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CHARACTERIZATION OF AQUATIC USE ATTAINMENT IN OKLAHOMA

The University of Oklahoma PH.D. 1984

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THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

CHARACTERIZATION OF AQUATIC USE ATTAINMENT IN OKLAHOMA

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

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by

Charles L. Marshall

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CHARACTERIZATION OF AQUATIC USE ATTAINMENT

IN OKLAHOMA

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CHAPTER I

GENERAL INFORMATION

Introduction

In Oklahoma, the responsibility to establish and maintain water quality standards rests with the Oklahoma Water Resources Board (82 O.S. Sec. 926.1,.13). The process for making changes, amendments, and revisions to water quality standards was set forth by the federal government in 40 CFR Part 130.17. Title 82 O.S. 1981, Section 926.6 provides the requirements for State revisions. These procedures included a systematic triennial review process of technical, administrative and public concerns. The National Environmental Policy Act (88), the Water Pollution Control Act (89), the Safe Drinking Water Act (90), and subsequent amendments (91), have all, separately and combined, been a force which has elevated the role water quality standards play in the management of environmental quality.

Water quality standards today go far beyond the concept of establishing criteria for environmental quality of water resources. They now hold the power to influence alternatives available, and the eventual course of events for projects which both directly and or indirectly affect water uses. An example of this dynamic relationship between the criteria established to protect beneficial uses, and the force they impart on the decision making process, can be illustrated by examining the changes which have taken place in the dissolved oxygen criteria; applied to Oklahoma's water quality standards over the last fifteen years. Table 1 contains a summary of Oklahoma's water quality standards for fish and wildlife beneficial uses for the period from 1968 through 1982.

The Recent History of Oklahoma's Water Quality Standards.

The 1968 Oklahoma Water Quality Standards (79) set the State's first dissolved oxygen (D.O.) criteria at 4.0 mg./l. In addition, a disclaimer was placed on the applicability of the standard in areas below waste discharge when there was less than a $2Q_s/Q_e$ relationship (ratio of stream flow to effluent flow). The relevance of this relationship will be discussed in subsequent chapters.

In 1973 (80) the fish and wildlife propagation benefical use criteria included two designations:

C_1 Fish and Wildlife Propagation.

C_2 Fish and Wildlife Propagation to the extent allowed by specifically stated water quality parameters.

Year	Description of Benefical Use and D.O. Criteria
1968	Code C- Fish and Wildlife Propagation The dissolved oxygen concentration shall not be less than 4.0 mg./l., except that this limitation of 4.0 mg./l. will not be applicable in the immediate vicinity of the point of waste discharge when stream flow is less than 200% of the waste flow. In addition, the relationship of dissolved oxygen, biochemical oxygen demand and chemical oxygen demand of the waste releases, and the flow characteristics of the stream shall not create conditions downstream that are detrimental to benefical uses.
1973	General Standard The dissolved oxygen concentration shall not be less than 5.0 mg./l. for all warm waters.... Under extreme conditions, the diurnal variations may cause the dissolved oxygen concentration to be as much as 1.0 mg./l. below the above value for short periods (not to exceed 8 hours) during any 24-hour period provided that the water quality is favorable in all other respects. Special Standards Return Flow Streams: Dissolved Oxygen- the dissolved oxygen content of a return flow stream shall not be less than 2.0 mg./l. The dissolved oxygen concentration just above the point where the flow of the stream combines with the flow of a stream of higher designated use shall not be less than 3.0 mg./l. Mixing Zones and Zones of Passage: Dissolved Oxygen- the dissolved oxygen shall not be less than 2.0 mg./l. within the mixing zone. C_1- Fish and Wildlife Propagation. General Standard (applies as above i.e. D.O. 5.0 mg./l.). C_2- Fish and Wildlife Propagation to the extent allowed by specifically stated water parameters (i.e. "b" designation for return flow stream as above with 2.0 mg./l. D.O. criteria).

Table 1. Summary of Oklahoma Water Quality Standards for Fish and Wildlife Propagation 1968-1982 (79,80).

Year	Description of Benefical Use and D.O. Criteria
1976	Fish and Wildlife Propagation (Sec. 4.3). There are no generalized water quality standards applicable for all kinds of fish and wildlife. Generally, unpolluted waters support a diverse aquatic community while only tolerant species can survive in comparatively polluted waters. The impact of a given chemical constituent on a biological community is not mutually exclusive of other constituents since synergistic interactions are common. General Standards. Apply for all perennial streams except when flow is less then the seven day, two year low flow value. This standard also applies for intermittent streams when the flow is less then 1.0 cfs. Sec. 6.9- Dissolved Oxygen: The dissolved oxygen concentration shall not be less than 5.0 mg./l. for all warm waters.... It is recognized that diurnal fluctuations of dissolved oxygen occur in natural aquatic systems due to production and respiration processes. Due to these natural processes, a 1.0 mg./l. dissolved oxygen concentration deficit shall be allowed for not more than eight hours during a twenty-four(24) hour period. At all other times the instream dissolved oxygen concentration shall be maintained to prevent nuisance conditions caused by mans activities. Special Standards. Mixing Zones: The dissolved oxygen concentration in a mixing zone shall not be less than 4.0 mg./l.
1979	Fish and Wildlife Propagation (same as 1976). General Standards (same as 1976). Special Standards (same as 1976).

Table 1 (cont.). Summary of Oklahoma Water Quality Standards for Fish and Wildlife Propagation 1968-1982 (81,82).

Year	Description of Benefical Use and D.O. Criteria
1982	Fish and Wildlife Propagation. Sec. 4.3 (added one additional sentence to the 1979 version). In addition, waters of diverse habitat will exhibit more species than waters with limited habitat variation. Dissolved Oxygen. Sec. 4.3(a)- Two dissolved oxygen (D.O.) standards are designated to protect the diverse warm water fisheries of Oklahoma. Streams designated as Primary Warm Water Fisheries are required at all times to meet a minimum dissolved oxygen of 5.0 mg./l. Streams designated as Secondary Warm Water Fisheries are required to meet a minimum dissolved oxygen of 3.0 mg./l. Allowable loading designed to attain these criteria shall be calculated at the low flow value and critical temperature as defined in Appendix C. Appendix C. Allowable Load: For Perennial Streams- the allowable load for oxygen demanding substances shall be based upon attaining an instream D.O. of 5.0 mg./l. for Primary Warm Water Fisheries, 3.0 mg./l. for Secondary Warm Water Fisheries.... at and above the seven-day, two year low flow value, and at the critical temperature. For Intermittent Streams- the allowable loading for oxygen demanding substances shall be based upon attaining an instream D.O. of 5.0 mg./l. for Primary Warm Water Fisheries, 3.0 mg./l. for Secondary Warm Water Fisheries.... at and above 1.0 cfs., and at the critical temperature. Critical Temperature: The seven day maximum temperature likely to occur with a 50% probability each year, or 90oF. Mixing Zones: No D.O. criteria presented. New language was added as follows: It is recognized that the water quality in the mixing zone may be unsuitable for certain beneficial uses.

Table 1 (cont). Summary of Oklahoma Water Quality Standards for Fish and Wildlife Propagation 1968-1982 (84).

These two levels of protection bear a striking resemblance to the present 1982 standards. The impact of the return flow stream concept is, at least from an regulatory viewpoint, analogous to the secondary warm water fishery designation introduced in the 1982 standards. The difference being that the D.O. level for return flow streams was 2.0 mg./l. and the secondary warm water fishery designation is 3.0 mg./l.

In 1976 (81), the Environmental Protection Agency (EPA) pressured the State to remove the return flow concept referred to as little 'b'-"an effluent dominated stream". The section 208 studies of the Clean Water Act were in full swing in many parts of the country including Oklahoma. This author remembers the many meetings he attended as a member of the Environmental Policy Advisory Council for the Association of Central Oklahoma Governments (ACOG). During these meetings the goals of the Clean Water Act (i.e. "fishable swimmable streams by July 1, 1983") were echoed as a force along with public sentiment which assisted in the eventual removal of the little 'b' designation. The result of the 1976 revision process was a strengthening of the D.O. criteria to 5.0 mg./l. with a eight hour excursion of 1.0 mg./l. to 4.0 mg./l. due to natural diurnal flucuations in dissolved oxygen. In addition, when the flows dropped below 1.0 cfs only the narrative standards preventing nuisance conditions would apply.

In 1979 (82), attempts to revise the standard for D.O. were minimized by the fact that the approval of the 1976 standards had taken practically three years. This meant that the 1979 review process saw no substantial change in the D.O. criteria for fish and wildlife propagation.

Then in 1982 (84), the revision process resulted in still another change in the fish and wildlife propagation beneficial use designation. Two separate categories were introduced, each with a different D.O. criteria. The criteria was divided between "primary warm water" and "secondary warm water" fishery designations. Primary warm water fisheries were assigned a D.O. criteria of 5.0 mg./l. and defined as areas with "water quality and habitat adequate to support sensitive warm water fish species in abundance". "Environment suitable for a full range of warm water benthos". Secondary warm water fisheries were assigned a D.O. criteria of 3.0 mg./l. These were defined as areas with "water quality and habitat not adequate to support sensitive warm water fish in abundance". "This can result from two conditions: a) Habitat and natural physical-chemical characteristics not suitable for a full range of aquatic organisms. b) Man induced conditions preclude the attainment of a full range of aquatic organisms including sensitive warm water fish species in abundance". These standards are to apply at all times in streams designated as such.

It becomes apparent from an examination of the various changes which have occurred over these 15 years that, the D.O. criteria has played an important role in the politics of water quality management and standards in Oklahoma. That is to say, that the underlying theme behind the continued revision has been to achieve some flexibility apart from the rigid across the board 5.0 mg./l. D.O. standard.

The Clean Water Act (91) set as national goals some of the following:

1. "it is the national goal that the discharge of pollutants into navigable waters be eliminated by 1985".
2. "it is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and which provides for recreation in and on the water be achieved by July 1, 1983".
3. "it is the national policy that the discharge of toxic pollutants in toxic amounts be

prohibited".

These were adopted by communities across the country including Central Oklahoma during the previously mentioned 208 study period.

In some cases, in spite of the best efforts of management agencies, the role decision making policy played in the setting of the D.O. criteria left the realm of science and entered the political setting of citizens advisory committees, public hearings and threats of federally promulgated standards. This I believe is at least some of the local color of what occurred in Oklahoma during the period between 1973 and 1983. The numerous changes in the standards for fish and wildlife beneficial uses, during that period, reflected a hard, rigid approach. This was tempered by the goal of the federal law rather than the reason and the calculated substantiation of wasteload allocation studies and scientific evaluations.

Development of the 1982 Oklahoma Water Quality Standards.

Towards the end of the 208 process in Oklahoma, and continuing since, the application of wasteload allocation methodologies has helped to return the decision making process for fish and wildlife benefical use criteria to a respectable blend of science and politics. In the 1982 revision process, several developments unfolded which set the stage for the present dichotomous criteria know as primary and secondary warm water fisheries.

First, the regional wasteload allocation process in Central Oklahoma (2) resulted in the proposal to develop a distinction between those rivers or stream segments which could support a 5.0 mg./l. criteria for D.O. and those which could not. Reasons for not being able to meet the existing criteria included: physical limitations (i.e. lack of adequate habitat) and economic factors (i.e. costs for treatment more advanced than secondary).

Second, the State's wasteload allocation process and 208 worktask 141 (83) revealed similar thoughts on the need for a special case criteria to allow for a lower D.O. standard in streams receiving domestic waste. The State's case was tempered by the status of numerous federal construction grants projects which could potentially be affected by any change in the D.O. criteria. Thirdly, the introduction of the new guidelines on the revision of water quality standards by EPA.

The net result of these three factors, and other managerial considerations of OWRB, was the consideration of certain streams and segments of streams for redesignation as secondary warm water fisheries. In the process, an attempt was made to utilize the developing EPA supported use attainability analysis methodology to collect data from those stream segments proposed for possible redesignation.

This dissertation will focus on certain aspects of the data collected as part of the process to support or contest the proposed revisions. An attempt is made to develop data management techniques which help differentiate between groups of related information. This approach attempts to classify the relative biological and environmental attributes of secondary and primary warm water fisheries and the factors which influence their occurrence.

The Problem.

The EPA policy for the revision of water quality standards requires supportive information and documentation for the redesignation of a beneficial use. Determining how to analyze Oklahoma's use attainability database and depict the present status of aquatic use attainment is the purpose of this research. The technique of depicting the existing environmental condition and the present status of use attainment is referred to as "use attainability analysis (UAA)". This procedure, as introduced by EPA (35), is addressed in more detail in a subsequent chapter of this dissertation.

Much of the information in the Oklahoma UAA database is qualitative or semi-quantitative data supported by the professional judgement of the investigators. Information on the community structure of fish and invertebrate species consists of presence and absence, and relative abundance designations. Habitat and other environmental variables differ in level of measurement and units of measure as well. Developing a data analysis methodology which helps to determine the patterns of association in the data, assess the degree of beneficial use attainment, distinguish between secondary and primary warm water fisheries, and account for the factors affecting their occurrence, is essential to the successful documentation of proposed revisions.

The importance of scientific documentation for beneficial use redesignation cannot be overstated. Section 130.17(c)(3) of the Federal Water Pollution Control Act specified that one of the following criteria must be documented before any downgrading of existing beneficial uses can be approved:

> "The State may establish less restrictive uses than those contained in existing water quality standards, however, only when the State can demonstrate that:
>
> (i) The existing designation is not attainable because of natural background;

(ii) The existing designated use is not attainable because of irretrievable man-induced conditions; or

(iii) Application of effluent limitations for existing sources more stringent than those required pursuant to Section 301(b)(2)(A) and (B) of the Act in order to attain the existing designated use would result in substantial and widespread adverse economic and social impact."

EPA issued its final rule on water quality standards review and revision on November 8, 1983 in 40 CFR Part 131. This regulation sets forth the present requirements for changing beneficial use designations. The details of these requirements and the future role of UAA in the standards revision process are discussed in Chapter IV.

The ability of the secondary warm water fishery designation to serve as an administrative short cut around the redesignation process should not be ignored. However, where it can be documented that the existing conditions are inherently limiting and unable to support a diverse and healthy community structure, UAA can serve as the method to support and document a proposed redesignation.

