions (e.g., dissolved oxygen, pH, conductivity, water temperature, and discharge) were measured in both locations using standard field techniques in order to quantify differences independent from the dam that may impact the fish community.

Results and Discussion

During the 12 sampling events (six pre-removal; six post-removal), a total 3,174 fish (belonging to 32 species) were identified, measured, assessed for condition and released. This included 408 juveniles (belonging to 8 species). Adult and subadult abundance per species for each of the twelve sample events are given in Table 1. This fish abundance and richness was remarkable for an urban river with a history of pollution and colloquially considered as 'a dead ditch'.

Up- and downstream measurements for dissolved oxygen, conductivity, pH, temperature and discharge were comparable at each sampling (Table 2). On any sampling date, all measurements were taken within a two hour time frame of each other to minimize the impact of time. Surface and near-bottom measurements of dissolved oxygen and temperature in the river never differed more that 0.2 mg/L and 0.5 ^{0}C. Due to the inflow of Heldman Ditch (Figure 1), discharge at the downstream site always exceeded that at the upstream sample location.

Following dam removal, adult/subadult fish abundance increased markedly upstream from an average of 118 to 221 fish per sample event (Figure 2). Variability in total catch was high among sample events as demonstrated by standard deviations of 82 and 102, respectively. Catastomids (e.g., *Catostomus commersoni*), several sunfish (*Lepomis cyanellus, Lepomis macrochirus*), percids (*Perca flavescens*, *Percina caprodes*), cyprinids (*Cyprinella spiloptera*, *Luxilus chrysocephalus, Notropis atherinoides*, *Pimephales promelas*) and *Dorosoma cepedianum* gained access to upstream habitat or became much more abundant upstream after dam removal. *Semotilus atromaculatus*, not found downstream during the 2003-2004 sampling, was netted in three of the six samples downstream after dam removal. Starting with the 2008 samples, the exotic *Neogobius melanostomus* became abundant in the Ottawa. In May of 2008 it was only found in the downstream location but in August it had also moved upstream. Averaged over all six post removal sampling events, *N. melanostomus* made up 21% and 9% of the total catch downstream and upstream of the old dam site, respectively.

