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IMPACTS OF AGRICULTURAL DRAIN MAINTENANCE IN BEAVER CREEK ON GRASS PICKEREL (*ESOX AMERICANUS VERMICULATUS*), A FISH SPECIES AT RISK

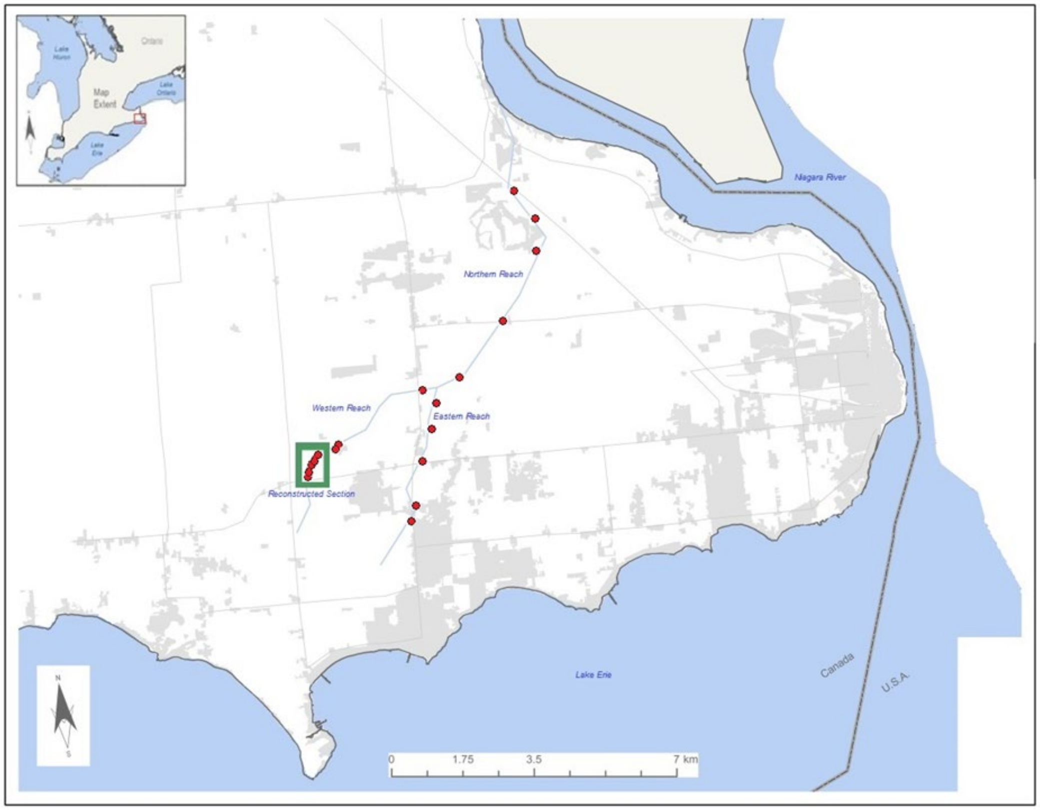

Figure 1. Study location of Beaver Creek, Fort Erie, ON. Green square represents the area where drain maintenance and reconstruction activities occurred.

Context:

*Drain maintenance was required on Beaver Creek to clear obstructions and improve drainage of private land. Beaver Creek has a large resident population of Grass Pickerel (*Esox americanus vermiculatus*), a species designated as Special Concern in Canada under the* Species at Risk Act *(SARA). Grass Pickerel has specific habitat requirements incompatible with typical drain maintenance. Fisheries and Oceans Canada (DFO) undertook a study of the fish community, habitat, and Grass Pickerel population in Beaver Creek, before and after maintenance works, to determine their impact and to develop monitoring techniques for future works.*

*This Science Advisory Report is from the October 4-5, 2016 regional peer review meeting on Impacts of agricultural drain maintenance in Beaver Creek on Grass Pickerel (*Esox americanus vermiculatus*), a fish species at risk. Additional publications from this meeting will be posted on [the Fisheries and Oceans Canada (DFO) Science Advisory Schedule] as they become available.*

