HABITAT PREDICTORS OF FISH SPECIES OCCURRENCE AND ABUNDANCE IN NEARSHORE AREAS OF SEVERN SOUND.

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by

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ABSTRACT

R.G. Randall, C.K. Minns, V.W. Cairns, J.E. Moore and B. Valere. 1998. Habitat predictors of fish species occurrence and abundance in nearshore areas of Severn Sound. Can. Manuscr. Rep. Fish. Aquat. Sci. 2440: vii+30 p.

The occurrence of fish species in nearshore areas of Severn Sound, Georgian Bay, is predictable from local habitat features. Discriminant function and classification analysis indicated that sampling sites could be classified into two groups, where individual fish species were present or absent, based on habitat attributes, including substrate, cover (submerged vegetation) and fetch. The classification success rate was significantly greater than that expected by chance alone. Habitats where individual species of fish were found were usually consistent with expectations of habitat requirements from the literature. Most fish species captured in the survey of five embayment areas of Severn Sound (236 samples with a total of 34 species and 8862 fish) prefer cool or warm waters, and highest species richness and fish densities occurred where substrates were fine, abundance of submerged macrophytes was high, and fetch (wind exposure) was low. Transect samples could also be classified into two or three fish density groups (e.g., low, medium and high fish densities) based on the habitat discriminators; the classification success rate was good for two groups (>70%) but only moderate for three groups (64%). These results are consistent with the hypothesis that habitat suitability and fish use of nearshore areas can be estimated using physical habitat indicators and area wide habitat inventories. Knowledge of fish-habitat links, after further field validation, will be useful for refining a fish habitat management plan for the Severn Sound region.

RÉSUMÉ

L'occurrence de certaines espèces de poissons dans les eaux littorales du passage Severn, dans la baie Georgienne, peut être prédite d'après les caractéristiques locales de l'habitat. L'analyse par fonction discriminante et classification indique que les sites d'échantillonnage peuvent se répartir en deux groupes selon la présence ou l'absence d'une espèce de poisson, à partir les attributs de l'habitat, notamment le substrat, le couvert (végétation immergée) et le fetch. Le taux de réussite de la classification était nettement supérieur au résultat prévisible par simple hasard. Les habitats où ont été observées les diverses espèces correspondaient généralement aux prévisions des besoins selon la littérature. La plupart des espèces capturées dans le relevé de cinq anses du passage Severn (236 échantillons, soit 34 espèces et 8 862 poissons) préfèrent les eaux tempérées ou chaudes, et on a retrouvé la plus grande richesse spécifique et les densités les plus fortes aux endroits où les substrats étaient fins, l'abondance des macrophytes immergées était forte, et le fetch (exposition au vent) était faible. Les échantillons sur transect ont aussi pu être répartis en deux ou trois groupes de densité (densité faible, moyenne ou forte) à partir des facteurs discriminants de l'habitat; le taux de succès de la classification était bon pour deux groupes (> 70 %), mais seulement modéré pour les trois groupes (64 %). Ces résultats concordent avec l'hypothèse selon laquelle il est possible d'estimer l'adéquation de l'habitat et l'utilisation par les poissons des eaux littorales à l'aide d'indicateurs physiques de l'habitat et d'inventaires de l'habitat à l'échelle de la zone. Les connaissances sur les liens poisson-habitat, après validation complémentaire sur le terrain, seront utiles pour la mise au point détaillée d'un plan de gestion de l'habitat du poisson pour la région du passage Severn.

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INTRODUCTION

Understanding the links between different microhabitats and fish utilization and productivity is a necessary and important prerequisite for the effective management and conservation of habitats in littoral areas of the Great Lakes. The productive capacity of nearshore habitats must be estimated to evaluate the potential impacts of proposed shoreline alterations on littoral fish assemblages, and to provide guidelines for conservation. Productive capacity has both quantitative (fish production) and qualitative (species composition, diversity) components (Minns 1995; Minns et al. 1996; Jones et al. 1996). Estimation of the productive capacity of habitats can be made by direct measurement of production, by measurement of biological indices of productivity (e.g. presence-absence, biomass), or by using habitat features as surrogates of productivity (Minns et al. 1995). Often the third option is desirable when large areas are involved, or when specific details of fish habitat use in an area are not available. Using habitat features as surrogates of productivity in nearshore areas of the Great Lakes, however, requires field validation.

Randall et al. (1996) investigated links between fish assemblage measures (species richness, density, biomass) and habitat variables, using data collected in 1990 from Hamilton Harbour and Bay of Quinte, Lake Ontario and from Severn Sound, Georgian Bay. Randall et al. (1996) found that the fish assemblage measures could be predicated, using multiple regression, from habitat attributes, including cover (macrophyte density), littoral slope and site exposure (fetch). Coefficients of determination of the regression models were usually ≤ 0.50. The fish communities differed among regions: species richness for example was lower at Hamilton Harbour than at the other two locations (Randall et al. 1996).

Coefficients of determination of about 0.50 indicate a power of resolution of 2 groups (Prairie 1996). Power of resolution is described by Prairie (1996) as being the number of classes or categories that a dependent variable can be divided into so that predictions among each class are different from one another. The larger the number of classes (finer resolution), the greater the predictive utility of the model. Clearly, the predictive power of the fish-habitat regression models (Randall et al. 1996) was only moderate.

This study is a further test of the hypothesis that field measures of habitat attributes can be used to predict the occurrence fish species in nearshore areas of the Great Lakes. Data from Severn Sound only are considered in this study; information on fish-habitat associations in Severn Sound is of current interest because of the need to refine a fish habitat management plan for this region (Severn Sound RAP 1993). Specifically, we investigated: 1. if habitat features could be used to predict the presence or absence of individual fish species; 2. if the same habitat attributes used by Randall et al. (1996) could be used to predict fish assemblage measures (richness, density) in Severn Sound, a more localized area than that considered by Randall et al.; and finally, 3. confirm the accuracy or power of resolution which can be expected in making inferences about fish occurrence from habitat indicators. To provide further contrasts in the types of habitats surveyed, the original data collected from the south shore (sedimentary rock) of Severn Sound in 1990 (Randall et al. 1993; 1996) were supplemented in 1992 with samples from sites exposed to high wind fetch, and in 1995 with samples from the north shore (precambrian rock).

METHODS

Study area: Severn Sound (127 km^2) is located in the southeastern region of Georgian Bay, Lake Huron, Ontario. Severn Sound was designated as an 'Area of Concern' (Hartig and Thomas 1988), because of elevated phosphorus levels in Penetang and Midland bays. In addition to water quality concerns, nearshore areas have been altered at some locations because of municipal development, marina construction and shoreline hardening. Loss or degradation of wetlands and nearshore habitats has prompted the development of an interim fish habitat management plan for the area, to conserve the remaining habitats and to promote restoration in areas that have been degraded (Severn Sound RAP 1993).

