



DEVELOPMENT OF A FISH HABITAT CLASSIFICATION MODEL FOR LITTORAL AREAS OF SEVERN SOUND, GEORGIAN BAY, A GREAT LAKES' AREA OF CONCERN

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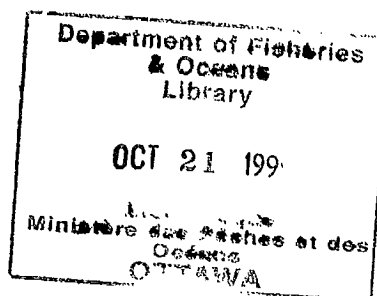
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ABSTRACT

C.K. Minns, P. Brunette, M. Stoneman, K. Sherman, R. Craig, C. Portt, and R.G. Randall. 1999. Development of a Fish Habitat Classification Model for Littoral Areas of Severn Sound, Georgian Bay, a Great Lakes' Area of Concern. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2490.

This report documents the GIS database assembled for the littoral habitat areas of Severn Sound, Georgian Bay, and describes the methods used to devise a fish habitat classification model for those littoral areas. Development of the classification model was undertaken to provide the implementers of the Remedial Action Plan in Severn Sound with a scientifically defensible update for their interim fish habitat management plan. The interim plan was prepared as a guidance document for local and regional planning authorities to promote increased regard for fish habitat and the legislated responsibilities where proposed developments impinge on littoral habitat. In that plan, a group of local fish habitat experts had classified shoreline lengths into one of three classes, Red, Yellow or Green. The different colours signaled different levels of importance of littoral areas as fish habitat and the lists of allowable and excluded activities were linked to the colour-codes. Most of the littoral habitat in Severn Sound between 0 and 1.5 metre depth was inventoried over a period of several years. Depth, substrate, and vegetation areas were mapped by field crews for much of the littoral zone. The data were digitized and brought into a geographic information system (GIS). The GIS database provided the foundation for the development of a new fish habitat classification model. The fish habitat model considered four types of information: 1) Composite suitability index values derived for all species and life stages of the fish assembly present in Severn Sound using the Defensible Methods suitability indexing model; 2) Identification of rare habitat types specific to particular thermal-life stage-trophic guilds of fish species; 3) Wetlands identified through Ontario's provincial wetland classification system; and 4) Local expert identification of important habitat areas for particular fish species and life stages. For the composite and rarity components of the model, method development and validation results are described. Each component was implemented as a map layer in the GIS database. The classification model separates of habitat units into three classes, low, medium, and high, using composite suitability indices. Then the rarity, wetland, and expert layers are used to override low and medium class memberships, reassigning them to the high class. The final high, medium, and low classes are then renamed Red, Yellow and Green. The results of the classification steps are illustrated. The complete GIS database including full implementation of the classification model are available on an enclosed CD-ROM. The limitations of the source data and the classification model are assessed and future steps required for iterative improvement are identified.

RÉSUMÉ

C.K. Minns, P. Brunette, M. Stoneman, K. Sherman, R. Craig, C. Portt, and R.G. Randall. 1999. Development of a Fish Habitat Classification Model for Littoral Areas of Severn Sound, Georgian Bay, a Great Lakes' Area of Concern. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2490.

Ce rapport présente la base de données SIG créée pour les zones d'habitat littoral de la baie Severn, dans la baie Georgienne, et décrit les méthodes utilisées pour la mise au point d'un modèle de classification de l'habitat du poisson pour ces zones littorales. L'élaboration du modèle de classification doit permettre aux réalisateurs du plan d'assainissement de la baie Severn de faire le point de façon scientifiquement justifiable sur leur plan provisoire de gestion de l'habitat du poisson. Ce plan provisoire constitue pour les autorités responsables de la planification locale et régionale un document d'orientation qui demande de porter une attention particulière aux habitats du poisson et aux responsabilités imposées par la loi, là où les développements proposés empiètent sur l'habitat littoral. Dans le cadre du plan, un groupe d'experts locaux sur l'habitat du poisson ont classé les longueurs de rivage en trois catégories : rouge, jaune et verte. Les différentes couleurs représentent les différents degrés d'importance des zones littorales en tant qu'habitat du poisson; les listes d'activités permises et défendues ont été associées aux codes de couleur. Une grande partie de l'habitat littoral de la baie Severn situé entre 0,5 et 1 mètre de profondeur a été inventoriée sur une période de plusieurs années. Des cartes de la profondeur, du substrat et des zones de végétation ont été réalisées par des équipes de terrain pour la plus grande partie de la zone littorale. Les données ont été numérisées et intégrées à un Système d'information géographique (SIG). La base de données SIG a fourni l'assise d'un nouveau modèle de classification de l'habitat du poisson qui a pris en compte quatre types de renseignements : 1) l'indice composite d'adéquation calculé pour toutes les espèces et les stades biologiques des assemblages de poissons présents dans la baie Severn en utilisant le modèle de l'indice d'adéquation à méthodes contrôlées; 2) l'identification de types d'habitat rares correspondant aux conditions thermiques, aux stades biologiques et aux états trophiques de guildes particulières d'espèces de poisson; 3) les terres humides identifiées à l'aide du système de classification des terres humides de l'Ontario et; 4) la désignation, par des experts locaux, de zones d'habitat importantes pour des espèces de poisson et des stades biologiques spécifiques. Pour l'indice composite d'adéquation et la composante de rareté du modèle, l'élaboration des méthodes et les résultats de la validation sont expliqués. Chaque composante a été représentée comme une couche dans la base de données SIG. Le modèle de classification utilise les indices composites d'adéquation pour séparer les unités d'habitat en trois catégories : basse, moyenne et haute. Ensuite, les couches correspondant à la rareté, aux terres humides et à l'avis des experts sont utilisées pour annuler les membres de la catégorie basse et moyenne afin de les transférer dans la catégorie haute. Les catégories finales haute, moyenne et basse sont alors renommées rouge, jaune et verte. Les résultats des étapes de classification sont illustrés. La base de données SIG finale comprend l'implantation complète du modèle de classification et se trouve sur le CD-Rom ci-joint. Les limitations des données sources et du modèle de classification sont évaluées, et les démarches ultérieures nécessaires pour une amélioration itérative sont identifiées.

TABLES OF CONTENTS

ABSTRACT.....	iii
RÉSUMÉ	iv
TABLES OF CONTENTS	v
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF APPENDICES	ix
INTRODUCTION.....	1
Severn Sound Littoral Zone Fish Habitat Database	2
Fish Habitat Thematic Layers in the GIS Database	3
Purpose and Objectives	4
METHODOLOGY	5
Fish Habitat Suitability Assessment Component	5
Fish Habitat Suitability Classification Component.....	5
FISH HABITAT SUITABILITY ASSESSMENT COMPONENT.....	6
Development of a Definition for Applying Defensible Methods	6
<i>Location Species List</i>	6
<i>Selection of Group and Life Stage Weights</i>	6
<i>Sensitivity Analysis for Weight Selection</i>	7
Defensible Methods Weights for Severn Sound Littoral Zone Habitat Suitabilities	9
Linking Fish Habitat Categories to Defensible Methods' Species Requirements	9
Computation of Habitat Suitabilities.....	10
Fish Habitat Suitability Index Validation.....	11
Fish Habitat Rarity Assessment	14
FISH HABITAT SUITABILITY CLASSIFICATION COMPONENT.....	16
Composite Suitability Classification.....	16
Rarity Classification.....	19
Role of Provincially Significant Wetlands.....	19
Importance of Site-Specific Expert Knowledge.....	20
Overall Rule-Based Classification Model.....	21
RESULTS	21
Spatial Accuracy of Topological Overlay	21
Fish Habitat Classification Results in Severn Sound.....	22

DISCUSSION	25
Geospatial Issues	25
<i>Spatial Data Accuracy</i>	25
<i>Sources of Positional Error</i>	26
<i>Sources of Attribute Error</i>	26
<i>Sources Analytical Error (Both Positional and Attribute)</i>	26
Future Research and Information Needs	27
<i>Expert site-specific knowledge database</i>	27
<i>A complete fish habitat inventory</i>	27
<i>A mechanism for updating the GIS inventory database</i>	28
Linkage to the Revised Fish Habitat Management Plan for Severn Sound	28
ACKNOWLEDGEMENTS	31
REFERENCES.....	32
APPENDIX A	60
APPENDIX B	77
APPENDIX C	78
APPENDIX D	82
APPENDIX E	86

LIST OF TABLES

- | | |
|----------|--|
| Table 1 | Combinations of thermal and trophic group, and life stage weights used to examine the sensitivity of composite suitability values obtained from Defensible Methods to the choice of weights. Combinations examined independently for each group with the others at reference values. Weights are expressed as percentages and each group sums to 100 percent. |
| Table 2 | Mapping of Severn Sound littoral zone physical habitat database (substrate, vegetation and depth) attributes to the corresponding categories in the Defensible Methods' freshwater species, habitat requirement database. |
| Table 3 | Pearson correlation coefficients between Defensible Methods' littoral zone habitat suitability database constituent indices and fish community measures. (Values in bold-face are significant at $P = 0.05$ after Bonferroni correction). |
| Table 4 | Percent of littoral zone fish habitat suitability composite classification (Low, Medium, High) passing (1) or failing (0) the <i>rarity threshold</i> (areas with composite suitability indices greater than 0.75 and falling within the upper 25 percent of the littoral zone cumulative area distribution). The shaded percentages indicated the areas that are reclassified as High when the rarity threshold is applied. |
| Table 5 | Average substrate composition by littoral zone habitat suitability composite suitability (Low, Medium, High) and rarity (0/1) classification for the seven fish group/life stage assemblages which meet the <i>rarity threshold</i> criteria (Littoral zone habitat suitability classifications Medium are reclassified to High). [See table 4 for an explanation of the shading.] |
| Table 6 | Total area of littoral zone physical habitat falling in Ontario Ministry of Natural Resources District provincially significant wetlands by percent littoral zone habitat suitability database composite and rarity classification (Low, Medium, High). |
| Table 7 | Total area (km ²) of littoral zone physical habitat database by suitability classification Low, Medium, High for each of the component criteria in the littoral zone habitat suitability classification model. |
| Table 8 | Average substrate and vegetation composition by colour class (Red, Yellow, Green) in the final habitat suitability classification. |
| Table 9 | Total area and relative percent by colour class (Red, Yellow, Green) in the final habitat suitability classification summarized by municipality. |
| Table 10 | Average substrate and vegetation composition summarized by municipality (averages obtain from the Substrate and Vegetation thematic habitat layers). |

- Table 11 Total length (km) of shoreline within Severn Sound watershed and relative percent of total littoral zone habitat classified summarized by municipality.
- Table 12 Total length (km) of shoreline within Severn Sound watershed and relative percent by colour class (Red, Yellow, Green) in the final habitat suitability classification, summarized by municipality.

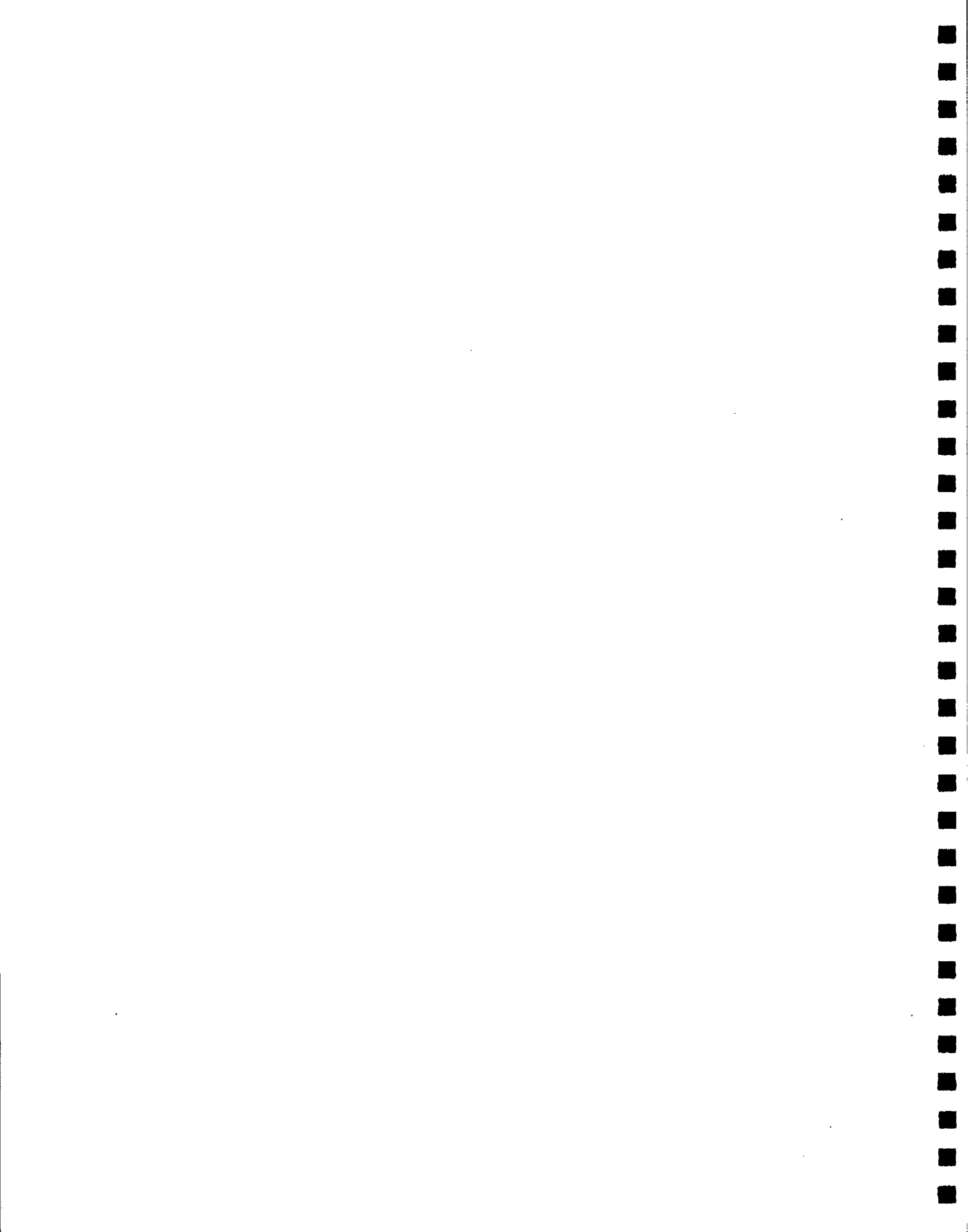
LIST OF FIGURES

- Figure 1 Study area map of Severn Sound, Georgian Bay, illustrating the extent of littoral zone physical habitat surveyed by field season years 1989-1994.
- Figure 2 Aquatic Habitat Suitability Assessment and Classification Object Flow Model.
- Figure 3 Graphs showing the Pearson correlation between pairs of composite habitat suitability values versus the Euclidean distance between the corresponding pairs of group and life stage weights for a representative sample of habitat polygons from the Severn Sound littoral zone database (N=1873): A) Trophic weights, B) Life stage weights, and C) Thermal weights.
- Figure 4 Graphs showing the relationships, and their statistical significance, between direct measures of the fish community (A- density, B – biomass, and C – species richness) and the Severn Sound littoral zone habitat suitability composite indices.
- Figure 5 Graphs showing the relationships, and their statistical significance, between raw (A) and adjusted (B) IBI values and the Severn Sound composite habitat suitability indices. (The adjusted IBI reduces the influence of offshore fish species).
- Figure 6 Graphs of cumulative area and weighted suitable area (WSA) illustrating the application of the 75 percent and 0.75 suitability cut-offs for identifying rare, highly suitable habitat. (In A, the WSA line enters the shaded quadrant from below representing common habitat, in C the WSA line does not enter the shaded area indicating the absence of high quality habitat, while in B and D enter from the side representing rare habitat).
- Figure 7 Process model illustrating the topological overlaying of multi-layer input coverage for producing the Final Habitat Suitability Layer.
- Figure 8 The frequency distribution of Severn Sound composite habitat suitability index values (N=1873).
- Figure 9 Resulting classification model from the classification and regression tree (CART) analysis used to classify Severn Sound littoral zone habitat database composite suitability index values into discrete categories Low, Medium, High. (CART Model pruned to four terminal nodes).

- Figure 10 Percentage frequency distributions for the sample of Severn Sound composite habitat suitability index values for the three groups derived from the CART analysis.
- Figure 11 Cumulative percent frequency curves for the three groups derived from the CART analysis: A) Group 1 versus group 2; B) group 2 versus group 3. (In each plot, the second cumulative curve is inverted to show the cross-over points in the distributions).
- Figure 12 Graphs showing the proportion of sample littoral habitat suitability areas misclassified versus composite suitability index cut-off values: A) Lower cut-off separating Low and Medium; B) Upper cut-off separating Medium and High. (The minimum misclassification rate occurs at cut-offs of 0.2342 and 0.5236).
- Figure 13 Rule-based decision tree showing the final methodological steps incorporating all information in the classification of littoral habitat area as High, Medium or Low.
- Figure 14 Sample shoreline areas with colour-coded habitat classifications indicated: A), B), C), D) (See Figure 1 for the locations of the samples).

LIST OF APPENDICES

- Appendix A Metadata documentation and data dictionary for the Severn Sound littoral zone physical habitat GIS database.
- Appendix B Freshwater fish species list for Severn Sound, Georgian Bay.
- Appendix C Plots showing the relationship between fish community measures (A - species richness, B - Density, and C - biomass per electro-fishing transect sample) and Defensible Methods assessed littoral zone habitat suitability database indices for all combinations of thermal (warm-water and cool-water), trophic (piscivore and non-piscivore), and life stage (adult and YOY) in Severn Sound.
- Appendix D Graphs showing cumulative area (dashed line) and cumulative weighted suitable area – WSA (solid line) versus Severn Sound littoral zone habitat suitability database indices for 1) warmwater, 2) coolwater and 3) coldwater fish groups. Suitability is further categorized by life stage and trophic group. [See main text for explanation of the derivation and application of these graphs.]
- Appendix E Inductive Littoral Zone Habitat Classification Pseudocode.
- Appendix F Severn Sound Littoral Zone Fish Habitat Suitability Map. Archived on CD-ROM in an Adobe® Acrobat Portable Document Format (suitmap.pdf). Also included is a freeware copy Adobe® Acrobat Reader 4.0 for Window® 95/98.



INTRODUCTION

In the 1980s, Severn Sound at the southern end of Georgian Bay was identified as one of 42 Areas of Concern (AOCs) on the Great Lakes by the International Joint Commission's Great Lakes Water Quality Board. Coupled with each site's designation as an AOC was the requirement that federal, provincial, and state agencies work together to develop a Remedial Action Plan (RAP) to restore fourteen defined beneficial human and ecosystem uses that were then impaired (Annex 2, Revised Great Lakes Water Quality Agreement of 1978). Degradation of fish and wildlife populations and degradation of fish and wildlife habitat were reported for many AOCs including Severn Sound. There is a broad consensus that fish population degradation is at least partially attributable to habitat degradation.

In the Severn Sound RAP Stage II Report, an interim fish habitat management plan was developed for littoral areas throughout Severn Sound (Severn Sound RAP 1993). The plan consisted of a guidance document and a 1:50,000 littoral zone fish habitat suitability map of the shoreline. The guidance document contains useful information about relevant legislation and policy as well as a scheme of site/development-specific advice linking different types of habitat (coded as Red, Yellow, or Green) to different types of potential shoreline development. The map was generated using local knowledge and expertise from local offices of environmental and natural resources agencies. The experts and RAP team assigned different ratings (Red, Yellow, or Green) to different stretches of shoreline depending on the perceived importance for fish attached to different physical habitat features. The rating schema corresponded with the Ontario Ministry of Natural Resources' (OMNR) habitat typing scheme (Red-Type1, Yellow-Type2-Green-Type3). Red indicated high quality habitat with greater sensitivity to development impacts; Green indicated low quality habitat often degraded as a result of past

indifference/negligence but with some potential for restoration and enhancement in future developments; and Yellow indicated habitat with intermediate qualities and potentials. Ratings assigned to sections of the shoreline were to be used in conjunction with habitat policies on various classes of development activity. This would assist local government planning offices and proponents of development to minimize or avoid impacts on fish habitat. Due to the lack of spatial detail and physical fish habitat information associated with the original Severn Sound habitat suitability map, the RAP team established a goal to revise and update the interim fish habitat management planning document. The RAP team initiated a systematic protocol for field data collection of littoral zone physical habitat features along the Severn Sound shoreline.

Severn Sound Littoral Zone Fish Habitat Database

Much of the Severn Sound shoreline was field-surveyed in six sections beginning in 1989 with Penetang Bay and finishing in 1994 at Honey Harbour (Figure 1). This survey provided an inventory of physical habitat data, including quantitative descriptions of bottom substrate materials, emergent and submerged vegetation composition and cover, shoreline materials, feature point information (e.g. docks etc.) and depth contours. Physical fish habitat data was collected from the shore to the 1.5-metre depth contour, which defined the littoral zone habitat area. The field methodology for physical habitat collection and shore-seining results of fish community composition and abundance at selected sites are described in Portt *et al* (unpublished MS report). The physical collection of littoral zone habitat data was conducted during summer months from June to September. In the field, habitat features were recorded onto 1:2,000 inventory maps that were generated either from Canadian Hydrographic Service (CHS) 1:10,000 charts or the Ontario Basic Mapping (OBM) 1:10,000 series. A digital spatial and attribute fish habitat database was created in 1992/93 using Arc/Info® geographic information system (GIS)

and mapped at a scale of 1:10,000 by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) GIS Unit. Selected OBM layers and the district evaluated wetlands layer were added to the database.

Fish Habitat Thematic Layers in the GIS Database

The following considerations influenced the overall design of the littoral zone habitat spatial attribute databases:

Compatibility: The spatial database was designed for maximum compatibility with the client's GIS systems. Arc/Info®, ArcView® (Environmental Research Institute, Inc., Redlands, CA 92373 USA.) and dBase® software are used by the OMNR and the Severn Sound RAP Team and local municipalities as GIS tools. Arc/Info® was used for creation, manipulation, storage and updating of the spatial database. dBase IV® was used for creation, manipulation, storage and updating of non-spatial or attribute data. ArcView® serves as an exploration tool for query, display and report generation (e.g. maps) of the spatial information. Knowledge of the client's GIS hardware and software allows for quick integration of the GIS datasets.

Portability: The spatial database was designed and corrected to fit existing GIS standards. These standards included choice of base mapping, coordinate system, spatial and attribute database structures and feature coding. This provided consistency and maximized the possibility of sharing attribute data and results with other GIS systems. Most importantly, following data standards allowed for further incorporation of other base or thematic information. All littoral zone habitat datasets have been archived on CD-ROM as an Arc/Info® uncompressed interchange format (e00) and as ArcView® shape files. (Contact Severn Sound Environmental Association for more information at PO Box 100, Wye Marsh Wildlife Centre, Midland, Ontario L4R 4K6). All Arc/Info® coverages are in UTM (Universal Transverse Mercator) map

projection and are referenced using North American Datum 1927 (NAD27).

Each section of the survey's thematic information was joined into a continuous coverage representing the Severn Sound shoreline stretching from Penetang Bay to Honey Harbour. A total of 343 kilometres of shoreline was surveyed over five years. The final five thematic coverages were shoreline materials, substrate composition, vegetation communities, depth contours, and shoreline features. A complete data dictionary describing the database structures and attribute definitions associated with the above coverages is provided in Appendix A.

This wealth of geospatial information was the basis for revising the interim, somewhat subjective, shoreline assessment and classification schema. GIS provided the tools for managing, manipulating, updating and analysis of geospatial fish habitat information as well as assisting in developing a scientifically defensible approach and methodology. The digital nature of the physical habitat data enabled new analysis operations and the comprehensive, explicit ability to spatially model and classify complex fish habitat information.

Purpose and Objectives

The purpose of this report is to document the sources of information, tools and methodologies used in developing a scientifically defensible approach for fish habitat assessment and classification to aid the management and conservation of littoral zone habitat areas in Severn Sound. This research builds on methods previously developed in the Bay of Quinte on Lake Ontario (McLeod *et al* 1995). The Defensible Methods model developed by Minns *et al* (1995) for assessing site-specific developments in nearshore habitats of the Great Lakes and the GIS-based habitat supply inventory for Severn Sound provided the framework for a Fish Habitat Suitability Classification Model. Given the content and format of the existing Interim Fish Habitat Management Plan, the modelling objective was to designate discrete areas of fish habitat

as belonging to one of three classes Red, Yellow, or Green representing different capabilities of supporting natural fish habitat productivity.

METHODOLOGY

An object flow representation for the Fish Habitat Suitability Classification Model is shown in Figure 2. The following describes the two main conceptual components, process/predictive models and classification models (Figure 2) and defines the logical steps required to develop the Fish Habitat Suitability Assessment and Classification Models.

