Development of a submerged aquatic vegetation model for the St. Clair and Detroit Rivers

Jonathan D. Midwood

Great Lakes Laboratory for Fisheries and Aquatic Sciences
Science Branch, Ontario and Prairie Region
Fisheries and Oceans Canada
867 Lakeshore Road
Burlington ON, L7S 1A1

2020

Canadian Technical Report of Fisheries and Aquatic Sciences 3399

Fisheries and Oceans Canada
Pêches et Océans Canada

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of Fisheries and Oceans Canada, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in the data base *Aquatic Sciences and Fisheries Abstracts*.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. II n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques de Pêches et Océans Canada, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications à part entière. Le titre exact figure au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la base de données *Résumés des sciences aquatiques et halieutiques*.

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre.

Les numéros 1 à 456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Canadian Technical Report of
Fisheries and Aquatic Sciences 3399

2020

Development of a submerged aquatic vegetation model for the St. Clair and Detroit Rivers

by

Jonathan D. Midwood

Great Lakes Laboratory for Fisheries and Aquatic Sciences
Science Branch, Ontario and Prairie Region
Fisheries and Oceans Canada
867 Lakeshore Road
Burlington ON, L7S 1A1

Cat. No. Fs97-6/3399E-PDF ISBN 978-0-660-35901-4 ISSN 1488-5379

Correct citation for this publication:

Midwood, J.D. 2020. Development of a submerged aquatic vegetation model for the St. Clair and Detroit Rivers. Can. Tech. Rep. Fish. Aquat. Sci. 3399: v + 13 p.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

ABSTRACT

Midwood, J.D. 2020. Development of a submerged aquatic vegetation model for the St. Clair and Detroit Rivers. Can. Tech. Rep. Fish. Aquat. Sci. 3399: v + 13 p.

Submerged aquatic vegetation (SAV) is an important component in aquatic ecosystems, providing numerous ecosystem services including habitat for fishes throughout their life history. In the St. Clair and Detroit River Areas of Concern (AOC), accurate maps of the distribution and cover of SAV are important for assessing the distribution and condition of fish habitat within these AOC. To support these efforts, this report details the development of random forest models for SAV presence and percent cover. The final SAV presence and percent cover models included all three available environmental parameters: depth, velocity, and effective fetch. A unique dataset indicated that the best SAV presence model had an overall accuracy of over 93% (Kappa >0.85) while the best SAV percent cover model explained the most variance (>75%) and had the lowest root mean square error (19.3). The resulting models are now available to be applied spatially within these AOC and should prove useful in the assessment of the status of the fish and wildlife populations beneficial use impairment.

RÉSUMÉ

Midwood, J.D. 2020. Development of a submerged aquatic vegetation model for the St. Clair and Detroit Rivers. Can. Tech. Rep. Fish. Aquat. Sci. 3399: v + 13 p.

La végétation aquatique submergée (VAS) est une composante importante dans les écosystèmes aquatiques qui fournit de nombreux systèmes écosystémiques, y compris un habitat pour les poissons tout au long de leur cycle biologique. Dans les secteurs préoccupants (SP) des rivières St. Clair et Détroit, des cartes précises de la distribution et du couvert de la VAS sont importantes, car elles permettent d’évaluer la distribution et la condition de l’habitat du poisson à l’intérieur de ces SP. Afin de soutenir ces efforts, le présent rapport détaille l’élaboration de modèles de forêt aléatoire pour la présence et le pourcentage de couverture de VAS. Les modèles finaux de présence et de pourcentage de couverture de VAS comprenaient les trois paramètres environnementaux disponibles : la profondeur, la vitesse et le fetch effectif. Un ensemble de données unique indiquait que le meilleur modèle de présence de VAS présentait une exactitude globale de plus de 93 % (Kappa >0,85), et que le meilleur modèle de pourcentage de couverture de VAS expliquait la plus grande variance (>75 %) et présentait l’erreur quadratique moyenne la plus faible (19,3). Les modèles qui en résultent peuvent désormais être appliqués dans l’espace à l’intérieur de ces SP et devraient s’avérer utiles pour l’évaluation de l’altération d’utilisation bénéfique de l’état des populations du poisson et de la faune.

INTRODUCTION

Submerged aquatic vegetation (SAV) is a critical component of nearshore freshwater ecosystems providing habitat for a wide variety of species while also stabilizing substrates, filtering nutrients, and oxygenating the water (Madsen et al. 2001; Lacoul and Freedman 2006). Freshwater fishes are reliant on SAV for many components of their life history such that areas with abundant SAV have been found to support a higher biomass of fish compared to non-vegetated regions (Randall et al. 1996). Given the importance of SAV, numerous studies have sought to develop models of SAV distribution and cover (Chambers and Kalff 1985; Hudon et al. 2000; Havens et al. 2002; Cho and Poirrier 2005); however, these models tend to be regionally focused and challenging to transfer elsewhere due to variations in regional environmental conditions and SAV species composition. Recent work in the Toronto and Region Area of Concern (AOC) tested a variety of SAV modelling approaches and found that random forest models provided the highest accuracy and that two-stage models, wherein SAV presence is modelled first, followed by SAV percent cover for areas only where SAV was predicted to occur, performed better than integrated models (Midwood et al. in press).