Fish and habitat data were collected from five areas of Severn Sound: Penetang, Hog, Sturgeon and Matchedash bays on the south shore, and in the vicinity of Green Island

and Severn Sound on the north shore (Fig. 1). The south and north shores are different geologically: the south shore is sedimentary, while the north shore is precambrian rock of the Canadian Shield. General descriptions of the geography , physical characteristics, and nature of the aquatic habitat of Severn Sound were provided by Severn Sound RAP (1993).

Fish surveys: Information on fish assemblages in nearshore areas of Severn Sound was collected in 1990, 1992 and 1995. Fish surveys, using a 6.1 m electrofishing boat, were conducted in the five areas described above. Electrofishing was conducted at 1.5 m depth, along 100 m transects parallel to the shore. Transects were sampled between June and October. In total, 236 samples were collected from 85 transects; transects were sampled from 2 to 5 times. The number of transects (and number of samples from repeat sampling) by area were: Penetang - 35 (96); Hog - 17(52); Sturgeon - 12(23); Matchedash - 12(38) and Green Island 9(27). Sampling chronology, the number of samples per transect, and survey objectives were described by Valere (1996). Information was recorded on species richness (SR, number of species per transect), number of fish collected (D, number per transect), and biomass (B, total g of fish per transect). Average fish size (g) per transect was calculated as B/D.

Habitat information: Macrophyte density was estimated at all transects by estimation of the percent bottom cover. In 1990, the percent cover was estimated at a subset (36) of the transects surveyed by visual estimates from above the water surface (Minns et al. 1993). Percent cover was correlated with stem density and stem height as measured by diving surveys at these transects (Minns et al. 1993). In 1992 and 1995, percent cover of the remaining transects (49) was estimated from echo sounding traces. Echograms from the 100 m transects were divided into 10 equal segments, and % bottom cover was estimated for each segment separately and averaged (after arcsine transformation). The presence and abundance of vegetation was confirmed by visual observations of percent bottom cover and plant species composition at the transects. Echogram and visual estimates of percent cover were correlated at these sites (B. Valere, pers. observ.). Echograms allowed estimates to be made at locations where water clarity was less than 1.5 m, where visual estimates were not possible.

Substrate was classified as: silt (<0.063 mm), sand (0.063 to < 2 mm), gravel (2 mm to < 16 mm), and rock (> 16 mm). Categories were assigned based on samples from an Ekman dredge (fine sediments), or by visual estimates (gravel or coarser). For the 1990 surveys, Ekman samples were collected at 6 locations per transect (26 transects, details provided in Randall et al. 1996). For substrate samples in later years (1992 and 1995, 59 transects), only two samples per transect were collected. Substrates were converted to a Phi scale according to Hakanson and Jansson (1983) as follows: silt = 6.5, sand = 2, gravel = -3.5 and rock = -6.0.

Exposure characteristics of the transect locations were measured from maps. Transect locations were marked on hydrographic charts, and shorelines and transects were digitised. Distances from transects to shore were measured for 16 compass points (i.e., 22.5 degree intervals). Three fetch-related variables were used in the analysis: 1. The minimum distance (m) from the transect to the shore. This also provided a measure of littoral slope since all transects were at the 1.5 m depth contour. Distance to shore was also measured in the field at a subset of the transects ($n = 36$), and compared to the distances as estimated from the maps. 2. Average fetch was the average over-water distance for the 16 compass directions from the transect to a shoreline. Average fetch was a measure of the openness or exposure (to wind effects) at the transect sampling location. Average fetch was highly correlated ($r = 0.91$, $p<0.01$) with maximum fetch (maximum over-water distance from the transect to a shoreline) and therefore maximum fetch was not used in the analysis, to reduce redundancy. 3. Effective fetch was based on the prevailing wind direction. Effective fetch (FETCH, km) was calculated for angles (θ) -45° to +45° at 22.5 degree intervals relative to the prevailing wind direction using a formula provided by Scheffer et al. (1992): $FETCH = sum(\cos(\theta)*F(\theta))/sum(\cos(\theta))$, where θ = angle to prevailing wind and F = distance along direction in km. A prevailing wind direction of southwest was used for all areas (Saulesleja 1986; see also Randall et al. 1996).

Surface water temperature was recorded for many transects. For a number of transects, where water temperature was not recorded at the time of electrofishing, temperatures were estimated as the average for that area and date. For specific areas and dates, temperatures usually varied less than 2 $^{\circ}$C among the different transect locations. For example, the range in temperature among 16 transects in Penetang Bay during June 1990 was 14 to 16 °C, with an average 15.5 °C. Remaining transects sampled in June (10) were assigned a temperature of 15.5 °C.

In summary, for each sampling date, data were recorded by transect for the following variables: fish number, biomass and number of species and water temperature. The following habitat variables were recorded only once for each transect: substrate, percent bottom cover by submerged macrophytes, distance from shore, average fetch, and effective fetch. Therefore, pseudo-replication (the same transects were surveyed more than once on different dates) applied to the habitat data set.

Statistical analyses: Correlation matrices were examined to identify relationships among the habitat variables. Pearson correlation coefficients were tested for significance ($p<0.05$) after Bonferonni adjustment for multiple comparisons (Systat 1996); habitat and fish variables were transformed. Scatterplot matrices were examined to detect non-linear relationships. Discriminant analysis was used to analyse data both for individual fish species, and for fish assemblages. For individual species, habitat variables were used to discriminate two groups: transects where species were absent or present. A second discriminant analysis was done on individual species but with three groups, absent, low, and high densities, where present. For fish assemblage data, four attributes were examined, species richness (number of species per transect), fish numbers, biomass and mean fish size. Fish measures were divided into 2 or 3 groups or classes (intervals), with the aim of achieving approximately equal sample sizes in each group.

Discriminant analyses were performed to determine if the habitat variables could separate the fish groups. A quadratic discriminant model was used (Wilkinson et al. 1996), since preliminary analysis indicated that the assumption of equality of covariance matrices was not met (Chi square test, $P<0.001$). For the discriminate analysis, Wilk's lambda was used as the multivariate analysis of variance statistic to test for equality of group means for the variables in the discriminant functions. Wilk's lambda statistic varies between 0 and 1, with smaller values denoting greater likelihood of significant differences among groups. Classification tables were examined to determine the classification success rate. Cohen's Kappa statistic was used to test if the number of cases (transect samples) successfully classified were significantly greater than that expected from chance alone (Titus et al. 1984). Kappa varies between 0 and 1; the asymptotic standard error of kappa can be used to construct a t statistic to test if kappa differs from 0 (Wilkinson 1996). The kappa test was important because samples sizes among groups were often unequal, particularly for the presence-absence data. Cross validation was also used to further test the classification success rate. For cross validation, about 65% of the cases were chosen randomly, discriminant analysis was performed, and the remaining 35% of cases were classified using the same discriminant model. Classification success of the test cases provided a further indication of predictive power.

Species presence-absence data were examined by cluster analysis. Bray-Curtis similarity indices (Systat 1996) were calculated by comparing the species data across transects, and fish species were then clustered using the similarity coefficients.

