1-1-2014

Effects of Dams on Fish and Macroinvertebrate Communities in the Vermilion River, IL

Ryan Patrick Hastings
Eastern Illinois University

This research is a product of the graduate program in Biological Sciences at Eastern Illinois University. Find out more about the program.

Recommended Citation
http://thekeep.eiu.edu/theses/1264

This Thesis is brought to you for free and open access by the Student Theses & Publications at The Keep. It has been accepted for inclusion in Masters Theses by an authorized administrator of The Keep. For more information, please contact tabruns@eiu.edu.
THESIS MAINTENANCE AND REPRODUCTION CERTIFICATE

TO: Graduate Degree Candidates (who have written formal theses)

SUBJECT: Permission to Reproduce Theses

An important part of Booth Library at Eastern Illinois University’s ongoing mission is to preserve and provide access to works of scholarship. In order to further this goal, Booth Library makes all theses produced at Eastern Illinois University available for personal study, research, and other not-for-profit educational purposes. Under 17 U.S.C. § 108, the library may reproduce and distribute a copy without infringing on copyright; however, professional courtesy dictates that permission be requested from the author before doing so.

By signing this form:

- You confirm your authorship of the thesis.
- You retain the copyright and intellectual property rights associated with the original research, creative activity, and intellectual or artistic content of the thesis.
- You certify your compliance with federal copyright law (Title 17 of the U.S. Code) and your right to authorize reproduction and distribution of all copyrighted material included in your thesis.
- You grant Booth Library the non-exclusive, perpetual right to make copies of your thesis, freely and publicly available without restriction, by means of any current or successive technology, including but not limited to photocopying, microfilm, digitization, or Internet.
- You acknowledge that by depositing your thesis with Booth Library, your work is available for viewing by the public and may be borrowed through the library’s circulation and interlibrary department or accessed electronically.
- You waive the confidentiality provisions of the Family Educational Rights and Privacy Act (FERPA) (20 U.S.C. § 1232g; 34 CFR Part 99) with respect to the contents of the thesis, including your name and status as a student at Eastern Illinois University.

Petition to Delay:

I respectfully petition that Booth Library delay maintenance and reproduction of my thesis until the date specified and for the reasons below. I understand that my degree will not be conferred until the thesis is available for maintenance and reproduction.

Date:

Reasons:

This form must be submitted in duplicate.

http://www.eiu.edu/graduate/forms/thesisreproductioncert.html 5/21/2014
EFFECTS OF DAMS ON FISH AND MACROINVERTEBRATE COMMUNITIES IN THE VERMILION RIVER, IL

BY

Ryan Patrick Hastings

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE – BIOLOGICAL SCIENCES

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

2014

I HEREBY RECOMMEND THAT THIS THESIS BE ACCEPTED AS FULFILLING THIS PART OF THE GRADUATE DEGREE CITED ABOVE
Abstract

Dams are a main source of anthropogenic disturbances on river systems and can affect rivers in a variety of ways. Dams have the ability to change rivers from lotic to lentic habitats, affect sediment transportation, connectivity, water quality, linkages with wetlands and the quality of in-stream and riparian habitats. The Danville Dam was constructed in 1914 on the Vermilion River in Danville, Illinois and is becoming a safety hazard for human recreation on the Vermilion River, resulting in three deaths in the last 10 years. The Illinois Department of Natural Resources in conjunction with the city of Danville has proposed to remove the Danville dam on the main channel fall 2015 and an additional low head dam, Ellsworth Dam, in its tributary the North Fork Vermilion in fall 2014.

To assess the impacts of removing the Ellsworth and Danville dams on the aquatic biota and stream habitat quality. Beginning October 2012, we assessed the fish and macroinvertebrate assemblages in twelve, 100 meter long sections of river. Six of the 12 sites were located in the North Fork, referred to as Ellsworth Dam, and six sites in the Vermillion, referred to as Danville Dam sites. Each dam consisted of two sites below the dam and four sites above the dam. The above dam sites consisted of a site directly above the dam, the last 100 meters of the pool, the first 100 meters of the river and an upstream site (the farthest accessible upstream location). This sampling captures the community composition both above and below the dam (immediate impacts) and characteristics of sites above the dam’s influence.

The effects of the dams were greatest seen at base flow, in the fall seasons. Data shows fall community composition demonstrates strong influences of both dams on fish assemblages and revealed compositional differences between the two drainages. In sharp contrast, a cluster analysis showed no separation in community composition between rivers or sites in the spring.
Therefore base flow was used to assess the fish and macroinvertebrate community structure. Non-metric Multidimensional Scaling was used to assess the structure of fish and macroinvertebrate communities. Per-Manova analysis verified river, location, and their interaction to be significant on fish assemblages. Mantel tests showed there was an effect of habitat on fish community structure but no significant effect of physical distance on fish assemblages. Per-Manova reflected the complexity of compositional relationships with both river and the interaction of river and location to be significant on macroinvertebrate assemblages. Unlike the fish, macroinvertebrate assemblages were affected by distance but not by local environment.

The Vermilion River system is one of the highest quality systems in Illinois. The removal of the dams will allow the main channel to reconnect and also provide access to upstream habitats in the North Fork tributary. Eliminating physical barriers will allow fish to move upstream allowing them to restore populations. Returning to a free flowing system will increase macroinvertebrate diversity increasing aquatic resources. The combination of these factors will increase the quality of the Vermilion River and return it to its natural environment. The goal of this study is to serve as a model to test the efficacy of dam removal in restoring the diversity and structure of river communities.
Dedication

I would like to dedicate my thesis manuscript to my fiancée, Kate Gdowski, for all of her love and support through my Master’s experiences at Eastern Illinois University. I would have never have been able to get through this process if it was not for her, nor ever applied to graduate school.

I would also like to dedicate my thesis manuscript to my mother, Pam Hastings, who was without a doubt my biggest fan in life. Whether her encouragement came in the form of comforting pep talk or a slap upside the head; she always believed in me and it was her unwavering love and support that led me to push myself in my career. She shared a genuine interest in my academics and work, and although she wouldn't live bait a hook; she would never say no to a day fishing together. It was her positive outlook on life and selfless nature that lead to my success so far in life and my gratitude to my mom will live on forever.
Acknowledgements

I would like to thank my advisor, Rob Colombo, for allowing me the opportunity to work in his lab. This opportunity has allowed me to gain the knowledge to become a better fisheries biologist and allowed me to present my data at multiple conferences.

I would like to thank my co-advisor, Scott Meiners, for mentoring me throughout my project throughout my Master’s degree. I was Scott’s first student working on fish and am very lucky to have had his guidance and support throughout my time at EIU.

I would like to thank the rest of my family, my dad Mike Hastings, Brother Chris Hastings and Sister Jamie Hastings for all their support through my Master’s Degree.

I would also like to thank my future in-laws, Rich and Nina Gdowski for all their love and support throughout my time being away.

