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**TECHNICAL REPORT E-83-14**

**EVALUATING CHANGES IN DIKE  
FIELD FISHES WITH COMMUNITY  
INFORMATION INDICES**

by

**Harry N. Polovino, Michael P. Farrell**

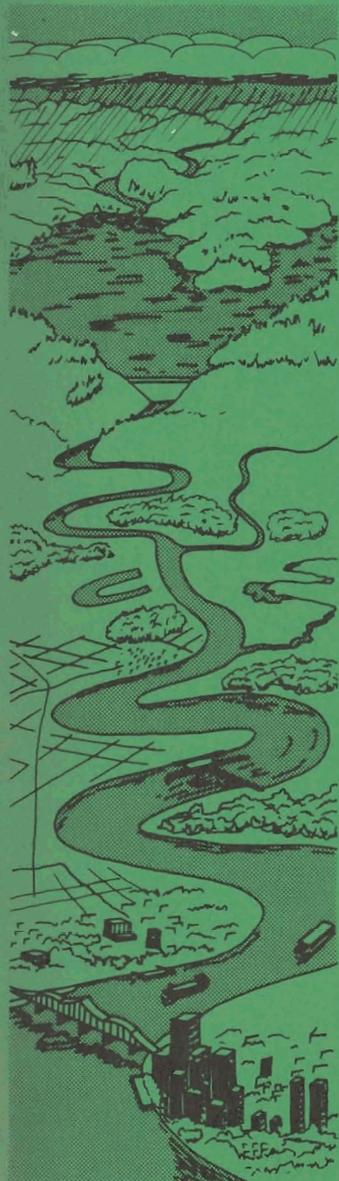
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for delineating community composition that may be more sensitive to sampling error.

This study evaluates the relative performance of (1) binary similarity coefficients, (2) dissimilarity measures, and (3) diversity indices, calculated for three sampling methods, in detecting changes in fish communities associated with two dike fields on the Mississippi River. Dike field fish communities were sampled and evaluated for five hydrologic seasons, based on water temperature and flow velocities, and were found to be least similar during high-water low-temperature conditions. During the evaluation, the information derived from electroshocking was the most representative when compared with hoop net and seine information. Of the three families of community information measures, binary similarity coefficients proved to be the most sensitive indicators of change in dike field fish communities. It was further found that measures based on species presence/absence represent a valid alternative method for characterizing change in community structure. This is especially true when species abundance data are highly variable, which is the case in many fisheries assessments.

## PREFACE

The study described in this report was sponsored by the Office, Chief of Engineers, U. S. Army, under the Environmental and Water Quality Operational Studies (EWQOS) Program, Work Unit VIIB, Waterway Field Studies. The EWQOS Program has been assigned to the U. S. Army Engineer Waterways Experiment Station (WES) under the direction of the Environmental Laboratory (EL). This project was conducted from April 1979 through September 1980. The research data base was managed by the Environmental Metrics Group, Oak Ridge National Laboratory (ORNL), under Intra-Army Order No. WESRF 81-95. Drs. J. C. Goyert and R. H. Strand and Ms. K. L. Daniels and D. Tidwell of the ORNL were instrumental in the successful completion of the report. Mr. M. E. Potter and Ms. C. L. Bond contributed toward field data collection.

This report was prepared by Mr. H. N. Polovino and Dr. M. P. Farrell, ORNL, and by Dr. C. H. Pennington under the supervision of Dr. T. D. Wright, Chief, Aquatic Habitat Group, and under the general supervision of Mr. B. O. Benn, Chief, Environmental Systems Division, and Dr. John Harrison, Chief, EL. Dr. J. L. Mahloch was Program Manager of EWQOS.

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EVALUATING CHANGES IN DIKE FIELD FISHES WITH  
COMMUNITY INFORMATION INDICES

PART I: INTRODUCTION

The General Problem

1. Researchers characterizing and comparing ecological communities are often faced with the problem of selecting an index or measure that is a reliable estimate of community composition. Historically, species diversity measures have been employed to collapse large species lists into single numerical expressions. Species diversity is usually defined as a function of the number of species (i.e. species richness) and the distribution of individuals with respect to the total number of species (i.e. species evenness or equitability) in a sample (Margalef 1958, Lloyd and Ghelardi 1964, Pielou 1969). The primary motivation for calculating species diversity indices based on richness or abundance is twofold: (a) the observation that samples containing equal numbers of species and individuals are seldom if ever identical and (b) the need to produce a single number that can characterize a large and diverse set of ecological data for comparative purposes (Hurlbert 1971).

2. Since the species diversity concept was conceived by Fisher, Corbett, and Williams (1943), diversity indices have been utilized to explain and interpret patterns of species abundance in both theoretical and applied ecological studies. A host of investigators has promoted the concept of species diversity by postulating that diversity was an intrinsic property in ecological processes and an important factor in defining ecosystem structure and function (McArthur 1955, Pimentel 1961). The concept was further popularized by the introduction of information and entropy-based mathematical functions to approximate community structure (Margalef 1958, Pielou 1969). As a result of these endeavors, the theoretical application of diversity indices to explain patterns of species abundance became widespread during the 1960's. Diversity

measures were used to summarize community information for a wide variety of taxonomic groups (e.g., birds (McArthur 1955), insects (Menhinick 1964), forests (Pielou 1966), macroinvertebrates (Wilhm 1968), fish (Sheldon 1968), and reptiles (Pianka 1966)).

3. In applied ecological studies, diversity measures have been utilized to express causal relationships between community composition and environmental degradation (Wilhm and Dorris 1968). In light of this, many contemporary ecologists have used diversity measures to compare community structure in pollution-altered environments (e.g., pesticides, Barrett 1968; aquatic effluents, Wilhm and Dorris 1968, Moore 1979, Mason 1977, and Godfrey 1978). However, correlations between species diversity and environmental quality do not suggest that relatively higher environmental quality will always reflect higher species diversity. In fact, several studies have shown that diversity indices are not robust indicators of environmental quality. A number of aquatic studies, for example, have shown that polluted systems do not possess lower species diversity than unaltered or reference systems (Archibald 1972 and Livingston 1975).

4. The use of diversity measures in both theoretical and applied research has certain limitations imposed by the available information, data type, and sampling design employed to collect the information. Diversity indices based on species richness, species abundance, or combinations of these components have specific underlying assumptions that must be addressed to ensure valid community comparisons. The species richness component of diversity is primarily dependent on sample size. When richness measures are employed in studies having equal sample effort, direct comparisons of species counts are a reliable measure of species richness (Peet 1974). Conversely, when sampling is unequal, direct comparisons of species richness across communities may not be valid because increased sampling effort may in itself increase the number of species. To circumvent these biases, a number of authors have supported species richness measures which purport to be independent of sample size. However, two important assumptions underlie these applications: (a) a priori knowledge of the expected number of species and (b) the

actual number of individuals in a sample (Fisher et al. 1943). Both assumptions are virtually untestable in most applications.

5. A fundamental problem with diversity measures that combine richness and evenness is the lack of an unequivocal definition of the weights that the richness or evenness components contribute to the index (Hurlbert 1971); another criticism of these indices questions the degree of bias that a few abundant species may have on the diversity estimate. In addition, many of these measures are dependent on absolute to maximum diversity ratios; for example,  $h'/h_{\max}$ , where  $h'$  = Shannon function and  $h_{\max} = \log$  of the total number of species. Ratios such as these may be subject to bias with especially small sample sizes (Dejong 1975).

6. Despite the many problems associated with using community information indices, applied ecologists persist in deriving diversity indices to facilitate comparisons of community structure. These efforts continue in spite of studies that indicate that diversity indices are not necessarily consistent indicators of the complexity of community structure (Green 1979). Furthermore, the use of species diversity indices is not the only methodology available for empirically comparing and contrasting ecological communities. Alternative measures such as species overlap and ordination techniques developed for taxonomic classification can be used by applied ecologists to contrast community structure (Sokal and Sneath 1963, Whittaker 1972). In particular, alternative methods for examining community structure that incorporate either binary, continuous, or meristic data are available. These methods include (a) similarity coefficients, (b) Euclidian Distance, and (c) multivariate analyses (Boesch 1977).

7. Many of the qualitative methods based on binary data have been ignored by contemporary ecologists because the use of quantitative data (i.e. species abundance) is thought to be superior to species presence/absence data for comparing ecological processes. A number of authors have argued that presence/absence data may be more meaningful and ecologically interpretable than species abundance data, which is often highly variable (Green 1979, Peterson 1976, Allen 1971).

8. Any classification methodology designed to collapse

community information into a single expression is destined to lose information. The exclusive use of diversity indices to characterize community structure is often fraught with additional problems related to unrealistic a priori sampling assumptions, index bias, and highly variable data. In spite of these problems, ecologists persist in deriving diversity indices when alternative classification measures are available, especially those based on species presence/absence.

### Objectives

9. The general purpose of this study was to contrast fish communities associated with dike field structures in the Mississippi River over hydrologic seasons defined by water temperature and flow velocity. The specific objectives of this study were as follows: (a) to evaluate the relative performance of binary similarity coefficients, dissimilarity measures, and species diversity indices in detecting changes in the fish communities associated with two Mississippi River dike fields during five discrete sampling periods (i.e., interdike field comparisons), (b) to evaluate the sensitivity of the three classification methodologies in detecting seasonal change in the fish communities within a dike field (i.e., intradike field comparisons), (c) to evaluate the relationship between measures of community composition based on a single sampling gear and measures based on all sampling methods combined, and (d) to relate the spatial and temporal changes measured in dike field fish communities to localized physical attributes of the river.

PART II: METHODS

Study Area

10. In the study area, dikes are constructed of stone material positioned perpendicular from the streambank into the main river channel. A dike field is a series of dikes placed to maintain channel width and depth as an aid to navigation. The dike fields being compared in this study, Leota and Cracraft, differ in dimensions, current, stream channel topography, and position within the mainstream river (Figure 1).

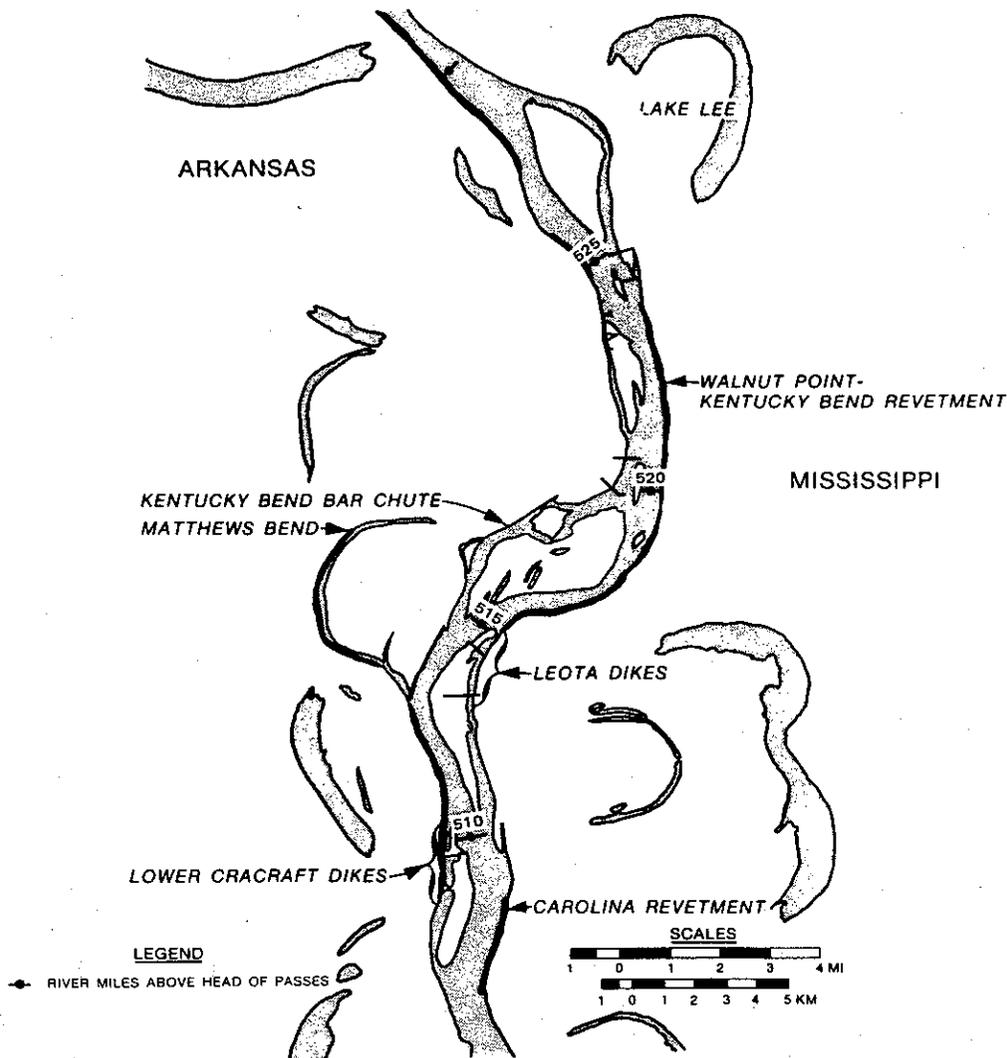


Figure 1. Study site on the Lower Mississippi River

11. Annual riverflow and water temperature regimes were used to define four sets of environmental conditions during which fish sampling was conducted. The four seasons vary, but are typically: summer low flow, warmwater season; fall increasing flow, decreasing water temperature season; winter/spring high flow, coldwater season; and spring decreasing flow, rising water temperature season. During the study period of April 1979 to September 1980, there were five sampling efforts in each dike field (Figure 2) corresponding to the river seasons described above.