RESULTS

General features of the habitat data: Many of the survey transects occurred in areas with submerged macrophytes and fine substrates. The median percent bottom cover by macrophytes was 80% and the median substrate was 4.9 phi units, which corresponded to a silty-sand particle size. *Vallisneria*, *Myriophyllum*, *Elodea* and *Potamogeton* spp. were the dominant genera at all locations, but the relative composition and abundance varied from bay to bay (see also Minns et al. 1993). Medians and ranges of % cover, substrate size and other habitat variables are provided in Table 1.

Transects were located 8 to 373 metres from shore (Table 1). The greater distances occurred where the water was shallow, or where emergent vegetation extended a considerable distance offshore (e.g., Matchedash and Sturgeon bays). Field measures of distance to shore at a subset of the sites were correlated with map estimates ($r = 0.65$; $n=35$, $p<0.001$). Average and range of field and map measures respectively were: field 44.4 m (2 - 177m); map 47.6 m (8 - 132m), n = 35 transects. Average fetch ranged between 0.2 and 2.8 km, and effective fetch between 0.01 and 1.8 km. The surveys were conducted mainly in June, July and August (ranging from early June to early October). Surface water temperatures ranged between 12.2 and 27.0 °C.

A correlation matrix of the habitat attributes measured at transects in August showed that several of the habitat attributes were correlated (Table 2). Macrophyte density was positively correlated with substrate and negatively correlated with average fetch; abundant submerged macrophytes occurred where the substrate particle size was fine (sand or silt) and average fetch was low (usually < 2 km, Fig. 2). Distance to shore was positively correlated with mean fetch and effective fetch ($P < 0.05$). Water temperature was negatively correlated with both mean fetch and distance to shore.

Principal component analysis of the habitat variables provided further information on the structure of the habitat and environmental data. Two components had eigenvalues > 1, and explained about 60% of the variance in the data set, after varimax rotation (Table 3). The first component was related to site exposure, with distance from shore, average fetch and effective fetch all loading positively. In contrast, water temperature loaded negatively on Component 1. Component 2 was related to cover, with both % cover of submerged vegetation and substrate loading positively. Sampling date also loaded positively on Component 2, and effective fetch loaded negatively.

Fish species occurrence and habitat: Thirty-four species of fish were captured in the 236 transect samples (Table 4), with a total catch of 8,862 fish. No fish were captured in 11 samples. Eighteen of the species of fish were rare in the samples, comprising less than 1% of the total catch. The median number of fish captured per transect was 24 (range 0-170), median biomass was 2.5 kg (0-34.8 kg), and the median richness was 5.0 species per transect (0-12 species). Median fish size at transects was 95.3 g. Few juveniles (age 0 fish) were caught in the surveys, as most of the sampling occurred during summer, when juvenile fish were too small to be vulnerable to the electrofishing gear.

All three fish assemblage measures (numbers, biomass and richness) were positively correlated with substrate (phi), and macrophyte abundance, and were negatively correlated with average fetch (Table 2). The highest correlations, in decreasing order, were with average fetch, macrophytes, and substrate; scatterplots of these habitat features and fish density and richness showed high variance but discernible trends (Fig. 3).

The occurrence of individual fish species at transects was related to habitat features. Discriminant analysis using two fish groups - present or absent - indicated that species occurrence could be predicted from the habitat attributes at the transect sites. Only the 15 common species of fish, which were present in at least 10% of the samples (n=> 23) were used in the analysis. The percent of transects correctly classified for the presence of fish species using the habitat discriminators ranged from 60 to 79% depending on species (Table 5). The multivariate Wilks lambda statistic was significant for all species except *Alosa pseudoharengus*, *Notropis hudsonius,* and *Cyprinus carpio* (species codes S61, S201, and S186, Table 5). The kappa statistics were also significant, indicating that the classification success rate was significantly greater than would be expected from chance alone, after adjustment for unequal sample sizes between the two groups.

Univariate F statistics were used to test for the habitat variables which differed between the two groups. Macrophyte abundance, substrate size, and average fetch were the most frequently identified habitat indicators (Table 6). Water temperature did not differ significantly between the present-absent groups for any of the fish species.

The relationship between the habitat attributes and the presence of individual fish species (positive or negative correlation) was usually consistent with the expected habitat preferences (Table 6). A large number of the species (e.g. *Lepomis gibbosus*, *Micropterus salmoides*) occurred in similar habitats - areas with high percent cover, fine sediments and low fetch, in agreement with the general habitat preferences for these species as described by Lane et al. (1995). The consistency between the field observations and expected habitat preferences was illustrated by contrasting *Micropterus dolomieu* and *M. salmoides.* Largemouth bass was found in areas with fine substrate and high submerged vegetation cover, and the opposite was true for smallmouth bass, as expected from the literature (Table 6).

Cluster analysis indicated one group of 6 species that was nested together, against the background of the other species in the assemblage (Fig. 4). The six species occurred in similar habitats (high cover, fine substrate, low fetch; Table 6), and comprised a majority of the fish catch (81% of the total catch in numbers). Other species clustered at varying distances from group 1. Smallmouth bass (S316), which had the clearest contrast in habitat requirements (Table 6), clustered at the furthest distance from group 1.

Classification success, when three rather than two groups were used, ranged between 54 and 68% (Table 7). Ten fish species were used in the analysis (species where the sample size where present equalled or exceeded 40). Wilks lambda and Cohens kappa statistics were significant for nine of the ten species (Table 7).

Results of the discriminant analysis for the four fish assemblage variables tested, species richness, density, biomass and fish size, were similar. The classification success rate was reasonably high (70 to 80 %) for two groups, but lower for three groups (59 to 64%) (Table 8). In all cases, the multivariate Wilks statistics and Cohen's kappa statistics were significant. For the three fish groups, the classification success was higher for the extreme groups (low and high density) than for the intermediate group (Table 8). Cross validation indicated a lower classification success rate, but confirmed that classification success was sometimes higher for extreme groups. The highest fish densities occurred where the substrate particle size was fine, submerged macrophytes were abundant, and mean fetch was low (Fig. 5). Results for fish biomass and species richness (not illustrated) were similar.

DISCUSSION

Habitat Indicators of Fish Species Occurrence

The results of this study are consistent with the hypothesis that habitat features in the nearshore areas of Severn Sound can be used to predict the presence or absence of individual fish species. In the absence of fish data, habitat surrogates can be used to make inferences about species occurrence, both for individual fish species and collectively as a measure of fish species richness and density. First order estimates of fish habitat suitability of different nearshore regions can be made from habitat inventories, although there are limits to accuracy, as will be discussed in the next section.

