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A Modelling-based Assessment of the Impacts of Drain Maintenance on Fish Species-at-Risk Habitat in Little Bear Creek, Ontario

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

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ABSTRACT

Little Bear Creek drain, a tributary to Lake St. Clair in southwestern Ontario, supports 61 freshwater fish species, six of which are listed under the federal *Species at Risk Act* (SARA). In 2012, a drain maintenance request was proposed by the Municipality of Chatham-Kent, under the provincial *Drainage Act*, to repair and improve the functionality of Little Bear Creek drain. Proposed drain maintenance activities included the removal of substrate and vegetation from the creek, which may lead to the loss of critical habitat for fish species at risk. To predict the impacts of drain maintenance, the distribution and habitat requirements of fish species at risk in Little Bear Creek were modelled. Regression tree analysis was used to develop a statistical model ($R^2 = 0.52$; AUC = 0.75) to predict vegetation cover as a function of water depth (m) and distance from the mouth of the creek (m). The vegetation cover model was used to predict suitable habitat (defined as vegetation cover > 50%) for two of the six fish species at risk: the Endangered Pugnose Shiner (*Notropis anogenus*); and, the Special Concern Blackstripe Topminnow (*Fundulus notatus*). Impacts to suitable habitat were assessed under three drain maintenance scenarios:

1. no drain maintenance;
2. the proponent's initial proposed maintenance; and,
3. the proponent's revised proposed maintenance.

The amount of suitable habitat permanently and temporarily lost under the initial drain maintenance proposal is 19% and 42%, respectively. The revised drain maintenance proposal reduces the amount of habitat temporarily lost by 2%. There is no significant difference in patch size ($p = 0.98$), or distance to the nearest patch ($p = 0.38$), for biologically distinct patches, among all three scenarios. However, under both the initial and revised scenarios there is a five-fold increase in the maximum distance to the nearest patch size. Increased fragmentation of remaining habitat patches is expected to have additional negative impacts on population viability. Mitigation and offsetting measures are provided to potentially minimize the impacts of drain maintenance on fish species at risk in Little Bear Creek.

Évaluation fondée sur la modélisation des impacts de l'entretien des drains sur l'habitat d'espèces de poissons en péril dans le ruisseau Little Bear, en Ontario

RÉSUMÉ

Le ruisseau Little Bear, qui se déverse dans le lac Sainte-Claire, dans le sud-ouest de l'Ontario, soutient 61 espèces de poissons d’eau douce, dont 6 sont inscrites sur la liste des espèces en péril du gouvernement fédéral. En 2012, une demande d'entretien des drains a été proposée par la municipalité de Chatham-Kent, en vertu de la *Loi sur le drainage* de l'Ontario, afin de réparer et d'améliorer le drain du ruisseau Little Bear. Les activités de maintenance proposées comprenaient l'enlèvement du substrat et de la végétation dans le ruisseau, ce qui peut mener à une perte d'habitat essentiel pour les espèces de poissons en péril. Afin de prévoir les impacts de l'entretien des drains, les exigences en matière de répartition et d'habitat des espèces de poissons en péril du ruisseau Little Bear ont été modélisées. Une analyse de l'arbre de régression a servi à élaborer un modèle statistique ($R^2 = 0,52$; aire sous la courbe = 0,75) visant à prévoir la couverture végétale en fonction de la profondeur de l'eau (en m) et de la distance de l'embouchure du ruisseau (en m). Le modèle de couverture végétale a permis de prévoir l'habitat propice (défini comme une couverture végétale supérieure à 50 %) pour deux des six espèces de poissons en péril : le méné camus (*Notropis anogenus*) (en voie de disparition) et le fondule rayé (*Fundulus notatus*) (préoccupante). Les impacts sur l'habitat propice ont été évalués en fonction de trois scénarios d'entretien des drains :

1. aucun entretien des drains;
2. l'entretien proposé au départ par le promoteur;
3. l'entretien révisé proposé par le promoteur.

La superficie d'habitat propice perdue de manière permanente et temporaire dans le cas de la proposition initiale d'entretien des drains est de 19 % et de 42 % respectivement. La proposition révisée d'entretien des drains réduit de 2 % la superficie d'habitat propice perdu. Il n'y a pas de différence notable entre la taille des parcelles ($p = 0,98$) ni la distance jusqu'à la parcelle la plus près ($p = 0,38$) dans le cas des parcelles distinctes sur le plan biologique, et ce, pour les trois scénarios. Cependant, dans les scénarios initial et révisé, on observe une augmentation par un facteur de cinq de la distance maximale jusqu'à la parcelle la plus proche. Une fragmentation accrue des autres parcelles d'habitat aurait probablement des impacts supplémentaires sur la viabilité des populations. Des mesures d'atténuation et de compensation sont fournies pour tenter de réduire au minimum les impacts de l'entretien des drains sur les espèces de poissons en péril dans le ruisseau Little Bear.

INTRODUCTION

Little Bear Creek drain in Chatham-Kent, Ontario is home to six fish species at risk listed under the federal *Species at Risk Act (*SARA*)*: the Endangered Pugnose Shiner (*Notropis anogenus*); the Endangered Lake Chubsucker (*Erimyzon sucetta*); the Special Concern Pugnose Minnow (*Opsopoeodus emiliae*); the Special Concern Blackstripe Topminnow (*Fundulus notatus*); the Special Concern Grass Pickerel (*Esox americanus vermiculatus*); and, the Special Concern Spotted Sucker (*Minytrema melanops*). The drain collects agricultural run-off from adjacent farmland. To accommodate an increase in water volume and reduce flood risk, the municipality of Chatham-Kent has submitted a drain maintenance request under the provincial *Drainage Act*. Proposed drain maintenance includes excavation and removal of accumulated sediment and riparian vegetation (i.e., small trees and large brush). The Little bear Creek drain is 29.5 km long, all of which could be potentially impacted by drain maintenance activities. There is concern that the proposed dredging activity will negatively affect fish species at risk. Past research has identified that agricultural drain maintenance can result in direct fish mortality, short-term reductions in aquatic macroinvertebrate abundance, and simplification of stream habitat (Stammler 2011; Grygoruk et al. 2015).

The proposed drain maintenance may degrade habitat that is critical for the survival and/or recovery of fish species at risk. Little Bear Creek has been designated as Critical Habitat for Pugnose Shiner, yet further local information is still needed to fill knowledge gaps on specific habitat requirements (DFO 2012). Mitigation measures, such as project staging, the application of fish exclusion methods, and timing windows for in-water work have been proposed to minimize the impacts of drain maintenance (DFO 2015). General information on the fish assemblage and population characteristics of species at risk along the creek are required to inform best management practices associated with drain maintenance. To minimize potential impacts on fishes at risk in Little Bear Creek, regions of suitable habitat need to be identified.

The objectives of this study are to provide advice on the potential impact of drain maintenance in Little Bear Creek. Specifically, science advice is required to:

1. Determine the impacts that the proposed maintenance would have on fish species at risk in Little Bear Creek.
2. Provide alternative maintenance scenarios and determine the impact they may have on fish species at risk in Little Bear Creek.
3. Provide mitigation measures that could be used to minimize the impacts of maintenance on fish species at risk in Little Bear Creek.
4. Provide offsetting options (qualitative) for each alternative drain maintenance scenario.

Brushing of woody riparian vegetation along the entire drain has already been completed (fall and winter of 2014–2015). As well, the middle of the drain has been dredged along reaches 6 and 7 (Figure 1). In this study, the potential impacts of aquatic vegetation removal in reaches 1–5 were modelled under three scenarios. Reaches 1-5 were modelled as bathymetry data were available only for these reaches. A predictive habitat-based model was used to identify and quantify suitable habitat along Little Bear Creek for Pugnose Shiner and Blackstripe Topminnow. Specifically, an aquatic vegetation model was chosen because of the importance of aquatic vegetation to fish species at risk. A habitat-based modelling approach was chosen, as it is expected to provide a more accurate assessment of critical habitat than could be developed from recent fish surveys. As a result of the poor detectability of rare fishes in Little Bear Creek, identifying habitat based on species occurrence data alone would have been strongly, negatively biased (Dextrase et al. 2014).