Lastly, I would like to thank my lab mates for all their help and support throughout my project. Especially, Clint Morgeson for all the long days in the field dipping more fish I could have ever asked for and Sarah Huck for helping me through my first year at Eastern Illinois University and teaching how to track Catfish.
# Table of Contents

Abstract .......................... i
Dedication ......................... iii
Acknowledgements ................ iv
List of Tables ....................... vi
List of Figures ..................... vii
Introduction ....................... 1
Chapter 1: When to Sample: Seasonal Shifts in Dam Effects on Fish Assemblages 5
Chapter 2: Separating Environmental and Barrier Effects of Dams on Fish and Macroinvertebrate Assemblages
   Introduction .................... 12
   Methods ......................... 16
   Results ........................ 19
   Discussion ..................... 22
Conclusions ....................... 38
Literature Cited ................... 42
List of Tables

Table 2.1. Laboratory water chemistry analysis of sites during the Fall 2012. 26

Table 2.2. Total catch of families by location within river. 27
List of Figures

**Figure 1.1.** Vermilion (D) and North Fork Vermilion River (E) sampling sites. Below dam sites (1,2), pool sites (3,4) and upper river sites (5,6).

**Figure 1.2.** Cluster analysis of fall 2012 (A) and spring 2013 (B) communities using species presence absence.

**Figure 2.1.** Map of the Vermilion River (D) and North Fork Vermilion River (E). Sites are numbered by location; Below Dam (1,2), Pool (3,4), and River (5,6).

**Figure 2.2.** Distribution of substrate types across the dams in the Vermilion River (A) and North Fork Vermilion (B).

**Figure 2.3.** Response of QHEI Scores to the presence of dams on the Vermilion (solid) and North Fork Vermilion (dashed).

**Figure 2.4.** Response of Simpson’s Diversity Index of fish to the presence of dams on the Vermilion River (solid) and North Fork Vermilion (dashed).

**Figure 2.5.** Response of index of biotic integrity scores to the presence of dams on the Vermilion River (solid) and North Fork Vermilion (dashed).

**Figure 2.6.** Simpson’s Diversity Index of macroinvertebrates from the Vermilion River (solid) and North Fork Vermilion (dashed).

**Figure 2.7.** Macroinvertebrate Biotic Index Scores of Vermilion (solid) and North Fork Vermilion (dashed).

**Figure 2.8.** Non-Metric Multidimensional Scaling of fish assemblages using presence-absence data from both years pooled.

**Figure 2.9.** Non-Metric Multidimensional Scaling of sites based on relative
abundance of Macroinvertebrates.

**Figure 2.10.** Average velocity (m/s) of water at sites. Vermilion (solid), North Fork (dashed).
Introduction

Dams are a main source of anthropogenic disturbances on river systems. Over 75,000 dams exist in the United States and 40,000 are greater than 50m tall (Bednarek 2001, Gregory et al. 2002,). Historically, dams were constructed to provide a wide array of services; power generation, flood control, navigation, water supply and recreation (Bednarek 2001, Leirmann, 2007). However, many dams in the United States have outlived their economic usefulness and are removed to reestablish natural conditions and to increase recreation safety. Over the last twenty years, roughly 600 dams have been removed in the United States (Collins et al., 2007). In the state of Illinois approximately 1,600 dams currently exist, 455 of which are over 50 years old and many are no longer serving their initial function (ASDSO, 2012; ASCE, 2012).

Ecologically, dams have the ability to change rivers in many of ways (Collins et al. 2007). The reduction of flow due to the impoundment causes habitat above the dam to become a slow moving reservoir with a concomitant change in biota. The process of upstream pooling also changes sediment transportation. Fine sediments settle in the reservoir area filling in existing cobble, boulder and other large particles (Bednarek 2001). Overtime, sediment builds up above the dam; this sediment is only transported downstream during large floods. The reduction in flow also reduces the natural transportation of larger boulders, cobble, and debris to downstream habitats. The accumulation of sediments and debris upstream may degrade downstream habitats because downstream ecosystems rely on this sediment and debris transportation for different life stages of biota (Leirmann et. al 2012). The retention of sediments also causes a “clear water effect”, which limits sediment and nutrients to downstream habitats changing water chemistry (Bednarek 2001). The temperatures in the upstream reservoir usually become stratified due to an increase in surface area and decrease in flow (Bednarek 2001). The discharge of hypolimnetic
water, water below the thermocline, downstream can decrease average water temperature in downstream habitats and is often low in dissolved oxygen and nutrients (Gregory et. al 2002, Bednarek 2001). The colder, low oxygen and low productivity water significantly alters downstream habitats to decrease in quality.

Because there are few monitoring programs, ecological effects of dams on biota are relatively unknown. As of 2005, 500 dams were removed in the United States and less than 5% of those dams underwent ecological studies (Thomson et. al 2005). Because dams are physical barriers for fish and macroinvertebrate species, assessing the impacts of dams is important. The physical transformation of river to reservoir habitat changes species composition by allowing lentic tolerant fish species to establish and displace native lotic species to an upstream location (Burroughs et. al 2010). The change from lotic to lentic also causes changes in water quality leading to a shift in macroinvertebrate species from tolerant lotic species such as Ephemeroptera, Plecoptera, and Trichoptera (EPT taxa), to intolerant species like Chironomidae.

Sediment transportation may be one of the key disturbances affecting biota. The accumulation of sediment above the dam reduces habitats for spawning of native species. Native species get displaced to upstream habitats where competition may increase. Similarly, the lack of sediment/debris transportation downstream greatly affects biotic assemblages. The buildup of sediment reduces nutrients and sediment transfer downstream that may be needed for nesting and refuge for species (Leirmann et. al 2012). Dams retain important nutrients including silica, changing phytoplankton community structures downstream (Gregory et. al 2002). The trapping of nutrients can lead to a cascade in food webs by changing the phytoplankton base which can alter the macroinvertebrate community, potentially causing in a change to the fish community composition.
Altercations of water temperature, and/or releasing epilimnetic or hypolimnetic water can change species composition between cold water and warm water species (Bednarek 2001). Biotic communities can also be affected by stream flow regulation. Many dams regulate stream flow based on power usage. When more power is needed, more water is released. The surge of flow downstream can disperse many organisms downstream (Vehanen et. al 2005). The velocity from water entering into the turbine can increase mortality of fish upstream not able to escape the high velocities (Vehanen et. al 2005).

Abiotic and biotic effects of dams can greatly influence the success of individual species by reducing or changing habitats, food webs, reproductive success and migration. The impacts of dam on individual species can, therefore, affect community structure. Within river systems, dispersal and recolonization are important for communities to remain stable. Dispersal allows species to move to new habitats, find new food sources and immigrate into other populations and communities. These inter-community interactions help define metacommunities. According to Leibold et al. (2004), a metacommunity is a set of local communities linked by dispersal of multiple interacting species.