To be useful, habitat inventories must include the measurement of physical attributes that are both good indicators of fish occurrence or abundance and are also readily 'mappable'. Minns et al. (1995) developed a method (Defensible Methods) for assessing the productive capacity of habitat in nearshore areas of the Great Lakes before and after habitat alteration. Habitat was characterized and mapped with respect to water depth, substrate and cover (including macrophytes). Habitat characteristics were linked to fish species utilization based on literature information of the habitat requirements of the individual species (see, for example, Lane et al. 1996). Our field data from Severn Sound provided field confirmation that substrate and cover (macrophytes) were important indicators of fish species occurrence. Habitat conditions where individual species were found were consistent with expectations of habitat preferences from the literature. Because all of our samples were collected at the 1.5 m depth contour, we could not test for the effect of depth on species occurrence or abundance. However, in addition to substrate and macrophytes, we also found other habitat indicators that were correlated with species occurrence, including average fetch and distance from shore or littoral slope. These results are consistent with an earlier study, which included data from Lake Ontario as well as Severn Sound (Randall et al. 1996). This study was important in showing that the habitat indicators could be applied to individual species, and they were applicable to Severn Sound, a more localized area than that used by Randall et al. (1996).

Incorporating a measure of fetch as a habitat indicator of species occurrence has merit. Average fetch, a measure of site exposure, probably has both direct and indirect affects on fish. As an indirect effect, fetch can influence the distribution of macrophytes which can in turn affect the distribution of fish (discussed by Randall et al. 1996). But there is evidence that fetch also has a direct effect on fish distribution, independent of any plant interactions. Using stepwise regression analysis to predict fish species richness or density, Randall et al. (1996) found that fetch variables remained in the regression models, even if macrophyte density was already included. Similarly, a preliminary examination of stepwise modeling to identify the important habitat variables used in the discriminant analysis (Table 6) indicated that both % cover and fetch were important predictors of fish presence-absence (group classification). Links between fetch and fish distribution are not well understood. Fetch is related to physical energy (water movement, wave energy, turnover) which fish may respond to (Randall et al. 1996). In a marine context, Hakanson (1990) used fetch as an indicator of productive capacity in a conceptual model to estimate fishery biological value in a coastal area of Sweden. Fetch can be estimated for any shoreline area from map data. In the Great Lakes, examining the influence of fetch on fish distributions and productivity , in a cause and effect context , should be a research priority.

Water temperature was not a good predictor in our study, but it was highly correlated with fetch and sampling date, both of which were indicators of species occurrence. Temperature will likely be a better predictor of fish distribution, when open lake, cool or cold water habitats, are compared to warm embayments (RGR and BV; personal observation). We used date in our analysis to help explain variability in our data, but it is not useful for defining fish-habitat linkages on a routine bases. Date was used in our analysis because the data were collected seasonally, and habitat use is temporally dynamic. Distance from shore (or conversely, littoral slope), and effective fetch were also important indicators for some species, but both were correlated with average fetch. Average fetch was more highly correlated to the fish measures at Severn Sound than minimum, maximum or effective fetch, and was a more consistent indicator of species occurrence or density.

Most of the fish captured at Severn Sound were cool or warmwater species which are usually associated with littoral habitats, often with submerged macrophytes, in embayments in the Great Lakes. Using correspondence analysis, Jude and Pappas (1992) assigned species of fish in the Great Lakes to one of three species associations or taxocenes: an upper Great Lakes and Lake Ontario open water complex, a coastal marshes complex and an intermediate complex associated with large bays and estuaries which utilize habitats of the the Great Lakes and wetlands. Not surprisingly, the 16 common species of fish captured in the nearshore areas of Severn Sound belonged to the latter two groups, with 8 species in each of the wetland and intermediate complexes. Most of the common species captured (15 of 16 species) in our survey have also been captured in larval fish surveys (Leslie and Timmins 1994 and 1995), indicating that these species spawn in the Severn Sound area. Many of the Severn Sound species use shallow water (< 5 m), fine substrate, and aquatic vegetation for cover (Table 6). Proximity to cover was a factor which probably affected the fish community at all sites. Low macrophyte areas could be considered to be 'spill-over' habitats, that supported similar species of fish to the vegetated areas, but at lower densities. Most of the species were associated with aquatic vegetation or cover at some time during their life history.

Habitat use of macrophyte areas by fishes is variable, and depends on the composition of the fish community, and the geographic scale and area being considered

(Killgore et al. 1993). Relationships between fish density and vegetation abundance in an inland lake or reservoir, which is heavily vegetated for much of the littoral zone, may be different from large lakes, where macrophytes grow and provide patchy nearshore habitat in protected embayments only. In the Severn Sound study area, all of the bays were contiguous with the large Georgian Bay and Lake Huron ecosystem. Fish species richness in these Great Lakes nearshore habitats (this study) is higher than in the inland lakes of Ontario (Minns 1989). The important habitat indicators in this study, including vegetation cover, apply to this species rich fish community in the littoral zone of Severn Sound, but they may not apply universally, without refinement, to inland vegetated littoral habitats.

Habitat Indicators and Power of Resolution

Using discriminant analysis to classify the transect samples into two groups, species presence-absence, has limitations. With field sampling, unequal sample sizes will occur for most species and, as Titus et al. (1984) point out, it becomes increasingly difficult to demonstrate significant discrimination power when the sample size for one group (e.g., proportion of transects where the species is absent) becomes predominant. Classification into the predominant group by chance alone is greater than 50%. Despite unequal sample sizes and the associated limitations, the chance-corrected Kappa statistics were significant for most of the species tested. Given the conservative nature of the test, these results suggest that the habitat indicators were robust discriminators, providing support from field observations for the contention that inferences can made about fish species occurrence on the basis of habitat indicators.

All four of the fish assemblage measures considered in this study are important, because together they are the key components of production, and provide a surrogate measure of productive capacity (Randall et al. 1996). The degree of resolution for predicting fish assemblage measures (e.g., fish density) using habitat information was only moderate. Individual sampling sites could be assigned to one of two categories (low, high) of fish abundance or species richness with reasonable accuracy (>70%), and into 3 groups (low, medium, high) with lower accuracy. The results of the discriminant analyses, and the moderate degree of resolution, were consistent with the results of regression analysis using the same habitat variables in an earlier study (Randall et al. 1996). The coefficient of determination (R^2) for the multiple regression for predicting fish density from habitat variables was 0.48 (Randall et al. 1996) which indicates a resolution power of about two classes (Prairie 1996). For the Severn Sound data, the multiple regression between fish density and the habitat variables (susbstrate, fetch, macrophytes) was highly significant ($F = 29.5$; $p<0.001$) and had a R^2 value similar (0.42) to Randall et al. (1996).

Randall et al. (1996) speculated that greater precision in the regression estimation of fish assemblage measures might be possible if the fish species were divided into subgroups, with each group having similar trophic or habitat preferences. However, the analysis of individual species from Severn Sound indicated that many of the common (abundant) species had similar habitat preferences. For the 6 species identified in the cluster analysis, which were found in similar habitats, the regression coefficient was similar ($R^2 = 0.43$) to the results for the whole fish assemblage combined. Regression analysis of the remaining common species resulted in a lower coefficient of determination. For the Severn Sound data, the precision of the regression models was low, even for the species subgroups.