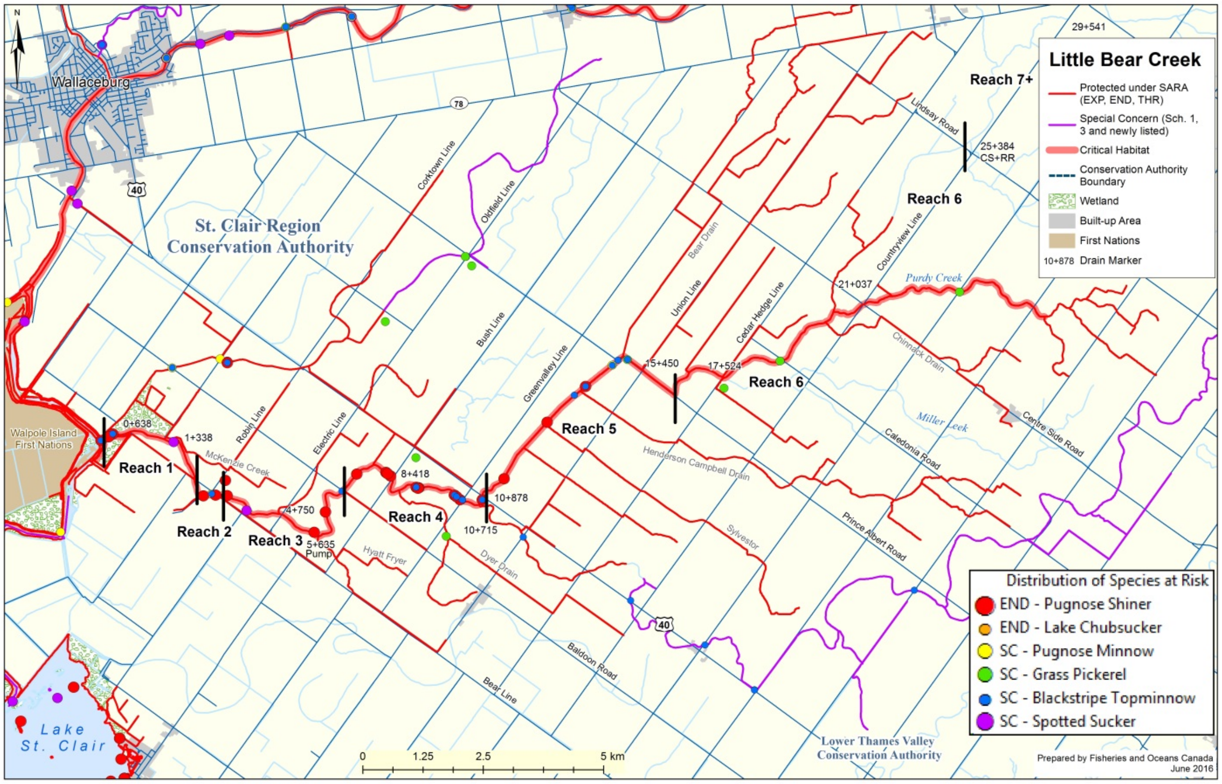

Figure 1. Little Bear Creek reaches (as defined by DFO) where drain maintenance has been proposed.

METHODS

For this project, vegetation and bathymetry data were collected and used to develop a predictive vegetation model in Little Bear Creek. Fish data were also collected to better understand the distribution and abundance of fish species at risk in Little Bear Creek, and to infer species-habitat relationships for Pugnose Shiner and Blackstripe Topminnow.

STUDY AREA

Little Bear Creek is a tributary of Lake St. Clair located in southwestern Ontario. It passes through the geographic townships of Dover, Chatham, and Camden, all located within the municipality of Chatham-Kent (Figure 1). The drain was originally constructed prior to 1886 and has since undergone drain maintenance (major repairs and improvement) twice, in 1919 and 1972. The Little Bear Creek drain is a permanent waterbody that collects water from the surrounding agricultural farmland through subsurface pipes known as tile drains. Little Bear Creek also serves as an outlet to several larger tributaries: Big Creek Drain, Sylvester Drain, Campbell Henderson Drain, Miller and Leak Drain, Purdie Creek Drain, and Danforth Creek Drain.

VEGETATION SURVEY

A vegetation survey was conducted from August 4 to 11, 2014 (Wiklund 2015). Twenty-five sites were sampled, each divided into one to three transects, and each transect was divided into 0.5 m^2 quadrats (n = 405). Stream width (m) was recorded at each transect. Water depth (m), water clarity (PAR), and coverage (%) of each macrophyte species, bare sediments, and detritus were recorded per quadrat. The coverage of each species per quadrat was measured independently of one another. Therefore, values can exceed 100% given the presence of two or more vegetation categories (e.g., emergent and floating) within a quadrat. For complete details of the vegetation survey see Wiklund (2015).

FISH AND HABITAT SURVEY

Fish data were collected from reaches 1-5 (Figure 1) during 2013 and 2015. In 2013, 26 sites were sampled. Five sites were sampled with a large pelagic Mamou trawl (3 m, 38 mm mesh), 16 with a small pelagic Mamou trawl (2.4 m, 38 mm mesh), and five with a bag seine (3 mm bag mesh, 3 mm wing mesh, 10 m length). At each site, three hauls were completed. In the summer of 2015, 51 sites were sampled with a large pelagic Mamou trawl, with three hauls per site. Sites were chosen with a stratified-random sampling approach. This was based on depths < 1.825 m and > 1.825 m, representative of the anticipated presence and absence of vegetation, respectively. Of the 51 sites sampled in summer 2015, 30 were randomly chosen and sampled in fall 2015. Each site was sampled using a large pelagic Mamou trawl and a Siamese trawl (4 m, 19 mm outer mesh, 4 mm inner mesh), one haul per gear type. For complete details of the 2015 trawling gear and methods see Reid et al. (2016).

At each site, counts of each fish species and habitat information were recorded. Habitat information included: proportion of submerged, emergent, and floating vegetation; turbidity (NTU); velocity (m/s); and, water depth (m). In summer 2015, three channel widths were recorded per site determine how much variation exists between field and GIS measured channel widths.

BATHYMETRY SURVEY AND ANALYSIS

A bathymetric survey of Little Bear Creek was conducted June 2–3, 2015 (Milne 2015). Data were collected using a Kongsberg-Mesotech Ltd. M3 multi-mode multibeam sonar system. Approximately 11 km of the creek was surveyed from the mouth (0 km) to highway 40 (10.87 km). For complete details of survey methods see Milne (2015).

The Convert to Raster tool in ArcGIS (v10.3.2) was used to present the bathymetry model as a raster layer of 0.5 x 0.5 m cell size (for a total area of 0.22 km^2). Mean depths were assigned to each cell. Depths were then converted to elevation to compare to the proposed elevations in the drainage report provided by the proponent. Elevation per cell was calculated by subtracting the depth per cell from the average elevation of Little Bear Creek. First, the average water surface elevation of Little Bear Creek was calculated using altitude data from the bathymetry survey. Altitude data with a ‘GPS_Mode’ of 4 and 5 (indicative of good quality bathymetry surveys) were extracted from the layer ‘GPGGA_From_RAWFile.shp’ (Milne 2015). These altitude data were corrected using data from the Hemisphere VS110 GPS (RTK), which was mounted on the vessel during the surveys (Figure 2).