The St. Clair and Detroit River systems form the connecting waters between Lake Huron and Lake Erie. Both lotic systems have experienced marked declines in the quality and quantity of aquatic habitat with a loss of 72% of wetlands (by area) along the U.S. shoreline and comparable losses on the Canadian side. Due to these losses, as well as impacts from industrialization, urbanization, and agriculture, both the St. Clair and Detroit Rivers were listed as AOCs in 1987. Historically, wetlands in these systems provided important nursery habitat for over 40 species of fish (Goodyear et al. 1982) and, despite the noted degradation and habitat loss, these systems and their connecting tributaries continue to support some of the highest fish biodiversity in Canada (Chu et al. 2014). Past studies of the fish community in the Detroit River system have identified structurally complex aquatic macrophytes as important habitat for small-bodied and early life stage fishes (Lapointe et al. 2007), emphasizing the importance of SAV within these systems. Hondorp et al. (2014) have further called for the classification of fish habitat types within the St. Clair and Detroit Rivers in order to assess threats against specific habitat types and to develop spatially explicit habitat restoration plans. The objective of this report is therefore to detail the development of SAV presence and cover models for the St. Clair River and Detroit River AOCs. These models are required to help quantify the amount and type of fish habitat within these AOCs and to support decisions on the location and type of future habitat remediation projects as well as in the assessment of the condition of aquatic habitat.

METHODS

FIELD DATA

Data used to develop the models were collected in the St. Clair and Detroit River (SCDR) systems over multiple years (2007, 2008, and 2010) using an echosounder

(BioSonics DT-X 430 kHz transducer with a 6.8° beam width; Remillard et al. 2020). A preliminary statistical review (i.e., histograms and dot plots) of this dataset suggested that insufficient data were available for high velocity areas in the SCDRs to properly parameterize the model. Therefore, targeted sampling was completed during the summer 2017 using a new but comparable echosounder (Biosonics MX 204.8 kHz transducer with a 8.3˚ beam width). Sampling was limited to water depths that were greater than 1 m since there are limitations on how far the beam can travel to yield meaningful results (see Gardner-Costa et al. 2018). Data processing steps for the 2007-2010 data are outlined in Remillard et al. (2020) and processing for the 2017 data followed a similar procedure as that outlined for data collected in the Toronto and Region AOC (Midwood et al. in press). In general, processing was completed using Visual Habitat software (Biosonics, Seattle, WA) to first detect the depth of the bottom and then determine if vegetation was present, the height off bottom of vegetation, and an estimate of the SAV percent cover (analysis parameters: rising edge threshold = -35 dB; plant detection threshold = -70 dB, minimum SAV height of 0.1 m). By combining data from past surveys with those completed in 2017, a substantial georeferenced dataset containing information on the presence and absence of SAV and estimates of SAV cover was developed to support modelling efforts (Figure 1). The hydroacoustic output also provided concurrent water depth information for each sampling position, which allowed for an integration of temporally distinct datasets that may otherwise have not been possible due to fluctuations in water level among years.

SPATIAL LAYERS

Several environmental metrics have been consistently shown to influence the presence of SAV, specifically light (typically incorporated as some measure of light attenuation driven by water clarity and suspended particles; Sand-Jensen and Madsen 1991; Middelboe and Markager 1997) and physical disturbances (i.e., exposure to wind and wave action or water velocity; Keddy 1983; Chambers 1987; Chambers et al. 1991; Riis and Hawes 2003). Additionally, factors such as substrate composition, ice scour, and temperature may influence SAV presence and growth (Barko and Smart 1986; Stewart and Freedman 1989; Capers and Les 2005; Lacoul and Freedman 2006). An effort was made to incorporate many of these factors into the models, but data limitations precluded the inclusion of all parameters (i.e., substrate, temperature, water clairty). To incorporate exposure to wave action, a spatial layer was created that represented the distance to the primary shipping channel within the system. This distance (herein dist_ship) from the channel was measured every 50 m along perpendicular lines that were spaced 50 m apart along the shipping channel. These lines were truncated at the nearest point of land, which would in theory act to reflect or block the waves generated by the large ships that regularly traverse the system (Figure 2). A velocity point layer was also available for the entire system and the average velocity (m/s) for the water column was used to estimate the potential physical disturbance from water flow (layer details in Remillard et al. 2020). Data from these layers were extracted for every hydroacoustic sampling point. Once data were extracted and merged, the dataset was exported and all further analyses were completed in R Studio v1.1.456 (RStudio, Inc., Boston, MA).

