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# THE INFLUENCE OF DAMS ON FISH COMMUNITIES AND ASSOCIATED HABITAT IN THE ST. JOSEPH RIVER WATERSHED, INDIANA

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**ABSTRACT**. We evaluated the influence of dams on fish communities and river habitat using data gathered on the St. Joseph River and Elkhart River in north-central Indiana from 1998 to 2016. Comparisons of Index of Biotic Integrity (IBI) and Qualitative Habitat Evaluation Index (QHEI) values above and below dams on these two rivers generally indicate moderate impairment to fish communities and habitat upstream of dams and in impounded areas of both rivers. Across all sites a comparison of mean index scores for the IBI, QHEI, and metrics within both indices indicate significantly higher quality fish communities and habitats outside of impounded areas on the St. Joseph River.

**Keywords:** Dams, fish community, IBI, QHEI, Saint Joseph River

## INTRODUCTION

The St. Joseph River in north-central Indiana, a tributary to Lake Michigan, drains 12,134 square kilometers. Along its 338 kilometer course from Hillsdale County, Michigan to its confluence at Lake Michigan, are 17 dams with an estimated 190 additional dams within the watershed as a whole (Wesley & Duffy 1999). In the Indiana section of the river, four dams remain; two active hydropower dams and two former hydropower dams.

Dams are known to have detrimental effects on the ecology of a river. They alter the physical conditions of a stream. Dams are generally constructed in high gradient areas where fish spawning habitat is often located. Fish spawning migrations and the associated movement of native mussel species upstream are blocked because of dams (Eads et al. 2015). Fish communities are separated and populations become isolated, thus limiting genetic dispersal and diversity (Zhao et al. 2016). Lentic conditions upstream of a dam reduce flow, causing a buildup of fine sediment and a change in river habitat. Downstream of a dam, streams are starved of sediment resulting in loss of habitat and negative impacts to stream banks and floodplains (Marren et al. 2014). Chemical changes also occur, often resulting in low dissolved oxygen concentrations above dams, limiting the streams ability to support aquatic life (Santucci et al. 2005).

Biological community monitoring is generally performed to evaluate the health of a stream due to impacts from pollution or immediate habitat destruction (Karr et al. 1986). In an effort to understand effects of dams on St. Joseph River Watershed fish communities, we compared fish community structure and habitat conditions above and below dams on the St. Joseph and Elkhart Rivers in Elkhart and St. Joseph Counties, Indiana.

## METHODS

Fish community data collected from the period 1998 to 2016 by the City of Elkhart Public Works and Utilities during routine fish surveys in the Saint Joseph River Watershed were analyzed. These data were from 23 stations on the St. Joseph River and nine stations on the Elkhart River. Fish communities were sampled annually at each station for three consecutive years, with follow up sampling events on a three year rotational basis. All stations were sampled twice during spring and summer months in a given year to account for seasonal variation in fish community assemblages. Fish were collected using a pulsed-DC boat mounted electrofishing unit, with a current output range of 12 to 16 amps, a voltage range of zero to 500 volts, and a pulse frequency setting of 120 pulses per second. All available

