Interspecific Association, Diversity, and Population Analysis of Fish Species in the Wood-Pawcatuck Watershed

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Introduction

In the summer and fall of 2002, Wood-Pawcatuck Watershed Association sampled sixteen stream sites in the Pawcatuck Watershed to identify fish assemblages and associated habitat characteristics. At the outset it should be clearly recognized that the methods and analyses, as well as any inferences drawn from these analyses, are limited by the relatively small number of sites which were sampled and the relatively small number of fish which were captured and released during the 2002 sampling period. However, it is believed that these methods and analyses will provide a suitable base which will increase in value with larger samples taken in the future.

We will briefly describe and provide some background for the methods utilized in this study. This will be followed by a more detailed definition of both methods and results. Some preliminary inferences from these methods and results are also provided. This section is then followed by a brief summary and conclusions.

Background

Species interactions are considered important in the process of understanding the overall ecology of species. In any given habitat there are a number biotic and abiotic factors which may influence the distribution, abundance, and interactions among species. A pattern of interspecific association between two species will depend upon whether or not the two species select or avoid the same habitat, have some natural repulsion or attraction, or have no interaction at all. Thus, interspecific association may be positive, negative or nonexistent. In this report methods for detecting the existence of association and for assessing the degree of association are applied to fish assemblages collected by electrofishing in the Pawcatuck Watershed area during the summer and early fall of 2002. The methods for interspecific association are based on the presence or absence of species at specific locations or sites, which are termed sampling units (SUs) in the analyses which follow. The detection of a pattern of interspecific association does not provide an understanding of the causation for such a pattern. It remains to generate and test various hypotheses for possible causalities in future studies.

Ecologists frequently use species diversity indices that can be utilized for characterizing some species abundance relationships. These methods are based on actual estimated numerical abundances in this report. It is useful to consider species diversity as consisting of two components. The first is the number of species in an assemblage (species richness), and the second component is species evenness or equitability. These terms refer to how abundances are distributed among the various species in the assemblage. Indices which attempt to combine richness and equitability into a single value are termed diversity indices, of which there are many kinds. It should be recognized that diversity indices may confound variables that characterize an assemblage by attempting to combine them, such as the number of species (richness) with relative species abundance (evenness). In spite of these apparent difficulties, diversity indices are commonly used by ecologists and fisheries scientists. A few of the very many diversity indices are described and utilized herein. A few evenness indices will also be described and utilized. In general, when all species in a SU are equally abundant it seems intuitively reasonable that the evenness index should be at its maximum value. As the relative abundance of one species increases and others decline, the evenness measure ultimately reduces to zero. In this report five evenness indices are described and utilized. These indices have numerical values ranging from 0 to 1.

Emphasis is placed on the analysis of interspecific associations in this report because it is believed that more realistic comparisons are possible with these limited data than by conventional habitat related analyses. Although habitat variables were measured and examined in an effort to establish relationships among these variables and the abundance of a given species (particularly brook trout), the number of sampling units was too small to effectively utilize any of the available multivariate techniques. In spite of this, an effort is made to provide initial estimates of relative population sizes of brook trout and a few other species. Only preliminary habitat characteristics and environmental influences in relation to brook trout abundance are suggested at this time due to the small amount of relevant data. However, a report on environmental factors affecting brook trout abundance (especially water temperature and flow) will be prepared when suitable data become available.

Methods and Method Application Results

Species Associations-

A data set appropriate for an application of an interspecific association method is provided by the electrofishing data results shown in Table SI 1. This data table shows the actual number of each species examined during the electrofishing survey at 16 sites sampled during the summer and fall of 2002. These numerical abundances were converted to presence-absence data where the presence of the species is indicated by 1 and absence is indicated by a 0. The results of this transformation are shown in Table SI 2 which includes the 16 species sampled at the 16 sites as a matrix. Using a program entitled *S P A S S O C. B A S* the following tables were generated from the presence-absence data matrix. Table SI 3 briefly indicates which statistics were utilized by this program and what the input options for this program include. Table SI 4 both describes the tests and provides results from the data analysis of Table SI 2 as well as describing the Chi-Square test for pair-wise species association (lower half of Table SI 4). Tables SI 5a, 5b, 5c and 5d provide results derived from the Chi-Square test and other indices. Table SI 5 describes every species pair in Column 1. Column 2 indicates whether or not the association is positive or negative. Chi-Square values (both basic and corrected) are shown in Columns 3 and 4. The results from applying three nonprobalistic indices (Ochiai, Dice and Jaccard) are indicated in the final three columns of Table SI 5.

These results, which were obtained from the preliminary analysis of limited data shown in the above tables, are interpreted as follows. Firstly, an overall positive association is suggested by the fact that the variance ratio (VR equals 1.76) is greater than unity. Furthermore, the value of the test statistic (W) is 28.17. This value lies outside of the 90% probability limits given by the Chi-Square distribution for 16 degrees of freedom. These limits are 7.062 and 26.296, which show that the test statistic value lies outside of this range. These suggest that we must reject the null hypothesis of no association among the 16 species. In examining the results in Table SI 5 we note that there are more positive than negative associations, but that the Chi-Square values for all pairs are biased. Therefore Yates's correction has been utilized. Careful examination of all possible pairs using the corrected values indicates that the positive association between species numbers 7 and 16 and between numbers 9 and 10 have adjusted Chi- Square values which exceed 3.84 for 1 degree of freedom. These limited data suggest that there is a positive association between brown bullhead (species No. 7) and white sucker (species No. 16). This seems plausible because both species are pollution tolerant and are somewhat non-specialized in terms of habitat choices. This is in spite of the fact that brown bullheads are typical pond dwellers and the white sucker is primarily associated with fluvial conditions. The statistically significant association between species No. 9 (common shiner) and species No. 10 (fallfish) are also reasonable although their habitat choices and pollution tolerances are generally somewhat different. It should be kept in mind that the small sample size used in this analysis will have some influence on the outcomes of these tests. Clearly, more data are required before it is possible to assign (or even suggest) causality to the observed statistically significant associations detected in this analysis.

The last three columns of Table SI 5 show calculated numerical values for the three association indices (Ochiai, Dice and Jaccard). These indices range in value from 0 at no association to 1 at maximum association. The Ochiai and Dice indices are means of the ratios a/m and a/r. These are interpreted as the number of joint occurrences of the two species compared to the total occurrences of species A and B respectfully. The Ochiai index is based on the geometric mean of a/m and a/r. The Dice index is based on the harmonic mean of a/m and a/r. The Jaccard index is based on the proportion of the number of SUs where both species occur to total number of SUs where at least one species is found. These indices are all indicative of the degree of association between two species. However, Jaccard's index (last column) is thought to be generally unbiased even at small sample sizes, and it is the preferred index among these three, but no formal inferences are drawn from these results at this time due primarily to the limited size of the sample.

In summary, these analyses and calculations have demonstrated the use of two components for the determination of species associations. These are the variance ratio test (VR) and the statistic (W) used to test whether or not a given value of VR is statistically significant. In addition three association indices were introduced and used herein. They are thought to be relatively easy to comprehend, and furthermore these indices have been found to have desirable statistical properties. Their value is expected to increase as the sample sizes becomes greater.

Finally, the reader is reminded that establishing the presence or absence of association does not tell us anything about possible causes. The use of small sample sizes, such as were obtained from this study, further reduces the strength of any inferences drawn from the data.

Species Diversity-

Species diversity is considered to be composed of two components. They are: 1) the number of species in the assemblage, which is often referred to as species richness; and 2) species evenness or equitability. In our study these latter terms refer to how the number of individuals sampled are numerically distributed among the species. Similar to species associations, there are also a large number of indices proposed for richness and evenness. There are also indices which combine both species richness and evenness into a single value. These are the so-called indices of diversity. All of the richness, diversity and evenness indices used in this diversity study are shown in Table D 1. The equations used to generate values for each index are also shown in this table. The two indices of richness, first derived by Margalef and Menhenick, are well known in ecology but they are based on certain assumptions which are not easily met in practice. As indicated previously, diversity indices incorporate both richness and evenness. The biggest problem in using diversity indices is the interpretation of exactly what this single index value means. The three diversity indices used in this study, namely the diversity indices of Hill, Simpson and Shannon are also shown in Table D 1. Finally, five evenness indices (labeled E1-E5) are included in Table D 1.