The results of the discriminant analysis, with confirmation from cross validation indicated however that the extreme groups could be classified with a higher success rate than the intermediate group. Fish species abundance and occurrence under extreme habitat conditions (e.g., high % cover, fine substrate and low fetch, Fig. 5) could be predicted with more accuracy than where habitat conditions were intermediate. This study suggests that the shoreline areas could be classified into two or possibly three fish groups (low, medium and high) based on habitat attributes, with reasonable confidence.

Application and Further Work

Links between habitat features and fish utilization of nearshore habitats in the Great Lakes are discernible. Field observations from Severn Sound on the occurrence of fish species, individually or collectively as an assemblage, are consistent with expectations of habitat preferences from the literature. Detailed habitat inventories which include the habitat indicators previously identified (substrate, cover, depth; Minns et al. 1995) and possibly others (exposure, as measured by average fetch - this study) can be used to determine habitat suitability. Since all of the habitat indicators are mappable, first order estimates of habitat supply can be determined for large areas, and habitat suitability indices can be assigned. Ground truthing and field validation will be an important component of this process. This study is a preliminary step towards ground truthing, but much more can be done. Habitat suitability will be determined using the Defensible Methods approach (Minns et al. 1995), and indices will be compared to the fisheries data available from Severn Sound. The development of habitat suitability indices, together with further ground-truthing of the fish-habitat links in the field, will be useful for future revisions of the Severn Sound Fish Habitat Management Plan, and for modeling fish habitat links elsewhere in the Great Lakes as well.

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Table 1. Summary statistics (sample size, median and range) of the habitat and fish variables measured in the study.

Variable	Sample size	Median	Range	Notes
Habitat				
Macrophyte % cover	85	80	0.0 to 100.0	
Substrate (phi units)	83	4.9	-6.0 to 6.5	-6.0 = gravel or coarser; 6.5 = silt or finer
Distance to shore (m)	85	58	8 to 373	
Average fetch (km)	85	0.64	0.20 to 2.83	
Effective fetch (km)	85	0.47	0.01 to 1.80	
Date (Julian)	236	198	156 to 277	Early June to October
Water temperature (°C)	236	22	12.2 to 27.0	
Fish				
Number of species	236	5.0	0 to 12	Eleven samples with 0 fish
Numbers	236	24.0	0 to 170	
Biomass (g)	236	2371.8	0 to 34823	
Mean size (g)	225	95.3	7 to 2850	

Table 2. Pearson correlation (r) matrix among 6 habitat variables and 3 fish assemblage variables, as measured during August (n = 83 transects; substrate information was not available for 2 transects). Habitat and fish measures are explained in the text. Significant Bonferroni-adjusted probabilities ($p<0.05$) are underlined.

	Date	Wtemp	Substrate	Macropytes	Shore	Average fetch	Effective fetch	NSP	Number
Wtemp	0.31								
Substrate	0.28	0.03							
Macrophytes	0.21	0.22	0.45						
Shore	-0.24	-0.53	0.12	0.12					
Average fetch	-0.35	-0.61	-0.32	-0.36	0.53				
Effective fetch	-0.10	-0.20	-0.05	0.08	0.45	0.24			
NSP	0.18	0.32	0.41	0.49	-0.12	-0.57	0.02		
Number	0.23	0.34	0.46	0.53	-0.14	-0.67	0.08	0.82	
Biomass	0.21	0.36	0.29	0.47	-0.17	-0.57	-0.08	0.76	0.79

Table 3. PCA analysis of the six habitat variables used in the study, after selection of the components with eigenvalues > 1.0, and varimax rotation. The highest component coefficient for each variable is underlined. Date (Julian) is also included in the analysis. Survey data from August only (n=85 transects) were used in the analysis.

	Principal Components	
Variable	1	2
Eigenvalue	2.51	1.66
% variance explained	32.69	26.92
Cumulative	32.69	59.61
Coefficients		
Distance to shore	0.90	0.10
Water temperature	-0.74	0.24
Average fetch	0.70	-0.55
Effective fetch	0.58	0.18
Macrophytes	0.08	0.80
Substrate	0.10	0.78
Date (Julian)	-0.32	0.48

Table 4. Relative abundance of fish species captured in Severn Sound. Species are sorted in descending order by total abundance.

Code	Common name	Scientific name	Total	Proportion
S331	Yellow perch	*Perca flavescens*	3591	0.41
S313	Pumpkinseed	*Lepomis gibbosus*	2648	0.30
S61	Alewife	*Alosa pseudoharengus*	539	0.06
S319	Black crappie	*Pomoxis nigromaculatus*	316	0.04
S317	Largemouth bass	*Micropterus salmoides*	296	0.03
S311	Rock bass	*Ambloplites rupestris*	229	0.03
S163	White sucker	*Catostomus commersoni*	180	0.02
S194	Golden shiner	*Notemigonus crysoleucas*	139	0.02
S199	Blackchin shiner	*Notropis heterodon*	138	0.02
S233	Brown bullhead	*Ameiurus nebulosus*	130	0.01
S316	Smallmouth bass	*Micropterus dolomieu*	107	0.01
S121	Rainbow smelt	*Osmerus mordax*	86	0.01
S208	Bluntnose minnow	*Pimephales notatus*	81	0.01
S201	Spottail shiner	*Notropis hudsonius*	73	0.01
S186	Common carp	*Cyprinus carpio*	52	0.01
S51	Bowfin	*Amia calva*	45	0.01
S361	Brook silverside	*Labidesthes sicculus*	31	0.00
S131	Northern pike	*Esox lucius*	30	0.00
S171	Shorthead redhorse	*Moxostoma macrolepidotum*	30	0.00
S196	Emerald shiner	*Notropis atherinoides*	27	0.00
S161	Quillback	*Carpoides cyprinus*	23	0.00
S63	Gizzard shad	*Dorosoma cepedianum*	14	0.00
S334	Walleye	*Stizostedion vitreum*	14	0.00
S302	White bass	*Morone chrysops*	7	0.00
S342	Logperch	*Percina caprodes*	7	0.00
S291	Trout perch	*Percopsis omiscomaycus*	6	0.00
S177	*Moxostoma* sp.		5	0.00
S181	Goldfish	*Carassius auratus*	4	0.00
S198	Common shiner	*Luxilus cornutus*	3	0.00
S301	White perch	*Morone americana*	3	0.00
S41	Longnose gar	*Lepisosteus osseus*	2	0.00
S75	Chinook salmon	*Oncorhynchus tshawytscha*	1	0.00
S168	Silver redhorse	*Moxostoma anisurum*	1	0.00
S200	Blacknose shiner	*Notropis heterolepis*	1	0.00
S261	Banded killifish	*Fundulus diaphanus*	1	0.00
	Unidentified		2	
Total			8862	1.00

Table 5. Results of discriminant function analysis using habitat variables as indicators of fish species presence-absence. A total of 233 samples were used: the number of samples where individual species were absent or present is indicated. Wilks lambda values are shown, significant at P<0.05 unless indicated with NS. Also indicated is the percent classification rate, the expected classification rate (based on chance alone), and kappa statistics (95% CL), all significantly > 0 (P<0.05). Species codes are defined in Table 4.