SUMMARY

- The Beaver Creek watershed in southwestern Ontario encompasses approximately 37.3 km^2 of primarily agricultural land and flows into Black Creek, a tributary to the Niagara River. Beaver Creek is classed as a municipal drain and, thus, subject to periodic drain maintenance. A large population of Grass Pickerel (*Esox americanus vermiculatus*), a species at risk in Canada, is found in Beaver Creek and would potentially be impacted by any drain maintenance activities undertaken in the watershed.
- The western branch of Beaver Creek was subjected to drain maintenance and reconstruction, using natural-channel principles, in the fall of 2011. This maintenance impacted 2.8 ha of fish habitat in Beaver Creek. The eastern branch of Beaver Creek was left in its naturalized state.
- To determine if there were impacts on the fish community, and specifically on the Grass Pickerel population, DFO conducted long-term monitoring of the fish community and habitat in Beaver Creek in 2009 to 2013 and in 2015.
- Two incidents of Grass Pickerel population decline were observed in Beaver Creek over the course of this study. The first occurred after the sample period in 2009 and was evidenced by reduced abundance observed during summer sampling of 2010. The second was observed after a significant drought in 2012. These declines were observed over the entire study area.
- An age-and-growth study of Grass Pickerel in Beaver Creek and Jones Creek (located in Eastern Ontario) showed Grass Pickerel in Canada were between young-of-the-year (YOY) and age 8, as determined by cleithral aging. Length-at-age estimates show that Grass Pickerel collected in Beaver Creek in 2009 had significantly slower growth rates than those collected in 2011.
- Comparison of aging structures showed that scales were not reliable for age estimation in Grass Pickerel and tended to underestimate age compared to age estimates based on cleithra. Length-at-age estimates were reliable and a strong relationship between cleithral radius and body length was observed.
- A population-genetics analysis, using tissue samples collected from across the Canadian range of Grass Pickerel was conducted to determine the species' population structure in Canada. Preliminary results show no evidence of population structure in Grass Pickerel in Canada, thus, findings from the study of Beaver Creek should be applicable across the species' range in Canada where habitats are similar.
- A study of the movement of Grass Pickerel in Beaver Creek using PIT tags showed that Grass Pickerel can undertake movements on the scale of drain maintenance (0.5–1.0 km), indicating potential for the species to recolonize areas following drain maintenance; however, few individuals (13.3% in 2009, 5.6% in 2010) were observed to move such distances.
- Long-distance movement (0.9 km–3.1 km) by Beaver Creek Grass Pickerel was dispersive in nature (not cyclical) and no evidence of migration was observed over the course of the movement study. Long-distance movement was undertaken by larger individuals in better condition than individuals that did not move between sites.
- Simulation modelling was conducted to determine the impact that changes in habitat quantity may have on Grass Pickerel population size in Beaver Creek, and to provide

estimates of minimum viable population size (MVP) and the minimum area for population viability (MAPV). When available, data specific to Beaver Creek were used to estimate model parameters; however, relationships from the literature were necessary to estimate fecundity, mortality, and individual area requirements.

- Based on life-stage specific estimates of habitat area, calculated from 2010–2011 water-level data and a GIS-based flooded area analysis, the population model predicted that the number of adult Grass Pickerel in the main tributary is limited by the quantity of age 1+ fish habitat. YOY habitat becomes limiting when the amount of habitat available is decreased below 60,000 m^2. Spawning habitat was not limiting unless a large area per individual female is required for successful spawning, or if flooded habitat was reduced below 100,000 m^2 during the spawning period.
- The MVP required to achieve a 99% probability of persistence over 100 years with a 15% chance of catastrophe (a one-time 50% reduction in population size) per generation was 1,653 age 3+ Grass Pickerel. Maintaining a population of this size required 14,853 m^2 of age 1+ fish habitat, 4921 m^2 of YOY habitat and 7,992 m^2 of spawning habitat.
- Before-after-control-impact (BACI) analyses were conducted at multiple time-scales to determine the impact of drain maintenance and reconstruction activities on the habitat, Grass Pickerel abundance, and the general fish community. Significant effects were observed in the Grass Pickerel abundance and several habitat variables including: conductivity; vegetation cover; water temperature; and, water depth. Effects were most pronounced within the reconstructed section.
- Following drain maintenance and reconstruction activities, the reconstructed section of Beaver Creek was recolonized by Grass Pickerel. Grass Pickerel abundance, as measured by catch per unit effort (CPUE), was increased in the reconstructed section following maintenance and reconstruction activities. It is unknown to what extent this increase in CPUE represents movement of individuals from other locations in the creek into the reconstructed section, or increased production of Grass Pickerel in the reconstructed section.
- The creation of deeper pools likely mitigated the effects of the drought observed in 2012, insulating the Grass Pickerel population in the reconstructed section from a mortality event.
- Due to the infrequent nature of long-distance movements undertaken by Grass Pickerel, drainage activities should be undertaken outside of areas with high Grass Pickerel abundance (preferably downstream), whenever possible.
- Future drain maintenance activities in areas with Grass Pickerel populations should incorporate natural-channel design features. The reconstruction activities should strive to include the creation of deeper pool habitats that will provide low-velocity habitat and refuge during low water-level events, along with shallow areas, with little flow, where submerged aquatic macrophytes can establish. Maintenance and reconstruction activities should also strive to retain channel complexity, a functioning floodplain habitat, and connections of the floodplain to the main stream channel. These features were incorporated during reconstruction of Beaver Creek; however, it is unknown what the effects on Grass Pickerel population and habitat would have been in the absence of these natural channel design features.
- The presence and dispersal ability of a source population to recolonize the reconstructed area following in-stream works should be considered when planning future maintenance and reconstruction activities.