Fish Habitat Suitability Assessment Component

- Assemble and organize the spatial and attribute littoral zone physical fish habitat data into a Geographical Information System;
- Couple the Defensible Methods habitat suitability assessment module with both the spatial and attribute substrate, vegetation and depth layers;
- Assess the suitability for fish habitat in littoral zone areas in Severn Sound by rating the habitat suitability for the fish community;
- Validate the composite suitability ratings calculated from the Defensible Methods model by statistically comparing it to actual fish catch information for Severn Sound;
- Develop criteria for assessing the rarity of habitat suitability for particular sub-components of the fish assemblage.

Fish Habitat Suitability Classification Component

- Use Classification and Regression Tree Modelling (CART) as a guide for classifying the continuous habitat suitability ratings into 3 discrete categories (High, Medium, Low);
- Topological overlay of explicit spatially modelled fish habitat suitability composite index, rarity, wetlands and expert knowledge layers to determine final suitability;

- Apply a multi-layer predictive and conditional rule-based induction classification schema (Low, Medium, High) for which a final Fish Habitat Suitability Map (Red, Yellow, Green) is generated.

FISH HABITAT SUITABILITY ASSESSMENT COMPONENT

Littoral zone habitat suitabilities were estimated using a refined version of 'Defensible Methods' software (D-M) described by Minns *et al.* (1996a). The refined version computes habitat suitabilities for three life stages of fish using literature-based databases assembled by Lane *et al.* (1996 a,b,c).

Development of a Definition for Applying Defensible Methods

There are several steps for computing suitability values for habitat areas:

Location Species List

A freshwater fish species list was assembled for Severn Sound drawing on all available sources (Robin Craig, personal communication). This list set the boundary for consideration of fish species habitat requirements in the estimation of littoral zone habitat suitability indices. The list includes 65 species (Appendix B).

Selection of Group and Life Stage Weights

The selection of group and life-stage weightings is an important step in the application of Defensible Methods. The location species list is divided into a series of groups, allowing different sub-assemblages to be weighed differently in the estimation of composite habitat suitability indices. Within a group, each species is assigned an equal weight. The choice of group weights should be guided by the fish community and fishery objectives for the ecosystem concerned and by the general nature of that ecosystem (biogeography, trophic status, morphometry, etc.). The criteria used to group fish species identified for an ecosystem can take several forms; however, in the development and testing of D-M, the criteria used have been

based on thermal preferences and trophic role. Other criteria such as exploitation (commercial, sport, forage, etc.) or endemism (native or exotic) could be used. In this application, the assemblage was divided into six groups representing three thermal preferences (warm, cool, and cold) and two trophic positions (piscivores and non-piscivores). Native and exotic species groups were not separated.

In the lacustrine applications of Defensible Methods, three habitat requirements data sets have been developed (Lane *et al* 1996a,b,c) representing the spawning, nursery (young-of-the-year or yoy), and adult habitat requirements of fishes present. These life-stage features are weighed and scaled so their sum is equal to one. Depending on the relative importance of habitat limitations to different life stages different weights are assigned. Minns *et al.* (1996) showed with a simple model for northern pike, *Esox lucius* L., that yoy habitat limitation had the greatest effect on population biomass and production and spawning habitat the least. This result was contrary to conventional wisdom based on anecdotal and non-quantitative criteria. At present, there is no objective way to determine life stage weights for all species and thus are set to be equal, giving equal importance to all life stages.

Each set of weights is scaled so they sum to one and the two sets are combined orthogonally and multiplicatively resulting in a combined sum of weights that remains equal to one. Whatever the criteria are, the proponent must present a rationale for the choice of criteria and the weights. The rationale has to be acceptable to the agencies managing fish habitat and fish.

Sensitivity Analysis for Weight Selection

To assess the relative sensitivity of habitat suitability to thermal, trophic, and life-stage weight selections, a series of combinations of weights was computed for a representative ten

percent sample of habitat polygons from the Severn Sound littoral zone physical habitat database (N = ~1873).

Taking the 18 unique suitability indices that can be computed for pure combinations of three thermal groups (Warm, Cool, Cold), two trophic groups (Piscivore, Non-piscivore), and three life stage (spawning, nursery and adult), composite suitability indices were computed for a range of weight combinations. To assess the relative sensitivity for each group type, only one group (thermal, trophic, or life stage) was varied at a time, while the other two were set at a reference value (Table 1). Composite indices were computed for all combinations across the sample data set and the correlation coefficient was calculated for each pair of weight assignments for the ten percent sample as a measure of sensitivity.

To evaluate the sensitivity of composite index values to differences in weight sets, we computed the Euclidean distance between weight sets. For example, if the piscivore/non-piscivore weights sets of P_1 and $(1-P_1)$, and P_2 and $(1-P_2)$ are used, the Euclidean distance $= \sqrt{((P_1 - P_2)^2 + (P_2 - P_1)^2)}$ where P_i is the proportional piscivore weight in each case. The distance allows the effect of weights changes on index values to be graphed.

For the Severn Sound species list, the sensitivity results show that composite indices were insensitive to changes in trophic weight (Figure 3A), moderately sensitive to changes in life-stage weights (Figure 3B), and highly sensitive to changes in thermal weights (Figure 3C). These results were consistent with general expectations. The habitat requirements across life stages of species at different trophic levels within the same thermal group might be expected to be similar and hence the thermal weights are expected to be the most sensitive. The greatest differences in habitat suitabilities arise between warmwater and coldwater species.

Judging by the results in Figure 3, step adjustments of weights can be on the order of 0.3

for trophic, 0.15 for life-stage, and 0.05 for thermal groups without unduly affecting the composite index when developing weight sets.

Defensible Methods Weights for Severn Sound Littoral Zone Habitat Suitabilities

Following the sensitivity analysis, the Defensible Methods weights were set and used to calculate suitability indices for Severn Sound littoral zone physical habitat database. The weights were assigned as follows: fish groups - warmwater piscivores 0.2, warmwater non-piscivores 0.2, coolwater piscivores 0.2, coolwater non-piscivores 0.2, coldwater piscivores 0.1, coldwater non-piscivores 0.1; and life stages – spawning 0.33, yoy 0.33, and adult 0.33. The fish group weights were based on giving equal treatment to piscivores and non-piscivores, offsetting the difference in numbers of species. Non-piscivore species greatly outnumber piscivores. The thermal weights were warm 0.4, cool 0.4, and cold 0.2, reflecting the fact that the inventory only covers the littoral zone where cold water species are occasionally found in spring, fall, and winter. However, warm and cool water species are found in differing proportions at various times of the year. The composite habitat requirements of piscivores and non-piscivores within a given thermal regime might be expected to be quite similar. Differences in spawning, nursery and adult habitats would lead one to expect some variation in suitability as life stage weightings varied. Thermal preference is strongly related to depth and, thus, to other habitat variable that are correlated with depth (i.e. macrophyte abundance). Therefore, it is not surprising that composite habitat suitability is most sensitive to thermal weights.

Linking Fish Habitat Categories to Defensible Methods' Species Requirements

As the habitat features and categories in the GIS database did not correspond one-to-one with those in the Defensible Methods fish habitat requirements database, a table for mapping one set into the other was devised (Table 2). The mapping of depths and substrates was

straightforward although it was necessary to split (50:50) the Severn Sound silt and organic categories between silt and clay in the Defensible Methods format. The vegetation presented a more complex problem. In the Severn Sound habitat inventory survey, submerged and emergent vegetation categories were treated as overlapping, non-exclusive measures. Since the sum of cover cannot exceed 100 percent, we computed no cover as the complement of the maximum of the submergent and emergent values. Then, to compute cover values for Defensible Methods, the three Severn Sound cover values were summed and used to scale the percentages so they summed to 100 again (Table 2 footnote).

Computation of Habitat Suitabilities

Preparation of spatial habitat characteristics for computing littoral zone habitat suitability values for Severn Sound required three thematic layers: bathymetry, substrate, and vegetation. Arc/Info® was used to perform a polygon intersection overlay of the three thematic input layers. The resulting thematic habitat suitability layer provided the unique habitat conditions required for suitability assessment. The following selection criteria used for defining the spatial extents of littoral habitat or the *wet zone* area exported into Defensible Methods application. First, the wet zone area was delineated by selecting polygons with depth values between zero and 1.5 metres (i.e. depth polygons coded as either Land or High Water Mark were excluded from the habitat suitability assessment). The wet zone areas excluded from the suitability assessment component were polygons with vegetation information and no substrate as well as polygons with depth information and no substrate or vegetation. The attribute information from the habitat suitability input layer was exported from the GIS and formatted as input records for Defensible Methods suitability rating. The composite and 18 constituent suitability values from Defensible Methods were joined to the unique condition or multiple thematic habitat suitability layer. This provided a

single GIS layer containing the spatial habitat information with a georelational model approach to linking the spatial wet zone areas to suitability values as attributes.

Fish Habitat Suitability Index Validation

As part of a project examining the productive capacity of littoral habitats in the Great Lakes, electro-fishing samples were collected at transects in 4 areas of Severn Sound (Hog Bay, Penetang Harbour, Green Island, and Sturgeon Bay) between 1990 and 1995. The methodology is outlined in Valere (1996) and in Randall *et al.* (1996, 1998) provides a description and analysis of the survey data linking fish community metrics to habitat characteristics in the nearshore zone. A total of 188 samples collected at 69 different transects with complete depth, substrate, and cover data were used for the validation analyses.

In addition to the fish capture data, habitat attributes were measured at each transect. Transects were laid out to follow the 1.5 metre depth contour, so the depth was considered to be a constant. The substrate composition was estimated visually and by “feel”, using an Ekman dredge to take samples of fine substrates. Vegetative cover was estimated either visually or by echogram. For each transect, a record was prepared which contained the mean percent vegetative cover, and the percent coverage by each category of substrate (Clay, Silt, Sand, Gravel, Rubble, Cobble, Boulder, Bedrock). These records were used as input to the Defensible Methods software. This enabled a direct comparison of suitability values with fish catches in Severn Sound.

The results of the Defensible Methods calculations consist of a series of 18 habitat suitability scores ranging between 0 and 1 for each combination of thermal preference (cold, cool and warm), trophic preference (piscivore and non-piscivore), and life history stage (adult, young-of-the-year, and spawning) categories. The individual scores were also pooled using the weights

defined above to produce a composite suitability index.

Electro-fishing capture data were also used to calculate an Index of Biotic Integrity (IBI) score for each sample as described in Minns *et al.* (1994). In addition to the IBI score, summaries of biomass, density, and species richness were calculated for each combination of thermal and trophic category and overall. For the purpose of statistical analysis, the summary variables apart from IBI and species richness were transformed using a natural logarithm ($x+1$) function.

As the electro-fishing surveys had been conducted in littoral areas during the summer, there were certain *a priori* expectations for the comparisons. As electro-fishing samples adult fish better than yoy, we expected correlations for adult indices to be higher than those for yoy. Correlations with spawning indices were expected to be low as the fish survey technique was not intended to assess spawning habitat use. Since the sampling was conducted nearshore during the warmer months of the year, we expected correlations with warmwater indices to be higher than those for coolwater and both warmwater and coolwater ones to be higher than those for coldwater.

Despite the presence of high constituent scores for some sites, none of the sites had a composite index value higher than 0.65 because the composite index was a weighted average of all of the constituent indices. Some of the constituent indices, mostly those associated with cold water species, rarely exceeded 0.2 and were negatively correlated with other indices. For instance, the scores for spawning cold water fish were negatively correlated with many of the warm water indices. Thus when indices for warm and cool species are high, those for cold species are low, limiting the maximum composite index value.

Merging the output of the IBI calculations with the output of the Defensible Methods calculations resulted in a file with 188 records containing the fish capture summary variables and

estimated suitability scores for the transect. This allowed a comparison to be made between the fish community present at a site and the predicted "suitability" of the site. Pearson correlation coefficients were calculated between the Defensible Methods suitability scores and the fish community measures, by thermal, trophic, and life stage. For example, the species richness, biomass and density of warm water piscivores were compared with the Defensible Methods scores for the adult, young of year, and spawning warm water piscivores. The total species richness, density and biomass were also compared with the Composite Index. Significance was tested at $p < 0.05$ after Bonferroni adjustment for multiple comparisons (Wilkinson, 1996).

Significant positive correlations were obtained in 10 of 36 cases among combinations of suitability indices and biomass, density and species richness values (Table 3). No cold water piscivores were caught and cold water non-piscivores were only caught at one location, therefore no conclusions could be drawn regarding the relationships between cold water fish and the Defensible Methods scores in Severn Sound. The greater abundance of non-piscivores resulted in generally stronger correlations than in the piscivores. The significant correlations were concentrated in yoy and adult comparisons for non-piscivores, and particularly for coolwater fishes.

Plots of the species richness, density and biomass versus the Defensible Methods suitability values for all non-coldwater index combinations show both the general tendency for higher fish catches to be associated with higher suitability values and the wide scatter in the relationships (Appendix C). Relationships between habitat variables and measures of the biotic community often show a high level of variability, with most of the data points lying within a "wedge shaped" area at the lower right corner of the graph (Terrell *et al.* 1996). The upper bound of the wedge provides an indication of the upper limit of the habitat's capacity. Points

which lie below that line could be depressed below the upper limit by some factor which was not included in the score, or they could simply be a result of the natural variability in the response of the biota to the environment. The lack of points in the upper left corner of the graphs suggests that the score does have relevance to the biota, as low scores are rarely associated with high measures of richness, density or biomass. Fish catch data often exhibits Poisson distributions, revealing a random distribution in the ecosystems and lessening the likelihood of obtaining strong fish-habitat correlations.

The correlations between the three total fish community catch measures and the composite suitability index were significant (Figure 4 A, B, C). Correlations between the composite index and both the raw IBI index and the IBI index adjusted for the influence of offshore species were significant (Figure 5 A and B). These results for the nearshore in Severn Sound showed that Defensible Methods habitat suitability indices provide measures of habitat quality consistent with the results obtained by directly sampling the fish communities using the habitat.

Fish Habitat Rarity Assessment

Following the completion of the composite suitability categorical classification, we were concerned that some habitat combinations, which were highly suitable for individual sub-components of the fish community, might be under-represented among the areas receiving the highest rating. To assess this concern, an analysis of the rarity of habitat was undertaken using the 18 constituent suitability indices as a guide. The objective of the analysis was to identify areas with high suitability for constituent indices that might be classified as Medium or Low using the composite suitability index.

Cumulative area and weighted suitable area (WSA) versus suitability curves were

generated for all 18 suitability indices using the sample dataset representing 10 percent of the complete dataset for Severn Sound (Appendix D). WSA is the product of area and suitability. Combinations of suitability and cumulative area and weighted suitable area percentage cut-offs were used to identify small aggregate areas with the highest suitability values. These areas were cross-classified with the composite suitability codes to evaluate the redundancy of assessing rareness. If a littoral zone area was identified as rare and was already coded High in the composite analysis, there was no reason to reclassify the area. In addition, when the rareness features were cross-classified with the composite suitability codes, the mean values of all habitat features and categories in the littoral zone physical habitat database were computed by class to reveal the nature of the habitats identified.

We used the combination of a 75 percent of area and a 0.75 habitat suitability index as a basis for identifying rare, high quality habitat. The dual criteria limited the consideration to habitats with high suitability values, as there seemed little point in protecting rare, low suitable habitat. The area percentage chosen as a cut-off was arbitrary and made the dual criteria symmetric. The habitat polygons with suitabilities greater than or equal to 0.75 and in the upper 25 percentiles of cumulative area were considered to be rare. If the cumulative area curve is 'concave' indicating that more area has higher suitability values, the cumulative line passes into the upper-right quadrant defined by 75 percent and 0.75 suitability criteria from below and indicates that high quality habitat is relatively common e.g., for coldwater yoy piscivores (Figure 6A). If the cumulative curve is 'convex' indicating more area has lower suitability values, the cumulative line enters the quadrant from the left and indicates that high suitability habitat is relatively rare e.g. for coolwater and warmwater spawning non-piscivores (Figure 6B,D). In some instances, there is no high suitability habitat e.g., for coldwater adult piscivores (Figure

6C). This approach was used to identify 'rare' habitats for each of the 18 suitability indices representing the thermal, trophic, and life stage groupings.

The habitat areas identified as rare for the 18 indices were intersected with the areas derived from the composite suitability index (Table 4). Five of the indices produced no rare areas (rows marked NA in Table 4) and none of the rare areas for the remaining 13 indices were in the areas assigned as Low using the composite suitability indices. Application of these results is described in a later section.

FISH HABITAT SUITABILITY CLASSIFICATION COMPONENT

The aim was to obtain a habitat classification that would be easily understood by fish habitat managers, planners, proponents of site-specific developments, and the general public. In the interim plan, the habitat classification scheme was qualitative and categorical from the outset. Here, we identified a methodology that divided the composite habitat suitability index scale with a continuous range from 0 to 1 into three discrete classes (Low, Medium, or High). A logical multi-layer process was used to derive the final suitability classification (Figure 7).

The following thematic layers were used for classifying littoral zone habitat:

1. *Suitability* - Composite habitat suitability values for the whole fish community assemblages estimated using the Defensible Methods approach.
2. *Rarity* - Derived from analysis of constituents of the Defensible Methods approach to identify high quality habitat for specific sub-components of Severn Sound's fish assemblage.
3. *Wetlands*- Coastal or provincially significant wetlands are known to be important contributors to fish productivity in lake ecosystems and were treated as a priority element in the model.
4. *Expert Knowledge* - Site and area-specific expert knowledge or observations are an important means of identifying important fish habitats and are treated here as a priority element

Composite Suitability Classification

Several factors were considered in developing the methodology. We wished to avoid an arbitrary selection of break-points on the suitability scale and were aware that the positioning of

the breakpoints would affect the amounts of littoral habitat area assigned to the different classes. We also wanted to avoid assigning break-points that would split groupings and associations evident in the underlying habitat data. We selected a statistical approach called Classification and Regression Trees (CART) (Breiman *et al.* 1984), developed by Salford Systems, CA, USA.

CART is a non-parametric statistical technique, which produces decision trees to predict a dependent variable based on a number of measured, independent variables. The dependent variable may be categorical or continuous. A tree is usually generated using a training data set and then used to classify other data. At each node in the tree, data records are classified by splitting the data into two groups. Each split is made on the basis of a single variable, with each record being assigned to one group if it is greater than a cut-off value and to the other group if it is less than or equal to the cut-off. Cut-offs at each node are set so as to minimize the error rate in the classification of the dependent variable. CART attempts to create a tree which best explains the groupings in the data, sometimes leading to very complex trees. Here, we have used CART for a slightly different purpose. CART analysis was used to divide the data records into groups using the Defensible Methods' composite suitability index as the dependent variable, and depth, substrate and cover parameters as the independent variables.

The frequency distribution of habitat suitability values covered the range from zero to less than 0.8 with prominent peaks in the 0.0-0.1 and 0.3-0.4 ranges (Figure 8). Using the sample database, we applied the implementation of CART. We used a ten-fold fitting procedure whereby 10 successive percent portions were used as a training set and the remaining 90 percent for testing. The software analyses the consistency for the ten sets of results to provide measures of the goodness of fit of the CART model developed.

Using the continuous variable regression mode, the optimal tree generated by CART had

132 nodes, far too many to use for creating a map. Via pruning, a much simpler tree was selected, which had only 3 decision nodes and 4 terminal nodes. This tree divided the data into one group of low composite suitability values, one group of high values, and two groups with medium values (Figure 9). To obtain the three classes needed for colour-coded mapping, the two medium groups were combined. This gave a dataset with each record classified into one of three groups on the basis of the predicted composite suitability, based on depth, substrate and cover. The frequency distributions show there is some overlap between adjacent groups (Figure 10).

The CART analysis generates groupings of data sets and regression trees, which predict the expected mean value at each terminal node. Assignment of individual data sets to a node is based on comparison of node membership probabilities. The break points between adjacent groups are not identified.

To complete the analysis with the identification of break points required further analysis beyond the scope of CART. Habitat areas in Severn Sound were assigned to one of three classes, using two cut-offs, upper and lower. The upper and lower cut-offs were applied so that all records with a composite suitability less than the lower cut-off were classified into Class 1 (Low); records greater than or equal to the lower cut-off but less than the upper cut-off were Class 2 (Medium); and records greater than or equal to the upper cut-off were Class 3 (High). Rough estimates of the cut-off points can be identified by inspection of plots of cumulative percent frequency distributions of the groups, with one group inverted in each plot (Figure 11). More precise cut-offs were obtained using iterative optimization whereby combinations of upper and lower cut-offs were examined and the misclassification rates calculated for each combination. Lower cut-offs varied from 0.2 to 0.4 and upper cut-offs varied from 0.4 to 0.6. A record was considered to be misclassified if the class assigned by the cut-offs was different from

the group assigned by the CART analysis. The pair of cut-offs, which gave the smallest percent misclassification, was used for the final map production (Figure 12). The lowest overall rate of misclassification, 17.6 percent, occurred with a lower cut-off value of 0.2342 and an upper of 0.5236. These values were used to reclassify the composite habitat suitability map into three classes.

Rarity Classification

This classification methodology follows from the results presented (Table 4) for assessing rarity. Areas classified as low or medium in the composite suitability classification but identified as being rare are reclassified as high. An analysis of the habitat attributes of those polygons converted from Medium to High after application of the rarity criteria is revealing (Table 5). For each fish sub-assemblage, fairly specific habitats are added to the High class. For coolwater adult non-piscivores, it is pebble-granule substrates with 100 percent submerged vegetation cover (weed-beds over coarse substrates); for spawning coolwater and warmwater piscivores, it is sand-silt substrates with high levels of emergent vegetation (wetlands); and for coolwater yoy, it is silt substrates with high submergent vegetation cover (weed-beds over fine substrates).

Role of Provincially Significant Wetlands

Wetlands have a significant role in the productivity of freshwater fishes (Jude and Pappas 1992). The Province of Ontario has a comprehensive system for classifying wetlands; it includes some consideration of fish use of wetlands but is predominantly concerned with the species composition of the wetland plants and the use by various forms of wildlife other than fish. Since the fish habitat management plan is concerned solely with fish use of habitat, we chose to recognize all coastal wetlands in Severn Sound as having significance for the maintenance of natural fish productivity. Hence, all coastal wetlands that have been classified by OMNR as

provincially significant were rated high.

The OMNR Districts Parry Sound and Midhurst provided the digital wetland layer for the Severn Sound study area. The wetland layer is associated with coastal areas in Severn Sound were assembled and added to the GIS database. Since the area coverage of the wetlands often extended beyond the ribbon of habitat covered in the littoral habitat survey, superimposition of a high class based on the presence of wetlands over the classification developed using composite suitability and rarity analyses did not seem reasonable. Instead, we chose to provide the wetland coverage as auxiliary, conditional information and to retain the composite suitability-rarity classification as the primary reference point. Wetland coverage was summarized using the Provincial wetland classification system and intersected with the littoral habitat coverage (Table 6). The wetland aerial coverage is much greater than the littoral survey.

Importance of Site-Specific Expert Knowledge

The intended approach in this portion of the fish habitat classification model was to use a compilation of local site-specific knowledge of significant, important, or critical fish habitat as an additional method of identifying Red areas. The composite suitability and rarity classification is based on generalized models and cannot supplant direct evidence of the significance of specific sites. Only two such areas, both walleye spawning shoals, were identified in Port Severn by OMNR staff Robin Craig (OMNR unpublished data) at the time this analysis was conducted. Newer information such as that collected on muskellunge spawning (OMNR Staff personal comm., Owen Sound, Ontario) will be incorporated in subsequent revisions of this scheme.

As with wetland information, we decided to provide this expert knowledge as auxiliary information for use in final habitat suitability map. The first area identified in Port Severn having previously received a composite rating of Low due to absence of vegetation was

consequently converted to High. The second walleye spawning shoal received both Medium and High rating from Defensible Methods composite suitability rating. The specific suitability index for spawning of coolwater piscivores for this area had values ranging from 0.117 to 0.621. Both spawning ground were converted to High for the final suitability classification.

In the future, as the information base for identification of specific sites grows, a more complete implementation of the classification model will be possible with expert knowledge information being used to over-ride the generalized suitability classification.

Overall Rule-Based Classification Model

For Severn Sound, a fish habitat suitability classification model uses multiple thematic layers to assign a final colour coded (Red, Yellow, or Green) suitability map for littoral zone areas of Severn Sound. Red indicating high habitat suitability, Yellow indicates medium and Green coding as low habitat suitability. This classification schema was an induction decision process by where the resulting topological intersection produced attribute information or criteria for final suitability classification. A decision tree illustrates the induction process and judgement applied to the habitat suitability layer (Figure 13). The inductive classification pseudocode is outlined in Appendix E.

RESULTS

In this section of the report we provide an overview of the results of applying the various elements of the fish habitat classification model to the Severn Sound GIS database. Results associated with method development were reported in previous sections. There were some geospatial results as well as those from the classification process.

