Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Research Document 2015/018

Central and Arctic Region

Impacts of dredging on fish species at risk in Lake St. Clair, Ontario

J. Barnucz[1], N.E. Mandrak[2], L.D. Bouvier[1], R. Gaspardy[1] and D.A. Price[1]

[1]Great Lakes Laboratory for Fisheries and Aquatic Sciences
Fisheries and Oceans Canada
P.O. Box 5050, 867 Lakeshore Road
Burlington, Ontario, L7R 4A6

[2]Department of Biological Sciences
University of Toronto Scarborough
1265 Military Trail
Toronto, Ontario, M1C1A4

December 2015

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.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1919-5044

Correct citation for this publication:

Barnucz, J., Mandrak, N.E., Bouvier, L.D., Gaspardy, R., Price, D.A. 2015. Impacts of dredging on fish species at risk in Lake St. Clair, Ontario. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/018. v + 12 p.

TABLE OF CONTENTS

ABSTRACT

This research document aims to provide recommendations and to inform management decisions related to the permitting of dredging activities in the waters of Lake St. Clair, Ontario. In addition, it aims to evaluate the potential impacts of maintenance dredging activities as it relates to fish species at risk. To evaluate the impacts of maintenance dredging Fisheries and Oceans Canada (DFO) Science sampled impact sites (dredged, dredgeate) and reference sites. Impact sites were locations experiencing periodic maintenance dredging and dredgeate disposal. Reference sites were nearby locations of similar depth and substrate with no known prior disturbance from maintenance dredging activities. DFO Science conducted a repeated trawling survey to compare the fish community and fish abundance between impacted and reference sites. The impact sites were paired with nearby reference sites with similar depths and substrate type. No fish species at risk were captured at any impact sites (dredged or dredgeate locations). One Eastern Sand Darter (*Ammocrypta pellucida*) was captured at one reference location. Catch per unit effort (CPUE) was compared between impact and reference treatments for both dredged and dredgeate locations. No significant difference in CPUE between the dredged and reference sites (p=0.6414), and between dredgeate and reference sites was observed (p=0.9156). Seasonal comparisons found a significant difference in CPUE between spring and fall (p=0.0026) as well as spring and summer (p=0.0102). Further, no significant difference in CPUE was observed between trawl repeated trawls (three passes) across all treatments (p=0.4831). These results suggest that the abundance of fish species at risk in Lake St. Clair is likely very low. As such, the direct impact of maintenance dredging on these fishes is expected to be low. Fish abundance within sites was lowest during the spring and fall sampling periods. This result supports the continued use of fisheries timing windows to mitigate impacts of maintenance dredging on the local fish community. Depletion of fishes by repeated trawling within each site was not significant across all treatments. This result does not support the use of repeated trawling as a fish removal technique. Future research on maintenance dredging activities using a before/after design to better understand the impacts on fishes and their associated habitats is recommended. It is also recommended that maintenance dredging activities including timing of activities, disposal locations and monitoring be better communicated between stakeholders, as this communication will aid in future assessment of maintenance dredging activities.

Impacts du dragage sur les espèces de poissons en péril dans le lac Sainte-Claire, en Ontario

RÉSUMÉ

L'objet de ce document de recherche est de fournir des recommandations et d'appuyer les décisions de gestion relatives à l'autorisation des activités de dragage dans les eaux du lac Sainte-Claire en Ontario. L'objectif est également d'évaluer les impacts potentiels des activités de dragage d'entretien sur les espèces de poissons en péril. Pour évaluer les impacts du dragage d'entretien, le Secteur des sciences de Pêches et Océans Canada (MPO) a échantillonné des sites touchés (sites dragués et sites de déblais de dragage) et des sites de référence. Les sites touchés sont des lieux où l'on effectue régulièrement du dragage d'entretien ou des endroits où l'on dépose les déblais de dragage. Les sites de référence sont des emplacements proches présentant une profondeur et des substrats semblables et qui n'ont pas été perturbés, pour autant que l'on sache, par du dragage d'entretien. Le Secteur des sciences du MPO a réalisé à plusieurs reprises un relevé au chalut afin de comparer la communauté de poissons et l'abondance du poisson entre les sites touchés et les sites de référence. Les sites touchés étaient associés à des sites de référence proches présentant une profondeur et des types de substrats semblables. Aucune espèce de poisson en péril n'a été capturée aux sites touchés (sites dragués ou sites de déblais de dragage). Un dard de sable (*Ammocrypta pellucida*) a été capturé à un site de référence. On a comparé les captures par unité d'effort (CPUE) entre les sites touchés (tant les sites dragués que les sites de déblais de dragage) et les sites de référence. Aucune différence notable n'a été constatée entre les CPUE des sites dragués et de référence (p=0,6414), ni entre les sites de déblais de dragage et de référence (p=0,9156). Des comparaisons saisonnières ont permis de relever une différence sensible entre les CPUE au printemps et à l'automne (p=0,0026) ainsi qu'entre le printemps et l'été (p=0,0102). En outre, aucune différence importante dans les CPUE n'a été observée entre les différents relevés au chalut répétés (trois relevés) pour tous les types de sites (p=0,4831). Ces résultats permettent de penser que l'abondance des espèces de poissons en péril dans le lac Sainte-Claire est probablement très basse. De ce fait, l'impact direct du dragage d'entretien sur ces poissons devrait être faible. L'abondance du poisson à ces sites était la plus basse pendant les périodes d'échantillonnage du printemps et de l'automne. Ce résultat appuie l'application continue des périodes de pêche pour atténuer les impacts du dragage d'entretien sur la communauté locale de poissons. Les relevés répétés à chaque site n'ont pas entraîné d'épuisement important des stocks de poissons à tous les sites visés. Ce résultat ne supporte pas l'utilisation de relevés répétés au chalut comme étant une technique de retrait des poissons. Il est recommandé de mener des recherches sur les activités de dragage d'entretien, en procédant par comparaison (avant/après) afin de mieux comprendre les impacts sur les poissons et leurs habitats. Il est aussi recommandé que les intervenants se communiquent mieux les activités de dragage d'entretien, notamment le moment où elles ont lieu, les sites de rejet et la surveillance, car cela aidera à mieux évaluer ces activités.