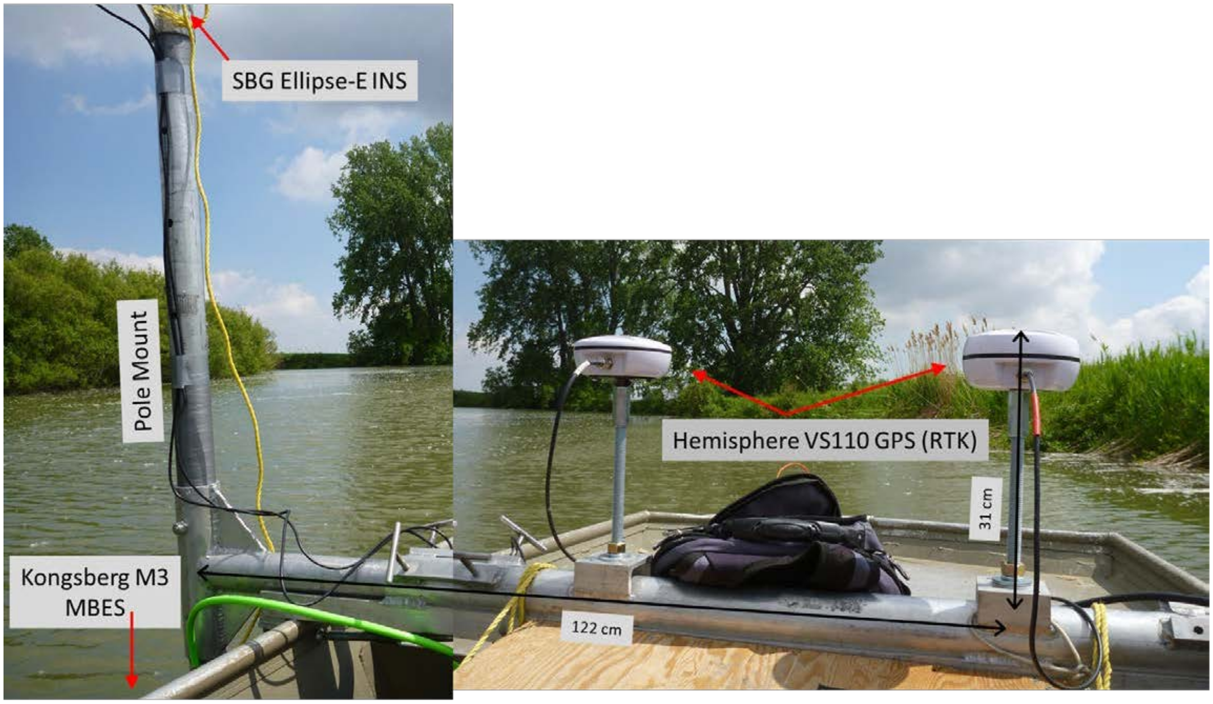

Figure 2. The position of the Hemisphere VS110 GPS (RTK) in the boat used to correct the elevation data collected from the bathymetry survey.

The distance from the GPS to the water surface (75 cm) was subtracted from the altitude data and averaged per bathymetry survey section (Table 1). Survey section 3 was removed due to an error in the data. Survey section 6 was removed due to a low value inconsistent with the anticipated grade of the channel at that reach. The remaining four reaches were used to calculate the average surface water elevation of Little Bear Creek (Table 1). Elevation per raster cell was then calculated by subtracting the depth per cell from the average surface water elevation of Little Bear Creek.

Table 1. Average elevation and standard deviation of each bathymetry survey section (Milne 2015).Survey sections refer to sections of Little Bear Creek where bathymetry data were collected.

Survey Section	Description (km from mouth)	Average elevation	Standard deviation
1	0 (Mouth) to 2.518 (Bear Line Bridge)	174.23	1.88
2	2.518 to 4.734 (Electric Line)	174.02	0.41
3	4.736 (Electric Line) to 7.097 (Baldoon Road)	181.88	0.04
4	7.098 (Baldoon Road) to 8.4145 (Bush Line)	174.43	0.28
5	8.4145 (Bush Line) to 10.329 (Greenvalley Line)	174.33	3.91
6	10.329 (Greenvalley Line) to 10.870 (Hwy 40)	173.35	0.19
	Total Average =	174.25	

Due to spatial inconsistencies between the bathymetry raster layer and the outline of Little Bear Creek from the National Hydro Network a modified channel outline was adopted from the bathymetry report (Milne 2015). The average difference between the channel width extrapolated from the modified channel outline in GIS, and the channel width measured in summer 2015 was 5.7 m. The distance from the mouth of the creek (m) was measured in ArcGIS (v.10.3.2) using a 1 m polyline down the axis of the modified channel outline.

VEGETATION MODEL

Model Development

A predictive vegetation model specific to Little Bear Creek was developed based on data from the vegetation survey (Wiklund 2015). Total vegetation (% coverage) was modelled as a function of water depth (m), channel slope (°), and distance from the mouth of the creek (m). Width was not used as a predictor variable in the vegetation model due to the high level of variation between the modified channel layer and field measurements.

The vegetation model was developed using Regression Tree Analysis (RTA) with the package tree v 1.0-33 (Ripley 2012) in R v.2.15.3 (R Core Team 2013). RTA is a machine-learning modeling approach that constructs a tree based on binary recursive partitioning (Franklin 2009). The constructed tree contains a set of splitting criterion based on threshold values of the predictors, which are used to classify observations of the response variables into the appropriate node (Franklin 2009). The observations used to build this model were continuous and, therefore, the response function of the terminal node represents an average value (i.e., average % cover of vegetation). Vegetation data were randomly partitioned into 70% training and 30% testing datasets. A complete tree was constructed with the training data and further pruned with a 10-fold cross validation. The model was pruned based on the most parsimonious tree (i.e., the greatest deviance explained with the fewest number of terminal nodes).

Model Evaluation

The pruned model was used to make predictions across the test dataset, which was compared against actual values. To analyze the continuous response variables, a linear regression was used to model predicted values against actual values. Model performance was evaluated with an R^2 value. Both predicted and actual values were then converted to binary outcomes (assigned a 1 if > 50% and a 0 if <50%) to evaluate the prediction error. Prediction error was analyzed using a confusion matrix and the AUC (area under the receiver-operating curve) with the package ROCR in R (Sing et al. 2013). AUC values range from 0.5 (model performance is no better than random) to 1.0 (perfect model performance), with a score of 0.7 or higher representative of good predictive power (Keller et al. 2007).

Model Application

The vegetation model was used to predict suitable habitat for two of the six fish species at risk in Little Bear Creek, Pugnose Shiner and Blackstripe Topminnow. The other species at risk were not modeled because there were insufficient non-zero species counts to inform the species-habitat relationship. The relationship between each species and vegetation cover was tested using regression tree analysis (Figure 3).

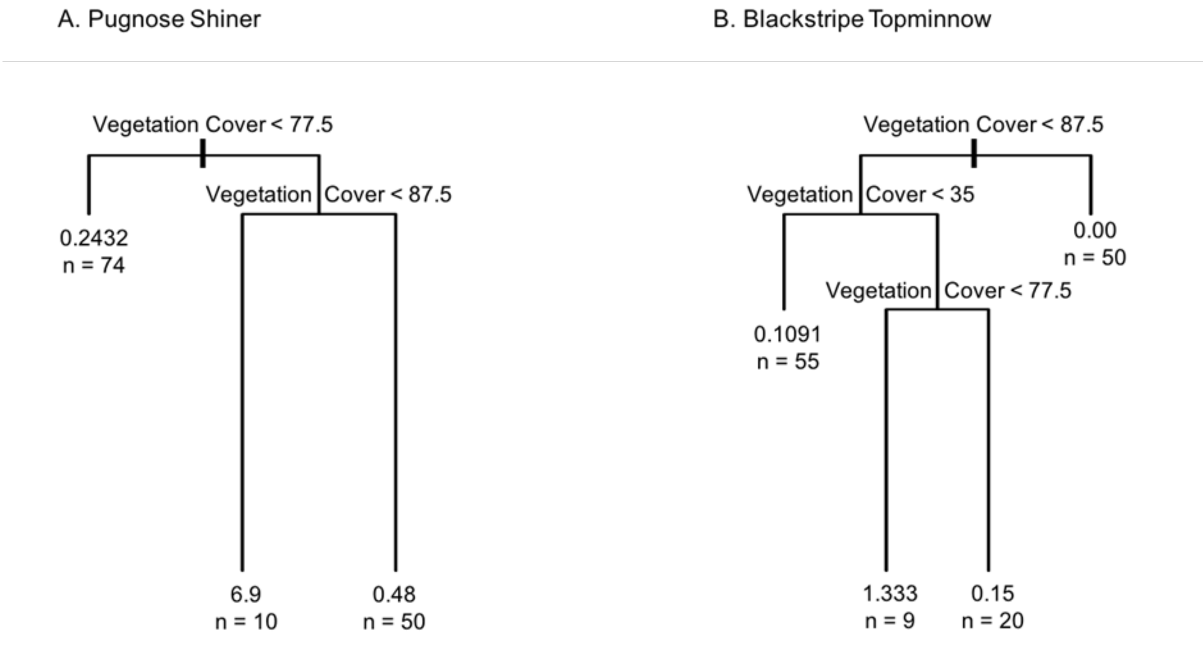

Figure 3. Most parsimonious regression trees for (a) vegetation cover and the Pugnose Shiner and (b) vegetation cover and the Blackstripe Topminnow. Branch lengths are proportional to deviance explained. Response functions represent the average species abundance and total number of data points in the terminal node (n).

Both Pugnose Shiner and Blackstripe Topminnow have a strong preference for well-vegetated habitats (COSEWIC 2012, 2013; DFO 2012; McCusker et al. 2014). The recovery strategy for Pugnose Shiner lists dense submerged vegetation as Critical Habitat for the survival throughout each life stage [spawn, young-of-the-year (YOY), adult] (DFO 2012). Similar to Pugnose Shiner, Blackstripe Topminnow requires aquatic macrophytes for reproductive success (COSEWIC 2012). Submerged and emergent vegetation are listed as preferred habitat in the management plan for Blackstripe Topminnow (Edwards and Staton 2009).