Spatial Accuracy of Topological Overlay

Sliver polygons generated during geoprocessing operations were removed by weeding out

areas of less than one metre square. The total wet zone area defined by the depth layer was 11.87 km²; where as the habitat suitability layer derived from a multiple thematic overlay was 11.83 km². The difference in spatial extent was 0.04 square kilometres or a 0.04% loss of wet zone habitat for suitability assessment. Out of 11.83 km² of wet zone area a total of 11.66 km² or 98.6% of littoral zone habitat meet the input requirements for Defensible Method's suitability assessment. The remaining 0.17 km² or 1.4% of the total wet zone area lacked either substrate or vegetation information necessary for using Defensible Methods to assess habitat suitability.

Fish Habitat Classification Results in Severn Sound

A total of 98.6% of wet zone area defined by the multiple thematic overlay process received a composite suitability classification of High, Medium or Low. In the wet zone area, 99.1% or 11.72 km² received a final suitability classification (Table 7). The 0.5%, or 0.06 km², difference consists of wet zone areas falling within provincially significant wetlands, which did not receive a Defensible Method's Suitability classification.

The addition of the provincial wetland information produced the biggest percentage changes in class assignments with large areas of Low and Medium habitat being reclassified to High (Table 7). As expected, the addition of the expert information produced the least change as only two small areas were identified. Overall, an area of 2.08 km² (17.3 %) was assigned low, 5.05 (42.1 %) medium, 4.59 (38.3 %) high, and 0.28 (2.3 %) as not rated. The average values for the habitat attributes reveal the primary characteristics of the three colour classes (Table 8). Bedrock, cobble, and boulder substrates with little vegetation predominantly covers low suitability areas. Medium suitability areas are dominated by sand with lesser proportions of silt and pebble with little vegetation cover; sand and silt with high levels of submergent and emergent vegetation cover dominate high suitability areas.

The distribution of final suitability classes by municipality shows some regional variation (Table 9). The greatest absolute area concentrations of all three-colour classes are in the Georgian Bay and Tay municipalities. The largest percentage of High, Medium and Low suitability occur in the municipalities of Georgian Bay, Tiny and Severn, respectively. Most of the highly suitability or Red areas lie in the northern, primarily igneous rock portion of Severn Sound. While medium suitability or Yellow areas dominate the three southern, mostly sedimentary rock, municipalities of Midland, Penetanguishene and Tay. A summary of the average percentages of the habitat attributes (Table 10) highlight the igneous-sedimentary differences among the areas. Georgian Bay, Severn and Tay municipalities have high average percentages of bedrock, pebble and emergent vegetation. High average percentages of sand and submergent vegetation are found in the southern municipalities.

The area values can be distorted by variations in the width of the littoral zone between the 0 and 1.5 metre depth. Therefore, shoreline lengths were also examined by colour-coded class. Colour-coding of the shoreline may be better suited to the needs of developers who bring landuse and shoreline edge-oriented perspectives when their activities impinge on fish habitat. Each segment of shoreline was classified as Red (high), Yellow (medium), Green (low) or Not Rated based on the final classification of the adjacent polygon (See Appendix A for database definitions of *shoresuit* coverage). The Severn Sound RAP is responsible for 491.75 km of shoreline within the watershed. A total of 343.48 km (69.9%) of shoreline was coded as Red, Yellow, Green or Not Rated. Table 11 shows the relative percent of shoreline suitability for each of the municipalities within the Severn Sound watershed. Within the municipalities of Midland, Penetanguishene, Severn and Tay, 100% of the shoreline was assigned suitability coding of Red, Yellow or Green. For the municipalities of Georgian Bay and Tiny, 58.5% and 56.2%

respectively, were surveyed and classified.

Overall, the relative percent of shoreline coded within the survey extents was 25.3% as Red, 34.6% as Yellow, 27.1% as Green and 13.0% Not Rated. The not rated classification includes sections of shoreline that were not surveyed and sections that had insufficient habitat information (Table 12). These sections of shoreline and areas that were classified as not rated identifies where further field surveys are required. It is important to note that the percentages of colour coded littoral areas (Table 9) and the shoreline length percentages by colour coding (Table 12) are not directly comparable. In the more highly developed parts of the Severn Sound littoral zone, there are large lengths of shoreline, which were not surveyed. The majority of these shoreline sections have vertical edges (docks, breakwalls etc.) with no measurable littoral zone. Within the extents of the total watershed, the relative percent of classified shoreline was 17.2% as Red, 24.4% as Yellow, 19.1% as Green, 9.1 as Not Rated and 30.1% Not Surveyed. The not surveyed represents the sections of shoreline inside the watershed but beyond the original extents of the field survey. Table 12 also examines the total length of shoreline for each municipality by final habitat classification suitability (Red, Yellow, Green and Not Rated). Due to the high shoreline development existing within the southern shoreline of Severn Sound, municipalities such as Midland and Penetanguishene show less than 2% of the shoreline having a Red classification. However, the municipality of Tay has 18.3% of the shoreline classified as Red while Georgian Bay exhibits the highest percentage of Red shoreline with 19.6%. The municipalities of Midland and Penetanguishene illustrate the highest percent of moderately suitable or Yellow shoreline with 50.6% and 71.3% respectively.

To illustrate via maps the results of colour classification, four sub-areas were selected with different surficial geology (sedimentary in the southern versus igneous in the northern areas

of Severn Sound) and level of past human development activity (low versus high) (Figure 14). In all cases, the maps show that large contiguous areas are formed by the colour-coded classification methodology rather than producing highly fragmented patches of Red, Yellow and Green. Areas with a limited littoral zone extent (Figure 15 A) and/or higher site exposure to wind and wave actions (Figure 15 B) lead to a predominance of Yellow and Green coded areas. In more sheltered locations with wide littoral zone extent (Figure 15 C, D) Red-coded areas are prevalent.

DISCUSSION

As the specific methods and results have been discussed individually, the discussion examines the broader topic areas of geospatial issues, future research and information needs, and linkage to fish habitat management plans.

Geospatial Issues

Spatial Data Accuracy

The real world is represented by both spatial and attribute components. Therefore, two main types of errors may occur: positional and attribute. Positional errors are used to gauge how well location, size and shape of real-world features are represented in a GIS or database.

Attribute errors reflect how the tabular or descriptive characteristics represent reality. Analytical or processing errors was also associated with using spatial data within a GIS. A continuing issue is that of spatial and/or attribute information within the GIS being out-of-date. Littoral zone habitat is a dynamic system and therefore it is difficult and often too expensive to capture the changes in substrate, vegetation and water levels. However, at this point, GIS with fisheries science and management are focusing on developing the methods required to capture these changes, in anticipation of applying them to current fish habitat supply conditions.

During the course of the field inventory 1:10,000 OBM coverage became available for

some portions of the study area. This was used to generate 1:2,000 field base maps where available, but for most of the area inventoried the field base maps were generated from 1:10,000 hydrographic charts. The field inventory and spatial database creation different base mapping was used (i.e. OBM and CHS 1: 10,000). This caused edge matching and joining problems between thematic layers of each survey section and incorporation of other thematic layers such as OBM layers required some spatial adjusting.

Sources of Positional Error

At this time, actual positional accuracy of the thematic data sets are unknown and difficult to determine for the following reasons:

- different systems of base mapping
- ground-truthing not feasible
- no coordinate system used for data collection
- lack of suitable check points
- no georeferencing available at time of survey

Sources of Attribute Error

For categorical attributes such as classified substrate and vegetation polygons, attribute accuracy is also difficult to determine. This is due to mainly two reasons: (1) fish habitats are dynamic, with both substrate and vegetation compositions changing over time; and (2) ground truthing required to test attribute accuracy is not currently feasible.

Sources Analytical Error (Both Positional and Attribute)

There are several sources of potential error in the analysis and modelling steps.

- Data Conversions
- Interpolation / Extrapolation
- Manual Editing (e.g. ArcEdit®)
- Overlay / Buffering
- Import/Export algorithms

The foundation, or cornerstone, of any geographical information system is the spatial and

attribute data. Most users of geographical information and GIS overlook these sources of error and, in most cases, do not state the possible errors and inaccuracies associated with their data. How spatial information is entered, stored, manipulated, analyzed and documented influences the quality of the decision making process. Since much of the data used in this project was collected in a period when digital mapping survey methods, positioning equipment and GIS were being developed, it is easy, in hindsight, to see the technical difficulties of the littoral zone database. However, projects like this have contributed significantly to the process of developing required methods for effective science, assessment and management.

Future Research and Information Needs

There are several needs that result from this work, which can be immediately recognized:

Expert site-specific knowledge database

Further effort needs to be directed to assemble local expert knowledge of specific sites having significance for particular elements of the fish community. Along with the ongoing development of information systems, an objective set of criteria must be established to screen potential sites. Without screening criteria, there is a risk that sites will be added and classified as Red with no defensible rationale in place.

A complete fish habitat inventory

The habitat inventory database used in this study only covers the littoral zone of Severn Sound of which some areas remain unsurveyed. These areas should be surveyed to ensure consistent assessment and decision making wherever development activity impinges on fish habitat. As many of the fish species present use sub-littoral, profundal, and offshore pelagic areas as well as the littoral zone, a habitat management plan should cover all fish habitat. In many areas the littoral inventory is incomplete as surveys only extended offshore until 1.5 metres

was encountered. In some bay areas, shallow areas may extend much further offshore. The current approach to habitat inventory is static and does not allow for seasonal changes in habitat features such as the growth and senescence of vegetation, vertical and horizontal thermal structure, fluctuations in water level or variations in inflows from tributaries. The inventory also excludes consideration of water quality parameters such as nutrient, oxygen, light penetration, and contaminant levels, many of which will exhibit both spatial and temporal variability.

A mechanism for updating the GIS inventory database

The current inventory database and habitat classification is static. No provision has been made for updating the database to reflect changes both natural and man-made. As time passes and development activities proceed, the relevance of the habitat classifications established in this study will decline. Changes in the rareness of certain habitat types, areas requiring special protection identified by local experts, and changes in the applicable fish habitat science will not be captured.

The need for a mechanism for updating the database and the classification model is closely tied to the need for an institutional home for the system. While the current application will be made available to local and regional planning offices as a stand-alone CD-ROM application, no permanent holder for the system has been identified.

Linkage to the Revised Fish Habitat Management Plan for Severn Sound

In all instances, development activities should be conducted in such a manner that the harmful alteration, disruption or destruction of fish habitat is avoided or minimized. Where a harmful alteration, disruption or destruction of fish habitat cannot be avoided, and the loss is acceptable, compensatory measures must be taken to achieve a No Net Loss in the productive capacity of fish habitat, as required under DFO's "Policy for the Management of Fish Habitat"

(1986). The habitat management plan and the associated colour-coded maps provide initial guidance and screening of activities.

The colour-coding derived from the classification model is linked to fish habitat management decision processes. The Red designation is intended to engender the highest level of care and attention whenever many forms of development are proposed. A Red designation for an area does not automatically lead to a blanket prohibition on all forms of development, although some forms will be excluded. Without the exercise of careful mitigation and compensation activities for an area, many development activities might be expected to produce losses of fish productivity. The Green designation is intended to identify areas of low value for fish productivity. This does not mean that any form of development will be tolerated in a Green area. Green areas have often been degraded in the past and provide greater opportunities for development activities to include elements which enhance or improve fish productivity. The Yellow designation lies between the previous two and covers areas of intermediate fish productivity value and moderate opportunities to enhance productivity.

No attempt was made to directly compare colour coding in the old interim plan with the colour codes assigned using the model described here. The interim colour codes were assigned at a very coarse level of spatial resolution and reflected a precautionary approach. The framers of the interim map anticipated that a finer resolution assessment would be available once the inventory database was analyzed and a classification developed.

To replace the interim, subjective suitability map for habitat management in Severn Sound, an updated Severn Sound Littoral Zone Fish Habitat Suitability map has been produced. Appendix F, included with this report, contains an E Size (36"x44") suitability map (suitmap.pdf). This is archived in Adobe Acrobat® Portable Document Format located on CD-

ROM enclosed in this report. This map represents the final suitability coding as Red, Yellow, Green or Not Rated and is intended for illustrative purposes only and provides a general overview of suitability for the fish community in Severn Sound. The map cannot be the only tool used for effective habitat management. Because the Severn Sound Littoral Zone Fish Habitat Suitability map was generated from a detailed field survey and a complex habitat suitability model, an informed decision regarding fish habitat must utilize a desktop GIS. The digital habitat data provides the foundation required for the implementation of a comprehensive Severn Sound Fish Habitat Management Plan.

The Severn Sound Restoration Council is currently revising the interim plan (Severn Sound RAP 1993) to take advantage of the information gathered and organized to produce the new assessment map and database, and to update information regarding the administration and management of fish habitat in Ontario.

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Table 1 Combinations of thermal and trophic group, and life stage weights used to examine the sensitivity of composite suitability values obtained from Defensible Methods to the choice of weights. Combinations examined independently for each group with the others at reference values. Weights are expressed as percentages and each group sums to 100 percent.

Thermal groups			Trophic groups		Life stages		
<i>Cold</i>	<i>Cool</i>	<i>Warm</i>	<i>Pisc.</i>	<i>Non-pisc.</i>	<i>Spawning</i>	<i>YOY</i>	<i>Adult</i>
100	0	0	100	0	100	0	0
80	20	0	90	10	80	20	0
80	0	20	80	20	80	0	20
60	40	0	70	30	60	40	0
60	20	20	60	40	60	20	20
60	0	40	50	50	60	0	40
40	60	0	40	60	40	60	0
40	40	20	30	70	40	40	20
40	20	40	20	80	40	20	40
40	0	60	10	90	40	0	60
20	80	0	0	100	20	80	0
20	60	20			20	60	20
20	40	40			20	40	40
20	20	60			20	20	60
20	0	80			20	0	80
0	100	0			0	100	0
0	80	20			0	80	20
0	60	40			0	60	40
0	40	60			0	40	60
0	20	80			0	20	80
0	0	100			0	0	100
			Reference weights				
33.3	33.3	33.3	50	50	33.3	33.3	33.3

Table 2 Mapping of Severn Sound littoral zone physical habitat database (substrate, vegetation and depth) attributes to the corresponding categories in the Defensible Methods' freshwater species, habitat requirement database.

Thematic Habitat Features	Severn Sound Littoral Zone Physical Habitat Database Categories	Defensible Methods Freshwater Species Habitat Requirement Categories
Depth (metres)	0.0-0.5 0.5-1.0 1.0-1.5	0-1 (Spawn and yoy), 0-2 (Adult) 0-1 (Spawn and yoy), 0-2 (Adult) 1-2 (Spawn and yoy), 0-2 (Adult)
Substrate	Rock Boulder Cobble Rubble Granule + Pebble Sand 50% Silt + 50% Organic 50% Silt + 50% Organic Clay Null	Bedrock Boulder Cobble Rubble Gravel Sand Silt Clay Hardpan Clay Pelagic
Vegetation*	100.%No Cover / %Total Cover 100.%Submergent / %Total Cover 100.%Emergent / %Total Cover	% No cover % Submergent % Emergent

* %No Cover = 100 – Maximum(%Submergent, %Emergent)

%Total Cover = %No Cover + %Submergent + %Emergent

Table 3 Pearson correlation coefficients between Defensible Methods' littoral zone habitat suitability database constituent indices and fish community measures. (Values in bold-face are significant at $P = 0.05$ after Bonferroni correction).

Defensible Methods Indices			Fish Community Measures		
Thermal Category	Trophic Status	Life Stage	Species Richness	Density	Biomass
Warmwater	Non-piscivores	Adult	0.249	0.383	0.243
		Yoy	0.389	0.522	0.389
		Spawning	0.171	0.265	0.180
	Piscivores	Adult	0.162	0.142	0.144
		Yoy	0.208	0.198	0.182
		Spawning	0.172	0.139	0.157
Coolwater	Non-piscivores	Adult	0.449	0.428	0.408
		Yoy	0.456	0.460	0.374
		Spawning	0.244	0.183	0.250
	Piscivores	Adult	0.120	0.133	0.100
		Yoy	0.152	0.159	0.122
		Spawning	0.127	0.136	0.107
Coldwater	Non-piscivores	Adult	Insufficient Catch for Correlation		
		Yoy	“		
		Spawning	“		
	Piscivores	Adult	None Caught		
		Yoy	“		
		Spawning	“		
Composite Index Score vs. Total Fish Variables			0.396	0.442	0.319

Table 4 Percent of littoral zone fish habitat suitability composite classification (Low, Medium, High) passing (1) or failing (0) the *rarity threshold* (areas with composite suitability indices greater than 0.75 and falling within the upper 25 percent of the littoral zone cumulative area distribution). The shaded percentages indicated the areas that are reclassified as High when rarity threshold is applied.

Life Stage	Thermal Group	Trophic Group	Low		Medium		High	
			0	1	0	1	0	1
Spawn	Warm	Piscivore	26.23	0.00	53.00	4.95	7.62	8.20
		Non-piscivore	na	na	na	na	na	na
	Cool	Piscivore	26.23	0.00	53.62	4.33	13.96	1.89
		Non-piscivore	na	na	na	na	na	na
Yoy	Cold	Piscivore	na	na	na	na	na	na
		Non-piscivore	26.23	0.00	46.70	11.25	15.82	0.00
	Warm	Piscivore	26.23	0.00	57.95	0.00	10.60	5.21
		Non-piscivore	26.23	0.00	57.95	0.00	9.32	6.50
	Cool	Piscivore	26.23	0.00	57.91	0.04	9.98	5.84
		Non-piscivore	26.23	0.00	57.91	0.04	9.83	5.99
	Cold	Piscivore	26.23	0.00	37.86	20.09	15.82	0.00
		Non-piscivore	26.23	0.00	35.88	22.07	10.52	5.29
Adult	Warm	Piscivore	26.23	0.00	57.95	0.00	7.48	8.33
		Non-piscivore	26.23	0.00	57.92	0.03	7.74	8.07
	Cool	Piscivore	26.23	0.00	57.67	0.26	8.96	6.86
		Non-piscivore	26.23	0.00	57.92	0.02	9.10	6.71
	Cold	Piscivore	na	na	na	na	na	na
		Non-piscivore	na	na	na	na	na	na

Table 5 Average substrate composition by littoral zone habitat suitability composite suitability (Low, Medium, High) and rarity (0/1) classification for the seven fish group/life stage assemblages which meet the *rarity threshold* criteria (Littoral zone habitat suitability classifications Medium are reclassified to High). [See Table 4 for an explanation of the shading]

Fish Group		Substrate											Vegetation	
Class	Clay	Silt	Sand	Granule	Pebble	Cobble	Boulder	Rock	Organic	Wood	Rubble	Slag	Sub.	Emerg.
ADULT														
Cool_Np														
Low 0	6.47	1.89	4.73	0.73	7.92	16.27	15.23	36.96	9.46	0.26	0.04	0.03	15.52	15.01
Medium 0	0.59	21.53	56.20	3.73	8.85	5.27	1.83	0.46	1.40	0.12	0.03	0.00	12.92	18.57
Medium 1	0.00	0.00	16.50	12.00	67.00	4.50	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
High 0	0.00	46.16	52.10	0.58	0.57	0.36	0.19	0.00	0.00	0.04	0.00	0.00	78.90	25.28
High 1	0.00	21.33	76.93	1.25	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.01
Cool_Ps														
Low 0	6.47	1.89	4.73	0.73	7.92	16.27	15.23	36.96	9.46	0.26	0.04	0.03	15.52	15.01
Medium 0	0.59	21.09	56.39	3.76	9.02	5.30	1.83	0.46	1.40	0.12	0.03	0.00	12.87	18.13
Medium 1	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	61.52	100.00
High 0	0.00	14.63	82.72	1.32	0.82	0.29	0.17	0.00	0.00	0.04	0.00	0.00	82.37	14.72
High 1	0.00	75.13	24.81	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	97.80	14.58
Warm_Np														
Low 0	6.47	1.89	4.73	0.73	7.92	16.27	15.23	36.96	9.46	0.26	0.04	0.03	15.52	15.01
Medium 0	0.59	21.50	56.09	3.73	8.98	5.28	1.83	0.46	1.39	0.12	0.03	0.00	13.04	18.50
Medium 1	0.00	0.00	76.67	15.56	7.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	87.22	50.00
High 0	0.00	56.38	42.08	0.57	0.46	0.29	0.20	0.00	0.00	0.02	0.00	0.00	77.30	25.06
High 1	0.00	18.82	79.27	1.10	0.60	0.15	0.04	0.00	0.00	0.03	0.00	0.00	96.33	6.16
SPAWNING														
Cool_Ps														
Low 0	6.47	1.89	4.73	0.73	7.92	16.27	15.23	36.96	9.46	0.26	0.04	0.03	15.52	15.01
Medium 0	0.63	19.85	56.19	3.99	9.61	5.64	1.95	0.49	1.49	0.13	0.03	0.00	14.00	12.73
Medium 1	0.00	44.31	55.09	0.26	0.18	0.14	0.02	0.00	0.00	0.00	0.00	0.00	0.60	99.81
High 0	0.00	33.34	64.78	0.93	0.58	0.23	0.12	0.00	0.00	0.03	0.00	0.00	88.69	8.12
High 1	0.00	66.29	33.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	75.84	98.03
Warm_Ps														
Low0	6.47	1.89	4.73	0.73	7.92	16.27	15.23	36.96	9.46	0.26	0.04	0.03	15.52	15.01
Medium0	0.64	19.61	56.04	4.06	9.76	5.73	1.98	0.50	1.52	0.13	0.03	0.00	13.94	11.44
Medium1	0.00	42.77	56.90	0.18	0.08	0.05	0.01	0.00	0.00	0.00	0.00	0.00	3.67	99.04
High0	0.00	48.55	48.04	1.69	1.05	0.41	0.21	0.00	0.00	0.05	0.00	0.00	79.65	14.14
High1	0.00	22.44	77.55	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	96.17	15.22
YOY														
Cool_Np														
Low 0	6.47	1.89	4.73	0.73	7.92	16.27	15.23	36.96	9.46	0.26	0.04	0.03	15.52	15.01
Medium 0	0.59	21.42	56.15	3.75	8.99	5.28	1.83	0.46	1.39	0.12	0.03	0.00	13.06	18.55
Medium 1	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	75.00	0.00
High 0	0.00	18.05	79.49	1.22	0.75	0.29	0.16	0.00	0.00	0.04	0.00	0.00	82.46	21.57
High 1	0.00	71.05	28.63	0.15	0.11	0.06	0.00	0.00	0.00	0.00	0.00	0.00	98.32	0.89
Cool_Ps														
Low 0	6.47	1.89	4.73	0.73	7.92	16.27	15.23	36.96	9.46	0.26	0.04	0.03	15.52	15.01
Medium 0	0.59	21.42	56.15	3.75	8.99	5.28	1.83	0.46	1.39	0.12	0.03	0.00	13.06	18.55
Medium 1	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	75.00	0.00
High 0	0.00	18.66	78.82	1.26	0.78	0.28	0.16	0.00	0.00	0.04	0.00	0.00	82.84	21.08
High 1	0.00	72.68	27.25	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	98.38	0.80

Table 6 Total area of littoral zone physical habitat falling in Ontario Ministry of Natural Resources District provincially significant wetlands by percent littoral zone habitat suitability database composite and rarity classification (Low, Medium, High).

OMNR District	Total Area Within Littoral Zone (km ²)	Percent of Littoral Zone		Composite	Percent Classified	Composite & Rarity	Percent Classified
Midhurst	0.80	6.7	High	0.17	21.20	0.21	26.50
			Medium	0.47	58.60	0.42	53.10
			Low	0.16	20.00	0.16	20.20
				*<0.01	0.20	*<0.01	0.20
Parry Sound	2.05	17.3	High	0.35	17.10	0.53	25.90
			Medium	0.83	40.50	0.65	31.70
			Low	0.81	39.50	0.81	39.50
				*0.06	2.90	*0.06	2.90
Total Area of Littoral Zone	11.83 km ²						

* Littoral zone areas that did not receive a Defensible Method's composite suitability rating but fell within a provincially significant wetland.

Table 7 Total area (km²) of littoral zone physical habitat database by suitability classification Low, Medium, High for each of the component criteria in the littoral zone habitat suitability classification model.

Suitability Classification Category	LOW	% Change	MEDIUM	% Change	HIGH	% Change	Totals (km ²)
Composite	3.06		6.76		1.84		
Composite + Rarity	3.06	0.00	6.12	-5.49	2.48	+5.49	
Composite + Rarity + Wetland	2.08	-8.40	5.04	-9.27	4.53	+17.58	
Composite + Rarity + Wetland + Expert	2.08	0.00	5.04	0.00	4.54	+0.09	11.66
<i>Percent of Total Littoral Zone</i>							98.56
	GREEN	% Change	YELLOW	% Change	RED	% Change	
Final Suitability Classes	2.08	0.00	5.04	0.00	4.60	+0.51*	11.72
<i>Percent of Total Littoral Zone</i>							99.08
<i>Total Area of Littoral Zone Survey</i>							11.83

* The change in Final Suitability classification Red is accounted for by the littoral zone physical habitat wet zone areas that did not receive a composite suitability rating due to lack of substrate and/or vegetation information but falling within a provincially significant wetland. Therefore, adding 0.06 km² to the classified littoral zone habitat suitability database.