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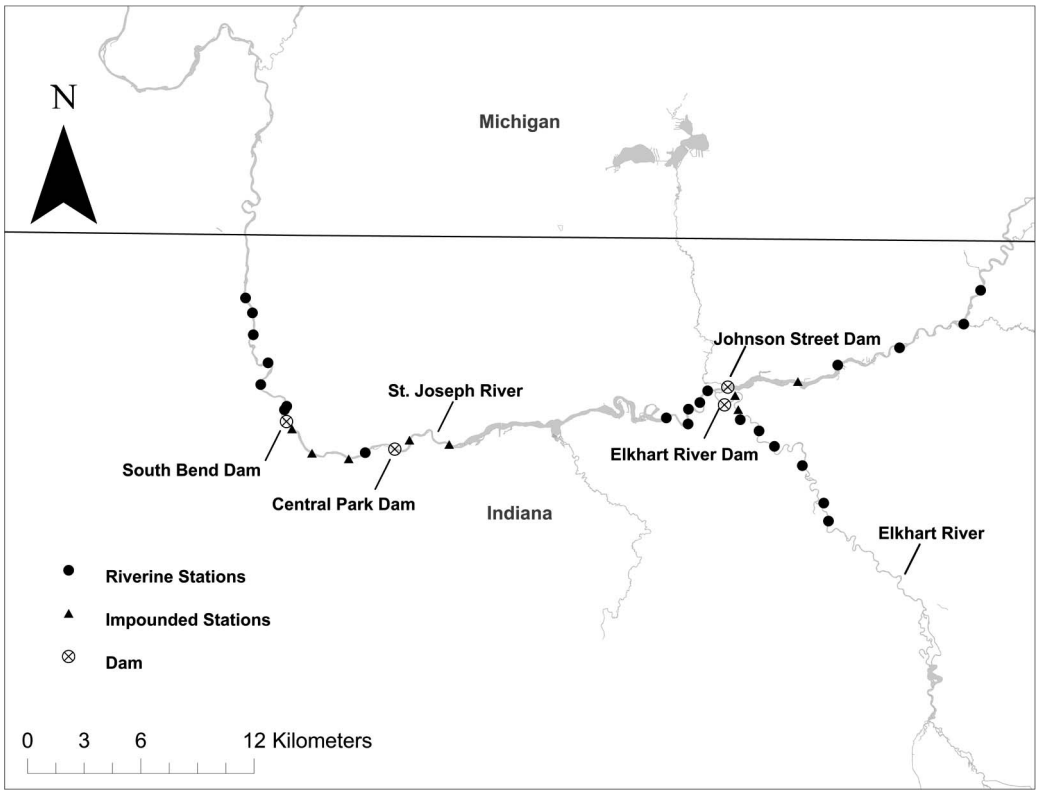


Figure 1.—A Map of the St. Joseph and Elkhart Rivers in Elkhart and St. Joseph Counties, showing dam locations and stations sampled from 1998–2016.

habitat types within a 500 m section of river were sampled at each station.

Fish communities were evaluated using the Index of Biotic Integrity (IBI) (Karr 1981) calibrated for use in warm water streams of the Northern Indiana Till Plain (Simon 1997). Habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) (Rankin 1989) following fish community surveys. Data analysis focused on sampling stations above and below three major dams on the St. Joseph River (Fig. 1): the Johnson Street Dam in Elkhart, the Central Park Dam in Mishawaka, and the South Bend Dam in South Bend. A general evaluation of IBI scores from stations above one low head dam on the Elkhart River in Elkhart was also performed (Fig. 1).

General comparisons of riverine versus impounded stations were made by averaging IBI and QHEI scores from all sampling events at a given station. Mean individual metric scores from the IBI and QHEI also were calculated. For the QHEI, individual metrics included substrate, cover, channel, riparian, riffle, and pool metrics. For the IBI, the individual metrics included number of species (species richness), total fish abundance, and % of lithophilic spawner metrics. Simple lithophilic spawners are species that require clean gravel or cobble for reproduction habitat. Statistical analyses used SigmaPlot ® software, Systat Software, Inc., San Jose, California, USA. Two sample T-tests were used to compare means of variables with the exception of channel and riparian metrics of the QHEI, and the total abundance of fish. The Mann-Whitney, non-parametric rank sum test (U-test) was used to compare the channel, riparian, and total fish abundance metrics given that variances between groups were not equal. To account for possible type I errors with multiple tests, significance levels were adjusted to 0.005 using the Bonferroni correction.

## RESULTS

**South Bend Dam**.—Mean IBI scores were lower at stations in the impoundment of the

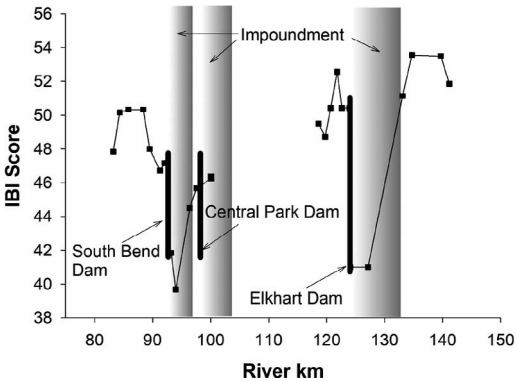


Figure 2.—Longitudinal depiction of mean IBI scores for stations along the St. Joseph River. Black dots represent sampling stations. Impounded areas are shaded. IBI scores may range from 12 to 60. All mean values are above 36 indicating that no stations are considered "impaired" (Simon 1997).