Based on preliminary analysis, a literature review, and expert opinion, it was interpreted that both Pugnose Shiner and Blackstripe Topminnow prefer well-vegetated habitat (> 50% coverage) over open water habitat (COSEWIC 2012, 2013; DFO 2012; Edwards and Staton 2009; McCusker et al. 2014). The vegetation model was forecast across Little Bear Creek and predicted total vegetation cover > 50% was considered suitable habitat for the Pugnose Shiner and Blackstripe Topminnow. The predicted layer was represented as a raster cell (0.25 m^2) to calculate the total area of suitable habitat (ASH) as predicted by the model.

SCENARIOS

The amount of suitable habitat in Little Bear Creek available to Pugnose Shiner and Blackstripe Topminnow was assessed under three scenarios:

1. no drain maintenance;
2. the initial drain maintenance proposal (Table 2); and,
3. the revised proposal (Table 3).

In the revised proposal, all bottom elevations and grade remain the same. Changes are proposed to the bottom widths and side slope. The objective of the revised proposal was to reduce the amount of area along the edges of the creek that would be impacted by maintenance. The decision to salvage habitat along the edge of the creek was based on general observations of increased vegetation in those regions.

Table 2. The proposed bottom elevations, bottom widths, and side slopes from the initial drain maintenance proposal submitted by the proponent.

Start station (m from the mouth)	Start bottom elevation	End station (m from the mouth)	End bottom elevation	Grade	Bottom width	Side slope
0 m	172.100	10950 m	173.219	0.01 m/100 m	18.3 m	1:1
10950 m	173.219	17600 m	174.549	0.02 m/100 m	12.2 m	1:1
17600 m	174.549	19050 m	174.839	0.02 m/100 m	9.1 m	1:1
19050 m	174.839	20450 m	175.121	0.02 m/100 m	9 m	1:1
20450 m	175.121	25198 m	176.542	0.03 m/100 m	7.62 m	1:1

Table 3. The revised bottom widths and side slope from the revised drain maintenance proposal submitted by the proponent.

Start station (m from the mouth)	End station (m from the mouth)	Initial proposed bottom width	Revised bottom width	Side Slope
0 m	8418 m	18.3 m	18.3 m	2:1
8418 m	10715 m	18.3 m	16 m	2:1
10715 m	15450 m	12.2 m	9 m	2:1
15450 m	16200 m	12.2 m	8 m	2:1

The impact of each scenario was evaluated in four steps:

1. The vegetation model was used to quantify the amount of suitable habitat currently in Little Bear Creek.
2. Based on the parameters in the initial and revised proposals (Tables 2 and 3), a GIS layer was created to represent the area of proposed drain maintenance.
3. The amount of suitable habitat within the proposed dredged layer was measured.
4. The size and number of suitable habitat patches, and the distance to the nearest patch, before and after drain maintenance, were compared.

To create a layer of proposed drain maintenance in GIS, the tool ‘Create Parallel Lines’ was used to create a polyline at a given width (according to the respective proposals in Tables 2 and 3) on both sides of the axis of the creek. Predicted suitable habitat that fell within the proposed drain maintenance layers was identified by location and exported as a new shapefile. The shape file was converted to a raster cell (0.25 m^2) to calculate the total ASH lost and conserved after drain maintenance under all three scenarios. Suitable habitat that would be removed by drain maintenance was classified as one of two types: permanently lost suitable habitat; or, temporarily lost suitable habitat (Figure 4). Suitable habitat was classified as permanently lost if the resultant bottom elevation, after drain maintenance, was deeper than 172.825 m in elevation (1.425 m water depth). The vegetation model would predict this area to be suitable habitat before maintenance and non-suitable habitat after maintenance. Suitable habitat was classified as temporarily lost if the resultant bottom elevation was not deeper than 172.825 m in elevation (1.425 m water depth). The vegetation model would predict this area to be suitable habitat before and after drain maintenance.

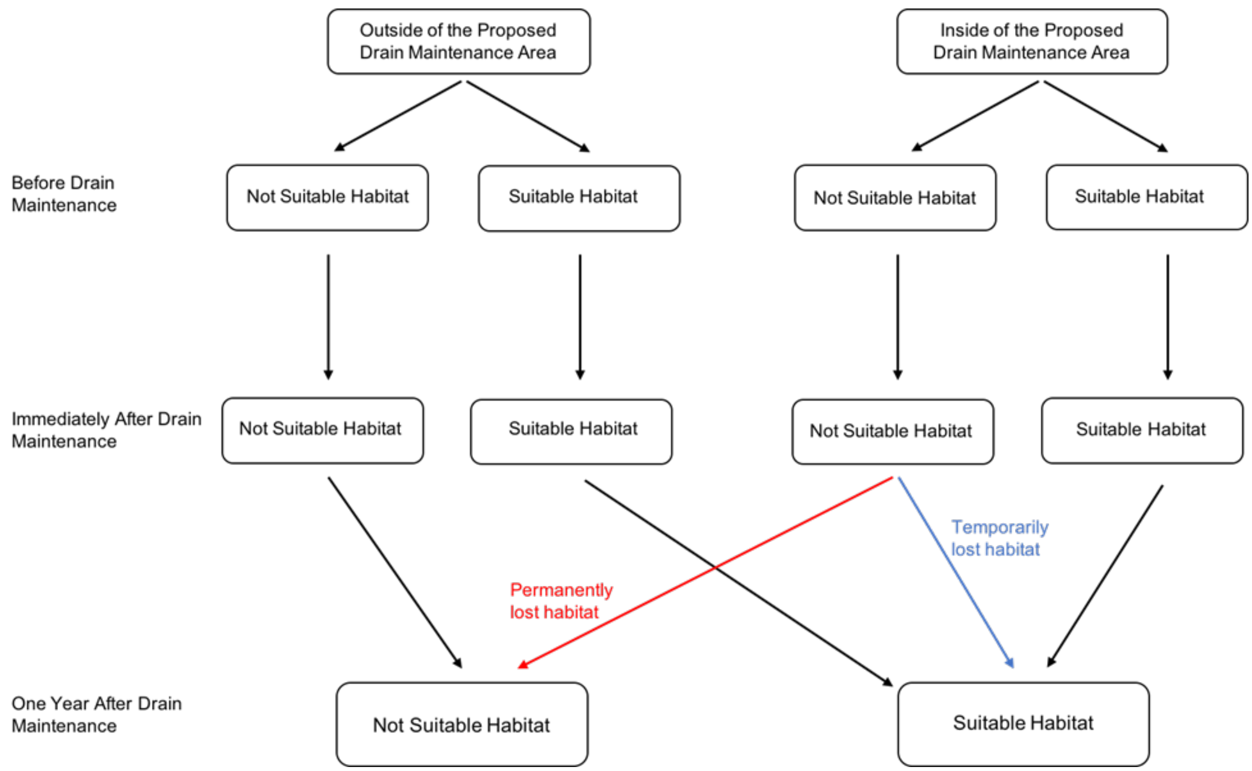

Figure 4. Concept map used to assess the impact of proposed drain maintenance on suitable habitat in Little Bear Creek.

The “Region Group” tool in ArcGIS (v.10.3.2) was used to identify the number of discrete suitable habitat patches given in all three scenarios. Discrete habitat patches were defined as > 0.5 m (in any direction) away from another raster cell. The “Near” tool was then used to evaluate the nearest distance (m) between each suitable habitat patch. To determine biologically distinct habitat patches, we considered the home range length of Pugnose Shiner and Blackstripe Topminnow. The home range (HR) for the Pugnose Shiner and Blackstripe Topminnow was calculated based on the Minns (1995) method:

$$\text{Log}_e\, HR = -2.907 + 1.651 \log_e L_{mm} + 3.137 * HAB$$

Where L_{mm} = body size, and HAB is a dummy variable for the habitat type (1 = lentic, 0 = lotic). Based on a mean width of 29.23 m and stagnant stream flow, Little Bear Creek was considered a lentic habitat. The HR length for both species was calculated as 27.48 m, using the following equation:

$$\text{HR length} = \text{HR} / \text{mean width of Little Bear Creek}$$

Habitat patches greater than the HR length (27.48 m) were considered biologically distinct patches. Significant differences in average patch size and distance to the nearest patch were assessed using the non-parametric Kruskal-Wallis Rank Sum Test using the package stats in R(R Core Team 2013).