INTRODUCTION

Lake St. Clair is centrally located in the connecting channel between Lake Huron and Lake Erie within the Laurentian Great Lakes (Thomas and Haas 2012). Lake St. Clair supports one of the most diverse fisheries in the Lower Great Lakes (Thomas and Haas 2004, 2012). Nearly 1.5 million people reside within the Canadian Counties bordering Lake St. Clair. This makes Lake St. Clair a very attractive recreational destination for anglers and boaters. The economic importance of Lake St. Clair is significant to both the residents of Canada and the United States (Thomas and Haas 2012). The dredging of lake sediments is considered a remedial technique to remove excess sediments and to increase lake depth for recreational boating. This maintenance dredging is regularly performed around the lake where needed. Along the south shore of Lake St. Clair, there are several tributaries that are regularly used by boaters to access the lake. These include Pike and Puce creeks, as well as Belle, Ruscom and Thames rivers. Marinas, boat ramps and docks are found within these tributaries. Maintenance dredging works are performed periodically by Essex Region and the Region of Chatham-Kent to maintain navigation within these waterways for all users.

Lake St. Clair contains incredible fish diversity with over 60 fish species documented (Thomas and Haas 2012). Within this diverse, shallow lake there are several fish species at risk. These species include the Northern Madtom (*Noturus stigmosus*), Pugnose Shiner (*Notropis anogenus*), Eastern Sand Darter (*Ammocrypta pellucida*), Channel Darter (*Percina copelandi*), Grass Pickerel (*Esox americanus*) and Spotted Sucker (*Minytrema melanops*). Northern Madtom, Channel Darter and Eastern Sand Darter are small, benthic species that are regularly found in the shallow, near-shore habitats of Lake St. Clair (Thomas and Haas 2004; Edwards et al. 2012; Thomas and Haas 2012; DFO 2013).

In 2012, Fisheries and Oceans Canada (DFO) conducted a trawling survey within areas regularly affected by maintenance dredging to investigate the impacts of maintenance dredging activities on fish species at risk. Dredging activities include both the removal of substrate (dredging) and the disposal of the removed substrate (dredgeate). Dredgeate disposal sites were identified in depths of 3 m within Lake St. Clair, relatively close to the maintenance dredging sites. This survey was conducted using a control-impact design with a reference site approach (Kwak and Peterson 2007; Power 2007). Dredged and dredgeate disposal sites were compared to local reference sites to determine the impact on fish species at risk, fish communities, and associated habitats. This survey focused on sites along the south shore of Lake St. Clair between the mouth of the Thames River and the Detroit River. All major south shore tributaries were sampled including Pike and Puce creeks, and Belle, Ruscom and Thames rivers (Figure 1).

The objectives of this study are to provide advice on the effects of dredging in Lake St. Clair on fish species at risk. Specifically, science advice is required to:

1. Determine whether fish species at risk are currently present at dredging and dredgeate deposition sites where they were known to exist historically;
2. Determine if fish species at risk are directly or indirectly being affected by the dredging activities both at the dredging and spoil deposition sites;
3. Review the potential use of fish salvage as a mitigation strategy; and,
4. Review whether there are alternatives to annual dredging activities or mitigation measures that would reduce the impacts on fish species at risk and their habitat.