The Objective.

The major objective of this study is to illustrate techniques which can be applied to assess the various categories of variables in the UAA database. Emphasis has been given to those aspects of the database which can serve to illustrate the possible distinctions between primary and secondary warm water fisheries (i.e. biological variables). In addition, because these differences might reflect the result of natural versus man induced conditions, an attempt is made to assess factors affecting the variations within the database.

Assumptions.

Analysis of the attainment status for fish and wildlife beneficial uses is a relatively new form of aquatic assessment technology. UAA is not like the classical limnological investigations which sampled the biological community in broad based framework designed to develop 'baseline data' for trend analysis. UAA is a more focused form of assessment. The methods employed in the Oklahoma study were developed by OWRB staff using EPA guidelines and assistance, as well as, advice from numerous local water quality specialists (including this author). The method must therefore be considered developmental and not rigid in application or evaluation. The database represents the best consensus of effort applied to date on a statewide level. Oklahoma's UAA program attempts to assess the existing level of attainment of fish and wildlife beneficial uses by implementation of EPA's developing guidelines on water quality standards revision.

CHAPTER II

LITERATURE REVIEW

Introduction.

The ability of any given stream environment to support aquatic life of a diverse and healthy assemblage is a function of intrinsic and extrinsic factors. Intrinsic factors, such as production and consumption, interrelate as forces which affect the balance of a given stream environment's trophic pyramid. This pyramid is also subject to stress from extrinsic factors, such as polluting sources of waste and extreme climatological conditions. Those streams which have the combined burden of both these forces are subject to substantial degradation. This degradation is reflected by changes in the community structure of organisms inhabiting the stream.

The following sections of this chapter expand upon the theme of how to measure change in a given stream environment. The methodologies which have been employed in the past to account for the stresses which nature or man produce are reviewed. There are three main areas of this review. These consist of the use of biological indices, the relationship of dissolved oxygen to fish and the ecology of stream environments, and multivariate analysis of aquatic ecology. The emphasis is on documenting those literary accounts which have potential for use as methods to analyze or evaluate Oklahoma's UAA database.

The Use of Biological Indices in the Assessment of Hydrobiocenosis

Introduction.

How should water quality be measured? That is our challenge. The use of indices and indicator organisms has been the subject of many reviews (15,42,58,71,118). Brown et. al. (15) referred to an index as a "yardstick" and the process of making decisions supported by a water quality index, an art more than a science. Translating the often random and seemingly uncorrelated data of biological, chemical and physical information into a well illustrated unambiguous account of the quality of a given environment is the focus of this review. Traditional and innovative assessment methodologies, such as the Biotic Index (131) and Communtiy Diversity (98), will be reviewed along with other comparison techniques.

Pollution Indices.

Monitoring of changes in the aquatic ecosystem and the assessment of community structure has long been a subject of interest to those involved in water quality research. European researchers such as Kolkwitz and Marrson (63,64) introduced the concept of the saprobien system in 1908. This is a form of zonal classification, based on the occurrence of saprobic organisms. This system was later modified by Liebmann (65,66), and Sladecek (100-103) to account for the range of occurrences of saprobic species and the saprobity of a given segment of a stream.

Use of the saprobic system of classification requires exact speciation of samples whether invertebrates are used to calculate these indices (104,105) or diatoms (67). This effort is extremely labor intensive and often, as was the case with the Oklahoma UAA study, cost prohibitive. The use of costly techniques, such as speciation of benthic invertebrates and diatoms, requires personnel with highly trained taxonomic skills. Most regulatory agencies do not possess the type of personnel trained to do this analysis. These levels of identification are perhaps better attended to by sub-contract with local universities and colleges.

Biotic Indices.

Another category of classification includes the Biotic

Index, developed by Woodiwiss (131) in 1964 for the Trent River Board. This method, represented in Table 2, is based on the presence or absence of certain critical groups of taxa. The index changes, decreasing in value from 10 to one, as the species composition shifts from samples containing higher numbers of pollution sensitive organisms to more varieties of pollution tolerant species. Numerous adaptations of the Biotic Index have been utilized to assess stream quality. Graham (45) inverted the scale of the original Biotic Index and shortened the values which ranged from one in clean streams to six in polluted areas. The classification scheme prepared by Graham is presented in Table 3. Chandler (25) radically expanded the Biotic Index to a 'score system' which assigns scores to given groups of species present and their relative abundance. The Chandler Score system is outlined in Table 4.

Unlike the saprobien system, biotic indices are less dependent on taxonomic classifications at the species level. Chandler's Score uses taxonomic group levels such as order, family, genus and only occassionally species. This concept of scoring the relative significance of taxonomic groups, and weighing the value as a function of pollution categories and relative abundance, has potential for application in use

TRENT BIOTIC INDEX

WATER QUALITY		NUMBER OF SPECIES	TOTAL NUMBER OF GROUPS PRESENT				
Clean			0-1	2-5	6-10	11-15	16+
	Plecoptera nymphs	> one	-	VII	VIII	IX	X
		only one	-	VI	VII	VIII	IX
	Ephemeroptera nymphs (exd.*Baetis*)	> one	-	VI	VII	VIII	IX
		only one	-	V	VI	VII	VIII
	Trichoptera larvae or *Baetis*	> one	-	V	VI	VII	VIII
		only one	IV	IV	V	VI	VII
	Gammarus	all above absent	III	IV	V	VI	VII
	Asellus	all above absent	III	IV	V	VI	VII
	Tubificid worms and/or Chironomid larvae	all above absent	I	II	III	IV	-
Polluted	All above absent	some species requiring low D.O. may be present(i.e. *E. tenax*)	-	I	II	-	-

Table 2. Trent River Board Biotic Index (131). Sample accumulates points based on the presence of these groups of taxa and the total number of different groups or organisms (i.e. families, genera, species) present in the sample.

GRAHAM'S BIOTIC INDEX

KEY GROUPS	NUMBER OF GROUPS FOUND	INDEX
Stoneflies and non-Baetid mayflies present	10+ 0-9	1 2
One or both of the above absent, caddis and shrimps present	10+ 0-9	2 3
Stoneflies, non-Baetid mayflies and caddis absent, _Baetis_, shrimps, _Asellus_, snails or leeches present	10+ 0-9	3 4
All above groups absent, fauna restricted to _Tubifex sp._, _Nias sp._, midge larvae or blood worms	-	5
No macroinvertebrates found	-	-

Annual Mean Index	Pollution Category
1-2	A. Clean
2-3	B. Poor
3-4	C. Polluted
4-5	D. Seriously polluted
5	E. Grossly polluted

Table 3. Graham's Biotic Index (45). A sample accumulates points on the basis of the presence of key taxonomic groups and the total number of taxa in the sample.

CHANDLER'S SCORE

GROUPS PRESENT IN SAMPLE	PRESENT	FEW	COMMON	ABUNDANT	VERY ABUNDANT
Planaria alpina, Taeniopterygidae, Perlidae, Isoperlidae Chloroperlidae	90	94	98	99	100
Leuctridae, Capniidae Nemouridae (exd. *Amphinemura*)	84	89	94	97	98
Ephemeroptera (exd. *Baetis*)	79	84	90	94	97
Cased Caddis, and Megaloptera	75	80	86	91	94
Ancylus sp.	70	75	82	87	91
Rhyacophila	65	70	77	83	88
Dicranota, Limnophora	60	65	72	78	84
Simulium	56	61	67	73	75
Coleoptera, Nematoda	51	55	61	66	72
Amphinemura	47	50	54	58	63
Baetis	44	46	48	50	52
Gammarus	40	40	40	40	40
Uncased Caddis (exd. Rhyacophila)	38	36	35	33	31
Tricladida (*P. alpna*)	35	33	31	29	31
Hydracarina	32	30	28	25	21
Mollusca (exd. *Ancylus*)	30	28	25	22	18
Chironomids (exd. *C. riparius*)	28	25	21	18	15
Glossiphonia)	26	23	20	16	13
Asellus sp.	25	22	18	14	10
Leeches (exd. *Haemopis* & *Glosiphonia*	24	20	16	12	8
Haemopis sp.	23	19	15	10	7
Tubifex sp.	22	18	13	12	9
Chironomus riparius	21	17	12	7	4
All air breathing sp.	19	15	9	5	1
No animal life	0	0	0	0	0

Table 4. Chandler's Biotic Index "Score" (25). The taxonomic composition of a sample accumulates points based on the number of different groups (i.e. species or genera) and their relative abundance.

attainability analysis.

Balloch et. al. (6) conducted studies on three river systems in England. They compared the Trent Biotic Index, Graham's Modified Index and Chandler's Score with the number of benthic invertebrate taxa, density of individuals, the Community Diversity Index, and Kothe's Species Deficit. They concluded that each method has specific advantages and disadvantages. Chandler's score was considered to be the most sensitive index for depicting changes in water quality between sampling stations. Cook (27) also reviewed indices for community structure and found the Shannon-Weaver index of diversity to be very imprecise and Chandler's Score a more reliable index highly correlated with B.O.D. and coliform counts.

Still another approach to classification based on the concept of the Biotic Index was prepared for the Department of the Environment (DOE), London England (48). Hawkes' thesis on the biological surveillance of rivers discusses the DOE model referred to as the BMWP Score (Biological Monitoring Working Party). This score system is much like the Trent Biotic Index in that it develops a scale from 1 to 10 based on the pollution tolerance of benthic organism to organic pollution. The occurrence of various taxa accumulates points for the sample and the sum represents the score for that sample or station. The Biotic Index and the BMWP Score are examples of data processing techniques which scale the quality of the environment based on the presence or absence of taxa and their pollution tolerance. They differ from Chandler's Score and the diversity index which include in the calculation quantitative analysis of the number of individuals in the sample.

Jones et.al. tested the use of the Biotic Index in assessing water quality of Missouri Ozark Streams (59). They used variations on the Biotic Index theme prepared by Chutter (26) and Hilsenhoff (50). They scored benthic invertebrates according to specific pollution tolerances ranging from zero to four. The Biotic Index was then calculated as the sum of the pollution tolerance values divided by the number of species and multiplied by the number of individuals present for each taxon at that sampling point. They remarked that seasonal changes in benthic assemblages could affect comparisons made between sampling stations.

Ghetti and Bonazzi (43) prepared a conversion table for correlating the Biotic Indices of Woodiwiss (131), Verneaux-Tuffery (125), the Saprobic Indices of Pantle and Buck (85) and Liebmann (65,66). The conversion table helps make associations between Biotic Index scores, which are based on the occurrence of organisms with specific pollution tolerance ratings, and the various saprobic classifications. Saprobic classifications are based upon identifying the zone or class of organic enrichment from nonpolluted to more organically enriched polysaprobic environments.

Water bodies are not static or steady state environments. Classifications such as the Saprobien System delimit major zones of change. These changes are reflected in both the biota and other parameters as well. Von Tumpling (126,127) described the relationship between levels of saprobity, dissolved oxygen, biochemical oxygen demand and ammonia ion concentrations. He proposed four classifications based upon the relationship between the biological state (saprobidity) and oxygen balance in the stream. The ability to make associations between the scale of a pollution index and other environmental factors such as B.O.D. and the degree of wasteloading have potential for application in UAA.

Schmitz (97) advocated the use of simpler and less technical methods in biological stream surveys to assess water quality and assist in technical planning. He described 5 classes of organic pollution loading based upon descriptive summaries of habitat features, biological characteristics and oxygen supply.

Diversity Indices.

The basis for comparisons of community structure includes as a prerequisite, accurate and thorough species identification. Resh and Unzicker (93) addressed the importance of species identification for benthic macroinvertebrates. Hellawell (49) summarized most of the properties of indices used to assess changes in aquatic ecosystems. Regardless of the varying adequacy of any given index, most if not all, would be affected by application of erroneous data containing misidentified species which are improperly included in account of other similar but perhaps ecologically distinct individuals. This is particularly true in the case of misidentification of a pollution sensitive species as a pollution tolerant variety.

Assessment methodologies which use accounts of the pollution tolerance of indicator organisms, such as the Biotic Index and to a greater degree the Saprobic Index, rely on the accuracy of taxonomic classifications. Numerous authors have reviewed the use of the indicator organism concept for different groups of aquatic organisms (42,47,58,54,). Resh (93) examined the adequacy of the pollution tolerance designations prepared by EPA (34). In this case, the pollution tolerance designations were assigned to species of benthic macroinvertebrates at the genus level.

Resh compared the outcome of assigning ratings to organisms identified at the genus level versus what would occur when species level identifications were used. As many as 61 of the 89 genera used in the comparison had received changes in their designation due to enhancing the level of identification from genus to species. This dramatically points out the sensitivity of indices based on pollution tolerance to both the affects of misclassification and inadequate levels of identification. Disregard for either can cause a distortion of the true account of water quality.

The search for the most applicable index to assess perturbation and disruption of the integrity associated with a healthy ecosystem has, in recent decades, relied upon the information theory proposed by Margalef (68,69). The Margalef Index allows for the calculation of diversity based upon a relationship among the number of species and the number of individuals present within each species category. It also allows for the calculation of both theoretical minimum and maximum diversity, and redundancy. Redundancy is the relationship of the theoretical maximum to the minimum diversity. High redundancy indicates dominance by one group of taxa which shifts the community structure from the desirable balance between minimum and maximum diversity.

Wilhm (128) and Dorris (129) have enhanced the application of Margalef's theories through practical examples of the application of community diversity in monitoring pollution ecology. Wilhm performed comparisons of diversity indices, species number and numbers of individuals during different seasons along Skeleton Creek near Enid, Oklahoma. He found that the diversity per individual measurements correlate best with the number of species rather than the number of individuals. As a result, many researchers prefer the use of Wilhm's community diversity formulation to other diversity formulas as an index with a lesser sensitivity to sample size.

Hurlbert (56) critiqued the use of diversity as an empirical measure of community structure. Quoting work done by Sanders (95), Hulbert pointed out how two collections can have identical diversities while having radically different species richness curves. Emphasizing the importance of measuring the patterns of a given species' population (i.e. number of individuals), and species richness over diversity; Hurlbert boldly stated "diversity per se does not exist". He went on to say that the use of correlations of diversity indices with environmental variables were not to be regarded as evidence of their utility or appropriateness.