RESULTS

SPECIES AT RISK

Four species at risk (139 individuals), Pugnose Shiner, Lake Chubsucker, Blackstripe Topminnow, and Grass Pickerel, were captured from Little Bear Creek in 2013 and 2015 (Table 4). Pugnose Shiner and Blackstripe Topminnow were the most abundant fish species at risk. Pugnose Shiner occurred at 20% of the sampled sites and Blackstripe Topminnow at 11.7% of the sampled sites. Blackstripe Topminnow was found in reaches 3–5, whereas, Pugnose Shiner was found in all sampled reaches (Figure 1).

Table 4. Species at risk captured in Little Bear Creek 2013 and 2015 field surveys .[1]SARA (Species at Risk Act*) status is from the SARA registry.*

Common name	Scientific name	SARA status[1]	Number captured
Pugnose Shiner	*Notropis anogenus*	Endangered	111
Lake Chubsucker	*Erimyzon sucetta*	Endangered	2
Blackstripe Topminnow	*Fundulus notatus*	Special Concern	23
Grass Pickerel	*Esox americanus vermiculatus*	Special Concern	3

VEGETATION MODEL

The full classification tree for the vegetation model identified 12 terminal nodes and two predictor variables (depth and distance from the mouth of the creek). Depth was identified as the most important predictor of vegetation cover. Following cross-validation, the most parsimonious model contained four terminal nodes (Figure 5). The splitting criterion that explains the most deviance (as represented by the length of the branch) is depths < 1.425 m. All terminal nodes after depths < 1.425 m had a mean total vegetation cover > 50% and, therefore, were considered suitable habitat. All terminal nodes > 1.425 m had an average total vegetation cover < 50% and, therefore, were considered non-suitable habitat. A water depth of 1.425 m is equivalent to an elevation of 172.825 m.

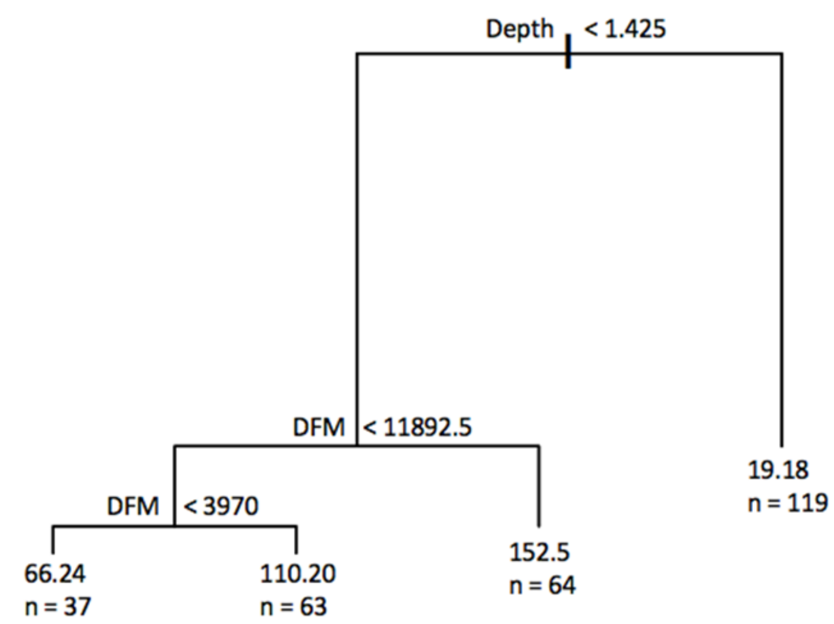

Figure 5. Most parsimonious regression tree of total vegetation cover (%) as a function of water depth (m) and distance from the mouth (DFM; m) of the creek. Branch lengths are proportional to deviance explained. Response functions represent the average total vegetation cover (%) and total number of data points in the terminal node (n).

The best fit, most parsimonious model has an R^2 value of 0.52. The moderately high AUC value (0.75) suggests that the model has good predictive performance. Specifically, the model is best able to predict the presence of suitable habitat with a true positive rate of 78% and the presence of non-suitable habitat with a true negative rate of 70% (Figure 6).

Predicted Vegetation

Actual Vegetation		**Suitable Habitat**	**Non Suitable Habitat**
	Suitable Habitat	True Positive Rate 0.78	False Negative Rate 0.22
	Non Suitable Habitat	False Positive Rate 0.3	True Negative Rate 0.7

Figure 6. Confusion matrix of predicted versus actual vegetation. Model sensitivity (true positive rate) and specificity (true negative rate) are shown.

PREDICTED SUITABLE HABITAT

The vegetation model predicted 0.032 km^2 of habitat suitable for Pugnose Shiner and Blackstripe Topminnow along Little Bear Creek (see Figure 7 for an example of predicted suitable habitat in Little Bear Creek).

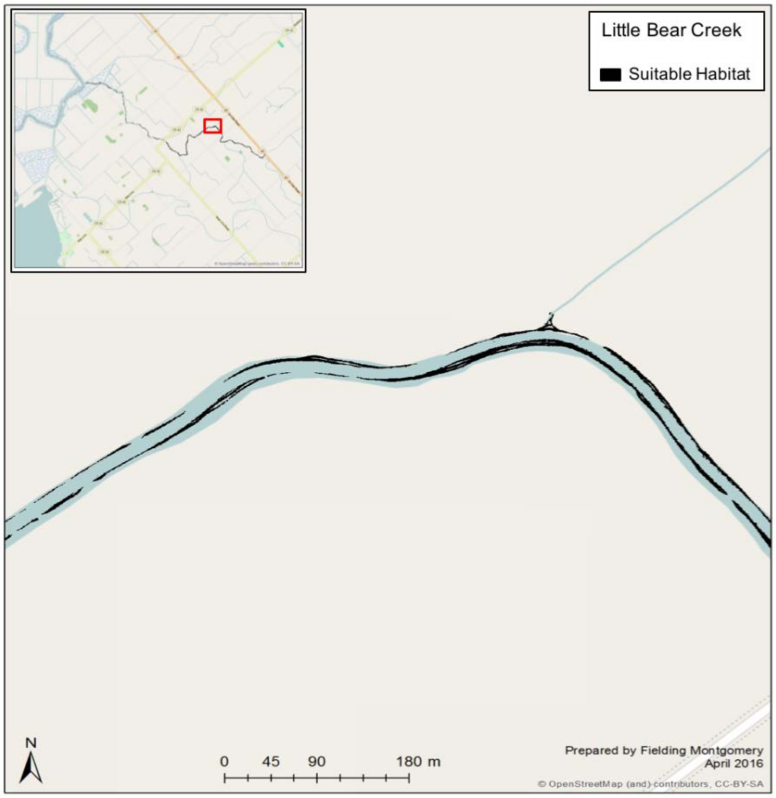

Figure 7. Example of suitable habitat (outlined in black) present in Little Bear Creek before drain maintenance.

Predicted habitat makes up 15% of the 0.22 km^2 area surveyed. The bathymetry survey covered only 59% of the modified channel outline (0.37 km^2). Non-surveyed areas in Little Bear Creek include: area along the periphery, below highway 40; and, all area of the creek above highway 40. Based on field observations, these regions are all likely < 1.425 m deep (Figure 8). Although there is likely suitable habitat, the area of suitable habitat in these regions cannot be accurately quantified.

Figure 8. Photo looking south/downstream from Prince Albert Road towards highway 40.

Under both the initial and revised scenarios, the ASH is anticipated to decrease permanently by 19%. Under the initial drain maintenance, 42% of the suitable habitat will be temporarily lost, compared to 40% in the revised drain maintenance (Table 5). Under the initial and revised scenarios, the number of suitable habitat patches is expected to permanently decrease by 35% and 31%, respectively.

Table 5. Estimated total area of suitable habitat (ASH) for Pugnose Shiner and Blackstripe Topminnow lost and conserved under three drain maintenance scenarios.