Table 8 Average substrate and vegetation composition by colour class (Red, Yellow, Green) in the final habitat suitability classification.

Percent Composition	Green	Yellow	Red	Not Rated
Clay	6.45	0.67	1.53	0.30
Silt	1.69	17.78	32.43	0.54
Sand	4.93	57.51	44.46	0.69
Granule	0.81	4.30	0.54	0.03
Pebble	8.55	10.27	1.27	0.21
Cobb	17.33	6.05	1.76	0.15
Boulder	16.28	2.05	1.45	0.03
Bedrock	37.87	0.50	4.70	0.15
Rubble	0.04	0.03	0.00	0.00
Metal	0.03	0.00	0.00	0.00
Slag	0.04	0.00	0.00	0.00
Organic	5.69	0.71	11.12	0.30
Wood	0.28	0.14	0.01	0.00
Submergent Vegetation	13.96	12.56	51.03	19.73
Emergent Vegetation	10.83	9.22	40.25	6.96

Total Percent of Littoral Zone Classification : 99.08%

Table 9 Total area and relative percent by colour class (Red, Yellow, Green) in the final habitat suitability classification summarized by municipality.

Municipality	<i>Area (sq. km)</i>				<i>Relative Percent (%)</i>			
	Green	Yellow	Red	Not Rated	Green	Yellow	Red	Not Rated
Georgian Bay	1.48	2.59	3.19	0.21	19.81	34.67	42.71	2.81
Midland*	0.04	0.18	0.01	<0.01	16.53	74.38	8.26	0.83
Penetanguishene*	0.04	0.44	0.12	0.02	6.45	70.97	19.35	3.23
Tay*	0.50	1.70	1.24	0.05	14.33	48.71	35.53	1.43
Severn	<0.01	0.01	<0.01	0.00	27.78	55.55	16.67	0.00
Tiny	<0.01	0.13	0.02	0.00	5.66	81.76	12.58	0.00
Total	2.08	5.05	4.59	0.28	17.33	42.08	38.25	2.33

* Municipalities with their entire shoreline having a littoral zone habitat inventory and habitat suitability assessment; the littoral zone survey only mapped partial shoreline areas of the remaining municipalities.

Table 10 Average substrate and vegetation composition summarised by municipality (averages obtain from the Substrate and Vegetation thematic habitat layers).

	Georgian Bay	Midland	Penetanguishene	Severn	Tay	Tiny
<i>SUBSTRATE</i>						
Clay	1.19	1.44	2.22	0.00	3.10	0.87
Silt	7.98	3.85	2.28	6.52	4.56	7.39
Sand	20.99	27.43	40.83	23.91	21.73	53.91
Granule	1.18	7.93	5.50	8.70	3.32	6.96
Pebble	3.99	24.25	17.86	6.09	14.72	16.09
Cobble	6.07	17.62	16.06	6.96	14.36	8.26
Boulder	5.55	13.25	10.86	12.17	11.04	3.91
Bedrock	18.25	0.00	1.11	13.91	13.61	0.00
Organic	2.68	0.00	0.33	8.70	0.61	1.74
Wood	0.06	0.87	0.72	0.00	0.13	0.87
Rubble	0.00	0.63	0.00	0.00	0.03	0.00
Metal	0.00	0.00	0.00	0.00	0.17	0.00
Slag	0.00	0.34	0.00	0.00	0.00	0.00
<i>VEGETATION</i>						
Submergent	16.35	44.49	36.93	14.58	29.03	35.89
Emergent	27.15	1.12	7.53	27.08	21.44	21.43

Table 11 Total length (km) of shoreline within Severn Sound watershed and relative percent of total littoral zone habitat classified summarized by municipality.

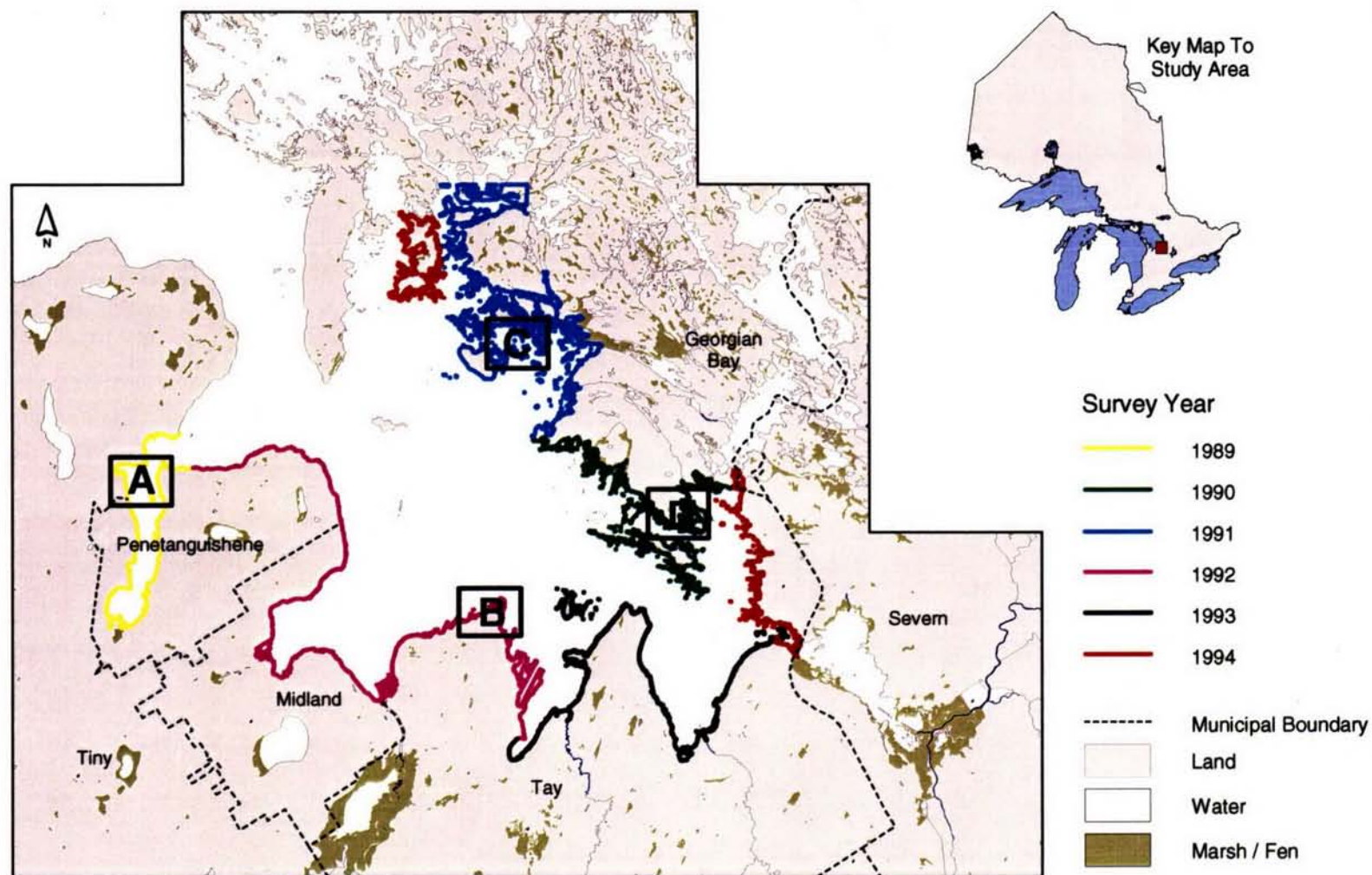
Municipality	Total Length of Shoreline within Severn Sound Watershed	Relative Percent of Watershed	Total Length of Classified Shoreline	Percent of Total Watershed Shoreline
Georgian Bay	351.68	71.50	205.54	58.45
Midland	16.25	3.30	16.23	*100.00
Penetanguishene	24.20	4.90	24.19	*100.00
Severn	1.44	0.30	1.43	*100.00
Tay	91.00	18.20	91.09	*100.00
Tiny	8.89	1.80	5.00	56.24
Total	491.75	100.00	343.48	69.85

* Between the surveyed shoreline and classified shoreline there is an additional 0.19km or 0.06% of the length of shoreline that has been classified. This is attributed to the multiple spatial geoprocessing applied to the coverage, which has caused “fuzzy creep” in the arc features representing the shoreline.

Table 12 Total length (km) of shoreline within Severn Sound watershed and relative percent by colour class (Red, Yellow, Green) in the final habitat suitability classification, summarized by municipality.

	Total Survey	Georgian Bay	Midland	Penetanguishene	Severn	Tay	Tiny	Total
Total Length of shoreline within Severn Sound watershed	343.48	351.68	16.25	24.20	1.44	91.00	8.89	491.75
Total Length Classified								
RED	86.85	68.77	0.28	0.33	0.01	16.65	0.81	86.85
YELLOW	118.88	54.15	8.22	17.26	0.50	34.98	3.77	118.88
GREEN	92.99	65.17	2.55	2.32	0.69	21.85	0.42	92.99
Not Rated	44.76	17.45	5.18	4.29	0.23	17.61	0.00	44.76
Not Surveyed		146.14	0.02	0.00	0.00	0.00	3.89	148.24
Percent Classified								
RED	25.29	19.55	1.72	1.36	0.62	18.28	9.11	17.21
YELLOW	34.61	15.40	50.58	71.32	34.72	38.40	42.41	24.41
GREEN	27.07	18.53	15.69	9.57	47.92	23.98	4.72	19.13
Not Rated	13.03	4.96	31.88	17.73	15.97	19.34	0.00	9.12
Not Surveyed		41.55	0.12	0.00	0.00	0.00	43.76	30.14
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Figure 1: Study area map of Severn Sound, Georgian Bay, illustrating the extent of littoral zone physical habitat surveyed by field season years 1989-1994.



Scale 1:175,000

Figure 2 Aquatic Habitat Suitability Assessment and Classification Object Flow Model

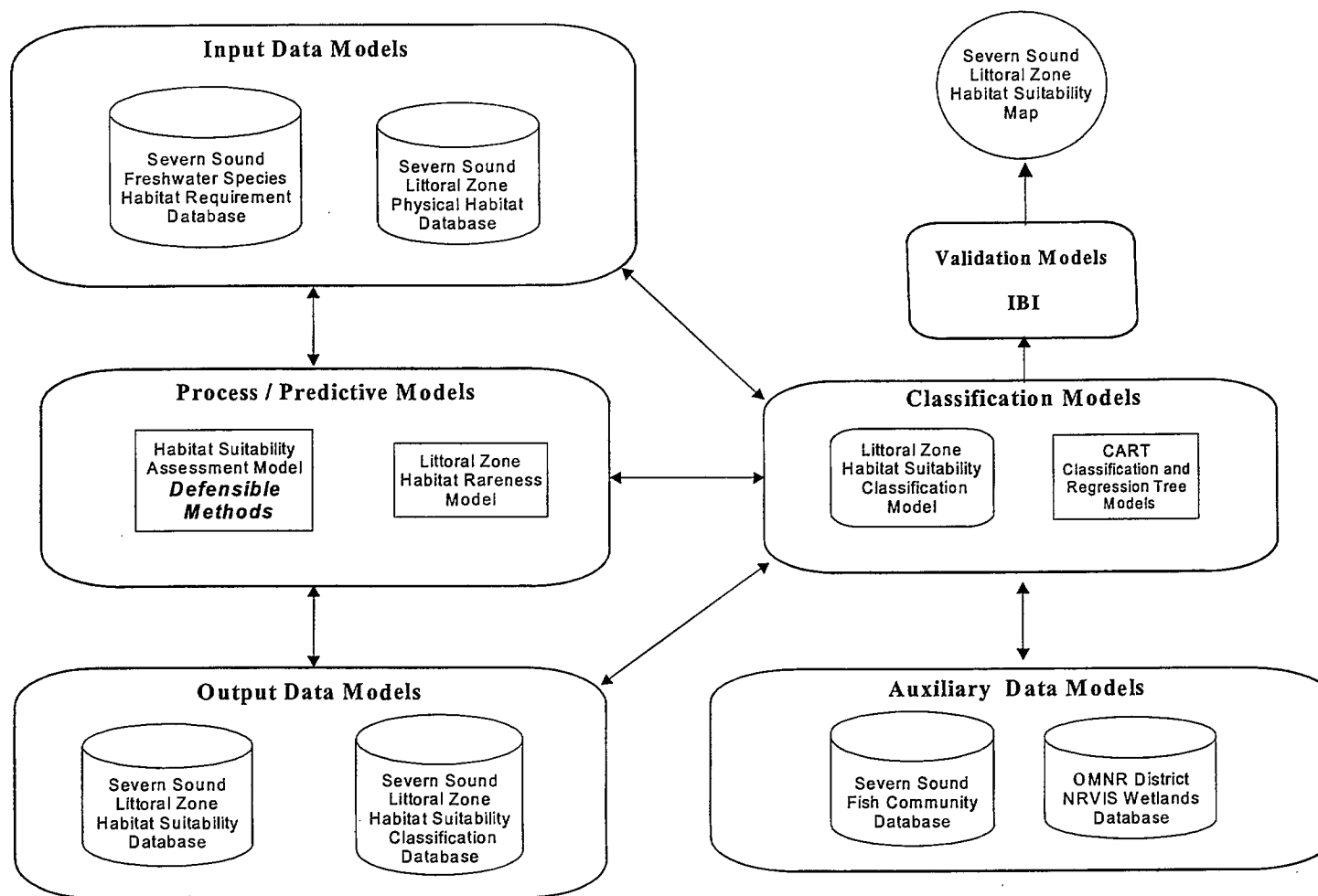


Figure 3: Graphs showing the Pearson correlation between pairs of composite habitat suitability values versus the Euclidean distance between the corresponding pairs of group and life stage weights for a representative sample of habitat polygons from the Severn Sound littoral zone database (N=1873): A) Trophic weights, B) Life stage weights, and C) Thermal weights.

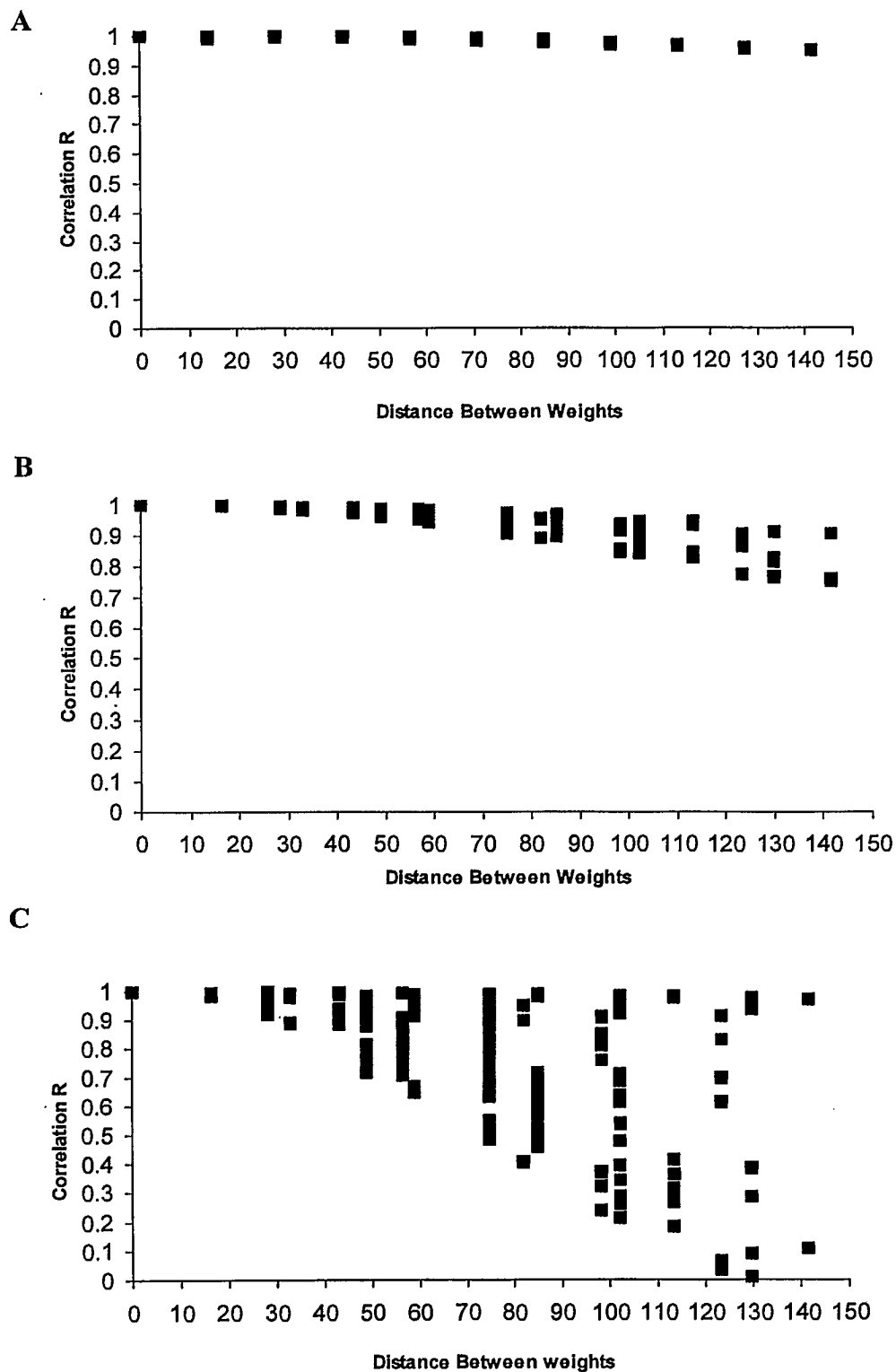


Figure 4: Graphs showing the relationships, and their statistical significance, between direct measures of the fish community (A- density, B – biomass, and C – species richness) and the Severn Sound littoral zone habitat suitability composite indices.

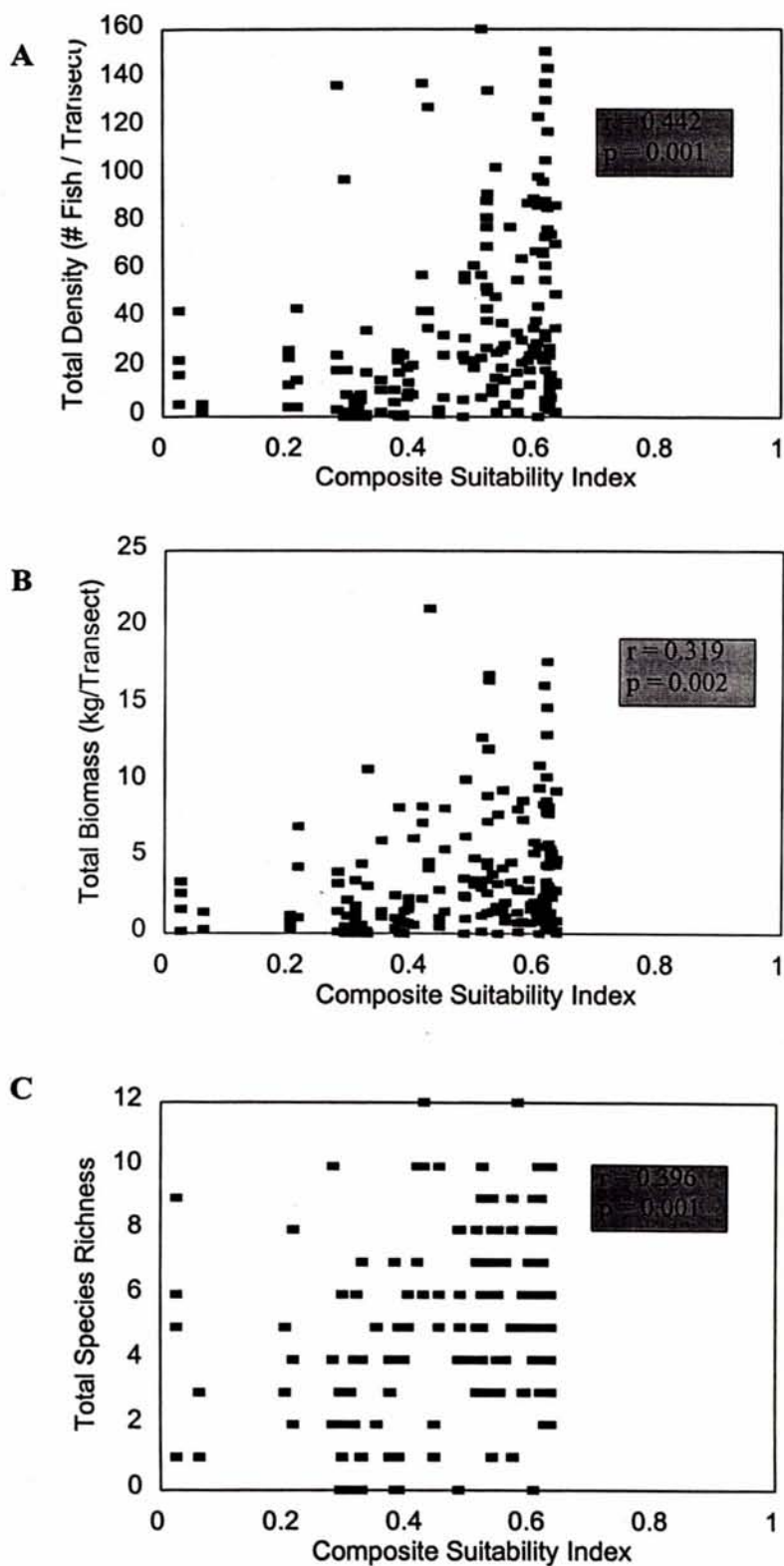


Figure 5: Graphs showing the relationships, and their statistical significance, between raw (A) and adjusted (B) IBI values and the Severn Sound composite habitat suitability indices. (The adjusted IBI reduces the influence of offshore fish species).

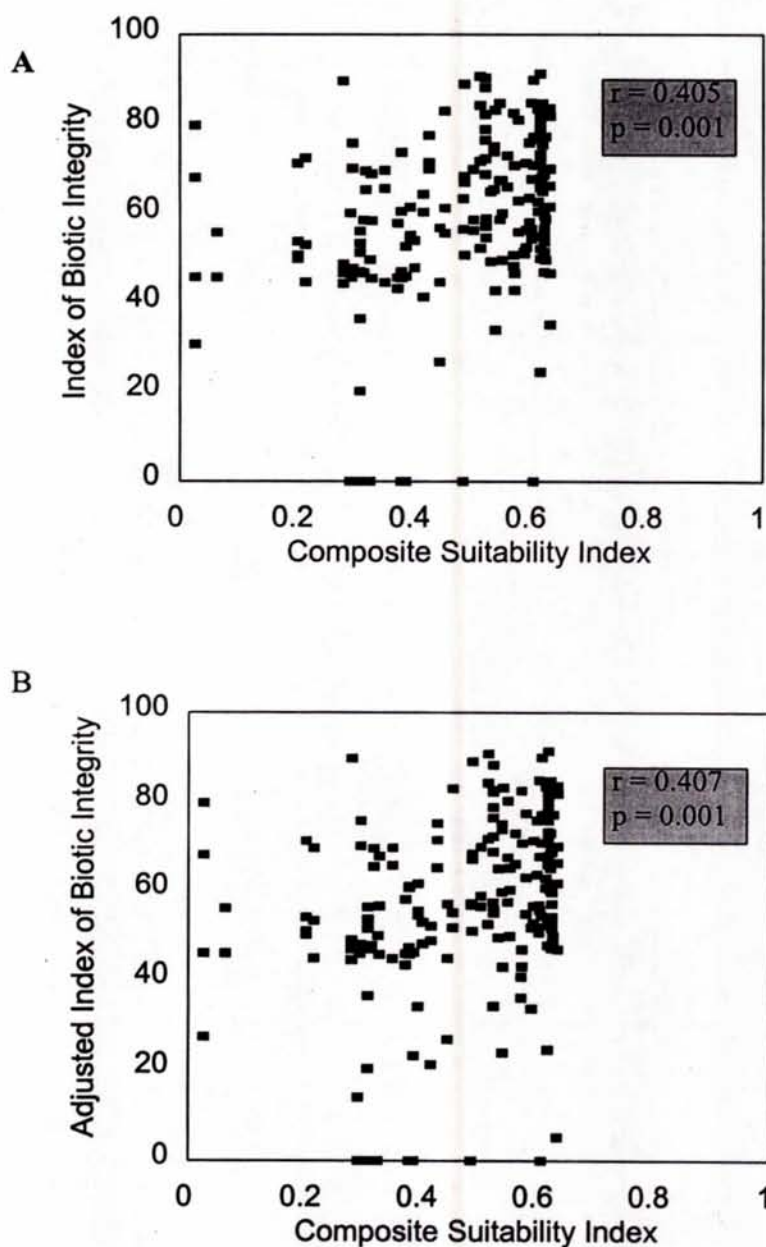
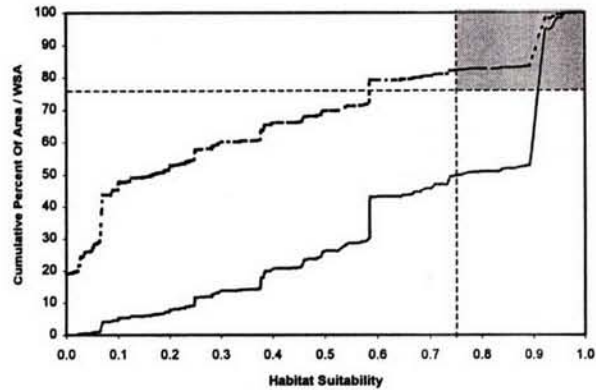
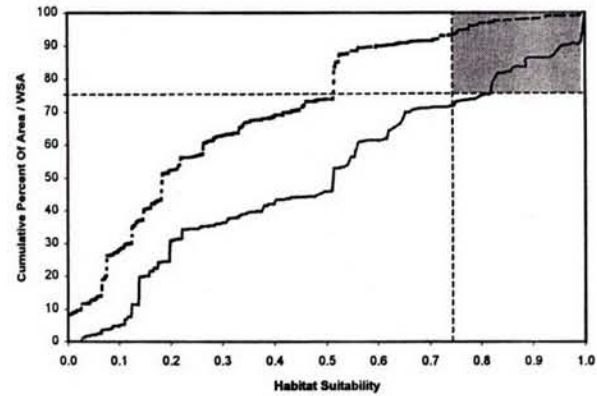


Figure 6: Graphs of cumulative area and weighted suitable area illustrating the application of the 75 percent and 0.75 suitability cutoffs for identifying rare, highly suitable habitat. (In A, the WSA line enters the shaded quadrant from below representing common habitat, in C the WSA line does not enter the shaded area indicating the absence of high quality habitat, while in B and D enter from the side representing rare habitat).