Karr (61,62) Holcutt (51,52) and others (112) reflect the thinking of Hurlbert by proposing the use of more qualitative methodologies which place more emphasis on the richness of species composition than diversity. Mathematical formulations or indices are most effective when used to evaluate species composition of the appropriate taxocenes (56). A taxocene is a taxonomic segment of a community or association. Hurlbert advocates that species composition be evaluated on appropriate taxocenes. Evaluation of diversity or species richness calculations need not always be performed on all fish or benthic macroinvertebrates as a unit. Community members acting in association or related by common encounters in the ecosystem can be segregated out for intraspecific measurement. Examples of this would be analysis of fish families such as Centrarchidae, or groups such as omnivores and carnivores. This trend to focus on groups of associated organisms or taxocenes is seen in the EPA guidelines on use attainability analysis.

In addition to the mathematical problems associated with the interpretation of diversity, other factors have been found to have influence on the diversity index. Hughes (55) studied the affects of several factors on the outcome of Shannon's Index. He stated that interpretations and comparisons made with diversity indices are affected by sampling methods, the area sampled, the time of the year, and the taxonomic level of identification.

Quantitative indices such as the diversity index require large numbers of samples to serve as estimates of population. Hellawell (49), determined that at least 10 samples were required to estimate the mean density of the macroinvertebrate population at the 95% confidence level. He showed that the number of individuals required to estimate density were inversely proportional to the percent error. Analysis of individual groups, such as Ephemeroptera (mayflies), requires much larger sample sizes to estimate the density of the population (604 at one standard deviation for 10% error).

One of the drawbacks of the diversity index is it's computational difficulties. The advent of personal computers are expected to assist biologists in calculating many of the more complex computational indices. Moore (75) recently published a computer program in the BASIC programing language which calculates the Shannon Index, Brillouin Index, Simpson Index, Pielou Eveness, Hiep Eveness, Fisher's Alpha, and some summary statistic's.

Comparison Indices.

Hellawell (49), in his review of major biological indices, pointed out that most of the literature recommends water quality surveillance by the monitoring of macroinvertebrates and algae. These are followed by protozoa, bacteria and fish respectively. Changes in biological communities can be reflected in either or both the form of the community and its functions. Changes in form or structural changes result from the influence of pollution. These factors create an imbalance in the community and are reflected in changes in the species composition, biomass, and diversity. Functional changes are detected in relation to the energy dynamics of the ecosystem. These can be monitored in terms of the net production (i.e. photosynthesis) or consumption (i.e. respiration) rates. Monitoring change in the context of Hellawell's definition means selecting the appropriately sensitive index.

Comparison indices are an additional category of methodologies apart from pollution or diversity indices. In general, these formula assess change by computing the effect of species presence or absence between stations. Two examples of these are the Jaccard Coefficient (57) and the Sorenson (107) Index of Similarity. The Sorenson Index is included in the Oklahoma Water Quality Standards as a method to assess change in the biological community structure, between stations, before and after a point source begins to discharge to a segment. Unlike the diversity index, the Sorenson Similarity Index has no clear definition in enforcement of the present State standards. The Jaccard Coefficient of Similarity has often been used in multivariate analysis of community structure(60,106). These applications are discussed in a subsequent section on multivariate analysis.

One comparison index, referred to as the Sequential Comparison Index, was reviewed by Cairns et. al. (17). He remarked that this method was capable of recognizing impacts on the biota similar to those ordinarily assessed by changes in diversity. The index has the property of simplicity requiring only a crude differentiation between organisms in a sample. This property makes it particularly useful for use in studies which utilize data of less taxonomic detail than that required for calculation of the diversity index.

Archibald (1) used the Sequential Comparison Index (SCI) along with diversity indices to assess relationships of diatom communities to pollution. He showed that as the relative density of dominant species declined in the samples, the SCI improved or increased. He also compared the SCI with the diversity index. The SCI showed a sensitivity to changes in diversity with a high positive correlation to Brilloun's diversity per individual (r=0.90) and a high negative correlation to redundancy (r=-0.89) and Simpson Index (r=-0.92) (120).

Fish and Dissolved Oxygen

Introduction.

Several authors have reviewed the effects which dissolved oxygen (D.O.) has on fish communities as a result of sewage discharge (29,30,31,33,40,120). Susceptability to the lethal effects of low dissolved oxygen vary among the species of warm water fish. During winter months, dissolved oxygen levels of 1.0 mg/l. or less were found to be fatal for most species of fish except the Black Bullhead Catfish. The ability of fish to acclimate to lower D.O. levels, thereby lowering their susceptibility to lethals has been demonstrated with Bluegill Sunfish, Largemouth Bass and Channel Catfish. Fish behavior (i.e. avoidance), respiration, growth and food consumption are also affected by low D.O. levels (121).

Tsai (121) presents an excellent review of D.O. levels proposed for the protection of warm water fish. Most researchers cited by Tsai advocated a D.O. standard of 5.0 mg./l., with a daily minimum of not less than 3.0 mg./l. The National Technical Advisory Committe of the Federal Water Pollution Control Administration recommended a standard of

5.0 mg./l. or better for the protection of a diverse fishery. The National Academy of Science and others recommended a floor value of 4.0 mg./l. Regardless of which source of scientific literature is cited to justify a criteria for D.O., setting standards eventually becomes the administrative problem of the regulatory agency. Purely scientific recommendations must be blended with the other concerns of the State to arrive at a just and equitable standard within the context of the law and the intent of a State's environmental policy. Still there are technical issues to address and this review will attempt to address some of the more critical items.

Fish as Indicators of Water Quality.

The use of fish as the focal point of water quality assessment has not been accepted by researchers who believe that other communities, such as the benthic invertebrates, or periphyton, are more suitable in detecting and assessing the affects of pollution (34,40). Nonetheless, there must be some degree of diversity available in the ecosystem if certain fish species are to be present and thrive in reasonable abundance.

Price (87) reviewed the applicability of fish as indicators of water quality and concluded that fish are a suitable indicator group. He emphasized that they were particularly useful in matters of public interest. He also concluded that other groups (i.e. invertebrates) are more suitable for detailed assessment. His position on the use of fish in studies of public concern, such as water quality standards, is noteworthy.

The present day application of fish in water quality assessment is divided among two basic categories of interest. The application of fish as test organisms in bioassay experiments, both in situ and in vitro, is a growing field. Cairns et. al. (18-20) and Sprague (108-110) have detailed the application of fish in research on aquatic toxicology. Locally, studies like those conducted by Burks (3) for the Association of Central Oklahoma Governments, are examples of research designed to assist management agencies in setting criteria to protect aquatic life from the acute and chronic exposure to toxic wastes. Application of these developing technologies can be expected to expand as techniques are standardized and incorporated in assessment methodologies like that proposed by EPA for setting site specific standards.

Karr (61) and Hocutt (52) are modern day proponents of methodologies which assess the integrity of aquatic ecosystems using fish as the focal point of the assessment methodology. Table 5 presents the classification methodologies used by Karr. This approach classifies the fish community into a scale from "very poor" to "excellent" based upon a discription of attributes. Another feature of this research is the use of qualitative and semiquantitative levels of measurement. The use atttainability analysis methods used in the research relied on similar levels of measurement to draw comparisons between categories of fish and environmental variables.

The Receiving Stream and Zones of Pollution.

In the past, the description of impacts from organic wastes on receiving streams included the classic account of little or no fish present below the outfall from the sewage plants. Bartsch and Ingram (7) produced several illustrations which graphically depict the changes in water quality and aquatic life which can result in a stream as a result of discharge of raw domestic waste. Figures 1 and 2 show the changes in D.O. and the resulting effects on a variety of aquatic life forms found at increasing distances downstream. These illustrations demonstrate the hypothetical consequences of excessive discharge of raw wastes. This relationship between oxygen demanding substances (i.e. B.O.D.) and the oxygen concentration of a stream has become a

KARR'S INDEX

CATEGORY	QUALITY POINTS (VALUE SCALE): 1	3	5
Total Species	<=6	>6 <=12	>12
Total Individuals	<=58	>58 <=106	>106
Darter Species	<1	1	>1
Sunfish Species	<1	1	>1
Intolerant Species	<1	1	>1
Sucker Species	<1	1	>1
Omnivores	>=56	<56 >=25	<25
Insectivore Cyprinids	<=13	>13 <=30	>30
Green Sunfish	>10	>2 <=10	<=2
Top Carnivores	<1	>=1 <=4	>4
Hybrids	>=1	-	<1
Diseased Fish	>=1	-	<1

Classification= sum of value scale of quality pionts.

Excellent= 57-60

Excellent to Good= 53-56

Good= 48-52

Good to Fair= 45-47

Fair= 39-44

Fair to Poor= 36-38

Poor= 28-35

Poor to Very Poor= 24-27

Very Poor= <=23

Table 5. The Karr Index. A summary of the fish community evaluation index proposed by Karr(61).

Karr's Index

CLASS	ATTRIBUTES
Excellent	Comparable to the best situations without influence of man; all regionally expected species for the habitat and stream size, including the most intolerant forms, are present with full array of age and sex classes; balanced trophic structure.
Good	Species richness somewhat below expectation especially due to loss of most intolerent forms; some species with less than optimal abundances or size distribution; trophic structure shows signs of stress.
Fair	Signs of additional deterioration include fewer intolerant forms, more skewed trophic structure (e.g. increasing frequency of omnivores); older age classes of top predators may be rare.
Poor	Dominated by omnivores, pollution-tolerant forms; hybrids common; few top carnivores; growth rates and condition factors commonly depressed; hybrids and diseased fish often present.
Very Poor	Few fish present, mostly introduced or very tolerant forms; hybrids common; disease, parasites, fin damage, and other anomalies regular.
No Fish	Repetitive sampling fails to turn up any fish.

Table 5 (cont.). The Karr Index. General descriptions of Karr Index classification attributes (61).

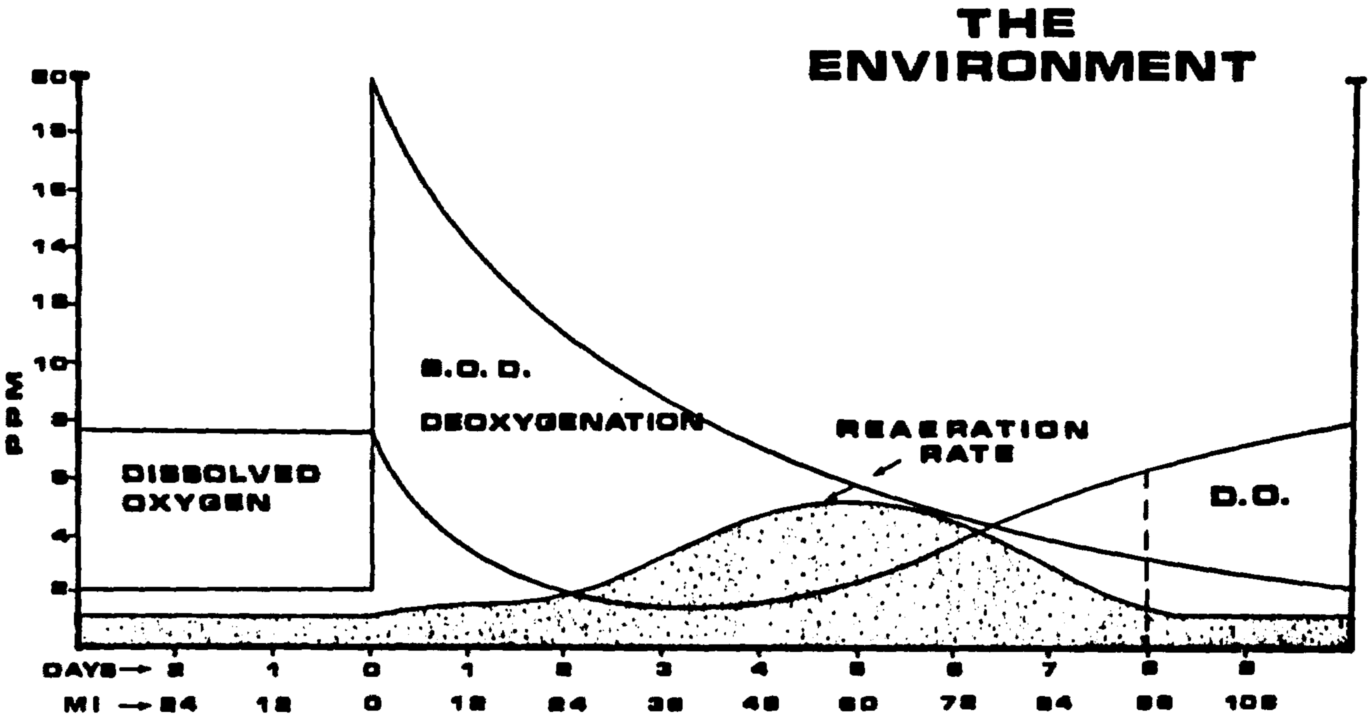


Figure 1. D.O. AND B.O.D. LEVELS IN A STREAM PARTIALLY DESTROYED BY A POLLUTION LOAD OF ORGANIC WASTES (7).