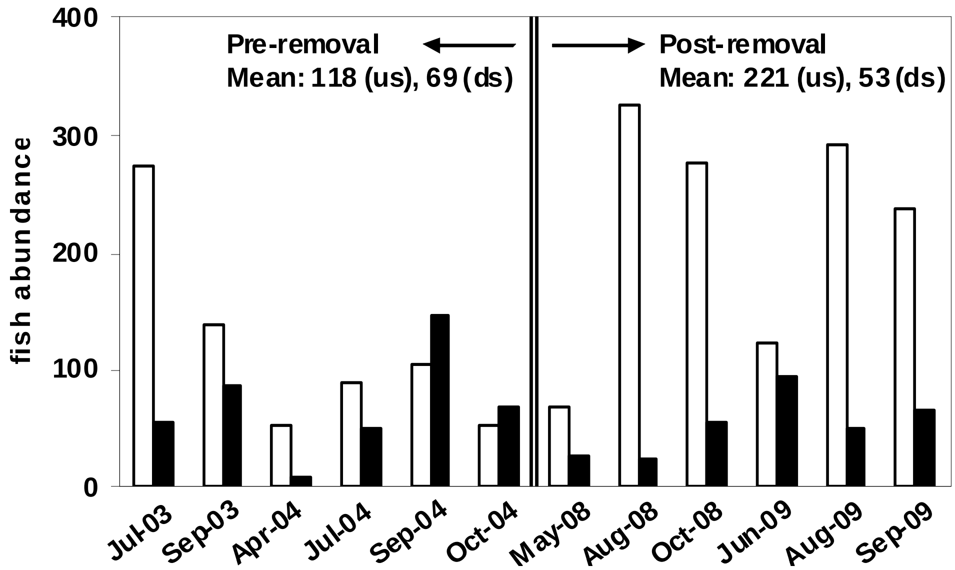
species	common name	31-Jul-03		11-Sep-03		17-Apr-04		11-Jul-04		22-Sep-04		21-Oct-04		29-May-08		15-Aug-08		1-Oct-08		17-Jun-09		6-Aug-09		16-Sep-09	
		ds	us	ds	us	ds	us	ds	us	ds	us	ds	us	ds	us	ds	us	ds	us	ds	us	ds	us	ds	us
Campostoma anomalum	Central stoneroller		16		3						1						58		12		1		31		1
Cyprinella spiloptera	Spotfin shiner	2															1								
Luxilus chrysocephalus	Striped shiner																		3						
Lythrurus umbratilis	Redfin shiner			1							1	1													
Notemigonus crysoleucas	Golden shiner																					1			
Notropis atherinoides	Emerald shiner			15				17		104	1	50		11	63	1	2	39	105	53	55	13	29	30	13
Pimephales notatus	Bluntnose minnow	5	202	12	65	4	23	9	72	20	41	5	1		2		37		10	7	22	1	66	6	29
Pimephales promelas	Fathead minnow		1														10		21		7		35	2	20
Semotilus atromaculatus	Creek chub		7		5				2								57		52	1	1	3	10	1	
Catostomus commersoni	White sucker	3	14		7	2	4			1	13						95	2	4			7	29	9	1
Minytrema melanops	Spotted sucker								1		1														
Moxostoma erythrurum	Golden redhorse																							1	
Moxostoma macrolepidotum	Shorthead redhorse						1																		
Dorosoma cepedianum	Gizzard shad	15		1						2						1			34			12			35
Esox lucius	Northern pike			1																				1	
Micropeterus salmoides	Largemouth bass										2						1	1	1			3			1
Lepomis cyanellus	Green sunfish	3		20				1		1		2				2		1	2						
Lepomis gibbosus	Pumpkinseed sunfish	1		5								4										1			
Lepomis humilis	Orangespot sunfish			1																					
Lepomis macrochirus	Bluegill sunfish			1														1	4	1					
Perca flavescens	Yellow perch	14		23	1			14		9		3	1			4	1	1	1				2	1	3
Etheostoma nigrum	Johnny darter	4	32	5	57	2	24	7	14	5	36	2	48	8	3	3	22	2	18	5	23	3	38	1	13
Etheostoma spectabile	Orangethroat												1												
Percina caprodes	Logperch			1						1						1	16	2	2		6		17	1	5
Percina maculata	Blackside darter				2					1	9		1		1			1	1		1	1	2	1	1
Noturus gyrinus	Tadpole madtom															1									
Ameiurus natalis	Yellow bullhead																			1					
Ictalurus punctatus	Channel catfish																	1							
Carassius auratus	Goldfish											1													
Cyprinus carpio	Carp	7						2		2		1													
Gambusia affinis	Mosquito fish																		2		4		1		66
Neogobius melanostomus	Round goby													8		11	26	4	5	28	5	6	32	10	49
	Total fish	**54**	**272**	**86**	**140**	**8**	**52**	**50**	**89**	**146**	**105**	**69**	**52**	**27**	**69**	**24**	**326**	**55**	**277**	**96**	**125**	**51**	**292**	**64**	**237**
	Species richness	**9**	**6**	**12**	**7**	**3**	**4**	**6**	**4**	**10**	**9**	**9**	**5**	**3**	**4**	**8**	**12**	**11**	**17**	**7**	**10**	**11**	**12**	**12**	**13**

Table 1. Adult and subadult fish abundance per species for each sampling event pre dam removal (2003-04) and post dam removal (2008-09), Ottawa River (NW Ohio). 'ds' and 'us' denote the sampling station downstream and upstream of the Secor Road dam, respectively.