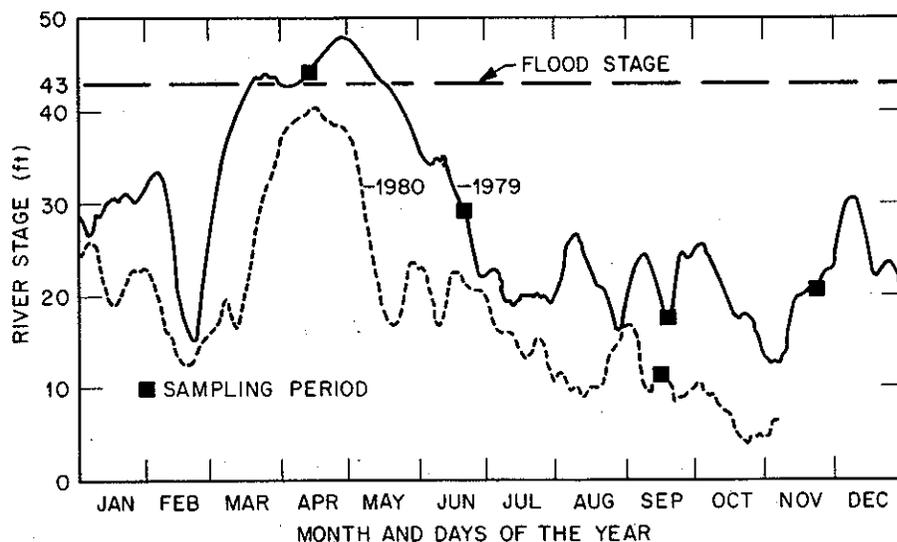


Figure 2. Hydrograph of the Mississippi River at the Vicksburg, Mississippi, gaging station, 1979 and 1980 (sampling periods are indicated as blocks on the hydrograph)

12. Interdike field comparisons of fish communities were made at each of the five hydrologic periods sampled; intradike field evaluations of community structure for each dike field were also made at each sampling period.

13. Intra- and interdike field evaluations of gear type used to sample fish communities were also made. Data derived from sampling dike field fish communities were evaluated for three gear types: (a) electroshocking, (b) hoop nets, and (c) seines. Variability in the physical conditions within the dike field, however, precluded the use of these gears at all river stages. Dike fields were compared across all river

stages using electroshocking data, across all river stages but September 1980 for hoop net data, and across all river stages but April 1979 for seine information.

14. Fish communities in three pools of each dike field were also compared (Figures 3 and 4). The surface areas of the pools varied considerably due to fluctuations in river height. Gear usage was restricted to the best available gear for the conditions present. Hence, consistent gear usage was difficult to maintain, making comparisons by gear type of fish communities in the pools impossible. No data were collected in the upper pool of either field during September 1980; all remaining combinations of pools and river stages were evaluated for each dike field.

#### Analytical Procedures

15. Estimates of community structure based on traditional summarization techniques were contrasted with other numeric indices to test the sensitivity of each in evaluating changes in dike field fish communities. The traditional measures included total number of species and total number of individuals. Other numeric classification estimates included similarity coefficients, dissimilarity coefficients, and diversity indices (Table 1).

##### Similarity coefficients

16. Binary similarity coefficients can best be explained with a 2-by-2 contingency table (Figure 5) where the categorical cell frequencies (i.e., A, B, C, and D) represent the number of species in common between locations (A), the number unique to a location (B and C), and the number of species not found in either location (D). Indices are developed using either empirical or theoretical relationships among the four cell frequencies. When only two samples are contrasted, the cell frequency of D is zero (i.e., there are no conjoint absences), in which case binary measures which incorporate D are undefined. However, when comparing multiple samples for any pairwise contrast, cell frequency D is defined and is usually greater than zero. Essentially, D represents those species not in common against a reference list of species found at all samples.

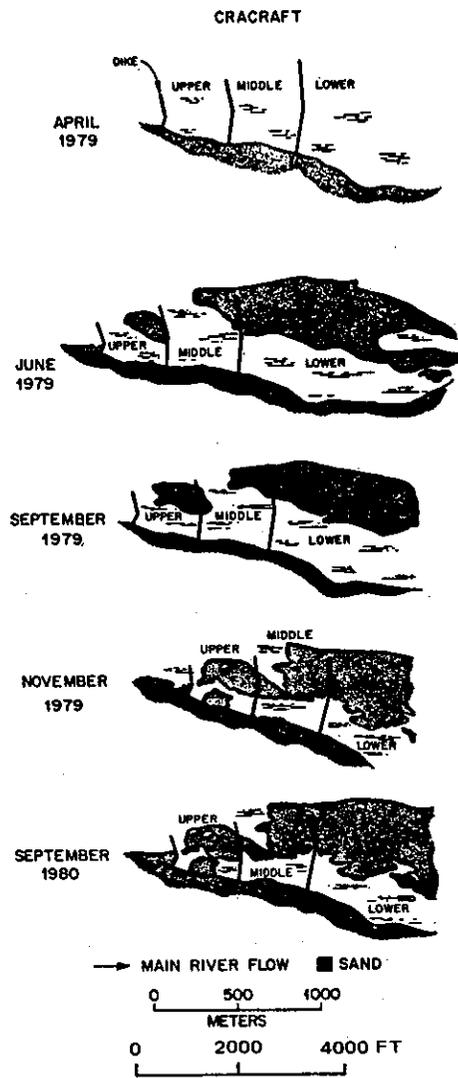


Figure 3. Upper, lower, and middle pool formation in the Cracraft dike field during all sample periods

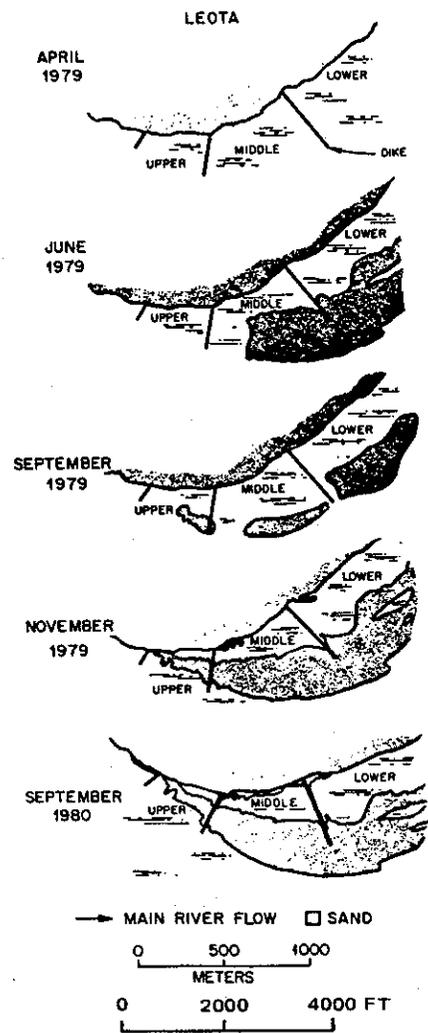


Figure 4. Upper, lower, and middle pool formation in the Leota dike field during all sample periods

		LOCATION 1	
		1	0
LOCATION 2	1	<b>A</b> NUMBER OF SPECIES IN COMMON	<b>B</b> NUMBER OF SPECIES IN 2 BUT NOT IN 1
	0	<b>C</b> NUMBER OF SPECIES IN 1 BUT NOT IN 2	<b>D</b> NUMBER OF SPECIES NOT REPRESENTED IN 1 OR 2

Figure 5. A 2-by-2 contingency table used to obtain the values of A, B, C, and D for calculating binary similarity coefficients (after Boesch (1977))

#### Dissimilarity coefficients

17. Quantitative dissimilarity coefficients are based on differences in the numbers of individuals for any pairwise comparison. These measures can be overtly biased because the dissimilarity estimate can be affected by a single large difference in the frequency of a given species. That is, any single large species count is incorporated into the index as an absolute value and increases the denominator of the estimate, which is essentially a sum of all individuals of all species over both locations (Clifford and Stephenson 1975).

#### Diversity indices

18. Diversity measures express results that are dependent on species and/or individuals. When the number of species sampled is relatively high, species richness measures produce greater values. Conversely, when the proportion of individuals is equally distributed, evenness measures produce higher values.

19. Correlations were performed to investigate the relationship between species composition data and diversity, dissimilarity, and similarity values in light of identified changes in the fish communities. Correlations were also used to evaluate the relationship between binary similarity coefficients that include cell frequency D and binary indices that did not include cell D.

20. The Statistical Analysis System (SAS) (Helwig and Council 1979) was used to compute the community information measures. A program was developed to generate community information indices for both temporal and spatial variables using species information (Polovino et al. 1981). Community information measures were also calculated for each sampling gear. The data base was managed with methods developed by Farrell, Magoun, and Daniels (1979), Farrell et al. (1980), Farrell (1981), Polovino et al. (1981), and Strand and Farrell (1980).

### PART III: RESULTS

21. Species composition data were calculated for the Leota and Cracraft dike fields based on a total of 8802 fish and 52 different species. For both dike fields, the greatest number of species collected occurred in June 1979 (for Cracraft, 39 and for Leota, 38). The lowest number of species sampled occurred in April 1979 (Cracraft, 12 and Leota, 12). Higher numbers of individuals were collected in the Cracraft dike field, over all river stages (Figure 6). Species diversity indices

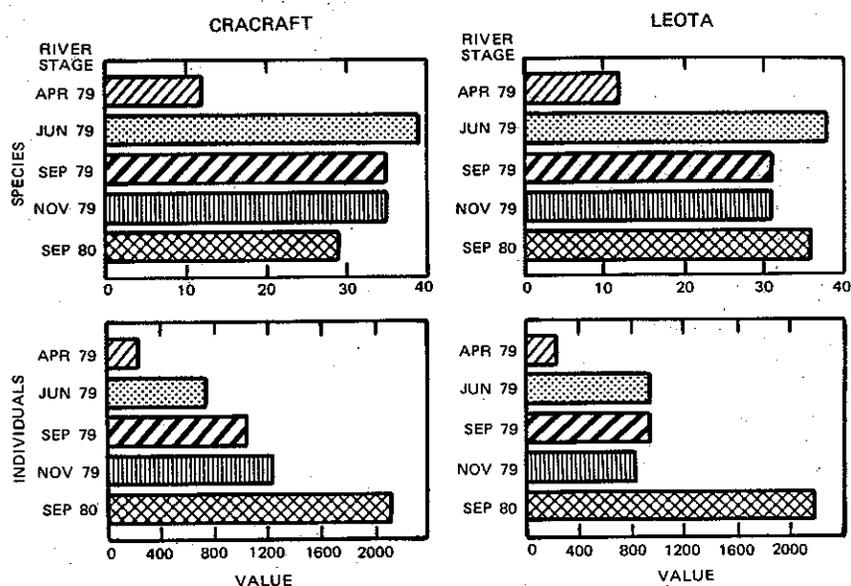


Figure 6. Total numbers of species and individuals obtained in Leota and Cracraft dike fields plotted by river stage

generally showed higher values at river stages where the numbers of species and individuals sampled were relatively high (i.e., in June 1979, November 1979, September 1979, and September 1980) (Figure 7). In the analysis of fish communities by sample gear, both the number of species and the number of individuals collected varied from the frequencies obtained for combined gears. The greatest numbers of species and individuals were collected with seines and electroshocking equipment; hoop nets accounted for the least number of species and individuals (Figure 8).