DATA EXPLORATION AND PREPARATION

The distribution of each independent (dist_ship, velocity, depth) and dependent (SAV presence/absence, and SAV percent cover) metric was explored and plotted using Cleveland dot plots. For the SAV data, a maximum possible SAV depth was set to 7.5 m and this was based on field sampling conducted concurrently with the 2010 data collection. This threshold resulted in the exclusion of approximately 1500 data points, which likely represented a misinterpretation of bottom features during hydroacoustic processing. A minimum SAV height threshold of 0.05 m was applied to points where SAV was present in the dataset because differentiating between true SAV and soft substrates at this level of resolution is challenging during hydroacoustic data processing; this resulted in the exclusion of 2704 data points. Data points where SAV was found to occur in waters with velocities >1.0 m/s were also excluded, as past studies have found velocities greater than this to preclude the establishment of SAV (Chambers et al. 1991). Data exploration revealed unequal sampling effort across depths in both systems, with greater effort (most sample points) in the 2-4 m depth range. To correct for this potential bias, a random subset of 3500 data points per depth bin was extracted, with bins ranging from <2 m up to >9 m in 1-m increments. From this final dataset, 66% of the samples (20790) were randomly selected and used as a training dataset to develop models, the remaining 34% (10710) were held in reserve and used to test the accuracy of the models (herein referred to as the testing dataset).

MODEL DEVELOPMENT

A random forest approach was selected for all models as this approach has low sensitivity to non-normal data and retains the high classification accuracy of other tree-based models while reducing issues of over-fitting (Cutler et al. 2007). It has also been found to yield accurate models for SAV presence and percent cover, relative to more simplistic tree-based and linear models (Midwood et al. in press). The randomForest function in the randomForest package (Liaw and Wiener 2018 – based on Breiman 2001) was used to develop all models with 1000 trees per model. All possible combinations of the independent variables were used to create random forest models for SAV presence using the entire training dataset. For the development and validation of the SAV percent cover models, only points where SAV was found to be present in the training datasets were used to develop the models (after Midwood et al. in press).

ACCURACY ASSESSMENT

The testing dataset was used for all model accuracy assessments with the entirety of this dataset used to evaluate the SAV presence models and only points where SAV was present in this dataset used to validate the SAV percent cover model. For the SAV presence models, accuracy was evaluated using both the overall percent accuracy (i.e., proportion of all data points correctly assigned to have SAV present or absent) and SAV presence accuracy (i.e., proportion of all data points correctly assigned to have SAV present [%]); for both estimate the best model will have the highest accuracy. Cohen’s Kappa statistic was also used to compare models. This measure incorporates the potential for agreement based solely on chance (Cohen 1960). Kappa values between 0.5-0.8 are generally considered to represent reasonable agreement, but values >0.8 are preferred (Cohen 1960). A different approach was required to assess the accuracy of the SAV percent cover models. Both the root mean square error (RMSE) and weighted absolute percentage error (WAPE) were calculated for each model with the “best’ model yielding the lowest RMSE and WAPE values while still having the highest percent variance explained. The RMSE is a scale-dependent measurement of error between predicted and observed values whereas WAPE can incorporate zero or near-zero values that may otherwise yield undefined mean absolute percentage error values (Kim and Kim 2016).

RESULTS

The occurrence of SAV in the training dataset showed declining trends with increasing depth, velocity, and dist_ship (Figure 3). For both the SAV presence and SAV percent cover models, the best fitting model included all three input independent variables (depth, dist_ship, and velocity). Specifically for the best fitting SAV presence model (SAV-P-A), overall accuracy and SAV presence accuracy were high (93.9% and 90.9%, respecitvely) and Kappa was >0.85 (Table 1). The best fitting SAV percent cover model (SAV-Cover-A) had the lowest RMSE (19.3) and explained the greatest amount of variance (>75%), but most other models had lower WAPE values. These other models, however, explained less variance within the dataset (10.5-71.6%) and were therefore not as optimal as SAV-Cover-A (Table 2).

DISCUSSION

This report details the development of both a presence and percent cover model for SAV in the St. Clair and Detroit River systems. A data-driven evaluation of the accuracy of these models suggests that they are accurate and explain a fair amount of variance within the available dataset (>75%), despite the limited number of input variables. The next step in the evaluation of these models is to apply them spatially within the SCDR systems to identify potential areas where these models perform poorly (e.g., mouth of tributaries with low water clarity, sand bars where substrates may be unsuitable). In order to complete this step, an accurate digital elevation model for the system is required and decisions will need to be made on what water surface elevation will be applied to the digital elevation model to provide continuous depth values throughout the system. If the models pass this spatial assessment, they can be applied within the St. Clair and Detroit River systems to map the distribution and cover of SAV, predict if and to what extent SAV will colonize remediated sites, and support the classification of fish habitat types.