Dams can affect metacommunity composition by acting as a barrier to immigration and emigration of species across the dam. Dams with improper fish passages cause fish species below the dam to be disconnected from populations above the dam and eliminate passage to quality habitats. Dams can prevent species upstream from immigrating downstream because of physical changes. Riverine species with larval drift are impacted by dams where reduction in flow prevents larval migration to downstream sites (Nislow et. al 2011). These barriers may lead to decreases in local abundance and potentially decrease population size and biodiversity (Nislow et. al 2011).
In this study we assessed the fish and macroinvertebrate assemblages of two impounded rivers in Danville Illinois, the Vermilion River and the North Fork Vermilion. Our goals were to: (1) assess seasonal effects of dams on fish assemblages; (2) assess species richness, diversity, and indexes of fish and macroinvertebrates; (3) determine habitat quality in relation to impoundments; (4) and use a metacommunity approach to assess community structuring of fish and macroinvertebrates in relation to impoundments. Overall, this study is to serve as a model to test the efficacy of dam removal in restoring the diversity and structure of river communities.
When to Sample: Seasonal Shifts in Dam Effects on Fish Assemblages

Anthropogenic forces are the main disturbances for waterways globally and typically involve dams, spillways, channel modification, industrial outflow and agriculture. Ecologically, dams cause habitat changes from lotic to lentic, affect sediment transportation, water quality, connectivity and the quality of in-stream habitats (Collins et al. 2007). The generation of new habitat types within impounded reaches increases the performance of species that would otherwise be rare in lotic systems, leading to distinct fish assemblages in the pools that form behind dams (Santucci et al. 2005; Butler & Wahl 2010).

Dams can affect metacommunity composition by altering immigration and emigration of fish species across the dam. Within river systems, dispersal is critical for community stability as it allows species to migrate to new habitats, locate shifting food sources and integrate with other populations. Dams with improper fish passages cause fish species below the dam to be excluded from upstream reaches and eliminate passage to quality habitats (Burroughs et al. 2010). Besides acting as physical barriers, dams can change can cause shifts in community assemblages both upstream and downstream.

The combined abiotic and biotic effects of dams can greatly influence the success of individual species by changing habitat, food web structure, reproductive success and migration (Nislow et al. 2011). The aggregate alteration of fish movement and habitat structure can therefore dramatically affect fish community structure. Fish community structure also changes seasonally based on life history differences, and habitat variability and accessibility (Taylor 2000; Taylor 1996). High flows can allow for different fish species to access habitats or may even alter preexisting habitats allowing for utilization for different fish species. (Taylor et al.
2006). Therefore, shifts in seasonal discharge may mask the impacts of impoundments on fish communities.

The purported impacts to fish communities are one of the major justifications for the removal of impoundments (Helms et al. 2011). However, there is no standard sampling protocol that defines when surveys to assess dam impacts on fish should be conducted. This paper aims to determine whether sampling season influences the perceived impacts of dams on fish community assemblages and determine appropriate sampling season for assessing anthropogenic disturbances.

The Vermilion River in Danville, Illinois is a tributary of the Wabash River with a low-head dam, Danville Dam, ~35 km upstream from the confluence. It is a 3.35 m high 67.25 m long dam that acts as a barrier for most of the year. Half a mile upstream from the dam is the confluence of the North Fork Vermilion River (Figure 1.1). This tributary also has a 30 m long low-head dam, Ellsworth Dam, 0.08 km upstream from the confluence. Both of these dams act as barriers to fish movement at base flows. During spring floods the Ellsworth Dam is typically submerged allowing for connectivity with the North Fork of the Vermilion. The Danville Dam can also become submerged, but only during ten year floods (Trent Thomas, pers. observation). These spring floods may reduce the effects of the dams for a brief period.

To assess impacts of the impoundments on fish assemblages, sampling was conducted sequentially during October 2012 and May 2013. Fish were sampled in twelve, 100 m sections of river; six located in the North Fork Vermilion (Ellsworth Dam sites) and six in the Vermilion (Danville Dam sites) (Figure 1.1). For each dam, sampling consisted of two sites below the dam,
two sites in the pool (directly above the dam and the last 100 meters of the pool) and two river sites (the first 100 meters of the river and the farthest accessible upstream location).

Ellsworth Dam fall sampling was conducted using DC barge shocking with a 2,500 watt generator. Each site was electrofished for a total of 30 minutes beginning downstream moving upstream. Danville Dam was sampled using DC boat shocking with a 4,000 watt generator with two Wisconsin droppers for a total of 30 minutes across the entire area. This methodology reflects the larger nature of this channel. Two seines were conducted at the Danville Dam sites at the nearest sandbar to ensure collection of smaller fish that DC boat shocking is not capable of sampling. Spring sampling protocols changed due to increased discharge; both rivers were sampled in using DC boat shocking with a 4,000 watt generator. These samples were supplemented with two mini fyke nets at each site for 24 hours to collect smaller fish.

A total of 54 fish species were collected in the fall and 56 species in the spring. Of these, ten species were only found in the fall and twelve species in the spring. The species found only in the spring were larger fishes, three native buffalo species (Ictiobus spp.), three species of gar (Lepisosteus spp.), and the non-native silver carp (Hypophthalmichthys molitrix). Species found only in the fall were mainly smaller darters and cyprinids that may have not been sampled in spring due to the increase in flow. Catostomidae abundances varied dramatically between seasons within pool sites. Abundances in Vermilion pool sites increased from <1.0% to 13.7% of the community (7 to 47 individuals) and from 0.0% to 5.0% (16 individuals) in North Fork pools. Also, Moxostoma species were not captured anywhere within North Fork sites in fall but found in all sites in the spring. Overall, there were large seasonal changes in composition, most of which would not be related to capture efficiency.
To examine spatial patterns of fish community composition, a hierarchical cluster analysis was conducted for each sampling using a presence/absence matrix in PCORD 6 (McCune & Grace 2002). Fall community composition showed strong influences of both dams on fish assemblages and revealed compositional differences between the two drainages (Figure 1.2a). In sharp contrast, the cluster analysis showed no separation in community composition between rivers or sites in the spring (Figure 1.2b).

These analyses show how fish assemblages change seasonally. The separation of sites in the fall cluster definitively show effects of the dams in the system and also show relationships among sites. Below dam and upper river sections of the Vermilion were similar (Figure 2a), revealing a spatially limited dam impact and a large shift in composition caused by the pool. Pool sections of the Vermilion were also compositionally similar to the below dam sites on the North Fork, reflecting their connectivity. In contrast, fish composition in the spring did not vary between the two drainages, suggesting that spatial structuring and dam influences only operate at base flow, whereas the communities mix at high flow. Seasonal variability in fish community composition is likely caused by greater fish movement during increased discharge. As a second measure of seasonal changes in fish community structure, we used Mantel tests to relate physical distance (stream length) between sites to compositional dissimilarity (Sorensen’s distance). These tests showed that sites located further apart were overall less similar in family composition (P=0.003) and species composition (P=0.002). In contrast, spring analyses showed no pattern for either family (P=0.100) or species (P=0.210) composition. Sites further in distance were less similar in family and species composition in the fall suggesting distance affected assemblage structure (Thompson & Townsend 2006; Ruiz-Gomez et al. 2008). The compositional similarity of downstream and river sections of the Vermillion shown in the cluster analysis was
not sufficient to disrupt this overall pattern. There was no spatial pattern in the spring, showing greater mixing of fish assemblages during increased discharge. Together, these results indicate that the timing of sampling to determine the effects of dams may have profound influences on the results.

