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Bria Spalding

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PAINTED TURTLE (*CHRYSEMYS PICTA*) HOME RANGE AND HABITAT USE IN A DAM IMPOUNDMENT

By

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Abstract:

Habitat fragmentation, including damming rivers, is a major threat to species conservation in urban areas causing reduced dispersal and biodiversity. Dam removal is typically beneficial to many species because dams restrict the movement of many organisms. However, the dam removal may negatively impact some species. The purpose of our study was to assess the potential effects that the removal of the Peninsular Paper Dam (Huron River, Ypsilanti) may have on painted turtles (*Chrysemys picta*) by monitoring their habitat use prior to dam removal. *Chrysemys picta* is a native species abundant in lentic systems (ponds and lakes) with muddy substrates, conditions found in the currently impounded area. Following dam removal, much of this habitat is likely to change dramatically to a rocky, fast-flowing river system that is less conducive to supporting *Chrysemys picta*. We tracked eight female turtles daily over the summer of 2019 using radio-telemetry. Using GPS location data and predicted river flow following dam removal, we found most of aquatic habitat currently used by *C. picta*, including overwintering sites, will disappear. Our results suggest that the future river may not be optimal *C. picta* habitat following the dam removal, and therefore this species should be actively managed throughout the dam removal process.

Introduction:

Habitat fragmentation exposes animals to potentially detrimental changes in their environment, such as reduction of juvenile dispersal ability (Cushman 2006), species richness (Rubio et al. 2014), and population size (Fahrig and Rytwinski 2009). For example, animals are forced to adapt their behavior to account for buildings and other types of development and traverse roads during dispersal and migration, which is dangerous. In terrestrial ecosystems, fragmentation occurs through deforestation, agriculture, urbanization, suburban sprawl, and road construction. A reduction in population size due to fragmentation leads to population isolation and therefore reduced genetic variability (Jaenike 1973). Fragmentation also leads to behavioral changes. Given the choice, mobile species such as small mammals will often select non-fragmented habitats (Foster and Gaines 1991). For example, Blandings turtles, *Emydoidea blandingii,* have larger home- ranges in less fragmented habitats due to the ability to move around more in unfragmented areas (Grgurovic and Sievert 2005). Similarly, Eastern box turtles also reduce their movements in more isolated areas (Iglay et al. 2007).

Dams have a number of negative ecological impacts. They are an important contributor to habitat fragmentation for riverine species. There are over 80,000 dams in the U.S. (Lieb 2015) used for flood prevention, navigation, and irrigation. Of the approximately 2,500 dams in Michigan, 93% of them are over 25 years old (Public Sector Consultants 2007). The habitat fragmentation caused by dams can cause many large-scale effects for species. Dams also alter habitats by changes in flow regime, thermal regime, water chemistry, and sedimentation (McCartney 2009). Habitat destruction and degradation resulting from dams has been linked to local and global extinction of freshwater invertebrates (Strayer 2006). Dams can also negatively affect populations and individuals (Mbaka and Wanjiru Mwaniki 2015, Fan et al. 2015). For example, dam-separated fish populations showed morphological differences in body size and shape, indicating the populations are substantially isolated (Radojković et al. 2018). Damming can also cause behavioral changes that could lead to limited species distribution, decreased population success, lowered biodiversity, limited adaptation ability, and lowered completive ability (Sih et al. 2012). Reptile species tend to avoid dams causing increased population density because the species have less room to spread out (Hunt et al. 2013).

While many species face negative effects relating to damming, some species are benefitted or unaffected by the flow associated with damming. A study on Western pond turtles, *Clemmys marmorata*, found little evidence that dams affected population density (Reese and Welsh 1997). The migration of short-nosed sturgeon (*Acipenser brevirostrum*) was assisted by the flow caused by a dam (Richter and Thomas 2007). These studies show that damming can have negative impacts on some species while being neutral for or even greatly benefiting another. These studies are important to determine whether native or endangered species are at risk.

With dams lasting only an average of 50 years, many dams will need to be removed or replaced in the coming years. There has been an exponential growth in dam removals over the past 20 years (Bellmore et al. 2017). While positive impacts of dam removals on native species, particularly lotic fish populations (Catalano et al. 2007), have been documented, there is a need for more research. Of the 1,200 dams removed in the US, less than 10% have been scientifically evaluated (Bellmore et al. 2017). It is important to study species before dam removal to understand if they are positively or negatively impacted by removal.