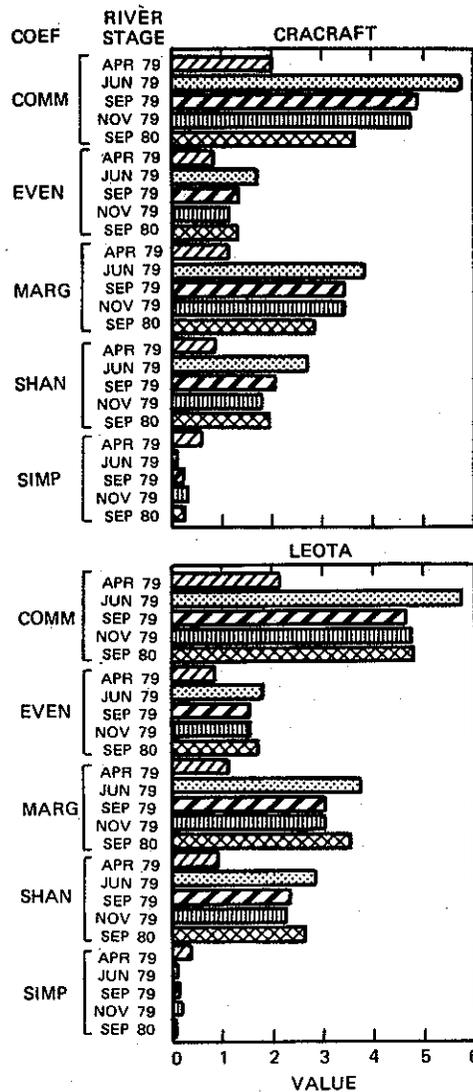


Figure 7. Species diversity indices for Cracraft and Leota dike fields plotted by river stage (see Table 1 for explanation of coefficient abbreviations)

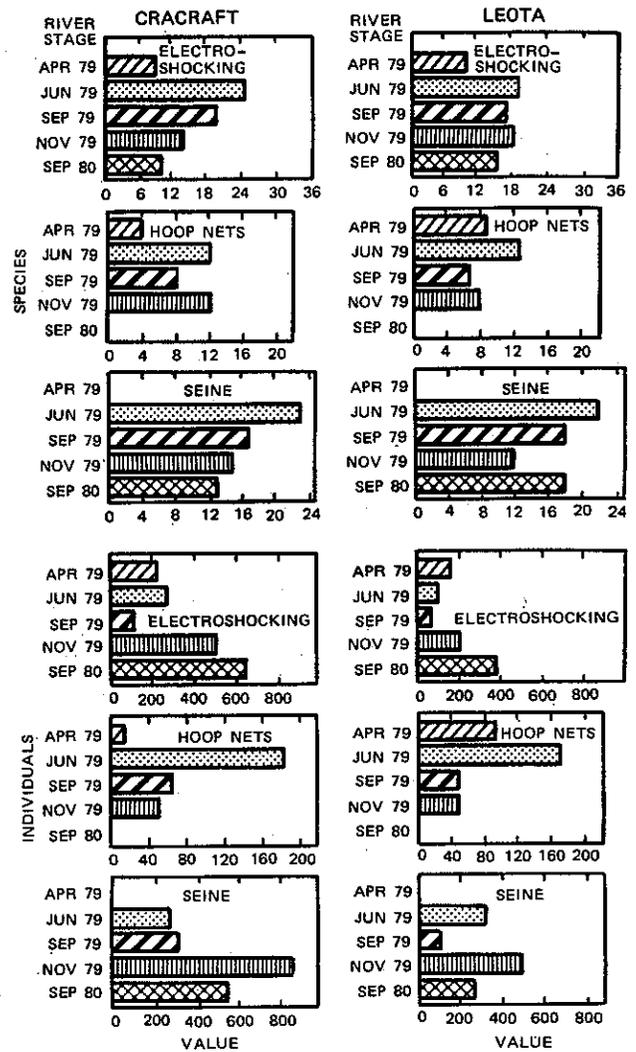


Figure 8. Total numbers of species and individuals obtained in Cracraft and Leota dike fields for each river stage and sample gear (no hoop net data were collected in September 1980, no seine information in April 1979)

Figure 9 shows the species diversity values derived when diversity indices were applied. Diversity values for electroshocking data showed low diversity in April 1979; diversity was also lower for the Cracraft dike field in November 1979. Hoop net and seine information revealed equivalent diversity values, with the former showing increased

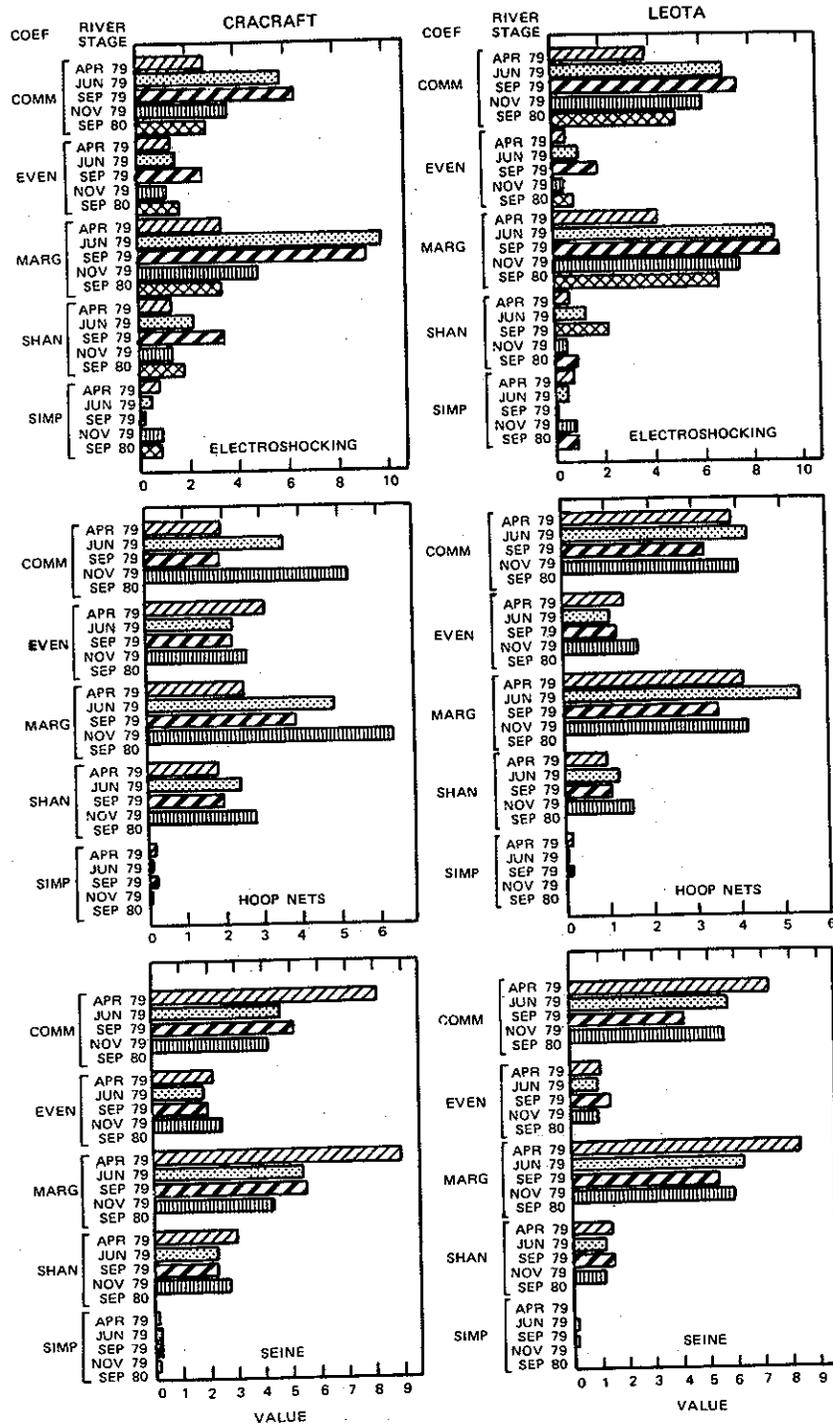


Figure 9. Species diversity values for Leota and Cracraft dike fields plotted by river stage and sample gear (no hoop net data were collected in September 1980, no seine information in April 1979; see Table 1 for explanation of coefficient abbreviations)

diversity during June 1979 and November 1979 and the latter, during June 1979.

22. In the intradike field pool analysis, least numbers of species and individuals were obtained in the upper pools (Figure 10). As Figure 11 shows, diversity was generally higher in the middle and lower pools of the Leota dike field; this was not true for Cracraft, especially in June 1979 when higher diversity values were evident in the upper pool.

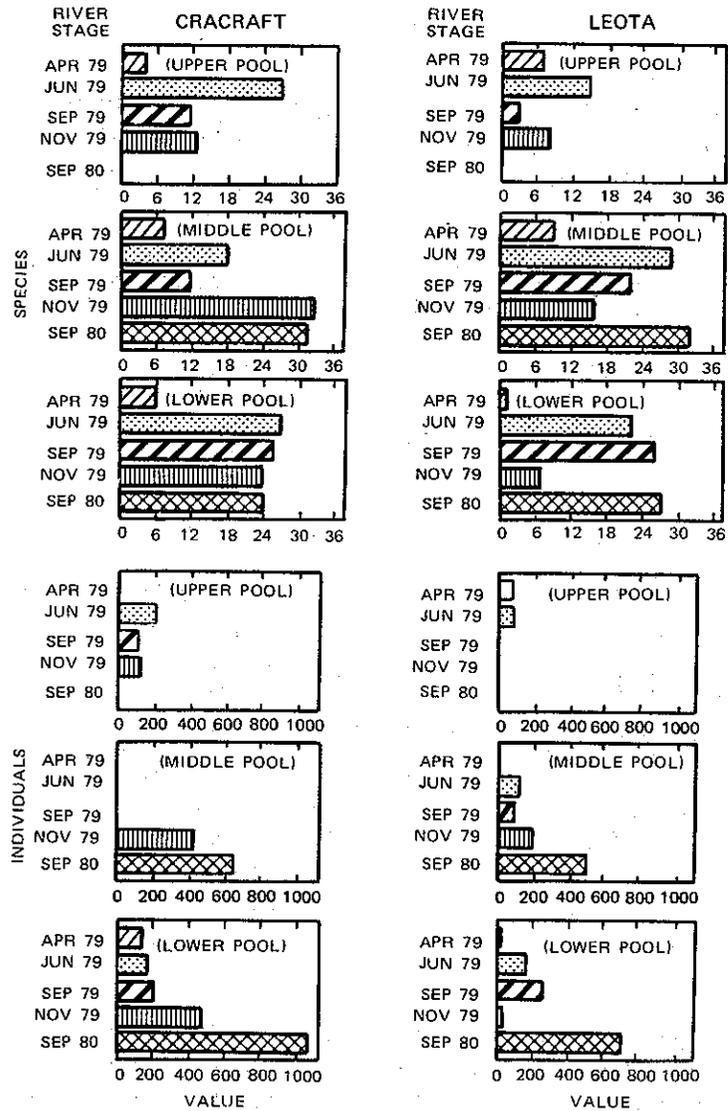


Figure 10. Total numbers of species and individuals for Leota and Cracraft dike fields and dike field pools plotted by river stage (no upper pool data were collected in September 1980)