The long term biological effects of dams are relatively unknown as there are few sufficiently long studies. Despite the lack of information, dam removal is increasing across the United States (Thomson et al. 2005). The Vermilion River system is one of the highest quality river systems in Illinois and is used as the reference site for the Illinois eastern region for indices of biotic integrity. Given the high quality of the river, there are few challenges to the system outside of the effects of the dams. Spring time floods in the Vermilion show reduced effects of the dams are in high flows by increasing connectivity. The presence of buffalo species (Ictiobus spp.) in the river as well as multiple redhorse species (Moxostoma spp.) in the pools reflects increased flow in the lentic zones.

Whether spring homogenization is driven by downstream fish migrating above the dam to spawn or upstream fish moving downstream is not clear. Nor is it clear whether this spring mixing is sufficient to ensure gene flow across dams. To adequately assess dam impacts on fish assemblages, sampling protocols must account for seasonal fluctuations in both rivers and the communities within them. To sufficiently document dam impacts on fish assemblages, sampling must occur once base flow has been re-established and the temporary mixing of communities has abated. These results also suggest that more work is needed to determine whether low-head dams are effectively isolating populations or whether high flow events allow sufficient contact between upstream and downstream populations.
Figure 1.1. Vermilion (D) and North Fork Vermilion River (E) sampling sites. Below dam sites (1,2), pool sites (3,4) and upper river sites (5,6).
Figure 1.2. Cluster analysis of fall 2012 (A) and spring 2013 (B) communities using species presence absence.
Separating Environmental and Barrier Effects of Dams on Fish and Macroinvertebrate Assemblages

Introduction

Dams are a major source of anthropogenic disturbance on river systems. Historically, dams were constructed to provide a wide array of services: power generation, flood control, navigation, water supply and recreation (Bednarek 2001, Leirmann, 2012). Attention to dam removal is increasing in response to ecological and socioeconomic pressures. Many dams in the United States outlived their economic usefulness and are being removed both to reestablish natural conditions and to increase safety. Over the last twenty years roughly 600 dams have been removed in the United States (Collins et al., 2007). In the state of Illinois approximately 1,600 dams currently exist, 455 of which are over 50 years old and many are no longer serving their initial function (ASDSO, 2012; ASCE, 2012).

Studies of dam impacts commonly focused on how they act as physical barriers to dispersal (Martinez et al. 1994, Nislow et al. 2011). Physical barriers in river systems can cause problems for a variety of biota at different life history stages. Many riverine fish taxa rely on natural flow regimes and channel connectivity to maintain reproductive success, genetic diversity, and access to food sources. The presence of these barriers can cause shifts in community structure by not allowing organisms to move freely throughout the system. Though egg and larvae stages of macroinvertebrate taxa are mainly aquatic, multiple taxa have flying adult stages (Hershey et al. 2001, Merritt and Cummings, 1996). Therefore, dispersal can potentially to be affected by dams as physical barriers in aquatic life history stages through drift. Though some impoundments addressed dispersal concerns by adding fish ladders, side channels, or pumps, they may still result in dispersal restriction (Nislow et al. 2011).
In addition to acting as physical barriers in river systems, dams also disrupt ecological processes by changing habitat structure. The reduction in flow due to impoundment causes river habitat to become a reservoir with a concomitant change in biota. The process of upstream pooling changes sediment transportation, filling in existing cobble, boulder and other large particles with fine sediments (Bednarek 2001). Over time, sediment builds up and may only be transported downstream during large flood events. Transportation of larger boulders, cobble, and debris to downstream habitats is also reduced leading to lower quality downstream habitats. Biota in the downstream ecosystem often relies on sediment and debris transportation at various life stages (Leirmann et. al 2012). In larger impoundments, there can also be alterations to dissolved oxygen levels, nutrient loading and suspended solid levels (Burroughs et. al 2010, Hammer 2003). Overall, these habitat changes may cause shifts from natural community structure within impacted areas.

The physical transformation of river to reservoir habitat changes species composition by allowing lentic fish species to establish and displace native lotic species (Burroughs et. al 2010). The accumulation of sediment above the dam reduces habitats for spawning of stream fish species. This accumulation also alters macroinvertebrate communities by filling in the interstitial spaces in substrate. Similarly, the upstream deposition of sediment reduces nutrients and sediment transfer downstream that may be needed for nesting and refuge certain taxa (Leirmann et. al 2012). This change from lotic to lentic causes changes water quality shifting macroinvertebrates abundances by decreasing Ephemeroptera, Plecoptera, and Tricoptera; while increasing intolerant species such as Chironomidae (Hammer and Linke 2003, Tiemann et al. 2004). Dams retain important nutrients such as silica, changing phytoplankton communities’ downstream which can cascade through invertebrate and fish food webs (Gregory et. al 2002).
Additionally, alterations of water temperature, and/or releasing epilimnetic or hypolimnetic water may also change species composition (Bednarek 2001). Episodic release events have the potential to cause surges that disperse many organisms downstream (Vehanen et al. 2005).

Abiotic and biotic effects of dams can greatly influence the success of individual species by changing habitats, food webs, reproductive success and migration; resulting in a potentially affecting community structure. Within river systems, dispersal and recolonization are important for community stability (Taylor et al. 2006, Slawski et al. 2008, Heino, 2012). Dispersal allows species to move to new habitats, find new food sources and integrate with other populations. The linkages among habitats reflect the metacommunity structure of riverine systems (Leibold et al. 2004). Therefore, metacommunity theory can be used as a conceptual framework to understand how communities function in fragmented landscapes such as rivers with impoundments. Leibold (2009) outlined four paradigms to model metacommunity dynamics including mass effects, patch dynamics, neutral dynamics, and species sorting. Of these, patch dynamics, species sorting and, neutral dynamics appear important for impounded river systems.

According to the patch dynamics paradigm, variation in community composition is generated by patterns of extinction and colonization of individual patches. Dams can affect metacommunity structure by acting as a barrier to immigration and emigration of species, disconnect populations and eliminate seasonal passage to different habitats. Dams may also prevent species migration because of physical changes in the environment acting as a behavioral deterrent rather than as physical barriers (Taylor et al. 2008). Variation in community composition may also be generated by species sorting along environmental gradients when dispersal is not sufficient to change distribution (Leibold et al. 2004). Environmental changes associated with alteration of flow and the formation of pools behind dams can increase lentic
species’ reproductive success, displacing lotic species upstream. Similarly, reduction in flow and changes in sediment structure may cause lotic fish species to disperse upstream to locate higher quality habitats. The displacement of fish upstream has the potential to increase competition which can lead to changes in community structure (Jackson et al. 2001). Finally, assemblage composition may be random, reflecting a lack of dispersal limitation or environmental filtering. Such neutral structuring (Leibold 2009) represents a null hypothesis for the system. Understanding how dams control metacommunity structure may directly suggests ways to ameliorate their impacts and predict the impacts of dam removal.