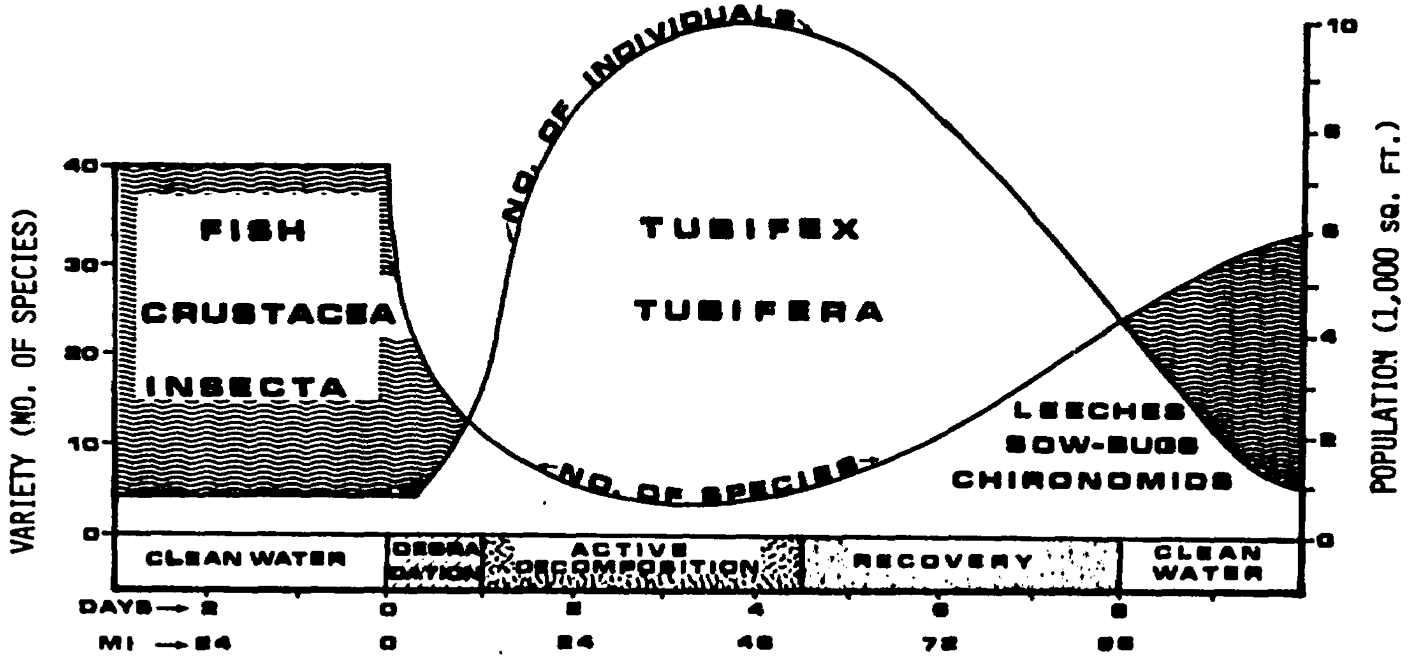


Figure 2. EFFECTS OF SEWAGE UPON THE VARIETY AND DENSITY OF AQUATIC ORGANISMS.(7).

major area of engineering study and mathematical simulation. These areas are discussed in subsequent sections of this chapter.

The zones of pollution referred to by Bartsch and Ingram represent patterns of physical, chemical and biological transformations which occur along a stream's length. The "River Continuum Concept" (123), as it is called, puts forth the view that a river is a blueprint. That it is marked along it's length by certain benchmarks or gradients of change or adjustment. These changes are the stream communities response to the effects of pollution loadings and changes in physical characteristics. These blueprints can be looked upon as overlays consisting of information on chemical, physical and biological responses to changes in water quality from upstream to downstream portions of the stream.

Unlike the macrobenthos and the periphyton, fish of necessity and opportunity must move along this "continuum" in the process of fulfilling life cycle functions such as spawning, predation or seasonal migration. They can be thought of as the birds of the "continuum" environment. Perturbation, while drastically altering the species composition and community structure of the benthos and periphyton, does not altogether eliminate these groups from occurring at any point within the "continuum". Indeed, it has been pointed out by various researchers (7,124) that members of these groups actively participate in the self-purification process of the stream's ecology. Fish, on the other hand, can be completely eliminated from occurring at a given point due to excessive oxygen depletion by organic wastes.

The importance of D.O. to the life of fish and their ecological distribution is the essential element influencing D.O. criteria for fish and wildlife beneficial uses. Camp (21), quoting Tarzell, remarked that "under actual stream conditions, a fish must maintain its position against the current, find, pursue and catch its food, avoid its enemies, and reproduce". Adequate oxygen supply is essential for all these processes. Water quality standards designed to protect fishery resources must have a minimum oxygen level which is capable of sustaining all life requisites of desirable fish species.

Factors Affecting Dissolved Oxygen and Fish Distribution.

D.O. in a stream is affected by temperature, pressure, oxygen demanding chemicals (i.e. B.O.D., sulfites), respiration, photosynthesis and natural reaeration phenomena (124). Winkler (130) summarized the physical effects of temperature and pressure. Numerous tables have been developed to calculate the maximum D.O. level at a standard temperature and pressure. Percent saturation can be calculated to represent the ratio of the actual D.O. available at a given temperature to the expected maximum value. The amount of difference that exists between these two values is referred to as the D.O. deficit.

Temperature, in addition to affecting the D.O. level, also affects the physiology of fish. The resulting tolerance and intolerance to low D.O. levels can also affect the toxicity of other materials as well (19). The synergistic effects of low D.O. levels, increased respiration, high temperature, and exposure to toxic materials remains to be included in factors which influence the determination of minimum D.O. criteria. Presently, most reviews (11,12) of the D.O. criteria applied in water quality standards address the concept of limitation of ecological distribution without regard to the synergistic effects referred to above.

Ultsch et. al. (122) studied the critical oxygen tension requirements of darters (Etheostoma). This genus of fish is noted for possessing a limited ecological distribution (74). They are more characteristically associated with moderate to high gradient streams, cooler water temperature and higher dissolved oxygen levels. Winter and summer ambient oxygen levels observed by Ultsch were as low as 5.0 mg./l. and 3.3

mg./l. respectively. They showed that members of this group could lower their critical oxygen tension to compensate for the lower ambient D.O. levels. Darters survived periods of stress by lowering their metabolic rates, remaining inactive near the bottom of the streams, under rocks or in crevices, and lowering the critical oxygen tension required to sustain life.

Age can be an influence on the distribution and occurrence of fish. Matthews and Hill (70) studied age specific differences in the distribution of *Notropis lutrensis*. They conclude that adults tended to occupy deeper waters with more shelter, while juveniles often selected areas of higher temperature and D.O..

The importance of habitat as a co-related variable with distribution, diversity and dissolved oxygen is further illustrated by work done by Gormn and Karr (44). Habitat serves to provide shelter which influences the pattern of fish distribution and community structure (i.e. diversity). The functional value of habitat arises from its ability to provide each variety of aquatic life shelter from stress. Hence, a stream with an abundant and diverse supply of habitats is functionally more capable of supporting a productive fishery characterized by numerous desirable species. These researchers went on to point out, that in streams where habitat has been modified by channelization, the affects of seasonal and man induced changes in water quality adversely affected the stability of the fish community.

Tsai (120) performed comparative studies on fish species diversity and water quality at points above and below sewage treatment plants. He was attempting to establish criteria for the protection of fish communities in sewage polluted streams. In addition to showing adverse effects of effluents on fish communities, he also demonstrated the effects which the type of discharge outfall structure had on fish diversity and water quality. He concluded that less complicated outfalls, located along stream banks, were more effective at protecting fish populations. The more sophisticated multiple outlet designs, which mixed the effluents more rapidly with the receiving stream tended to produce concentrated zones or barriers of sewage across the stream. This factor adversely affected the fish migration, and caused a net depletion of the fishery resource as measured by diversity and species composition.

The ability to relate the effects of environmental variables with observed changes in the biological community is the focus of use attainability analysis. Methodologies which assess the relative health status of a biological community can serve to assist researchers in determining the degree of impact of limiting factors such as D.O. Relating all the potential influences from compounding and competing sources of stress into one coherent assessment is a difficult task. Many researchers have attempted to achieve this goal by integrating many of the factors discussed so far with the use of multivariate statistics, a topic discussed in a subsequent section.

Mathematical Relationships Governing Dissolved Oxygen Concentrations in Streams.

The process of deoxygenation and reaeration of receiving streams has become a major area of engineering study. Streeter and Phelps (116,117) studied these phenomena in streams and proceeded to unify these contrasting properties into what has been referred to as the "dissolved oxygen sag curve". These relationships were summarized by Canter (22) as follows:

$$D_t=(K_1L_a/K_2-K_1)(10^{-K_1t} - 10^{-K_2t})+D_a10^{-K_2t}$$

where: D_t =dissolved oxygen deficit at any flow time t expressed in days (saturation D.O. concentration - actual dissolved oxygen concentration).

$k1$ =coeficient of deoxygenation, day-1.

k_2 =coefficient of reaeration, day-1.

L_a =ultimate B.O.D. in the stream after mixing.

D_a =dissolved oxygen deficit upstream of the waste discharge (mg./l.)

k_1, k2, Da and Dt are influenced by temperature.

Solving even the basic Streeter-Phelps equation requires extensive field and laboratory work to determine levels of D.O., B.O.D., time of travel and rate constants. McBride (72) offerred the use of nomographs as rapid solutions to the Streeter-Phelps relationship. This technique lacks the sophistication of traditional methods, yet it does have potential for use in qualitative studies such as UAA. In this approach, a limited number of field or laboratory measurements could be related to rate constants by nomographic methods. These could then serve as variables to assess the streams' limitations for sustaining fish and wildlife beneficial uses at desired levels of D.O.

In the years since the development of the B.O.D. removal and oxygen sag relationships, numerous other phenomena affecting D.O. relationships have been researched and modeled. Velz (124) discussed the concept of D.O. balance as an accounting system. In this system each stream has components of debt (i.e. oxygen demanding factors) and credit (i.e. oxygen producing factors). These components or debits and credits are accounted for in the combined oxygen balance equation summarized by in Rau and Wooten (92):

$$dD.O./dt=-K_{1c}L_c-K_{1n}Ln-B-R+P+K_2(D.O._s-D.O.)$$

where L_c =ultimate carbonaceous B.O.D.

Ln =ultimate nitrogenous B.O.D.

k_{1c} =rate constant for utilization of carbonaceous B.O.D.

k_{1c} =rate constant for utilization of nitrogenous B.O.D.

B= sink resulting from aerobic decompostion of benthic materials.

R= respiration oxygen demand exerted by algae and other aquatic plants.

P= oxygen concentration by photosynthetic activity of algae and other aquatic plants during daylight hours.

$D.O._s$ =saturation dissolved oxygen.

Numerous authors have reviewed the basic relationships of carbonaceous demands (117,124), reaeration (77,78) nitrogenous demands (113), photosynthesis and respiration (53) and sediment oxygen demands (13,14). Further discussion of these relationships is outside the scope of this research. Nevertheless, all these factors (carbonaceous B.O.D., nitrogenous B.O.D., benthic and sediment oxygen demand, immediate oxygen demands, the dissolved oxygen deficit and reaeration) influence the level of D.O. which a given stream segment can support. The wasteload allotment assigned to a given effluent therefore accounts for the major source of man induced perturbation affecting the attainment of aquatic uses.

Multivariate Analysis in Assessment of Hydrobiocenosis

Introduction.

Cluster analysis is a form of multivariate analysis which is intended to sort out data into groups (96). These groups can be thought of as having similarity within themselves and dissimilarity between or among themselves and members of other groups or clusters. The interest in cluster analysis as a methodology for processing, organizing and summarizing data has produced a large array of methodologies. Blashfield and Aldenderfer (9) reviewed the status of cluster analysis and referred to its modern day applications as "an explosion of interest". This interest stems from the power of these techniques, which assist researchers in outlining patterns of association or dissimilarity among data when no predefined or a priori relationships are assumed.

There are two basic types of clustering procedures. Hierarchial methods organize clusters within groups of other clusters. These methods can be adapted to procedures which graphically illustrate the similar groups or clusters within a given hierarchial classification scheme. Such procedures are referred to as dendrograms, phenograms, or hierarchial tree diagrams. The second major category consists of partitioning the classification based upon some predetermined judgement and then producing clusters which improve these distinctions until the resulting members of a cluster represent the best group of homogeneous members. This review deals with the application of hierachial classification of ecologically related groups of data.

Cluster Analysis.

As cluster analysis methodologies became more popular, and computers more accessable to researchers, various statistical packages were developed, computerized and applied in analysis of biological and environmental data. Sokal and Sneath (106) are credited for advancing both the understanding of statistical techniques used by various clustering methodologies, and promoting the use of rapid computerized solutions to many of the various methods. The NT-SYS computer programs were developed by Rohlf et. al.

(94). Included among its clustering algorithms were various subroutines, such as calculation of the Jaccard Coefficient of similarity, which allow for rapid data matrix transformations. These and other features of the NT-SYS software package allow researchers in taxonomy, ecology and biology to perform cluster analysis as a rapid means of classifying information.

Kaesler and Cairns (60) studied data from limnological surveys performed along the Potomac River using NT-SYS clustering methodologies. They chose the Jaccard Coefficient in generating the data matrix on species presence or absence because it uses binary data (i.e. species presence or absence) and because it leaves out the influences of negative matches. Negative matches in comparison indices are significant when the sampling techniques are the same at all locations. That is to say that, the absence of a species cannot be accounted for by any reason associated with the design of the study, the sampling procedures or other variables inherent to the techniques used. Therefore, the presence of a species is considered a better standard of comparison (i.e. similarity) than absence for the reason stated above.

Kaesler and Cairns produced dendrograms using Q-mode cluster analysis of fish, aquatic insects and algae. The clustering method used was the unweighted pair-group method (UPGMA). UPGMA is discussed by Sokal and Sneath (106) and was developed for computerization by Rohlf (94) in the NT-SYS software package. Analysis of the correlation of similarity coefficients computed between groups indicated that aquatic insects and algae correlated better with the various groups of organisms than fish, protozoa and "other" invertebrate species. This led to the recommendaion that only aquatic invertebrate and diatom species be used in monitoring and assessment saving some of the cost for analysis for other components.

Gammon et. al. (41) studied the fish community of the Wabash River using cluster analysis and concluded that it was a "powerful technique for identifying similar fish communities and species associations". Bruno and Lowe (16) used cluster analysis to define four distinct assemblages or clusters of diatom species. They went on to relate the differences in the distribution of these clusters to environmental factors, such as calcium, pH, and nutrients using regression analysis.

Cluster analysis can be utilized as the first step in the process of associating groups of variables or species with other categories of data. In addition to the use of similarity coefficients, other matrices such as correlation coefficients can be used to develop clusters. Many researchers have coupled the results of cluster analysis with other multivariate methodologies such as principal component and factor analysis (10), discriminant analysis (46,76,115), and canonical correlation (73). The ultimate goal of such assessments is to decipher the ecological relationship between meaningful sets of variables. The use of cluster analysis in this research will follow the principal of assisting in sorting out groups of related species and habitat variables for use in subsequent multivariate analysis.