Scenario	ASH before drain maintenance	ASH after drain maintenance							
		Permanently lost		Temporarily lost		Conserved without regrowth of temporarily lost habitat		Conserved with regrowth of temporarily lost habitat	
		km^2	%	km^2	%	km^2	%	km^2	%
No drain maintenance	0.032	0	0	0	0	0.032	100	0.032	100
Initial drain maintenance	0.032	0.0062	19	0.0135	42	0.0123	38	0.0258	80
Revised drain maintenance	0.032	0.0062	19	0.0129	40	0.0129	40	0.0268	80

There were no significant differences in average patch size (p = 0.98) and distance to the nearest patch (p = 0.38) of biologically distinct habitat patches, among scenarios (Figures 9 and 10). While the number of biologically distinct habitat patches does not vary greatly, there is a five-fold increase in the maximum distance to the nearest habitat patch following any form of drain maintenance (Figure 9).

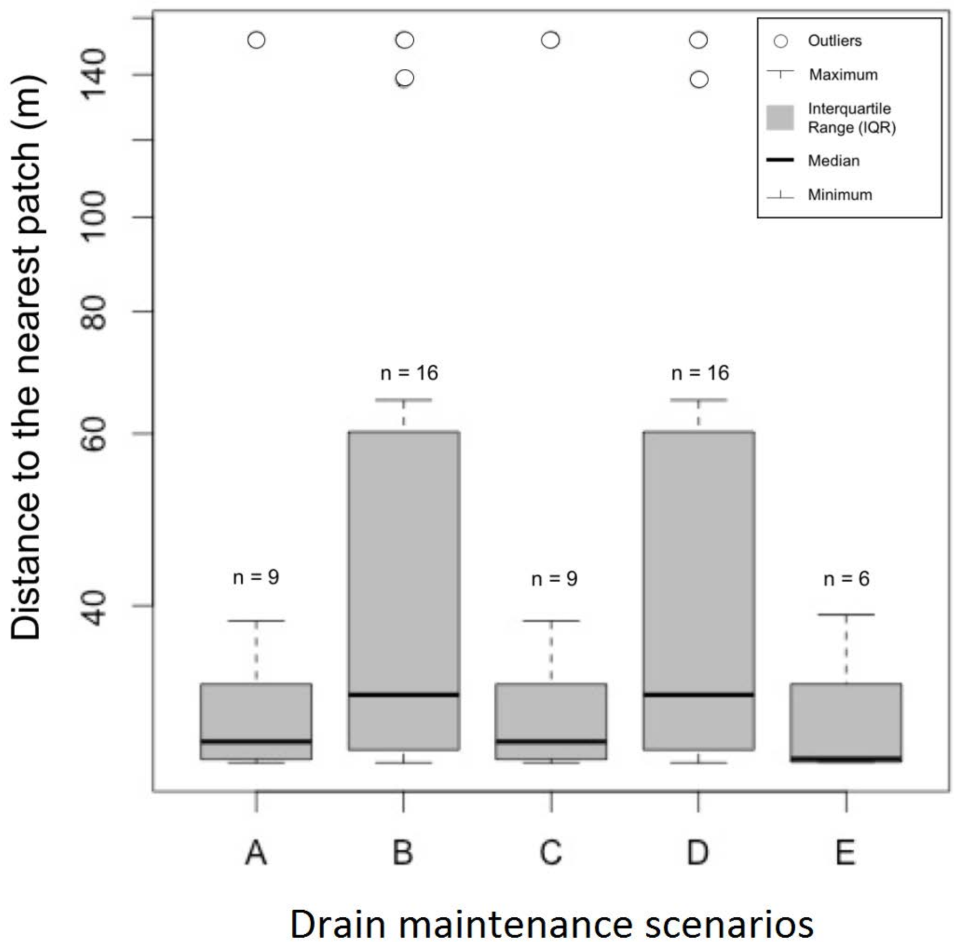

Figure 9. Distance to the nearest patch (m) for biologically distinct patches analyzed under five scenarios: (A) habitat patches after the initial drain maintenance proposal; (B) habitat patches if regrowth occurs after the initial drain maintenance; (C) habitat patches after the revised drain maintenance; (D) habitat patches if regrowth occurs after the revised drain maintenance and, (E) habitat patches after no drain maintenance. Plotted on a log y-axis.

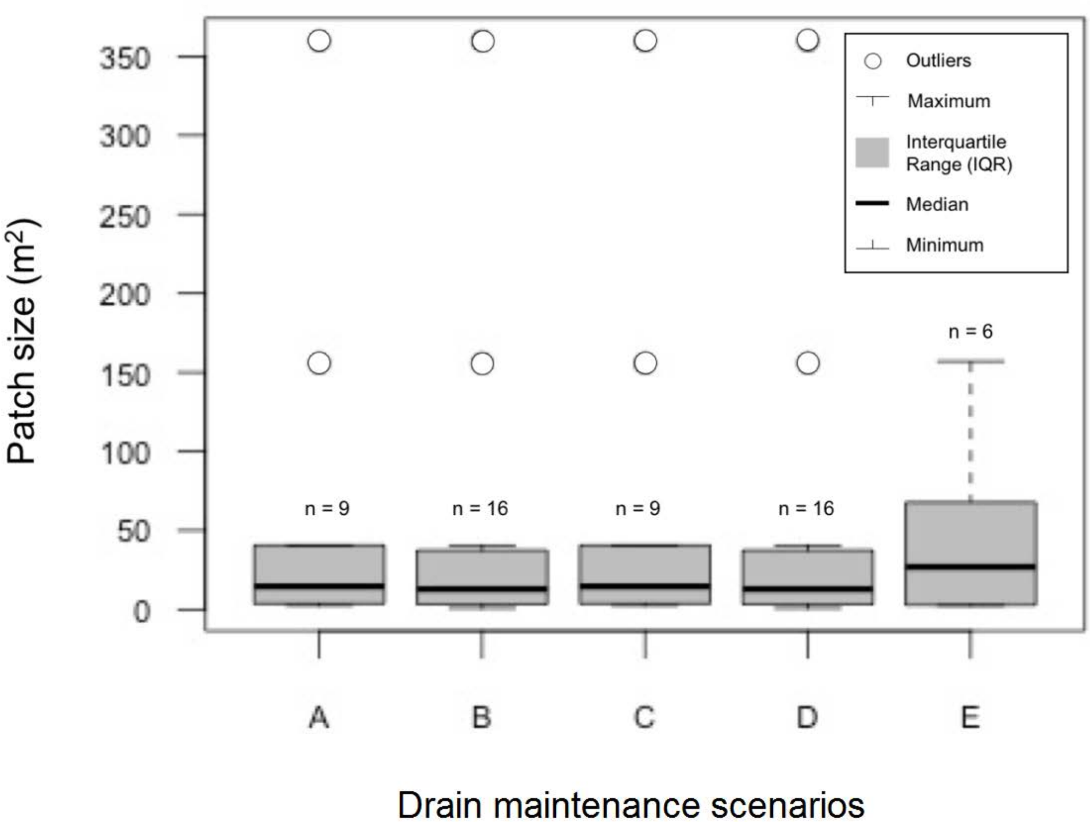

Figure 10. Patch size (m^2) of biologically distinct patches analyzed under five scenarios: (A) habitat patches after the initial drain maintenance proposal; (B) habitat patches if regrowth occurs after the initial drain maintenance; (C) habitat patches after the revised drain maintenance; (D) habitat patches if regrowth occurs after the revised drain maintenance and, (E) habitat patches after no drain maintenance.

DISCUSSION

IMPACTS TO SPECIES AT RISK

Determine the impacts that the proposed maintenance would have on species at risk fishes in Little Bear Creek

Under the initial proposal submitted by the proponent (Table 2), approximately 61% of predicted suitable habitat in Little Bear Creek (0.032 km^2) will be impacted by drain maintenance. The amount of remaining suitable habitat (0.0123 km^2) will be less than the minimum area for population viability (MAPV) for Pugnose Shiner (0.015 km^2) (Venturelli et al. 2010), but greater than the MAPV for Blackstripe Topminnow (0.003 km^2) (Malcolm 2015) (Table 6). Through the direct removal of well-vegetated habitat, drain maintenance will result in a permanent decrease of suitable habitat of 19%. The predicted loss of suitable habitat will put the survival and recovery of the Pugnose Shiner population in Little Bear Creek at risk. The lack of habitat models prevents similar impacts assessments for other fish species at risk in Little Bear Creek.

Table 6. Minimum area for population viability (MAPV) estimates for the Pugnose Shiner (Venturelli et al. 2010) and Blackstripe Topminnow (Malcolm 2015). The area per individual (API) and minimum viable population (MVP) estimates are also reported. Due to data limitations, the API, MVP, and MAPV estimates for the Blackstripe Topminnow YOY are not available (NA).