A computer program termed *S.P.D.I.V.E.R.S.B.A.S.* was utilized in estimating the richness, diversity and evenness indices described in Table D 1. The results of applying these indices to 16 SUs in the Wood-Pawcatuck watershed area are illustrated in Table D 2. A somewhat arbitrary decision was made to partition the data from the 16 sampling units into two periods, roughly corresponding to summer and early fall. That is, the summer season extended from 7/29/02 to 8/21/02 and the fall season from 8/28/02 to 10/9/02. Each of the two seasons contained eight SUs. The major reason for establishing this partition is to illustrate how the various indices can be compared over time or space. Again, larger samples sizes resulting from more extended sampling periods would have improved the precision and accuracy of the results obtained. However, in this case we are primarily interested in illustrating a simple application of the method with a few tentative interpretations of the results. The output from all calculations are shown in Table D 2. It is evident that the richness indices, R1 and R2, increased from summer to fall. This is reflected by the increase in the number of species sampled. Nine species were sampled in the summer and 15 were sampled in the fall. This observed increase could have been a result of increasing efficiency by the team of fish samplers or could reflect a seasonal increase in aggregation by fish assemblages. Spawning aggregations of brook trout are also expected at suitable spawning sites during the fall period. Although it is clear that the richness index increased from summer to fall, no adequate causal explanation is evident from this limited analysis.

All of the three diversity indices (H', N1 and N2) increased from summer to fall in this study. Lambda (which is Simpsons index) declined instead of increased because this index value estimates the probability that two individuals drawn at random from a population belong to the same species. That is, if there is a high probability that both individuals belong to the same species, then assemblage diversity is low. These numbers suggest an increase in dominance for a few species during the summer with a decrease in the fall samples. These statements must again be treated cautiously due to insufficient data.

The five evenness indices are even more difficult to interpret than the previously described indices. The first three indices of evenness (E1, E2, and E3) appear to be quite sensitive to the number of species in the samples. Clearly there are differences between the summer and fall with respect to number of species, which may influence results from these three indices. Both the E4 and E5 indices, which are the Hill ratio and modified Hill ratio respectively, decrease from summer to fall. This could be related to the increasing dominance of brook trout which tend to aggregate for spawning purposes during the fall. However, without further detailed information this inference is speculative at present.

All of the above indices were also calculated in a similar manner for the combined data. These results are shown in Table D 3. Comparing this table with the partitioned data described previously indicates that most of the indices lie somewhere between the summer and fall for the most part. This is to be expected since the combined data are derived from the sum of the two seasons.

Electrofishing-

Electrofishing is a commonly used and effective method for estimating population abundance of fishes in streams. The material which follows will briefly describe this procedure and its relative effectiveness. Some concern has been expressed regarding possible physiological and/or behavioral effects of electrofishing. With respect to behavior, Dunham et al (2002) have clearly demonstrated that electrofishing does not influence the movements of brook trout in streams. The anesthetizing effect of electricity on fish is produced as a result of the drop in voltage from head to tail along the spine. Thus, large fish, which possess a longer spinal column are more susceptible to the effects of an electric field, such as the one achieved by a an electrofishing device. Cowx and Lamarque (1990) provide a detailed description of virtually all aspects of electrofishing which include possible adverse effects. Our electrofishing operations involved minimal mortality to fish in the capture and handling process. This was attributed to both the small average size of most of the captured fish as well as rapid handling and release. Only seven fish were lost due to capture and handling from a total of more than four hundred fish which were successfully released.

A section of stream, usually 20 meters but with varying lengths up to 50 meters, was closed by means of blocking seines at both ends of the section. Three passes with the electrofishing device were made in each closed section, or SU, in an attempt to obtain a population estimate. However, not all SUs produced enough fish to obtain reasonable population estimates. Special emphasis was placed upon brook trout in the choice of SUs. All fish captured on each pass were identified to species, counted and measured (total length) to the nearest millimeter. The only exceptions were American eels, which were difficult to measure without anesthesia. Eels were measured approximately to the nearest 10 millimeters. All captured fish were released downstream from the lower blocking seine after each pass. The equipment used in this study was a Cofelt back-pack electrofishing device consisting of a 350 watt AC generator powered by a two-cycle gasoline engine with a conversion unit to produce DC current. Voltage settings during operation were usually set at 350 V at 60 Hz. This setting was found to be suitable for the relatively low conductivity streams which characterize this watershed.

Population Estimates-
Special attention was given to brook trout and selected species associated with them in our study of relative abundance. A preliminary assessment of possible habitat related variables was made at each site in order to later assess these as possible influences on the population assessments. In the data analysis it became apparent that only a few sampling units had adequate data for a population estimate or for a formal analysis of size frequency distributions.

The population estimation procedure applied in this report is an extension of the method of Zippin which utilizes a maximum likelihood estimation procedure for the removal-depletion model. This method is described in detail by Saila et al (1988) and will not be reproduced herein. It should be emphasized that these results are all preliminary in nature and are only indicative of changes in relative and not the absolute abundance.

All SUs, including those with variable lengths of stream were adjusted to common values in order to obtain numbers and weights per acre. It was thought that these would be more readily interpreted by readers, and therefore they are used for the preliminary inferences and suggestions made in material which follows.

Population Analyses, Results and Discussion-
Table P 1 shows the results from applying the Zippin population estimator to the electrofishing data obtained from Locke Brook, which is a tributary of the Queen River. Obviously, this estimate is very crude due to the small sample size. However, this analysis suggests that the population of brook trout ranges from about 467 to 600 individuals per acre. If it is assumed that the average weight of these fish (mostly juveniles) was 0.1 pound per fish, then this abundance amounts to approximately 47 to 60 lb. of fish per acre as a standing stock. At Locke Brook a relatively large number of Atlantic salmon parr and larger juveniles were also captured and released. The estimated population size of these Atlantic salmon range from 1000 to 1667 individuals per acre. This population estimate is shown in Table P 2. This numerical abundance roughly translates to about 100 to 167 lbs. per acre under the same weight assumption. Although these estimates for both brook trout and Atlantic salmon are very crude they suggest, at least on a relative basis, that the Atlantic salmon were more abundant than brook trout in that particular reach of stream. Figure P 2 illustrates the length frequency distribution of Atlantic salmon (parr and older juveniles). It is evident that this distribution is bimodal. It suggests that the recently stocked parr separate into the 60 to 78 mm total length category and that the larger fish (probably in their second year of stream life) make up the second segment of the bimodal distribution with sizes ranging from 125 to more than 170 mm in total length. The brook trout frequency distribution (Figure P 1) consists of much sparser data. However, it seems to suggest it may be partitioned into three year classes. It is generally believed that the brook trout is short lived. The major finding from these data suggests that the Atlantic salmon are abundant in this area and may be serious competitors with indigenous brook trout.

It is also recognized that this Locke Brook sampling site may be a preferred habitat for the Atlantic salmon because it is primarily a riffle area. In spite of this, it is suggested that heavy stocking of Atlantic salmon in streams where brook trout are native and numerous may impose significant competition. Therefore, it would seem that this potential problem should receive careful additional attention from a management point of view. That is, management should probably be directed toward favoring one of these two species due to likely competition during early life history stages.

Another site where brook trout seem to be quite abundant is the Beaver River at Punch Bowl Trail. Table P 3 demonstrates the results of a preliminary population estimate of brook trout which indicates that their numerical abundance ranges from 680 to 1000 individuals (mostly juveniles) per acre. These values, if converted by assuming a similar weight of 0.1 lb. per individual, provide a biomass (standing stock) of 65 to 100 lbs. per acre. Although this estimate is crude it suggests that a higher standing stock of brook trout may occur when no competition with Atlantic salmon is present.