Principal Component and Factor Analysis.

Principal component analysis (PCA) is a multivariate data analysis technique which is used to exhaust patterns of linear relationship among variables (111). It can be looked upon as a method of data exploration which helps to determine which variable, or combination of variables, account for most of the variation in the overall set of measurements. Like cluster analysis, PCA and its corollary factor analysis (FA), are available in numerous computer software statistical packages. NT-SYS (94), SAS (96), and SPSS (111) are three of the more commonly use packages.

PCA and FA have been used in the analysis of environmental variables for numerous purposes. Sherwani and Moreau (99) put together a summary of strategic guidelines for water quality monitoring programs. Their work discusses the application of PCA and FA in the analysis of water quality data (e.g. flow, temperature, BOD, coliforms, etc.). They proposed, and illustrated, the use of these techniques to select from among a group of water quality monitoring parameters only those which accounted for most of the variability in the characteristics of stream water quality.

PCA and FA extract sets of factors which contain the variables of the study. These sets are referred to as factors or components. Within each factor are the loadings or correlations of the components (i.e. variables) on the factor. Each factor is orthogonal (uncorrelated) to the next. The first principal component represents the best linear combination of variables which accounts for the largest variance in the correlation matrix. The second principal component is independent from the first (i.e. uncorrelated) and it represents the next best fit of linear relationships accounting for the next highest degree of variation. This process is repeated until as many principal components have been extracted as there are variables in the data set.

FA uses a similar iteration to PCA. In addition to performing these steps on the straight forward linear relationship between variables, FA rotates the correlation matrix to produce a terminal solution which often improves the relevance of a given components loading on the factor. SPSS (111) presents an excellent review of rotational methodologies in FA.

Statistically, only those factors which account for the variation of at least one variable are considered reliable in interpretation of component loadings of PCA or FA solutions. This is interpreted by a statistics referred to as the eigenvalue. The eigenvalue is the measure of the relative importance of a principal component or factor. The ratio of a given component's eigenvalue to the sum of eigenvalues for all the factors (a function of the number of variables) is the percent of variance accounted for by that factor. Individual loads <0.50 are not considered to be significant in accounting for a given factor's proportional variance.

In the work referenced by Sherwani and Moreau (99), twenty water quality parameters were analyzed by both PCA and FA. Ten principal component factors were produced accounting for 95 percent of the variance. Only the first five accounted for the variation of at least one variable (i.e. eigenvalue >=1.0), corresponding to 79 percent of the variance. They then rotated the matrix in factor analysis using the VARIMAX method to determine if better linear combinations of variables might exist. These rotated factors are considered statistically more realistic than the straight forward (empirical) factors extracted by PCA. The results provided a method to examine the importance of a given parameter's loading in monitoring network designs. Clusters of collinear parameters such as orthophosphate and total phosphate were identified. The network was then recommeded which contained only the relevant and non-redundant parameters which had significant loading in PCA and FA. This process produced a network which saved money by reducing the dataset required to monitor the environment.

They also used PCA and FA to evaluate the data from trend monitoring stations along the same stream. This analysis helped determine which stations were not adding additional information on dissolved oxygen levels. Stations which depicted similar information were recommened for deletion from the monitoring network, thereby producing the most cost effective design.

Boesch (10) classified the community structure of benthic invertebrates using cluster analysis and PCA. In this research, PCA was used to optimize the classification of

28 species from four clusters which were judged to be questionable groupings. Meeter and Livingston (73) used PCA and FA to explain the proportion of variance accounted for by numerous physical and chemical variables. They wanted to reduce the number of variables considered in the research to those which had the most influence on estuarine water quality. Four factors were extracted, each with specific component loadings or correlations. One factor was highly influenced by river flow, another by tidal action. The components with the highest loadings often have other variables associated with them. In this case, the factor affected by river flow was directly associated with color and turbidity.

Meeter and Livingston also explain the use of canonical correlation between groups or clusters of fish species and physiochemical variables. Segregation of variables into groups of association by cluster analysis, PCA and FA, and then performing canonical correlation on sets of biological versus physicochemical variables (i.e. dependent versus independent variables), is a further means of strengthening the conclusions of association. These associations among variables are judged by the canonical variate score. Matching the inference gained by the loadings on the factors generated in PCA and FA with associations gained in cluster analysis and canonical correlation helps enhance the conclusions reached concerning the influence of the variables on environmental quality.

Several studies have been performed in Oklahoma using PCA and FA to elucidate associations among variables related to fish community structure. Stevenson, Schnell and Black (114) used FA to study the distribution patterns of western and central Oklahoma fishes. The presence or absence of 53 species of fish and 13 environmental variables were grouped into six factors after oblique rotation of the principal axes. Environmental components influencing the distribution of groups of fishes were discussed and predictions made reqarding how the environmental components (e.g. salinity) might influence patterns of fish distribution if concentrations of limiting substances increase.

Echelle and Schnell (32) studied the associations of 48 fish species in the Kiamichi River drainage in south eastern Oklahoma. FA was used to describe components which influence the distribution of groups of fish. The grouping of fish species was determined by the loadings or correlations of the components in each factor. A review of the grouping of species with their distributions in the basin showed that some groups were segregated based on location in the drainage basin. One group was found in the upper portion of the basin and another was primarily restricted to the main stream lower portions of the river basin.

Felley and Hill (38,39) used PCA and FA to assess environmental preferences of 10 species of cyprinid fishes of the Illinois River in eastern Oklahoma. Seasonal variation in the preferences for types of food, slow versus fast water habitat, and upstream and downstream locations were assessed. This methodology allowed them to demonstrate which components influenced preferences for habitat and other variables.

Appropriate interpretation of the components of PCA and FA is critical to the solution of these multivariate methodologies. Diaz (28) wrote that two basic phenomena influenced the quality of results obtained in PCA and FA. First, inherent in the data base is the question of linearity. This problem was reviewed by Austin (4). Linearity in a bivariate sense is straightforward, but linearity in a multivariate approach may include the associations of both linear and curvilinear relationships among sets of variables. Second, interpretation of high loadings or correlations of a given component in a factor as the cause of effects on dependent variables (i.e. flow affecting fish species abundance) should be approached with caution. If the association between one component and another is clearcut and direct (such as the case with low D.O. and fish distribution), and the influences of other competing components (i.e. predation, disease, acute toxicity) are ruled out, then such direct predictions of cause and effect are more readily substantiated and the value of multivariate analysis is optimized.

CHAPTER III

METHODOLOGY AND

ANALYSIS OF USE ATTAINABILITY DATA

Introduction.

The framework for Use Attainability Analysis (UAA) was developed to a large extent by EPA. EPA organized a water body assessment guidance work group during 1981 to help develop a program which would assist state agencies and EPA in supporting changes in water quality standards. In October, 1982, EPA issued the Water Quality Standards Handbook (35). This draft publication set forth guidelines on setting "site specific standards". UAA is one segment of the overall process which addresses the need for setting site specific standards in the standard's revision protocol. Table 6 outlines the steps which could be applied in any given State's revision protocol depending upon the specific nature of the proposed revisions and the need for site specific criteria.

PROTOCOL FOR WATER QUALITY STANDARDS
REVIEW AND REVISION

1. List water bodies with water quality limiting problems.

2. Prioritize water quality limiting segments and select those in greatest need for immediate assessment.

3. Assess existing data bases and organize site specific surveys. These should be focused surveys designed to establish and/or enhance data bases and determine why specific uses may be precluded.

4. Review causes impairing designated uses. Identify categories of limitation (i.e. natural vs. man induced). Determine the potential for mitigation by engineering intervention.

5. Assess the degree of relief dischargers may obtain by changing beneficial use designation. Determine the ability to reach the desired use if the discharge quality is upgraded by performing necessary wasteload allocation studies and related cost benefit assessment.

6. Determine suitability of existing beneficial uses for meeting the desired level of environmental quality.

7. If existing uses cannot be met, propose appropriate use designations and associated levels of quality criteria.

8. Conduct public hearings.

9. Revise use designations, adopt new quality criteria for the segment based upon scientifically justifiable assessments, the results of wasteload allocations and cost benefit assessment.

10. Follow through on the recommendations of wasteload allocations, set revised discharge limitations, issue new permits, and follow up with necessary monitoring and enforcement to assure designated uses are met.

Table 6. Protocol for The Water Quality Standards Review and Revision Process(35).

Oklahoma's Use Attainability Program.

Introduction.

The UAA portion of the standards revision process is only one part of the overall guidelines proposed by EPA. The type of UAA used in Oklahoma during the 1982 standards revision was an adaptation of the EPA guidlines with various input from regional EPA, state agency and local water quality specialists. The components of their recommendations were structured into a sampling program by OWRB staff. The framework of sampling, data collection and field data sheets were presented by OWRB at the Sixth Annual Meeting of the Oklahoma Water Pollution Control Association (8) and are provided for review in Appendix A.

Table 7 contains EPA's recommendations on the typical physical, chemical and biological components necessary to evaluate use attainability for aquatic uses (i.e. fish and wildlife propagation). These recommended components and factors discussed in the EPA guidelines were tailored into a proposal for site specific surveys on various priority stream segments found in Oklahoma. Table 8 lists these priority stream segments and Figure 3 shows the statewide location of the sampling location for these sites.

Sampling took place at three locations along each stream. These locations were determined by the team

SUMMARY OF TYPICAL USE ATTAINABILITY ANALYSIS PROGRAM

PHYSICAL FACTORS	CHEMICAL FACTORS	BIOLOGICAL FACTORS
-stream size	-dissolved oxygen	-fish
-flow & velocity	-toxicants	-macrobenthos
-total volume	-nutrients as nitrogen & phosphorus	-microinvertebrates
-reaeration rates		-phytoplankton
-stream gradient	-S.O.D.	-macrophytes
-pools/riffles	-B.O.D.	-diversity indices
-temperature	-salinity	-habitat suitability
-suspended solids	-hardness	-tissue analysis
-sedimentation	-alkalinity	-recovery index
-channelization	-pH	-pollution tolerance
-substrate	-dissolved solids	-omnivore/carnivore
-channel debris		-biotic potential
-sludge deposits		-reference reach comparison
-riparian habitat		

Table 7. EPA Recommendations of the Typical Components of a Aquatic Use Assessment Program(35).

LIST OF SITES CHOSEN FOR OKLAHOMA'S

1982 USE ATTAINABILITY SURVEYS

STREAM OR RIVER	LOCATION	FISH AND WILDLIFE DESIGNATION		
		UPSTREAM	IMPACT	RECOVERY
Pryor Creek (PRC)	Pryor	P	P	P
Big Cabin Creek (BCC)	Vinita	P	P	P
Coal Creek (COL)	Henryetta	P	S	S
Dog Creek (DOG)	Claremore	P	S	P
Elk Creek (ELK)	Elk City	P	P	P
Rush Creek (RSC)	Pauls Valley	P	S	
Wildhourse Creek (WHC)	Marlow	P	P	
Muddy Boggy Creek (MBC)	Atoka	P	P	P
South Canadian River (SCR)	Norman	S	S	S
North Canadian River (NCR)	Oklahoma City	S	S	P
Wewoka Creek (WEC)	Seminole	S	S	S
Little Deep Fork (LDF)	Bristow	P	S	P
Skeleton Creek (SKC)	Enid	P	S	P
Stillwater Creek (STW)	Stillwater	P	P	P
Chisholm Creek (CHC)	Oklahoma City	P	P	P
North Canadian River (NCW)	Woodward	P	P	P

Table 8. List of Priority Stream Segments Sampled as Part of Oklahoma's 1982 Use Attainability Assessment Program. Station codes are listed in parentheses. P=primary S=secondary warm water fishery.

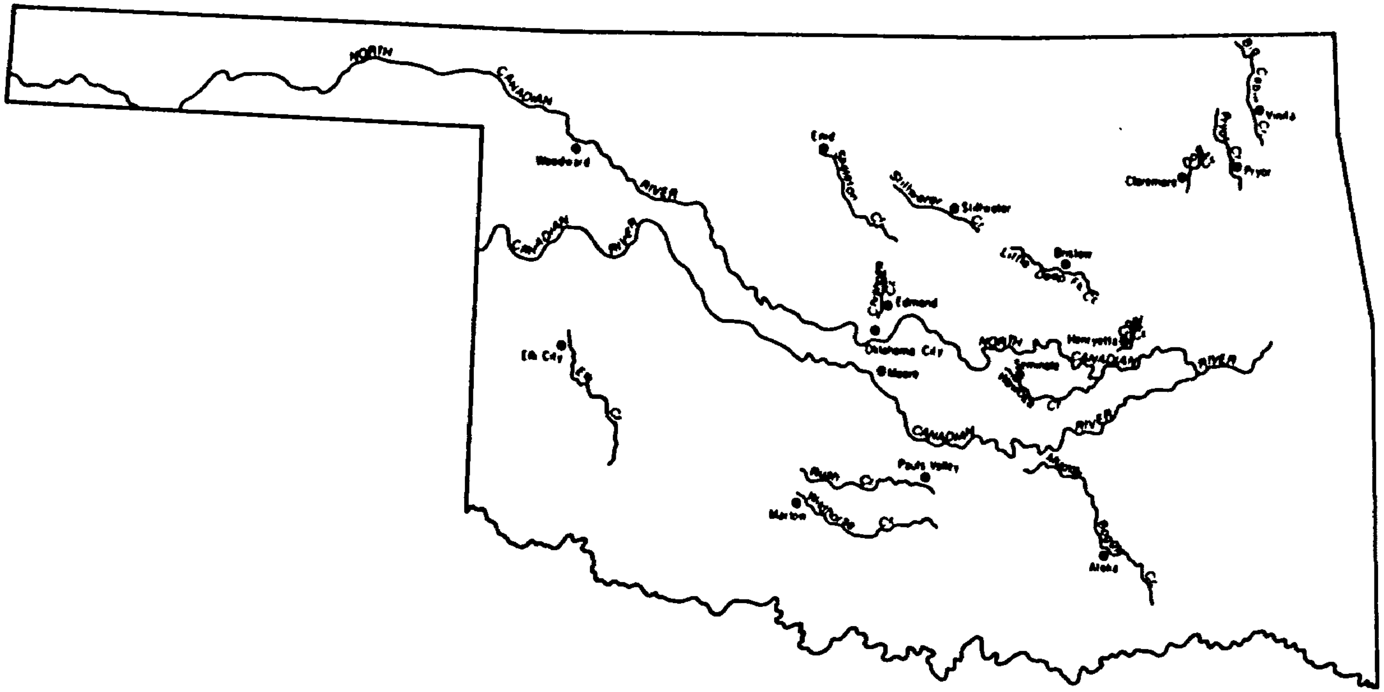


Figure 3. Map of Oklahoma Showing the Location of Streams Sampled as Part of the UAA Program.

biologists and OWRB staff and included an upstream, impact, and recovery zone station on each stream. Additional information on site selection is discussed in the OWRB document provided in Appendix A. The following sections refer to these zones as upstream or zone 1, impact or zone 2 and recovery or zone 3. These codes, denoting the sampling zones, and the triplex station codes are shown in Table 8 are referred to throughout this dissertation in tables, figures and discussion. Selection of the streams was based upon OWRB staff, OSDH construction grants program priorities, regional water quality management agency recommendations (i.e. ACOG), and input from the public and the concern of environmental interest groups.