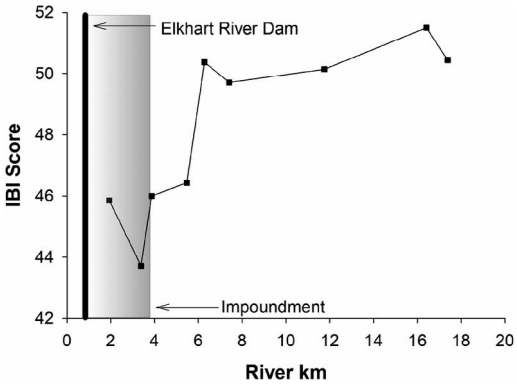


Figure 3.—Longitudinal depiction of mean IBI scores for stations along the Elkhart River. Black dots represent sampling stations. Impounded areas are shaded. IBI scores may range from 12 to 60. All mean values are above 36 indicating that no stations are considered "impaired" (Simon 1997).

South Bend Dam than those downstream of the South Bend Dam (Fig. 2). A mean IBI score of 41 occurred at the station directly above the South Bend dam. At the next station, approximately 0.8 km upstream, the mean IBI score was lower at 39. Scores increased upstream with respective mean IBI scores of 44.5 and 45.7 at river km stations 96.4 and 97.5. At the station immediately below the South Bend Dam, the mean IBI score was 47.1. At the next station, approximately 0.8 km downstream, the mean IBI score was slightly lower at 46.7. However, the mean IBI scores increased to 50 farther downstream of the dam.

**Central Park Dam**.—IBI scores above and below the Central Park Dam were relatively similar. The station downstream of the dam at river km 97.5 had a mean IBI score of 45.7, while the station above the dam had an IBI score of 46.7. The IBI score dropped slightly at the second most upstream station above the dam to 46.2. The station below the Central Park Dam is located just on the upstream edge of the impoundment caused by the South Bend Dam.

**Johnson Street Dam**.—Mean IBI scores around the Johnson Street Dam resulted in a similar pattern as the South Bend Dam (Fig. 2). The mean IBI score at the station immediately above the dam was 41, lower than the score of 50 at the station immediately below the dam. At the next station above the Johnson Street Dam, which is upstream of the impoundment, the mean IBI score was higher at 51. Mean IBI scores increased with upstream distance from the Johnson Street impoundment. Below the dam, the mean IBI score increased to 52.6 at river km 122, but decreased below 50 farther downstream.

**Elkhart River Dam**.—The Elkhart River dam is approximately 0.8 km upstream of the St. Joseph River confluence, thus no sampling stations were located below the dam. However, upstream of the dam, our results had similar IBI trends as above the South Bend Dam and the Johnson Street Dam (Fig. 3). At the station immediately upstream of the dam, the mean IBI score was 46, dropped slightly to 44 at the next most upstream station, and increased to 46 at the third station upstream of the dam. This third station was located just upstream of the impoundment. Further upstream, with distance from the impoundment, the mean IBI scores were nearly 50.

**Comparison of Indices**.—A general comparison of several parameters, including the number of fish species, IBI scores, QHEI scores, and individual QHEI metrics, revealed significant differences in fish community and habitat integrity in impounded versus riverine sections of the St. Joseph River (Table 1, Fig. 4). Values were significantly lower for most parameters in impounded sections of the river with the exception of the riparian, cover, and pool metrics in the QHEI and total fish abundance (Table 1, Fig. 5).

Table 1.—Fish community and habitat parameters for stations above and below dams on the St. Joseph River (1998 to 2016). Mean values are presented for all parameters except for channel and riffle/run metrics of the QHEI and for total abundance, which are presented as median values. Significance was determined at *P* values less than 0.005.

| | Impounded stations | (n=6) Std. dev. | SEM | Riverine stations | (n=17) Std. dev. | SEM | *t or u value* | *P value* |
|---|---|---|---|---|---|---|---|---|
| # of Species | 21.30 | 1.59 | 0.65 | 25.60 | 2.75 | 0.67 | t 4.343 | 0.002 |
| Total Abundance | 508 | (median) | | 461 | (median) | | u 33.00 | 0.220 |
| % Simple Lithophils | 11.75 | 5.51 | 2.25 | 27.17 | 8.88 | 2.15 | t 3.959 | <0.001 |
| IBI | 43.30 | 2.90 | 1.20 | 49.90 | 2.30 | 0.56 | t 5.603 | <0.001 |
| QHEI | 61.10 | 3.30 | 1.40 | 74.30 | 5.10 | 1.20 | t 5.876 | <0.001 |
| QHEI Metrics | | | | | | | | |
| Substrate | 11.12 | 1.99 | 0.81 | 14.81 | 1.50 | 0.36 | t 3.691 | <0.001 |
| Cover | 12.24 | 1.20 | 0.50 | 13.44 | 1.20 | 0.29 | t 0.209 | 0.049 |
| Channel | 12.40 | (median) | | 15.15 | (median) | | u 3.000 | <0.001 |
| Riparian | 5.64 | 0.89 | 0.36 | 6.65 | 1.35 | 0.30 | t 1.707 | 0.103 |
| Riffle/Run | 0.98 | (median) | | 4.71 | (median) | | u 0.000 | <0.001 |
| Pool/Glide | 8.89 | 0.29 | 0.12 | 9.58 | 0.50 | 0.13 | t 2.990 | 0.007 |