There is little to no research on the effects of dams on *Chrysemys picta*, the painted turtle, despite this being the most common turtle species in North America and a potential surrogate for native turtle species. Four out of the ten native turtle species in Michigan are listed as threatened or species of special concern (DNR 2020). *Chrysemys picta* is a medium sized turtle that can reach a length of 6 inches (Conant and Collins 1998). It is native to Michigan and prefer slow, stagnant water to open rivers (Anderson et al. 2002). *Chrysemys picta* overwinter underwater to prevent from freezing above water and uptake oxygen from the surrounding water (Ultsch 2006). Their home ranges, like many other turtles, increase with mass (Slavenko et al. 2016). Damming could cause a change in any aspect of painter turtle behavior and life history. Although they may avoid crossing dams (Marchand et al. 2019), we do not know how they respond to the habitat modification and fragmentation created by damming a river.

The goal of this study was to examine the behavior and habitat use of *C. picta* in the region of the Peninsular Dam on the Huron River in Ypsilanti, MI. With the dam targeted for removal in the next several years, this study will provide important baseline data for a similar post- removal study that will further our knowledge of the costs and benefits of removing dams. We hypothesized that dam removal will have some negative impacts on this species, due to the loss of current habitat and predicted increase in the speed of the river flow. This hypothesis lead to three predictions. First, we predicted that *C. picta* would be found in the portion of the river that that will disappear after dam removal more often than in the predicted river following dam removal. Second, we predicted that the temporal home ranges, as well as the complete summer home ranges, would increase in size as turtle size increases. Finally, we predicted the overwintering locations for each turtle would be near the edge of the river. To test our hypothesis, we tracked the individuals in the impounded portion of the river to gather baseline data on habitat use and home range size. The study was conducted in the area that will be the most affected by dam removal. These data will give us the opportunity to compare the currently used habitat to what we expect to be available following dam removal.

Methods

Study Site:

Figure 1: Peninsular Paper dam located in Ypsilanti, MI.

Field surveys of turtle populations were conducted in Ypsilanti, MI on the Huron River between Superior Rd and Leforge Rd. in the impoundment of the Peninsular Paper dam (Figure 1). This 16 foot dam was built in 1914 and operated as a hydropower dam until 1970 when it was retired (Princeton Hydro 2018). On Tuesday, May 7th 2019, Ypsilanti City Council voted to remove the dam in the future (Slagter 2019); however, the timeline is uncertain as additional funding needs to be obtained.

<u>Turtle Trapping:</u>

In order to track behaviors of *C. picta*, we trapped turtles and attached a transmitter to each. Eight individuals were caught from the impoundment of the river using baited mesh hoop traps, nets, or by hand. We set baited traps using fish-based wet cat food and checked them within 24 hours, being sure to leave several inches of the trap above water so turtles could breathe. After an individual was captured, we recorded sex, mass, carapace (upper shell) length, and any distinguishing features. We also notched the turtles' shells using a 3mm triangular file to help with individual identification (Nagle, *et. al.* 2017). To further assist in identification, we took two photographs of each individual, one of the carapace and one of the plastron (lower shell). Lastly, we attached an ATS transmitter to the carapace using PC7 epoxy putty and thin wire (Figure 2). We ensured the device was less than 5% of their body mass, following recommended protocols of the manufacturer. This work was approved by the EMU Institutional Animal Care and Use Committee (IACUC permit number 2019-093).

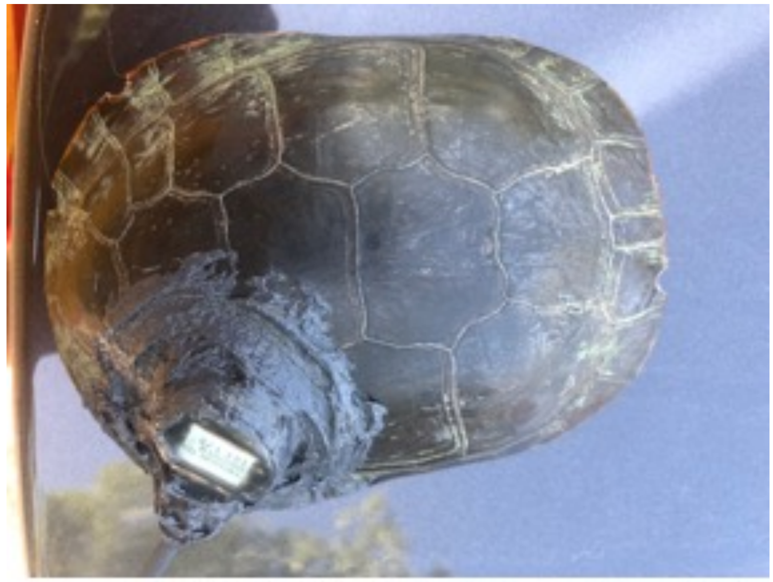

Figure 2: Turtle 151.172, AVX, with transmitter affixed.