A major limitation with the current models is that water clarity was not used as a predictor variable, despite it being regularly identified as critical to determining the maximum depth where SAV can colonize (Chambers and Kalff 1985; Lacoul and

Freedman 2006). In the present models, water depth was used as a surrogate for water clarity and is assumed to be consistent throughout the systems. This is not an accurate assumption as inflowing waters from tributaries like the Canard River and Turkey Creek are known to have high turbidity, which would act to increase light attenuation and therefore decrease the maximum depth of SAV colonization in some portions of the SCDR systems. Some water clarity information was available for parts of the SCDR systems, but comparable data were not available throughout and this led to the exclusion of these data from the final model. Without incorporating this critical metric into the model, results from the application of these models to the SCDR systems should be considered as maps of potential SAV habitat (within the constraints of depth, fetch, and water velocity) rather than realized SAV habitat. That being said, if spatially complete water clarity information does become available in the future (i.e., through the application of remote sensing technology or spatially and temporally extensive field sampling), the easy implementation of the random forest modelling approach would allow for it to be incorporated and results from the present report can be used to explore the benefits (in terms of model accuracy) of including this parameter. Alternately, water clarity can be applied as a *post hoc* modifer to the model output wherein available Secchi depth or light attenuation data are used to restrict the distribution of SAV. One option may be to apply an equation to estimate the euphotic depth (i.e., the depth reached by 1% of the surface irradiance) that has been derived for turbid waters (Eq. 1, where Secchi depth is measured in metres; Holmes 1970). Using the euphotic depth as a surrogate for the maximum depth where SAV can colonize could help restrict SAV distributions where appropriate in a scientifically defensible manner.

$$Eq. 1 \quad Euphotic\ Depth = 1.4\ \times (Secchi\ Depth)$$

An additional environmental metric that was not included in the present modelling efforts was substrate composition. Past studies have shown that abundant sand (>75%) or organic material (>20%) can impair the growth and establishment of SAV (Barko and Smart 1986; Capers and Les 2005); however, these metrics are also strongly correlated to the magnitude of exposure or flow (i.e., wind or wave action and water velocity) such that organic materials are generally absent in high energy regions where sand is more likely to be dominant (Madsen et al. 2001). As a result, substrate was not included in the present models as some element of its effects were likely captured by the dist_ship and water velocity metrics. Additionally, detailed spatial information on substrate composition is challenging to acquire in the SCDR systems, which would have limited the spatial application of a model containing substrate composition to those areas where detailed substrate surveys have been conducted. Future data collection and compilation efforts may yield additional environmental metrics (e.g., water clairty, substrate composition) at spatial resolution that would allow for their integration with the hydroacoustic data used the present works. At this time, an additional evaluation of the benefits of integrating these metrics into the SAV models should be explored to help guide the development and refinement of SAV models both within the SCDR systems and in other aquatic ecosystems.

CONCLUSION

Despite the noted limitations regarding water clarity and substrate, the SAV models presented in this report have comparable or better accuracies than those presented in previous studies (>90% in the current study compared to ~80% in Midwood et al. in press and Altartouri et al. 2014). This bodes well for the application of this model in the St. Clair and Detroit River systems and for future efforts that may integrate some measure of water clarity into the model, which will only serve to improve model accuracy. This model can now be applied spatially within the St. Clair and Detroit River AOCs to help quantify the amount and quality of fish and aquatic habitat and support the assessment of the degradation to fish and wildlife habitat beneficial use impairment.

ACKNOWLEDGEMENTS

Thank you to Kathy Leisti, David Reddick, Dr. Susan Doka, and other DFO staff for assistance with collecting field data. Thank you also to Jesse Gardner-Costa and Daniel Weller for input on earlier drafts of this report. Funding for this project was provided by the Great Lakes Action Plan (Enivronment and Climate Change Canada).

REFERENCES

Altartouri, A., Nurminen, L., and Jolma, A. 2014. Modeling the role of the close-range effect and environmental variables in the occurrence and spread of Phragmites australis in four sites on the Finnish coast of the Gulf of Finland and the Archipelago Sea. Ecol. Evol. 4: 987–1005.

Breiman, L. 2001 Random Forests, Mach. Learn. 45(1): 5-32.

Barko, J., and Smart, R. 1986. Sediment-related mechanisms of growth limitation in submersed macrophytes. Ecology 67: 1328–1340.

Barko, J. 1991. Sediment interactions with submersed macrophyte growth and community dynamics. Aquat. Bot. 41: 41–65.

Capers, R., and Les, D. 2005. Plant community structure in a freshwater tidal wetland. Rhodora 107: 386–407.

Chambers, P., and Kalff, J. 1985. Depth distribution and biomass of submersed aquatic macrophyte communities in relation to secchi depth. Can. J. Fish. Aquat. Sci. 42: 701–709.

Chambers, P. 1987. Nearshore occurrence of submersed aquatic macrophytes in relation to wave action. Can. J. Fish. Aquat. Sci. 44: 1666–1669.