The mean species richness at stations in the impounded areas of the St. Joseph River was 21.3. At riverine stations, the mean species richness was 25.6. IBI scores averaged 43.3 at impounded stations versus 49.9 at riverine stations. Median fish abundance at riverine stations (508) was higher than impounded stations (461), however, the difference was not statistically significant (Table 1). Mean total fish abundance was highly variable among the riverine stations ranging from 354 to 952. Mean total fish abundance at impounded stations was not as variable, ranging from 327 to 532. Several impounded stations had higher mean total abundance than several riverine stations. The mean % of simple lithophils collected at each station was significantly higher at riverine stations (27.2) than at impounded stations (11.8) (Table 1).

Average QHEI scores were very low at impounded stations (61.1) relative to riverine stations (74.3) (Table 1). The highest variation in individual QHEI metrics was for the riffle metric (Table 1). For impounded stations, the mean riffle QHEI score was 0.98, while the riverine stations had a mean score of 4.71 (Table 1). Mean riparian, cover, and pool QHEI metric scores were similar for the impounded stations and riverine stations (Table 1).

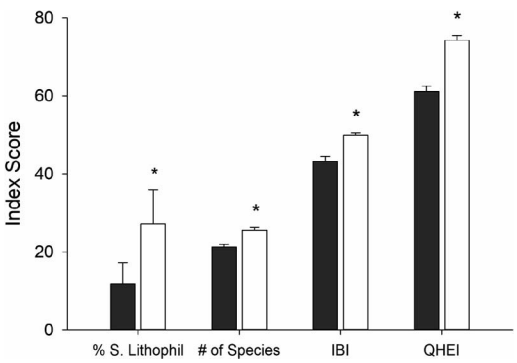


Figure 4.—Percent simple lithophils, number of species, IBI scores, and QHEI scores for stations on the St. Joseph River. Dark bars represent values for stations in impounded areas, while white bars represent values for stations in riverine areas. Data are means ± SEM. Asterisks denote a significantly higher value.

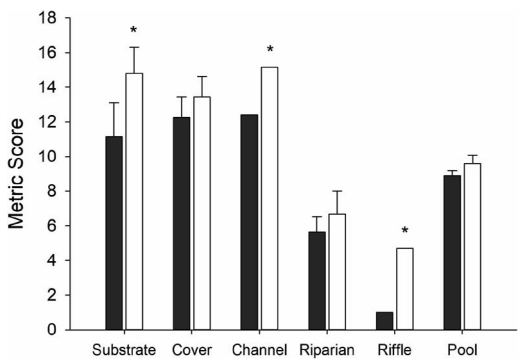


Figure 5.—QHEI metric scores for stations on the St. Joseph River. Dark bars represent mean values for stations in impounded areas, while white bars represent mean values for stations in riverine areas. Channel and riffle metric data are medians. Substrate, cover, riparian and pool data are means ± SEM. Asterisks denote a significantly higher value.