In order to determine a turtle's location, we canoed the river until our portable receiver displayed the highest signal for the specific turtle's frequency. To determine the highest signal, we lowered the gain as we got closer to get the most accurate location. When we were confident in our location, we recorded locations, behaviors, and habitat data for individuals. We tracked our individuals between May and September 2019, for a total of 49 days. During the summer months, turtles were tracked nearly daily.

<u>Habitat Use:</u>

To predict the impact the undammed future river may have on turtle behavior, we compared their habitat use in the current river to the predicted river path after dam removal. First, we first created shapefiles for both the existing impoundment and undammed river paths. We used ArcGIS to create a polygon using heads-up digitizing to trace the shape of the Huron River on the base map. This gave us the entire area of the current river. In order to create the predicted river, we used the images provided by the HRWC Feasibility study (Princeton Hydro 2018), and georeferenced them to the base map. Georeferencing is important to make sure the dimensions and proportions are precise. To visualize if the current locations the turtles are found in will be in the predicted river after dam removal, we used our two river polygons and our turtle locations. This allowed us to count the number of turtle locality points found inside versus outside of the predicted river for each individual.

We calculated the amount of area each turtle used inside and outside of the predicted river. We used the 100% Minimum Convex Polygon (MCP) as a measure of the home range for each turtle. The MCP is a polygon of the entire area a specific turtle used over the specified time range. In order to create this, we used a minimum convex hull to create a minimum bounding polygon around the location points. Due to the aquatic lifestyle of these turtles, we then clipped the land area found within the MCP to give us a more accurate representation of their habitat use. In order to determine the amount of area in the predicted river used by each turtle, we clipped the area found both in the 100% MCP and the predicted river (Figure 3). This provided a separate polygon, to serve as the turtle's home ranger, that we could use to calculate area.

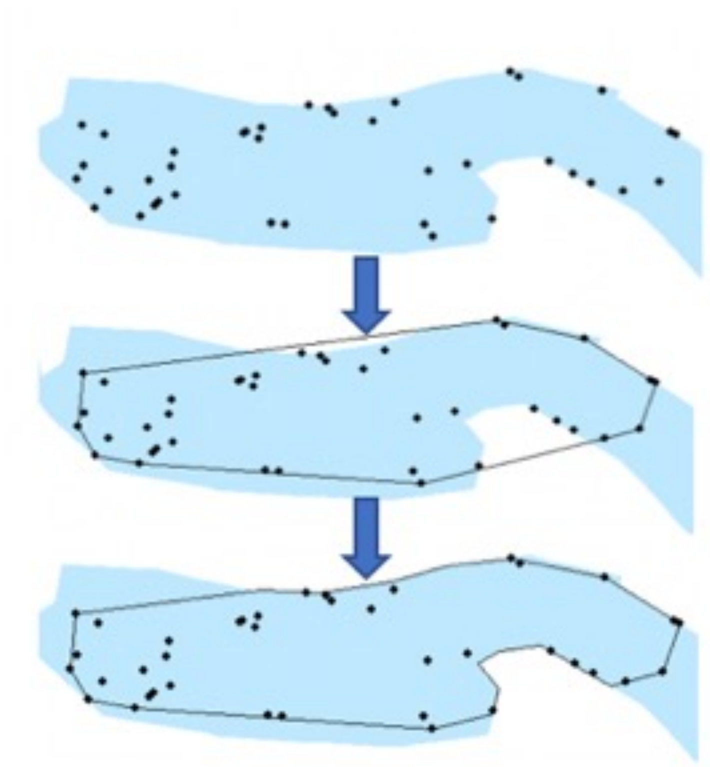

Figure 3:Process of 100% Minimum Convex Polygon, MCP, construction in ArcGIS utilizing the convex hull function in the first step and clip function in the second step.