- Whenever opportunities are presented, future drainage projects should incorporate pre- and post-construction monitoring to increase the number of case studies available to reduce uncertainty related to the effects of these activities and to inform future management decisions regarding drain maintenance effects on at-risk fish species. Monitoring should be conducted for as long as possible prior to, and following, the drainage activities to detect changes in habitat and abundance. This study has shown that changing the amount of time that monitoring is conducted can alter the ability to detect the effects of drain maintenance and reconstruction on fish population and habitat.
- Monitoring projects should include standardized sampling effort between sites and among years, and care should be taken to implement a study design that allows for rigorous statistical analyses.

INTRODUCTION

Many of the streams in southern Ontario are classed as municipal drains and, as such, are subject to drain maintenance under the *Drainage Act* (1990) to ensure adequate water capacity and flow to prevent flooding of agricultural lands and rural infrastructure. Traditionally, drain maintenance involves the removal of accumulated sediment and associated aquatic vegetation to improve water flow by dredging and through channelization of the stream. Despite this, municipal drains are used by fishes (Stammler et al. 2008), thus, any drain maintenance activities have the potential to impact fish communities and their habitat. Impacts to fish habitat due to drain maintenance can include altered flow regimes (Bukaveckas 2007), reduced riparian vegetation (Hupp 1992), increased suspended sediments (Simon 1989), and reduced substrate complexity (Lau et al. 2006). These changes in habitat can lead to a reduction in the fish community diversity, particularly affecting environmentally sensitive species (Lau et al. 2006).

Grass Pickerel (*Esox americanus vermiculatus*) is a species that often inhabits agricultural (municipal) drains across its range in Canada, which includes southern Ontario and Quebec (COSEWIC 2005). Grass Pickerel is a visual predator that inhabits slow-moving, heavily vegetated waters, often containing woody debris (Scott and Crossman 1998). Due to its habitat preferences and its propensity to occupy municipal drains throughout its Canadian range, drain maintenance has been identified as one of the largest potential threats to the species' recovery in Canada (COSEWIC 2005).

The Beaver Creek watershed in southern Ontario encompasses approximately 37.3 km^2 of primarily agricultural land (UEM 2011) and flows into Black Creek, a tributary of the Niagara River. Beaver Creek is classed as a municipal drain (incorporated in 1903), although there is no record of recent drain maintenance. The creek was presumed to be in a naturalized state (UEM 2011). Beaver Creek is home to a large population of Grass Pickerel that would potentially be impacted by any drain maintenance activities. Drain maintenance and reconstruction was performed on a 988 m section of the western branch of Beaver Creek in the fall of 2011, impacting 2.8 ha of fish habitat from the work area to the downstream outlet. Natural stream channel features were incorporated into the design of the reconstruction to mitigate the impacts of a traditional drain cleanout on Grass Pickerel. Five instream pools were created, along with two offline floodplain pools, to improve storage and create additional seasonal fish habitat.

DFO undertook a study of the fish community, habitat, and Grass Pickerel population in Beaver Creek, before and after the drainage works, to determine its impact and to develop monitoring techniques for future projects.

This report summarizes the conclusions and advice from the Canadian Science Advisory Secretariat (CSAS) peer-review meeting, held in Burlington, Ontario on October 4–5, 2016.

Three research documents were presented: a summary of sampling activity in Beaver Creek (Colm and Mandrak 2021); an age and growth study of Grass Pickerel from two northern populations (Colm et al. 2020); and, a study of the effect of drain maintenance and reconstruction on the fish community, habitat, and Grass Pickerel population in Beaver Creek (Glass et al. 2021). The research documents that were reviewed provide in-depth accounts of the summarized information below. Presentations on the movement of Grass Pickerel in Beaver Creek, population modelling of Grass Pickerel in Beaver Creek, and the population genetics of Grass Pickerel in Canada were provided. Additionally, revisions to the mitigation guide for activities impacting Grass Pickerel (Coker et al. 2010) were discussed and the guide was updated (Coker et al. 2021). Proceedings documenting the discussions and conclusions of the meeting are also available (DFO 2017).