A metacommunity approach was used to understand dam impacts on assemblage structure of two impounded rivers in Danville Illinois, the Vermilion River and the North Fork Vermilion. This was done separately for two groups of organisms, fish and macroinvertebrates, which should respond to dams differently to provide an ecological contrast in susceptibility to impoundment. Dams represent physical barriers to fish movement, but should not alter dispersal of macroinvertebrates with flying adult stages. In contrast, dams should influence macroinvertebrate communities primarily by altering habitat structure. Therefore, their metacommunity responses to impoundment are expected to differ dramatically. Assemblage composition data across these two impoundments were used to address the following goals: (1) to assess species richness, diversity, and biotic integrity of fish and macroinvertebrate assemblages in response to dams, (2) to assess fish and macroinvertebrate community structure responses to dams, and (3) to determine metacommunity drivers of fish and macroinvertebrate community structure. The overall goal of this study is to serve as a model to test the efficacy of dam removal in restoring the diversity and structure of river communities.
Methods

Study Area

The Danville Dam was constructed in 1914 on the Vermilion River in Danville, Illinois. This dam was historically used for hydropower, but this function is now obsolete (Thomas 2012). The Danville Dam is becoming a safety hazard for human recreation on the Vermilion River resulting in four fatalities since 1995 (IDNR). The Illinois Department of Natural Resources in conjunction with the city of Danville has proposed to remove the Danville Dam on the main channel in the fall of 2015. An additional proposal to remove/reconstruct Ellsworth dam on the North Fork Vermilion was created as well for the fall of 2014. The Vermilion river basin is 1,485 square miles with three tributaries, the Salt Fork, Middle Fork and North Fork (IDNR, 2000). The North Fork tributary is a total of 48.2 miles and drainage of 292 square miles (IDNR, 2000). There is an impoundment approximately 0.53 miles upstream, Ellsworth Dam, from the confluence. The Vermilion River drains into the Wabash River near Cayuga, Indiana with an impoundment (Danville Dam) 22 miles upstream of the confluence (IDNR, 2000; Thomas, 2012).

Site Description

To assess the impacts of removing the Ellsworth and Danville dams on the aquatic biota and stream habitat quality a three phase project was initiated. Beginning October 2012, assessment of the fish and macroinvertebrate assemblages in twelve, 100 meter long sections of river began. Six of the 12 sites surveyed were located in the North Fork Vermilion six sites in the Vermilion River (Figure 2.1). Each dam consisted of two sites below the dam and four sites above the dam. The above dam sites consisted of locations directly above the dam, the last 100 meters of the pool, the first 100 meters of the river and an upstream site (the farthest accessible
upstream location). This sampling captures the community composition both above and below the dam (immediate impacts) and characteristics of sites above the dam’s influence.

**Fish Sampling**

A multiple gear approach for fish sampling was used to maintain capture efficiency across the system. Ellsworth Dam sites used DC barge shocking with a 2,500 watt generator and a five person crew (three probe/netters and two extra netters). Each site was electrofished for a total of 30 minutes moving upstream. Reflecting the larger nature of the Vermilion River, Danville Dam sites were sampled using DC boat shocking with a 4,000 watt generator with two Wisconsin droppers for a total of 30 minutes across the entire area. Two seine pulls were conducted for all Danville Dam sites at the nearest sandbar to ensure collection of smaller fish the DC boat shocking may have missed. Cyprinids and fish less than 100 mm were euthanized and preserved in 10% formalin solution for identification in the laboratory.

**Macroinvertebrate and Habitat Sampling**

Water conditions were collected using an YSI Professional Plus (YSI Incorporated, Yellow Springs, OH) at all sites during all sampling periods measuring temperature (°C), dissolved oxygen (mg/L), pH and conductivity. Water samples were also collected at each location (river, pool, below dam) seasonally and brought back to the laboratory to measure suspended solids, dissolved solids, nitrogen, phosphorus and ammonia. Preliminary analyses showed little variation among sites, so these measures were dropped from all subsequent analyses. Velocity was recorded at each site, taking the average of six measurements, thalweg of start, middle, and end of each site.
Habitat quality and macroinvertebrate communities were assessed at all wadeable sites (n = 8) using the Ohio Qualitative Habitat Evaluation Index (QHEI). A set of 20 jabs with a D-frame net was conducted based on QHEI outcome to sample habitats proportionally. Habitat assessment for the upper Danville Dam sites was done using a modified QHEI. Macroinvertebrate sampling for these sites included a random set of 20 samples collected as the sites are non-wadeable. To ensure consistency, seven random jabs (D-frame net) were conducted on each bank side and six ponar grabs in the main channel. All macroinvertebrate samples were preserved in 95% ethanol for identification in the laboratory. A subset of 300 macroinvertebrates was sampled using sample a splitter and identified to genus (or to family in the chironomidae).

Statistical Methods

To assess metrics of fish and macroinvertebrate assemblages between sites and rivers nested one way ANOVAs were conducted in SAS v9.3. Non-metric multidimensional scaling (NMDS) was used to determine compositional variation among sites for fish assemblages (presence/absence) and macroinvertebrate assemblages (relative abundance). Presence/absence data were used for fish assemblages due to differences in gear types between rivers and seasons as a more conservative measure of composition. Macroinvertebrate assemblages were assessed with relative abundance data as all sites were sampled equivalently. Permutational MANOVAs were conducted to statistically assess compositional differences among sites and rivers. Mantel and partial Mantel tests were used to determine mechanisms of dam impacts by relating compositional distance in macroinvertebrate or fish assemblages (Sorensen’s dissimilarity) to physical distance (river channel length) and environmental dissimilarity (based on substrate
abundance, flow, and water quality). Mantel tests, ordinations and permutational MANOVA were all conducted in PC-ORD 6 (McCune and Grace, 2002).

Results

System Quality

Habitat

The substrate of the Vermilion River below the Danville Dam (D1, D2) consisted mainly of gravel and cobble whereas upstream of the dam the substrate was highly dominated by sand (Figure 2.2a). The North Fork Vermilion had a consistently high gravel proportion both below and above the dam. Upstream of the Ellsworth pool there was an increase in cobble whereas there was only appreciable sand at the lowest below dam site (Figure 2.2b). QHEI scores ranged from 42 to 81 for both rivers. The lowest rated site was D3 with a poor rating of 42, and is the closest upstream site to the Danville Dam (Figure 2.3). The highest rated site of 81 “excellent” was the most upstream site in the North Fork Vermilion, the furthest site from the Danville dam (Figure 2.3).

Fish

A total of 10,345 fish from 62 species were collected in the Vermilion (53 species) and North Fork Vermilion (41 species) Rivers in the fall of 2012 and 2013. Of the 62 species collected, there were two state endangered and two state threatened species; threatened: Eastern Sand Darter (Ammocrypta pellucidum), River Redhorse (Moxostoma carinatum); endangered Bluebreast Darter (Etheostoma camurum), Bigeye Chub (Hybopsis amblopos). Of the 13 families collected, distribution of Catostomidae (F$_{1,5}$=12.23, P =0.002), Centrarchidae
(F_{1,3}=23.83, P<0.001,), Clupeidae (F_{1,5}=16.13 P=0.008,), and Cyprinidae (F_{1,5}=8.28, P=0.010,) varied significantly between rivers (Table 2.2). Simpson’s Diversity Index showed similar patterns within each river; highest scores immediately below each dam, followed by a decrease in the pool reach, and an increase beyond the pool (F_{11,12}=8.16, P=0.0005,) (Figure 2.4). Overall the Vermilion River exhibited higher IBI scores than the North Fork (Figure 2.5) Both rivers pool sites exhibited the lowest IBI scores in the system (F_{11,12}=13.06, P<0.001) (Figure 2.5). The index of biotic integrity scores ranged from 16.5 (restricted) to 52.5 (unique). The highest score of 52.5 was right below Danville Dam and the lowest score of 16.5 at the upper end of the North Fork pool (Figure 2.5).