We analyzed changes in home range size over the study period and overwintering habits. To assess temporal changes in home range size, we divided the location data for each individual into four subperiods: first half of July, last half of July, first half of August, and last half of August. We then used these data to construct home ranges for each subperiod for subsequent statistical analysis. Finally, we overlaid the winter location data for all the turtles on the existing and predicted river.

Statistical Analyses:

To determine whether turtles spent more or less time in the predicted or existing river, we ran two-tailed t-tests on the location points that fell in and out of the predicted river, as well as area in and out of the predicted river. We used a least squares regression with the factors of mass, subperiod, and their interaction to determine if there was a significant relationship between turtle mass and the subperiod home ranges for these turtles.

Results

After their initial processing and release, we typically found each turtle on each tracking day; however, some days we were not able to find all turtles eight turtles due to transmitter interference or weather restrictions. Out of the 49 days of tracking, the turtle notched with the code ACU was found 33 times between the dates of 6/30/19 and 11/4/19. Turtle AUV was found 45 times between the dates of 6/27/19 and 11/4/19. Turtle AUW was found 48 times between the dates of 6/27/19 and 11/4/19. Turtle AVW was found 28 times between the dates of 7/8/19 and 11/4/19. Turtles AVX was found 35 times between the dates of 7/12/19 and 11/4/19. Turtle AVY was found 37 times between the dates of 7/14/19 and 11/4/19. Turtle AWX was found 33 times between the dates of 7/14/19 and 11/4/19. Turtle AWY was found 32 times between the dates of 7/21/19 and 11/4/19.

Table 1: 100% Minimum Convex Polygons, home ranges, for turtles (n=8). The average and standard deviation, Std Dev, is given below

Turtle ID	100% MCP (m^2)
AUW	74626
AUV	115254
ACU	95530
AVY	95407
AVX	94985
AUY	42689
AWX	69149
AVW	120931
Average	88571
Std Dev	25557

Home ranges based on the location points of each turtle ranged from 42,689 m^2 to 120,931 m^2 (Table 1). The total area of the existing river polygon was 206,358 m^2. The total area of the predicted river polygon was reduced by 72% to 57,454 meters squared.

Individuals were found out of the predicted river more than 5 times more often than they were found within the predicted river ($P<0.005$; Figure 4), indicating that dam removal will greatly reduce the available turtle habitat. The area of an individual's home range in the predicted river was 59% less than the mean area outside of the predicted river (25,718 m^2 vs, 62,853 m^2; $P<0.005$). With the exception of the first subperiod, the size of home ranges increased with the size of turtles (Figure 5; $p < 0.005$). None of the turtles' overwintering sites fall within the predicted river (Figure 6).

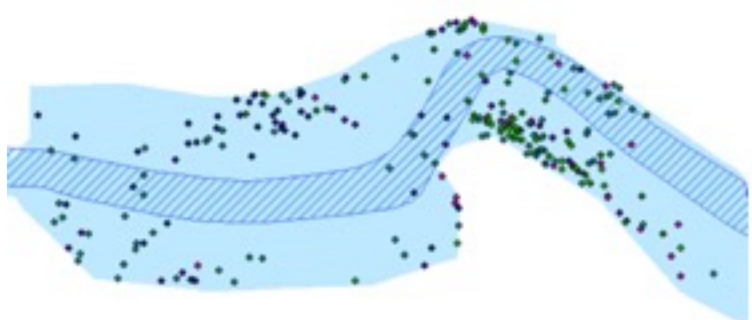

Figure 4: Turtle summer location data in relation to the predicted river (striped) and existing river (solid).