ASSESSMENT

Methods

Study Design

This study was conducted on three reaches of Beaver Creek: the eastern branch was left in its naturalized state; the western branch where drain maintenance and reconstruction, incorporating natural-channel features, was conducted on a 988 m segment in the fall of 2011; and, the northern branch, downstream of the confluence of the eastern and western branches (Figure 1).

Sampling of the fish community was conducted by DFO staff in 2009–2013 and 2015. In 2009 and 2010, four sites were sampled on the eastern branch (road crossings at Nigh Rd., Gorham Rd., Garrison Rd., and Bertie St.; Table 1). In subsequent years, the sites at Nigh Rd. and Gorham Rd. were replaced by a single site at a crossing on private land between Garrison Rd. and Bertie St. (referred to as Ben’s Place in Table 1), due to access issues. The western branch was sampled at road crossings at Garrison Rd., House Rd., and Stevensville Rd. The northern branch was sampled at Winger Rd., Bowen Rd., Eagle St., and College Rd (Table 1). Within the western branch, the reconstruction conducted in the fall of 2011 created five pools within the main stem of the creek (one of which replaced the existing pool at Garrison Rd.) and two offline pools (Figure 1). Sampling was conducted in pool habitats, usually adjacent to road crossings for ease of access, using a 9.1 m bag seine with 3.2 mm mesh. Fishes were identified to species, counted, and released back at the sample site once all seine hauls had been conducted. Habitat variables measured at time of sampling included: water temperature (°C); conductivity (µs/cm); dissolved oxygen (mg/l); pH; turbidity (ntu); Secchi depth (m); sampling depth (m; average of three measurements across sample area); channel cover (%); substrate (% composition by type); riparian vegetation (% composition by type); and, aquatic vegetation (% composition by type).

All Grass Pickerel caught were placed in a separate bin for processing. All specimens were measured (TL) on a fork board and weighed using an O’Haus 3 kg scale. Scale samples were taken from the left side of the body, on the dorso-lateral surface behind the dorsal fin, and used to age a sub-sample of Grass Pickerel. Fin clips were also taken from Grass Pickerel in 2013 and 2015 as part of a range-wide genetic analysis. All individual Grass Pickerel over 120 mm total length were checked for a passive integrated transponder (PIT) tag using a hand-held PIT tag reader. If a tag was detected, the code was recorded. If no tag was present and the individual measured at least 160 mm TL and/or weighed at least 20 g, it was anaesthetized and tagged.

Multiplexer stations were placed at eight sampling sites (Table 1) to record PIT-tagged Grass Pickerel detections. The multiplexer stations consisted of three or four antenna arrays spread across the creek bottom connected to a reader/logger device. When PIT-tagged individuals passed over the antenna arrays, their unique code was recorded.

Table 1. Sampling sites on Beaver Creek.

Site Name	Branch	Latitude	Longitude	Multiplexer station	Level Logger
College	North	42.95520	-79.01582	N	N
Eagle	North	42.94807	-79.01698	N	Y
Bowen	North	42.93282	-79.02800	Y	Y
Winger	North	42.92125	-79.04175	Y	Y
Ben's Place	East	42.91614	-79.04842	Y	Y
Bertie	East	42.91075	-79.05157	N	N
Garrison East	East	42.90371	-79.05490	Y	Y
Nigh	East	42.89380	-79.05730	N	N
Gorham	East	42.89075	-79.05960	N	N
Stevensville	West	42.91959	-79.05395	Y	Y
Bertie ROW	West (constructed)	42.91080	-79.07170	N	N
House	West	42.90859	-79.08007	Y	Y
Upstream of House	West	42.90770	-79.08115	N	N
Pool 5	West (constructed)	42.90306	-79.08874	N	N
Offline Pool 2	West (constructed)	42.90325	-79.08895	N	N
Pool 4	West (constructed)	42.90465	-79.08805	N	N
Pool 3	West (constructed)	42.90525	-79.08715	N	N
Offline Pool 1	West (constructed)	42.90545	-79.08715	N	N
Pool 2	West (constructed)	42.90660	-79.08625	Y	N
Garrison West	West (constructed)	42.90225	-79.08974	Y	Y

Age and growth

In 2009, 153 Grass Pickerel were harvested from Beaver Creek during two sampling events in June, representing all age and size classes present at the sites. In 2011, young-of-year (YOY) Grass Pickerel were targeted and 110 individuals were harvested from Beaver Creek throughout the summer from several sites. Specimens were preserved in 95% ethanol, measured, weighed, sexed, and tissue samples, including cleithra (and scales in 2009), were taken.