Table P 4 illustrates the results of the brook trout population estimate at Breakheart Brook in the vicinity of the foot bridge above Breakheart Pond. The population of brook trout was estimated to range from 2000 to 2667 individuals or 222- 267 lbs. per acre under the same assumptions as used previously. This site produced the highest brook trout density observed during the 2002 survey. This very high population estimate and standing stock was probably influenced to some extent by the fact that there were no other fish species sampled in this area. This lack of other species may further support the suggestion that the largest populations of brook trout may occur when competition is minimal.

A final site for brook trout population estimates is found at Brushy Brook near Saw Mill Road. The results of the population estimation are shown in Table P 5. The estimated population size is 1167-3750 per acre, and this number roughly translates to between 117-375 individuals and between 117-375 lbs. per acre. The above estimate is extremely high but it compares favorably with that from Breakheart Brook. Note the substantially wider confidence limits for this estimate in comparison to Breakheart Brook. These results were obtained in a sample which also had virtually no predators or competitors. Only one other fish species, the brown bullhead, was found in this area.

No other sites were considered suitable for preliminary population estimates of brook trout. Two other species were utilized for population estimates. A description of these results follows. Table P 6 illustrates the results of a population estimate of fallfish at a location in Canonchet Brook immediately above the Lindbrook golf course. The estimated fallfish population ranged from 600 to 1040 individuals per acre when adjusted to the area sampled. These results suggest that the fallfish is a dominant species, which may limit the abundance of brook trout or other salmonid species in this area. However, other factors, such as the proximity to impoundments, may also limit trout abundance here.

Table P 7 illustrates the results of the Zippin estimate applied to redfin pickerel at a sampling area which was located just below the Lindbrook golf course. Redfin pickerel were the most abundant species in this site and the projected population was between 635 and 1000 individuals per acre with a standing stock of 31 to 50 lbs. per acre under the assumption of each fish weighing approximately .05 lb. It is believed that the stream segment, which passes through the golf course, may have been a favorable environment for an increased redfin pickerel population. Redfin pickerel are a voracious predator and juvenile brook trout have been found in the stomachs of these fish. The redfin pickerel may also have benefited from the slight warming

effect to the stream passing through the golf course. However, this statement is speculative without more detailed information.
No further population analyses were possible due to inadequate samples.

In summary, this information is very preliminary and is based on small sample sizes, but it does seem to suggest that brook trout abundance is increased in situations where competition by other species is minimized. The abundance of competitors should be limited, if possible, where brook trout are to be favored in particular areas. So-called warm water species, such as brown bullheads, sunfish, golden shiner, and bass seem to be associated with stream reaches in relatively close proximity to impoundments. Although no distances to impoundments were carefully measured, it is believed that locations such as Meadow Brook #3 near the turf farm as well as Canonchet Brook above the golf course were influenced by nearby impoundments. Clearly, further study of this situation is justified. It is believed that the biomass of fishes at a given site will be fairly constant, but the species composition will be influenced by altered environmental conditions, such as those associated with relatively large impoundments resulting from dams.

Habitat Related Analyses
Although habitat related analyses were attempted, the results obtained were not considered to be informative. This was due primarily to the small sample size and the statistical difficulties encountered in building models with many variables but with very few samples. Many of the habitat variables collected also involved judgments made by several people. This resulted in a low precision for these variables. Table H 1 illustrates the raw data, namely nine variables and only 16 sites where these variables were estimated. The second half of Table H 1 shows standardized values of these variables, which were obtained by subtracting the mean and dividing by the standard deviation. This operation provides standardized values for variables measured in different units, and these are thought to be more appropriate for multivariate analyses. Table H 2 shows the summary statistics for the habitat variables. It is evident that both the standard deviations and coefficients of variation for each variable indicate a high degree of variability. A matrix of rank correlation coefficients for the nine environmental variables and their P-values are shown in Table H 2, lower panel. This table indicates only a few significant correlations with P-values below 0.05. In summary, a larger number of SUs is required for this type of analysis, which would then provide data for a quantitative population model for evaluating habitat factors in relation to brook trout abundance.

Summary and Conclusions
1. Measures of interspecific association and diversity were described and applied to fish assemblages captured by electrofishing at selected sites in the Pawcatuck Watershed. The sites were selected initially as possible brook trout habitats. A limited amount of interspecific association was found. Statistically significant associations between brown bullheads and white suckers as well as between common shiner and fallfish were detected. However small sample sizes may have affected the results of these findings.

2. Species diversity, species richness and species evenness were also measured and analyzed. It was demonstrated that species richness increased from summer to fall. The diversity indices also increased from summer to fall. The calculated measures of evenness were difficult to interpret,

but some of the evenness indices decreased from summer to fall. This might be related to increasing dominance of brook trout, which tend to aggregate in the fall season.

3. The results of electrofishing with respect to brook trout provided some interesting observations. Among these were the possibility of interspecific association between brook trout and Atlantic salmon juveniles in Locke Brook, which might have adverse effects on brook trout abundance. Another finding of potential interest was that the more abundant brook trout populations were found at SUs that seemed to be associated with the absence or minimal occurrence of other species. These SUs were Breakheart Brook above Breakheart Pond and Beaver River at Punch Bowl Trail.

4. Two other species, fallfish and redfin pickerel, were caught in sufficient numbers to provide preliminary population estimates. Some possible reasons for the dominance of these species at particular sites were proposed. These included habitat changes and possible influences of nearby impoundments.

5. It became evident that the number of currently achieved SUs was too small to permit the development of a predictive model for brook trout based on measured habitat variables. Such a model will require considerably more sampling units and effort.

6. Some suggestions for future work involve not only a larger number of sampling units but also the following:

a) Better quantification of habitat variables, such as sediment composition, pool depth and flow estimates.

b) Developing more objective criteria for judgmental estimates in order to improve their consistency and accuracy.

c) Choosing sites with more uniform environmental conditions in order to increase within site precision with respect to habitat variables.

d) Improving the efficiency of the electrofishing device, and consideration of methodologies for sampling larger stream sites.

e) Developing temperature and flow related prediction models for brook trout and for stream protection.

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Table SI 1a. Fish species inventory by site

Common Name(s)	Species	7/29/02 Queen River (Wm. Reynold Rd.)	7/29/02 Fisher-ville Brook	8/2/02 Queen River (Mail Rd.)	8/2/02 Locke Brook	8/5/02 Falls River (lower)	8/6/02 Falls River (upper)	8/21/02 Beaver River (play-ground)	8/21/02 Beaver River (Punch Bowl Tr.)	*Macro-Habitat*	*Pollution Tolerance*
American Eel (3)	*Anguilla rostrata*	2	4	4		1	1	3	4	*MG*	*T*
Atlantic Salmon (2)	*Salmo salar*		3		29	1				*FS*	*I*
Banded Sunfish (**)	*Enneacanthus obesus*									*MG*	*M*
Blacknose Dace(**)	*Rhinichthys atratulus*					1	1			*FS*	*I*
Bluegill (4)	*Lepomis macrochirus*									*MG*	*T*
Brook Trout (5)	*Salvelinus fontinalis*		4	7	7	1	1	5	17	*FS*	*I*
Brown Bullhead/ Catfish (**)	*Ameiuras nebulosus*									*MG*	*T*
Brown Trout (4)	*Salmo trutta*							1		*FD*	*I*
Common Shiner (**)	*Luxilus cornutus*	29								*MG*	*T*
Fallfish (**)	*Semotilus corporalis*									*FS*	*M*
Golden Shiner (**)	*Notemigonus crysoleucas*									*MG*	*T*
Largemouth Bass (4)	*Micropterus salmoides*									*MG*	*M*
Pumpkinseed/ Common Sunfish (**)	*Lepomis gibbosus*									*MG*	*M*
Redfin Pickerel/Grass Pickerel (**)	*Esox americanus*		1	3					1	*MG*	*M*
Tesselated /Johnny / Fantail Darter (**)	*Etheostoma olmstedi*					1		1		*FS*	*I*
White Sucker/ Common Sucker (**)	*Catostomus commersoni*	2		2	1	6	12	3	2	*FD*	*T*
	Total of each site	**33**	**12**	**16**	**37**	**11**	**15**	**13**	**24**		