Parameter	Units	31-Jul-03		11-Sep-03		17-Apr-04		11-Jul-04		22-Sep-04		21-Oct-04		29-May-08		15-Aug-08		1-Oct-08		17-Jun-09		6-Aug-09		16-Sep-09	
		ds	us	ds	us	ds	us	ds	us	ds	us	ds	us	ds	us	ds	us	ds	us	ds	us	ds	us	ds	us
Discharge	(m^3/sec)	0.42	0.18	0.46	0.30	0.75	0.57	0.48	0.34	0.74	0.16	0.46	0.16	1.11	0.76	0.52	0.43	0.39	0.37	0.47	0.31	0.24	0.16	0.27	0.16
Temperature	(ºC)	22.0	24.0	21.5	21.9	13.9	13.7	23.4	23.6	18.9	19.0	11.5	10.5	16.4	16.0	20.3	23.0	15.8	16.4	19.1	19.3	19.9	21.5	18.9	19.9
pH				8.2	8.2	8.1	8.0	7.8	7.8	8.1	7.7	7.7	7.7	8.3	8.4	7.9	8.0	8.1	8.3	7.9	8.1			7.5	7.7
Dissolved oxygen	(mg/L)			7.3	8.1	11.9	11.4			12.2	10.5	7.8	5.3	10.6	9.5	8.2	7.6	6.8	6.8	6.9	6.6	6.4	8.0	8.2	8.6
Specific conductivity	(µS cm^{-1})			1187	1195	898	1220	1155	1221	1157	1280	763	840	912	1109	940	1010	950	770	1220	1000	1258	1080	1025	1175

Table 2. Discharge, temperature, pH, dissolved oxygen and specific conductivity measurements recorded for each date and sampling site on the Ottawa River, Toledo, Ohio (USA). Blank box indicates that the measurement was not taken for that date and site.

Figure 2. Adult/subadult fish abundance per sample event upstream (open bars) and downstream (closed bars) from the Secor Road dam pre- and post removal.



Species richness and Shannon diversity nearly doubled upstream after the removal of the dam while they remained unchanged in the downstream site (Figure 3 and 4). The Shannon index of diversity combines aspects of species richness and eveness. At the same time, average Simpson's dominance dropped from 0.53 to 0.30 upstream, while downstream value remained unchanged by the dam removal (Figure 5). The Simpson's index is a measure of how 'concentrated' the dominance species is in a sample. It expresses the chance that the next individual fish in a sample belongs to the same species as the previous individual and is less sensitive to rare species than the Shannon index. The trophic composition upstream shifted from an omnivore-dominated assemblage to a 61% invertivore community with an average of 4% piscivores (measured by abundance). A similar shift occurred at the downstream site (Figure 6). As predicted, the index of similarity between the downstream and upstream sites increased from 0.45 to 0.72 following dam removal. Abundant juvenile fish upstream of the old dam site pointed to improved spawning success after dam removal. Before dam removal we netted an average of 9 juvenile fish per sampling event (belonging to only two species) in the upstream location. Following dam removal, that number jumped to 46 juvenile fish belonging to seven species (Figure 7). Because the presence and abundance of juvenile fish fluctuates greatly over time, error bars for these averages are large and make little ecological sense.

Figure 3. Adult/subadult richness of fish species per sample event upstream (open bars) and downstream (closed bars) from the Secor Road dam pre- and post removal.