Species	Sample size absent,present	Wilks lambda	Classification %	Expected %	Kappa (95% CL)
S331	40,193	0.79	77	62	0.39 (0.25,0.53)
S313	46,187	0.78	78	60	0.45 (0.33,0.57)
S61	191,42	0.97NS	59	52	
S319	131,102	0.82	71	49	0.44 (0.32,0.56)
S317	130,103	0.72	75	49	0.51 (0.41,0.61)
S311	145,88	0.91	68	50	0.36 (0.24,0.48)
S163	154,79	0.87	68	49	0.37 (0.25,0.49)
S194	183,50	0.83	70	51	0.37 (0.27,0.47)
S199	195,38	0.89	75	57	0.42 (0.30,0.54)
S233	170,63	0.82	65	46	0.34 (0.24,0.44)
S316	186,47	0.79	79	60	0.48 (0.36,0.60)
S208	210,23	0.93	71	61	0.26 (0.16,0.36)
S201	209,24	0.94NS	66	56	
S186	202,31	0.93NS	65	56	
S51	194,39	0.91	60	50	0.20 (0.10,0.30)

Table 6. Habitat variables which were indicators of fish species occurrence. Significant variables (underlined) were identified using univariate F tests. The magnitude of the canonical loadings was a measure of the importance of each variable for separating the samples for the presence or absence of individual fish species. Habitat preferences are from Lane et al. (1995); substrate categories are: Si - silt, S - sand, G - gravel, R - rock; C - cobble; pelag. - pelagic. Species codes are defined in Table 4.

Species	Preference			Canonical loadings for the habitat variables						
	Macrophyte	Substrate	Depth (m)	Macrophyte	Substrate	Shore	Average Fetch	Effective Fetch	Temp	Date
S331	med	S,Si	0-5+	+0.72	+0.62	+0.01	-0.64	+0.25	+0.07	+0.04
S313	high	S,Si	0-2	+0.87	+0.51	+0.29	-0.40	+0.12	+0.09	+0.10
S319	high	G,S,Si	0-5	+0.68	+0.62	+0.11	-0.46	+0.32	+0.20	+0.38
S317	high	S,Si	0-5	+0.75	+0.48	+0.17	-0.40	-0.02	+0.12	+0.43
S311	high	C,R,G	0-2	+0.33	+0.45	-0.36	-0.72	+0.20	-0.07	+0.28
S163	none	G,S	0-5+	+0.32	+0.39	-0.21	-0.89	-0.13	-0.16	-0.11
S194	high	S,Si	0-5	+0.56	+0.72	+0.24	-0.38	+0.01	+0.21	+0.49
S199	high	G,S,Si	0-2	+0.70	+0.70	-0.15	-0.75	-0.17	+0.17	+0.17
S233	high	S,Si	0-5	+0.66	+0.69	+0.15	-0.52	+0.25	+0.07	-0.23
S316	low	C,R,G	0-5+	-0.64	-0.68	-0.41	+0.14	-0.10	-0.20	-0.43
S208	high	G,S,Si	0-5	+0.45	+0.28	-0.55	-0.43	-0.26	+0.41	+0.47
S51	high	G,S,Si	0-5+	+0.45	+0.79	-0.06	-0.68	-0.18	-0.04	+0.21

Table 7. Results of discriminant analysis of 3 fish density groups, using habitat variables as indicators. A total of 233 samples was used. Fish density was divided into three groups (zero catch, and low and high density where present); sample sizes are given for each group separately. Wilks lambda statistics were significant (P<0.05) unless indicated (NS). The percent classification rate, and kappa statistics (significantly > 0, P<0.05) are also given. Species codes are given in Table 4.

Species	Sample	Wilks lambda	% classification	kappa (95% CL)
S331	40,100,93	0.65	65 (70,49,81)	0.45 (0.35,0.55)
S313	46,97,90	0.70	61 (76,36,81)	0.42 (0.32,0.52)
S61	191,22,20	0.94 NS		
S319	131,55,47	0.82	57 (55,49,72)	0.35 (0.25,0.45)
S317	130,58,45	0.69	64 (62,57,78)	0.44 (0.34,0.54)
S311	145,56,32	0.89	54 (59,25,84)	0.27 (0.17,0.37)
S163	154,53,26	0.85	57 (53,57,77)	0.33 (0.25,0.41)
S194	183,33,17	0.79	65 (60,88,71)	0.36 (0.26,0.46)
S233	170,33,30	0.80	57 (51,67,77)	0.32 (0.24,0.40)
S316	186,28,19	0.79	68 (68,68,68)	0.36 (0.26,0.46)

Table 8. Discriminant function analysis of fish assemblage measures (species richness, density, weight and biomass), using habitat discriminators (substrate, macrophytes, fetch). Fish measures were divided into 2 or 3 groups, based on approximating equal sample sizes. Sample sizes are given for each group, as well as the classification rate. Wilks lambda (all significant at $P<0.001$) and kappa statistics are provided, and the results of the cross validation (see text). Kappa statistics were significantly > 0 ($P<0.05$).

Fish Group	No.	Sample	Wilks lambda	Classification (%)	kappa (95% CL)	Cross validation (%)
Species richness	2	121,112	0.74	73 (66,80)	0.46 (0.34,0.58)	69 (54,85)
	3	58,98,77	0.61	59 (81,29,81	0.39 (0.29,0.49)	55 (64,34,70)
Density	2	118,115	0.73	78(74,82)	0.55 (0.45,0.65)	77 (64,90)
	3	75,79,79	0.67	64(76,30,86)	0.46 (0.38,0.54)	56 (58,38,68)
Weight	2	112,111	0.85	73 (77,68)	0.45 (0.33,0.57)	65 (63,67)
	3	67,84,72	0.75	59 (73,50,56)	0.38 (0.28,0.48)	49 (54,60,34)
Biomass	2	116,117	0.80	75 (65,85)	0.50 (0.38,0.62)	66 (61,71)
	3	82,71,80	0.71	61 (65,48,69)	0.41 (0.31,0.51)	54 (56,38,66)