(**) native primary freshwater species; (2) anadromous, but may also have resident ("landlocked") populations; (3) catadromous; (4) introduced; (5) primarily resident, but also has anadromous populations

Macrohabitat: FD= Fluovial Dependant; FS= Fluvial Specialist; MG= Microhabitat Generalist
Pollution Tolerant: I= Intolerant; M= Intermediate; T= Tolerant

Table SI 1b. Fish species inventory by site

Common Name(s)	Species	8/28/02 Breakheart Brook (Frosty Hollow Pond)	8/28/02 Breakheart Brook (footbridge)	9/5/02 Moscow Brook	9/5/02 Brushy Brook (Saw Mill Rd.)	9/20/02 Canonchet Brook (Palmer Property)	9/20/02 Canonchet Brook (Below Golf Course)	10/01/02 Meadow Brook #3	10/09/02 Meadow Brook #2	Total of each Species at all Sites	*Macro-Habitat*	*Pollution Tolerance*
American Eel (3)	*Anguilla rostrata*					5	2		1	**27**	*MG*	*T*
Atlantic Salmon (2)	*Salmo salar*	6								**39**	*FS*	*I*
Banded Sunfish (**)	*Enneacanthus obesus*							1		**1**	*MG*	*M*
Blacknose Dace(**)	*Rhinichthys atratulus*	3				1				**6**	*FS*	*I*
Bluegill (4)	*Lepomis macrochirus*			4						**4**	*MG*	*T*
Brook Trout (5)	*Salvelinus fontinalis*		35		24	1	1	1	4	**108**	*FS*	*I*
Brown Bullhead/ Catfish (**)	*Ameiuras nebulosus*			7	1			22		**30**	*MG*	*T*
Brown Trout (4)	*Salmo trutta*									**1**	*FD*	*I*
Common Shiner (**)	*Luxilus cornutus*					5	15			**49**	*MG*	*T*
Fallfish (**)	*Semotilus corporalis*					29	2			**31**	*FS*	*M*
Golden Shiner (**)	*Notemigonus crysoleucas*							3		**3**	*MG*	*T*
Largemouth Bass (4)	*Micropterus salmoides*			2		1		1		**4**	*MG*	*M*
Pumpkinseed/ Common Sunfish (**)	*Lepomis gibbosus*							7		**7**	*MG*	*M*
Redfin Pickerel/Grass Pickerel (**)	*Esox americanus*					8	8	1	3	**25**	*MG*	*M*
Tesselated /Johnny /Fantail Darter (**)	*Etheostoma olmstedi*					15	40	1	3	**61**	*FS*	*I*
White Sucker/ Common Sucker (**)	*Catostomus commersoni*	18				22	5		2	**75**	*FD*	*T*
	Total of each site	**27**	**35**	**13**	**25**	**87**	**73**	**37**	**13**	**471**		

(**) native primary freshwater species; (2) anadromous, but may also have resident ("landlocked") populations; (3) catadromous; (4) introduced; (5) primarily resident, but also has anadromous populations

Macrohabitat: FD= Fluovial Dependant; FS= Fluvial Specialist; MG= Microhabitat Generalist
Pollution Tolerant: I= Intolerant; M= Intermediate; T= Tolerant

Table SI 2

LISTING 0F THE DATA SET. R0WS=species, C0LUMNS=SUs

1	1	1	0	1	1	1	1	0	0	0	0	1	1	0	1
0	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	1	1	0	0	1	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1
0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0
0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	1	1	0	0	0	0	1	0	0	0	0	1	1	1	1
1	0	0	0	1	0	1	0	0	0	0	0	1	1	1	1
1	0	1	1	1	1	1	1	1	0	0	0	1	1	0	1

Table SI 3

S P A S S O C. B A S

-

THIS PROGRAM COMPUTES:

1. Variance Ratio Test for Detecting Presence of OVERALL Associations in a Group of Species
2. Chi-Square Test for Detecting Association between PAIRS of Species based on 2x2 Contingency Table. Statistics computed:
   A. UNCORRECTED CHI-SQUARE
   B. CORRECTED CHI-SQUARE (YATE'S)
3. Indices that Measure the DEGREE of Association between pairs of species:
   a. Ochiai Index
   b. Dice Index
   c. Jaccard's Index

-

PART I. DATA ENTRY

This program utilizes PRESENCE/ABSENCE data of S species found in N sampling units (SUs) (plots, stands, locations, etc.)

These data are organized into a DATA MATRIX where the PRESENCE of a species in a SU is indicated by a 1 and its ABSENCE by a 0.

	SU
	1 2 3 4 5 6 7 ...N
SPECIES	
1.	1 1 0 1 1 1 0 ...1
2.	0 0 0 0 0 1 1 ...0
3.	1 1 1 1 1 0 0 ...0
S	1 1 0 0 0 1 0 ...1

Data INPUT options:
Option 1- Data already exists in a STORED data file
Option 2 -Data is to be manually entered from keyboard (and subsequently STORED, if desired)

Table SI 4

VARIANCE RATIO TEST

This Section of the program computes V' an INDEX of ASSOCIATION .
Under the NULL hypothesis of NO ASSOCIATION between the S SPECIES, the EXPECTED value of V lS 1.0. , ,
If V > 1, possible OVERALL POSITIVE association
If V < 1, possiple OVERALL NEGATIVE association
This test is a method for assessing simultaneously whether the species in the group are associated (Schluter, Ecology 65:998-1005, 1984)

A statistic, 'W', is computed that may be used to test whether deviations from 1 are significant. For example if the species are NOT associated, then there is a 90% probability that W lies between limits given by the CHI-SQUARE distribution:

$X^2_{.05,N} <= W <= X^2_{.95,N}$

VR, Index of OVERALL Association 1.760518
(Since V > 1 possible POSITIVE association)
W, Test Statistic 28.16829

CHI-SQUARE TEST FOR PAIR-WISE SPECIES

This portion of the program computes a CHI-SQUARE statistic for testing the NULL hypothesis that a PAIR OF SPECIES are independently distributed among the sampling units.

This statistic is computed from a 2 X 2 CONTINGENCY TABLE and is compared to a Chi-Square TABLE with 1 df; This critical value is 3.84. A CORRECTED Chi-Square value is also computed using Yates correction factor

NOTE: If any cell in the CONTINGENCY TABLE has an expected frequency < 1 OR if more than 2 of the cells have expected frequencies < 5, then the resulting CHI-SQUARE will be biased (Zar, Biostatistical Analysis, Prentice-Hall 1984 pp 70) SUCH BIASED CHI-SQUARE VALUES ARE SO-INDICATED IN THIS PROGRAM

NOTE: If any species is present or absent in ALL of the sampling units, it is considered INDETERMINATE and a Chi-Square value cannot be computed.