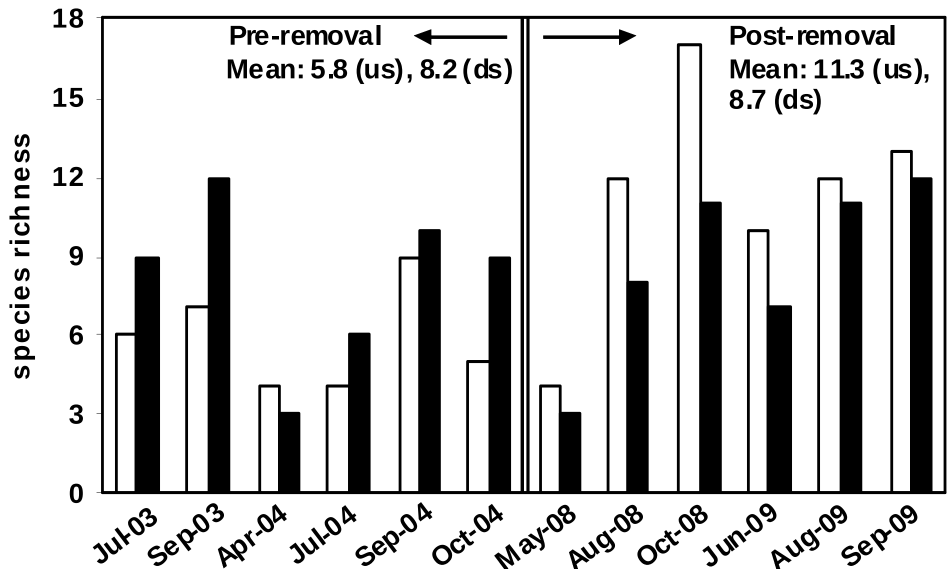


Figure 4. Shannon diversity index for adult/subadult fish per sample event upstream (open bars) and downstream (closed bars) from the Secor Road dam pre- and post removal.

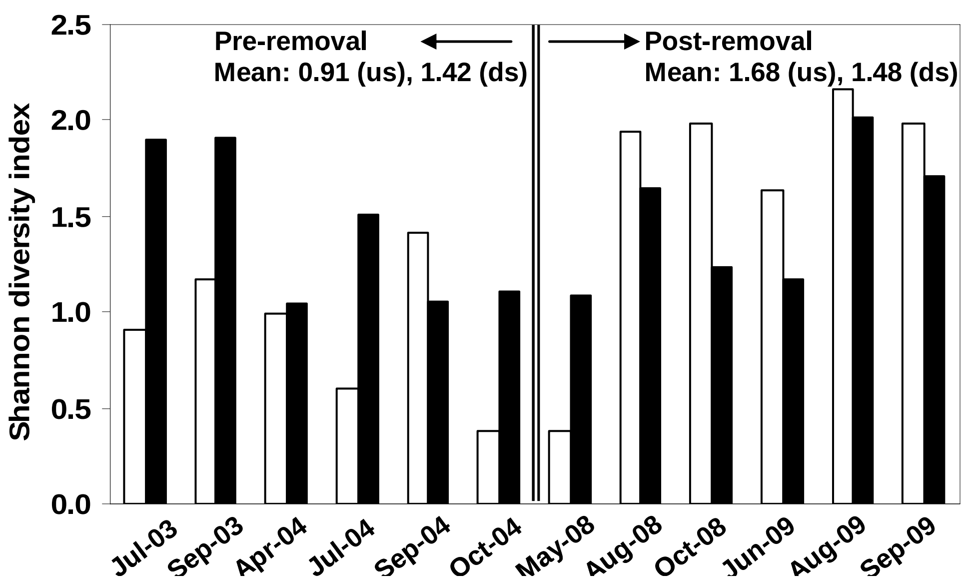


Figure 5. Simpson's index for adult/subadult fish per sample event upstream (open bars) and downstream (closed bars) from the Secor Road dam pre- and post removal.

