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SELECTING GROUPS OF FISH TO OPTIMIZE ACQUISITION OF INFORMATION ON THERMAL DISCHARGES[1]

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ABSTRACT: A national trend over the last 25 years has been to require increasing amounts of biological information on industrial waste discharges. Acquisition of this essential information frequently involves complex assessments. In order to optimize the value of information gathered and to minimize the cost of this information, it is essential that analyses of redundancy be accompanied by the determination of which groups of organisms give the most information relative to a particular problem. Studies of the effect of temperature on the fishes of the New River, Glen Lyn, Virginia, provide us with the opportunity to evaluate the redundancy of information relative to the influence of temperature on fish distribution. Information of this type will be useful in selecting groups of organisms for laboratory temperature preference and avoidance tests. It was shown that the distribution of three genera (*Notropis, Micropterus,* and *Etheostoma*) had the highest correlation with the distribution of the total fish fauna and, therefore, provided the most information relative to temperature selection of the New River ichthyofauna. The final temperature preferences of the most abundant species of *Notropis* and *Micropterus* were representative of the response of the entire fish community based on the distribution of diversity indices relative to temperature.
(KEY TERMS: thermal discharges; optimizing data acquisition.)

INTRODUCTION

In the United States, the effects of most industrial waste discharges upon the aquatic environments were not assessed to any significant degree until after World War II. The few tests that were performed dealt mainly with chemical or physical properties, and in many cases the only "biological" test was the biochemical oxygen demand (B.O.D.). From the late 1950's to the late 1960's, some industries did simple bioassays to test the effects of their wastes on aquatic organisms, and a small number conducted comprehensive ecological surveys on the receiving systems into which the wastes were discharged. More recently pressure has increased for more extensive tests on the effects of waste discharges on the biota of the receiving systems. The response to this pressure was uneven, with some industries making extensive and comprehensive tests and with others resisting to the point of doing virtually nothing. The burden of proof during this time shifted from a requirement that the regulatory agency prove harm to a proof of no harm based on a substantial body of evidence gathered at the expense of the discharger. An early example of this trend was the Ontario Law (Ontario Water Resources Commission, pg. 9, item 1, 1970); more recent examples are the publication of *The Principles for Evaluating Chemicals in the Environment* (National Academy of Sciences, 1975), and the enactment of PL92-500. Thus, the trend is toward requiring more information. The rationale is fairly straightforward: (1) it is clear that the ecological evidence upon which predictions of environmental protection were based was entirely inadequate, with a few notable exceptions; (2) pressures on finite ecosystems increased as the industrial base and population expanded; (3) the accelerated rate at which new technologies and chemicals were produced and utilized was unaccompanied by a comparable development in our ability to predict their ecological effects; (4) some public opinion polls (e.g., Gallup) have ascertained that the public is willing to pay more for improved environmental protection and environmental quality, although there are upper cost limits; and (5) the energy crisis, which severely restricts travel, has made "close to home" recreation increasingly important.

The trend toward requiring increasingly complex and comprehensive information has been thwarted, at least as far as implementation is concerned, by three major blocks: (1) the shortage of professional personnel and well trained technicians, (2) an economic recession, and (3) an understandable resistance by industry and other dischargers to comply with demands for an apparently never ending increase in comprehensive information related to environmental protection.

The need for this information has been intensified with the introduction of the Environmental Protection Agency's (1973) concept of important species. The EPA (1973) defined important species as: (1) important commercial or sport fishes, (2) abundant forage fishes, and (3) rare and endangered species. Although this concept is biologically sound, it may also be appropriate to examine species which most closely mimic the response of the total fish community.