Table SI 5a

SPECIES PAIR		ASSOCIATION (+ OR -)	Chi-Square (* = biased)	Chi-Square (Continuity correction)	-- ASSOCIATION INDICES -- OCHIAI	DICE	JACCAR
1	2	-	* 0.356	0.000	0.316	0.286	0.167
1	3	-	* 1.778	0.071	0.000	0.000	0.000
1	4	+	* 0.356	0.000	0.474	0.429	0.273
1	5	-	* 1.178	0.071	0.000	0.000	0.000
1	6	+	* 1.185	0.132	0.770	0.762	0.615
1	7	-	* 6.154	3.309	0.000	0.000	0.000
1	8	+	* 1.371	0.152	0.447	0.333	0.200
1	9	+	* 2.215	0.684	0.548	0.462	0.300
1	10	+	* 1.371	0.152	0.447	0.333	0.200
1	11	-	* 1.778	0.071	0.000	0.000	0.000
1	12	-	* 1.340	0.246	0.183	0.154	0.083
1	13	-	* 1.778	0.071	0.000	0.000	0.000
1	14	+	* 2.861	1.371	0.717	0.706	0.545
1	15	+	* 2.861	1.371	0.717	0.706	0.545
1	16	+	* 5.605	3.278	0.858	0.857	0.750
2	3	-	* 0.356	0.356	0.000	0.000	0.000
2	4	+	* 1.778	0.444	0.500	0.500	0.333
2	5	-	* 0.356	0.356	0.000	0.000	0.000
2	6	-	* 0.091	0.253	0.433	0.375	0.231
2	7	-	* 1.231	0.137	0.000	0.000	0.000
2	8	-	* 0.762	0.000	0.000	0.000	0.000
2	9	-	* 1.231	0.137	0.000	0.000	0.000
2	10	-	* 0.762	0.000	0.000	0.000	0.000
2	11	-	* 0.356	0.356	0.000	0.000	0.000
2	12	-	* 1.231	0.137	0.000	0.000	0.000
2	13	-	* 0.356	0.356	0.000	0.000	0.000
2	14	-	* 0.762	0.085	0.189	0.182	0.100
2	15	-	* 0.762	0.085	0.189	0.182	0.100
2	16	+	* 0.097	0.097	0.452	0.400	0.250
3	4	-	* 0.356	0.356	0.000	0.000	0.000
3	5	-	* 0.071	3.484	0.000	0.000	0.000
3	6	+	* 0.286	0.794	0.289	0.154	0.083
3	7	+	* 4.622	0.684	0.577	0.500	0.333
3	8	-	* 0.152	1.371	0.000	0.000	0.000
3	9	-	* 0.246	0.684	0.000	0.000	0.000
3	10	-	* 0.152	1.371	0.000	0.000	0.000
3	11	+	* 16.000	3.484	1.000	1.000	1.000
3	12	+	* 4.622	0.684	0.577	0.500	0.333
3	13	+	* 16.000	3.484	1.000	1.000	1.000
3	14	+	* 1.371	0.017	0.378	0.250	0.143
3	15	+	* 1.371	0.017	0.378	0.250	0.143
3	16	-	* 2.347	0.175	0.000	0.000	0.000
4	5	-	* 0.356	0.356	0.000	0.000	0.000
4	6	-	* 0.091	0.253	0.433	0.375	0.231
4	7	-	* 1.231	0.137	0.000	0.000	0.000
4	8	-	* 0.762	0.000	0.000	0.000	0.000
4	9	+	* 0.137	0.137	0.289	0.286	0.167
4	10	+	* 0.762	0.000	0.354	0.333	0.200
4	11	-	* 0.356	0.356	0.000	0.000	0.000
4	12	+	* 0.137	0.137	0.289	0.286	0.167
4	13	-	* 0.356	0.356	0.000	0.000	0.000
4	14	-	* 0.762	0.085	0.189	0.182	0.100
4	15	+-	* 0.085	0.085	0.378	0.364	0.222
4	16	+	* 2.424	0.873	0.603	0.533	0.364

Table SI 5b

SPECIES PAIR		ASSOCIATION (+ OR -)	Chi-Square (* = biased)		Chi-Square (Continuity correction)	-- ASSOCIATION INDICES -- OCHIAI	DICE	JACCAR
5	6	-	*	4.571	0.508	0.000	0.000	0.000
5	7	+	*	4.622	0.684	0.577	0.500	0.333
5	8	-	*	0.152	1.371	0.000	0.000	0.000
5	9	-	*	0.246	0.684	0.000	0.000	0.000
5	10	-	*	0.152	1.371	0.000	0.000	0.000
5	11	-	*	0.071	3.484	0.000	0.000	0.000
5	12	+	*	4.622	0.684	0.577	0.500	0.333
5	13	-	*	0.071	1.371	0.000	0.000	0.000
5	14	-	*	0.830	0.017	0.000	0.000	0.000
5	15	-	*	0.830	0.017	0.000	0.000	0.000
5	16	-	*	2.347	0.175	0.000	0.000	0.000
6	7	-	*	0.444	0.049	0.333	0.267	0.154
6	8	+	*	0.286	0.794	0.289	0.154	0.083
6	9	-	*	0.444	0.049	0.333	0.267	0.154
6	10	+	*	0.615	0.068	0.408	0.286	0.167
6	11	+	*	0.286	0.794	0.289	0.154	0.083
6	12	-	*	0.444	0.049	0.333	0.267	0.154
6	13	+	*	0.286	0.794	0.289	0.154	0.083
6	14	+	*	3.500	1.341	0.764	0.737	0.583
6	15	+	*	0.074	0.206	0.589	0.556	0.385
6	16	+	*	0.000	0.569	0.730	0.727	0.571
7	8	-	*	0.527	0.059	0.000	0.000	0.000
7	9	-	*	0.852	0.011	0.000	0.000	0.000
7	10	-	*	0.356	0.356	0.000	0.000	0.000
7	11	+	*	4.622	0.684	0.577	0.500	0.333
7	12	+	*	5.565	2.367	0.677	0.677	0.500
7	13	+	*	4.622	0.684	0.577	0.500	0.333
7	14	-	*	0.163	0.059	0.218	0.200	0.111
7	15	-	*	0.163	0.059	0.218	0.200	0.111
7	16	-	*	8.123	4.662	0.000	0.000	0.000
8	9	-	*	0.527	0.059	0.000	0.000	0.000
8	10	-	*	0.327	0.327	0.000	0.000	0.000
8	11	-	*	0.152	1.371	0.000	0.000	0.000
8	12	-	*	0.527	0.059	0.000	0.000	0.000
8	13	-	*	0.152	1.371	0.000	0.000	0.000
8	14	+	*	0.036	0.327	0.267	0.222	0.125
8	15	+	*	0.036	0.327	0.267	0.222	0.125
8	16	+	*	1.039	0.042	0.426	0.308	0.182
9	10	+	*	9.905	4.747	0.816	0.800	0.667
9	11	-	*	0.246	0.684	0.000	0.000	0.000
9	12	+	*	0.515	0.011	0.333	0.333	0.200
9	13	-	*	0.246	0.684	0.000	0.000	0.000
9	14	+	*	0.788	0.059	0.436	0.400	0.250
9	15	+	*	4.747	2.351	0.655	0.600	0.429
9	16	+	*	1.678	0.366	0.522	0.429	0.273
10	11	-	*	0.152	1.371	0.000	0.000	0.000
10	12	+	*	1.465	0.059	0.408	0.400	0.250
10	13	-	*	0.152	1.371	0.000	0.000	0.000
10	14	+	*	2.939	0.907	0.535	0.444	0.286
10	15	+	*	2.939	0.907	0.535	0.444	0.286
10	16	+	*	1.039	0.042	0.426	0.308	0.182
11	12	+	*	4.622	0.684	0.577	0.500	0.333
11	13	+	*	16.000	3.484	1.000	1.000	1.000
11	14	+	*	1.371	0.017	0.378	0.250	0.143

Table SI 5c

SPECIES PAIR	ASSOCIATION (+ OR -)	Chi-Square (* = biased)	Chi-Square (Continuity correction)	-- ASSOCIATION INDICES -- OCHIAI	DICE	JACCAR
11 15	+	* 1.371	0.017	0.378	0.250	0.143
11 16		* 2.347	0.175	0.000	0.000	0.000
12 13	+	* 4.622	0.684	0.577	0.500	0.333
12 14	+	* 0.788	0.059	0.436	0.400	0.250
12 15	+	* 0.788	0.059	0.436	0.400	0.250
12 16		* 2.156	0.604	0.174	0.143	0.077
13 14	+	* 1.371	0.017	0.378	0.250	0.143
13 15	+	* 1.371	0.017	0.378	0.250	0.143
13 16		* 2.347	0.175	0.000	0.000	0.000
14 15	+	* 0.907	0.198	0.571	0.571	0.400
14 16	+	* 0.042	0.115	0.570	0.556	0.385
15 16	+	* 1.667	0.559	0.684	0.667	0.500