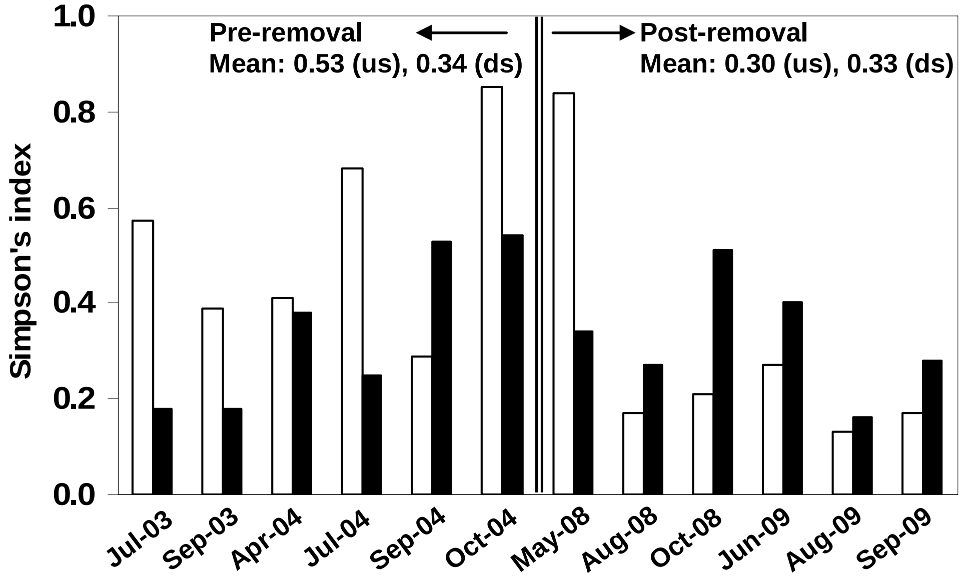


Figure 6. Trophic composition of the adult/subadult fish community upstream and downstream from the Secor Road dam pre- and post removal.

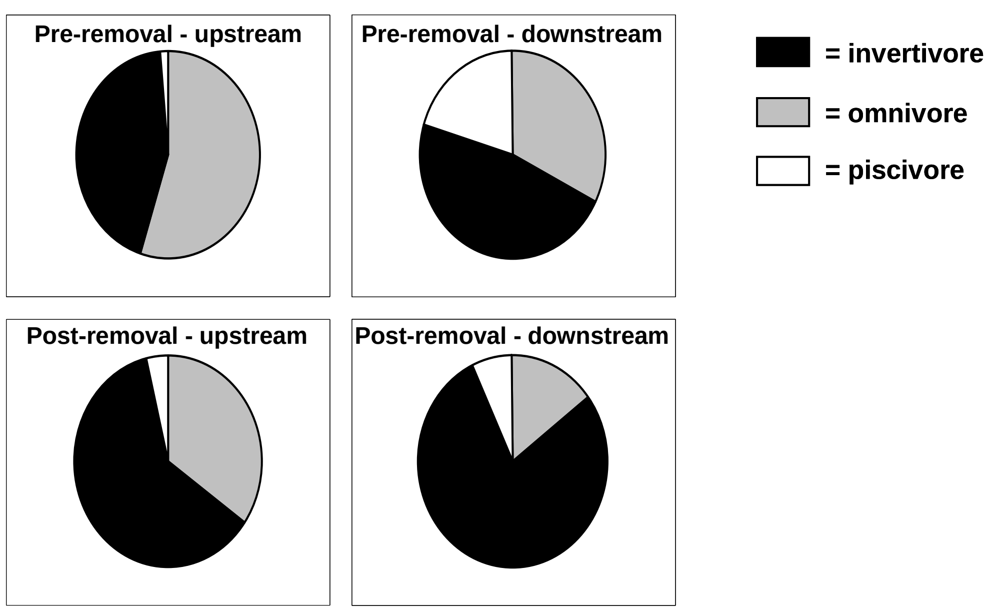
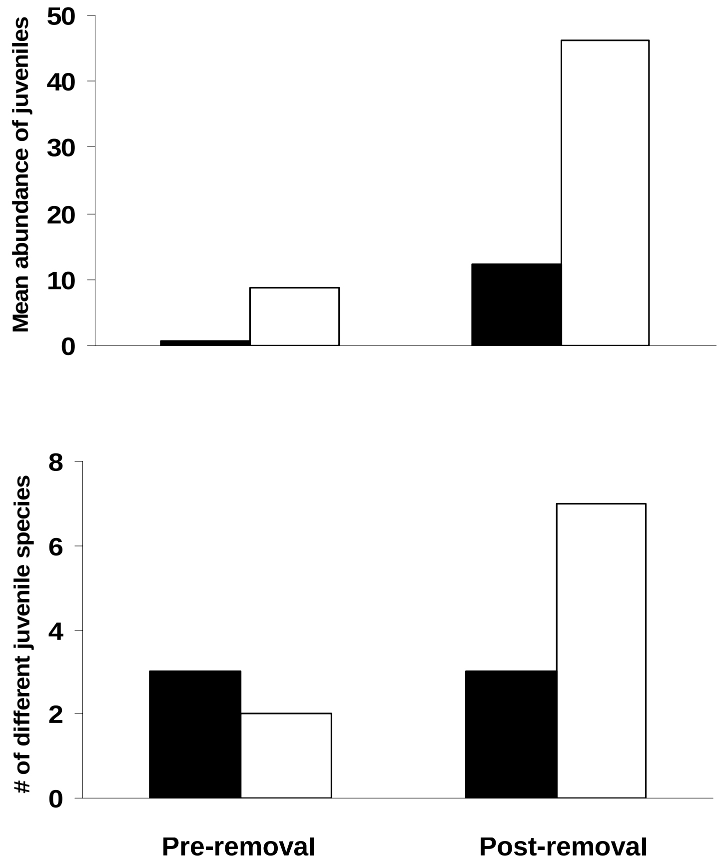