## DISCUSSION

Species richness is a parameter that demonstrates the negative effects of dams (Agostinho et al. 2008; Gardner et al. 2011; Liermann et al. 2012; Yun-zhi et al. 2013; Magilligan et al. 2016). Similar to these studies, we found that mean species richness was significantly higher in riverine sections of the St. Joseph River. Our QHEI scores and QHEI metrics suggest that fish community integrity is linked to habitat variation, which is limited in impounded sections of the St. Joseph River. While poor habitat may contribute to decreased species richness above a dam, the presence of a dam as a barrier can inflate species diversity and abundance on the downstream side of the dam (Dodd et al. 2003). Gardner et al. (2011) found that fish species richness and abundance decreased significantly at the downstream site following dam removal on the Sedgeunkedunk in Maine, USA. Catalano et al. (2007) reported similar findings on the Bamboo River, Wisconsin, USA following dam removals, but also found that species richness recovered to pre-removal levels after two years at two dam removal sites. The presence of dams on the St. Joseph River undoubtedly interferes with the natural migration of fish species and may inflate species richness below the dams. However, the lack of suitable habitat above the dam also limits species richness. We observed a reduced number of species with limited habitat variability. For example, substrate scores (QHEI metric) were significantly lower in impounded areas, corresponding with a significantly lower abundance of simple lithophilic spawners that require high quality coarse substrate for reproduction.

Our study found that fish abundance did not differ significantly in impounded versus riverine sections of the St. Joseph River. These findings are not consistent with other studies. Santucci et al. (2005) found significantly higher fish abundance in free flowing sections of the Fox River, Illinois, than in impounded areas. Yun-zhi et al. (2013) also reported that fish abundance was lower in impoundments caused by lowhead dams. We found that mean total abundance of fish in riverine stations varied significantly among riverine stations with the lowest of 354 at a station below the South Bend dam and the highest at 952 below the Johnson Street Dam. Beyond the presence of dams, it is likely that other factors, such as pollutants from point and non-point sources, urban habitat disturbance, and unsteady stream discharge may have influenced the fish communities in the St. Joseph River (Deegan 2012). Baldwin et al. (2016) found several organic compounds in the St. Joseph River at levels with the potential to cause adverse effects on aquatic organisms.

Several impounded stations also had higher mean total abundance than several riverine stations; the highest mean total abundance for an impounded station was 532, which was 178 more than mean total abundance at a riverine station below the South Bend Dam. Agostinho et al. (2008) suggested that the upper third of a reservoir can have high relative abundance due to an increase in primary productivity in the transitional area between the impoundment and free flowing river. We speculate that impoundment to riverine transitional areas may have inflated IBI scores and IBI metrics given the presence of both lentic and lotic factors and the associated increase in habitat diversity.

Mean IBI and QHEI scores demonstrated significantly lower fish community integrity and habitat in impounded sections of the St. Joseph River. IBI scores on the Elkhart River also increased upstream of the Elkhart River dam impoundment. Santucci et al. (2005) recorded significantly higher IBI and QHEI scores in fish communities in free flowing sections of the Fox River, Illinois, USA than those in impounded sections. In the riverine sections of the St. Joseph River, substrate diversity and quality was superior, contributing to higher QHEI scores. The channel metric of the QHEI was also significantly lower in the impounded sections of the St. Joseph River, a result of floodplains being underwater, decreased sinuosity, and a decrease in the quality and quantity of pool, riffle, and run complexes.

Mean IBI scores in the Mishawaka section of the St. Joseph River, where riverine habitat is most limited, were inconsistent with our findings for the others sections of the St. Joseph River. At the Central Park Dam, the mean IBI score above the dam is slightly higher than the score below the dam. Within 2 km downstream of the Central Park dam, the river transitions into the impoundment caused by the South Bend Dam. The Central Park Dam also creates an impoundment that is approximately 5 km long and extends upstream to another St. Joseph River dam. Rolls et al. (2013) suggested that there is a spatial complexity on rivers with several dams, with interacting effects from fragmentation and altered habitat. With impoundment influences upstream and down-

 

stream of the Central Park Dam, it is likely that there are negative interacting effects of multiple dams on the fish communities present.

The riparian QHEI metric was one QHEI parameter that did not differ significantly between riverine and impounded stations. The predominate land use surrounding the St. Joseph River in northern Indiana is urban, with heavy urban land use in the downtown areas of South Bend, Mishawaka, and Elkhart, and residential land use on the river segments between these cities. The three main St. Joseph River dams in this study are located in the downtown areas of each city with significant urban impacts to the riparian zones on the upstream and downstream side of each dam.

Given the above dam versus below dam data, the negative influence of dams on the St. Joseph River are apparent. Within the context of the South Bend-Mishawaka-Elkhart municipal area, however, we acknowledge additional influences beyond the presence of dams. Other major influences include non-point sources of pollution, urban habitat disturbance, and unsteady stream discharge. The spatial complexity associated with the presence of multiple dams likely has interacting effects on fish communities in the St. Joseph River, particularly in the Mishawaka section of the St. Joseph River.

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