NOTE: Chi-Square values are considered BIASED if:

1. The EXPECTED FREQ of ANY cell in 2X2 TABLE < 1 and/or
2. The EXPECTED FREQ of MORE than 2 CELLS < 5 (Zar 1984)

Table SI 6

I N T E R A C T I V E B A S I C P R O G R A .M
S P D I V E R S - BAS

THIS PROGRAM COMPUTES:

1. RICHNESS INDICES
   Margalef R1
   Menhinick R2
2. DIVERSITY INDICES
   Hill's Numbers NO, N1, N2
   Simpson's Index Lambda
   Shannon's Index H'
3. EVENNESS INDICES
   EI-E5,

$$\mathbf{E1} = \frac{H'}{\ln(S)} = \frac{\ln(N1)}{\ln(N0)} \quad \mathbf{E2} = \frac{e^{H'}}{S} = \frac{N1}{N0} \quad \mathbf{E3} = \frac{e^{H'} - 1}{S-1} = \frac{N1-1}{N0-1} \quad \mathbf{E4} = \frac{1/\lambda}{e^{H'}} = \frac{N2}{N1} \quad \mathbf{E5} = \frac{(1/\lambda) - 1}{e^{H'}} = \frac{N2-1}{N1-1}$$

$$\mathbf{R1} = \frac{S-1}{\ln(n)} \qquad \mathbf{NO} = S \qquad \lambda = \sum_{i=1}^{s} p_i^2 \qquad \mathbf{H'} = -\sum_{i=1}^{s} \left[\left(\frac{ni}{n}\right) \ln\left(\frac{ni}{n}\right)\right]$$

$$\mathbf{R2} = \frac{S}{\sqrt{n}} \qquad \mathbf{N1} = e^{H'}$$

$$\mathbf{N2} = 1/\lambda$$

S=total number of species in a community
n=total number of individuals observed
p_i=proportional abundance of the ith species

PART I. DATA ENTRY-

This program utilizes abundance data (e.g., # of individuals, biomass, percent cover, etc.) of S species in a sample e.g., trees in a plot, fish in a catch, insects in a light trap, etc.

Data INPUT options:
Option 1- Data already exists in a STORED data file
Option 2- Data is to be manually entered from keyboard (and subsequently STORED, if desired)

Table SI 7

```
LISTING OF THE DATA SET.
   19
   33
   2
   42
   1
   29
   5
   2
   28
```

COMPUTATION OF INDICES

RICHNESS

NO = 9
R1 = 1.574368
R2 = .7092994

DIVERSITY

LAMBDA = .1829192
H` = 1.788955
N1 = 5.983198
N2 = 5.466894

EVENNESS

El = .8141887
E2 = .6647998
E3 = .6228998
E4 = .9137076
E5 = .8963909

```
LISTING OF THE DATA SET.
   8
   6
   1
   4
   4
   66
   30
   20
   31
   3
   4
   7
   20
   59
   47
```

RICHNESS

NO = i5
R1 = 2.440482
R2 = .8519427

DIVERSITY

LAMBDA = .1315795
H` = 2.229132
N1 = 9.291797
N2 = 7.599968

EVENNESS

El = .8231501
E2 = .6194531
E3 = .5922712
E4 = .8179224
E5 = .7959635

Table SI 8

COMPUTATION OF INDICES

<u>RICHNESS</u>

NO = 16

R1 = 2.437099

R2 = .7372411

DIVERSITY

LAMBDA = .1255997

H` = 2.268382

N1 = 9.663751

N2 = 7.961804

EVENNESS

El = .8181457

E2 = .6039845

E3 = .5775834

E4 = .8238834

E5 = .8035554

Table P 1. Locke Brook at Mail Road brook trout population estimate, O8/02/02

Population estimation using removal- depletion, maximum likelihood method ZIPPIN
From: Zippin, C. 1958. J. Wildl. Mgt. 22(1):82-90.

INPUT DATA

Removal Period	Number Removed
1	4
2	2
3	1

RESULTS OF ANALYSIS

Removal periods	3
Total removals-	7
Population estimate, N*	7
Standard error of N*	0.8690787
Capture probability, P(c)	0.636
Standard error of P(c)	0.2173
Asymptotic confidence interval for N*:	
Lower asymptotic 95% conf. limit	7
Upper asymptotic 95% conf. limit.	8.703394
Asymptotic confidence interval for P(c):	
Lower asymptotic 95% conf. limit	0.211
Upper asymptotic 95% conf. limit	1.062
For Ho: P(c) is constant,	
Chi-square statistic (d.f.= 2)	* 0.439

* NOTE: Rejection of Ho indicates violation of assumptions.

Estimated population in numbers per acre: 467-580

Estimated standing stock in pounds per acre: 47-58

Table P 2. Locke Brook
Atlantic salmon population estimate, 08/02/02

Population estimation using removal- depletion, maximum likelihood method ZIPPIN
From: Zippin, C. 1958. J. Wildl. Mgt. 22(1):82-90.

INPUT DATA

Removal Period	Number Removed
1	18
2	6
3	6

RESULTS OF ANALYSIS

Removal periods	3
Total removals	30
Population estimate, N*	33
Standard error of N*	3.618943
Capture probability, P(c)	0.526
Standard error of P(c)	0.1218

Asymptotic confidence interval for N*:

Lower asymptotic 95% conf. limit	30
Upper asymptotic 95% conf. limit	40.09313

Asymptotic confidence interval for P(c):

Lower asymptotic 95% conf. limit	0.287
Upper asymptotic 95% conf. limit	0.765

For Ho: P(c) is constant,

Chi-square statistic (d.f.= 2) * 1.769

* NOTE: Rejection of Ho indicates violation of assumptions.

Estimated population in numbers per acre:	2000-2667 I
Estimated standing stock in pounds per acre:	100-133