Additionally, Grass Pickerel were harvested in 2011 from the lower reaches of Jones Creek, in Mallorytown, Ontario, using a Smith-root electrofishing boat as part of an unrelated project. Cleithral age interpretations and growth parameters for Jones Creek samples were compared to the Beaver Creek samples.

Cleithra were excised from specimens, had soft tissues removed using careful Trypsin digestion, and cleaned with soap and water. Annuli were identified and counted using the method of Casselman (1996). Scales were removed from the dorso-lateral surface posterior to the dorsal fin on the left side of the fish. Scales were mounted on acetate slides, viewed under a microscope, and annuli were counted.

A linear regression was conducted on the bone and body lengths for Grass Pickerel captured in 2011 and the von Bertalanffy growth function was calculated for the Grass Pickerel samples collected in 2009 and 2011 from Beaver Creek and in 2011 from Jones Creek. Mean lengths-at-age were compared between the 2009 and 2011 Beaver Creek samples and 2011 Jones Creek samples. Growth rates of the 2011 Beaver Creek YOY during their first summer were determined by linear regression of body length and Julian date during the first growing season.

Population genetics

Fin-clip tissue samples were collected from Grass Pickerel populations across the species' range in Canada. A total of 45 tissues were collected from 12 geographic locations and preserved in 95% ethanol. DNA was extracted from the tissues and amplified and sequenced using next-generation sequencing. Loci containing single nucleotide polymorphisms (SNP) were identified and the Bayesian structural analysis program STRUCTURE v.2.3 (Pritchard et al. 2000) was used to determine if population genetic structure was present based on the SNP matrix.

Movement

Detection data for individual Grass Pickerel with implanted PIT tags were analyzed to determine the movement between three of the sites (Stevensville, Ben's Place, Bowen), one in each branch, where multiplexer stations were set up. The proportion of individuals moving between sites (detection at more than one site), the temporal distribution of movement, and the directionality of movement were calculated for 2009 and 2010.

Population modelling

A population model was constructed to demonstrate how habitat availability affected Grass Pickerel population size in Beaver Creek. An age-structured matrix model was employed with age-7 assumed to be the maximum age of Grass Pickerel in Beaver Creek and sexual maturity between age-2 and age-4. Fecundity was estimated based on a Wisconsin population (Kleinert and Mraz 1966), and survival-at-size estimates were based on a length-dependent mortality schedule (Lorenzen 2000). Variation was incorporated into the model using stochastic simulations and density dependence was also incorporated. Three independent habitat types (spawning habitat, YOY habitat, and age-1+ habitat), estimated based on water-level data from 2010–2011 and GIS analysis of flooded area, were also incorporated into the model.

Simulations using a Leslie matrix to project population size in one-year increments were run to determine how changes in habitat availability affect population size. Minimum area of population viability (MAPV) and minimum viable population size (MVP) were also estimated.

Before-After-Control-Impact analyses

Catch per unit effort (CPUE) was used as a surrogate for abundance of Grass Pickerel at a site during each sampling event and was calculated as the average number of Grass Pickerel per seine haul.

A series of before-after-control-impact (BACI) analyses to determine the effect of drain maintenance and reconstruction were conducted using factorial ANOVA in Statistica v6.0. An interaction term of the factorial ANOVA with a P value < 0.05 represented a significant effect on the variable of interest. BACI analyses examining effects on each of the habitat variables and Grass Pickerel abundance were conducted. Separate BACI analyses were conducted comparing the control (eastern) reach with the impact (western) reach, the control reach with the reconstructed section of the impact reach, and the control reach with the northern reach. To determine the temporal extent of the effects and to inform monitoring decisions, analyses were also conducted on three different time scales: one year before maintenance compared with one year after reconstruction; pooled samples before maintenance compared with one year after; and, all samples before maintenance compared to all samples after reconstruction.

The fish community analyses were conducted using a non-parametric multivariate analysis of variance using distance matrices. CPUE was used to represent the abundance of each species. The CPUE for each species per site was log+1 transformed to normalize the data. The analyses were completed with the function *Adonis* in the vegan package in R (Oksanen et al. 2010). These analyses were conducted using the same spatial and time-scale comparisons as the other BACI analyses.