Evaluation of Physical Parameters.

Evaluation of physical conditions consisted of three major categories of physical parameters. These included:

1. Channel and Instream Measurements.
    - mean stream depth (ft).
    - width (ft.).
    - velocity(ft./sec.).
    - flow (ft.3/sec.).
    - width to depth ratio (discrete).
    - temperature (oC.).

2. The presence or absence of instream cover or fish habitats.

-pools.	-tree stumps.
-riffles.	-brush piles.
-backwater.	-flat runs.
-undercut banks.	-rocky areas.
-deep channel.	-large pool or oxbow.
-submerged logs.	-emergent vegetation.

3. The presence, absence and percentage of substrate compostion.
   - -organic debris and detritus.
   - -clay.
   - -silt.
   - -sand.
   - -gravel.
   - -large rocks.
   - -mud and sludge.
   - -bedrock.

Appendix A contains examples of field data sheets. Members of the sampling team completed each portion for the above variables prior to leaving the site.

Evaluation of Riparian Characteristics and Potential Nonpoint Source Impacts.

Development of evaluation criteria for these characteristics was done by OWRB staff using guidelines provided in the EPA handbook (35) and specifically, a system of classification developed by the Wisconsin Department of Natural Resources (5). Riparian and nonpoint source characteristics were evaluated by the sampling team as percentage estimates of the following categories:

Bankside characteristics.

-proportion of cover composed of rock, grass, shrubs, and trees.

-proportion of bankside composed of sand or mud.

-proportion of bankside with vegetation.

-bank stability as a percentage of slope as flat, moderate, steep, or vertical.

-erosion potential as percent evident, likely or unlikely.

-percentage of immediate area land uses as urban agricultural, pasture, cropland, and forest like.

Evaluation of Community Structure of Fish and Benthic Macroinvertebrates.

The fish and benthic community structure was sampled as described in the OWRB "One Day Site Specific Survey" publication provided in Appendix A. Taxons of fish and benthic organisms were enumerated as present or absent and assigned relative abundance designations. This researcher was responsibile for the collection, identification and relative abundance designations for all fish samples and some of the benthic samples as well. Components of these data bases are discussed further in subsequent sections on each dataset.

Instream Water Quality.

Water quality parameters analysed in the field at each sampling location consisted of dissolved oxygen, temperature, conductivity and pH.

Point Source Data.

Although not a part of the OWRB study, data for the purpose of evaluating effluent quality and it's relationship to the UAA database was collected by this resarcher. This information was obtain from the Oklahoma State Department of Health (OSDH) compliance monitoring, and individual sewage treatment plant NPDES monthly operational reports. This data, extracted from OSDH files for the periods during which the OWRB UAA study was conducted (i.e. August thru October 1982), is discussed in a subsequent section.

OWRB Assessment of Oklahoma's Use Attainability Data.

The principal method of data assessment for the aforementioned parameters consisted of utilization of a ranking methodology. This Methodology is outlined in the report produced by OWRB provided in Appendix A. This method utilized the professional judgement of two committees of professionals. One consisting of three prominent biologists from state and federal agencies, and a university professor. Another utilized the expertise of the three OWRB staff members who comprised the sampling team. The two biologists who participated in the surveys (which included this researcher) assisted in a advisory capacity only. The results of the OWRB staff evaluations were not utilized for the purpose of the analysis performed as a part of this research. This choice was made due to the considerably greater amount of field experience and academic expertise of the committee members from academia and government.

The evaluation committee ranked the stream for quality based fish, benthic, habitat and water quality information obtained during the UAA sampling program. Tables 3 and 4 in the OWRB report provided in Appendix A list the ranks assigned by the evaluation committees and final benefical use designations respectively. These benefical use designations as primary and secondary warm water fisheries, were incorporated into the 1982 Oklahoma Water Quality Standards.

OWRB'S administrative decisions to assign specific beneficial use designations were based upon the combination of the ranks provided by the committees and social and economic considerations such as those mentioned in the report provided in Appendix A. It is important to note that these decisions did not, in every case, result in designations consistent with those of the ranking committees. The reasons for the differences in the committee determinations and the final beneficial use designations are to some extent explained in the report provide in Appendix A. However, some of the discrepancies between committee ranks and use designations do not appear to be explained in the report and are presumably the result of other factors considered by OWRB.

Analysis of Data.

Introduction.

The analysis of data collected as part of the Oklahoma UAA study consisted of two major categories of work. The first consisted of transferring the raw data from field data sheets into computer datasets. These datasets were comprised of matricies of 48 records corresponding to three stations for each of the 16 streams sampled and 'n' number of variables for each of the following categories (hereafter referred to as SAS datasets):

Category	SAS Data Set Name
Hydrologic Variables	Diskfile.Hydro
Water Quality Variables	Diskfile.Water
Point Source Variables	Diskfile.Psource
Riparian & Nonpoint Source Variables	Diskfile.NPS
Substrate Variables	Diskfile.Substrat
Habitat Variables	Diskfile.Habitat
Fish Variables	Diskfile.Rawfish
Invertebrate Variables	Diskfile.Insects

All data was entered and verified onto computer disk for storage on the Data General M600 computer at the University of Oklahoma Health Sciences Center, Research and Education System, using an interactive data entry system (IDES). Data management and statistical analysis was performed using SAS operating in OS batch through the University of Oklahoma, Merrick Computer Center. Copies of the SAS datasets containing format information, explanatory comment statements and raw data are provided in Appendix B.

Hydrologic Variables.

Assessment of stream characteristics for hydrologic and morphometric data consisted of instream measurement of stream width, depth and velocity. Calculations were then made to determine flow and width to depth ratio. Table 9 gives the

Variable	N	Mean	Median	STD	Min.	Max.	Skew.	Kurt.
Flow	41	14.9	5.0	33.6	0.1	150	3.32	10.23
(cfs.)	38	5.8	3.8	6.3	0.1	25	1.60	2.62
Velocity	41	0.5	0.4	0.4	0.1	1.8	1.05	0.82
(ft./sec.)	38	0.4	0.4	0.3	0.1	1.2	0.54	-1.10
Width	41	25.7	23.0	15.3	6.0	70	1.05	0.72
(ft.)	38	23.4	21.0	12.7	6.0	60	0.97	0.72
Depth	41	1.5	1.2	1.2	0.2	6.0	1.56	3.54
(ft.)	38	1.5	1.1	1.2	0.2	6.0	1.58	3.31
Width/Depth	41	24.5	18.0	17.3	3.0	83	1.62	2.61
Ratio	38	23.7	17.5	17.3	3.0	83	1.78	3.25

Table 9. Summary Statistics for Hydrologic Variables. Included are the number of observations(N), mean, median, standard deviation(STD), minimum, maximum, skewness(Skew.), and kurtosis(Kurt.). N=38 does not include NCR-OkC stations.

summary statistics for these variables. Seven of the stations were not sampled because of either a lack of flow or difficultly with access.

The North Canadian River below Oklahoma City represented an example of a set of values whose flow was not in the range of the other stations. The flow for the North Canadian River was 110-150 cfs with a velocity of 1.8 ft/sec., while the flow for the rest of the dataset only ranged as high as 25 cfs with velocities less than 1.2 ft./sec. Table 9 presents the summary statistics for hydrologic variables with and without the NCR-OKC data. In the case of flow and velocity, removal of these data points improved the values for mean, standard deviation, skewness and kurtosis markedly.

Figure 4 shows the distribution of flow by categories of flow magnitude (excluding the NCR-OKC). Twenty seven percent of the stations had a flow <1.0 cfs, and 53% had flows <5.0 cfs. No upstream stations had flows greater than 10 cfs. Stream depth is illustrated in Figure 5. Two-thirds of the streams had a depth of less than 1.5 ft. Figure 6 shows the width to depth ratio distribution which tended to be clustered in the range of 10 to 40 ft. (69%).

Water Quality Variables.

Measurement of water quality consisted of only a limited number of measurements. This was primarily due to the lack

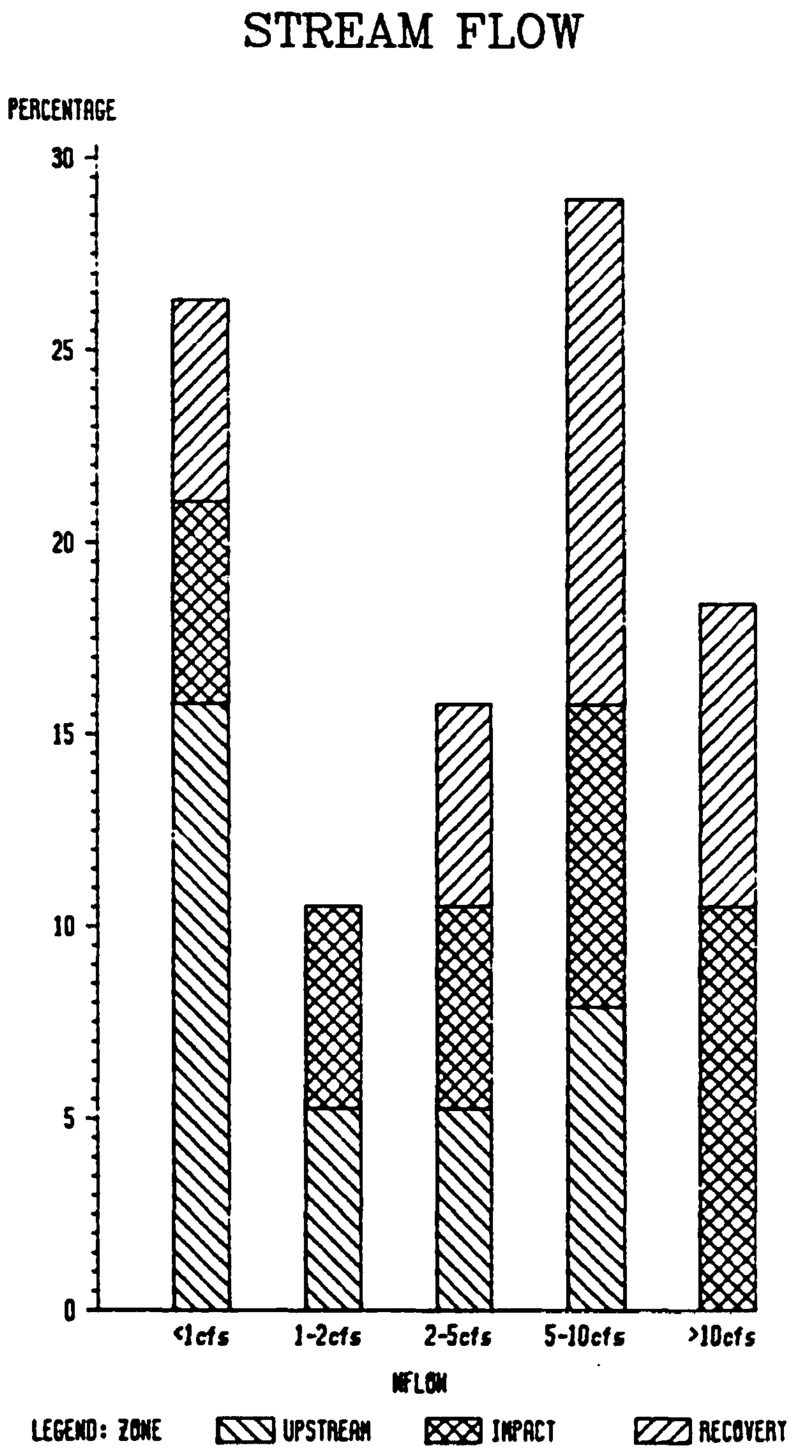


Figure 4. Distribution of Stream Flow.