**Macroinvertebrates**

A total of 7002 macroinvertebrates from 109 taxa were identified in collections from fall 2012 and fall 2013. The Vermilion River had the highest invertebrate diversity below the dam (Figure 2.6). Diversity in sites above the Danville Dam decreased and showed high variability (Figure 2.6). The North Fork had the lowest macroinvertebrate diversity downstream, just above the confluence with the Vermilion, and the highest below the dam. There was a similar decrease in diversity upstream of the dam as seen in the Vermilion River. MBI patterns showed better differentiation among systems (Figure 2.7). The best quality sites were in the Vermilion below the dam with consistent increased MBI scores upstream of the dam. Analysis of North Fork MBI scores showed the most downstream site farthest from the dam was the poorest rated site. Unlike the Vermilion, the North Fork MBI increased to a “good” rating quality in the most upstream site (Figure 2.7). The MBI scores were significantly different among locations between rivers (F_{2,5}=8.82, P=0.0021).
Community Structure

Fish

NMDS revealed compositional separation between the rivers (Figure 2.8). The Vermilion River sites below the dam and upper river sites had similar fish structure whereas Vermilion River pool sites grouped on their own based on dominance of Gizzard Shad (Dorosoma cepedianum). The separation of the North Fork sites in the NMDS was heavily dependent on Ethostoma spp., Percina spp., and Noturus spp. (Figure 2.8). Per-Manova analysis verified river, location, and their interaction to be significant factors affecting fish assemblages (River: $F_{1,18}=15.199$, $P=0.0002$. Location: $F_{2,18}=2.3694$, $P=0.006$. RxL: $F_{2,18}=3.1503$, $P=0.0032$).

Mantel tests showed there was an effect of habitat on fish community structure ($t=0.375$, $P=0.039$) but no significant effect of physical distance ($t=0.218$, $P=0.104$) on fish assemblages. This association with habitat dissimilarity was positive, indicating the more similar the physical habitat, the more similar the fish communities were. Consistent with these results, the partial Mantel test controlling for distance still showed a strong environment effect ($t=0.291$, $P=0.039$) and the partial Mantel test of distance controlling for environment was non-significant ($t=-0.001$, $P=0.500$).

Macroinvertebrates

Patterns of macroinvertebrate community structure differed from fish assemblages in these sites. NMDS resulted in three distinct groups of invertebrate composition (Figure 2.9). Sites below the dam on the Vermilion River are clustered together and had high abundances of Potamanthidae (crawling mayflies). Sites located between impoundments, except E2, were
clustered together as well (Figure 2.9). These sites had high abundances of Odonata, Chironomidae, and other Diptera. The remaining North Fork sites show high variation in macroinvertebrate assemblages. Permutational MANOVA reflected the complexity of compositional relationships; both river and the interaction of river and location were significant (River: $F_{1,18}=5.2968, P=0.002$; Location $F_{2,18}=1.6853, P=0.112$; River $\times$ Location: $F_{2,18}=3.3693, P=0.005$). Macroinvertebrate communities showed different structuring patterns than fish assemblages. Unlike the fish, macroinvertebrate assemblages were affected by distance (Mantel test: $t=0.407, P=.004$), but not by local environment ($t=0.209, P=0.089$). Partial Mantel tests controlling for environmental conditions retained distance as a significant effect ($t=0.367, P=0.010$). Partial Mantel tests when controlling for distance removed any chances of environmental effects ($t=-0.088, P=0.728$). Distance effects were positive, reflecting that the greater the separation of sites in physical distance, the greater their compositional dissimilarity.

Discussion

The Danville Dam and Ellsworth Dam are having negative impacts on habitat quality as well as affecting fish and macroinvertebrate assemblages in the system. Both dams are creating extensive pool reaches leading to a decrease in flow and habitat quality. As with other studies, higher quality sites were located outside the pool reaches (Hammer and Linke, 2003, Tiemann et al. 2004, Butler and Whal, 2010). The North Fork had a different pattern in substrate due to the confluence of the rivers. This resulted in site E1 being heavily silted, and showing pool type characteristics. This suggests the pooling effect from the Danville Dam is being extended into the North Fork. The combination of substrate types and QHEI scores illustrate the physical impact of these dams in generating an environmental gradient in habitat structure that may influence assemblage composition.
The Vermilion River had the highest IBI in sites below the dam. This is common in many impounded river systems due to the lack of efficient fish migration devices (Hammer and Linke, 2003, Nislow et al. 2011). For example, several fish species of Catostomidae and Cyprinidae were found in high abundances below the dams. In both rivers, almost 50% of the total catch occurred in the below dam sites. Removal of the dams should allow for greater abundances of these taxa to be found upstream (Burroughs et al. 2010). The combination of the IBI scores and abundances of fish enforce that these dams are acting as barriers to fish movement in the system. The existing fish ladder on the Danville Dam is highly degraded with poor flow most of the year and the Ellsworth Dam has no fish migration structure and often has no flow. Therefore, both dams effectively eliminate upstream and downstream connectivity except at high flow.

Diversity and biotic indexes of fish followed the expectation that fish should be affected by the dams as physical barriers. Analytical results of composition revealed the exact opposite. Compositionally there was strong separation between rivers and strong clustering of below dam (D1, D2) and upper river sites (D5, D6) of the Vermilion River. Vermilion below dam sites and upper river sites were similar in QHEI and had the highest flows in the Vermilion. The clustering of these sites in the NMDS reflected that fish assemblages were similar in the Vermilion based on environmental similarity. The lack of flow and lower habitat quality in the Vermilion River pool sites caused many species of fish to utilize upstream or downstream habitats (Santucci et al. 2005). Sites in the North Fork had higher variability in flow and QHEI which may result in their greater compositional dissimilarity. There were significantly fewer fish caught in the pool sites of the North Fork compared to the sites immediately below the dam and upper river sites.
Overall, the North Fork is smaller river with distinct pool, riffle, and run habitats which may directly lead to heterogeneity in fish assemblages (Pyron and Taylor, 1993).