Results

A total of 27,310 fishes from 37 different species were captured in 677 seine hauls during the study from throughout the sampled area of Beaver Creek. The most abundant species captured across all sites and years were Emerald Shiner (*Notropis atherinoides*; 36% of all fishes captured), Grass Pickerel (18%), and Golden Shiner (*Notemigonus crysoleucas*; 16%). The most frequently detected species were Grass Pickerel (91% of sampling events), Golden Shiner (75%), and Pumpkinseed (*Lepomis gibbosus*; 74%). Of the fishes captured, 4,971 Grass Pickerel were captured. Five of the Grass Pickerel captures came from the constructed offline pools in the first sampling event after the reconstruction was completed. All subsequent sampling in the offline pools failed to detect Grass Pickerel. Two incidents of Grass Pickerel population decline were observed in Beaver Creek over the course of this study. The first occurred after the sample period in 2009 and was evidenced in the reduced abundance observed during summer sampling of 2010. The second was observed after a significant drought in 2012. These declines were observed throughout the entire study area.

Age and growth

Aging Grass Pickerel using scales consistently underestimated the age of the specimen when compared to age determinations using cleithra. Grass Pickerel aged (using cleithra) between YOY and eight years in the Beaver Creek population. There was a significant positive linear relationship between bone (cleithrum) length and body length. Reconstructed length-at-age differed for fish collected in 2009 and 2011 in Beaver Creek and those collected in Jones Creek. The older fish collected in 2011 had faster growth rates than the older fish that were collected in 2009 in Beaver Creek. The growth rate in Jones Creek was slower, particularly for older fish, than was exhibited in Beaver Creek in either 2009 or 2011. The greater abundance of Grass Pickerel observed in Beaver Creek in 2009, along with the lower growth rate observed for individuals captured in that year, suggests that density-dependent growth is present in the Grass Pickerel population of Beaver Creek.

Population genetics

The population genetic survey resulted in isolation and sequencing of 5,188 loci of 56 base-pairs in length. Each of the loci was present in at least 40 of the 45 individuals that were successfully sequenced and 1,001 single nucleotide polymorphisms were identified. The STRUCTURE analysis showed no evidence of population structuring throughout the geographic range of Grass Pickerel that was sampled and analyzed to date; genetic results from Severn River drainage are pending.

Movement

A small proportion of individuals were detected at two or more sites (13.3% in 2009, 5.6% in 2010), indicating they had undertaken long-distance movement (0.9 – 3.1 km between detections) during the study period. The pattern of movement of individuals was non-cyclical and asynchronous, indicating that there was no evidence of migration by Grass Pickerel in Beaver Creek. Long-distance movements tended to be undertaken by larger individuals that were in better condition relative to the average in the population.

Population modelling

Based on life-stage specific estimates of habitat area, calculated from 2010–2011 water-level data and a GIS-based flooded area analysis, the population model predicted that the number of adult Grass Pickerel in the main tributary is limited by the quantity of age 1+ fish habitat. Model results indicate that this area of habitat can support a mean long-term population of 6,000 mature individuals. YOY habitat becomes limiting when the amount of habitat available is decreased below 60,000 m^2. Spawning habitat was not limiting unless a large area per individual female is required for successful spawning, or if flooded habitat was reduced below 100,000 m^2 during the spawning period.

The MVP required to achieve a 99% probability of persistence over 100 years with a 15% chance of catastrophe (a one-time 50% reduction in population size) per generation was 1,653 age 3+ Grass Pickerel. Maintaining a population of this size required 14,853 m^2 of age 1+ fish habitat, 4921 m^2 of YOY habitat and 7,992 m^2 of spawning habitat.

Before-After-Control-Impact analyses

CPUE ranged from a high of 29.13 Grass Pickerel per seine haul in the eastern (control) reach in 2009 to a low of 0.5 Grass Pickerel per seine haul in the reconstructed reach in 2013. In all cases, CPUE was highest in the first year of the study period. CPUE was lowest in 2013 for all but the northern reach, which was lowest in 2015 (Table 2).

Table 2. Average number of Grass Pickerel captured per seine haul in each of the sampled reaches. Drain maintenance and reconstruction activities were conducted in the fall of 2011 after sampling was competed that year.

Year	Control Reach	Reconstructed Section	Impact Reach	Northern Reach
2009	29.1	6.2	25.6	9.5
2010	13.8	1.9	6.8	6.5
2011	12.4	1.2	3.6	8.6
2012	6.7	1.5	2.6	2.1
2013	1.9	0.5	2.1	2.3
2015	4.3	4.1	3.3	1.9

The ANOVA comparisons showed significant effects of drain maintenance and reconstruction for several variables (Tables 3–5). These effects were most often evident within the reconstructed section of Beaver Creek.