Figure P 1

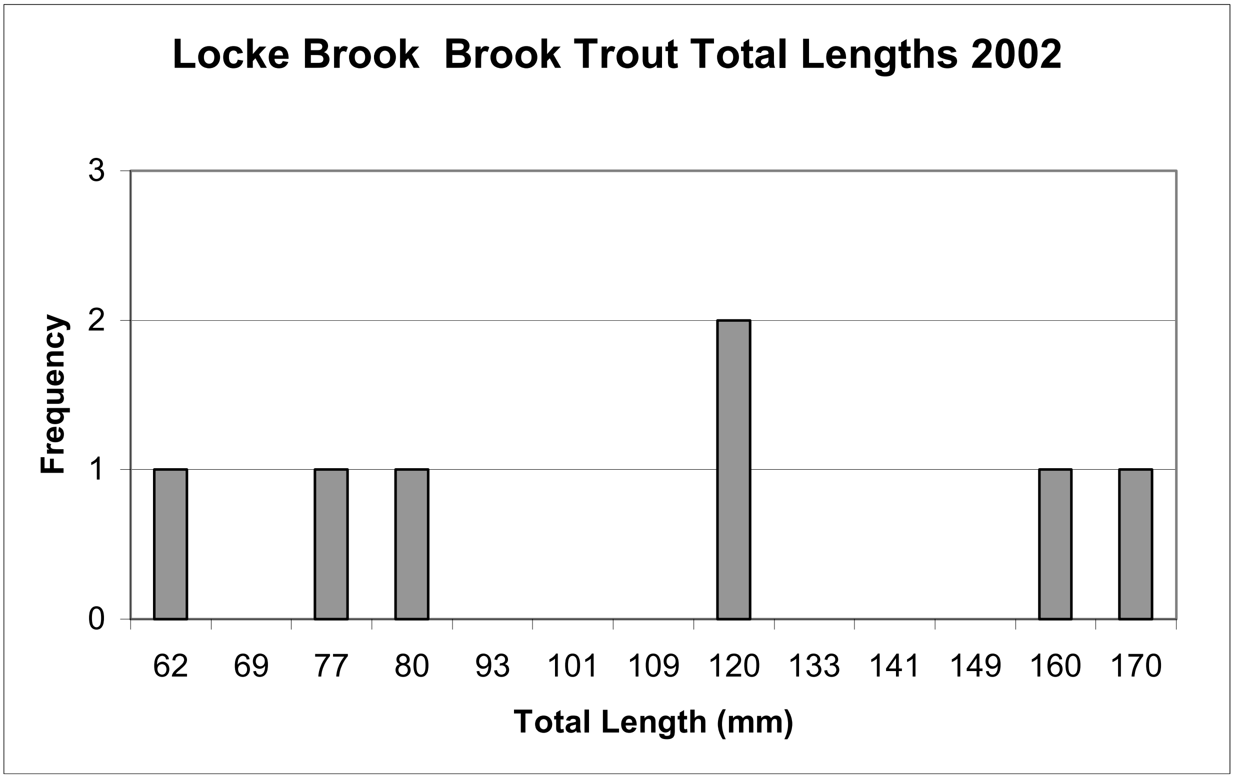

Figure P 2

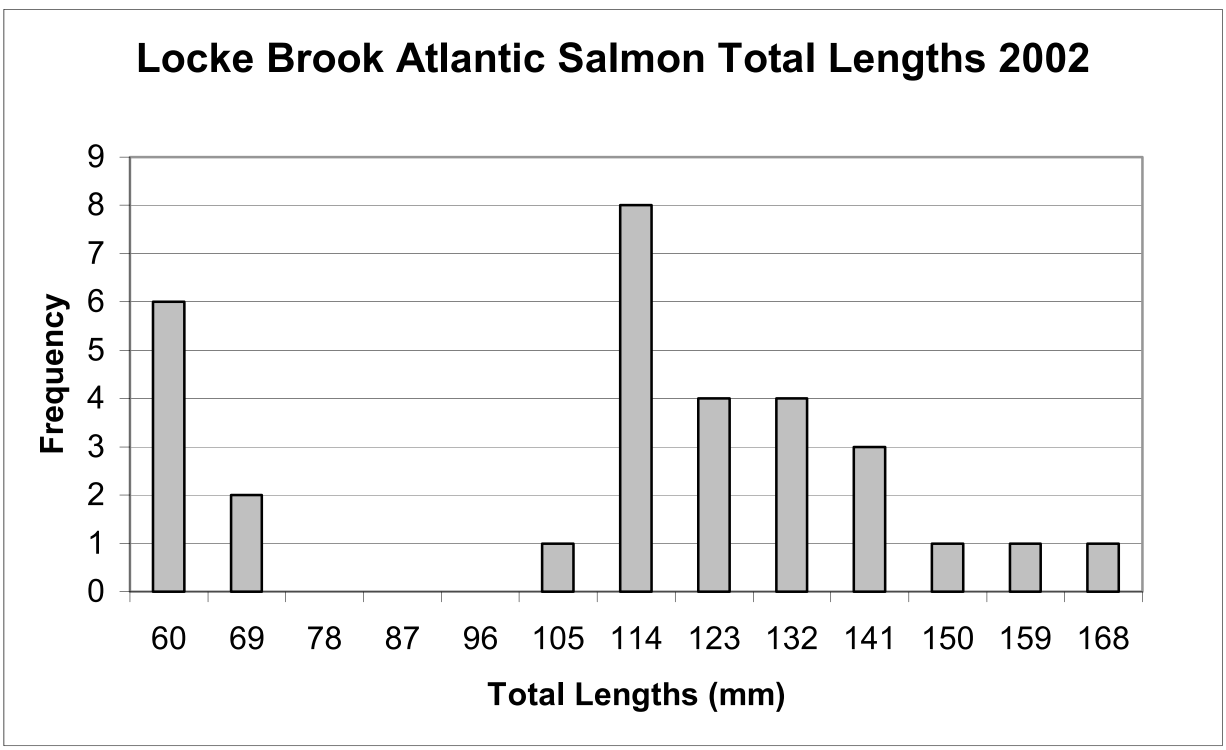

Table P 3. Beaver River at Punch Bowl Trail brook trout population estimate, O8/22/02

Population estimation using removal- depletion, maximum likelihood method ZIPPIN
From: Zippin, C. 1958. J. Wildl. Mgt. 22(1):82-90.

INPUT DATA

Removal Period	Number Removed
1	9
2	5
3	3

RESULTS OF ANALYSIS

Removal periods	3
Total removals-	17
Population estimate, N*	19
Standard error of N*	3.198558
Capture probability, P(c)	0.500
Standard error of P(c)	0.1683
Asymptotic confidence interval for N*:	
Lower asymptotic 95% conf. limit	17
Upper asymptotic 95% conf. limit.	25.26917
Asymptotic confidence interval for P(c):	
Lower asymptotic 95% conf. limit	0.170
Upper asymptotic 95% conf. limit	0.830
For Ho: P(c) is constant,	
Chi-square statistic (d.f.= 2)	* 0.212

* NOTE: Rejection of Ho indicates violation of assumptions.

Estimated population in numbers per acre:	680-1000
Estimated standing stock in pounds per acre:	68-100

Table P 4. Breakheart Brook, Foot Bridge brook trout population estimate, O8/28/02

Population estimation using removal- depletion, maximum likelihood method ZIPPIN
From: Zippin, C. 1958. J. Wildl. Mgt. 22(1):82-90.

INPUT DATA

Removal Period	Number Removed
1	19
2	11
3	3

RESULTS OF ANALYSIS

Removal periods	3
Total removals-	33
Population estimate, N*	35
Standard error of N*	2.580053
Capture probability, P(c)	0.589
Standard error of P(c)	0.1058
Asymptotic confidence interval for N*:	
Lower asymptotic 95% conf. limit	33
Upper asymptotic 95% conf. limit.	40.05691
Asymptotic confidence interval for P(c):	
Lower asymptotic 95% conf. limit	0.382
Upper asymptotic 95% conf. limit	0.797
For Ho: P(c) is constant,	
Chi-square statistic (d.f.= 2)	* 0.955

* NOTE: Rejection of Ho indicates violation of assumptions.

Estimated population in numbers per acre: 2200-2667

Estimated standing stock in pounds per acre: 220-267

Table P 5. Brushy Brook at Saw Mill Road brook trout population estimate, O9/05/02

Population estimation using removal- depletion, maximum likelihood method ZIPPIN
From: Zippin, C. 1958. J. Wildl. Mgt. 22(1):82-90.

INPUT DATA

Removal Period	Number Removed
1	9
2	6
3	5

RESULTS OF ANALYSIS

Removal periods	3
Total removals-	20
Population estimate, N*	27
Standard error of N*	9.385964
Capture probability, P(c)	0.351
Standard error of P(c)	0.18979
Asymptotic confidence interval for N*:	
Lower asymptotic 95% conf. limit	20
Upper asymptotic 95% conf. limit.	45.39649
Asymptotic confidence interval for P(c):	
Lower asymptotic 95% conf. limit	0.000
Upper asymptotic 95% conf. limit	0.719
For Ho: P(c) is constant,	
Chi-square statistic (d.f.= 2)	* 0.289

* NOTE: Rejection of Ho indicates violation of assumptions.

Estimated population in numbers per acre: 1667-2750

Estimated standing stock in pounds per acre: 167-275

Table P 6. Canochet Brook, above Lindbrook Golf Course; fall fish population estimate, O9/20/02

Population estimation using removal- depletion, maximum likelihood method ZIPPIN
From: Zippin, C. 1958. J. Wildl. Mgt. 22(1):82-90.

INPUT DATA

Removal Period	Number Removed
1	21
2	6
3	3

RESULTS OF ANALYSIS

Removal periods	3
Total removals-	30
Population estimate, N*	30
Standard error of N*	**1**.086362
Capture probability, P(c)	0.714
Standard error of P(c)	0.0905
Asymptotic confidence interval for N*:	
Lower asymptotic 95% conf. limit	30
Upper asymptotic 95% conf. limit.	32.12927
Asymptotic confidence interval for P(c):	
Lower asymptotic 95% conf. limit	0.537
Upper asymptotic 95% conf. limit	0.892
For Ho: P(c) is constant,	
Chi-square statistic (d.f.= 2)	* 0.922

* NOTE: Rejection of Ho indicates violation of assumptions.