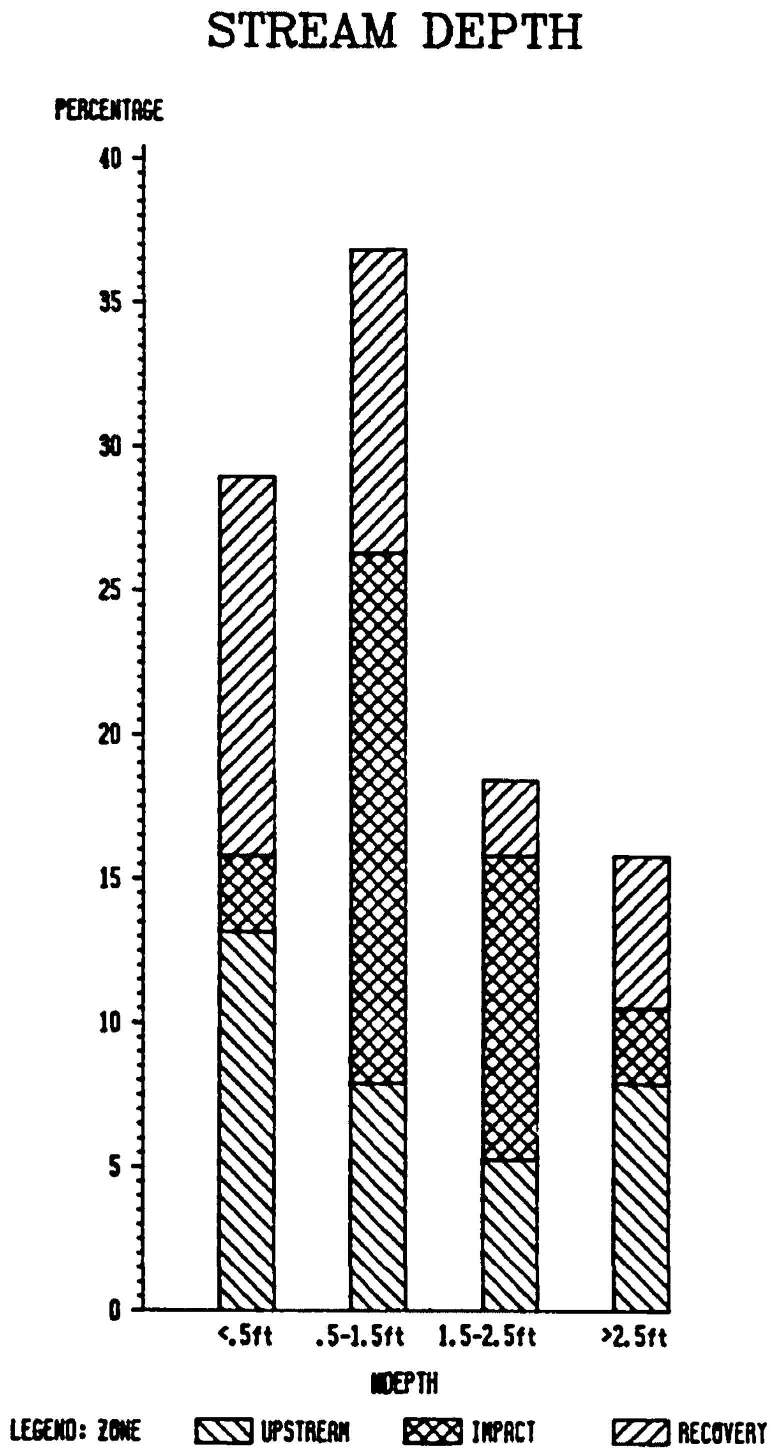


Figure 5. Distribution of Stream Depth.

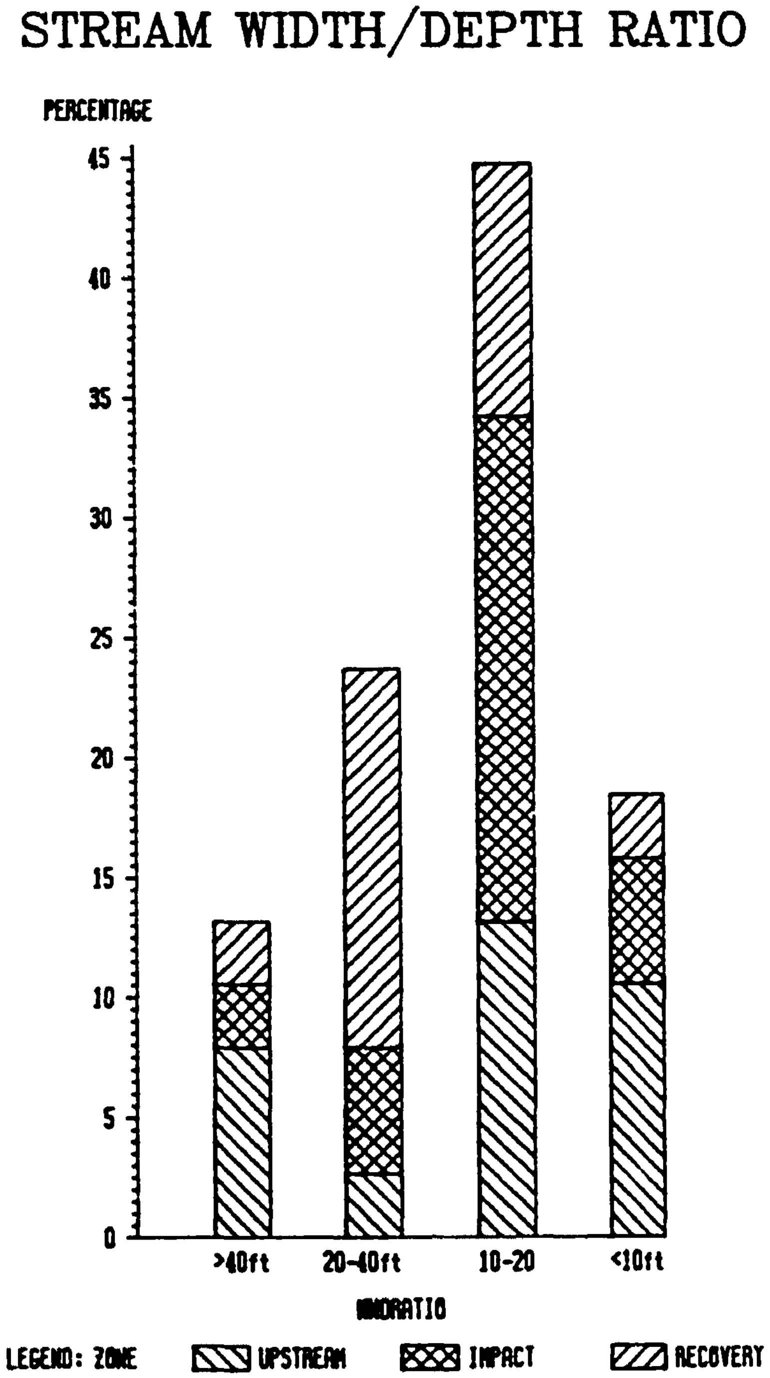


Figure 6. Distribution of Stream Width to Depth Ratio.

of funds and the time required to perform a more detailed water quality assessment. The value of increasing the repertoire of physical and chemical measurements in future UAA programs is discussed in the following chapter. Table 10 gives the summary statistics for those water quality parameters sampled as part of this UAA sampling program.

The water quality measurements focused on the relationship of dissolved oxygen in these streams. Figure 7 shows a plot of the direct relationship (inversely proportional) which exists between D.O. levels and the D.O. deficit (r=-0.96). A similar relationship exists between D.O. and percent saturation (r=0.97). Figure 8 shows the relationship between the level of D.O. and ranges of D.O. deficit from supersaturated water (negative values) to poorly saturated waters (values >3.0). Those streams which had D.O. deficits >3.0 mg./l. could be expected to have D.O. levels at or below the 5.0 mg./l. standard for primary warm water fisheries. The frequency distribution of sampling stations over these categories of D.O. deficit is illustrated in the block chart presented in Figure 9.

Temperature and conductivity had wide ranges in the data set as a whole. Temperature averaged 3.0oC. less in upstream sampling stations (20oC.). Impact and recovery zone stations

Variable	N	Mean	Median	STD	Min.	Max.	Skew.	Kurt.
Temperature (oC.)	43	21.8	21.9	5.4	9.9	32.5	-0.25	-0.24
pH	39	-	-	-	6.0	8.1	-	-
Dissolved Oxygen (mg./l.)	43	7.9	7.6	3.5	2.1	18.0	0.68	0.36
Conductivity (micromhos)	40	1186	1169	636	277	3040	0.75	0.56
Saturation D.O. Level (mg./l.)	43	8.8	8.7	1.0	7.2	11.3	0.74	0.32
Percent Saturation D.O. (mg./l.)	43	91	80	44	23	225	0.98	1.06
D.O. Deficit (mg./l.)	43	0.9	2.0	3.7	-10	8.1	-0.75	0.69

Table 10. Summary Statistics for Water Quality Variables. Included are the number of observations (N), mean, median, standard deviation (STD), minimun, maximum, skewness (Skew.) and kurtosis (Kurt.).

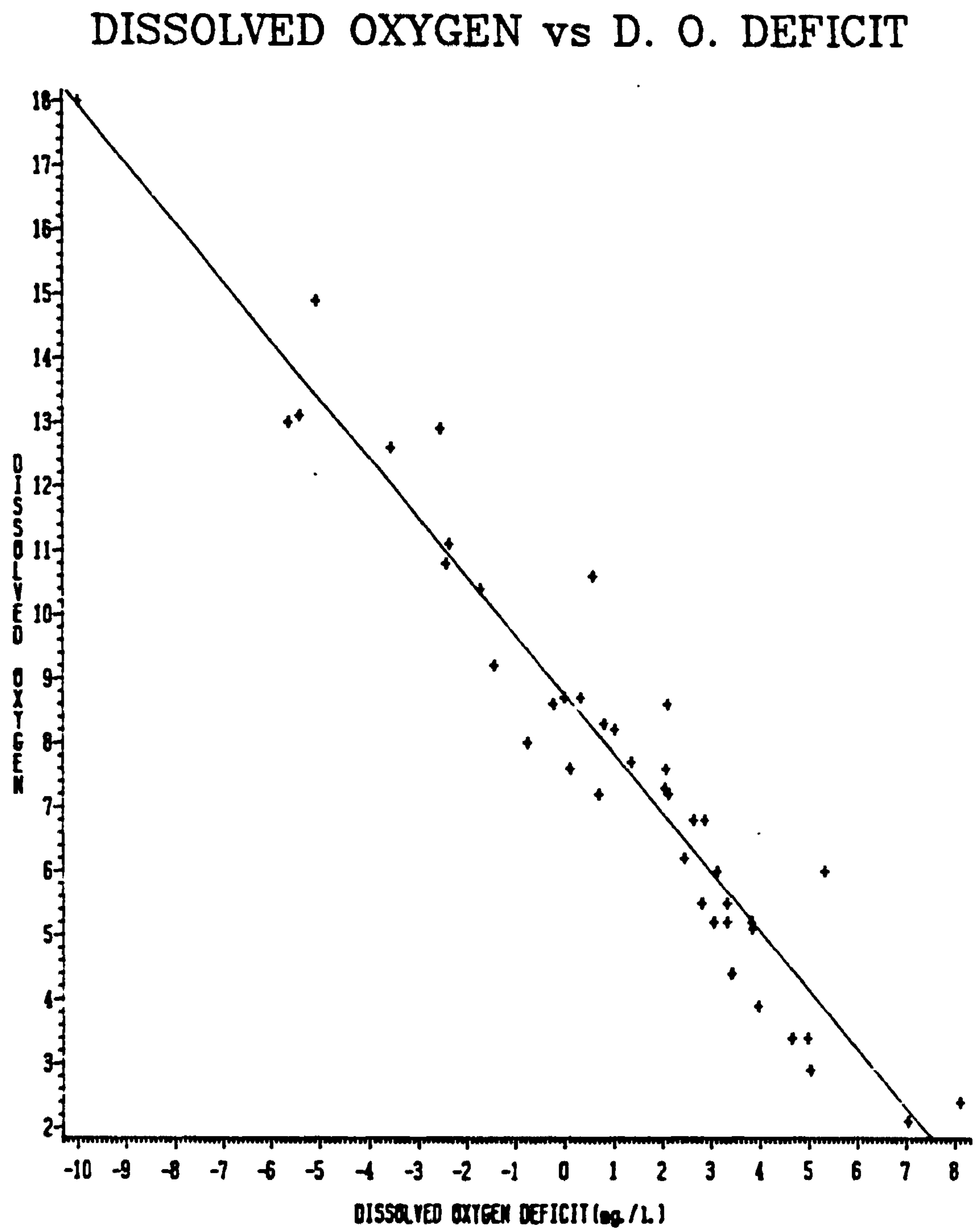


Figure 7. Relationship of Dissolved Oxygen to the Dissolved Oxygen Deficit.

DISSOLVED OXYGEN AND D.O. DEFICIT

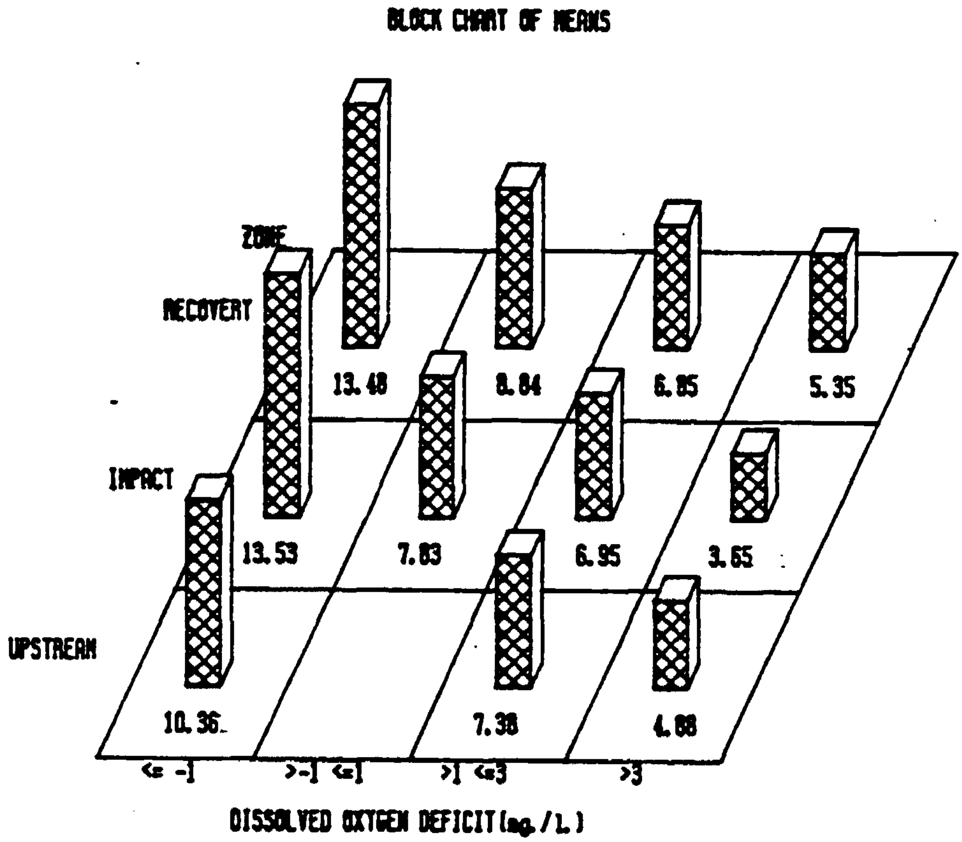


Figure 8. Block Chart of Dissolved Oxygen versus the Dissolved Oxygen Deficit by Sampling Zone.