Chambers, P., Prepas, E., Hamilton, H., and Bothwell, M. 1991. Current velocity and its effect on aquatic macrophytes in flowing waters. Ecol. Appl. 1: 249– 257.

Cho, H., and Poirrier, M. 2005. A model to estimate potential submersed aquatic vegetation habitat based on studies in Lake Pontchartrain, Louisiana. Restor. Ecol. 13: 623–629.

Chu, C., Minns, C.K., Lester, N.P. and Mandrak, N.E. 2014. An updated assessment of human activities, the environment, and freshwater fish biodiversity in Canada. Can. J. Fish. Aquat. Sci. 72(1): 135-148.

Cohen, J. 1960. A Coefficient of Agreement for Nominal Scales. Educ. Psychol. Meas. 20: 37–46.

Cutler, D.R., Edwards, T.C., Beard, K.H., Cutler, A., Hess, K.T., Gibson, J. and Lawler, J.J. 2007. Random forests for classification in ecology. Ecology 88(11): 2783-2792.

Gardner Costa, J., Leisti, K.E., Midwood, J.D., and Doka, S.E. 2018. Submerged aquatic vegetation survey in the Bay of Quinte, 2015. Can. Tech. Rep. Fish. Aquat. Sci. 3285: viii + 33 p.

Goodyear, C.D., Edsall, T.A., Demsey, D.M., Moss, G.D., and Polanski, P.E. 1982.Atlas of the spawning and nursery areas of Great Lakes fishes. FWS/OBS-82/52, vol. I-XIV. U.S.Fish and Wildlife Service.

Havens, K., Harwell, M., Brady, M., Sharfstein, B., East, T., Rodusky, A., Anson, D., and Maki, R. 2002. Large-scale mapping and predictive modeling of submerged aquatic vegetation in a shallow eutrophic lake. Sci World J. 2: 949–965.

Holmes, R.W. 1970. The Secchi disk in turbid coastal water. Limnol. Oceanogr. 15(5): 688-694.

Hondorp, D.W., Roseman, E.F. and Manny, B.A. 2014. An ecological basis for future fish habitat restoration efforts in the Huron-Erie Corridor. J. Great Lakes Res. 40:23-30.

Hudon, C., Lalonde, S., and Gagnon, P. 2000. Ranking the effects of site exposure, plant growth form, water depth, and transparency on aquatic plant biomass Can. J. Fish. Aquat. Sci. 57: 31–42.

Keddy, P. 1983. Shoreline vegetation in Axe Lake, Ontario: effects of exposure on zonation patterns. Ecology 64: 331–344.

Kim, S. and Kim, H. 2016. A new metric of absolute percentage error for intermittent demand forecasts. Int. J. Forecast. 32: 669–679.

Lacoul, P., and Freedman, B. 2006. Environmental influences on aquatic plants in freshwater ecosystems. Environ. Rev. 14: 89–136.

Lapointe, N.W., Corkum, L.D. and Mandrak, N.E. 2007. Seasonal and ontogenic shifts in microhabitat selection by fishes in the shallow waters of the Detroit River, a large connecting channel. Trans. Am. Fish. Soc. 136(1):155-166.

Madsen, J., Chambers, P., James, W., Koch, E., and Westlake, D. 2001. The interaction between water movement, sediment dynamics and submersed macrophytes. Hydrobiologia 444: 71–84.

Middelboe, A., and Markager, S. 1997. Depth limits and minimum light requirements of freshwater macrophytes. Freshw. Biol. 37: 553–568

Midwood, J.D., Gardner-Costa, J., Doka, S.E., and Tang, R. In Press. Comparison of approaches for modelling submerged aquatic vegetation in the Toronto and Region Area of Concern. J. Great Lakes. Res.

Randall, R., Minns, C., Cairns, V., and Moore, J. 1996. The relationship between an index of fish production and submerged macrophytes and other habitat features at three littoral areas in the Great Lakes. Can. J. Fish. Aquat. Sci. 53: 35–44.

Rémillard, C.Y.L., Dosen, J.M., Gardner Costa J., MacEachern, J., Midwood, J.D., Liesti, K.E., and Doka, S.E. 2020. St. Clair-Detroit River System (SCDRS) gap analysis and geodatabase report: St. Clair River and Detroit River Areas of Concern. Can. Tech. Rep. Fish. Aquat. Sci. 3367: xiii + 97 p.

Rohweder, J., Rogala, J. T., Johnson, B. L., Anderson, D., Clark, S., Chamberlin, F., and Runyon, K. 2012. Application of wind fetch and wave models for habitat rehabilitation and enhancement projects — 2012 update. Contract Report Prepared for U.S. Army Corps of Engineers' Upper Mississippi River Restoration — Environmental Management Program. 52 pp.