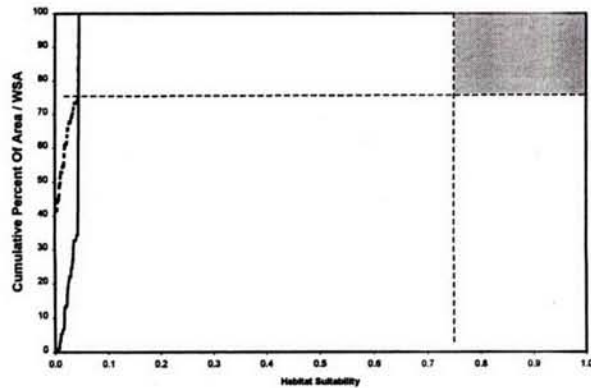
A) YOUNG OF THE YEAR COLD PISC.



B) SPAWN COOL NON-PISC.



C) ADULT COLD PISC.



D) SPAWN WARM NON-PISC.

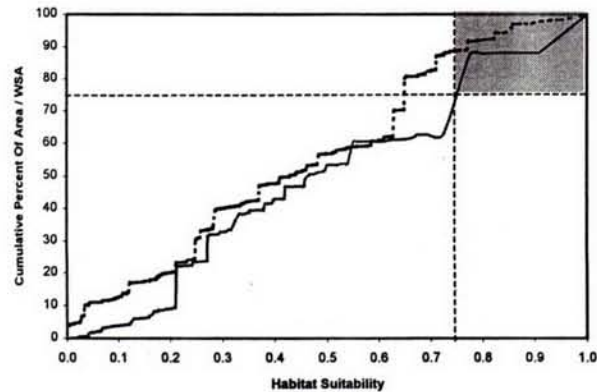


Figure 7: Process model illustrating the topological overlaying of multi-layer input coverage for producing the Final Habitat Suitability Layer.

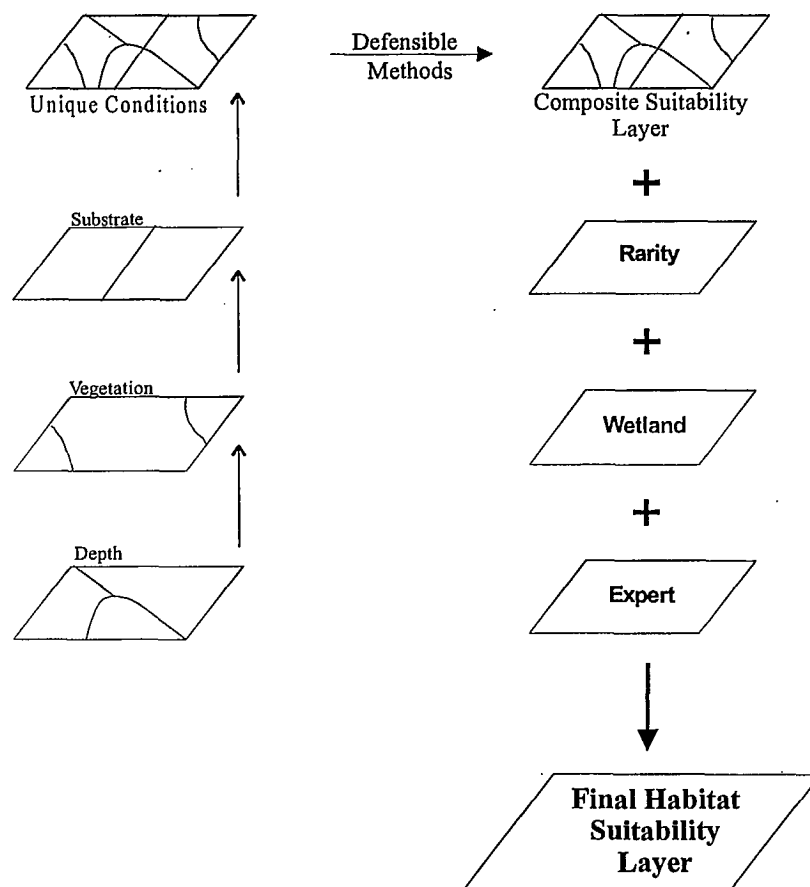


Figure 8: The frequency distribution of Severn Sound composite habitat suitability index values (N=1873).

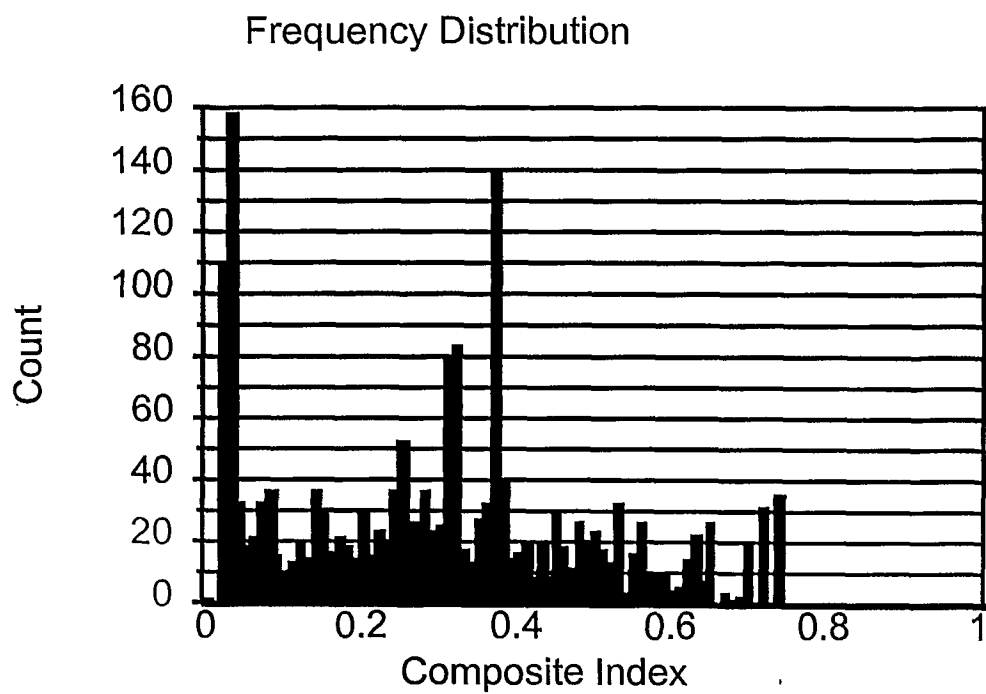


Figure 9: Resulting classification model from the classification and regression tree (CART) analysis used to classify Severn Sound littoral zone habitat database composite suitability index values into discrete categories Low, Medium, High. (CART Model pruned to four terminal nodes).

54

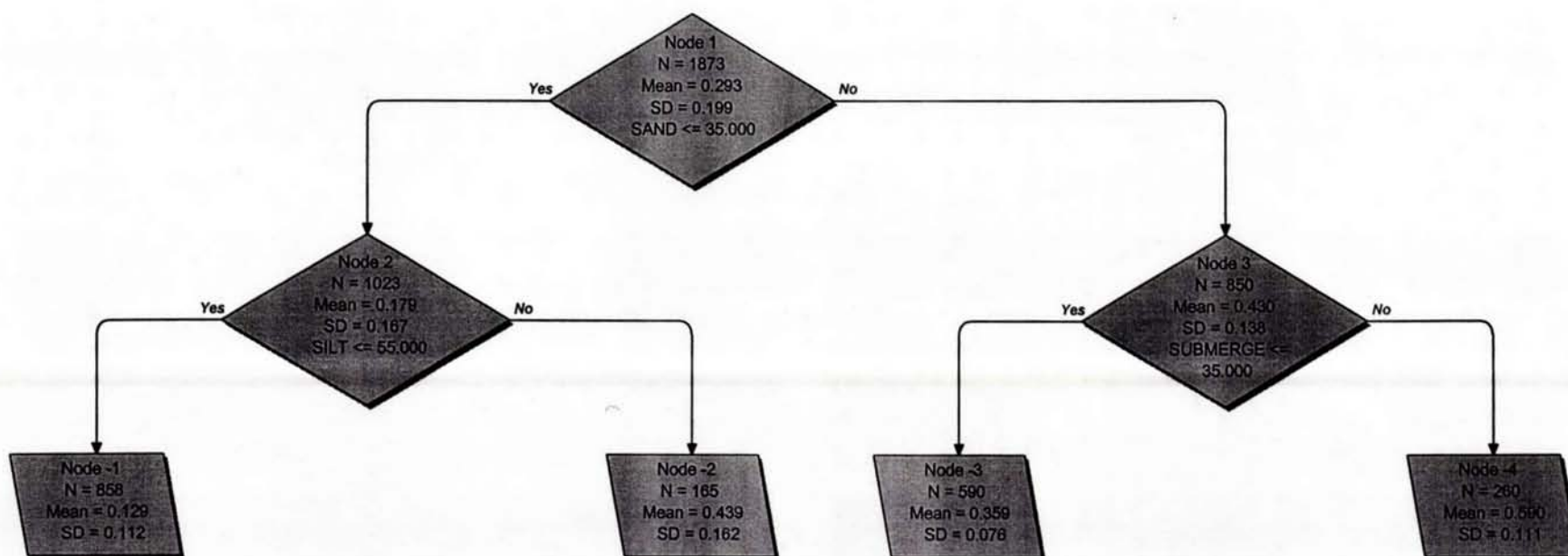


Figure 10: Percentage frequency distributions for the sample of Severn Sound composite habitat suitability index values for the three groups derived from the CART analysis.

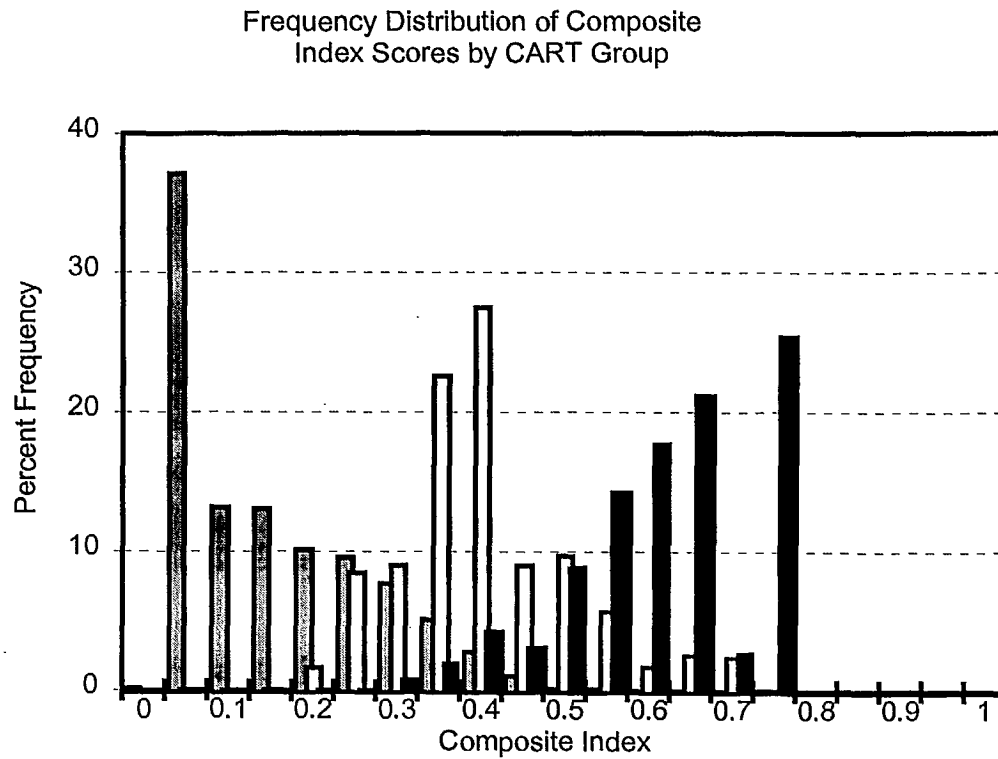


Figure 11: Cumulative percent frequency curves for the three groups derived from the CART analysis: A) Group 1 versus group 2; B) group 2 versus group 3. (In each plot, the second cumulative curve is inverted to show the cross-over points in the distributions).

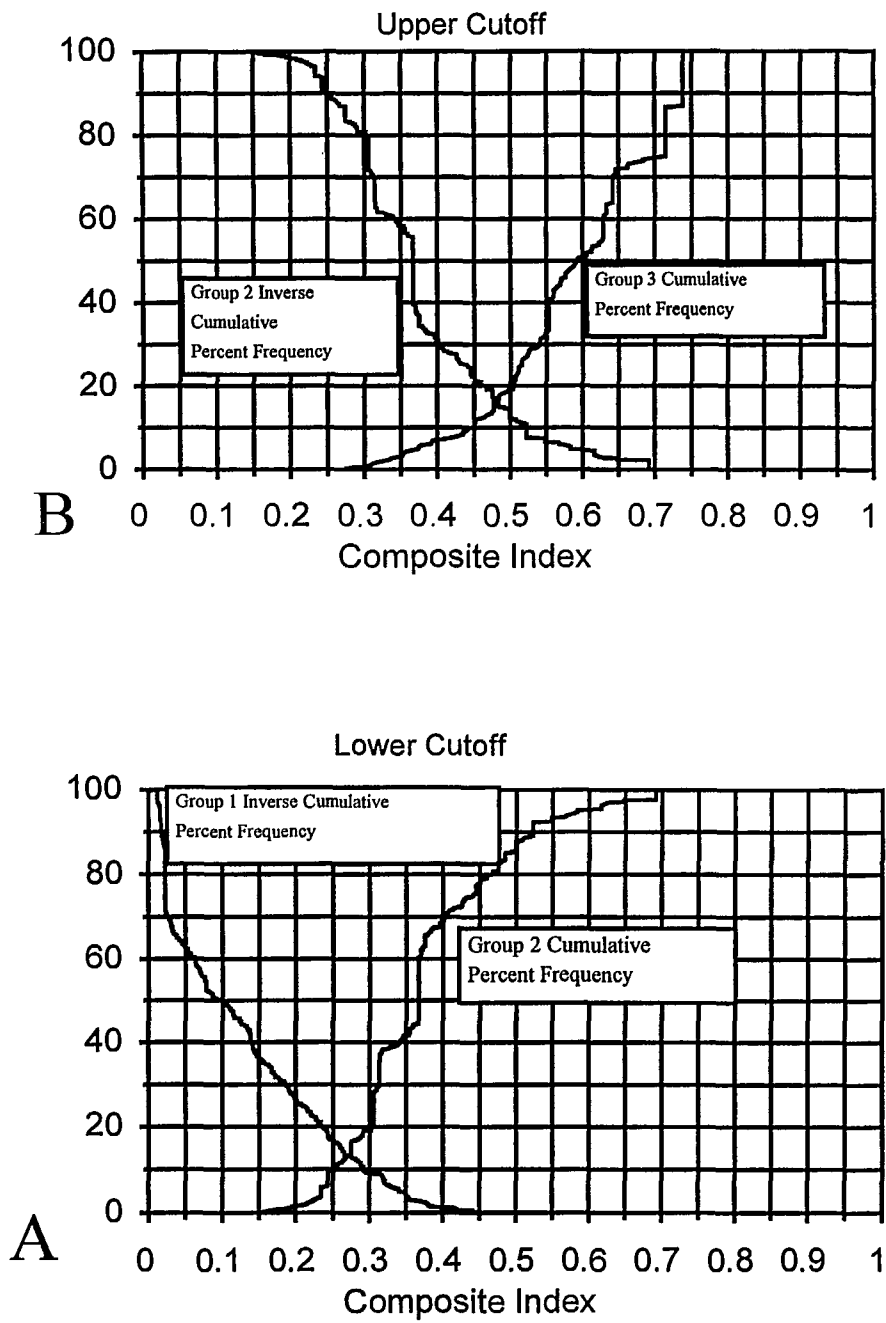
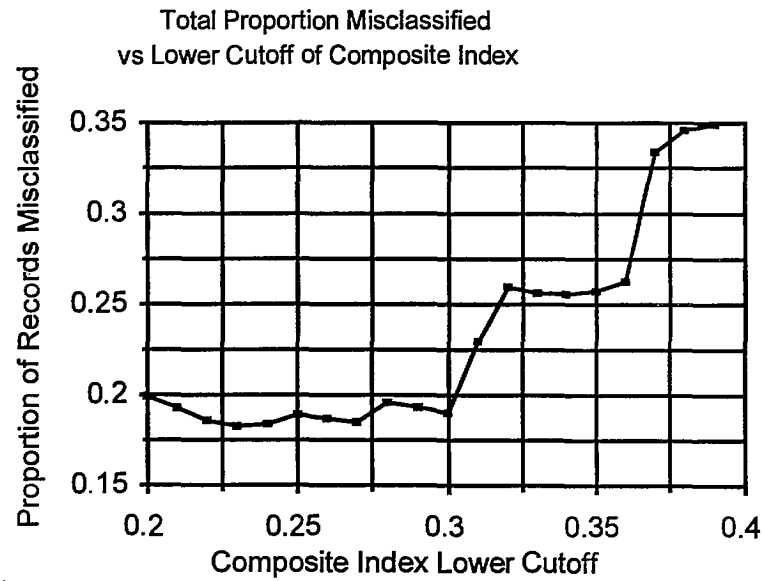
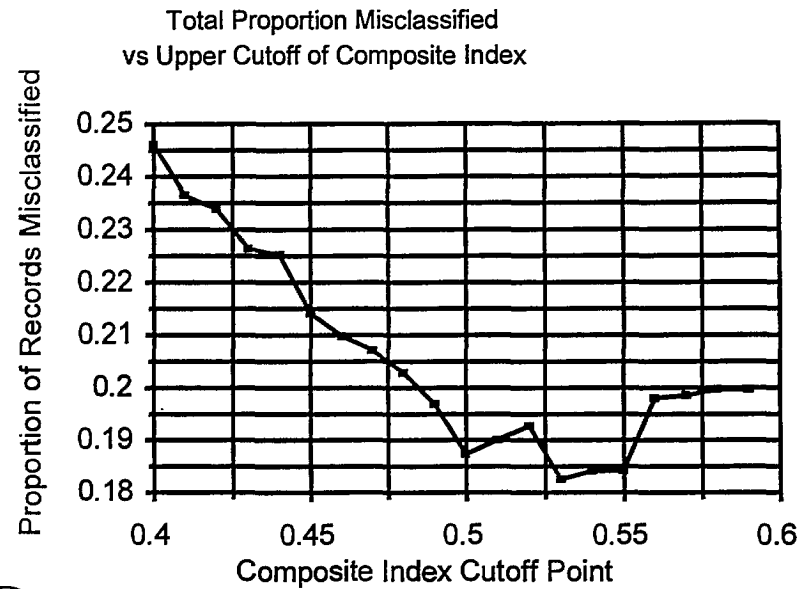


Figure 12: Graphs showing the proportion of sample littoral habitat suitability areas misclassified versus composite suitability index cutoff values: A) Lower cutoff separating Low and Medium; B) Upper cutoff separating Medium and High. (The minimum misclassification rate occurs at cutoffs of 0.2342 and 0.5236.)



A



B

Figure 13 - Rule-based decision tree showing the final methodological steps incorporating all information in the classification of littoral habitat area as High, Medium or Low.

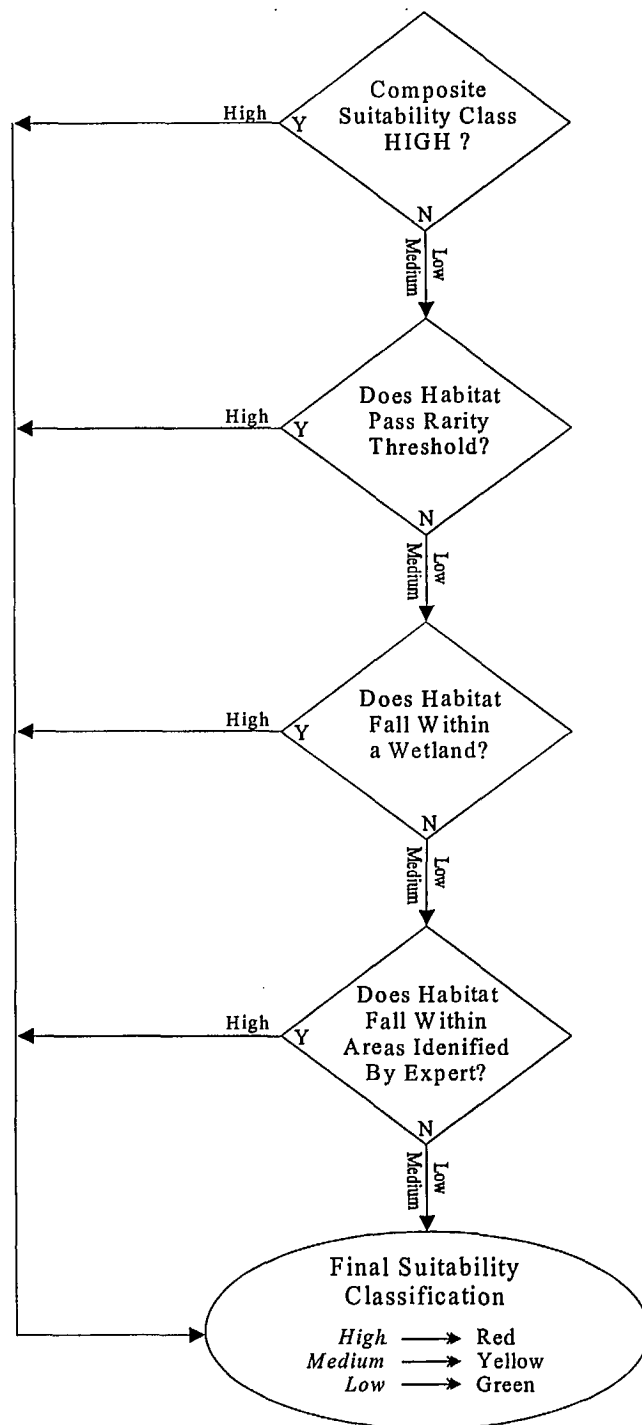
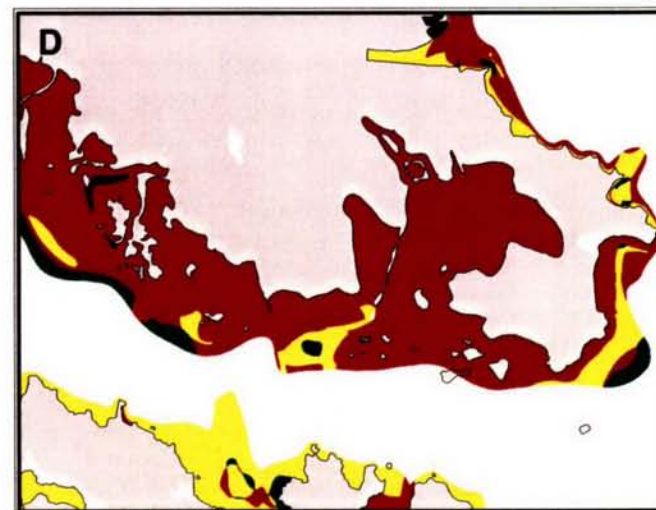
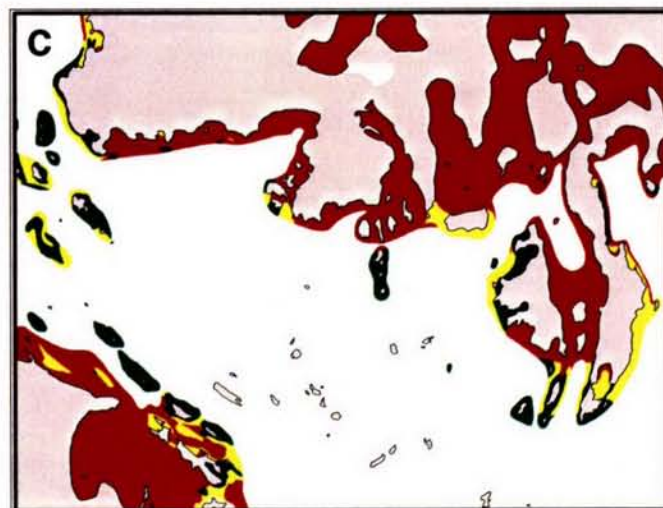
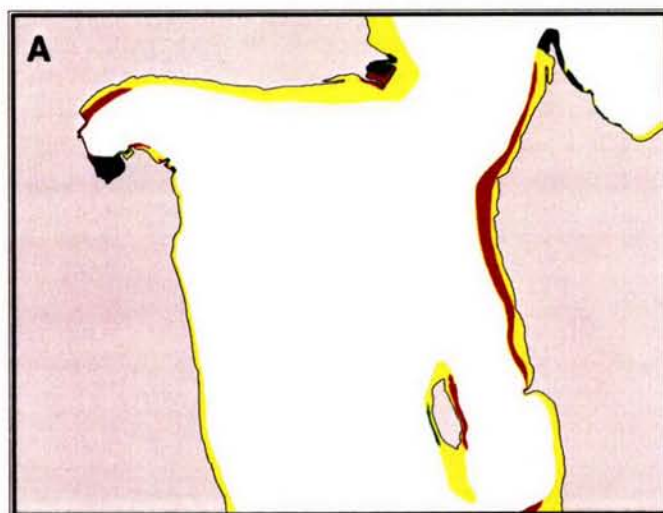


Figure 14: Sample shoreline areas with colour-coded habitat classifications indicated A B C D (See Figure1 for sample locations.)