Species	Life Stage	API	MVP	MAPV (km^2)
Pugnose Shiner	Adult	0.2	14325	0.0028
	YOY	0.01	1231237	0.012
Blackstripe Topminnow	Adult	0.15	1161	0.0029
	YOY	NA	NA	NA

There are several important assumptions related to interpreting the results of the modelling exercise. First, it was assumed that no individuals are directly removed, killed, or harmed in any way that would affect survival. The assumption will be best met through proper mitigation, such as seasonal timing windows and fish-exclusion techniques (DFO 2015). However, if the assumption is not met, drain maintenance impacts to Pugnose Shiner and Blackstripe Topminnow populations would be greater than those predicted from habitat loss exclusively.

The second modelling assumption is that any aquatic vegetation removed from areas less than 1.425 m deep will grow back in the next growing season. The likelihood of macrophyte colonization and re-establishment in the growing season following drain maintenance depends on the regenerative strategy of the species in the macrophyte community (Vári 2012). With the exception of Slender Naiad (*Najas flexilis*), all macrophyte species in Little Bear Creek observed in the vegetation survey are perennial. In a perennial life cycle, seeds can be produced every one or two years. If, after one year, the above ground portion dies, then the below ground portion will remain dormant and sprout the following growing season (Rohde and Bhalerao 2007). If the below ground root system is removed during drain maintenance, the probability of recolonization will be greatly reduced. In this case, the presence of seed banks (from the accumulation of seeds that do not germinate), play an important role in re-establishment following extreme local disturbance (Van Wijk 1989). If the recolonization assumption is met, 0.0135 km^2 of suitable habitat is predicted to grow back. ASH would exceed MAPV estimates for Pugnose Shiner and Blackstripe Topminnow. However, we must also assume that enough Pugnose Shiner and Blackstripe Topminnow can survive after drain maintenance, in order to populate the suitable habitat after vegetation reestablishes. If the recolonization of macrophytes is delayed, or mortality of species at risk fishes occurs due to maintenance activities, this assumption may not be met.

The lack of bathymetric data available to model the impact of drain maintenance to fish habitat above Highway 40 (Figure 1) is a knowledge gap. Field observations indicate that habitat is less than 1.425 m deep across the width of the creek and, therefore, contains suitable vegetative cover (Figure 8). Despite habitat protection along the creek edges (as identified in the initial and revised proposals), a large amount of habitat would be dredged from the middle of the creek. However, compared to other reaches modelled in this study, the reach above Highway 40 is predicted to be less vulnerable to permanent habitat loss. In both initial and revised scenarios, proposed drain maintenance will result in a bottom depth < 1.425 m. Therefore, habitat alterations should be temporary.

ALTERNATIVES TO DREDGING

Provide alternative maintenance scenarios and determine the impact they may have on species at risk fishes in Little Bear Creek

No drain maintenance

If no drain maintenance is performed in Little Bear Creek, there would be 0.032 km^2 of suitable habitat. The predicted amount of suitable habitat exceeds the MAPV for both Pugnose Shiner and Blackstripe Topminnow. Drain maintenance can result in direct removal of aquatic vegetation and increased turbidity, both major threats to Pugnose Shiner (Gray et al. 2014). Both threats would be avoided if no maintenance occurred.

Revised drain maintenance

Under the revised drain maintenance proposal submitted by the proponent (Table 3), approximately 59% of suitable habitat in Little Bear Creek will be impacted (Table 5). The revised proposal would conserve 2% more suitable habitat than the initial drain maintenance proposal. However, neither the initial nor the revised proposal protects enough habitat to meet the MAPV target for Pugnose Shiner.

For small-bodied fishes, like Pugnose Shiner and Blackstripe Topminnow, reduced size and connectivity between habitat patches can greatly impact the likelihood of survival (Levin et al. 2000). Removal of suitable habitat after the revised drain maintenance will result in a five-fold increase in the maximum nearest distance between biologically distinct patches (Figure 9). The revised drain maintenance scenario will isolate a large patch of habitat (360 m^2) from the next nearest habitat patch by 152 m. If Pugnose Shiner and Blackstripe Topminnow populations are lost after drain maintenance, habitat patches at a distance greater than their home range are at risk of not being recolonized.

To ensure Pugnose Shiner and Blackstripe Topminnow population viability, the amount of habitat permanently lost would need to be greatly reduced. Based on proposed bottom elevations in both maintenance scenarios, habitat along the creek within 7.2 km of its confluence with Chenal Ecarte will be dredged deeper than 1.425 m and is predicted to be permanently lost. To reduce the amount of habitat permanently lost along this reach of Little Bear Creek, the width of the bottom of the creek to be dredged should be reduced. Decreasing the bottom width from 18.3 m would allow for larger areas along the edge of the creek with suitable habitat. Larger patches of habitat (and connectivity between patches) along the edges of the creek would be preserved.

ADDITIONAL MITIGATION MEASURES

Provide mitigation measures that could be used to minimize the impacts of maintenance on species at risk fishes in Little Bear Creek

For suggested mitigation measures to minimize the impacts of maintenance we refer to Coker et al. (2010). The in-water activities Pathways of Effect (PoE) relevant to the proposed drain maintenance are:

1. dredging pathway (11);
2. addition or removal of aquatic vegetation (15); and,
3. flow management pathway (16).

Within the dredging pathway refer to the link 11-1 (change in channel morphology or shoreline morphology) and 11-8 (change in aquatic macrophytes/vegetation). For the addition or removal of aquatic vegetation all mitigation measures should be considered as they pertain to the removal of aquatic vegetation. Lastly, mitigation measures for links 16-1 to 16-3 within the flow management pathway should be considered.

OFFSETTING SCENARIOS

Provide offsetting scenarios (qualitative) for each alternative drain maintenance scenario

When potential impacts cannot be avoided or fully mitigated, the residual effects may be offset by activities to maintain or increase fisheries productivity. Loughlin and Clarke (2014) reviewed methods used to offset residual impacts of development projects on fisheries productivity and classified those methods as:

- physical habitat manipulations including habitat restoration, rehabilitation, enhancement, and creation;
- biological manipulations such as stocking;
- and, chemical manipulations such as nutrient alteration.

Using spatially explicit population viability analyses, McCusker et al. (in revision) examined the potential effectiveness of these offsetting options for Pugnose Shiner in the St. Lawrence River under scenarios of habitat loss related to vegetation removal. Specifically, they explored the potential for offsetting habitat loss by:

1. habitat manipulation - increasing habitat elsewhere or increasing connectivity; and,
2. biological manipulation - increasing vital rates or increasing abundance through a single introduction.

Although this study was conducted on Pugnose Shiner populations from the St. Lawrence River, and the spatial scale and populations sizes differ from those of Little Bear Creek, results from the application of offsetting options can be considered.

McCusker et al. (in revision) concluded that habitat loss is best compensated with habitat gain, provided the restored habitat is of a similar quality to the habitat lost and the new habitat is accessible within an appropriate timeframe (Bekessy et al. 2010). In the Pugnose Shiner, a sustainable population has been identified as one that exceeds 2,000 adults (Venturelli et al. 2010), and the amount of habitat required to ensure a sustainable population will vary with vital rates, stochasticity of vital rates, catastrophe severity and probability, and Allee effects. To avoid offsetting a source population with a sink population, they recommended that habitat gain should occur within a patch of similar size and quality to the patch where habitat was lost. In Little Bear Creek, using this approach would require establishing new areas of suitable habitat, at a minimum, equal in area to the habitat lost, accessible to Pugnose Shiner, or to which Pugnose Shiner are translocated in sufficient numbers (e.g., >2,000 adults).

McCusker et al. (in revision) concluded that offsetting habitat loss with an increase in vital rates would have a relatively high chance of success, if the species is below carrying capacity and limited by growth rates. Specifically, the benefit to population viability of increasing vital rates (e.g., removing predators or competitors) has an upper limit because the carrying capacity remains unchanged. In Little Bear Creek, this would be difficult to do as the potential predators and competitors are native and abundant. In contrast, increasing carrying capacity (e.g., habitat availability) has no upper limit as an increase in carrying capacity will result in a proportional increase in abundance.

McCusker et al. (in revision) concluded that the effectiveness of increasing connectivity among habitat patches was dependent on dispersal potential, spatial arrangement and amount of suitable habitat, and the stability of subpopulations in the system. If subpopulations are continuously extirpated and re-established by dispersal, connectivity may increase the final abundance of the metapopulation. However, if most habitat patches are stable, if dispersal potential is low, or if most subpopulations are very small, then increasing connectivity will not compensate for habitat loss. In Little Bear Creek, the dispersal potential of most fish species at risk is low and the subpopulations in the habitat patches is expected to be low after drain maintenance; therefore, increasing connectivity between remaining habitat patches is unlikely to increase abundance greater than the simple gain of habitat in the connected areas.