Riis, T., and Hawes, I. 2003. Effect of wave exposure on vegetation abundance, richness and depth distribution of shallow water plants in a New Zealand lake. Freshw. Biol. 48: 75–87.

Sand-Jensen, K., and Madsen, T. 1991. Minimum light requirements of submerged freshwater macrophytes in laboratory growth experiments. J. Ecol. 79: 749–764.

Stewart, C., and Freedman, B. 1989. Comparison of the macrophyte communities of a clearwater and a brownwater oligotrophic lake in Kejimkujik National Park, Nova Scotia. Water Air Soil Pollut. 46: 335–341.

Table 1. Details on the structure, variance explained, and accuracy for models developed to predict the presence of submerged aquatic vegetation in the St. Clair and Detroit River systems. Each model used 1000 trees.

Model	Independent Variables	Overall Accuracy (%)	SAV Presence Accuracy (%)	Kappa
SAV-P-A	Depth, Dist_ship, Velocity	93.9	90.9	0.86
SAV-P-B	Depth, Dist_ship	88.0	80.5	0.72
SAV-P-C	Depth, Velocity	91.1	86.2	0.80
SAV-P-D	Dist_ship, Velocity	90.0	83.0	0.77
SAV-P-E	Depth	88.5	84.2	0.74
SAV-P-F	Dist_ship	80.1	58.4	0.52
SAV-P-G	Velocity	88.7	82.9	0.74

Table 2. Details on the structure, variance explained, and accuracy for models developed to predict the cover of submerged aquatic vegetation in the St. Clair and Detroit River systems. Each model used 1000 trees.

Model	**Independent Variables**	**% Variance Explained**	**Mean Squared Residuals**	**Root Mean Square Error**	**Weighted Absolute Percentage Error**
SAV-C-A	Depth, Dist_ship, Velocity	78.8	372	19.3	114
SAV-C-B	Depth, Dist_ship	59.4	715	26.7	104
SAV-C-C	Depth, Velocity	71.6	499	22.4	112
SAV-C-D	Dist_ship, Velocity	68.0	563	23.6	105
SAV-C-E	Depth	53.5	818	28.3	117
SAV-C-F	Dist_ship	29.7	1235	35.2	83
SAV-C-G	Velocity	62.2	664	25.8	111