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The academic community can make a constructive contribution to this situation in three ways: (1) training the necessary personnel, (2) developing a series of protocols so that dischargers can have definite schedules of required tests and guidelines that elucidate when further testing or information is not required, and (3) an evaluation of the redundancy of information in the assessments now being carried out and an identification of those tests and groups of organisms which furnish the most useful information. Where particular genera or species of organisms can be collected selectively, eliminating redundant information may reduce the cost of environmental assessment as well as the time required. In other situations when information must be generated in the laboratory, the knowledge of which groups give the most information can be used to select test organisms. This paper addresses the latter problem and is based on the assumption that for a particular waste discharge into a particular type of ecosystem some organisms furnish more useful information than others. This strategy was employed by Kaesler, *et al.* (1974). The goal has not been to find indicator species in the customary sense (i.e., that they indicate *pollution*) but rather to identify for a certain type of waste discharge into a particular type of ecosystem, in this case heated waste water into a river, certain groups of organisms and certain species within these groups which furnish more useful information than others. The words *indicator species* would be appropriate in this context were it not for the much earlier usage which has been interpreted by a substantial number of persons to mean indicators of all forms of pollution. The "indicator groups or species" identified in this paper have a much more specific and limited capability although it is highly probable that the concept can be extended to comparable ecosystems and discharges elsewhere. More importantly, it is hoped that the process can be used in other ecosystems to reduce the amount of data gathering necessary to acquire definitive information.

It is important to note that this paper was not designed to disparage the ecological value of any species or higher taxonomic group, nor to indicate that they may not be as useful as other groups in other situations to analyze the effects of other types of discharges. In this specific situation, however, some fish taxa did furnish more useful information than others. Fish were used because appropriate data were available, but there is no reason to assume that taxonomically dissimilar species, for example, a protozoan and a fish, might not furnish quite similar information.

The academic community should feel the responsibility for making analyses of the cost effectiveness of assessment methods it has developed as compelling as the responsibility to identify problems created by waste discharges.

MATERIALS AND METHODS

Rotenone was used in conjunction with a block net to sample pool and riffle habitats on the New River, Glen Lyn, Virginia (Hocutt, 1973), from May 1972 to October 1974. A complete description of the sampling stations and the heated discharge was given by Stauffer, *et al.* (1974). A total of 25 samples was collected in water temperatures which ranged from 20.5°C-35.5°C. For each sample a section of water within a certain temperature range was delimited by a block net and then rotenone applied.

Series of matrices were computed in the Q-mode to show similarities and differences among the 25 samples based on abundances of groups of fish (Table 1) (Sneath and Sokal, 1973). Some of these matrices were compared with each other by computing a product-moment correlation coefficient between them using corresponding pairs of elements of the matrices as data (Kaesler, *et al.*, 1974). High correlation coefficients between two matrices indicated that the organisms on which the matrices were based have similar distributions among the stations sampled.

TABLE 1. Groups of Organisms for Which Q-Mode Correlation and Distance Matrices Were Computed.

Taxon or Group of Organisms	Number of Species
All Fish	47
Cyprinidae (minnows)	24
Notropis	10
Pimephales	2
Nocomis	2
Centrarchidae (sunfishes)	9
Lepomis	4
Micropterus	3
Percidae (perches)	6
Etheostoma	3
Percina	3
Combined *Notropis, Micropterus,* and *Etheostoma*	16

In addition, Q-mode cluster analyses were performed on key matrices using the unweighted pair group method with arithmetic averages (UPGMA). The amount of distortion introduced during clustering was measured by computing coefficients of cophenetic correlation (Sneath and Sokal, 1973).

RESULTS AND DISCUSSION

Tables 2 and 3 contain the correlation coefficients that show the similarities in distribution between the various groups of fish. The distributions of *Notropis, Micropterus,* and *Etheostoma* have the highest correlations with the distribution of the total fish fauna, being, respectively, 0.460, 0.342, and 0.345 (Table 3). Individually, none of these genera was a particularly good indicator of the distribution of the total fish fauna, but combined they had a correlation of 0.635. It seems likely that experimentation with these three genera alone, representing three different families, could provide a reasonable approximation to the distribution of the total fish fauna. Correlations between distance matrices (Table 3) showed essentially the same pattern, except that *Percina* was more

TABLE 2. Correlation Coefficients Computed Between Corresponding Elements of Matrices of Q-Mode Correlation Coefficients. *Combined* refers to *Notropis*, *Micropterus*, and *Etheostoma* computed together.