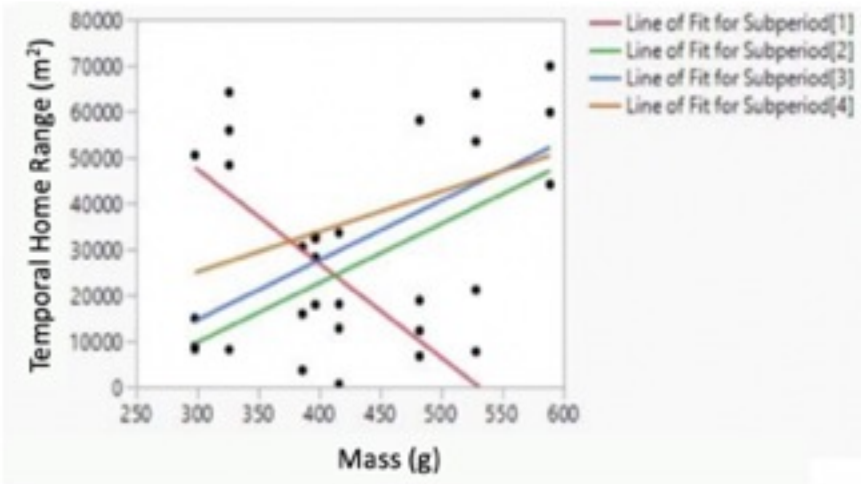

Figure 5:Least Squares Regression plot of Temporal Home Ranges v. Mass over 4 subperiods.

Figure 6: Winter data for all turtles (in black) and the predicted river(striped polygon).

Discussion

While dam removal often has positive ecological outcomes by improving habitat for many species and overall biodiversity, some species may be negatively impacted. Our findings supported the hypothesis that *C. picta* could be negatively impacted by the removal of the Peninsular Paper Dam, due to the predicted loss of currently used habitat. Our three predictions, that much of their current habitat would not be in the predicted river, that home range size would increase with turtle size, and that overwintering sites would fall close to shore, were all at least partially supported. These findings suggest the need for specific management strategies for these turtles when dam removal occurs. Since dam removal will likely result in a loss of habitat for these turtles, potential relocation, seasonal consideration, or strict management of the species during the process may be necessary.

Dam removal leads to changes in river flow and shape, which can lead to a loss of habitat. Our first prediction that much of the current habitat used by individuals would not be found in the predicted river was supported. This prediction was supported by the minimal number of *C. picta* recorded in the existing river. If the river shifts to its predicted shape following dam removal, these native turtles will be forced to shift their home ranges to account for the loss of aquatic habitat in their current habitat. Another possibility is that they may need to travel longer distances. Changes in behavior due to dam removal have been found in other turtle species. *Chelodina longicollis* living in impounded areas were tracked for a year and altered their behavior by travelling longer distances compared to individuals living in free-flowing areas (Rees et al. 2009). Whether or not *C. picta* will be able to disperse to suitable habitat following dam removal could be studied post dam removal. By tracking the summer after dam removal, we could determine if there is a shift or increase in home ranges.

Larger turtles tend to have larger home ranges, but there is little research about the impact of damming on this relationship. Our second prediction that home range size would increase with turtle size was partially supported. This hypothesis was supported for each temporal subperiod except for the first subperiod. Further research would be required to determine the cause of this relationship. It is possible that this smaller home range early in the summer has to do with the nesting behavior of females during the first subperiod this time. *Chrysemys picta* nest up until early July (Morjan 2003). We found a significant positive relationship between overall summer home range size and turtle mass, with an increase in mass of 100g there is approximately a home range increase of 8,000 square meters. This is similar to other studies that have found turtle home range size increased with mass (Slavenko et al. 2016), although that study did not look at the temporal aspect of home ranges as we did in our study. Further long-term research would also be required to see if this trend remains over many years.

Loss of overwintering sites due to dam removal could be the strongest negative impact of dam removal on native turtles. Our final prediction that overwintering sites would fall close to shore and, therefore, be lost when the dam is removed was supported. However, a major finding was that each of the eight turtles overwintered in nearly the same location. If the dam were removed during the winter, turtles would be in danger of freezing. The importance of overwintering habitat has been described in other studies such as hatchling *C. picta* overwintering in shallow, subterranean locations (Packard and Packard 2001). There is little to no information on overwintering sites of adult *C. picta*. Our findings indicate that further research is needed to determine if this might be true for other native turtle species. It would also be interesting to see if their overwintering sites remain clustered together after dam removal.

<u>Considering ecological trade-offs involved in dam removal</u>

Overall, dam removal is considered good for river health and most riverine species. For example, dam removal leads to an increased catch per unit effort in crayfish (Packard and Packard 2001), and restored flow regime due to dam removal leads to increased biotic diversity and increased fish passage (Bednarek 2001). Dam removal can also contribute to native species populations recovering (Marks et al. 2010) and increasing (Hitt et al. 2012). These positive effects are typically found over long time periods.