**Habitat Suitability
For Fish Productivity**



0.2 0 0.2 Kilometres

APPENDIX A

Metadata documentation and data dictionary for the Severn Sound littoral zone physical habitat GIS database.

Software Requirements

- Arc/Info®
- ArcView®

The GIS coverages for the Littoral Zone Habitat Database are archived on CD-ROM as an Arc/Info® uncompressed interchange format (e00) and as ArcView® shape files.

Shape File Naming Convention

Coverage Name-p - represents a polygon feature type.

Coverage Name-a - represents a line or arc feature type.

Coverage Name-pt - represents a point feature type.

Background

The Severn Sound Littoral Zone Habitat Database is a collection of physical habitat data. This wealth of fish habitat data includes substrate materials, vegetation composition, shoreline materials, feature point information and depth contours, in addition to selected OBM layers and district wetland layers.

The entire Severn Sound shoreline has been field surveyed in six sections beginning in 1989 with Penetang Bay and finishing in 1994 at Honey Harbour See Figure 1, for the location of the study area and survey sections. All thematic information was field surveyed by C. Portt & Associates. All 1:2,000 field inventory maps were generated either from CHS (Canadian Hydrographic Service) 1:10,000 charts or the OBM 1:10,000 series. Physical fish habitat data was collected to a depth of 1.5 metres, which defines the littoral zone habitat. The digital spatial fish habitat database was created in 1992/93 using Pc Arc/Info 3.4d (ESRI 1994) and mapped at a scale of 1:10,000 by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), GIS Unit.

The Department of Fisheries and Oceans (DFO) contracted Baytech Environmental in late fall 1996 to complete the spatial fish habitat database. The digital spatial database was transferred to NT ArcInfo®. Finalised work to the fish habitat database included spatial transformation and correction, edge matching and map joining of six survey sections, QA/QC, incorporation of other thematic layers such as wetlands and drainage, and documentation of spatial and attribute information. The final fish habitat spatial database has been archived on a Compact Disc. (For more information contact: Keith Sherman c/o Severn Sound Environmental Association, PO Box 100, Wye Marsh Wildlife Centre, Midland, Ontario L4R 4K6)

Habitat Survey Sections

The following is a brief description of each survey section surveyed for the Severn Sound Littoral Zone Habitat Database outlining the choice of shoreline base mapping.

1989 Survey Section

This portion of shoreline was digitised as one coverage representing a 21.88 km section of shoreline stretching around Penetang Bay to Asylum Point. Paper base maps (from CHS 1: 10,000 charts) significantly deviated from the OBM digital basic mapping. Therefore, it was decided that the CHS shoreline would be digitised as the base information.

1990 Survey Section

The 1990 survey section represents a 72.85 km portion of shoreline stretching between Port Severn and Moore Point. Paper base maps (from CHS) followed the OBM digital shoreline fairly well. Therefore, it was decided that the digital OBM 1:10,000 series would be used as the base information.

1991 Survey Section

The 1991 survey section represents a 101.39 km portion of shoreline stretching between Honey Harbour and Moore Point. Base mapping for the shoreline came from the digital 1:10,000 OBM series.

1992 Survey Section

The 1992 survey section represents a 53.41 km portion of shoreline stretching between Asylum Point and Hog Bay. Base mapping for this survey year was generated from CHS 1:10,000 sheets.

1993 Survey Section

The 1993 survey section represents a 39.15 km portion of shoreline stretching between Hog Bay and Matchedash Bay. Base mapping for this survey year was generated from CHS 1:10,000 sheets.

1994 (South) Survey Section

The 1994S survey section represents a 26.05 km portion of shoreline stretching between Port Severn and Matchedash Bay. Paper base (from CHS) followed the OBM digital shoreline fairly well. Therefore, it was decided that the digital OBM 1:10,000 shoreline would be used as the base information.

1994 (North) Survey Section

The 1994N survey section represents a 29.26 km portion of shoreline around Roberts Island. Base mapping for this survey year came from the digital OBM series (1:10,000 sheets).

Fish Habitat Thematic Layers

Each survey section's thematic layers have been joined into one layer representing the entire Severn Sound shoreline stretching around Penetang Bay to Honey Harbour. A total of 344 km of shoreline has been surveyed and represented by the following layers:

- SEVSHORE (Poly/Line) - Shoreline substrate Arcs
- SEVSUBST (Poly) - Substrate Polygons & Arcs
- SEVEG (Poly) - Vegetation Polygons & Arcs
- SEVDEPTH (Poly) - Depth Polygons & Arcs
- SEVFEAT (Point) - Shoreline Feature Points

The five thematic layers are located in the directory [CD]\Sev-E00\Litt-Survey\ and [CD]\Sev-ShpFiles\Litt-Survey\ containing the ArcInfo® export and ArcView® shape files, respectively.

Ontario Basic Mapping Layers

The Severn Sound study area is defined by 25 OBM tiles which have been appended together to create new coverages. These new appended layers were created for the purpose of having one entire coverage, rather than 25 coverages, representing the study area. The following appended coverages are located in the directory [CD]\Sev-E00\OBM-Base\ and [CD]\Sev-ShpFiles\OBM-Base\ containing the ArcInfo® export and ArcView® shape files, respectively:

- DRAINPOI – Drainage points.
- DRAINLIN – Drainage lines.
- DRAINOBM - Drainage - Original OBM shoreline.
- TRANSPOR - Transportation.
- NEAT – Study area neatline.
- OBMGRID – OBM tiles neatline.

The Provincial Mapping Office Digital Topographic Database Overview, Version 2 (March 1994) provides the data dictionary associated with OBM layers.

Incorporation of Other Data

Any further integration of other thematic information must incorporate the base shoreline arcs from the SEVSHORE coverage. All additional information should conform to the geographical referencing methodologies used in this project. The following projection and referencing parameters were used:

- Projection: Universe Transverse Mercator
- Zone: 17 Units:
- Meters Datum: NAD27
- Easting: 6 digit
- Northing: 7 digit

Any new coverages added to the Severn Sound Littoral Zone Fish Habitat Database should use the above referencing, ensuring easy integration. Note: The surveyed shoreline does not necessarily follow the OBM shoreline. Caution should be taken when incorporating other datasets.

Specific Severn Sound Base Layers

The sections of original OBM shoreline contained in the DRAINOBM coverage that overlapped the surveyed shoreline were removed and replaced with the shoreline from the SEVSHORE coverage, creating the DRAINSEV coverage. The DRAINOBM and DRAINSEV layers are the main base drainage coverages. The purpose of these coverages is to supply the user with the surrounding drainage features. The DRAINOBM layer can be used with other existing OBM information; however the DRAINSEV layer *must be used* for displaying any littoral zone habitat information. These replaced shoreline arcs in the DRAINSEV coverage originally coded as MNRCODE = 127 have been recoded as 199. The sections of shoreline in the DRAINSEV coverage that have a NMRCODE = 199 are the actual shoreline arcs appended from the SEVSHORE coverage and the original shoreline arcs from the OBM tiles have been removed. Therefore, all the thematic fish habitat layers can be overlaid with the DRAINSEV coverage, providing a seamless view. The user can also choose not to display the DRAINSEV arcs coded 199 and use the SEVSHORE or other littoral zone habitat layers instead. The DRAINSEV coverage is located in the directory [CD]\Sev-E00\Sev-Base\ and [CD]\Sev-ShpFiles\Sev-Base\ containing the ArcInfo® export and ArcView® shape files, respectively.

Wetlands Layers

NRVIS® wetlands layers were provided by the Midhurst and Parry Sound Districts OMNR offices. Each district wetland has been updated to the Severn Sound surveyed shoreline (i.e. sevshore). Therefore, two version of each district's wetlands exist:

Midhurst

The original Midhurst wetland coverage follows the OBM shoreline and is archived in [CD]\Sev-E00\OBM-Wetland\mhwetlnd.e00 and [CD]\Sev-ShpFiles\OBM-Wetland\mhwetlnd-p.shp. The wetland coverages that have been updated with the SEVSHORE shoreline are archived in [CD]\Sev-E00\Sev-Wetland\mh-sswetl.e00 and [CD]\Sev-ShpFiles\Sev-Wetland\mh-wetl-p.shp. The open water / marsh polygons (GUT = 2061) have be appended to the coverages but are not provincially or locally significant according to the OMNR wetland evaluation. Documentation for the Midhurst wetland layers can be located in [CD]\Sev-E00\OBM-Wetland\ *mh-readme.txt*

Parry Sound

The original Parry Sound wetland coverage follows the OBM shoreline and is archived in [CD]\Sev-E00\OBM-Wetland\pswetlnd.e00 and [CD]\Sev-ShpFiles\OBM-Wetland\pswetlnd-p.shp. The wetland coverages that have been updated with the SEVSHORE shoreline are archived in [CD]\Sev-E00\Sev-Wetland\ps-sswetl.e00 and [CD]\Sev-ShpFiles\Sev-Wetland\ps-sswetl-p.shp.

Documentation for the Parry Sound wetland layer can be found in the following locations:

- [CD]\Sev-E00\OBM-Wetland\ps-Potatoi.txt
- [CD]\Sev-E00\OBM-Wetland\ps-Quarryi.txt
- [CD]\Sev-E00\OBM-Wetland\ps-Tobiesb.txt

Defensible Methods Suitability Layers

The following layer represents the results of the *Habitat Suitability Classification Model*. The coverage [CD]\Sev-E00\Litt-Suitblty\habsuit.e00 and [CD]\Sev-ShpFiles\Litt-Suitblty\ habsuit-p.shp consists of the intersection or combined overlay of the substrate, vegetation and depth layers. This coverage contains all attribute information from the respective input layers (See Database Structures and Attribute Definitions in Appendix A). Additional attribute information added to the polygon attribute tables includes county and municipality names as well as the 18 constituent indices and a composite index. The following fields were added to the polygon attribute table, which define the information required for the condition rule based inductive final classification schema:

Compsuit: contains LOW, MEDIUM and HIGH suitability ratings for the Severn Sound fish community;

Raresuit: rareness calculations - areas of the littoral zone were indicated as RARE;

Wetland_si: areas of the littoral zone were coded "P" if located within a Provincially or Locally significant wetland;

Expert_sui: areas of the littoral zone area were identified as highly productive by local experts within the fisheries and other biological communities (80 char text field).

Final_suit: field represents the overall habitat suitability rating. Suitability ratings coded as Red, Yellow, Green and Not Rated.

Please refer to the draft manuscript report titled "*Development of a Fish Habitat Classification Model For Littoral Areas of the Severn Sound, Georgian Bay, A Great Lake Area of Concern*" for details on how the rule-based final suitability rating was calculated using the four components or fields defined above.

Due to the enormous size of the multiple overlay *habsuit* coverage (i.e. 21768 polygons) an Arc/info® dissolve routine was performed on the *Final_suit* attribute column (Red, Yellow, Green). The dissolved coverage named *Finalsuit* contains 3166 polygon features and is archived in:

[CD]\Sev-E00\Litt-Suitblty\Finalsuit.e00
[CD]\Sev-ShpFiles\Litt-Suitblty\Finalsuit-p.shp

The following database structure describes the polygon attribute table (PAT) for the *Finalsuit* coverage:

Polygon Attribute Table (FINAL_SUIT.PAT)

Field	Field Name	Type	Width	Dec	Index	Description
1	AREA	Numeric	8	5	N	Polygon Area
2	PERIMETER	Numeric	8	5	N	Polygon Perimeter
3	FINAL_SUIT_	Numeric	4		N	Internal ID Number
4	FINAL_SUIT_ID	Numeric	4		N	User ID Number
5	FINAL_SUIT	Character	7		N	Habitat Suitability

Polygon Suitability

FINAL_SUIT	Description
RED	High Suitability
YELLOW	Medium Suitability
GREEN	Low Suitability
NR	Not Rated*

* These polygons are not rated because insufficient information (i.e. substrate and vegetation) was missing for classification. The high water marks were also coded as not rated.

An interactive line and polygon attribute exercise was performed in order to code all shoreline arcs as Red, Yellow or Green according to the adjacent polygon code from the *Finalsuit* coverage. For example, if the adjacent polygon to the shoreline arc was Yellow, then the arc was assigned an arc suitability of Yellow. The new coverage created is located in:

[CD]\Sev-E00\Litt-Suitblty\Shoresuit.e00
[CD]\Sev-ShpFiles\Litt-Suitblty\Shoresuit-a.shp

The following database structure describes the arc attribute table (AAT) for the *Shoresuit* coverage:

Arc Attribute Table (SHORESUIT.AAT)

Field	Field Name	Type	Width	Dec	Index	Description
1	FNODE	Numeric	4		N	From Node
2	TNODE	Numeric	4		N	To Node
3	LPOLY_	Numeric	4		N	Left Polygon
4	RPOLY_	Numeric	4		N	Right Polygon
5	LENGTH	Numeric	8	5	N	Length of Arc Segment
6	SHORESUIT#	Numeric	4		N	Internal ID Number
7	SHORESUIT_ID	Numeric	4		N	User ID Number
8	ARC_SUIT	Character	7		N	Arc Suitability

Arc Suitability

ARC_SUIT	Description
RED	High Suitability
YELLOW	Medium Suitability
GREEN	Low Suitability
NR-GRN	Not Rated*

* These arcs are not rated because the adjacent polygon was coded as NR. Also captured in the not rated class are sections of shoreline that were not surveyed and the high water marks. This coverage provides identification on shoreline areas that need further field surveys conducted.

Database Structures and Attribute Definition – Littoral Zone Habitat Layers

This sections outlines the database structures and attribute definitions such as arc codes and polygon descriptions for each of the thematic layers contained in the Severn Sound Littoral Zone Habitat Inventory.

SHORELINE THEMATIC LAYER

Arc Attribute Table (SEVSHORE.AAT)

Location of ArcInfo® export: [CD]\Sev-E00\Litt-Survey\sevshore.e00

Location of ArcView® shape file: [CD]\Sev-ShpFiles\Litt-Survey\sevshore-a.shp

Field	Field Name	Type	Width	Dec	Index	Description
1	FNODE_	Numeric	11		N	From Node
2	TNODE_	Numeric	11		N	To Node
3	LPOLY_	Numeric	11		N	Left Polygon
4	RPOLY_	Numeric	11		N	Right Polygon
5	LENGTH	Numeric	13	6	N	Length of Arc Segment
6	SEVSHORE_	Numeric	11		N	Internal ID Number
7	SEVSHORE_ID	Numeric	11		N	User ID Number
8	SURVEY	Numeric	4		N	Year Of Survey
9	ARC_ID	Numeric	11		N	See Table 1A for ID Codes
10	FEATURE	Character	15		N	See Table 1A for ID Definition
11	HP_CLAY	Numeric	1		N	1-Presence & 0-Absence
12	SILT	Numeric	1		N	1-Presence & 0-Absence
13	SAND	Numeric	1		N	1-Presence & 0-Absence
14	GRAVEL	Numeric	1		N	1 -Presence & 0-Absence
15	PEBBLE	Numeric	1		N	1-Presence & 0-Absence
16	COBBLE	Numeric	1		N	1 -Presence & 0-Absence
17	BOULDER	Numeric	1		N	1-Presence & 0-Absence
18	BEDROCK	Numeric	1		N	1-Presence & 0-Absence
19	STEEL	Numeric	1		N	1-Presence & 0-Absence
20	CONCRETE	Numeric	1		N	1-Presence & 0-Absence
21	GABION	Numeric	1		N	1-Presence & 0-Absence
22	ORGANIC	Numeric	1		N	1-Presence & 0-Absence
23	WOOD	Numeric	1		N	1-Presence & 0-Absence
24	RUBBLE	Numeric	1		N	1-Presence & 0-Absence
25	OTHER	Character	19		N	Other Shoreline Material

Table 1A: Shoreline Codes and Definitions

ARC ID	FEATURE	ARC ID	FEATURE	ARC ID	FEATURE
10	SB (Survey Boundary)	253	S/P/G/C	294	W/ST
200	NR (Not Rated Shoreline)	254	G/P	295	W/B/CO
211	S (Sand)	255	G/P/C	297	P/R
212	R (Bedrock)	256	SLAG	298	B/ORG
213	CO (Concrete)	257	P/C/B/SLAG/RU	299	S/P/C/B/R
214	B (Boulder)	258	RU (Rubble)	300	S/C/B
215	B/R	259	S/GA	301	C/ORG
216	B/C	260	BW (BreakWall)	302	P/C/ORG
217	P (Pebble)	261	B/RU	303	TIRES
218	G (Gravel)	262	GA/CO/B	306	SAWDUST
219	SI (Silt)	263	S/G/P/C/B	307	CY/C
221	S/P/C	264	CY/S/P/C/B	308	W/C
222	P/C	265	CY/P/C/B	309	CY/GIP
223	S/B	266	SI/ORG	310	CY/S/C/B
224	ORG (Organic)	267	BRICK (Interlocking Brick)	311	CY/P/C
225	P/C/R	268	SI/ORG/S	312	B/C/ORG
226	S/P/C/R	269	S/P/BRICK	313	ARMOUR STONE
227	S/SI	270	BLOCK (Concrete)	314	ORG/S/P/C/B/R
230	C/R	271	S/G/P/C/B	315	ORG/C/B/R
231	S/C	272	CY/P	316	ORG/P/C/B
232	S/G	273	W/P/C/B	317	ORG/B/R
233	C/B/R	274	CO/C/B	318	ORG/S/P/C
234	CY (Hp_Clay)	275	S/RU	319	G/C/P/B
235	S/ORG	276	CO/B/RU	320	ORG/R
236	S/P	277	S/C/B/W	321	CO/R
237	S/R	278	S/G/P/W	322	W/CO/ST
238	S/P/G	279	C/B/RU	323	SI/S/G
239	GA (Gabion)	280	S/P/C/W	324	S/G/P/B
240	S/P/B	281	W/RU	325	B/CO
241	S/P/C/B	282	C/B/W	326	ASPHALT
242	S/G/C/P/B/R	283	FILL	327	P/C/B/CO
243	P/C/B/R	284	ST (Steel)	328	W/C/CO
244	C/B/P	286	W (Wood)	329	C/B/BRICK
247	B/ST	287	C (Cobble)	331	C/B/FILL
248	CO/ST	289	CO/C	332	GA/CO
249	P/B	290	W/B		
250	CY/S	291	CO/W		
251	S/G/P/R	292	GA/W		
252	CY/SI	293	SPOIL		

Polygon Attribute Table (SEVSHORE.PAT)

Location of ArcInfo® export: [CD]\Sev-E00\Litt-Survey\sevshore.e00

Location of ArcView® shape file: [CD]\Sev-ShpFiles\Litt-Survey\sevshore-p.shp

Field	Field Name	Type	Width	Dec	Index	Description
1	AREA	Numeric	13	6	N	Polygon Area
2	PERIMETER	Numeric	13	6	N	Polygon Perimeter
3	SEVSHORE_	Numeric	11		N	Internal ID Number
4	SEVSHORE_ID	Numeric	11		N	User ID Number
5	SURVEY	Numeric	4		N	Year of Survey
6	TERRA	Character	4		N	LAKE or LAND

SUBSTRATE THEMATIC LAYER

Arc Attribute Table (SEVSUBST.AAT)

Location of ArcInfo® export: [CD]\Sev-E00\Litt-Survey\sevsubst.e00

Location of ArcView® shape file: [CD]\Sev-ShpFiles\Litt-Survey\sevsubst-a.shp

Field	Field Name	Type	Width	Dec	Index	Description
1	FNODE	Numeric	11		N	From Node
2	TNODE	Numeric	11		N	To Node
3	LPOLY_	Numeric	11		N	Left Polygon
4	RPOLY_	Numeric	11		N	Right Polygon
5	LENGTH	Numeric	13	6	N	Length of Arc Segment
6	SEVSUBST	Numeric	11		N	Internal ID Number
7	SEVSUBST_ID	Numeric	11		N	User ID Number
8	SURVEY	Numeric	4		N	Year Of Survey
9	ARC_ID	Numeric	11		N	See Table2A For ID Definitions
10	MNRCODE	Numeric	11		N	Ministry Of Natural Resources OBM Codes

Table 2A: Substrate Arc Codes and Definitions

ARC_ID	FEATURE
10	Survey Boundary
200	Shoreline
100	Substrate Boundary

Polygon Attribute Table (SEVSUBST.PAT)

Location of ArcInfo® export: [CD]\Sev-E00\Litt-Survey\sevsubst.e00

Location of ArcView® shape file: [CD]\Sev-ShpFiles\Litt-Survey\sevsubst-p.shp

Field	Field Name	Type	Width	Dec	Index	Description
1	AREA	Numeric	13	6	N	Polygon Area
2	PERIMETER	Numeric	13	6	N	Polygon Perimeter
3	SEVSUBST_	Numeric	11		N	Internal ID Number
4	SEVSUBST_ID	Numeric	11		N	User ID Number
5	SURVEY	Numeric	4		N	Year of Survey
6	HECTARES	Numeric	10	2	N	Polygon Area in Hectares
7	HP_CLAY	Numeric	3		N	Percent Hardpan Clay
8	SILT	Numeric	3		N	Percent Silt
9	SAND	Numeric	3		N	Percent Sand
10	GRAN	Numeric	3		N	Percent Granule
11	PEBB	Numeric	3		N	Percent Pebble
12	COBB	Numeric	3		N	Percent Cobble
13	BOULD	Numeric	3		N	Percent Boulder
14	BEDROCK	Numeric	3		N	Percent Bedrock
15	ORG	Numeric	3		N	Percent Organic (Muck)
16	OCLAY	Numeric	3		N	Over Clay *
17	WO	Numeric	3		N	Percent Wood Waste
18	RU	Numeric	3		N	Percent Rubble
19	METAL	Numeric	3		N	Percent Metal
20	OROCK	Numeric	3		N	Over Rock **
21	SLAG	Numeric	3		N	Percent Slag
22	OTHER	Character	10		N	Other Substrate Materials & Features (i.e. Islands, Concrete, Lake, Shoal)

Note: Use the OTHER field to differentiate between Islands and substrate polygons.