	Total	Cyprinidae (minnows)	*Notropis*	*Pimephales*	*Rhinichthys*	*Nocomis*	Centrarchidae (sunfishes)	*Lepomis*	*Micropterus*	Percidae (perches)	*Etheostoma*	*Percina*	Combined
Total	– –												
Cyprinidae (minnows)	0.640	– –											
Notropis	0.460	0.680	– –										
Pimephales	0.181	0.331	0.271	– –									
Rhinichthys	0.099	0.144	–0.007	–0.027	– –								
Nocomis	0.165	0.207	–0.036	–0.026	0.162	– –							
Centrarchidae (sunfishes)	0.463	0.007					– –						
Lepomis	0.219						0.265	– –					
Micropterus	0.342		–0.013				0.691	–0.002	– – –				
Percidae (perches)	0.354	0.003					0.303			– –			
Etheostoma	0.345		–0.036						0.391	0.830	– –		
Percina	0.218									0.751	0.440	– –	
Combined	0.635		0.546						0.565		0.426		– –

TABLE 3. Correlation Coefficients Computed Between Corresponding Elements of Matrices of Q-Mode Distance Coefficients.

	Total	Cyprinidae (minnows)	*Notropis*	*Pimephales*	*Rhinichthys*	*Nocomis*	Centrarchidae (sunfishes)	*Lepomis*	*Micropterus*	Percidae (perches)	*Etheostoma*	*Percina*	Combined
Total	– –												
Cyrpinidae (minnows)	0.878	– –											
Notropis	0.577	0.883	– –										
Pimephales	0.448	0.472	0.241	– –									
Rhinichthys	0.379	0.405	0.077	0.018	– –								
Nocomis	0.577	0.619	0.246	0.720	0.300	– –							
Centrarchidae (sunfishes)	0.648	0.337					– –						
Lepomis	0.551						0.895	– –					
Micropterus	0.585		0.138				0.763	0.481	– –				
Percidae (perches)	0.467	0.270					0.091			– –			
Etheostoma	0.381		–0.047						0.111	0.942	– –		
Percina	0.474									0.939	0.779	– –	
Combined	0.847		0.800						0.520		0.398		– –

representative than *Etheostoma,* and *Nocomis* was as good an indicator as *Notropis.*

Many of the correlation coefficients in both tables were close to zero, suggesting that the genera so correlated were independent of each other in their distributions. Other genera were highly correlated in their distribution with the distribution of their families. It is perhaps noteworthy that in Table 2 Cyprinidae have very low correlations with both Centrarchidae and Percidae although they are somewhat higher in Table 3. Perhaps these families were more or less independent in their distributions. If so, it could account for the fact that no single genus could be found whose distribution was representative of the entire fish fauna and, therefore, genera from each family had to be combined to give a good representation.

Interpretation of these correlation coefficients was hampered by the fact that they cannot be tested for statistical significance because the data do not meet the assumptions of the parametric test. Moreover, the great differences in the number of species accounted for much of the disparity among correlation coefficients. It is not surprising, for example, that the Cyprinidae had a high correlation with the total fish fauna (0.640 and 0.878), given the fact that they comprised more than half of the species in the study.

The dendrograms in Figures 1 and 2 show cluster analyses of two of the matrices referred to in Tables 2 and 3. Figure 1 was computed from the Q-mode matrices of correlation coefficients for the total fish fauna. Figure 2 shows dendrograms from Q-mode cluster analysis using only *Notropis, Micropterus,* and *Etheostoma* and should be compared with Figure 1. In dendrograms based on correlation coefficients, samples from the same stations were quite often grouped together, but had very low similarities. From these data we hypothesized that one can gain a good understanding of the distribution of fish relative to heated discharges in this portion of the New River by studying only *Notropis, Micropterus,* and *Etheostoma.*

Although with fishes it is exceedingly difficult to collect quantitively only three genera thereby eliminating redundancy, the data generated by this analysis could be applied to selecting species for laboratory work. Cherry, *et al.* (1975), and Stauffer, *et al.* (1975), conducted temperature preference studies on *Notropis rubellus, N. spilopterus, Micropterus dolomieui,* and *M. punctulatus* collected at the Glen Lyn, Virginia, site. These studies showed the final temperature preference of *Notropis rubellus* was 28.8°C; *N. spilopterus,* 29.8°C; *Micropterus dolomieui,* 28.3°C; and *M. punctulatus,* 30°C. *Etheostoma* and *Percina* species did not respond to their test chambers. Stauffer (1975) found that the fish community exhibited the highest diversity index at 26.7°C in 1973 and at 27.8°C in 1974.