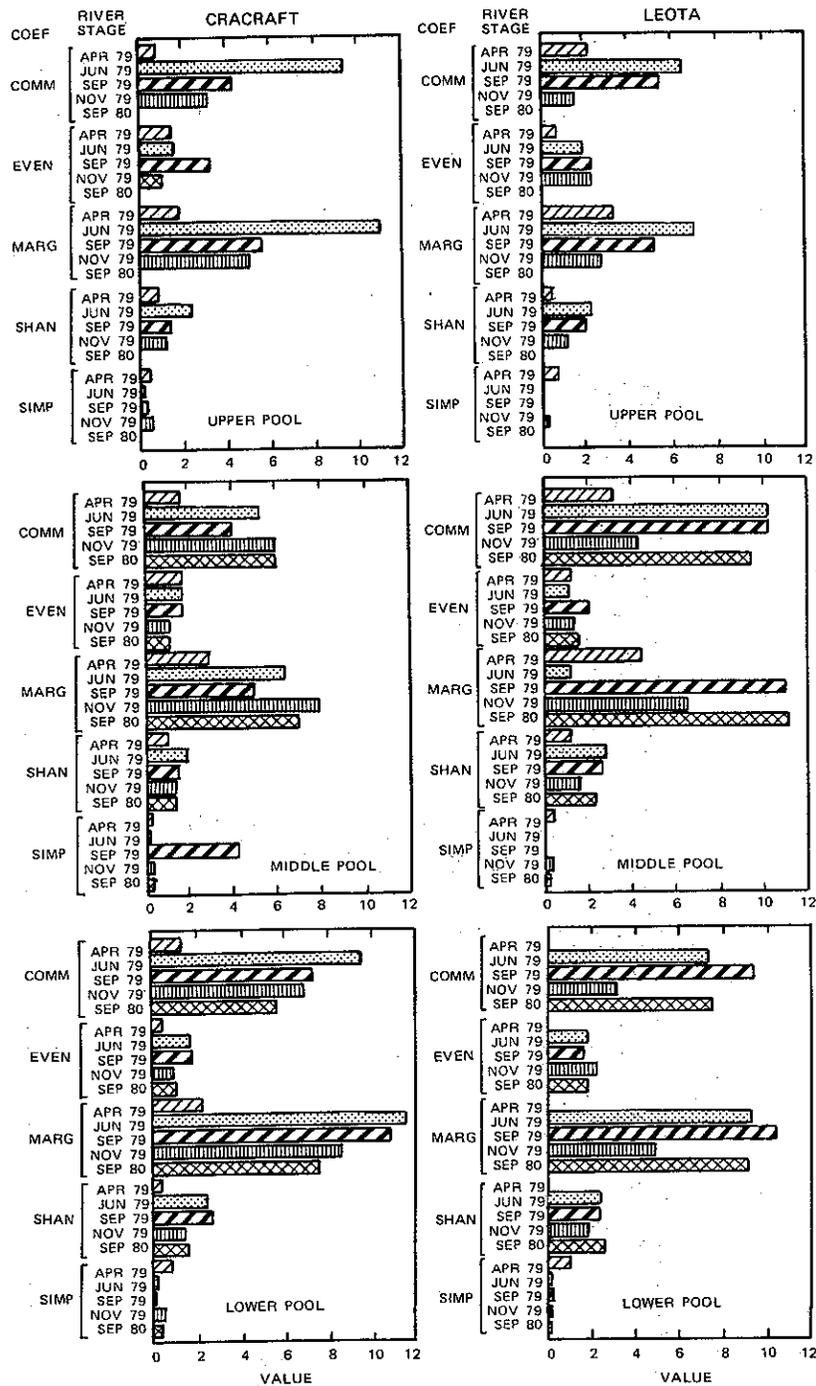


Figure 11. Species diversity indices for Leota and Cracraft dike fields and dike field pools plotted by river stage (no upper pool data was collected in September 1980; see Table 1 for explanation of coefficient abbreviations)

### Interdike Field Comparisons

23. The majority of binary similarity measures revealed highest values of similarity between dike fields in June 1979 and lowest values of similarity in April 1979 (Figure 12). Similarity was approximately equal for September 1979 and September 1980 and slightly lower in November 1979. However, three of the ten coefficients revealed inconsistent

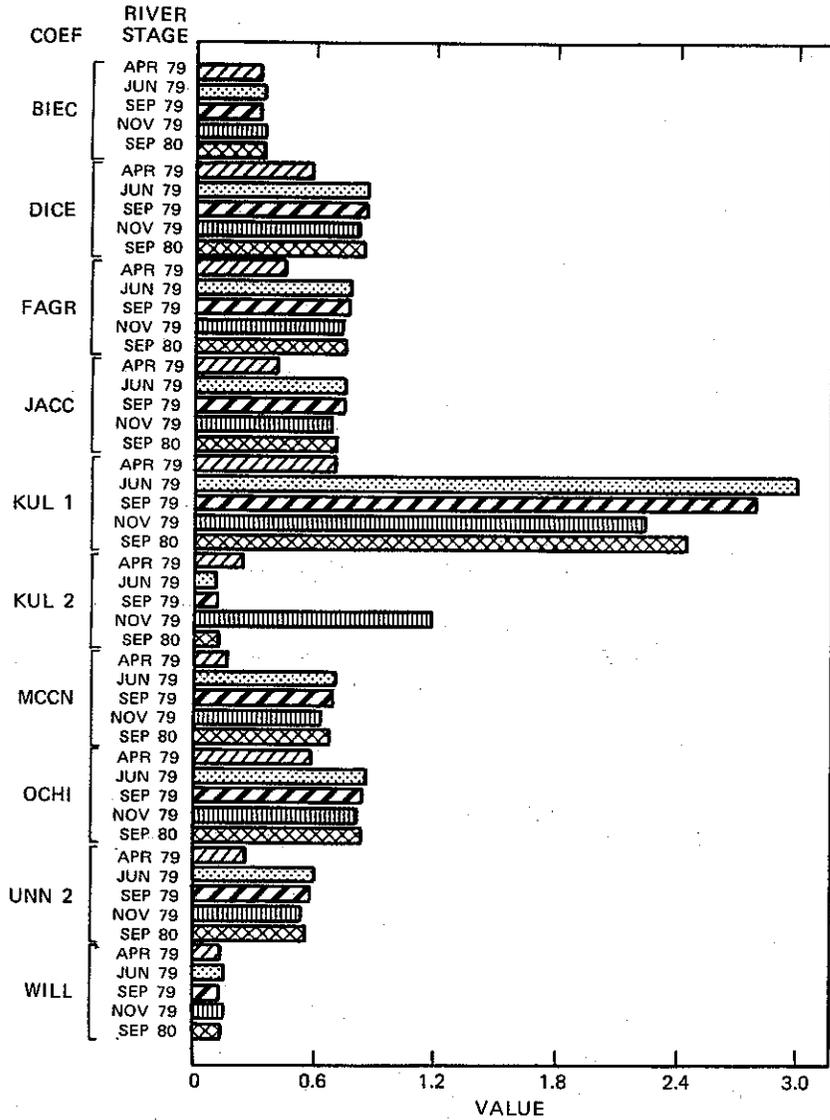


Figure 12. Interdike field binary similarity measures plotted for five river stages (see Table 1 for explanation of coefficient abbreviations)

or opposite trends in similarity. The Kulczynski Second showed higher similarity values in November 1979 and approximately equal values for the four other river stages. Both the Williams and Binary Euclidian Distance measures varied only slightly across all river stage comparisons.

24. Binary Euclidian Distance and Bray-Curtis measures revealed the highest dissimilarity at the lower river stages (Figure 13); lower values were exhibited for these indices in April 1979 and June 1979. The Canberra coefficient showed an opposite trend, revealing highest dissimilarity at April 1979 and lower but approximately equal dissimilarity at the remaining river stages.

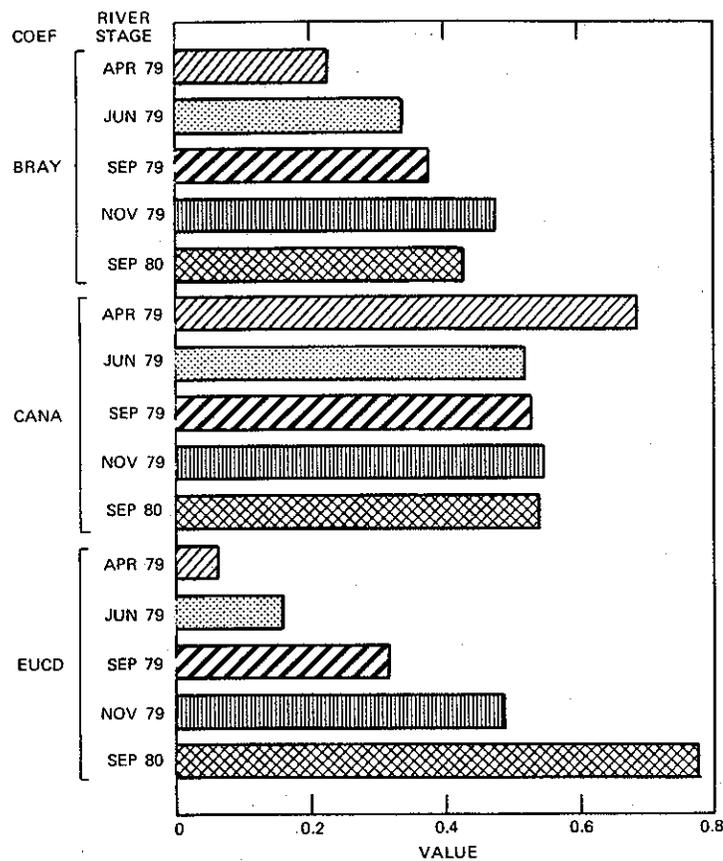


Figure 13. Interdiike field dissimilarity values plotted for five river stages (see Table 1 for explanation of coefficient abbreviations)

### Intradike Field Comparisons

25. Since intradike field comparisons involve ten specific contrasts, ten binary similarity measures which incorporate conjoint absences (cell frequency D, see Table 1) were included in this analysis.

26. In both dike fields the majority of binary similarity coefficients, both D-inclusive and non-D, had the highest similarity among river stage comparisons involving November 1979, September 1979, September 1980, and June 1979. Figure 14 shows that again, as in the interdike field analysis, the Williams, Binary Euclidian Distance, and Kulczynski Second coefficients did not exhibit this general pattern. The Williams and Binary Euclidian Distance measures showed opposite trends in similarity (i.e., higher values) when contrasting April 1979; the Kulczynski Second value remained constant for all river stage comparisons. All binary indices which included cell frequency D (see Figure 15) revealed the same trends as non-D measures: values of similarity were positive and greater for pairwise comparisons that did not include April 1979. The only notable exception was relatively lower similarity for June 1979 versus September 1980.

27. Figure 16 demonstrates that in both dike fields the Euclidian Distance measure was greatest, indicating highest dissimilarity, for all combinations with river stage September 1980, except for April 1979-September 1980. The Bray-Curtis index of dissimilarity was greatest when comparing April 1979 and September 1979 in both dike fields. The Canberra measure was greatest in Cracraft for the April 1979-September 1980 contrast, in Leota for the April 1979-June 1979 comparison, and in both dike fields for April 1979-November 1979 and June 1979-November 1979 comparisons. The pattern of agreement among the three dissimilarity measures was generally the same for both dike fields: agreement was greatest when comparing April 1979 with September 1980 and June 1979 with September 1979; agreement was least for April 1979-September 1979 and for September 1979-September 1980 comparisons.