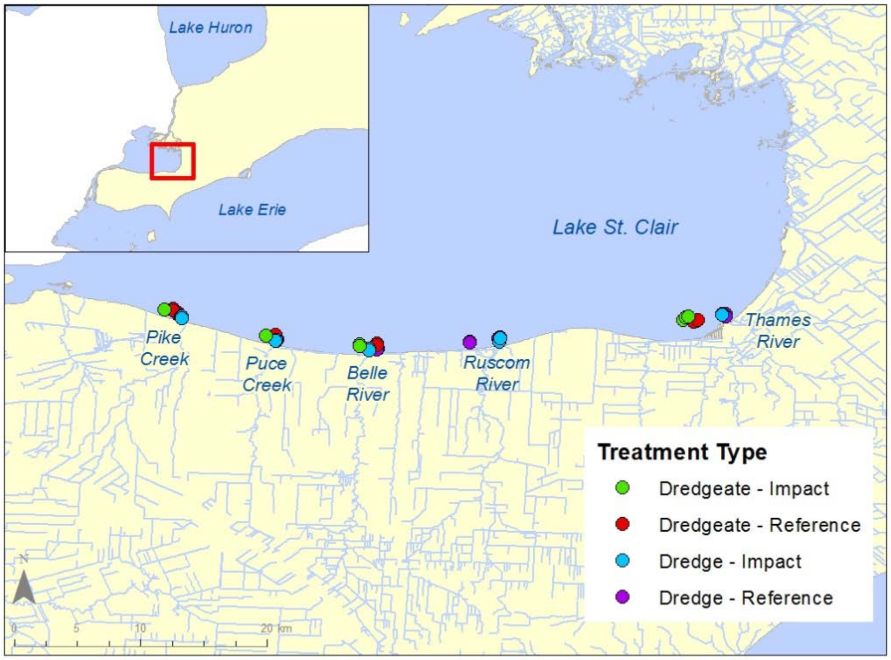

Figure 1. Location of dredging and dredgeate (impact, reference) survey sites within Lake St. Clair, Ontario.

METHODS

STUDY AREA

Trawling sites were selected from historically known dredging locations within the Ontario waters of Lake St. Clair. Dredging locations and dredgeate disposal locations were identified using historical maintenance dredging reports and permits from DFO, Essex Region and Chatham-Kent Region. To determine the impact of dredging activities on fish species at risk a reference site approach was developed. All selected impact sites were paired with a suitable reference site. Reference sites were identified as locations with no previous record of dredging. Reference sites were selected within close proximity (within 1 km) of impact sites. Reference sites were characterized as having similar habitat features (e.g., substrate, water depth, distance from shore). Sampling treatments and descriptions are summarized in Table 1. Trawling was conducted over two-week periods in 2012 (summer, fall) and 2013 (spring). All dredging sites were sampled over the three seasons. Dredgeate sites were only sampled during the fall of 2012 and spring of 2013 as the location of these sites could not be determined when fish sampling started.

Table 1. Categorization of the four types of sites included in this study.

Treatment	Description
Dredging – Impact	Sites within permitted areas where periodic maintenance dredging is known to occur.
Dredging – Reference	Sites within areas where periodic maintenance dredging has not occurred, or has not been recorded.
Dredgeate – Impact	Sites within areas where periodic maintenance dredging disposal is known to occur.

Treatment	Description
Dredgeate – Reference	Sites within areas where periodic maintenance dredging disposal has not occurred, or has not been recorded.

FISH SAMPLING

Sampling locations were surveyed using a Gerken siamese trawl with a 2.9 m footrope, 2.5 m headrope, 19 mm outer-mesh, and a 4 mm inner-mesh separator within the cod end (Guy et al. 2009; Fischer et al. 2012). A 4 m length of stainless steel wire with circular pieces of PVC pipe was attached approximately 0.2 m ahead of the foot rope/chain. This device was used to help disturb the sediments and dislodge fishes into the trawl. This trawl was deployed and retrieved manually from the bow of a 5.5 m vessel equipped with a 90 hp outboard motor. Sampling sites were field verified for obstructions and adequate survey depths (>1.5 m) using a commercially available side imaging sonar unit. Trawls were deployed from the bow of the boat while the boat was traveling in reverse. Sampling transects were 100 m in length and placed approximately in the middle of the site. The length of rope deployed was dependent on the depth of water along the sampling transect (Guy et al. 2009). Effort was recorded as the distance travelled (m) and the time sampled (s).

All fishes captured were sorted, counted and identified to species. Digital or physical vouchers preserved in formalin (10% formaldehyde solution) were taken of all species captured. All other specimens were identified to species and released. If the survey crew captured fish species at risk these specimens were photographed, individually measured (mm), clipped for genetic confirmation and released. Fin clips were collected from the upper caudal lobe of all fish species at risk. Fin clips were stored in individual vials and preserved in 95% ethanol.

HABITAT SURVEYS

Habitat surveys were completed following trawling surveys to minimize disturbance to the fishes. Habitat surveys consisted of measuring the following habitat parameters: water temperature (°C), water depth (m), and % substrate (qualitative measurement).

DATA ANALYSIS

Three data analyses were performed for this study. The first analysis compared the catch per unit effort (CPUE) between impact sites and reference sites to determine the potential effects of maintenance dredging on fish abundance. This analysis was performed on impact and reference sites for dredged and dredgeate sites, respectively. This analysis was performed to determine if the fish community was different between impact and reference sites. Statistical analysis for the comparison of dredging and dredgeate pairs was conducted in JMP using the ANOVA function ($\alpha = 0.05$).

The second analysis compared CPUE between seasons to determine if variation in fish abundance was observed between seasons. This analysis was performed to determine if there was seasonal variation between sampling sites. If there were differences between seasons (spring, summer, fall) this would provide some insight into the use of timing windows as a mitigation techniques. Statistical analysis for the comparison of seasonal CPUE was conducted in JMP using the Kruskal-Wallis test ($\alpha = 0.05$). This allowed for a comparison of fish CPUE between seasons.

The third analysis compared CPUE between repeated trawls. This analysis was performed to determine if there were variations in fish abundance between repeated trawls within the same sampling event. This analysis would provide some insight into the use of trawling as a fish salvage technique. Statistical analysis for comparison of repeated trawling CPUE was conducted in JMP using the ANOVA function (α = 0.05).