Figure 7. Mean abundance of juvenile fish and mean number of different juvenile species upstream and downstream from the Secor Road dam pre- and post removal. Because the presence and abundance of juvenile fish naturally fluctuates greatly over time, error bars for these averages are large, make little ecological sense and are left out.



Conclusions

Even though the Ottawa is generally considered degraded riverine habitat, we found abundant fish belonging to a total of 32 species. Despite its small size, the Secor Road dam impacted the fish community in the Ottawa River. The impact was most obvious in the composition of the fish community (e.g., species lists, absence/presence of migratory species) and in indices that reflect such composition (diversity, trophic structure). Because many fish species play a critical role in the distribution of freshwater mussel larvae, the dam removal may indirectly promote the spread of native unionid mussels in the Ottawa drainage.

As predicted, upstream and downstream fish communities differed substantially before dam removal. The communities became similar following its removal. A more than five-fold increase in juvenile fish abundance attested to improved habitat upstream for fish spawning. Every year, as a routine part of our curriculum, we conduct student field exercises on the stream invertebrate community in the Ottawa River approximately 10 km upstream of the old dam site. Starting in the spring of 2008, following the November 2007 dam removal, record densities of juvenile fish were encountered during student sampling for invertebrates.

Our study design, used for this evaluation on the impact of dam removal on fish, was low-cost and worked well in small rivers that are fit for seines (i.e., with a minimum of obstacles such as concrete blocks, snags, large debris and trash in the channel). Because our team sampled the fish community structure and composition in the same locations during two years before and two years after dam removal, we had to concern ourselves with the effect of dependency among measurements at each site ('repeated measures'). We minimized this effect by allowing a relatively long time interval between repeated measures (a minimum of one month) and by using a non-destructive sampling technique (all fish were immediately returned following measurement and identification).

In northern Ohio alone, there are 632 dams registered by the National Inventory of Dams (NID 2006). Almost 60% of these dams are considered to be a high or significant hazard because of age, obsolescence, and/or lack of maintenance and thus should be considered for removal (Roberts et al. 2007). Quantitative data on the impact of such removals on fish and other biota (e.g., unionid mussels) are needed to predict ecological impacts, help guide dam removals, and make better decisions about river management.

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