McCusker et al. (in revision) concluded that compensating habitat loss by stocking has the lowest chance of success of all options examined, especially if strong density dependence exists. Following habitat loss, abundance is likely to be high relative to the remaining carrying capacity and, therefore, stocking is likely to be an ineffective compensation for habitat loss. Standards for offsetting emphasize that biodiversity offsets should be self-sustaining and not require continuous anthropogenic intervention (McKenney and Kiesecker 2010). In Little Bear Creek, abundance may be initially high relative to carrying capacity, but if the loss of habitat persists for more than a generation (1–2 years), then the abundance may decrease dramatically due to natural and anthropogenic mortality. Therefore, stocking may be appropriate if habitat regeneration is slower than the generation time of Pugnose Shiner. Using brood stock from Little Bear Creek would be important to maintain the locally adapted genome present prior to it going through the bottleneck of habitat loss. However, culture of the fish species at risk in Little Bear Creek has not been previously undertaken, and the methods and brood stock would have to be developed prior to hatchery production. Possible alternatives to developing hatchery stocks would be to seed a nearby offline pond with fishes from Little Bear Creek or translocate individuals from local extant populations.

As Little Bear Creek is already eutrophic, there is no obvious chemical manipulation option for offsetting.

SUMMARY

- Suitable habitat for the Pugnose Shiner and Blackstripe Topminnow was predicted at depths < 1.425 m. There is 0.032 km^2 of predicted suitable habitat for the Pugnose Shiner and Blackstripe Topminnow, which exceeds the minimum area for population viability (MAPV) for both species.
- Under both the initial and revised drain maintenance scenarios, 19% of suitable habitat in Little Bear Creek will be permanently lost.
- Under the revised drain maintenance scenario, 40% of suitable habitat will be temporarily lost, 2% less than under the initial drain maintenance scenario. If regrowth of temporarily lost habitat does not occur, the suitable habitat that remains will be less than the MAPV for the Pugnose Shiner.
- To minimize the impacts to drain maintenance in Little Bear Creek, the most relevant mitigation pathway from Coker et al. (2010) is the dredging pathway (link 11.1 and 11.8).

- Habitat loss should be compensated through habitat gain of suitable habitat quality, and made accessible to the species within the first 2-3 years after impact (considering a generation time of 2 years and a maximum age of 3 years).

REFERENCES

Bekessy, S.A., Wintle, B.A., Lindenmayer, D.B., Mccarthy, M.A., Colyvan, M., Burgman, M.A., and Possingham, H.P. 2010. The biodiversity bank cannot be a lending bank. Conserv. Lett. 1: 151–158.

Coker, G.A., Ming, D.L., and Mandrak, N.E. 2010. Mitigation guide for the protection of fishes and fish habitat to accompany the species at risk recovery potential assessments conducted by Fisheries and Oceans Canada (DFO) in Central and Arctic Region. Version 1.0. Can. Manusc. Rep. Fish. Aquat. Sci. 2904. vi + 40 p.

COSEWIC. 2012. COSEWIC assessment and status report on the Blackstripe Topminnow *Fundulus notatus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. ix + 29 p.

COSEWIC. 2013. COSEWIC assessment and status report on the Pugnose Shiner *Notropis anogenus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. x + 32 p.

Dextrase, A.J., Mandrak, N.E., Barnucz, J., Bouvier, L., Gaspardy, R., and Reid, S.M. 2014. Sampling effort required to detect fishes at risk in Ontario. Can. Manuscr.Rep. Fish. Aquat. Sci. 3024: v + 50 p.

DFO. 2012. Recovery strategy for the Pugnose Shiner (*Notropis anogenus*) in Canada. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. x +75 p.

DFO. 2015. Fish exclusion options for aquatic species at risk for drainage activities in Little Bear Creek, Ontario. DFO Can. Sci. Advis. Sec. Sci. Resp. 2015/036.

Edwards, A.L. and S.K. Staton. 2009. Management plan for the Blackstripe Topminnow, Pugnose Minnow, Spotted Sucker and Warmouth in Canada. Species at Risk Act Management Plan Series. Fisheries and Oceans Canada, Ottawa. viii + 43 pp.

Franklin, J. 2009. Mapping species distributions: spatial inference and prediction. Cambridge University Press, Cambridge.

Gray, S.M., Bieber, F.M.E., Mcdonnell, L.H., Chapman, L.J., and Mandrak, N.E. 2014. Experimental evidence for species-specific response to turbidity in imperilled fishes. Aquat. Conserv. 24: 546–560.

Grygoruk, M., Frąk, M., and Chmielewski, A. 2015. Agricultural rivers at risk: dredging results in a loss of macroinvertebrates. Preliminary observations from the Narew Catchment, Poland. Water 7: 4511–4522.

Keller, R.P., Drake, J.M., and Lodge, D.M. 2007. Fecundity as a basis for risk assessment of nonindigenous freshwater molluscs. Conserv. Biol. 21: 191–200.

Levin, P.S., Tolimieri, N., Nicklin, M., and Sale, P.F. 2000. Integrating individual behavior and population ecology: the potential for habitat-dependent population regulation in a reef fish. Behav. Ecol. 11: 565–571.

Loughlin, K.G., and Clarke, K.D. 2014. Review of methods used to offset residual impacts of development projects on fisheries productivity. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/097. vi + 72 p.

Malcolm, G. 2015. An objective method to quantify the location criterion used to classify species at risk in Canada. Thesis (M.Sc.). University of Toronto, Toronto, ON. 56 p.

McCusker, M.R., Mandrak, N.E., Doka, S., Gertzen, E.L., van Wieren, J.F., McKenna, J.E., Carlson, D.M., and Lovejoy, N.R. 2014. Estimating the distribution of the imperiled Pugnose Shiner (*Notropis anogenus*) in the St. Lawrence River using a habitat model. J. Great Lakes Res. 40: 980–988.

McCusker, M.R., Curtis, J.M.R., Lovejoy, N.R. and Mandrak, N.E. (in revision). Exploring uncertainty in population viability analysis and its implications for the conservation of a freshwater fish. Aquat. Conserv.

McKenney, B.A., and Kiesecker, J.M. 2010. Policy development for biodiversity offsets: a review of offset frameworks. Environ. Manage. 45: 165–176.

Milne, S.W. 2015. 2015 Little Bear Creek multibeam bathymetry survey: field notes and data processing methodology. Report prep. for DFO Great Lakes laboratory for Fisheries and Aquatic Science, Burlington, ON. 32 p.

Minns, C.K. 1995. Allometry of home range size in lake and river fishes. Can. J. Fish. Aquat. Sci. 52: 1499–1508.

R Core Team. 2013. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Reid, S.M., LeBaron, A., and Barnucz, J. 2016. Seasonal variation in the composition of fishes caught during trawl-based surveys of Little Bear Creek, Ontario. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/070. v + 16 p.

Ripley B. 2012. tree: classification and regression trees. R package version 1.0-33.

Rohde, A., and Bhalerao, R.P. 2007. Plant dormancy in the perennial context. Trends. Plant. Sci. 12: 217–223.

Sing, T., Sander, O., Beerenwinkel, N. and Lengauer. T. 2005. “ROCR: visualizing classifier performance in R.” Bioinformatics, 21(20), pp. 7881.

Stammler, K.L. 2011. Extent, characteristics and downstream effects of stream enclosure in southwestern Ontario. Thesis (Ph.D.) University of Western Ontario, London, ON. 143 p.

Van Wijk, R.J. 1989. Ecological studies on *Potamogeton pectinatus* L. III. Reproductive strategies and germination ecology. Aquat. Bot. 33: 271–299.

Vári, A. 2012. Propagation and growth of submerged macrophytes in Lake Balaton. Eötvös Loránd University, Hungary. 125 p.

Venturelli, P.A., Vélez-Espino, L.A., and Koops, M.A. 2010. Recovery potential modelling of Pugnose Shiner (*Notropis anogenus*) in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/007. iv + 22 p.

Wiklund, J.A. 2015. Little Bear Creek, Dover & Chatham Townships, Kent County Ontario: aquatic vegetation and fish habitat survey 2014. Report prep. for DFO, Great Lakes laboratory for Fisheries and Aquatic Science, Burlington, ON. 47 p.