RESULTS

FISH SAMPLING

A total of 30 dredging sites (Impact, Reference) and 24 dredgeate sites (Impact, Reference) were sampled during this survey. A total of 162 trawls were performed across all sampling sites. This resulted in a total catch of 4736 fishes consisting of 26 species (Table 2). Of the 26 fish species identified in this survey, 24 of these species were observed within dredging impact sites. Dredging reference, dredgeate impact and dredgeate reference sites accounted for 16, 15 and 15 species respectively (Table 2).

Table 2. Summary of all fishes captured by treatment type and season, including number of fishes, number of species and mean catch per unit effort (CPUE).

Treatment	Sampling Period	No. of sites	No. of fish	No. of species	Mean CPUE (SD)
Dredging - Impact	Summer (2012)	5	899	24	0.44 (0.44)
Dredging - Impact	Fall (2012)	5	357		0.18 (0.25)
Dredging - Impact	Spring (2013)	5	67		0.03 (0.04)
Subtotal		15	1323		
Dredging - Reference	Summer (2012)	5	803	16	0.38 (0.48)
Dredging - Reference	Fall (2012)	5	231		0.11 (0.10)
Dredging - Reference	Spring (2013)	5	16		0.01 (0.01)
Subtotal		15	1050		
Dredgeate - Impact	Fall (2012)	6	893	15	0.38 (0.40)
Dredgeate - Impact	Spring (2012)	6	325		0.15 (0.19)
Subtotal		12	1218		
Dredgeate - Reference	Fall (2012)	6	748	15	0.33 (0.21)
Dredgeate - Reference	Spring (2013)	6	397		0.17 (0.18)
Subtotal		12	1145		
Total		54	4736	26	

SPECIES AT RISK COLLECTION

A single fish species at risk, Eastern Sand Darter, was detected during the study. A single individual was captured from a dredgeate reference sampling site near the Thames River (Appendix I).

DREDGING SITES

A total of 2373 fishes were captured at all dredging survey sites. This includes 1323 and 1050 fishes captured from dredged impact sites and reference sites, respectively (Table 2). Seasonal CPUE data (spring, summer and fall) were pooled for the Wilcoxon/Kruskal-Wallis test. The analysis found no significant difference between the CPUE of impact sites and reference sites (p=0.6414).

DREDGEATE SITES

A total of 2363 fishes were captured at all dredging survey sites. This includes 1218 and 1145 fishes captured from dredgeate impact sites and reference sites, respectively (Table 2). Seasonal CPUE data (spring, summer and fall) was pooled for this analysis. There was no significant difference between the CPUE of impact sites and reference sites (p=0.9156) (Figure 2).

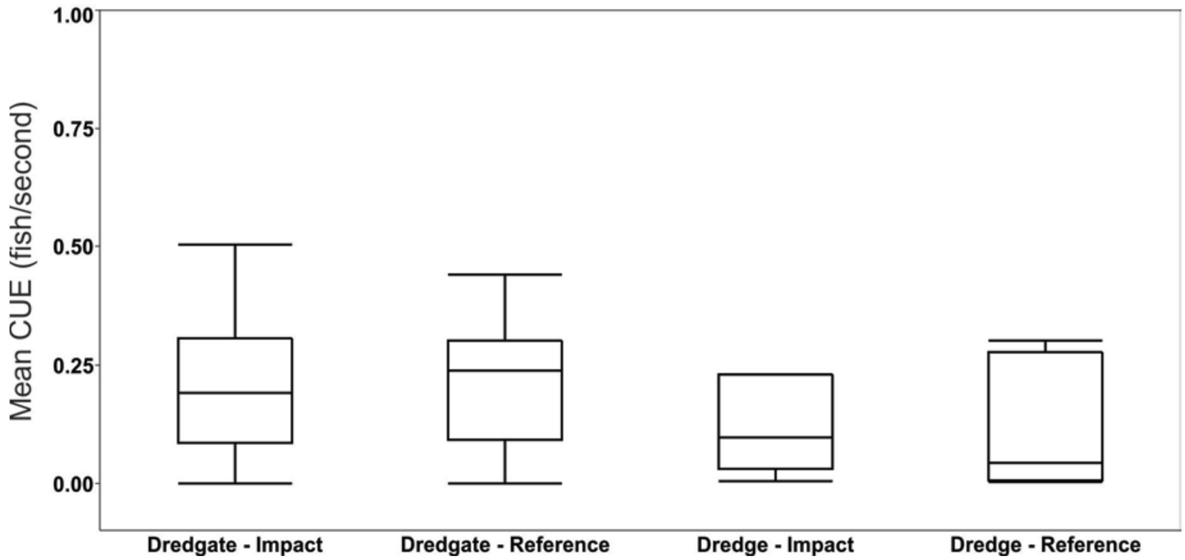

Figure 2. Comparison of pooled catch per unit effort (CPUE) for all trawling sites by treatment.

SEASONAL SAMPLING

The number of sampling sites by season was 10, 22 and 22 for summer, fall and spring, respectively. Fishes captured across the three sampling seasons was 2229, 805 and 1702 for summer, fall and spring, respectively. The CPUE varied between seasons and was found to be significantly different across sampling sites between the three sampling seasons (p=0.0007) (Figure 3). Further analysis using the Steel-Dwass test (JMP® 2010) was performed to determine significant differences in CPUE between seasons. This analysis found no significant difference between summer CPUE and fall CPUE (0.7567). However, significant differences were noted between spring CPUE and fall CPUE (p=0.0026), and between spring CPUE and summer CPUE (p=0.0102).