Estimated population in numbers per acre: 600-640

Estimated standing stock in pounds per acre: 60-64

Table P 7. Canochet Brook, below Lindbrook Golf Course; redfin pickerel population estimate, O9/20/02

Population estimation using removal- depletion, maximum likelihood method ZIPPIN
From: Zippin, C. 1958. J. Wildl. Mgt. 22(1):82-90.

INPUT DATA

Removal Period	Number Removed
1	6
2	1
3	3

RESULTS OF ANALYSIS

Removal periods	3
Total removals-	10
Population estimate, N*	11
Standard error of N*	2.433737
Capture probability, P(c)	0.500
Standard error of P(c)	0.2212
Asymptotic confidence interval for N*:	
Lower asymptotic 95% conf. limit	10
Upper asymptotic 95% conf. limit.	15.77013
Asymptotic confidence interval for P(c):	
Lower asymptotic 95% conf. limit	0.066
Upper asymptotic 95% conf. limit	0.934
For Ho: P(c) is constant,	
Chi-square statistic (d.f.= 2)	* 3.094

* NOTE: Rejection of Ho indicates violation of assumptions.

Estimated population in numbers per acre: 625-1000

Estimated standing stock in pounds per acre: 31-50

Table H 1.

Top panel- Raw Data consisting of the nine habitat variables examined in 2002. ..

Lower panel- Standardized form for the nine habitat variables.

The nine variables are: stream width (feet), percent shelter, percent vegetative cover, percent pool area, percent sand and gravel, percent silt and vegetation, percent cobble and boulders, stream velocity (cfs), and average water depth (ft).

CASE	SWIDTH	SHELTER	VEGCOV	POOLA	SANDGR	SILTVEG	COBBOL	VELOC	DEPTH
1	10.5	10	90	30	85	10	5	0.6	0.5
2	10	15	70	1	30	1	70	2.6	0.3
3	15	15	70	30	85	15	1	1.3	0.6
4	11.1	10	80	20	45	50	50	1.2	0.6
5	16	10	90	1	20	1	80	1.2	0.5
6	16	15	80	15	15	1	85	1.5	0.4
7	15	40	60	50	85	5	10	2.5	1.2
8	13.5	40	75	15	50	1	50	2.5	1
9	11	15	85	10	40	1	60	1.6	1.1
10	5	25	10	40	45	15	40	0.14	0.61
11	8	30	95	20	15	10	55	1.6	0.4
12	6.5	20	90	1	40	0	60	1.5	0.5
13	13	15	70	15	35	40	25	0.9	1
14	7	10	50	25	80	15	5	1.4	0.5
15	9	30	90	60	60	10	30	1.5	0.5
16	10	20	90	20	25	70	5	1.6	1

CASE	NSWIDTH	NSHELTER	NVEGCOV	NPOOLA	NSANDGR	NSILTVEG	NCOBBOL	NVELOC	NDEPTH
1	-0.155130 -	0.854637	0.7395786	0.2652374	1.4998748	-0.145475	-1.208211	-1.475783	-0.5825
2	-0.299572	-0.557372	-0.787372	-1.003631	-0.795617	-0.669188	1.1143786	1.4684234	-1.296785
3	1.1448463	-0.557372	-0.787372	0.2652374	1.4998748	0.1454757	-1.351139	-0.445311	-0.225357
4	0.0181997	-0.854637	-0.023896	-0.172303	-0.169574	-0.436427	0.3997356	-0.592521	-0.225357
5	1.4337301	-0.854637	0.7395786	-1.003631	-1.21298	-0.669188	1.4717001	-0.592521	-0.5825
6	1.4337301	0.0371581	-0.787372	-0.391074	-1.421661	-0.669188	1.6503609	-0.150890	-0.939642
7	1.1448463	0.9289536	-1.550847	0.2652374	1.4998748	-0.436427	-1.029550	1.321213	1.91758
	0.7115207	0.9289536	-0.405634	-0.391074	0.0391068	-0.669188	0.3997356	1.321213	1.2032143
9	-0.010688	-0.557372	0.3578409	-0.609844	-0.378255 -	0.669188	0.7570571	-0.003680	1.5603571
10	-1.743991	0.0371581	0.7395786	2.8904835	-0.169574	0.1454757	0.0424141	-2.152951	-0.189642
11	-0.87734	0.3344233	1.1213162	-0.172303	0.247788	-0,145475 -	-0.136246	-0.003680	-0.939642
12	-1.310665	-0.260107	0.7395786	-1.003631 -	0.795617	-0.145475	0.7570571	-0.150890	-0.5825
13	0.5670788	3.0098098	0.7395786	-0.391074	-0.586936	1.0183299	-0.136246	0.4379508	0.8460714
14	-1.166223	-0.854637	-2.314322	0.0464669	1.2911937	0.1454757	-1.208211	1.1740026	-0.5825
15	0.588456	0.3344233	0.7395786	1.5778604	0.4564691	-0.145475	-0.314907	-00150890	-0.5825
16	-0.299572	-0.260107	0.7395786	-00172303	-1.004298	3.3459412	-1.208211	-0.003680	1.2032143

Table H 2.

Top panel- Summary statistics for the nine habitat variables.
Lower panel-Spearman rank correlations and Probability values.

	COBBOL	POOLA	SANDGR	DEPTH	SHELTER
N	16	16	16	16	16
MEAN .	38813	23.938	49.063	0.663	24.357
SD	27.986	22.855	23.960	0.2800	282.92
VARIANCE	783.23	522.23	574.06	0.0784	282.92
SE MEAN	6.9966	5.7136	5.9899	0.0700	4.2050
C.V.	72.106	95.476	48.835	42.230	69.006
MINIMUM	1.0000	1.0000	15.000	0.3000	10.000
MAXIMUM	85.000	90.000	85.000	1.2000	75.000

	SILTVEG	SWIDTH	VEGCOV	VELOC
N	16	16	16	16
MEAN	12.500	11.037	80.313	1.6025
SD	17.185	3.46 1	3.098	0.6793
VARIANCE.	295.33	11.982	171.56	0.4614
SE MEAN	4.2963	0.8654	3.2745	0 1698..
CV	137.48	31.362	16.309	42.389
MINIMUM	10000	5.0000	50.000	0.1400
MAXIMUM.	70.000	16.000	95.000	2.6000

SPEARMAN RANK CORRELATIONS, CORRECTED FOR TIES

	SWIDTH	SHELTER	VEGCOV	POOLA	SANDGR	SILTVEG	COBBOL
SHELTER	0.0388						
P-VALUE	0.8824						
VEGCOV -	0.3643	0.1561					
	0.1653	0.5560					
POOLA	-0.2312	0.1252	-0.0125				
	0.3852	0.6406	0.9694				
SANDGR -	0.1221	0.0262	-0.2088	0.7250			
	0.6485	0.9171	0.4363	0.0020			
SILTVEG	-0.4563	0.1163	0.2894	0.5241	0.2624		
	0.0779	0.6644	0.2731	0.0385	0.3207		
COBBOL	0.2044	-0.0135	0.0294	-0.7360	-0.7424	-0.7475	
	0.4430	0.9607	0.9084	0.0017	0.0014	0.0013	
VELOC	0.0445	0.4159	-0.4360	-0.3208	0.0067	-0.1582	0.0074
	0.8651	0.1089	0.0936	0.2257	0.9781	0.5560	0.9781
DEPTH	0.2017	0.3010	-0.1018	0.2089	0.2006	0.1813	-0.2955
	0.4496	0.2534	0.7049	0.4297	0.4496	0.4979	0.2631

	VELOC
DEPTH	0.1387
P-VALUE	0.6015

MAXIMUM DIFFERENCE ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 16 MISSING CASES 0