While dam removal is generally a positive environmental action, negative ecological impacts should also be considered. Dam removal has been noted to cause some short-term negative impacts such as sediment release (Bednarek 2001) and modification of flow regime can affect the spawning of salmon (Quiñones et al. 2015). However, these impacts are typically short-term and can be addressed with active management strategies. The loss of lentic species, such as warm water fish species (Cooper et al. 2016) and *C. picta,* could be considered another trade-off associated with dam removal. While our study shows that these turtles may potentially lose the majority of their current habitat, they are known to live in a wide range of habitats and persist in sub-optimal conditions (Herpetological Resource and Management 2017). Therefore, they may be a strong candidate for relocation, or succeed in the predicted river with some close monitoring efforts.

<u>Management Recommendations</u>

In order to minimize the potential trade-offs associated with dam removal, we propose that *C. picta* be considered for relocation to minimize negative impacts. We recommend removing the dam in spring or summer during the turtles' active season. This will prevent the loss of many turtles due to exposure to cold temperatures. We also recommend potential relocation for these turtles. This might mean moving them a farther downstream into an area where flow may be less affected. Further research would be required to determine if this is a possible option.

These specific dam removal management strategies could be executed at the same time as other management strategies. For example, the current impoundment and its species would benefit from some river clean up. There is quite a bit of debris that could be removed during dam removal. It would be beneficial to study population demographics to analyze the hatchling survival rate of this population. Predation is a risk to hatchling turtles, so we should determine if this is a large problem in our study area. Addressing multiple aspects of threat to turtle species is needed to better conserve our native species.

Literature Cited

Adams, S. B. 2013. Effects of small impoundments on downstream crayfish assemblages. Freshwater Science 32:1318–1332.

Anderson, R. V., M. L. Gutierrez, and M. A. Romano. 2002. Turtle Habitat Use in a Reach of the Upper Mississippi River. Journal of Freshwater Ecology 17:171–177.

Bednarek, A. T. 2001. Undamming Rivers: A Review of the Ecological Impacts of Dam Removal. Environmental Management 27:803–814.

Bellmore, R. J., J. J. Duda, L. S. Craig, S. L. Greene, C. E. Torgersen, M. J. Collins, and K. Vittum. 2017. Status and trends of dam removal research in the United States: Status and trends of dam removal research in the U.S. Wiley Interdisciplinary Reviews: Water 4:e1164.

Catalano, M. J., M. A. Bozek, and T. D. Pellett. 2007. Effects of Dam Removal on Fish Assemblage Structure and Spatial Distributions in the Baraboo River, Wisconsin. North American Journal of Fisheries Management 27:519–530.

Conant, R., and J. T. Collins. 1998. A Field Guide to Reptiles & Amphibians: Eastern and Central North America. Houghton Mifflin Harcourt.

Cooper, A. R., D. M. Infante, K. E. Wehrly, L. Wang, and T. O. Brenden. 2016. Identifying indicators and quantifying large-scale effects of dams on fishes. Ecological Indicators 61:646–657.

Cushman, S. A. 2006. Effects of habitat loss and fragmentation on amphibians: A review and prospectus. Biological Conservation 128:231–240.

DNR. 2020. DNR - Turtles. https://www.michigan.gov/dnr/0,4570,7-350-79135_79218_79616_83200---,00.html.

Fahrig, L., and T. Rytwinski. 2009. Effects of roads on animal abundance: An empirical review and synthesis. Ecology and Society 14.

Fan, H., D. He, and H. Wang. 2015. Environmental consequences of damming the mainstream Lancang-Mekong River: A review. Earth-Science Reviews 146:77–91.

Foster, J., and M. S. Gaines. 1991. The Effects of a Successional Habitat Mosaic On a Small Mammal Community. Ecology 72:1358–1373.

Grgurovic, M., and P. R. Sievert. 2005. Movement patterns of Blanding’s turtles (Emydoidea blandingii) in the suburban landscape of eastern Massachusetts. Urban Ecosystems 8:203–213.

Herpetological Resource and Management. 2017. Boardman River Dam Removal Amphibian and Reptile Inventory Report. Herpetological Resource and Management Chelsea, MI:35.

Hitt, N. P., S. Eyler, and J. E. B. Wofford. 2012. Dam Removal Increases American Eel Abundance in Distant Headwater Streams. Transactions of the American Fisheries Society 141:1171–1179.

Hunt, S. D., J. C. Guzy, S. J. Price, B. J. Halstead, E. A. Eskew, and M. E. Dorcas. 2013. Responses of riparian reptile communities to damming and urbanization. Biological Conservation 157:277–284.