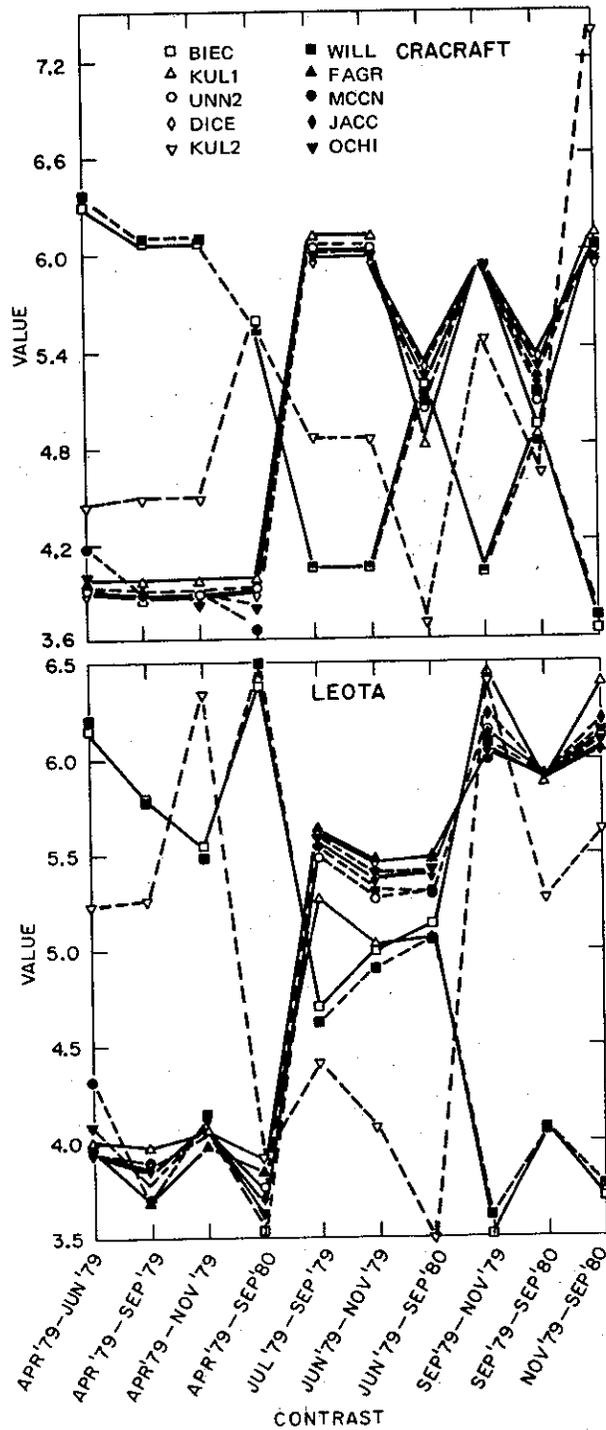


Figure 14. Intradike field values for Leota and Cracraft of binary similarity coefficients that exclude conjoint absences (cell D) for all combinations of river stages (see Table 1 for explanation of coefficient abbreviations)

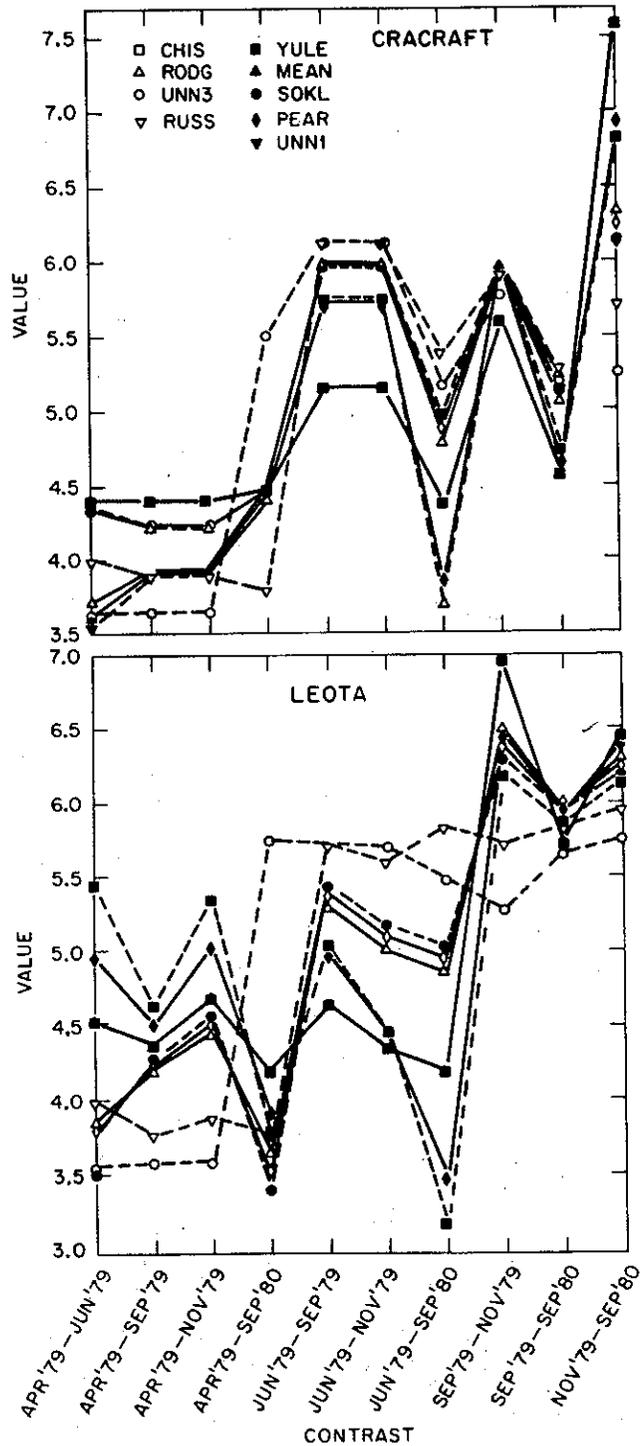


Figure 15. Intradike field values of binary similarity coefficients that include all cell frequencies (A, B, C, and D) for Leota and Cracraft dike fields for all combinations of river stages (see Table 1 for explanation of coefficient abbreviations)

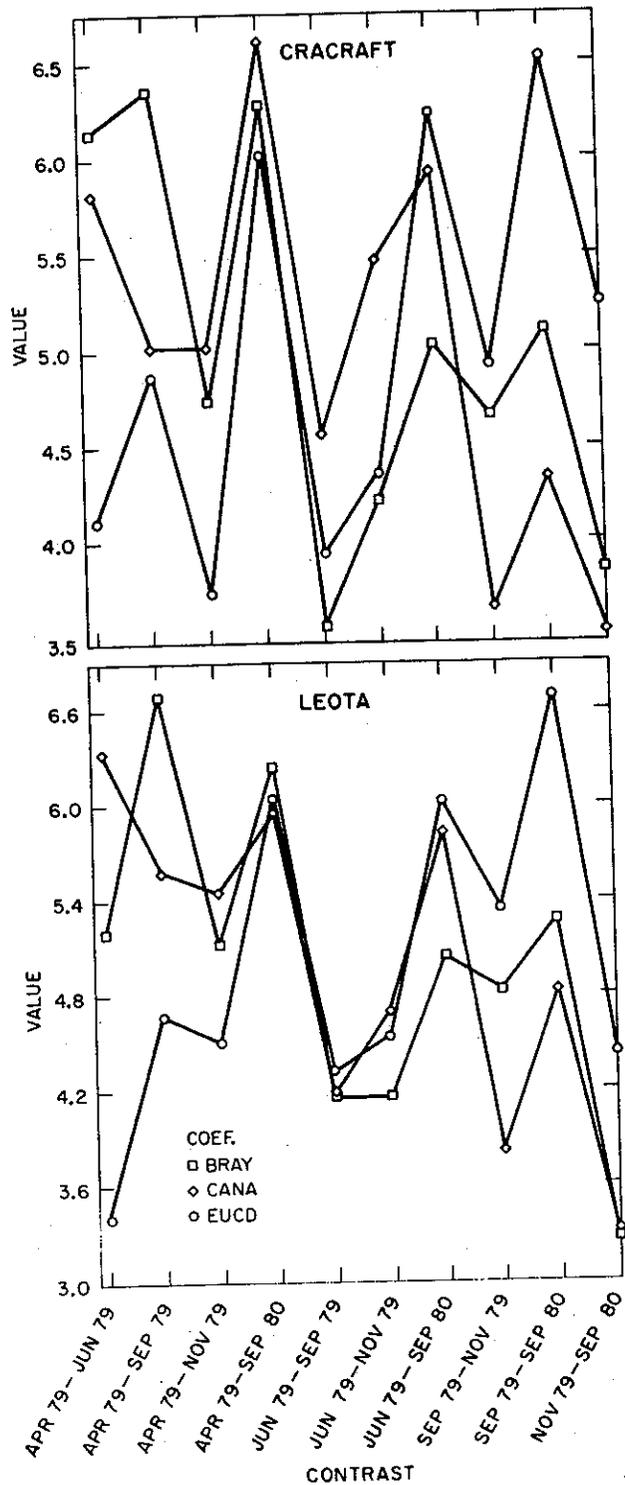


Figure 16. Intradike field dissimilarity indices for Leota and Cracraft dike fields for all combinations of river stages (see Table 1 for explanation of coefficient abbreviations)

### Interdike Field Comparisons by Gear

28. Leota and Cracraft dike fields were compared by gear type for the five sampling periods. For electroshocking information, binary similarity values (see Figure 17) were lowest in April 1979 and November 1979. The remaining river stages showed equivalent values of similarity. Hoop net data showed low similarity in April 1979 and consistently higher similarity in June 1979, September 1979, and November 1979. Seine information showed consistent values of similarity for the four sampling periods when this gear was utilized.

29. Figure 18 shows that dissimilarity values for electroshocking data produced high values for the Bray-Curtis and Euclidian Distance measures during November 1979. The Canberra coefficient varied little over all sampling period comparisons. Hoop net data showed higher dissimilarity during April 1979 for the Bray-Curtis and Canberra measures, while Euclidian Distance was lowest during this period. Seine information yielded higher values for Euclidian Distance and Canberra coefficients during September 1980. The Bray-Curtis measure varied little for all sampling periods except September 1979, which was relatively low.

### Intradike Field Evaluations by Gear

30. Binary indices, which exclude cell D, for electroshocking and hoop net gear types showed lower values of similarity for any pairwise comparison involving April 1979. The exception to this trend of reduced similarity was found in the hoop net data for the September 1979-November 1979 contrast for both dike fields. Electroshocking data for the Cracraft dike field did not reveal marked changes in similarity for the high-water comparisons. Similarity measures based on seine data varied little over all sampling period comparisons. In Cracraft dike field, similarity was greatest for the November 1979-September 1980 contrast; in Leota, similarity was greatest for the September 1979-September 1980 contrast. For the most part, binary measures which include D show trends of increasing similarity for comparisons involving June 1979

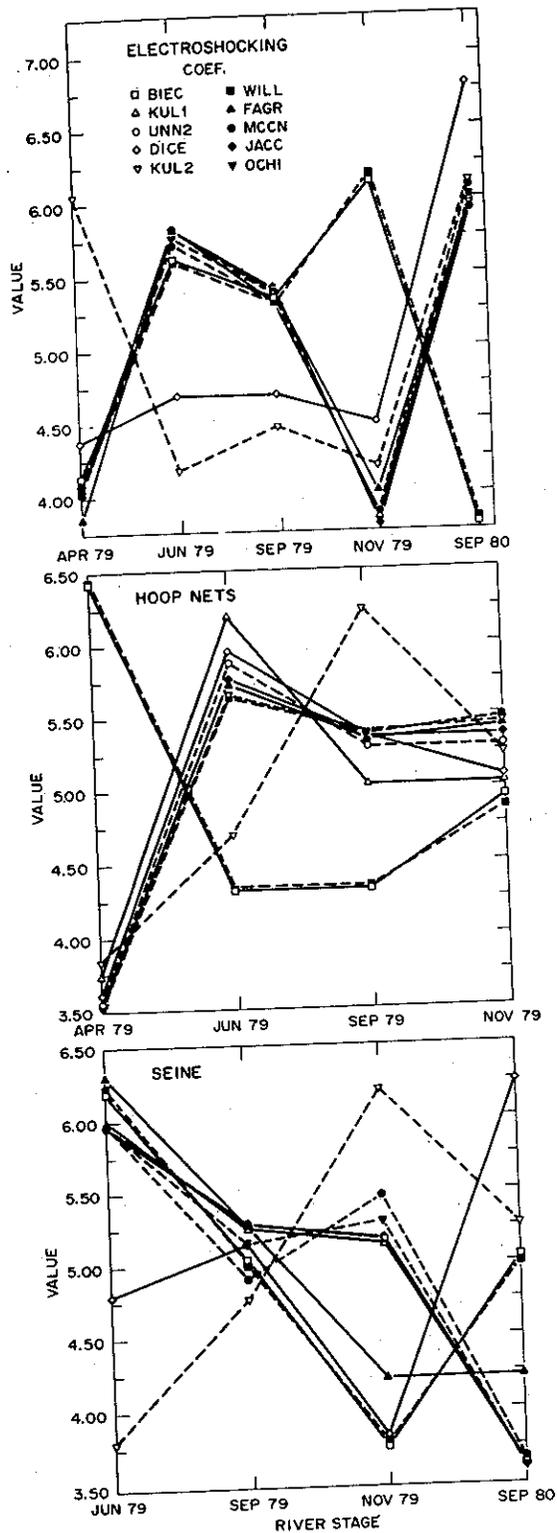


Figure 17. Interdiike field boundary similarity coefficients plotted by river stage and sample gear (see Table 1 for explanation of coefficient abbreviations)