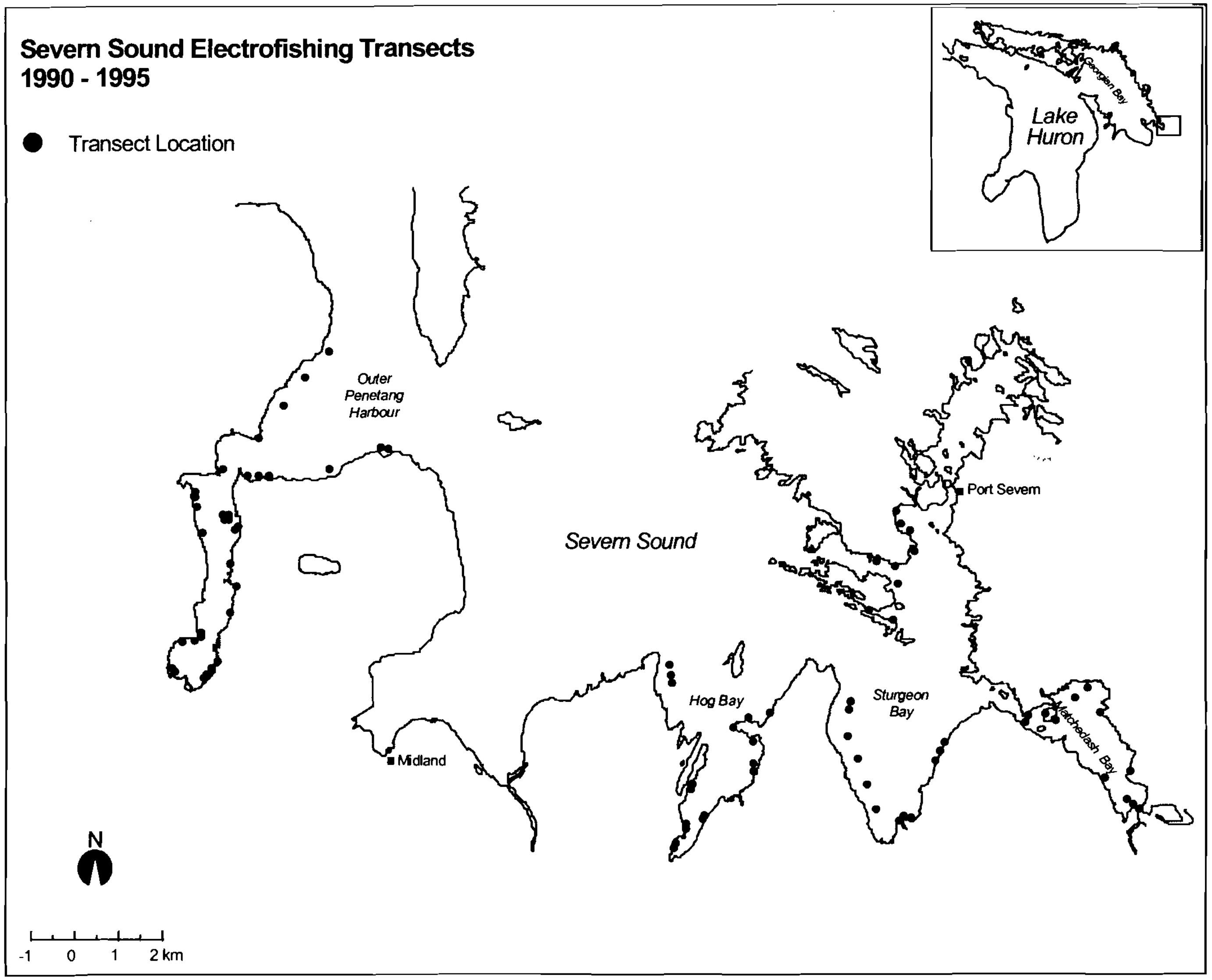

Fig. 1. Map of Severn Sound showing the location of the fish and habitat survey transects

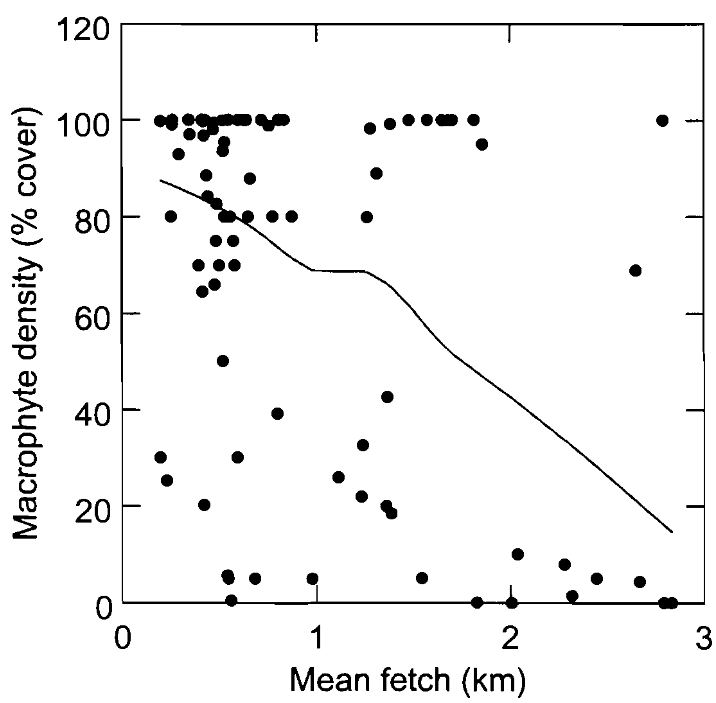

Fig. 2. Scatterplot showing the relationship between mean fetch (distance in km) and the density of submerged macrophytes (measured as % bottom cover). The line was estimated by weighted average smoothing (LOWESS procedure of Systat, Wilkinson 1996).