These results indicate that the final temperature preference of selected fish species were representative of how the fish community reacted to the thermal discharge. This does not mean that laboratory studies on other fish species are not important, but that this method may be used to aid in the selection of test organisms when time and money are limited. Special consideration must also be given to rare and endangered species. It should be noted that species within the same genus may respond differently to an environmental parameter. Therefore, we do not propose that these techniques replace existing criteria for selecting test organisms, but we feel that when quantitative field data are available, cluster analysis can provide valuable insight into the selection of test species for continuous biological monitoring or other on-going programs that preclude examining all species.

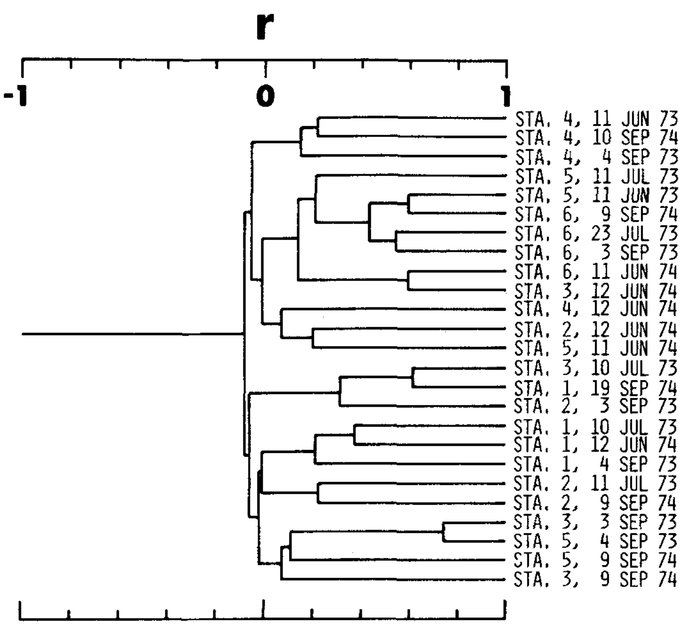

Figure 1. Dendrogram Prepared From Q-Mode Cluster Analysis (UPGMA) of a Matrix of Product-Moment Correlation Coefficients Showing Correlations Among Samples on the Basis of all 47 Species of Fish Collected; r_{cc} = 0.730.

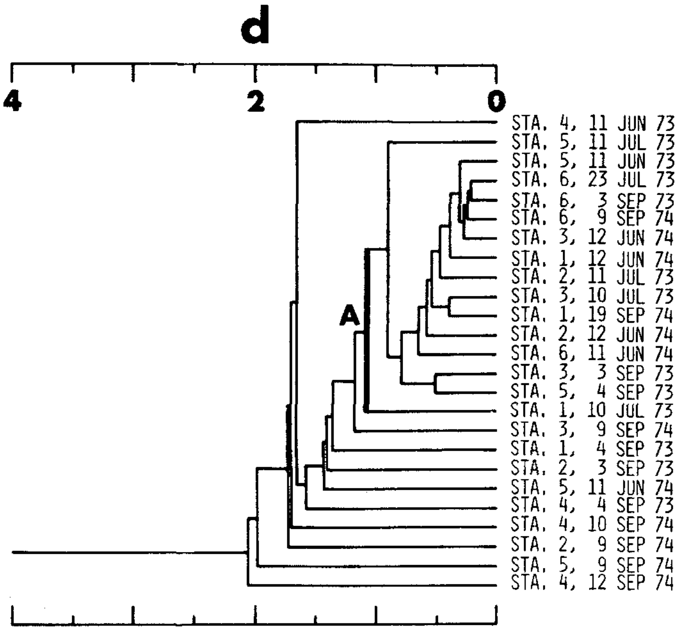

Figure 2. Dendrogram Prepared From Q-Mode Cluster Analysis (UPGMA) of a Matrix of Product-Moment Correlation Coefficients Showing Correlations Among Samples on the Basis of 16 Species of *Notropis, Micropterus,* and *Etheostoma* Collected; r_{cc} = 0.794.

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