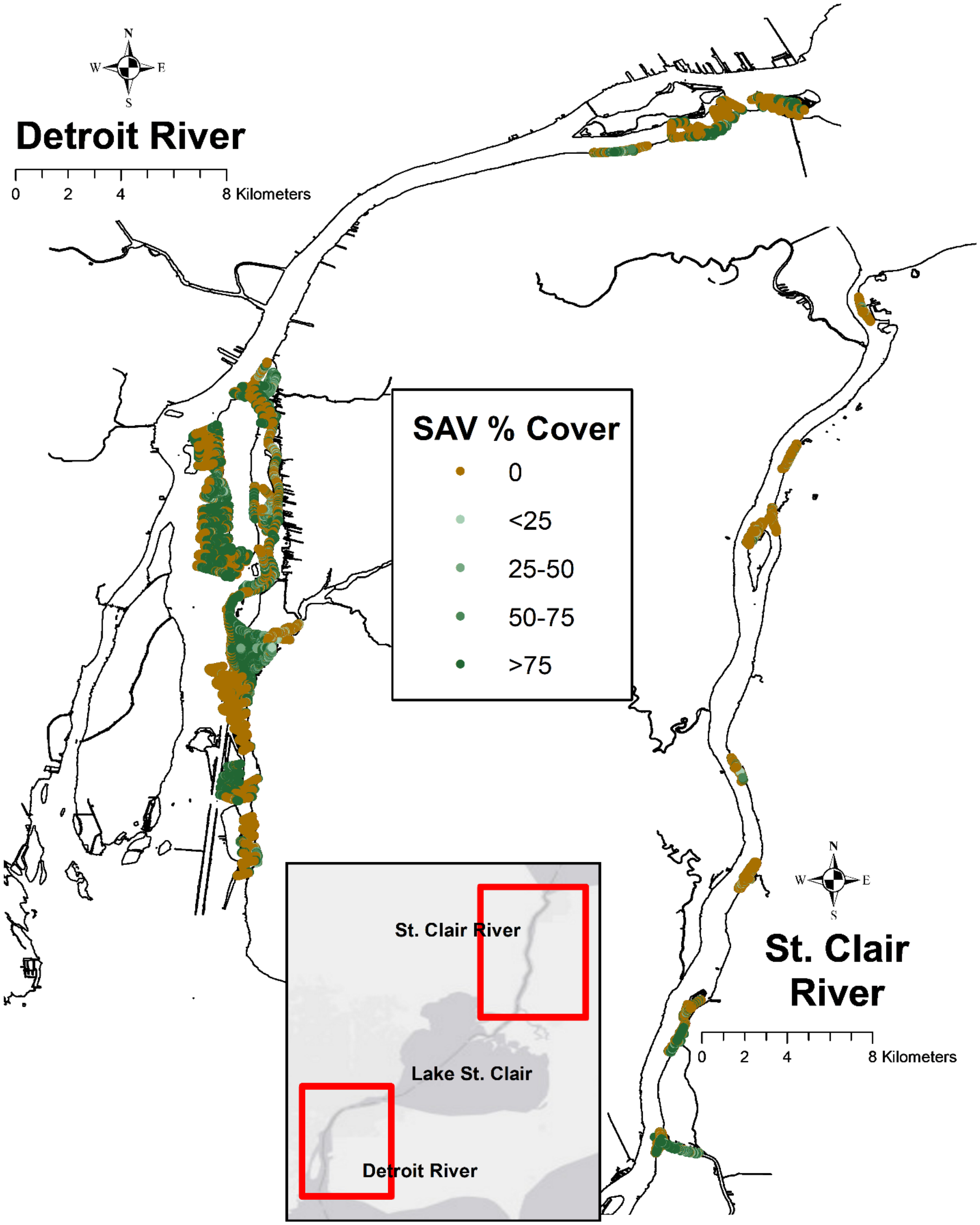

Figure 1. Map of St. Clair and Detroit Rivers with the locations of the input data used in model development and testing (green = submerged aquatic vegetation [SAV], brown = no SAV). Important to note that the total spatial extent of SAV within these systems is not shown.