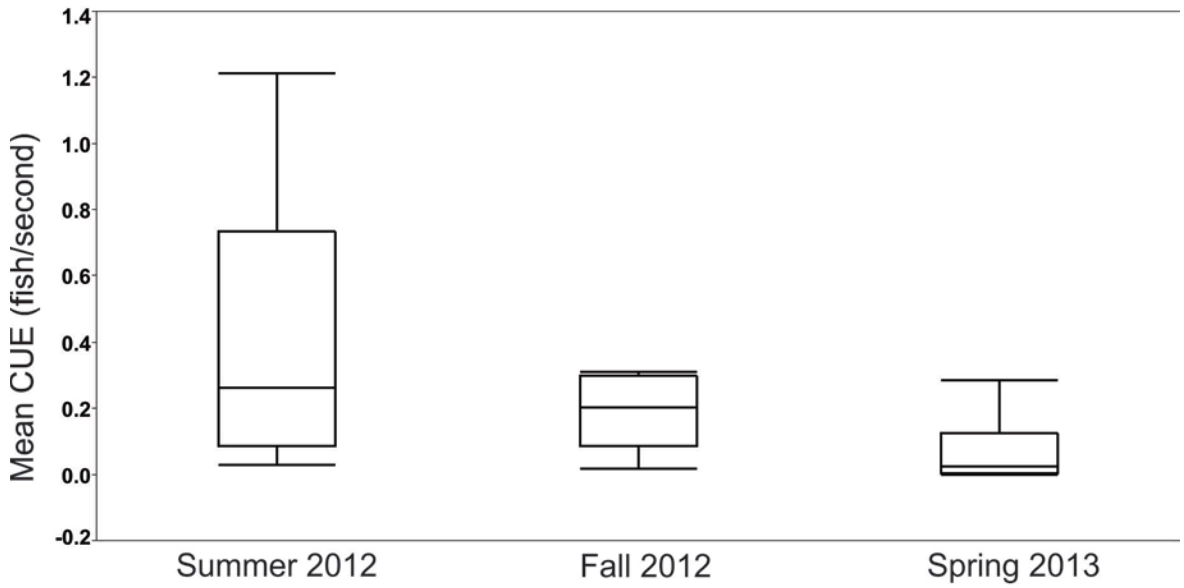

Figure 3. Comparison of pooled catch per unit effort (CPUE) across all sampling sites by season.

REPEATED TRAWLING

The CPUE between trawls was compared to determine if fish abundance varied between trawls within the same sampling event. This analysis found no significant difference in CPUE between trawls within the same sampling event (p=0.4831) (Figure 4).

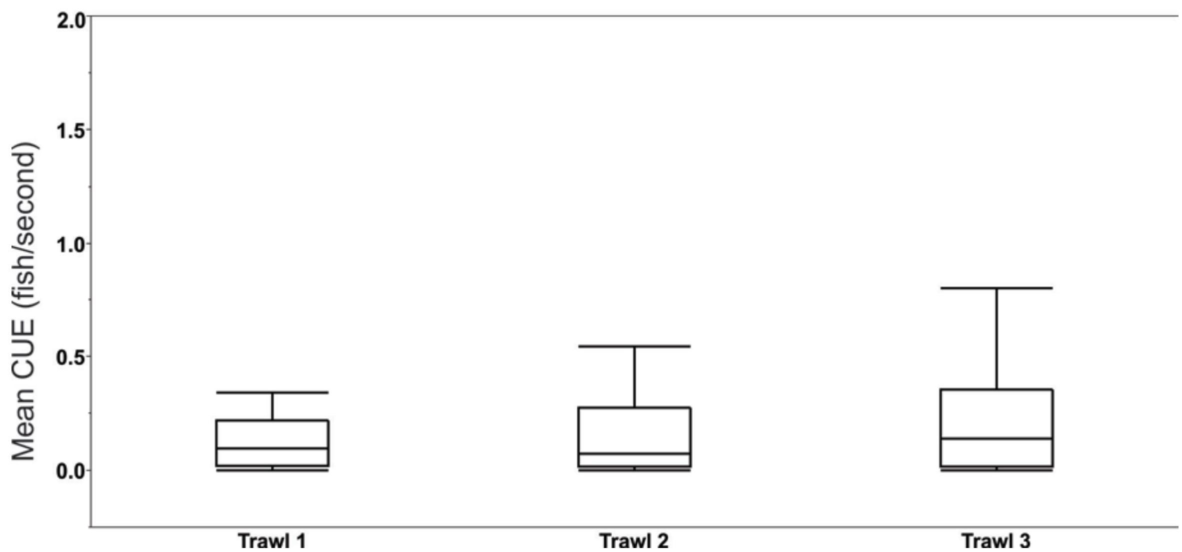

Figure 4. Comparison of pooled catch per unit effort (CPUE) by individual trawl for all sampling events and all treatments.

HABITAT SURVEY

Habitat data were collected from all 54 sampling sites. The mean water temperature across all sampling sites was 23.95°C (SD ± 0.47) in summer, 11.54°C (SD ± 0.75) in fall and 8.82°C (SD ± 1.16) in spring (Table 3). The mean depth across all sampling sites was 1.13 m (SD ± 0.54) in summer, 1.88 m (SD ± 0.75) in fall and 2.50 m (SD ± 0.81) in spring (Table 3). The dominant substrate within all sampling sites was sand with some clay and cobble observed (Table 3).