The diversity and biotic indexes of macroinvertebrate assemblages followed the expectation that macroinvertebrates should primarily be affected by changes in habitat. Analyses of composition, as with the fish, revealed the exact opposite. However, macroinvertebrate assemblages were affected by the dams differently than the fish. For macroinvertebrates, physical distance was the main determinant of assemblage structuring, even when environmental effects were controlled for. The NMS ordination, clearly illustrates that sites were clustered based on the number of impoundments downstream. The most downstream sites were compositionally distinct from all sites above the Danville Dam. Likewise, sites above the Ellsworth Dam were compositionally distinct from all other sites above the Danville Dam, regardless of strong variation in habitat quality. This suggests that the dams are acting as physical barriers to macroinvertebrate assemblages at the larval stage. As eggs and larvae largely move with current, dispersal of macroinvertebrates should be primarily from upstream to downstream (Hersey and Lamberti, 2001). Reduced flows from each dam may effectively filter out dispersing macroinvertebrates, reducing diversity and altering composition. Environmental filtering may then reduce the ability of upstream less tolerant taxa to persist behind impoundments. Alternatively, adjacent terrestrial habitats may be controlling habitat selection by flying adults, leading to spatial heterogeneity, though this seems unlikely.

**Implications**

Overall these dams are causing significant changes in the biota of the Vermilion River and North Fork River by creating lentic habitats and reducing habitat quality. The reduction of
flow in these pools is causing high sedimentation as well as reducing the downstream transportation of different substrate types (Connolly and Brenkman, 2008). These changes in habitat types are seen though the changes in fish assemblages. There was a decrease in fish, abundance, diversity as well as a degradation of biotic integrity in the pool reaches. They are also acting as physical barriers for many fish species especially, Catostomidae which are concentrated below the Danville Dam. These dams are affecting macroinvertebrate assemblages as well by not having enough flow for larval dispersal, trapping larvae in the different impounded sections.

The Vermilion River system is one of the highest quality systems in Illinois. The removal of the dams will allow the main channel to reconnect and also provide access to upstream habitats in the North Fork tributary. Eliminating physical barriers may allow fish to move upstream allowing them to restore populations (Brenkman et al. 2008). Endangered and threatened species such as the Big Eye Chub (*Hybopsis ambloides*), Bluebreasted Darter (*Etheostoma camurum*), Eastern Sand Darter (*Ammocrypta pellucida*), and the River Red Horse (*Moxostoma carinatum*) may be able to increase their range and allow them to unite with upstream populations and increase the population size, similar to responses in sport fish in other dam removals (Kanehl et al. 1997). Removal of the dams will increase flow in the impounded areas of the river, removing sediment and nutrient loads. Returning to a free flowing system will decrease lentic biota and increase lotic biota (Bushnaw-Newton et al. 2002, Burroughs et al. 2010). The combination of these factors may increase the quality of the Vermilion River and return it to a more natural environment.
Table 2.1. Laboratory analysis of water chemistry of sites in Fall 2012. Total Nitrogen (TON), Ammonia (NH\textsubscript{4}), Total Phosphorous (TP), Soluble Reactive Phosphorous (SRP), Total Suspended Solids (TSS in ppm), Total Dissolved Solids (TDS in ppm), and Total Solids (TS in ppm).

<table>
<thead>
<tr>
<th>Site</th>
<th>Season</th>
<th>Hardness</th>
<th>TON</th>
<th>NH\textsubscript{4}</th>
<th>TP</th>
<th>SRP</th>
<th>TSS</th>
<th>TDS</th>
<th>TS</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>Fall</td>
<td>229.95</td>
<td>0.439</td>
<td>0.029</td>
<td>0.264</td>
<td>0.023</td>
<td>15</td>
<td>113</td>
<td>128</td>
</tr>
<tr>
<td>E2</td>
<td>Fall</td>
<td>229.95</td>
<td>0.439</td>
<td>0.029</td>
<td>0.264</td>
<td>0.023</td>
<td>15</td>
<td>113</td>
<td>128</td>
</tr>
<tr>
<td>E3</td>
<td>Fall</td>
<td>222.65</td>
<td>0.518</td>
<td>0.021</td>
<td>0.178</td>
<td>2.42E-05</td>
<td>31</td>
<td>94</td>
<td>125</td>
</tr>
<tr>
<td>E4</td>
<td>Fall</td>
<td>222.65</td>
<td>0.518</td>
<td>0.021</td>
<td>0.178</td>
<td>2.42E-05</td>
<td>31</td>
<td>94</td>
<td>125</td>
</tr>
<tr>
<td>E5</td>
<td>Fall</td>
<td>222.65</td>
<td>0.483</td>
<td>0.067</td>
<td>0.128</td>
<td>0</td>
<td>40</td>
<td>77</td>
<td>117</td>
</tr>
<tr>
<td>E6</td>
<td>Fall</td>
<td>222.65</td>
<td>0.483</td>
<td>0.067</td>
<td>0.128</td>
<td>0</td>
<td>40</td>
<td>77</td>
<td>117</td>
</tr>
<tr>
<td>D1</td>
<td>Fall</td>
<td>204.4</td>
<td>3.988</td>
<td>0.041</td>
<td>0.247</td>
<td>0.112</td>
<td>90</td>
<td>178</td>
<td>268</td>
</tr>
<tr>
<td>D2</td>
<td>Fall</td>
<td>204.4</td>
<td>3.988</td>
<td>0.041</td>
<td>0.247</td>
<td>0.112</td>
<td>90</td>
<td>178</td>
<td>268</td>
</tr>
<tr>
<td>D3</td>
<td>Fall</td>
<td>200.75</td>
<td>4.774</td>
<td>0.090</td>
<td>0.320</td>
<td>0.184</td>
<td>90</td>
<td>207</td>
<td>297</td>
</tr>
<tr>
<td>D4</td>
<td>Fall</td>
<td>200.75</td>
<td>4.774</td>
<td>0.090</td>
<td>0.320</td>
<td>0.184</td>
<td>90</td>
<td>207</td>
<td>297</td>
</tr>
<tr>
<td>D5</td>
<td>Fall</td>
<td>204.4</td>
<td>3.464</td>
<td>0.035</td>
<td>0.181</td>
<td>0.112</td>
<td>90</td>
<td>183</td>
<td>273</td>
</tr>
<tr>
<td>D6</td>
<td>Fall</td>
<td>204.4</td>
<td>3.464</td>
<td>0.035</td>
<td>0.181</td>
<td>0.112</td>
<td>90</td>
<td>183</td>
<td>273</td>
</tr>
<tr>
<td>Family</td>
<td>Vermilion</td>
<td></td>
<td></td>
<td>North Fork</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------</td>
<td>-----------</td>
<td>----------</td>
<td>----------</td>
<td>------------</td>
<td>----------</td>
<td>----------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Below Dam</td>
<td>Pool</td>
<td>River</td>
<td>Below Dam</td>
<td>Pool</td>
<td>River</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atherinopsidae</td>
<td>85</td>
<td>36</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catostomidae</td>
<td>390</td>
<td>69</td>
<td>180</td>
<td>7</td>
<td>1</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Centrarchidae</td>
<td>386</td>
<td>411</td>
<td>322</td>
<td>829</td>
<td>404</td>
<td>857</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clupeidae</td>
<td>117</td>
<td>40</td>
<td>152</td>
<td>31</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyprinidae</td>
<td>1838</td>
<td>490</td>
<td>1647</td>
<td>910</td>
<td>23</td>
<td>351</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Esocidae</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fundulidae</td>
<td>5</td>
<td>16</td>
<td>4</td>
<td>37</td>
<td>25</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ictaluridae</td>
<td>35</td>
<td>4</td>
<td>8</td>
<td>3</td>
<td>4</td>
<td>69</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lepisidae</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lepisosteidae</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moronidae</td>
<td>10</td>
<td>2</td>
<td>53</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percidae</td>
<td>18</td>
<td>0</td>
<td>4</td>
<td>55</td>
<td>4</td>
<td>111</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poeciliidae</td>
<td>1</td>
<td>67</td>
<td>22</td>
<td>73</td>
<td>1</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sciaenidae</td>
<td>43</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td>2929</td>
<td>1138</td>
<td>2400</td>
<td>1945</td>
<td>462</td>
<td>1471</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 2.1. Map of the Vermilion River (D) and North Fork Vermilion River (E). Sites are numbered by location; Below Dam (1,2), Pool (3,4), and River (5,6).
Figure 2.2. Distribution of substrate types across the dams in the Vermilion River (A) and North Fork Vermilion (B).
Figure 2.3. Response of QHEI Scores to the presence of dams on the Vermilion (solid) and North Fork Vermilion (dashed).
Figure 2.4. Response of Simpson’s Diversity Index of fish to the presence of dams on the Vermilion River (solid) and North Fork Vermilion (dashed).
Figure 2.5. Response of index of biotic integrity scores to the presence of dams on the Vermilion River (solid) and North Fork Vermilion (dashed).
Figure 2.6. Simpson’s Diversity Index of macroinvertebrates from the Vermilion River (solid) and North Fork Vermilion (dashed).
Figure 2.7. Macrionvertebrate Biotic Index Scores of Vermilion (solid) and North Fork Vermilion (dashed).
Figure 2.8. Non-Metric Multidimensional Scaling of fish assemblages using presence-absence data from both years pooled.
Figure 2.9. Non-Metric Multidimensional Scaling of sites based on relative abundance of Macroinvertebrates.
Figure 2.10. Average velocity (m/s) of water at sites. Vermilion (solid), North Fork (dashed).
Conclusions