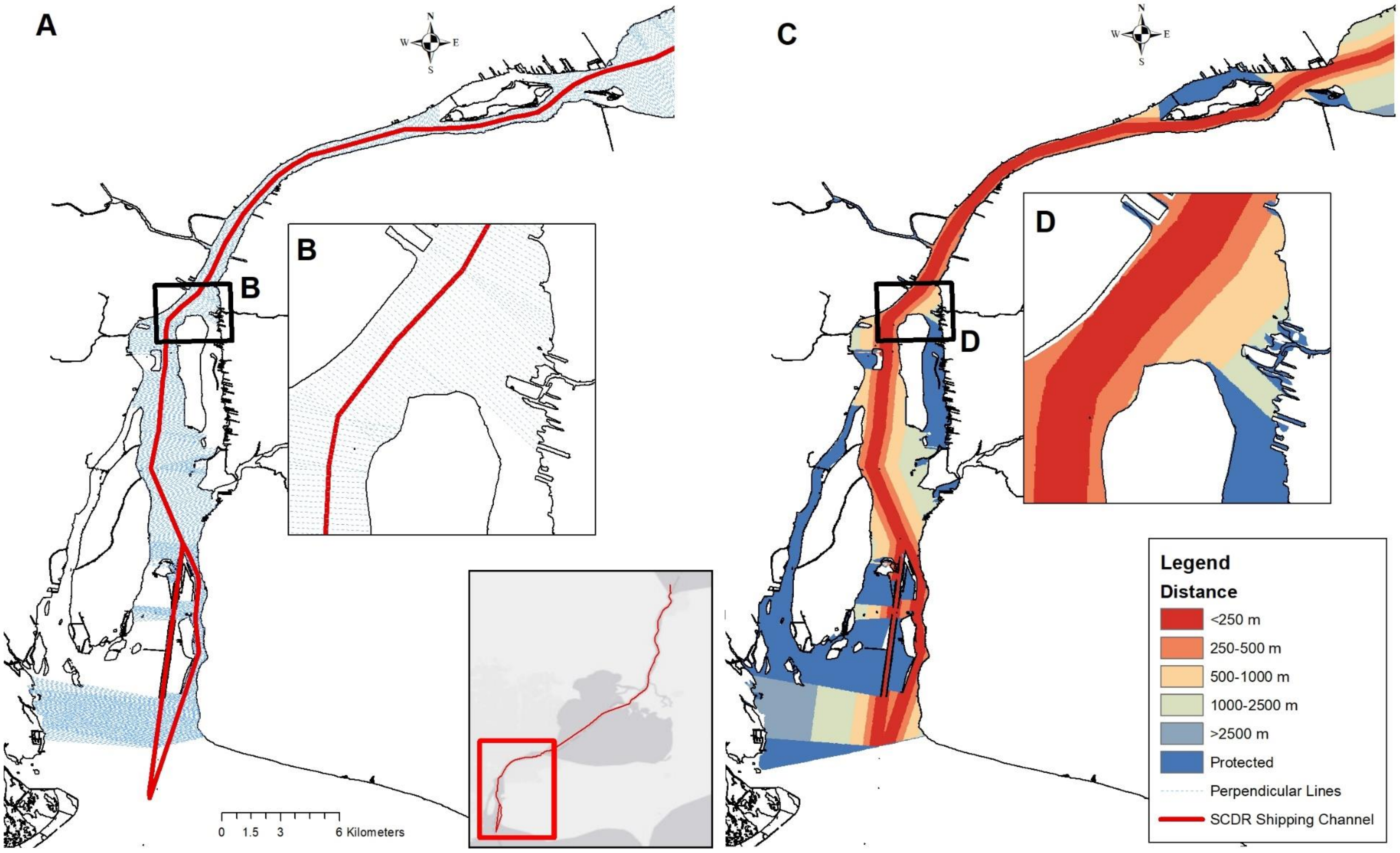

Figure 2. Example of the calculation of the distance to the shipping channel in the Detroit River. Panel A and inset B show the channel (red) and perpendicular lines from the channel that are spaced at 50 m intervals along the channel. Panel C and inset D show the resulting distances from the channel in the system as well as areas that were deemed to be protected by land (dark blue).

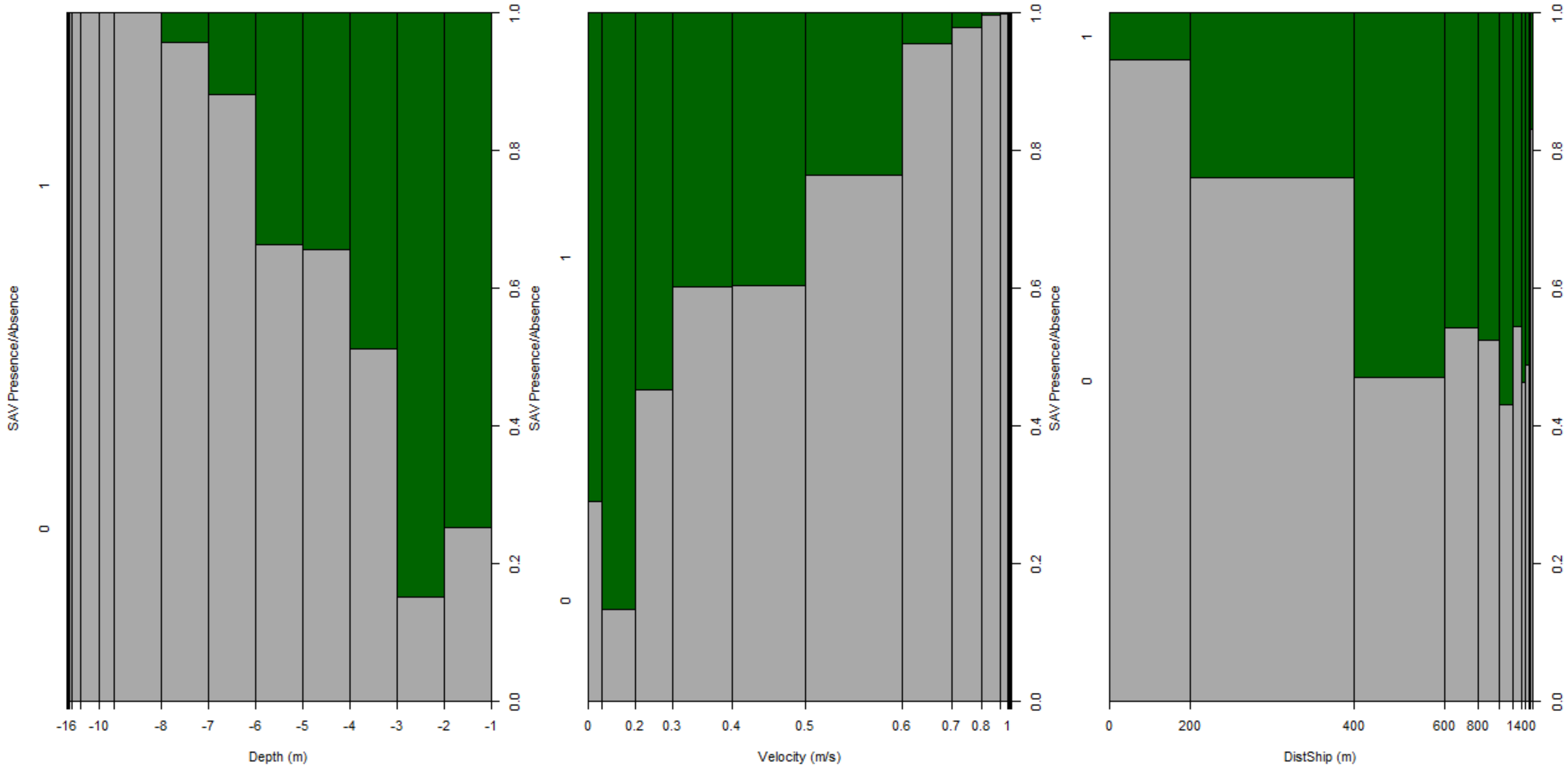

Figure 3. Stacked histograms showing the presence (green bars) and absence (grey bars) of submerged aquatic vegetation relative to the input environmental metrics for all data (both training and testing datasets).