Table 3. Summary of habitat survey data recording during all sampling events pooled by season.

Season (# of sites)	Water temperature (°C)		Depth (m)		Dominant substrate % (# of sites)
Summer 2012 (10)	23.95	Mean	1.13	Mean	Sand (9) Clay (1)
	23.32	Min	0.62	Min	
	24.78	Max	2.53	Max	
	0.47	SD	0.54	SD	
Fall 2012 (22)	11.54	Mean	1.88	Mean	Sand (19) Clay (2) Cobble (1)
	9.00	Min	0.73	Min	
	12.86	Max	3.00	Max	
	0.75	SD	0.75	SD	
Spring 2013 (22)	8.82	Mean	2.50	Mean	Sand (18) Clay (1) Unknown (3)
	6.49	Min	1.13	Min	
	10.35	Max	3.73	Max	
	1.16	SD	0.81	SD	

DISCUSSION

IMPACT OF DREDGING ACTIVITIES

Trawling surveys detected 26 fish species and 4736 individual fishes across all sampling sites. No significant difference was observed in the CPUE between impact sites or references sites. These results suggest that maintenance dredging and dredgeate disposal may not have a significant impact on fishes within the areas along the south shore of Lake St. Clair. Fischer et al. (2012) reviewed the impact of dredging activities on fish communities in the Kansas River and found no detectable impact of dredging on fish communities in the Kansas River. The survey by Fischer et al. (2012), occurred in a relatively small geographic area with a relatively small number of sampling locations. Findings from Fischer et al. (2012) were consistent with findings from our survey on Lake St. Clair. There is no measurable impact on the fish community between impacted sites (dredged and dredgeate) and reference sites. From these results, we conclude there is little impact of maintenance dredging work on the fish community at study sites in Lake St. Clair.

PRESENCE OF SPECIES AT RISK

Determine whether fish species at risk are currently present at dredging and dredgeate sites where they were known to exist historically

Dextrase et al. (2014) reviewed the sampling effort required to detect fish species at risk in Ontario. Dextrase et al. (2014) indicated the probability of detection for any species is related to the abundance of the species and the probability of capture. Detection probability can also be influenced by many other factors including sampling method, the amount of sampling effort, time of year and habitat (Dextrase et al. 2014). Dextrase et al. (2014) concluded that sites surveyed with a repeated sampling design may require 26 to 39 replicates to achieve 95% detection. For this study, a total of 54 sites were surveyed across three seasons (summer, fall and spring). Each sampling site was 100 m in length and each site was sampled with three passes of a small mesh, benthic siamese trawl. During this survey only one fish species at risk specimen was captured, an Eastern Sand Darter at a reference site near the Thames River (Appendix I). To date, no detection analysis has been conducted on Northern Madtom, Channel Darter or Eastern Sand Darter within lentic systems using a small benthic trawl. Considering the results of this survey, and the recommendations from Dextrase et al. (2014), we can assume the abundance of Northern Madtom, Channel Darter and Eastern Sand Darter is low, if present, within the sampling sites of this survey.

IMPACT TO SPECIES AT RISK

Determine if fish species at risk are directly or indirectly being affected by the dredging activities both at the dredging and dredgeate sites

Results of this study indicate that it is difficult to determine if fish species at risk are directly or indirectly impacted by dredging activities at either the dredged or dredgeate sites. Historic records of Northern Madtom and Eastern Sand Darter do exists from the southern shore of Lake St. Clair (Thomas and Haas 2004; Edwards et al. 2012; DFO 2013). During this survey only one fish species at risk specimen was captured. This was an Eastern Sand Darter which was captured at a reference site near the Thames River (Appendix I). The results of this survey suggest that fish species at risk abundance within the surveyed areas of Lake St. Clair is low. If sufficient mitigation steps are followed through the maintenance dredging activities the direct and indirect impacts to fish species at risk could be considered minimal.

POTENTIAL FOR FISH SALVAGE

Review the potential use of fish salvage as a mitigation strategy

Results of this study indicate that it may be difficult to implement fish salvage as a mitigation strategy for maintenance dredging in Lake St. Clair. This study consisted of 54 sites that were sampled in a repeated fashion. Each survey site was sampled using three repeated passes of a trawl. Analysis of this repeated trawling data found there was no significant difference between fish abundance (CPUE) between repeated trawls across all sites. This result suggests there was no depletion of fishes between trawling passes across all sites. This result suggests that trawling is not an effective mitigation strategy for removing fishes in lentic systems. In 2012 and 2013, the Great Lakes Laboratory for Fisheries and Aquatic Sciences partnered with the Sea Lamprey Control Centre (SLCC) to evaluate the impacts of chemical lamprey assessment on fish species at risk (DFO, unpublished data). One objective of this project was to determine if fish salvage was an effective mitigation strategy for SLCC staff during chemical lamprey assessment. SLCC survey sites were located in the St. Clair River, Detroit River, Sydenham River, and Thames River. The SLCC survey found no significant difference in fish abundance between trawls within the site indicating lack of depletion (DFO, unpublished data). The use of trawling for fish salvage prior to maintenance dredging is not a recommended mitigation strategy.