Iglay, R. B., J. L. Bowman, and N. H. Nazdrowicz. 2007. Eastern Box Turtle (Terrapene carolina carolina) Movements in a Fragmented Landscape. Journal of Herpetology 41:102–106.

Jaenike, J. R. 1973. A Steady State Model of Genetic Polymorphism on Islands. The American Naturalist 107:793–795.

Lieb, A. 2015. The Undamming of America. https://www.pbs.org/wgbh/nova/article/dam-removals/.

Marchand, K. A., C. M. Somers, and R. G. Poulin. 2019. Spatial ecology and multi-scale habitat selection by Western Painted Turtles (Chrysemys picta bellii) in an urban area. The Canadian Field-Naturalist 132:108–119.

Marks, J. C., G. A. Haden, M. O'Neill, and C. Pace. 2010. Effects of Flow Restoration and Exotic Species Removal on Recovery of Native Fish: Lessons from a Dam Decommissioning. Restoration Ecology 18:934–943.

Mbaka, J. G., and M. Wanjiru Mwaniki. 2015. A global review of the downstream effects of small impoundments on stream habitat conditions and macroinvertebrates. Environmental Reviews 23:257–262.

McCartney, M. 2009. Living with dams: managing the environmental impacts. Water Policy 11:121–139.

Morjan, C. L. 2003. Variation in nesting patterns affecting nest temperatures in two populations of painted turtles (Chrysemys picta) with temperature-dependent sex determination. Behavioral Ecology and Sociobiology 53:254–261.

Packard, G. C., and M. J. Packard. 2001. The Overwintering Strategy of Hatchling Painted Turtles, or How to Survive in the Cold without FreezingNeonatal turtles, like many cold-tolerant insects, exploit a capacity for supercooling to withstand exposure to subzero temperatures. BioScience 51:199–207.

Princeton Hydro. 2018. Ypsilanti Peninsular Paper Dam.

Public Sector Consultants. 2007. The Growing Crisis of Aging Dams: Policy Considerations and Recommendations for Michigan Policy Makers:74.

Quiñones, R. M., T. E. Grantham, B. N. Harvey, J. D. Kiernan, M. Klasson, A. P. Wintzer, and P. B. Moyle. 2015. Dam removal and anadromous salmonid (Oncorhynchus spp.) conservation in California. Reviews in Fish Biology and Fisheries 25:195–215.

Radojković, N., Z. Marinović, A. Milošković, M. Radenković, S. Đuretanović, J. Lujić, and V. Simić. 2018. Effects of Stream Damming on Morphological Variability of Fish: Case Study on Large Spot Barbell Barbus balcanicus. Turkish Journal of Fisheries and Aquatic Sciences 19:231–239.

Rees, M., J. H. Roe, and A. Georges. 2009. Life in the suburbs: Behavior and survival of a freshwater turtle in response to drought and urbanization. Biological Conservation 142:3172–3181.

Reese, D. A., and H. H. Welsh. 1997. Use of Terrestrial Habitat by Western Pond Turtles, Clemmys marmorata: Implications for Management:6.

Richter, B. D., and G. A. Thomas. 2007. Restoring Environmental Flows by Modifying Dam Operations. Ecology and Society 12.

Rubio, A. V., R. Ávila-Flores, and G. Suzán. 2014. Responses of Small Mammals to Habitat Fragmentation: Epidemiological Considerations for Rodent-Borne Hantaviruses in the Americas. EcoHealth 11:526–533.

Sih, A., J. Cote, M. Evans, S. Fogarty, and J. Pruitt. 2012. Ecological implications of behavioural syndromes. Ecology Letters 15:278–289.

Slagter, M. 2019, May 8. Ypsilanti city council votes to remove Peninsular Dam. https://www.mlive.com/news/ann-arbor/2019/05/ypsilanti-city-council-votes-to-remove-peninsular-dam.html.

Slavenko, A., Y. Itescu, F. Ihlow, and S. Meiri. 2016. Home is where the shell is: predicting turtle home range sizes. The Journal of Animal Ecology 85:106–114.

Strayer, D. L. 2006. Challenges for freshwater invertebrate conservation. Journal of the North American Benthological Society 25:271–287.

Ultsch, G. R. 2006. The ecology of overwintering among turtles: where turtles overwinter and its consequences. Biological Reviews 81:339–367.