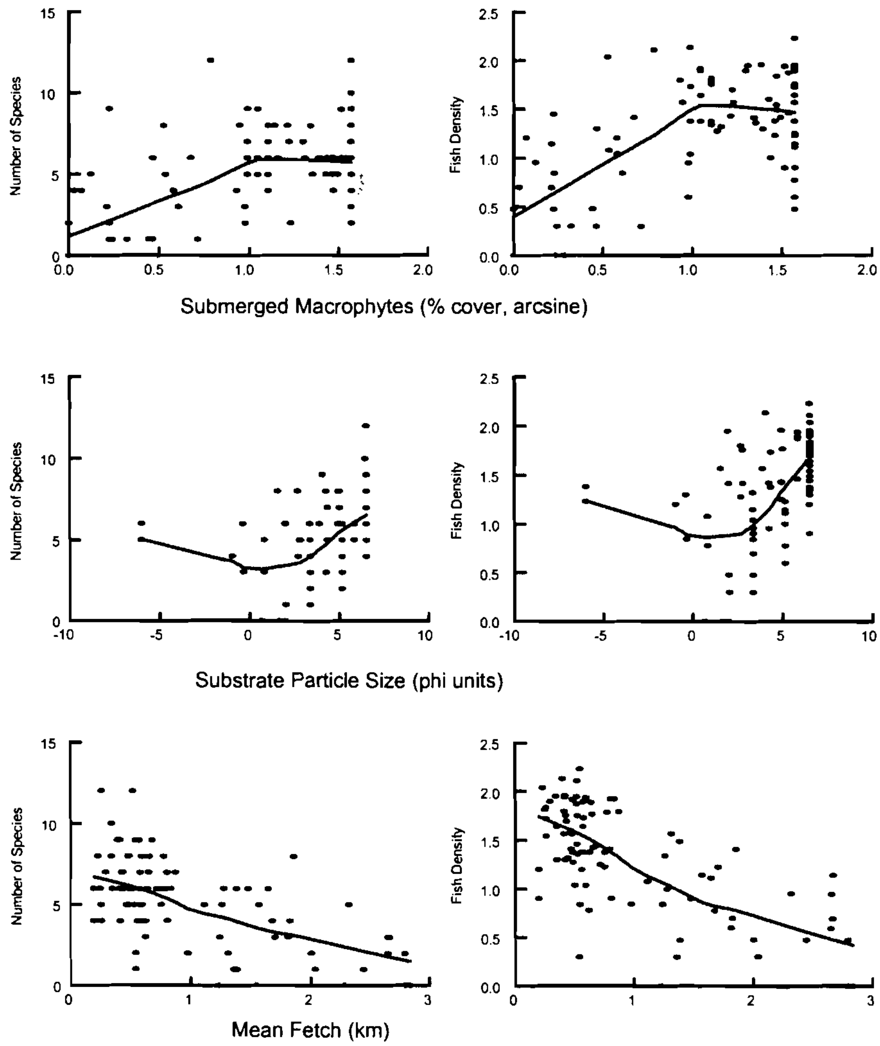

Fig. 3. Scatterplots showing the relationship between two fish assemblage measures, species richness and fish density, and three habitat attributes - abundance of submerged macrophytes, substrate size, and mean fetch. Data were collected during August at 85 different transect locations. Trend lines were determined by weighted average smoothing (LOWESS procedure of Systat, Wilkinson 1996).

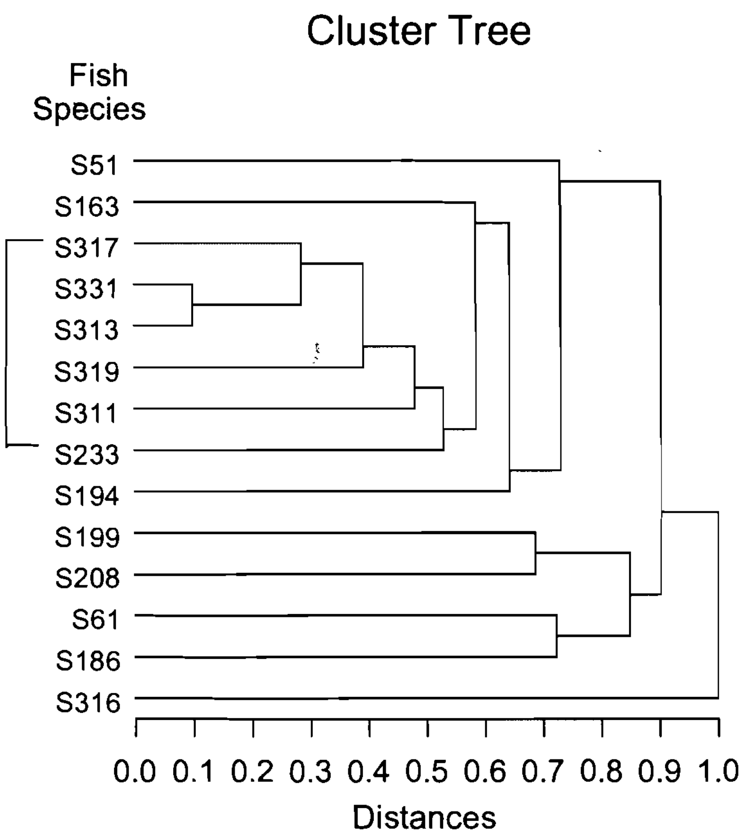

Fig. 4. Cluster tree of the 14 common species of fish captured at Severn Sound. Species were clustered on the basis of presence-absence data at the 85 transects surveyed in August. Dissimilarity increases from left to right; the square bracket identifies the 6 species with the most similarity in the presence-absence pattern among transects. Common and scientific names for the species codes are provided in Table 4.

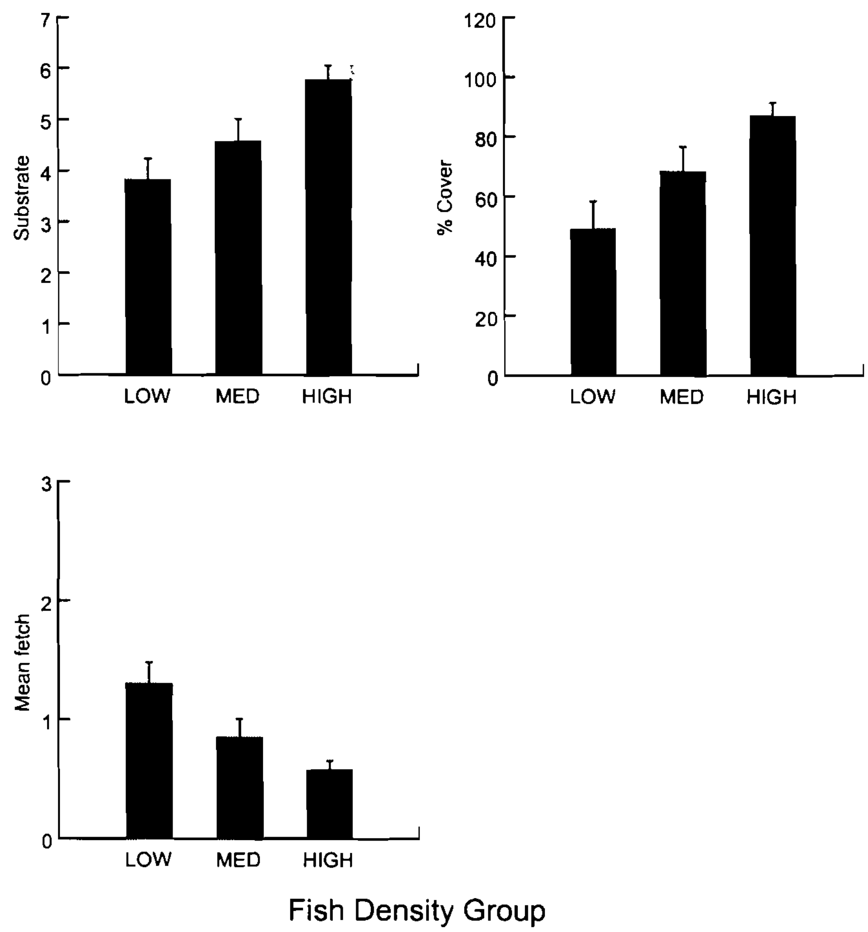

Fig. 5. Habitat conditions (substrate, cover and fetch) for the three fish density groups classified by discriminant analysis in Table 8. The three fish groups represent low, medium and high abundances, with about equal sample sizes in each. Histograms indicate average habitat values and SE's for each group.