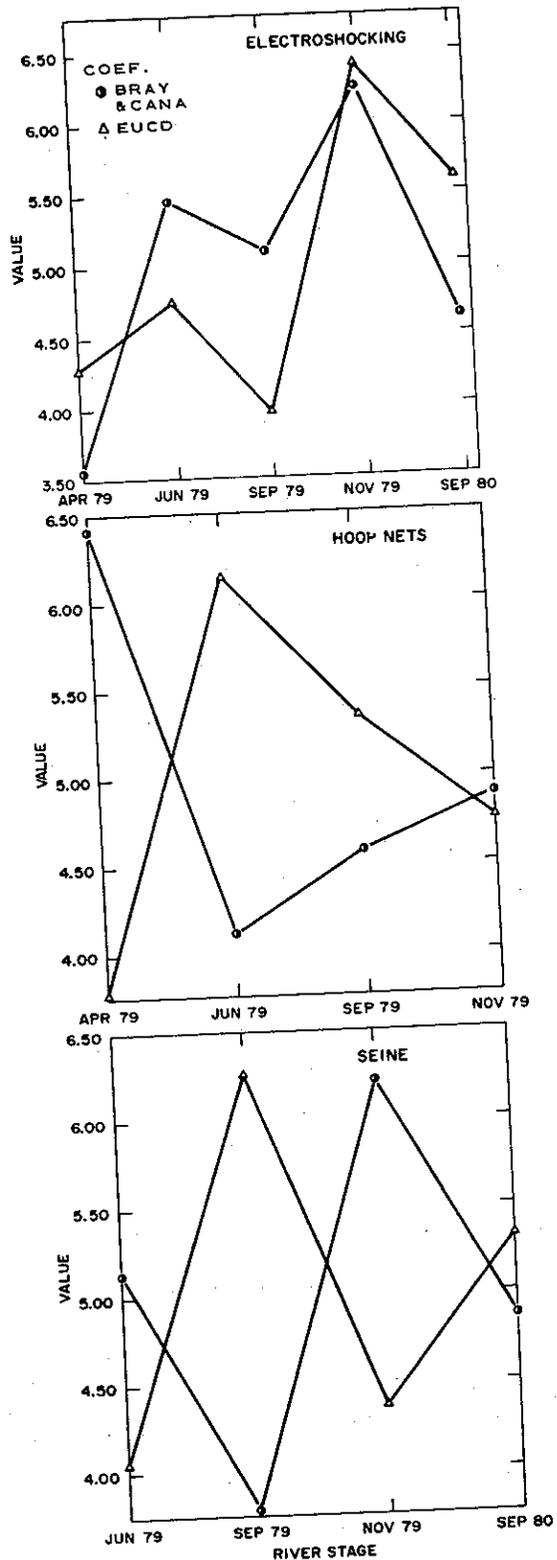


Figure 18. Interdiike field dissimilarity values plotted by river stage and sample gear (see Table 1 for explanation of coefficient abbreviations)

and November 1979. The lowest values of similarity were obtained for the April 1979-September 1979 contrast.

31. In Cracraft dike field electroshocking data exhibited trends that suggest decreasing dissimilarity when comparing high water, April 1979, and lower water (i.e., June 1979 and September 1979) stages.

#### Intradike Field Pool Analysis

32. Figure 19 demonstrates that non-D binary similarity measures were generally highest when comparing the middle and lower pools during low-water periods, i.e., for September 1980. For comparisons of the upper and lower pools, similarity was usually highest during April 1979 and June 1979 in both dike fields. Comparisons of the upper and middle pools show high similarity during June 1979 and September 1979. In November 1979, similarity was low for Leota but relatively high for Cracraft. Binary measures that include D show varied trends in similarity (see Figure 20). For the most part, equivalent values of similarity were obtained for both families of binary indices, the most notable difference being varied similarity in November 1979 for both dike fields. Negative values of binary similarity for both D and non-D indices reflect relatively lower similarity.

33. For Cracraft, the Bray-Curtis and Euclidian Distance indices showed lower values of dissimilarity for comparisons of the middle and lower pools in November 1979 and September 1980 (see Figure 21). In Leota this trend was exhibited for June 1979. The Canberra coefficient revealed higher dissimilarity values for these same pools in June 1979, September 1979, and November 1979. Dissimilarity values obtained for both dike fields using the Bran-Curtis and Canberra indices were consistently higher than the values derived with the Binary Euclidian Distance measure.

#### Index Relationships

34. Significant correlations between members of the three



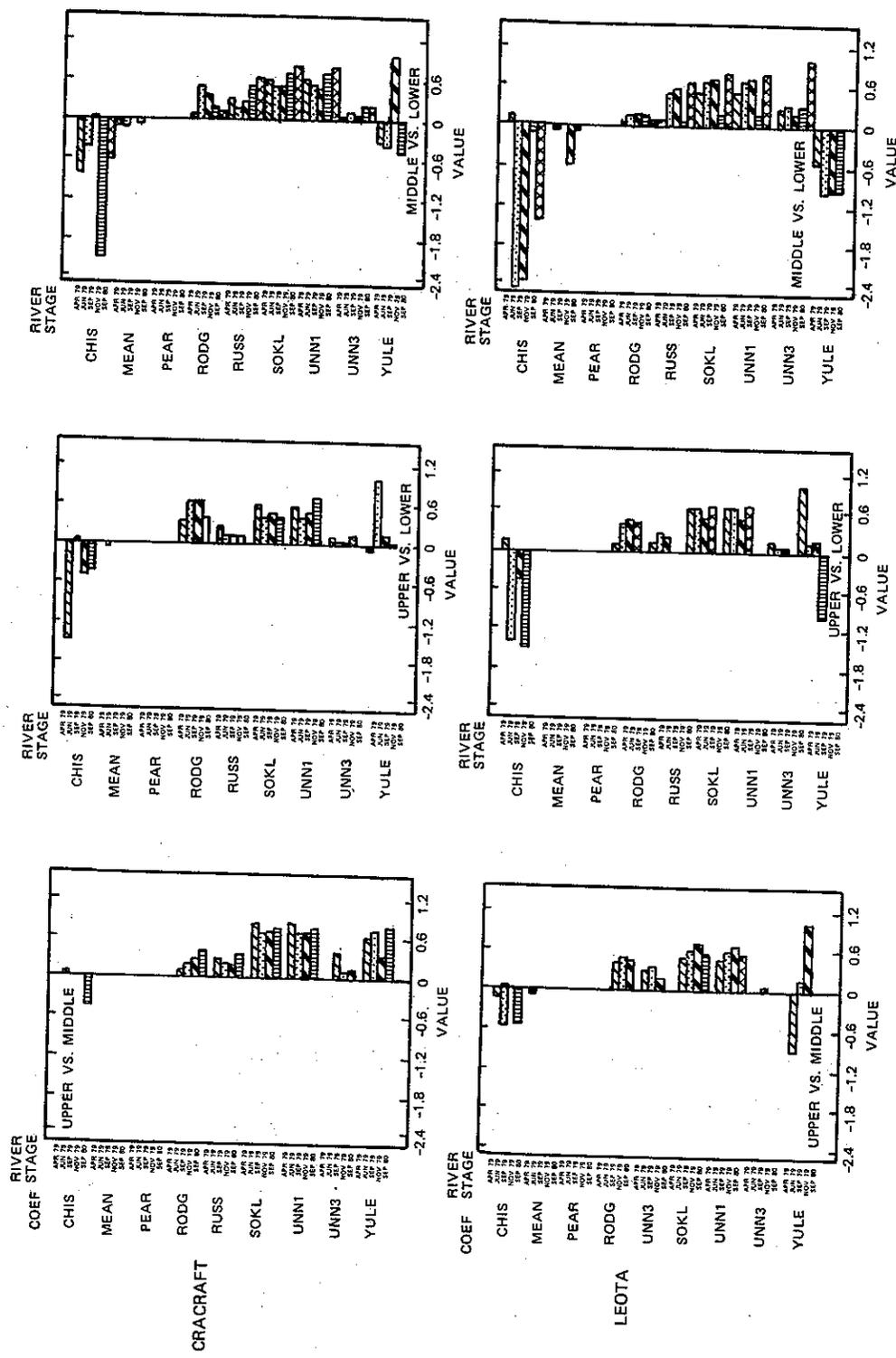


Figure 20. Binary similarity coefficients that include all cell frequencies (A, B, C, and D) for Leota and Cracraft dike field pools plotted by river stage (no upper pool data were collected for September 1980; see Table 1 for explanation of coefficient abbreviations)

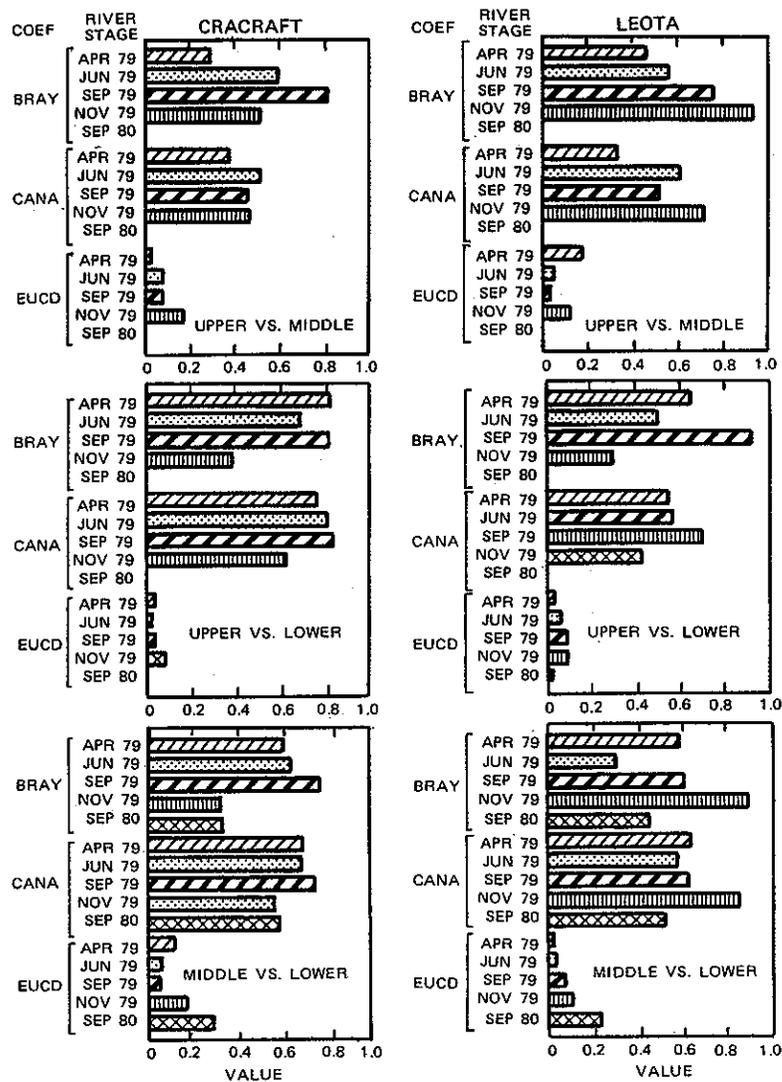


Figure 21. Quantitative dissimilarity values for Leota and Cracraft dike field pools plotted by river stage (no upper pool data were collected for September 1980; see Table 1 for explanation of coefficient abbreviations)

families of indices were evident for species evenness and binary similarity (Kulczynski First); for Euclidian Distance and Shannon's, Simpson's, Margalef's, and species information; and for species information and Margalef's (Table 2). Additionally, significant correlations existed for the Canberra coefficient and both Kulczynski First and species evenness. No significant correlations within the various families of measures (e.g., Canberra to Bray-Curtis) were found.