ALTERNATIVES TO DREDGING

Review whether there are alternatives to annual dredging activities or mitigation measures that would reduce the impacts on fish species at risk and their habitat

DFO currently permits dredging activities if the activity follows these criteria:

1. there is no increase in the previous footprint;
2. the dredged material is deposited and stabilized on land or at an approved marine disposal site; and,

3. dredging has occurred within the last 10 years (DFO 2014b).

DFO also uses restricted timing windows for works in, and near water. These timing windows are implemented to protect fishes during spawning and other critical life history stages, and are established using recreationally, commercially or Aboriginally important species (DFO 2014a). If timing windows are considered, there are several species in the Lake St. Clair area that could be impacted by dredging activities. These would include Largemouth Bass (*Micropterus salmoides*), Muskellunge (*Esox masquinongy),* Northern Pike (*Esox lucius*), Smallmouth Bass (*Micropterus dolomieu*) and Walleye (*Sander vitreus*). Considering these species, the restricted work period for Lake St. Clair dredging is currently March 15th until July 15th (DFO 2014a). The results of this survey suggest there is a low abundance of fishes during the spring of each year within both the dredged and dredgeate disposal areas. The low abundance of fishes in dredging and dredgeate locations may provide an opportunity for maintenance dredging during the early spring of each year (early spring has been identified as the window before water temperatures reached 10°C). If maintenance dredging occurs during this time period it is likely going to have the greatest positive impact on marina facilities, boat ramp operators and dock owners, and have little impact on fishes. In addition, maintenance dredging in the summer and fall may be less effective for maintaining navigation channels, as sand may move into the previously dredged areas prior to the start of the following boating season.

DFO collaborated with the University of Windsor to locate and quantify dredgeate disposal locations within Lake St. Clair (Gardner Costa et al. 2015). These nearshore bathymetry surveys were conducted between October 5 and November 29, 2013, independent of DFO trawling surveys (Gardner Costa et al. 2015). Dredged channels were mapped in Mitchell's Bay, Thames River, Ruscom River, Belle River, Puce River and Pike Creek. The bathymetry of dredgeate disposal locations from this study was only mapped at the Ruscom River, Belle River, Puce River and Pike Creek. Gardner Costa et al. (2015) did not observe many obvious reductions in depth that would be an indicator of a dredgeate disposal site. Prior to their survey, Gardner Costa et al. (2015) had expected that spoil sites would be characterized by sudden decreases in depth. Dredgeate materials would appear on maps as shallow areas surrounded by deeper water. Gardner Costa et al. (2015) described most dredgeate disposal locations as being featureless with no drastic changes in depth. These findings lead to two possible conclusions. First, the dredgeate disperses quickly after disposal into Lake St. Clair. Second, the surveyed locations were not the exact locations of dredgeate disposal. Additional research may be required to determine how quickly dredgeate material disperses after disposal. It is recommended that disposal areas should be well defined to reduce potential impacts of dredgeate disposal. It is also recommended that DFO review the current monitoring program with the Ministry of Natural Resources and Forestry (MNRF) and other agencies to develop consistent and agreeable mitigation strategies for dredgeate disposal within Lake St. Clair.

Substrates that are dominated by sand are very dynamic in nature. Fischer et al. (2012) discussed how the fish community in the Kansas River quickly recovered from channel maintenance dredging, and described how quickly substrates redistributed themselves after maintenance dredging activities. This result was attributed to the sand-dominated substrate of the Kansas River. Sites surveyed by Fischer et al. (2012) in the Kansas River, a large lotic system, are likely more dynamic than similar sites in Lake St. Clair, a large lentic system. Of the 54 sites in our survey, 46 (85%) survey sites were dominated by sand (Table 3). It is likely the habitats in Lake St. Clair may respond quickly to disturbances from maintenance dredging activities; however, habitats dominated by sand in lotic systems likely respond faster to disturbances from maintenance dredging than similar habitats in lentic systems due to increased water velocity. Sampling performed during this study followed a control-impact study design using a reference condition approach (Power 2007). A better test of habitat recovery from maintenance dredging activities may consist of a more robust before-after survey using a time sequence (Power 2007). This type of survey would allow researchers to better evaluate how the fish community adjusts from maintenance dredging. Unfortunately, this was not feasible during the timeframe of this study. The survey sites for this study were dominated by sand with very little vegetation. Vegetation in Lake St. Clair is an important habitat feature for many species. It is recommended that maintenance dredging and dredgeate disposal only occur within habitats that are dominated by sand. Habitats dominated with vegetation are considered more sensitive and would likely not respond as quickly as habitats dominated by sand. From our results there appears to be a quick response to habitat alterations that are dominated by sandy substrates but additional research is required.

Gardner Costa et al. (2015) described inconsistencies with dredgeate disposal sites. These inconsistencies were related to site depth and site area. Dredgeate disposal sites are required to be located in areas with a minimum water depth of 3 m. These depths were not observed at any of the dredgeate disposal site (Table 3). This suggests that dredgeate disposal is not occurring at a water depth of 3 m, as recommended by the MNRF. It is recommended that agencies review the current compliance monitoring within dredged areas and dredgeate disposal sites within Lake St. Clair to ensure compliance.