* OCLAY = 1 Substrate material is over Hardpan Clay

** OROCK = 1 Substrate material is over BedRock

VEGETATION THEMATIC LAVER

Arc Attribute Table (SEVVEG.AAT)

Location of ArcInfo® export: [CD]\Sev-E00\Litt-Survey\sevveg.e00

Location of ArcView® shape file: [CD]\Sev-ShpFiles\Litt-Survey\sevveg-a.shp

Field	Field Name	Type	Width	Dec	Index	Description
1	FNODE_	Numeric	11		N	From Node
2	TNODE_	Numeric	11		N	To Node
3	LPOLY_	Numeric	11		N	Left Polygon
4	RPOLY_	Numeric	11		N	Right Polygon
5	LENGTH	Numeric	13	6	N	Length of Arc Segment
6	SEVVEG	Numeric	11		N	Internal ID Number
7	SEVVEG-ID	Numeric	11		N	User ID Number
8	SURVEY	Numeric	4		N	Year of Survey
9	ARC_ID	Numeric	11		N	See Table 3A for ID Definitions
10	MNRCODE	Numeric	11		N	Ministry Of Natural Resources OBM Codes

Table 3A: Vegetation Arc Codes and Definitions

ARC_ID	FEATURE
10	Survey Boundary
200	Shoreline
160	Vegetation Boundary

Polygon Attribute Table (SEVSUBST.PAT)

Location of ArcInfo® export: [CD]\Sev-E00\Litt-Survey\sevsubst.e00

Location of ArcView® shape file: [CD]\Sev-ShpFiles\Litt-Survey\sevsubst-p.shp

Field	Field Name	Type	Width	Dec	Index	Description
1	AREA	Numeric	13	6	N	Polygon Area
2	PERIMETER	Numeric	13	6	N	Polygon Perimeter
3	SEVVEG_	Numeric	11		N	Internal ID Number
4	SEVVEG_ID	Numeric	11		N	User ID Number
5	SURVEY	Numeric	4		N	Year of Survey
6	SUB	Numeric	4		N	Percent Submergent Vegetation
7	C	Numeric	3		N	<i>Chara spp.</i> - stonewort
8	E	Numeric	2		N	<i>Elodea canadensis</i> - elodea
9	MY	Numeric	3		N	<i>Myriophyllum spp.</i> - water milfoil
10	NA	Numeric	3		N	<i>Najas spp.</i> - bushy pondweed
11	NI	Numeric	2		N	<i>Nitella spp.</i> - muskgrass
12	V	Numeric	2		N	<i>Vallisneria americana</i> - wild celery
13	P	Numeric	2		N	<i>Potamogeton spp.</i> - pondweed
14	A	Numeric	2		N	<i>Cladophora</i> - filamentous algae
15	CE	Numeric	3		N	<i>Ceratophyllum demersum</i> - coontail
16	EM	Numeric	4		N	Percent Emergent Vegetation
17	SA	Numeric	3		N	<i>Sagittaria spp.</i> - arrowhead
18	SC	Numeric	3		N	<i>Scirpus spp.</i> - bullrush
19	SP	Numeric	3		N	<i>Sparganium spp.</i> - burreed
20	TY	Numeric	3		N	<i>Typha spp.</i> Cattail
21	N	Numeric	3		N	<i>Nuphar spp.</i> water lily
22	Z	Numeric	3		N	<i>Zizania aquatica</i> - wild rice
23	PD	Numeric	3		N	<i>Pontederia cordata</i> - pickerel weed
24	PT	Numeric	3		N	<i>Potamogeton spp.</i> - floating leaves
25	SE	Numeric	3		N	Sedges
26	GR	Numeric	3		N	Grasses
27	WM	Numeric	3		N	Wet meadow
28	FB	Numeric	3		N	Floating bog
29	OTHER	Character	10		N	Other Features (i.e. Island, Lake, Shoal)

Note: Vegetation species may be numbered from 1 through x number of observed species This represents the order of abundance for observed species in a single polygon or record (a value of 1 represents the most dominant species).

DEPTH THEMATIC LAYER

Arc Attribute Table (SEVDEPTH.AAT)

Location of ArcInfo® export: [CD]\Sev-E00\Litt-Survey\sevdepth.e00

Location of ArcView® shape file: [CD]\Sev-ShpFiles\Litt-Survey\sevdepth-a.shp

Field	Field Name	Type	Width	Dec	Index	Description
1	FNODE_	Numeric	11		N	From Node
2	TNODE_	Numeric	11		N	To Node
3	LPOLY_	Numeric	11		N	Left Polygon
4	RPOLY_	Numeric	11		N	Right Polygon
5	LENGTH	Numeric	13	6	N	Length of Arc Segment
6	SEVDEPTH_	Numeric	11		N	Internal ID Number
7	SEVDEPTH_ID	Numeric	11		N	User ID Number
8	SURVEY	Numeric	4		N	Year of Survey
9	ARC_ID	Numeric	11		N	See Table 4A for ID Definitions
10	MNRCODE	Numeric	11		N	Ministry Of Natural Resources OBM Codes

Table 4A: Depth Arc Codes and Definitions

ARC_ID	FEATURE
10	Survey Boundary
200	Shoreline
300	0.5 meter Contour
301	1.0 meter Contour
302	1.5 meter Contour
305	High Water Mark

Polygon Attribute Table (SEVDEPTH.PAT)

Location of ArcInfo® export: [CD]\Sev-E00\Litt-Survey\sevdepth.e00

Location of ArcView® shape file: [CD]\Sev-ShpFiles\Litt-Survey\sevdepth-p.shp

Field	Field Name	Type	Width	Dec	Index	Description
1	AREA	Numeric	13	6	N	Polygon Area
2	PERIMETER	Numeric	13	6	N	Polygon Perimeter
3	SEVDEPTH_	Numeric	11		N	Internal ID Number
4	SEVDEPTH_ID	Numeric	11		N	User ID Number
5	SURVEY	Numeric	4		N	Year of Survey
6	DEPTH	Character	9		N	See Table 4B For Depth Attributes

Table 4B: Depth Polygon Attributes

Depth Attributes (meters)
0.0-0.5
0.5-1.0
1.0-1.5
>1.5
HW (High Water Mark)
LAND

FEATURE POINT THEMATIC LAYER

Point Attribute Table (SEVFEAT.PAT)

Location of ArcInfo® export: [CD]\Sev-E00\Litt-Survey\sevfeat.e00

Location of ArcView® shape file: [CD]\Sev-ShpFiles\Litt-Survey\sevfeat-pt.shp

Field	Field Name	Type	Width	Dec	Index	Description
1	AREA	Numeric	13	6	N	Polygon Area
2	PERIMETER	Numeric	13	6	N	Polygon Perimeter
3	SEVFEAT	Numeric	11		N	Internal ID Number
4	SEVFEAT-ID	Numeric	11		N	User ID Number
5	SURVEY	Numeric	4		N	Year of Survey
6	FEATURE	Character	9		N	See Table 5A for Features
7	MATERIALS	Character	34		N	Construction Material of Feature
8	FLWSOLID	Numeric	3		N	Water Can Flow Through Structures (Yes = 1 & No = 2)
9	PRIMARY	Numeric	3		N	Number of Primary Docks (See Figure #1)
10	SECONDARY	Numeric	3		N	Number of Secondary Docks (See Figure #1)
11	TERTIARY	Numeric	3		N	Number of Tertiary Docks (See Figure #1)
12	WATERLAND	Numeric	3		N	Boathouse (Over Water = 1 & Over Land = 2)
13	ACCOMMOD	Numeric	3		N	BoatHouse Accommodations (Yes = 1 & No = 0)
14	MARINA	Numeric	3		N	Unique Marina Complex Number

Figure 1: Description of Docks

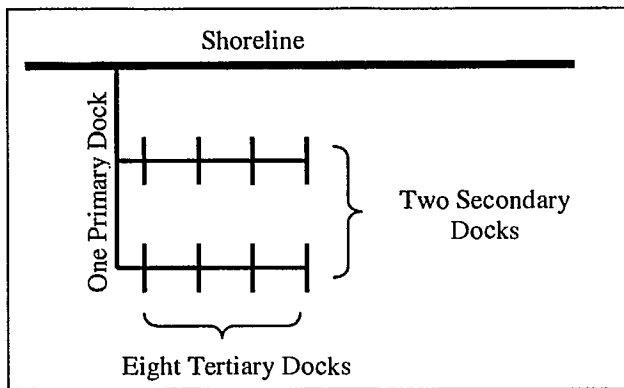


Table 5A: Feature Point Descriptions

Field Name	Description
AR	aircraft railway
BH	boathouse
BL	boat lift
BR	boat railway
BRD	bridge
BW	breakwall
BWAT	breakwater
C	cottage
CR	Crib Dock
D	deck
DC	dry culvert
F	concrete post
FB	floating boom
FD	floating dock
FP	fuel pump
G	groyne
GA	gabion
L	boat launch
LO	locks
PD	permanent dock
PSP	pipd spring
R	raft
S	shed
SD	seasonal dock
SD/FIXED	fixed seasonal dock
SP	spring
ST	stairs
TL	travel lift
W	wharf

APPENDIX B

Freshwater fish species list for Severn Sound, Georgian Bay.

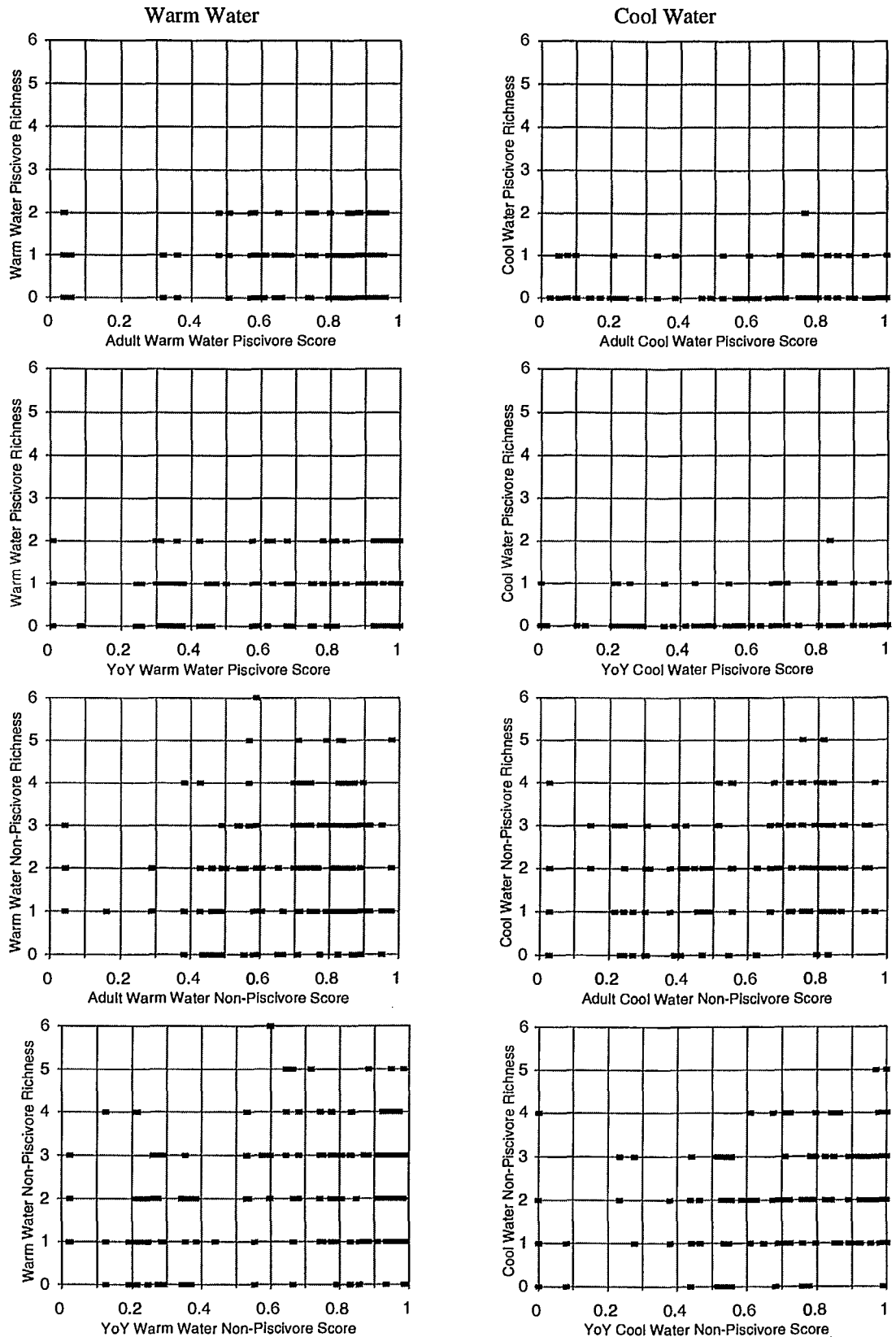
Warmwater	Coolwater	Coldwater
Non-piscivores	Non-piscivores	Non-piscivores
S319, Black crappie	S061, Alewife	S093, Lake herring
S314, Bluegill	S261, Banded killifish	S031, Lake sturgeon
S208, Bluntnose minnow	S169, Black redhorse	S091, Lake whitefish
S233, Brown bullhead	S199, Blackchin shiner	S162, Longnose sucker
S186, Carp	S200, Blacknose shiner	S381, Mottled sculpin
S141, Central mudminnow	S189, Brassy minnow	S014, Sea lamprey
S234, Channel catfish	S361, Brook silverside	S382, Slimy sculpin
S209, Fathead minnow	S281, Brook stickleback	S291, Trout-perch
S063, Gizzard Shad	S198, Common shiner	
S315, Longear sunfish	S212, Creek chub	
S206, Mimic shiner	S196, Emerald shiner	
S165, Northern hog sucker	S194, Golden shiner	
S313, Pumpkinseed	S338, Iowa darter	
S161, Quillback	S341, Johnny darter	
S311, Rock bass	S342, Logperch	
S204, Sand shiner	S182, Northern redbelly dace	
S203, Spotfin shiner	S121, Rainbow smelt	
S236, Tadpole madtom	S013, Silver lamprey	
S301, White perch	S201, Spottail shiner	
	S282, Threespine stickleback	
	S163, White sucker	
	S331, Yellow perch	
Piscivores	Piscivores	Piscivores
S051, Bowfin	S251, American eel	S080, Brook trout
S317, Largemouth bass	S041, Longnose gar	S078, Brown trout
S316, Smallmouth bass	S132, Muskellunge	S271, Burbot
S302, White bass	S131, Northern pike	S075, Chinook salmon
	S334, Walleye	S081, Lake trout
		S071, Pink salmon
		S076, Rainbow trout

Codes refer to the Ontario Ministry Of Natural Resources species coding scheme.

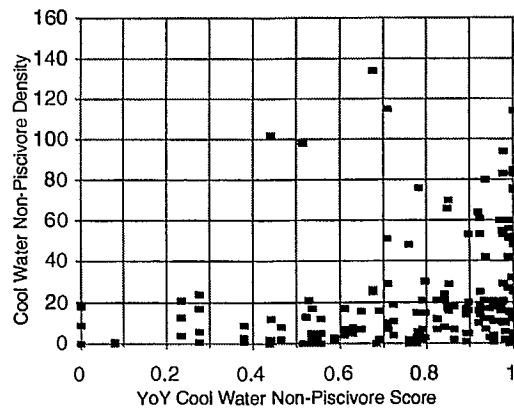
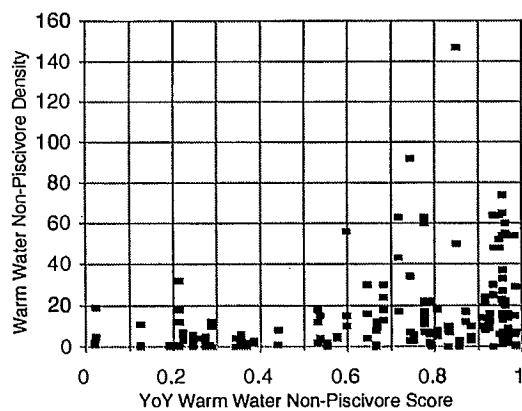
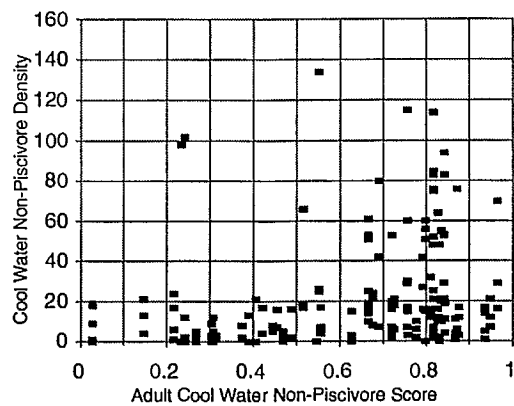
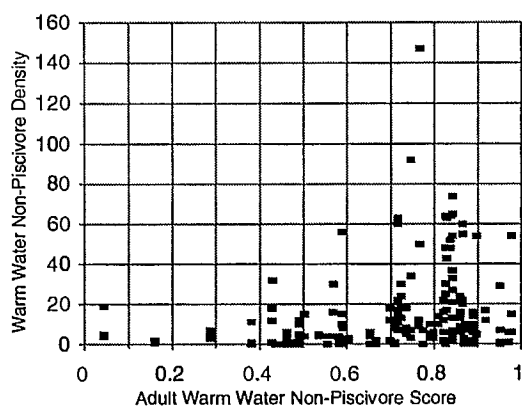
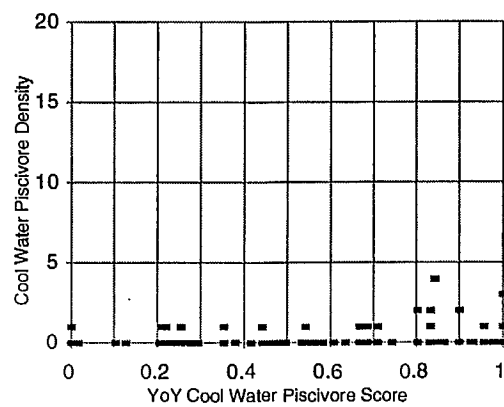
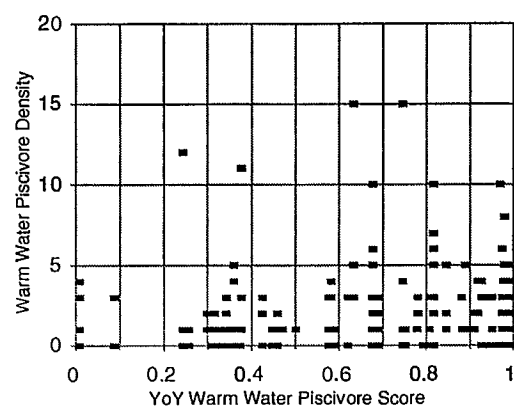
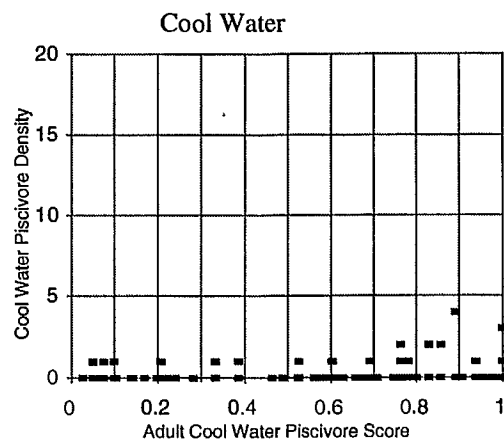
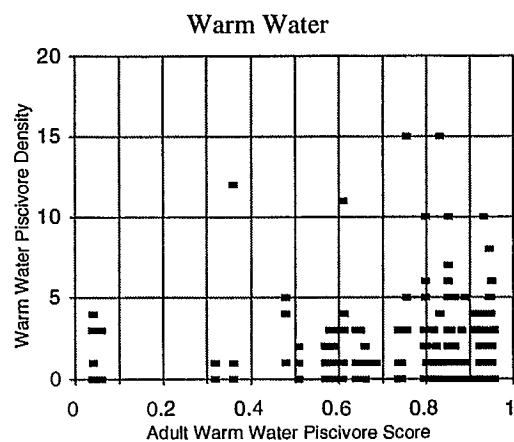
Appendix C

Plots showing the relationship between fish community measures (A - species richness, B - Density, and C - biomass per electrofishing transect sample) and Defensible Methods assessed littoral zone habitat suitability database indices for all combinations of thermal (warm-water and cool-water), trophic (piscivore and non-piscivore), and life stage (adult and YOY) in Severn Sound.

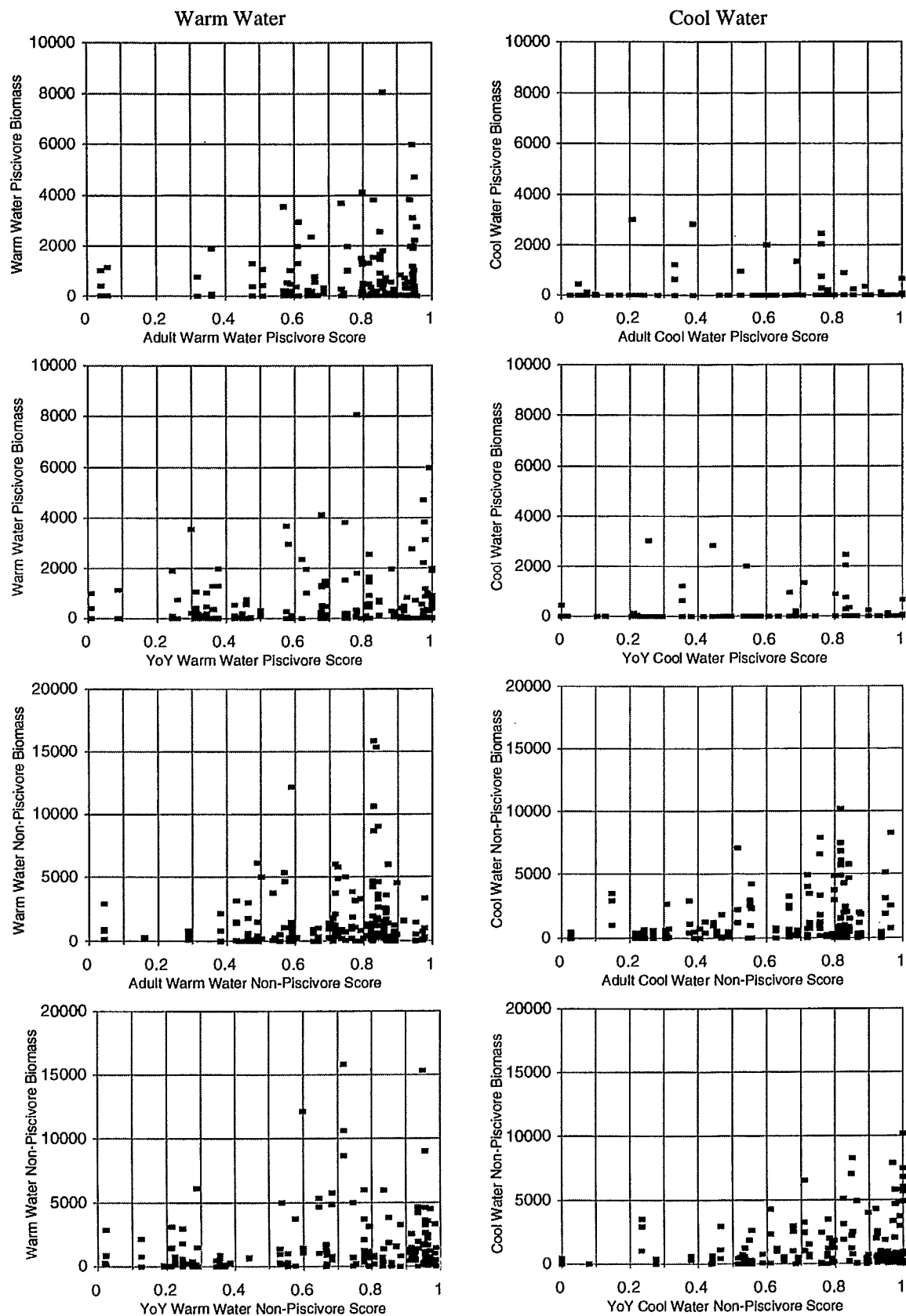
A) Species Richness (# species / transect)



B) Density (# fish / transect)