35. Correlations between D and non-D binary similarity measures (Table 3) were also evident for the intradike field comparison. In fact, only the Kulczynski Second coefficient showed any nonsignificant correlations. Intradike field comparisons of these indices by gear type showed a high incidence of significant correlations for all three gear types (Tables 4, 5, and 6).

#### PART IV: DISCUSSION

36. When comparing the performance of community information indices in detecting changes in the fish communities of both dike fields, all measures consistently indicate differences in community structure for combinations of high water (April 1979) and all other river stages.

37. The majority of binary similarity measures had higher values of similarity when species overlap (i.e., cell A, or cojoint presences) was high, the summation of the mismatches (i.e., cells B and C, or reciprocal absences) was minimal, and the number of species not in common for any comparison (i.e., cell D, or cojoint absences) was low. Most binary similarity coefficients are regulated by cojoint presences or absences (see Table 1). Binary similarity measures that exclude D, have single expressions of A in the numerator and some function of the mismatches in the denominator; because of this relationship, these indices are usually correlated to the degree of species overlap and inversely related to the sum of the mismatches. The Williams, Binary Euclidian Distance, and Kulczynski Second coefficients are not dependent on species overlap and do not follow the general trend of increasing similarity with greater species overlap (the Kulczynski Second minimizes the impact of cojoint presences by including two inverse functions with A in the denominator and by multiplying the entire expression by one half the value of A; both the Binary Euclidian Distance and Williams coefficients do not include A in computation of the index).

38. The results from this study indicated that Kulczynski First may be the simplest and most consistent indicator of computational change in dike field fish communities. The Kulczynski First is a ratio of cojoint presence to the sum of reciprocal absences  $[A/(B + C)]$ . In a biological sense, this index is intuitively interpretable as a simple expression of the total number of species in common to the total number of species unique for any comparison. As the number of cojoint absences or unique species approaches the number of cojoint occurrences, the value of similarity decreases. The Kulczynski First proved to be an excellent measure for both inter- and intradike field investigations. For

interdike field comparisons, cojoint occurrences fluctuated greatly while cells B and C remained relatively constant. Conversely, in the intradike field comparison, cells B and C varied markedly and cojoint occurrences remained relatively constant. In both cases this measure was sensitive to change in the mismatches and cojoint occurrences, and it recorded values of similarity accordingly. While this study shows that the Kulczynski First may be a more appropriate index, Boesch (1977) supports the Jaccard, Dice, or Ochiai coefficients of binary similarity. However, each of these indices is constrained between 0 and 1 and can be intuitively difficult to interpret because of the limited range of possible values (Clifford and Stephenson 1975). Conversely, the Kulczynski First ranges from 0 to infinity, making differences in similarity much easier to characterize.

39. Two measures that did not reveal trends that were consistent with the majority of binary measures, the Williams and Binary Euclidian Distance, might be considered better indicators of binary dissimilarity rather than of similarity. Green (1979) states that little information is contained in cojoint presences and absences; therefore, the important criterion for similarity is dependent on reciprocal absences. If the reciprocal absences (cells B and C) are large relative to the cojoint presences (cell A), binary measures which include A show lower similarity. The Williams and Binary Euclidian Distance measures do not include A (see Table 1) and show higher similarity when B and C are large. The problem with considering indices of this type which contain only one group of cell values is that in most cases the indices are only meaningful when the relationship between groups (e.g., A to B and C) is known. For example, when comparing two locations over time where the values of species overlap at Time One were  $A = 2$ ,  $B = 2$ , and  $C = 2$  and at Time Two were  $A = 20$ ,  $B = 2$ , and  $C = 2$ , the values of similarity for Williams and Binary Euclidian Distance would be identical. In actuality, similarity might be greater at Time Two because of a tenfold increase in the number of species in common.

40. The Bray-Curtis and Euclidian Distance dissimilarity measures reflect differences in the number of individuals for any pairwise

comparison. In fact, large differences in the numbers of dominant species are prevalent for both dike fields in November 1979 and September 1980. Additionally, certain gear comparisons also reflect higher values of dissimilarity at different river stages. For example, the large value of Euclidian Distance at November 1979 for dike fields contrasted for electroshocking data can be attributed to a skewed frequency of the most dominant species and a lack of additional species with appreciable numbers. However, the Canberra coefficient differs from the Bray-Curtis and Euclidian Distance indices in being a grand summation of a series of fractions involving the differences (numerator) and summation (denominator) of species in common for any pairwise comparison (see Table 1). Unlike other dissimilarity measures, the Canberra is not biased by large differences in individuals because the individuals are treated as fractions, thus tempering the estimate. The Canberra measure also includes an inverse function that represents the total number of species being compared and therefore reduces the value of dissimilarity when the number of individuals being compared is high.

41. In order to compare the relative performance of different community information indices, species composition data and diversity measures must be expressed as single numeric values that characterize the differences between samples and not the relationship within a sample. A series of diversity values for a contrast contains little information other than a simple comparison in value between the locations and dates. Changes in diversity values for a particular contrast expressed as a percentage change may contain valuable information about the differences in species composition for that contrast. The interdike field analysis provided a means for comparing species diversity indices and species composition data as single numeric expressions with coefficients of similarity and dissimilarity. The consistency in correlations between the Euclidian Distance index of dissimilarity and most of the percent changes in diversity suggests that the expression of diversity as a percent change is, in fact, analogous to a measure of dissimilarity between the two dike fields. This hypothesis is further supported by the inverse relationship exhibited between binary similarity and the

Canberra coefficient on the one hand and species evenness on the other: when the percent change in diversity increases, dissimilarity increases and binary similarity decreases.

42. The lower incidence of significant correlations involving binary similarity and the lack of significant correlation among diversity, species composition, and dissimilarity suggest that no single numeric classification technique measures change in fish communities in an equivalent way. A typical paradoxical situation is evident when comparing both dike fields in April 1979. Binary similarity is low for this comparison because there were fewer common species than unique species in each dike field. However, the species and individuals which comprise 90 percent of the communities by number, in each dike field, are identical. Invariably, rare species were obtained in each dike field, which served to lower binary similarity by increasing the values of the mismatches. Conversely, diversity measures were very similar at this river stage due to similar proportions of abundant species; however, only 41 percent of the species in either dike field were in common. Whether rare species are a product of sampling effort or do, in fact, delineate lower similarity at this river stage cannot be ascertained.

43. Relationships between index values calculated for different gear types compared to the same indices calculated for combined gears were also of considerable importance. Consistency in index values for binary similarity measures were found for electroshocking and hoop net data. Dissimilarity and diversity indices were also similar for electroshocking information compared to combined gear values. Electrofishing data appear to parallel combined gear data in a consistent fashion exhibiting equivalent values of binary similarity, dissimilarity, and diversity. In this study electroshocking was the single most representative gear type in comparison to combined gear evaluations. Pennington et al. (1982) have suggested that in riverine systems electroshocking is the most suitable gear because of its adaptability to fluctuating water conditions. Perhaps of greater importance is the observation that binary similarity measures represent a better

Pielou's Evenness in dike field Leota) may indicate that a greater number of fish species utilize the pools during low water. Fish species may be selectively vacating dike fields at high water, or many species may be using the pools in lieu of natural back- or low-water habitats during falling river stages.

46. Increasing interest in regional fish community structure mandates the use of empirical classification methodologies as tools for environmental management and decisionmaking. Levenson and Stearns (1980), suggest using diversity indices under conditions outlined by Whittaker (1972) for regional assessment of community structure. They recommend the use of classical diversity measures to characterize total diversity in a large geographic area, a method for defining regional diversity which is subject to errors and biases. Total (gamma) diversity in any geographic area is a function of both inter- (alpha) and intra- (beta) habitat diversity. Alpha diversity is measured using indices of diversity, which are simply proportional trends in species and individuals within a given sample and contain no information on differences in species composition. Beta diversity is measured using coefficients of similarity, which are based on species presence/absence and abundance and represent differences in species composition between sites but contain little information about community structure. Inferring total diversity from intra- and interhabitat diversities is therefore inappropriate. In addition, limitations and biases inherent in diversity indices calculated for single areas (i.e., alpha diversity) are not circumvented when these single-area indices are used to generate an index of diversity for a region. Thirdly, compiling data on species information on a regional scale entails collating data from a variety of studies with different objectives, rationales, and research algorithms into a single index; hence, data pertaining to species abundance collapsed from a regional scale are extremely suspect. Furthermore, as Levenson and Stearns (1980) themselves point out, regional ecological data often consist of species lists generated from single-survey studies. For all these reasons, binary similarity coefficients may indeed be more representative and robust measures for determining changes in community

structure. A recent study by Winner et al. (1975) supports measures based on species or species presence/absence which are sensitive to change in community structure. Specifically, Hocutt et al. (1974) found that the Jaccard coefficient offered a more critical analysis of change in fish communities than diversity indices for biological assessments of water quality.

47. Another finding from this study is that binary similarity measures which include cell frequency D reflect the same patterns of similarity as non-D indices. Realistically, a regional or time-series investigation of community similarity might incorporate more than two locations and/or sample dates. In these cases, binary measures which include cell frequency D might be considered preferable. Essentially, these measures are carried out as follows: (a) a master list of species is developed that represents all species found in a location for various sampling dates; (b) comparisons made for any pair of locations summarize the similarity of the locations in light of the total number of species that could conceivably be present; (c) these comparisons theoretically delineate higher similarity when species overlap (A) is large and the mismatches (B and C), as well as the species not in common (D), are minimal. On the other hand, the significance of the high correlations among D and non-D similarity coefficients might suggest that pairwise comparisons need not be performed on a master list of species. In other words, these data suggest that evaluations of dike field fish communities at specific river stages, in reference to the total number of species obtained for all river stages, are simply not necessary.

48. In summary, binary similarity indices appear to be an attractive alternative method for comparing change in fish communities. The use of these coefficients has a number of practical benefits for fisheries studies. First, these measures are very simple to compute since only four elements of species overlap are used. Second, they are not influenced by unbalanced sampling designs, although a representative species list is assumed for the communities being compared. Third, binary measures are most attractive for regional assessments of species composition data where very different sampling methods are utilized. In

addition, the consistency in values for different gear types and the high correlations found when comparing D and non-D measures further support the use of these measures. Finally, binary similarity indices do not involve quantitative data and are therefore exempt from bias evident in dissimilarity and diversity measures. In fisheries assessments, large differences in the frequency and numbers of dominant species are a criterion on which diversity and dissimilarity measures fluctuate. Whether these differences suggest greater dissimilarity is not clear. This is especially evident when the respective assemblages of dominant species are equivalent but the total numbers of individuals differ.

49. Binary similarity coefficients should not be considered a "cure-all" for assessing change in community structure. Under certain conditions, e.g., when only a few species constitute the community, these measures are clearly inappropriate. As Levenson and Stearns (1980) point out, index values should rarely be the sole criterion on which environmental judgements are based. Rather, the components of the indices or other trends in the data should also be considered in the decisionmaking process.

## PART V: CONCLUSIONS

50. The following conclusions were derived from this study:
- a. Binary similarity coefficients are successful indicators of change in fish communities. However, some coefficients are better than others, and this study indicates that the Kulczynski First may be the simplest and most consistent indicator of computational change in dike field fish communities.
  - b. Both D and non-D binary measures revealed consistent results, indicating that regional assessments of fish communities can be made in reference to the total number of species of a community over a given interval of time.
  - c. Diversity measures expressed as absolute values for any two locations being compared can probably be used as indices of dissimilarity. Although the Williams and Binary Euclidian Distance are measures of similarity, theoretically they are appropriate indicators of binary dissimilarity.
  - d. Dissimilarity and diversity measures are probably the least desirable methodologies available for detecting change in fish communities for single ecological survey studies.
  - e. Fish seem to exhibit a preference for dike field habitats at low water levels because these structures increase the heterogeneity of the river system by providing a variety of habitats such as sandbars and riffle areas.
  - f. Based on community information measures, electroshocking data proved to be the most representative in comparison with indices generated for hoop net and seine information, making electroshocking the single most representative gear type.