RECOMMENDATIONS FOR FUTURE SAMPLING

Maintenance dredging is a common practice to deal with issues related to sedimentation and safe navigation in waterways. This study was limited to the nearshore waters of Lake St. Clair and waterways used mainly by smaller, recreational vessels. Results suggest that fish abundance was not significantly different between impact and reference sites. However, a more robust approach to determine the impacts of maintenance dredging activities on fish species at risk would be to adopt a before-after design using a time series of sampling post-impact for both impact and reference sites (Power 2007). However, future studies of this nature would require more information of dredged and dredgeate sites. A control-impact design with a reference system approach would require careful co-operation with agencies. The survey could be conducted immediately following maintenance dredging works, allowing for fish community recovery to be monitored. Methods similar to those presented could be repeated over a time series, taking into consideration temporal variation (i.e. seasonality), providing more robust information regarding the impacts of maintenance dredging in Lake St. Clair on fish species at risk, fish communities, and their associated habitats.

REFERENCES

Gardner Costa, J., Wang, L., Mackey, S.D., and Ciborowski, J.J.H. 2015. Remote sensing of the bathymetry and substrate of selected areas of Lake St. Clair - using the Remote Operated Vehicle for Environmental Research (ROVER) to detect dredging spoil piles near selected river mouths. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/017. v + 23 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. 2013. Recovery strategy for the Eastern Sand Darter (*Ammocrypta pellucida*) in Canada: Ontario populations. Species at Risk Act Recovery Strategy Series, Fisheries and Oceans Canada, Ottawa. vii + 58 p.

DFO. 2014a. Project near water: Ontario restricted activity timing windows for protection of fish and fish habitat. Accessed: 26 October 2015.

DFO. 2014b. Projects near water: Does my project need review? Accessed: 28 January 2015.

Edwards, A.L., Laurin, A.Y., and Staton, S.K. 2012. Recovery Strategy for the Northern Madtom (*Noturus stigmosus*) in Canada. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. viii +42 p.

Fischer, J., Paukert, G., and Daniels, M. 2012. Fish community response to habitat alteration: Impacts of sand dredging in the Kansas River. Trans. Am. Fish. Soc. 141: 1532-1544.

Guy, C.S., Braaten, P.J., Herzog, D.P., Pitlo, J., and Rogers, R.S. 2009. Warmwater fish in rivers. *In* Standard methods for sampling North American freshwater fishes. Edited by S. A. Bonar, W. A. Hubert, and D. W. Willis. Am. Fish. Soc., Bethesda, Maryland. p. 59-84.

JMP®, 2010. Version 10. SAS Institute Inc. Cary, North Carolina.

Kwak, T.J., and Peterson, J.T. 2007. Community Indices, Parameters and Comparisons. *In* Analysis and Interpretation of freshwater fisheries data. Edited by C. S. Guy and M. L. Brown. Am. Fish. Soc., Bethesda, Maryland. p. 677-763.

Power, M. 2007. Fish Population Bioassessment. *In* Analysis and Interpretation of freshwater fisheries data. Edited by C. S. Guy and M. L. Brown. Am. Fish. Soc., Bethesda, Maryland. p. 561-624.

Thomas, M.V., and Haas, R.C. 2004. Status of Lake St. Clair fish community and sport fishery, 1996-2001. Fisheries Research Report 2067, Michigan Department of Natural Resources, Fisheries Division. 27 p.

Thomas, M.V., and Haas, R.C. 2012. Status of Lake St. Clair fish community and sport fishery. Fisheries Research Report 2099, Michigan Department of Natural Resources, Fisheries Division. 90 p.

APPENDIX I. SUMMARY OF SPECIES CAPTURED BY SAMPLING TREATMENT

Table A1. Fish species captured by sampling treatment at impact and reference sites.

Species	No. of fish	Dredge		Dredgeate	
		Impact	Reference	Impact	Reference
Ambloplites rupestris	105	24	49	21	11
Ammocrypta pellucida	1	0	0	0	1
Cyprinid sp.	2	2	0	0	0
Dorosoma cepedianum	60	48	11	0	1
Ictalurus punctatus	7	6	0	0	1
Labidesthes sicculus	22	10	12	0	0
Lepomis macrochirus	34	11	18	5	0
Lepomis sp.	3	2	1	0	0
Micropterus dolomieu	7	1	4	2	0
Micropterus salmoides	1	0	0	0	1
Morone americana	40	32	4	3	1
Morone chrysops	1	1	0	0	0
Neogobius melanostomus	974	65	283	430	196
Notropis atherinoides	44	10	27	4	3
Notropis buchanani	387	176	0	110	101
Notropis hudsonius	2435	756	442	471	766
Notropis sp.	1	0	0	1	0
Notropis volucellus	506	158	180	123	45
Noturus miurus	2	1	1	0	0
Osmerus mordax	1	1	0	0	0
Perca flavescens	16	5	5	4	2
Percina caprodes	53	7	2	38	6
Percopsis omiscomaycus	15	4	0	1	10
Pimephales notatus	1	1	0	0	0
Proterorhinus semilunaris	17	2	10	5	0
Sander vitreus	1	0	1	0	0
Total individuals	**4736**	**1323**	**1050**	**1218**	**1145**
Total species	**26**	**23**	**16**	**14**	**14**
Unique species		**10**	**2**	**4**	**4**