Table 3. Interaction term P values for each of the BACI comparisons assessing the control reach and the reconstructed section.

Parameter	Pooled Before - After	Pooled Before – 1 year after	1 year before – 1 year after
Abundance	0.004*	0.054	0.317
Temperature	0.018*	0.000*	0.038*
Conductivity	0.075	0.015*	0.138
Vegetation Coverage	0.105	0.029*	0.245
Secchi Depth	0.589	0.703	0.345
Water Depth	0.002*	0.009*	0.423
Water Velocity	0.204	0.357	0.422

*indicates a significant interaction and, thus, a significant effect of the drain maintenance and reconstruction activities on the particular variable at that reach.

Table 4. Interaction term P values for each of the BACI comparisons assessing the control reach and the impact reach.

Parameter	Pooled Before - After	Pooled Before – 1 year after	1 year before – 1 year after
Abundance	0.122	0.392	0.164
Temperature	0.049*	0.014*	0.060
Conductivity	0.240	0.045*	0.010*
Vegetation Coverage	0.218	0.125	0.507
Secchi Depth	0.797	0.716	0.194
Water Depth	0.291	0.870	0.792
Water Velocity	0.057	0.152	0.131

*indicates a significant interaction and, thus, a significant effect of the drain maintenance and reconstruction activities on the particular variable at that reach.

Table 5. Interaction term P values for each of the BACI comparisons assessing the control reach and the northern reach.

Parameter	Pooled Before - After	Pooled Before – 1 year after	1 year before – 1 year after
Abundance	0.019*	0.163	0.832
Temperature	0.029*	0.125	0.230
Conductivity	0.521	0.746	0.955
Vegetation Coverage	0.920	0.307	0.977
Secchi Depth	0.258	0.382	0.420
Water Depth	0.491	0.269	0.395
Water Velocity	0.256	0.420	0.417

*indicates a significant interaction and, thus, a significant effect of the drain maintenance and reconstruction activities on the particular variable at that reach.

Within the reconstructed section, Grass Pickerel abundance was significantly increased, relative to the control reach, when comparing the pooled before and after CPUE data (Table 3).

Water temperature was increased, relative to the control reach, within the reconstructed section, within the impact (western) branch as a whole, and within the northern branch (Tables 3–5). Conductivity was increased in the reconstructed section, and impact reach as a whole, compared to the control reach (Table 3 and 4). The water depth increased in the reconstructed section, due to the creation of new pools, while vegetation coverage significantly decreased (Table 3).

No effect of drain maintenance and reconstruction was observed in the overall fish community in Beaver Creek during the course of the study.

Sources of Uncertainty

Several sources of uncertainty were identified throughout the course of the studies conducted on the Grass Pickerel population in Beaver Creek.

One source of uncertainty is that the individuals sampled for the age and growth study were not a random sample of the population in Beaver Creek. The samples collected in 2009 were taken during a single sampling event at two sites and, in 2011, smaller and YOY individuals were targeted for the study. It is unknown to what extent the actual age distribution in the Beaver Creek Grass Pickerel population may differ from the sampled individuals.

The lack of individuals in the population genetic analysis from the Severn River watershed is a source of uncertainty. The Severn population is the most northerly Grass Pickerel population in the province and is geographically isolated from the southern Canadian populations that are represented in the study. The isolation and different environmental conditions that characterize the habitat of the Severn population may have led to genetic divergence of this population. Without sequences from this population, the extent of differentiation in the Severn population remains unknown. The applicability of advice derived from research conducted in southern Ontario to the Severn River watershed population is, therefore, also unknown. Tissue samples from the Severn population were collected in the summer of 2016 and analyses are pending.

Only three sites, one in each branch of Beaver Creek, were included in the movement study. The movement of Grass Pickerel beyond these sites in Beaver Creek is not included in the analysis and, thus, is unknown. The movement study also characterized movement upstream and downstream in Beaver Creek, however, the movement of individuals laterally (i.e. to the flood plain and back to the main channel) remains an unknown.

There are several uncertainties inherent in the parameterization of the population model. The model assumes that all flooded habitat is suitable and there is no adjustment for habitat quality. It is unknown what proportion of this floodplain habitat is actually suitable for spawning. It is also unknown how much space each individual Grass Pickerel requires for spawning. Additionally, the required habitat space per individual used in the model was based on an allometric relationship, rather than measured densities, thus, the estimation of both of these required space parameters constitute additional uncertainties and the actual required space are unknowns. Finally, the fecundity estimate was based on data from a Grass Pickerel population in Wisconsin. The fecundity of Grass Pickerel in Beaver Creek was not measured and remains an unknown.