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Table 1  
Summary of Numeric Classification Estimates for Comparing Ecological Community  
 Structure, with Principal Secondary References Cited

Coefficient	Formula	Abbreviation	Reference
<b>I. Binary Similarity Coefficients</b>			
Jaccard	$\frac{A}{A + B + C}$	JACC	Boesch (1977)
Dice	$\frac{2(A)}{2(A) + (B + C)}$	DICE	Boesch (1977)
Kulczynski First	$\frac{A}{B + C}$	KUL1	Boesch (1977)
Kulczynski Second	$\left(\frac{A}{2}\right)\left(\frac{1}{A+B}\right)\left(\frac{1}{A+C}\right)$	KUL2	Boesch (1977)
Ochisi	$\frac{A}{\sqrt{(A+B)(A+C)}}$	OCHI	Boesch (1977)
Fager	$\frac{A}{\sqrt{(A+B)(A+C)}} - \frac{1}{\sqrt{2(A+B)}}$	FAGR	Boesch (1977)
Russell and Rao	$\frac{A}{A + B + C + D}$	RUSS	Clifford and Stephenson (1975)
Rodgers and Tanimoto	$\frac{A + D}{A + B + 2(C + D)}$	RODG	Clifford and Stephenson (1975)
Chi Square	$\frac{AD - BC^2(A + B + C + D)}{(A + B)(C + D)(A + C)(B + D)}$	CHIS	Clifford and Stephenson (1975)
Mean Square Contingency	$\frac{CHIS}{A + B + C + D}$	MEAN	Clifford and Stephenson (1975)
Binary Euclidian Distance	$\sqrt{B + C}$	BIEC	Clifford and Stephenson (1975)
Williams	$[2(B + C)(\text{Log}(2))]$	WILL	Williams et al. (1966)
Unnamed 1	$\frac{2(A + D)}{2(A + D) + (B + C)}$	UNN1	Sokal and Sneath (1963)
Unnamed 2	$\frac{A}{A + 2(B + C)}$	UNN2	Sokal and Sneath (1963)
Unnamed 3	$\frac{A + D}{C + B}$	UNN3	Sokal and Sneath (1963)
Sokal	$\frac{2(A + D)}{2(A + D) + (B + C)}$	SOKL	Sokal and Sneath (1963)
McConnaughy	$\frac{A^2 - BC}{(A + B)(A + C)}$	MCCN	Clifford and Stephenson (1975)
Yule	$\frac{AD - BC}{AD + BC}$	YULE	Clifford and Stephenson (1975)
Pearson	$\frac{AD - BC}{(A + B)(C + D)(A + C)(B + D)}$	PEAR	Clifford and Stephenson (1975)

(Continued)

Table 1 (Concluded)

Coefficient	Formula	Abbreviation	Reference
<u>II. Dissimilarity Coefficients</u>			
Euclidian Distance	$D = \left[ \sum_1^n (X_1 - X_2)^2 \right]^{1/2}$	EUCD	Clifford and Stephenson (1975)
	where $X_1, X_2 =$ succession scores for the nth attribute		
Bray-Curtis	$D = \frac{\sum_1^n (X_{1j} - X_{2j})}{\sum_1^n (X_{1j} + X_{2j})}$	BRAY	Clifford and Stephenson (1975)
	where n = total number of attributes $X_{1j}, X_{2j} =$ values for j total attributes for any pair of entities		
Canberra	$D = \frac{1}{n} \sum_1^n \frac{(X_{1j} - X_{2j})}{(X_{1j} + X_{2j})}$	CANA	Clifford and Stephenson (1975)
<u>III. Diversity Indices</u>			
Margalef's Richness	$D = \frac{S - 1}{\log n}$	MARG	Odum (1971)
	where S = total number of species n = total number of individuals		
Shannon-Weaver	$H^1 = -\sum p_i \times \log p_i$	SHAN	Odum (1971)
	where $p_i =$ proportion of individuals of species i in the population		
Simpsons	$D = 1 - \sum_{i=1}^s (p_i)^2$	SIMP	Odum (1971)
Pielou's Evenness	$E = \frac{H^1}{H_{max}}$	EVEN	Odum (1971)
	where $H^1 =$ Shannon-Weaver diversity index $H_{max} = \log S$ S = total number of species		
Community Richness	$R = \frac{1}{S - \log(N)}$	COMM	Odum (1971)
	where S = total number of species N = total number of individuals		

Table 2

## Correlation Matrix Among Binary Similarity and Dissimilarity, Species

## Diversity, and Species Composition Data for Dike Field Contrasts

## Over Five River Stages, Absolute Percent Change

	<u>KULL*</u>	<u>CANA</u>	<u>BRAY</u>	<u>EUCD</u>	<u>SHAN</u>	<u>SIMP</u>	<u>COMM</u>	<u>EVEN</u>	<u>MARG</u>	<u>Species</u>	<u>Individuals</u>
<u>Binary Similarity</u>											
KULL		-0.94	0.58	0.38	0.22	0.01	-0.09	-0.99**	0.45	0.47	-0.10
<u>Dissimilarity</u>											
CANA			-0.44	-0.46	-0.17	-0.15	-0.19	0.92**	0.55	0.56	0.26
BRAY				0.72	0.83	0.46	0.01	-0.65	0.74	0.75	0.71
EUCD					0.90**	0.92**	0.68	-0.42	0.97**	0.96**	0.32
<u>Species Diversity</u>											
SHAN						0.81	0.40	-0.30	0.82	0.82	0.65
SIMP							0.86	-0.03	0.86	0.85	0.30
COMM								0.10	0.65	0.64	-0.15
EVEN									-0.48	-0.50	0.03
MARG										0.99**	0.39
Species											0.40
Individuals											--

\* See Table 1 for explanation of abbreviations.

\*\*  $P < 0.01$ .

Table 3  
Correlation Matrix of Binary Similarity Measures for Cracraft and Leota Dike Fields  
and Ten Combinations of Five River Stages (indices which include cell  
frequency D are listed vertically)

	JACC*	DICE	FAGR	WILL	MCCN	OCHI	BIEC	UNN2	KUL1	KUL2
RODG	0.96**	0.94**	0.94**	-0.99**	0.94**	0.95**	-0.99**	0.97**	0.98**	0.45†
RUSS	0.98**	0.98**	0.98**	-0.90**	0.97**	0.98**	-0.88**	0.97**	0.92**	0.02
SOKL	0.96**	0.95**	0.95**	-0.99**	0.94**	0.95**	-0.99**	0.96**	0.95**	0.41
YULE	0.57**	0.54†	0.53†	-0.71**	0.62**	0.57**	-0.73**	0.60**	0.67**	0.84**
PEAR	0.67**	0.64**	0.63**	-0.79**	0.70**	0.66**	-0.82**	0.70**	0.77**	0.79**
CHIS	0.64**	0.62**	0.61**	-0.76**	0.66**	0.64**	-0.79**	0.68**	0.76**	0.75**
MEAN	0.65**	0.62**	0.61**	-0.76**	0.67**	0.64**	-0.79**	0.69**	0.77**	0.75**
UNN1	0.96**	0.95**	0.95**	-0.99**	0.94**	0.95**	-0.99**	0.96**	0.95**	0.41
UNN3	0.74**	0.74**	0.78**	-0.69**	0.68**	0.72**	-0.68**	0.74**	0.71**	-0.14

\* See Table 1 for explanation of abbreviations.  
 \*\* P < 0.01.  
 † P < 0.05.

Table 4  
Correlation Matrix Derived from Electroshocking Data of Binary Similarity Measures  
for Cracraft and Leota Dike Fields and Ten Combinations of Five River Stages  
(indices which include cell frequency D are listed vertically)

	JACC*	DICE	FAGR	WILL	MCCN	OCHI	BIEC	UNN2	KUL1	KUL2
RODG	0.56**	0.56**	0.48†	-0.97**	0.45	0.52†	-0.97**	0.56**	0.55†	0.88**
RUSS	0.92**	0.91**	0.95**	-0.29	0.89**	0.91**	-0.24	0.93**	0.92**	0.04
SOKL	0.58**	0.58**	0.48†	-0.98**	0.46†	0.53†	-0.98**	0.58**	0.57**	0.82**
YULE	0.57**	0.59**	0.49†	-0.85**	0.60**	0.60**	-0.85**	0.56**	0.53†	0.88**
PEAR	0.60**	0.61**	0.51†	-0.87**	0.61**	0.62**	-0.88**	0.59**	0.57**	0.90**
CHIS	0.45	0.46†	0.39	-0.70**	0.49†	0.48†	-0.73**	0.44	0.42	0.89**
MEAN	0.47†	0.48†	0.42	-0.77**	0.51†	0.50†	-0.75**	0.46†	0.46†	0.88**
UNN1	0.58**	0.58**	0.48†	-0.98**	0.46†	0.54†	-0.98**	0.58**	0.57**	0.82**
UNN3	0.59**	0.59**	0.67**	-0.11	0.48†	0.56†	-0.11	0.59**	0.59**	-0.13

\* See Table 1 for explanation of abbreviations.  
 \*\* P < 0.01.  
 † P < 0.05.

Table 5

Correlation Matrix Derived from Hoop Net Data of Binary Similarity Measures for Cracraft and Leota Dike Fields and Six Combinations of River Stages (indices which include cell frequency D are listed vertically)

	JACC*	DICE	FAGR	WILL	MCCN	OCHI	BIEC	UNN2	KUL1	KUL2
RODG	0.73**	0.71**	0.68**	-0.99**	0.67†	0.69†	-0.99**	0.74**	0.74**	0.72**
RUSS	0.94**	0.95**	0.96**	-0.61†	0.89**	0.93**	-0.61†	0.97**	0.95**	0.59†
SOKL	0.72**	0.71**	0.68†	-0.98**	0.67†	0.70**	-0.97**	0.72**	0.71†	0.74**
YULE	0.60†	0.63†	0.61†	-0.78**	0.75**	0.69†	-0.77**	0.57	0.52	0.90**
PEAR	0.63†	0.66†	0.64†	-0.81**	0.76**	0.72**	-0.81**	0.60†	0.56	0.90**
CHIS	0.61†	0.57	0.58	-0.53	0.62†	0.60†	-0.57	0.63†	0.67†	0.52
MEAN	0.61†	0.57	0.57	-0.53	0.62†	0.60†	-0.57	0.63†	0.67†	0.52
UNN1	0.72**	0.71**	0.68†	-0.99**	0.67†	0.70**	-0.97**	0.72**	0.71†	0.74**
UNN3	0.74**	0.69**	0.74**	-0.46	0.57	0.64†	-0.47	0.76**	0.77**	0.25

\* See Table 1 for explanation of abbreviations.  
 \*\* P < 0.01.  
 † P ≤ 0.05.

Table 6

Correlation Matrix Derived from Seine Data of Binary Similarity Measures for Cracraft and Leota Dike Fields and Six Combinations of River Stages (indices which include cell frequency D are listed vertically)

	JACC*	DICE	FAGR	WILL	MCCN	OCHI	BIEC	UNN2	KUL1	KUL2
RODG	0.96**	0.96**	0.94**	-0.99**	0.96**	0.64†	-0.99**	0.95**	0.89**	0.99**
RUSS	0.66†	0.67†	0.68†	-0.43	0.62†	0.91**	-0.45	0.64†	0.60†	0.35
SOKL	0.91**	0.93**	0.92**	-0.98**	0.94**	0.54†	-0.96**	0.88**	0.79**	0.95**
YULE	0.81**	0.84**	-0.84**	-0.94**	0.87**	0.65†	-0.90**	0.77**	0.66†	0.90**
PEAR	0.90**	0.91**	0.89**	-0.98**	0.93**	0.73†	-0.96**	0.87**	0.80**	0.96**
CHIS	0.88**	0.86**	0.85	-0.86**	0.87**	0.60†	-0.90**	0.89**	0.88**	0.93**
MEAN	0.88**	0.84**	0.85**	-0.86**	0.88**	0.70†	-0.91**	0.90**	0.90**	0.93**
UNN1	0.91**	0.93**	0.92**	-0.99**	0.94**	0.71†	-0.97**	0.88**	0.79**	0.95**
UNN3	0.11	0.16	0.30	-0.09	0.21	0.43	-0.05	-0.06	-0.04	0.07

\* See Table 1 for explanation of abbreviations.  
 \*\* P < 0.01.  
 † P ≤ 0.05.