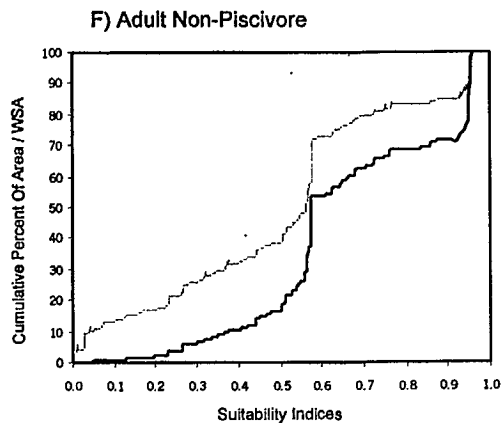
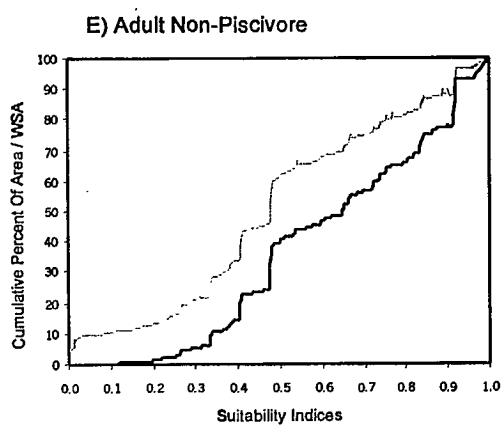
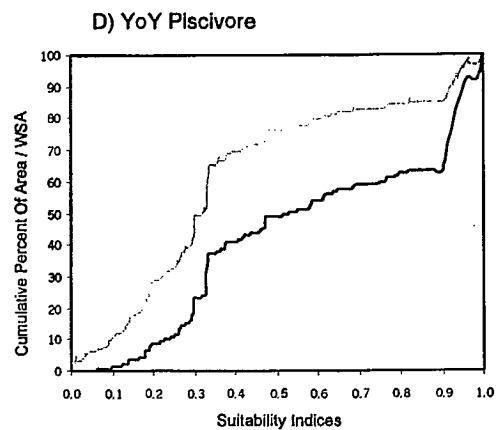
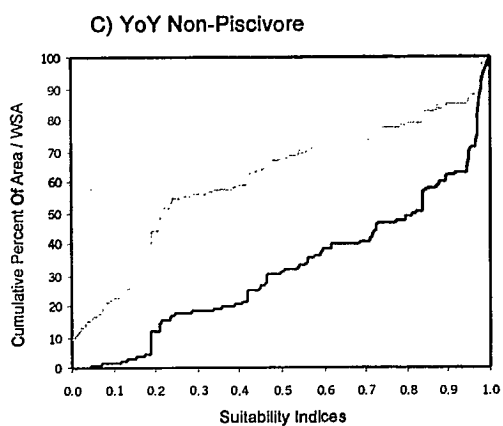
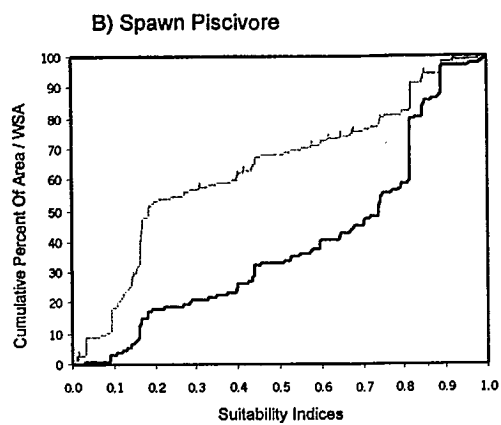
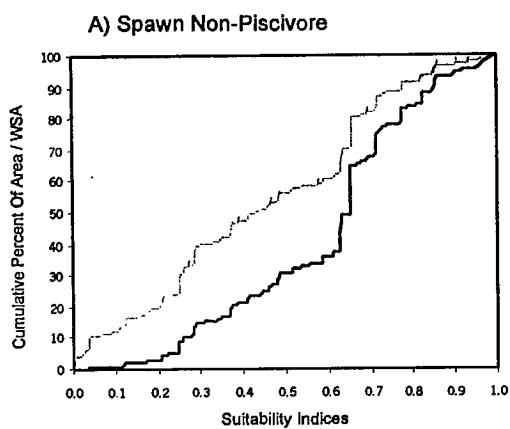
C) Biomass (gm / transect)



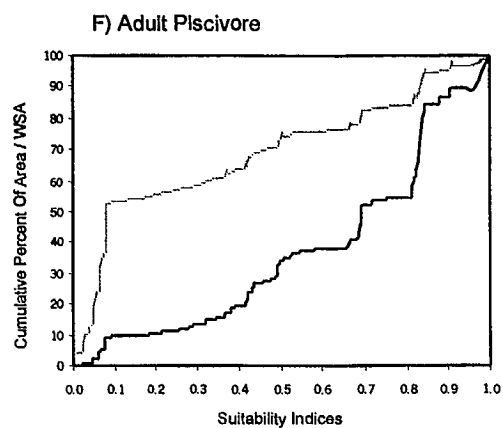
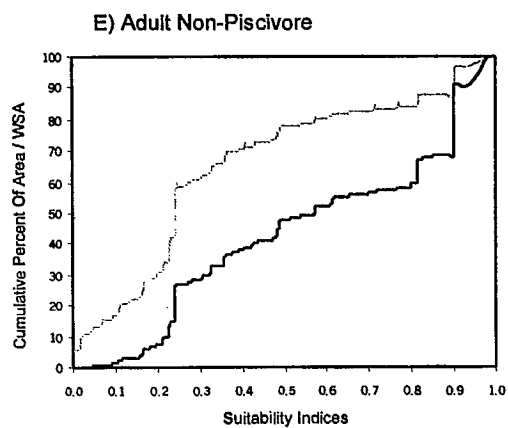
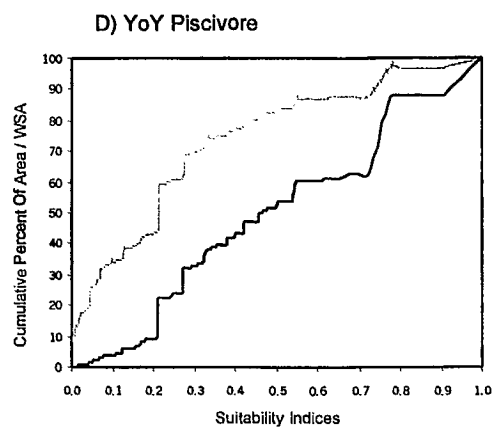
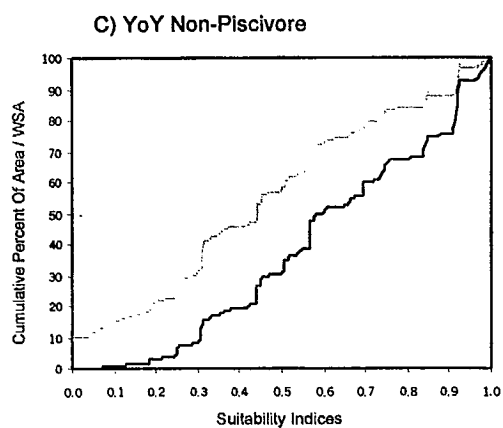
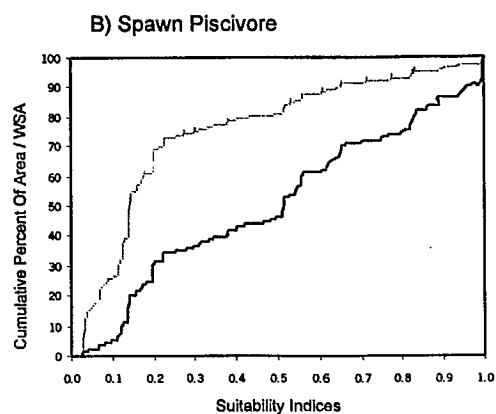
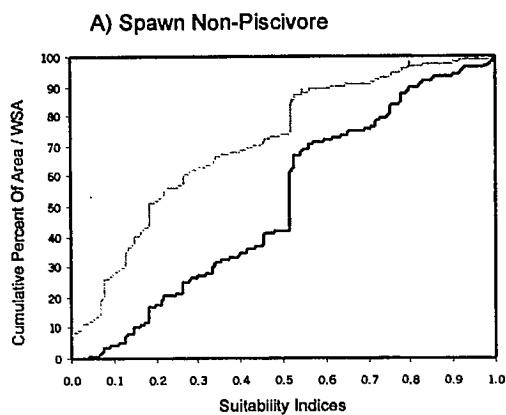
Appendix D

Graphs showing cumulative area (dashed line) and cumulative weighted suitable area – WSA (solid line) versus Severn Sound littoral zone habitat suitability database indices for 1) warmwater, 2) coolwater and 3) coldwater fish groups. Suitability is further categorised by life stage and trophic group. [See main text for explanation of the derivation and application of these graphs.]

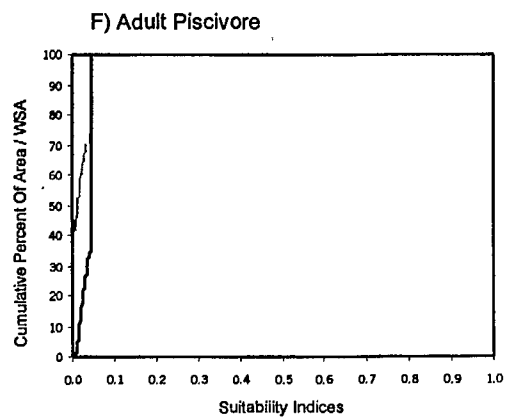
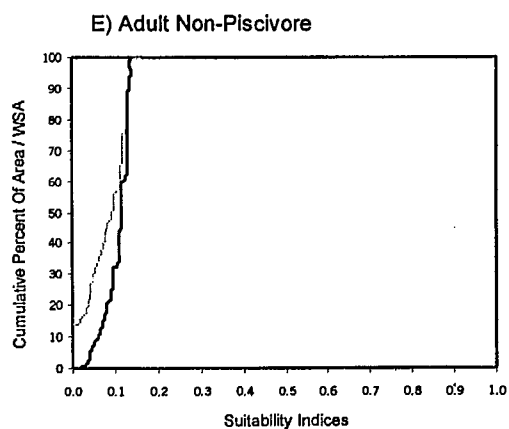
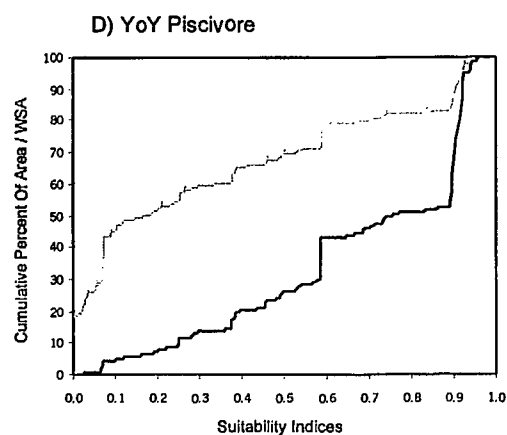
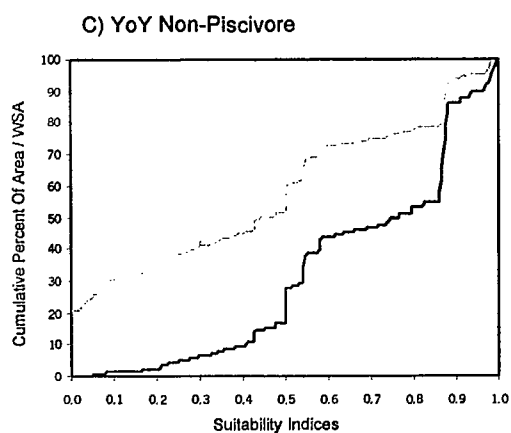
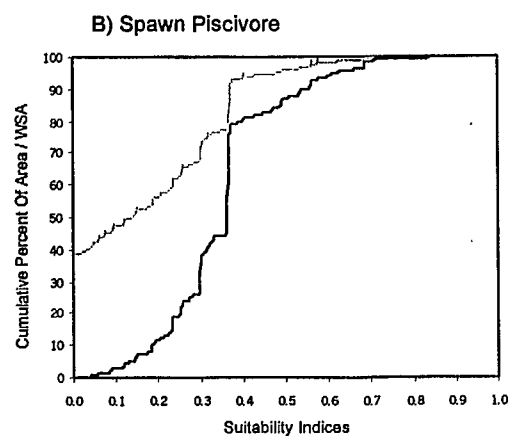
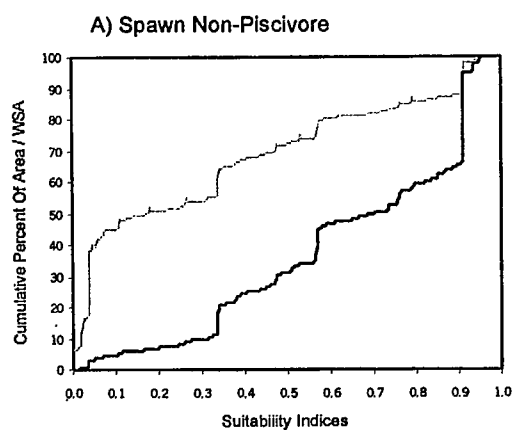
1. Warm Water Indices



2. Cool Water Indices



3. Cold Water Indices



Appendix E

Inductive Littoral Zone Habitat Classification Pseudocode.

The following corresponds to the field or attribute descriptions in the habitat suitability layer named *habsuit*, where:

CompSuit = Composite suitability index class

RareSuit = Rarity class

CR_Suit = CompSuit&Rarity class

CRW_Suit = CR_Suit&Wetland (P = Provincially Significant)

CRWE_Suit = CRW_Suit&Expert Knowledge (non null records)].

Inductive Classification Pseudocode

If CompSuit = "*High*" or RareSuit = "*Rare*"

Then CR_Suit = "*High*"

Else Then CR_Suit = CompSuit

If CR_Suit = "*High*" or Wetland_si = "*P*"

Then CRW_Suit = "*High*"

Else Then CRW_Suit = CR_Suit

If CRW_Suit = "*High*" or Expert_sui = "*Any field value*"

Then CRWE_Suit = "*High*"

Else Then CRWE_Suit = CRW_Suit

The CRWE_Suit attribute contains the final *High, Medium, Low* suitability classification.

These discrete categories are directly mapped to the final suitability coding *Red, Yellow,*

Green. The following pseudocode simply provides a mechanism to display the final suitability classes:

If CRWE_Suit = "*High*"

Then Final_Suit = "*Red*"

If CRWE_Suit = "*Medium*"

Then Final_Suit = "*Yellow*"

If CRWE_Suit = "*Low*"

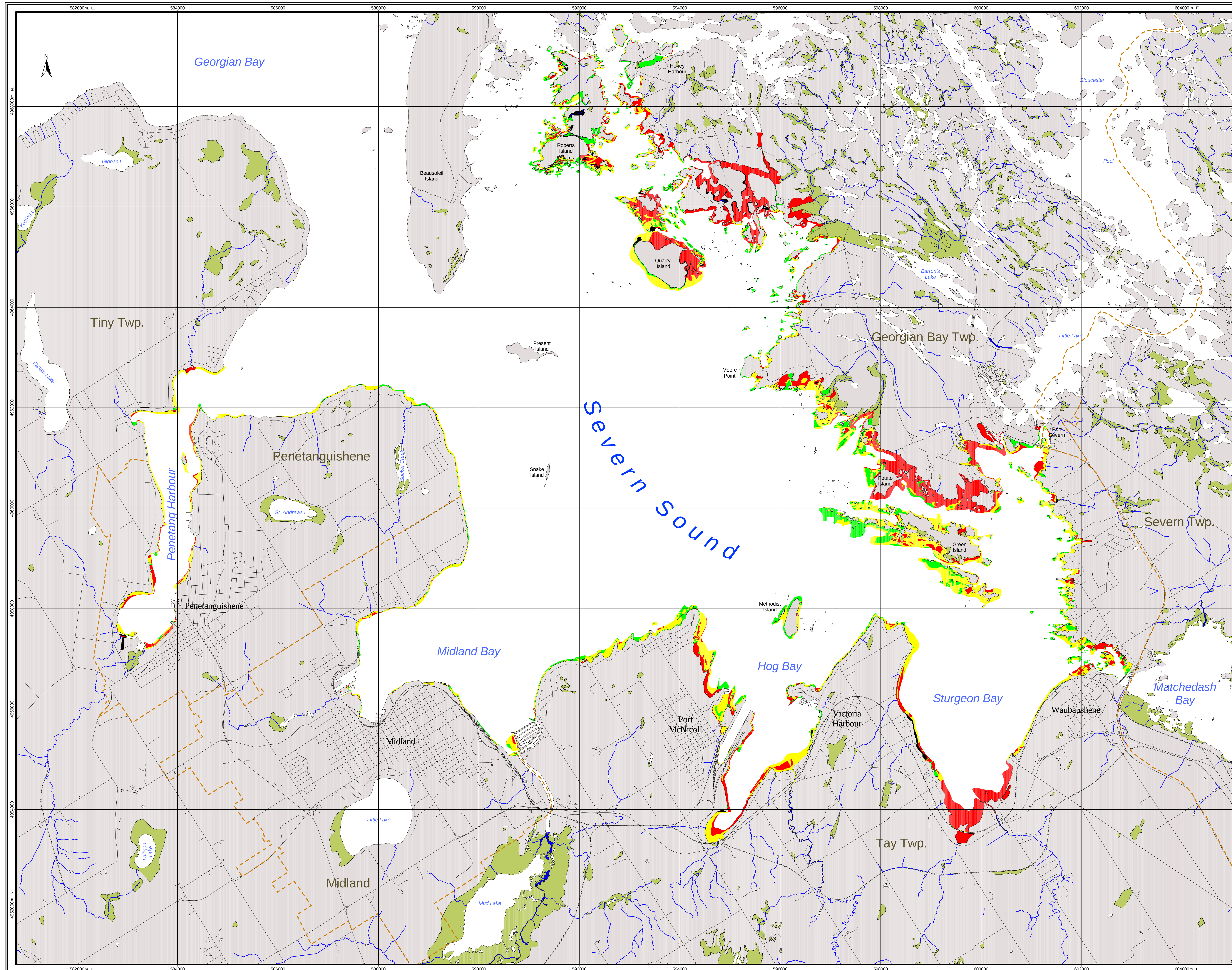
Then Final_Suit = "*Green*"

The following pseudocode decision captures wet zone areas not receiving a Composite Suitability rating but falling within a provincially significant wetland.

```
If Wetland_si = "P" and CompSuit <> ""  
Then Final_Suit = "Red"
```

Littoral Zone Fish Habitat Suitability

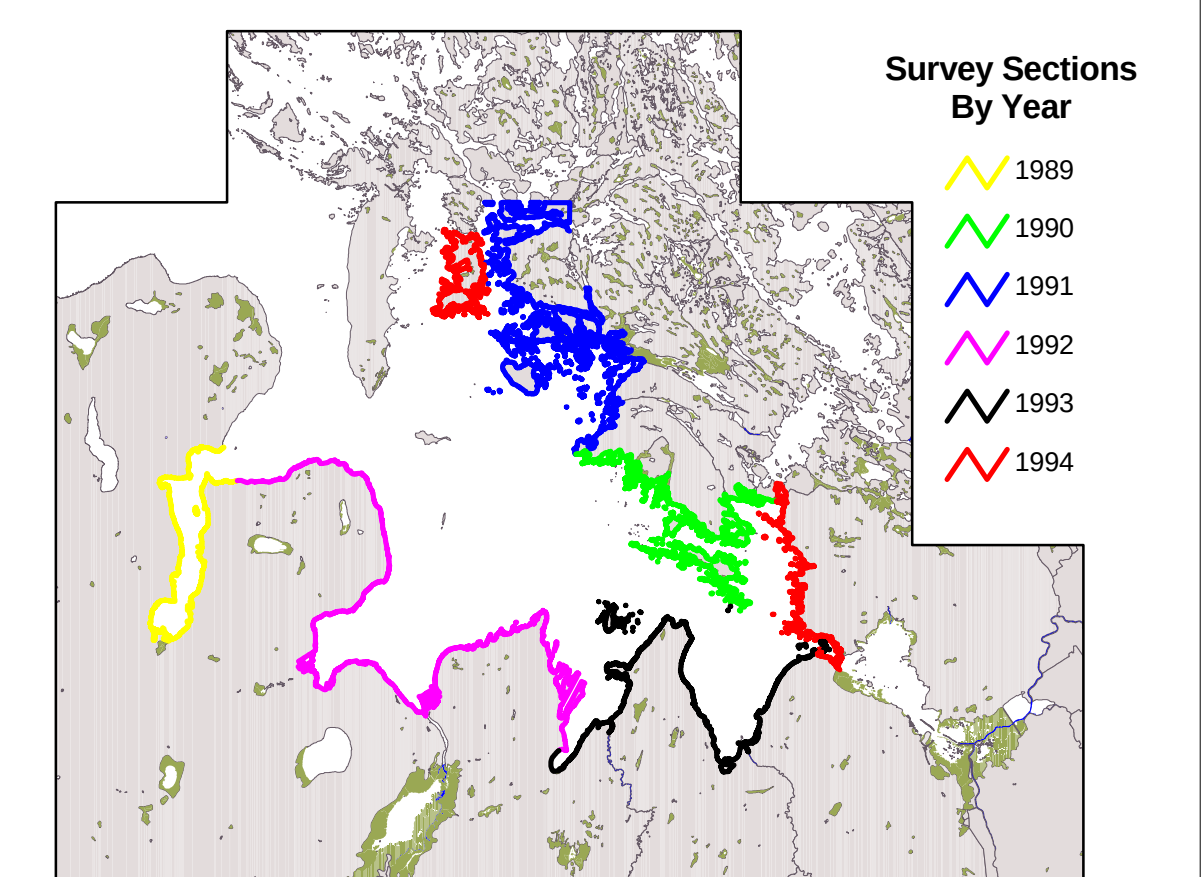
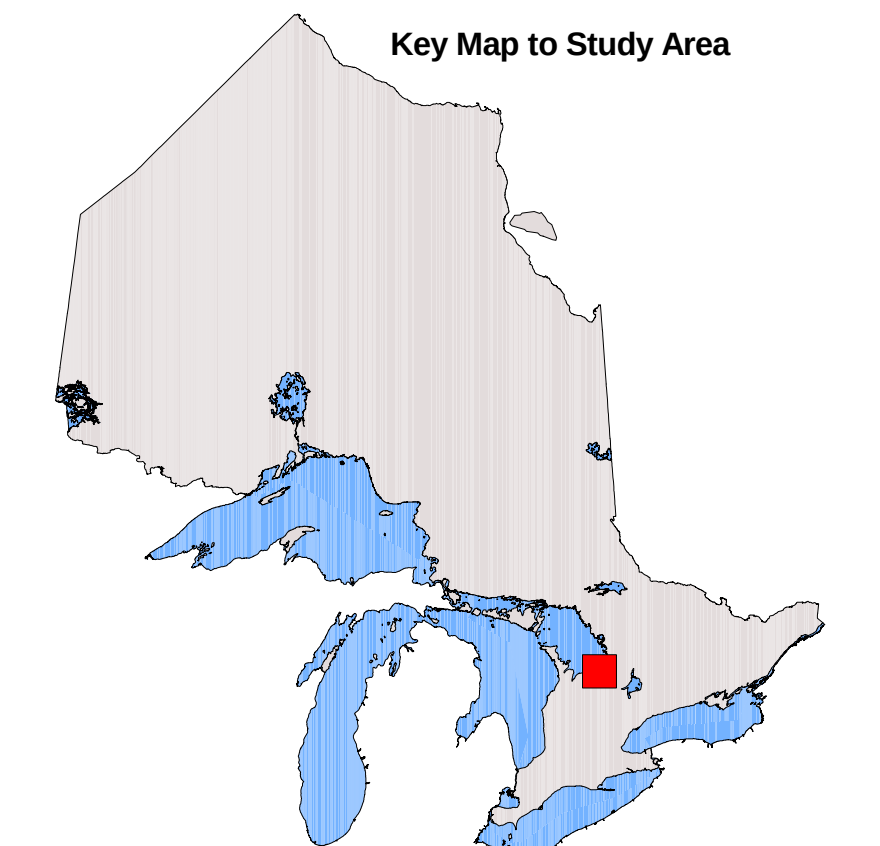
Severn Sound, Georgian Bay



Habitat Suitability Class For Fish Productivity

- High
- Medium
- Low
- Not Rated

- Road
- Rail Line
- Municipal Boundary
- River
- Land
- Water
- Marsh / Fen

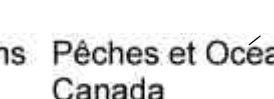


The preparation of this map was based on the methodology reported in the Development of a Fish Habitat Classification Model For Littoral Areas Of Severn Sound, Georgian Bay, A Great Lakes' Area of Concern, (Canadian Manuscript Report of Fisheries and Aquatic Sciences 2490)

This habitat suitability map is intended to be used in conjunction with the revised Fish Habitat Management Plan For Severn Sound, under agreement with the Severn Sound Environmental Association.

Map Source: Ontario Basic Mapping 1:10,000

Map production:
Peter Brunette, Baytech Environmental
August 1, 1999.



2 0 2 4 Kilometres