Following drain maintenance and reconstruction, the CPUE of Grass Pickerel was increased in the reconstructed section that incorporated natural channel features. It is unknown to what extent this represents movement of individuals into the reconstructed area or increased production of Grass Pickerel. It is also unknown how maintenance performed without reconstruction incorporating natural channel features would have affected the Grass Pickerel population, relative to the maintenance and reconstruction activities that were carried out in Beaver Creek.

CONCLUSIONS AND ADVICE

This project incorporated natural stream channel features in the reconstruction activities in an effort to maintain channel complexity and enhance habitat features that are required by Grass Pickerel. Following the drain maintenance and reconstruction in Beaver Creek, the reconstructed section was recolonized by Grass Pickerel. The abundance of Grass Pickerel was increased in the reconstructed section, relative to the control reach that was untouched by drainage activities. The creation of deeper pools during reconstruction has likely mitigated the effects of a severe drought in 2012 by providing a refuge during low-water periods.

Where feasible, future drainage projects in areas with Grass Pickerel habitat should incorporate natural stream channel principles to mitigate effects of drain maintenance on the habitat that supports functions vital to maintaining, or enhancing, Grass Pickerel populations. These habitat features include: deeper pools that serve as refuge habitat during winter or low-water periods and provide low velocity habitat preferred by Grass Pickerel; access to shallow waters (< 0.5 m) with ample aquatic or flooded terrestrial vegetation; and, a functioning floodplain habitat with a connection maintained to the main stream channel. Design of drain maintenance and reconstruction projects should also consider the presence of a source population that will enable recolonization of the area affected by drainage activities and the dispersal capability of the species.

Due to the infrequent nature of long-distance movements undertaken by Grass Pickerel, drainage activities should be undertaken outside of areas with high Grass Pickerel abundance (preferably downstream), whenever possible.

The research conducted on the Beaver Creek drain maintenance and reconstruction represents a single case study, however robust it may be. There is a need for more case studies to inform future decisions regarding drainage activities in areas with populations of species at risk fishes. Wherever opportunities are presented, future drain projects should incorporate pre- and post-construction monitoring to increase this body of knowledge and reduce uncertainty regarding the effect of drain maintenance and reconstruction on species at risk and their habitats. These monitoring studies should be conducted for as long as possible prior to, and following, the drainage activities to detect changes in habitat and abundance of fishes. The results of this study show that changing the amount of time that monitoring is conducted can alter the ability to detect effects of these activities on fish populations and habitat.

Consideration of study design to detect the effects of drain maintenance and reconstruction should be made when planning future projects. This study incorporated a BACI design which is ideal for determining the effects of drain maintenance activities. When implementing BACI design, control sites that are as similar as possible to the potentially impacted sites should be selected and sampling effort should be standardized between sites and among years, however, BACI design is not always possible. In the absence of BACI design, regional stratified-random design, reference condition design, or longer-term monitoring that encompasses the breadth of climatic and biological variability prior to maintenance may be considered. Regardless of which monitoring design is implemented, care should be taken to ensure a study design that allows for rigorous statistical analyses.

OTHER CONSIDERATIONS

During discussions, a participant noted that upstream impacts or changes may have occurred that could have affected the system downstream. Unfortunately, only limited anecdotal information could be provided at the time. In follow up, it was determined that drainage activities were completed in 2011 in two headwater drains, Baer Drain and Schooley Drain, that outlet approximately 2.5 km upstream of the reconstructed reach in Beaver Creek. In Baer Drain, a 1,668 m section was cleaned out and a culvert was replaced at Matthews Road. In Schooley Drain, a 418 m section was cleaned out, a section was moved from the east side to the west side of Point Abino Road (723 m of new drain created, and an equivalent length of former drain filled and abandoned) connecting it to Baer Drain, and a new culvert was installed across Point Abino Road. These activities were not known prior to the science advisory meeting and, thus, were not considered in the analyses. Impacts from these works on the habitat and fish community in Beaver Creek and their effect on the results presented are unknown.

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SOURCES OF INFORMATION

This Science Advisory Report is from the October 4-5, 2016 regional peer review meeting on Impacts of agricultural drain maintenance in Beaver Creek on Grass Pickerel (*Esox americanus vermiculatus*), a fish species at risk. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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