Dam removal is becoming an activity to allow rivers and streams to return to their natural flow regimes, for natural sediment transportation and dispersal of riverine organisms. Both the Danville Dam and Ellsworth Dam in the Vermilion River system are causing changes in habitat quality, and influencing fish and macroinvertebrate composition. Seasonal variation in water flow can mask the effects of low head dams; therefore studies should be conducted at base flow when the impacts of dams are most distinct. At base flow reduce the habitat quality in the pool reaches of each river resulting in altered fish community structures. Unlike fish communities, macroinvertebrate community assemblages were more affected by dams as physical barriers that did not allow natural dispersal of macroinvertebrate larvae and eggs.

Both dams are approved for complete removal in the fall of 2014 (Ellsworth Dam) and fall of 2015 (Danville Dam). The removal of these dams will have an immediate impact on the river systems by increasing sediment transportation to downstream. Over time, these sediments should be dissipating allowing for natural sediment transportation to occur. Larger sediments (large gravel, cobble) will now be able to be transported into the pool sites increasing habitat quality. Overall, the removal of the dams should cause QHEI ratings to be no lower than a good status due to higher abundances of larger substrates to be transported to the pool sites. Below dam sites will also benefit from the removals over time by attaining larger substrates as well as gaining new habitat structure from debris transported downstream.

The removal of the dams will also have an impact on the water quality and flow. In fall 2013 there was a large matted algal bloom in the North Fork reaching from the dam to the first upper river site, and a diatom bloom in the Vermilion reaching from the dam into the North Fork as well up to the first river site. Such algal blooms can be dangerous to fish species in the river
by causing over saturation of oxygen in the day and hypoxia at night. These strong fluctuations in oxygen levels can be deadly to many fish species. The removal of these dams will cause pool sites to become free flowing and prevent such large algal masses.

Immediate impacts of removal may have a negative effect on fish assemblages in below dam sites. Removal will cause a high discharge of water which may displace fish. Additionally, fine sediments may fill in gravel and cobble habitats. These impacts should be temporary and as the river develops natural flow regime and the sediments are be displaced evenly downstream. The removal of the dams should allow for fish species to be able to disperse upstream. The Danville Dam removal with be most important to species such as the Red Horse. This genera of fish is the most abundant immediately below Danville Dam and in the upper river sites of the Vermilion. The removal of the dam should not only allow these two populations to connect but also allow for a greater potential habitat area when the pool reaches are removed. Furthermore, this removal should benefit the threatened species of the Vermilion River, River Redhorse \textit{(Moxostoma carinatum)}, Eastern Sand Darter \textit{(Ammocrypta pellucida)}, and the endangered Bigeye Chub \textit{(Hybopsis amblopus)}. All three of these species were found only in the below dam sites and upper river sites of the Vermilion. The removal of the Danville dam may allow for higher reproductive success of these species, increasing the stability of their populations.

Like the Danville Dam, removal of the Ellsworth Dam should alter habitat and community assemblages. Given the North Fork Vermilion is a smaller tributary to the Vermilion, removal of the dam may be more beneficial to smaller fish species. The North Fork had the highest abundances of darters and madtoms in the system. Like the Vermilion, these species were only collected immediately below the dam and in upper river sites. The removal of the dams should allow these smaller species to occupy all habitats upstream and have more
success. The site immediately below the dam in the North Fork also had the only occurrence of the endangered Bluebreasted Darter (*Etheostoma camurum*). As seen with the QHEI, there are excellent rated habitats in the upper river of the North Fork and access to these habitats has the potential to increase the success of this species.

Removal of the dams should also be beneficial to the macroinvertebrate community structure. After removal, a large sediment release from the pools may allow for new larger sediments to be transported increasing taxa quality. Over time, as lower quality substrate gets displaced from the pool sections of both rivers, higher quality taxa will utilize the new habitat and increasing MBI. The removals should also allow for natural dispersal of eggs and larvae in the system which should cause all sites to have similar assemblages and similar macroinvertebrate biotic indexes.

This study will continue to monitor the fish and macroinvertebrates in this system until the dams are removed, immediately after removal, and post removal as the rivers return to their natural flow regimes. Given the high flows in the spring which may have been displacing fish from upstream, we were not able to determine whether fish populations were genetically distinct. To further assess the potential impacts of removal, in the spring (2013, 2014) and fall (2013) multiple fish species were sampled for genetics. At each site multiple taxa were finclipped for genetic sampling. To ensure differences in life histories and dispersal capabilities a plethora of taxa were chosen. Larger species, highest dispersal, were the Black Redhorse (*Moxostoma duquesnei*), Golden Redhorse (*Moxostoma erythrurum*), River Redhorse (*Moxostoma carinatum*), Shorthead Redhorse (*Moxostoma macrolepidotum*), and Silver Redhorse (*Moxostoma anisurum*). These species have high abundances in the Vermilion River especially immediately below the dam and in the upper river sites. We also took genetic samples from our most abundant species.
which was the Longear Sunfish (*Lepomis megalotis*), and smaller cyprinids such as the Spotfin Shiner (*Notropis spiopterus*) and Steel Color Shiner (*Notropis spiopterus*). Assessing the genetics of these species can give more insight to full the influences of dams on fish populations.
Literature Cited