DISSOLVED OXYGEN AND D.O. DEFICIT

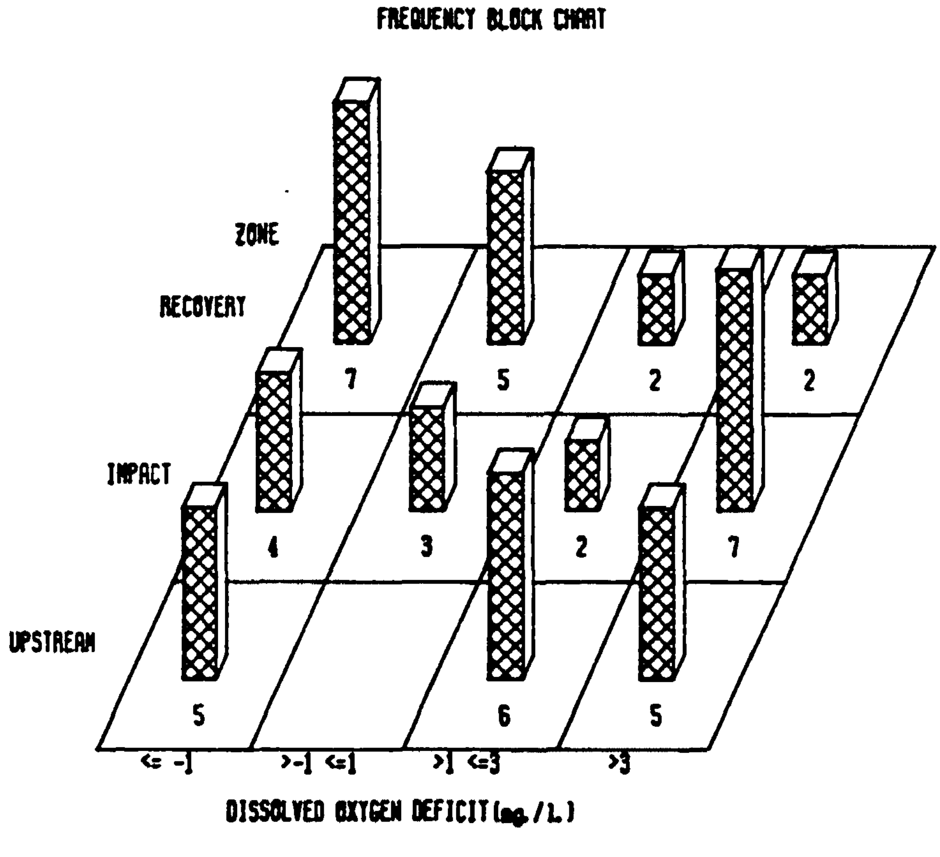


Figure 9. Frequency Distribution of Sampling Stations by Category of Dissolved Oxygen Deficit.

averaged 23oC. Conductivity averaged 1019, 1247 and 1285 micromhos respectively for upstream, impact and recovery zone stations.

Point Source Variables.

As mentioned previously, data on the effluent quantity and quality, for facilities which discharge municipal waste into the streams studied in the UAA sampling program, were obtained from OSDH compliance monitoring records and NPDES monitoring reports. Table 11 summarizes the list of parameters and summary statistics for the point source data base. The data presented was, for the most part, obtained as an attempt to categorize the levels of wasteloading which were occuring in the various streams sampled as part of the UAA program. This information should not be considered as reliable as it could have been if it were collected in concert with the overall UAA program. The utility of integrating a wasteload sampling program into the UAA program for future work of this kind is discussed in the following chapter. Nevertheless, this data does serve as additional information to help assess the factors influencing the attainment of aquatic uses in Oklahoma streams.

Several calculations were performed on the data to estimate the approximate levels of organic demanding substance (i.e ultimate B.O.D, ultimate oxygen demand,

Variable	N	Mean	Median	STD	Min.	Max.	Skew.	Kurt.
Effluent Flow (cfs.)	14	3.2	2.2	2.6	0.6	8.8	0.97	0.07
Stream Flow (cfs.)	15	6.1	5.6	5.1	0.4	15	0.41	-1.35
Stream/Effluent Flow Ratio	14	2.4	1.3	1.8	0.8	5.9	0.92	-0.62
Average August Water Temp. (oC.)	11	24.9	26.0	2.8	20	28	-0.59	-0.91
Effluent D.O. (mg./l.)	11	4.5	3.4	3.1	1.1	11.9	1.36	2.16
Effluent Percent Saturation	10	40	30	26	13	79	0.74	-1.33
B.O.D. (Five Day) (mg./l.)	14	24.4	24.3	14	1.3	50.7	0.31	-0.54
Ultimate Carbonaceous B.O.D. (est.)	14	35.8	35.8	21	2.0	74.6	0.31	-0.53
U.C.B.O.D. Load (lbs/day est.)	14	902	404	1053	76	3009	1.47	0.62
Ammonia Nitrogen (mg./l.)	13	7.3	6.3	-	0.1	17.3	0.98	-1.62
Ultimate Oxygen Demand (est.)	13	70	71	39	2.6	143	0.07	-0.14
Total Carbonaceous Nitrogenous Demand (est.)	13	2083	664	2639	101	7429	1.28	0.17
TKN (mg./l.)	13	11.5	13.2	6.5	1.6	22.5	-0.16	-0.93
Nitrate Nitrogen (mg./l.)	11	4.0	2.9	3.7	0.5	11.1	0.61	-0.77
Total Phosphorus (mg./l.)	12	5.4	4.7	2.1	2.7	9.5	0.73	-0.37
Total Suspended Solids (mg./l.)	14	30.2	13.0	21	3.3	77.5	1.09	1.09
Total Suspended Solids Load(lbs/day)	14	861	1006	491	63	3645	1.88	3.86
Alkalinity (mg./l.)	9	218	226	44	157	300	0.52	0.10
Chloride (mg./l.)	7	123	83	81	40	242	0.47	-1.89
C.O.D. (mg./l.)	12	74	75	31	23	123	-0.17	-0.85
T.O.C. (mg./l.)	11	17.3	12.4	13	7.4	48.5	1.74	2.54

Table 11. Summary Statistics for Point Source Variables.

combined ultimate carbonaceous and nitrogenous B.O.D.) and their respective loadings from each facility. These estimates were performed according to methods presented by Pavoni (86) for use in water quality management planning.

As was the case with hydrologic variables, the North Canadian River below Oklahoma City represented values for wasteloading far beyond the range of the other streams and as such it was deleted from the summary statistics provided in Table 11. Figure 10 shows a plot of the pattern of effluent flow versus the log base 10 of the organic loading. The North Canadian River in Oklahoma City is included in the plot and has the highest loading value as a function of it's high effluent volume (>40 cfs.). Figure 11 shows the proportion of stream dilution capacity with subgrouping based on the level of organic loading. Sixty percent of the streams had dilution capacities <2.0. The major category of wasteloading consisted of those effluents discharging an estimated 500 lbs./day or less of carbonaceous B.O.D. This is reflected in the median statistic of 404 lbs./day of carbonaceous B.O.D.

Substrate Variables.

The subjective estimates of the evaluation team for proportions of substrate type are summarized in Table 12. Figure 12 presents a horizontal bar chart of the substrate

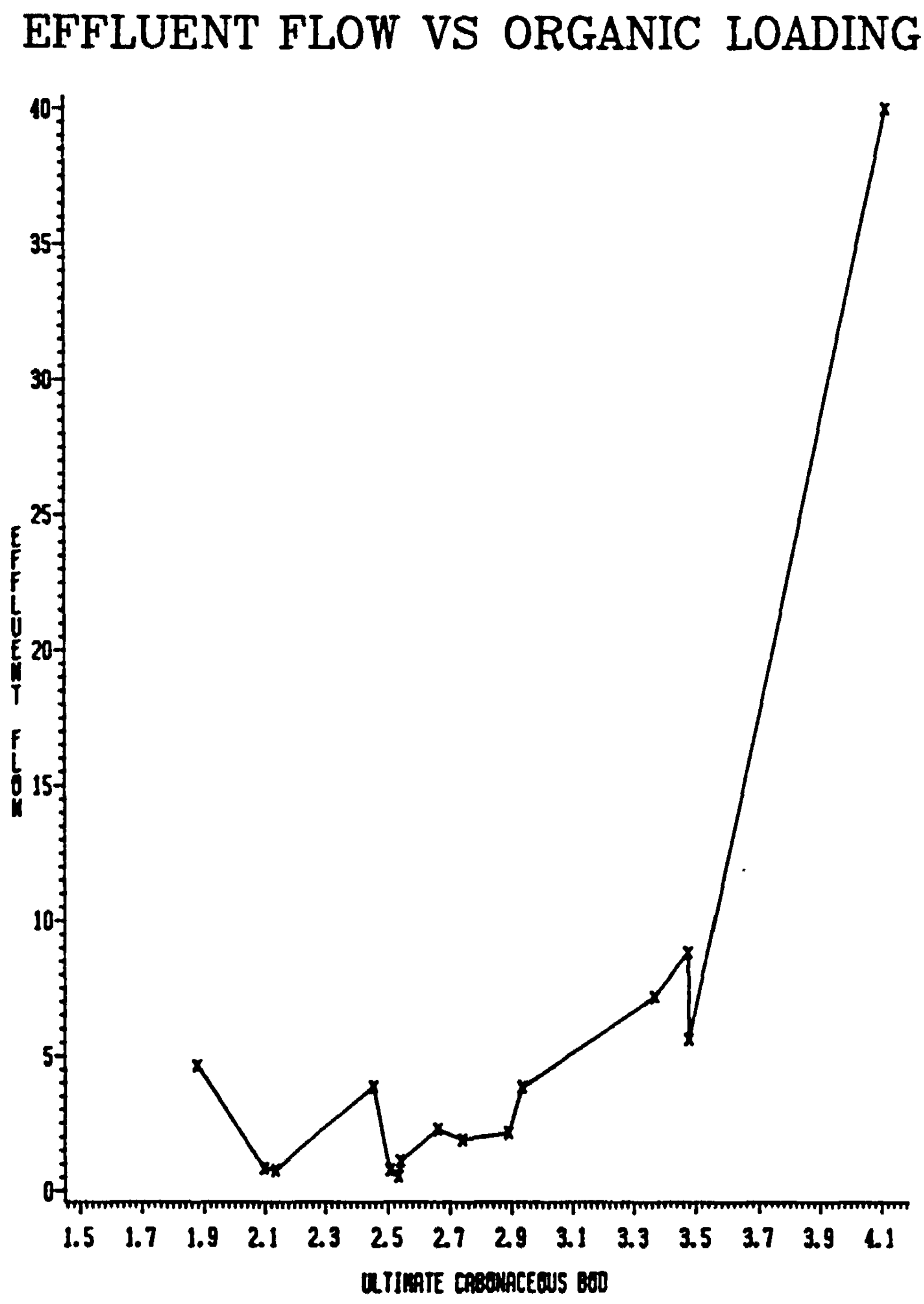


Figure 10. Effluent Flow versus Organic Wasteload.

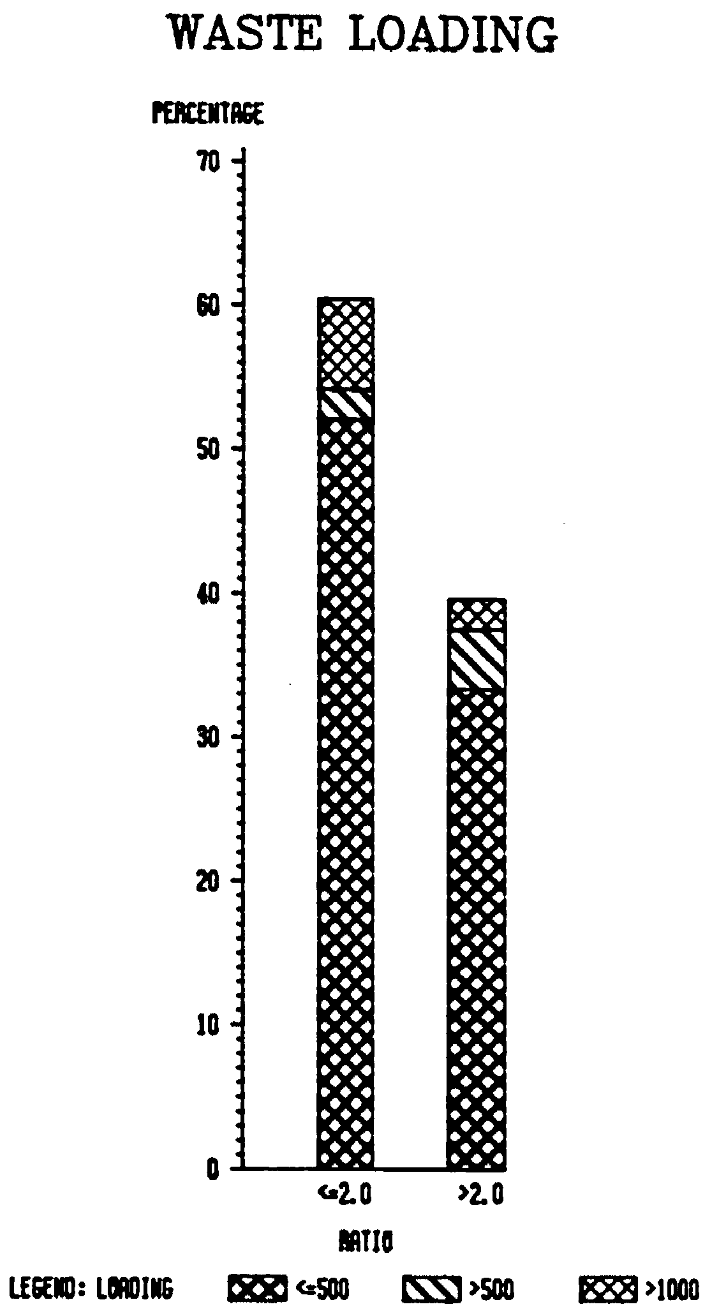
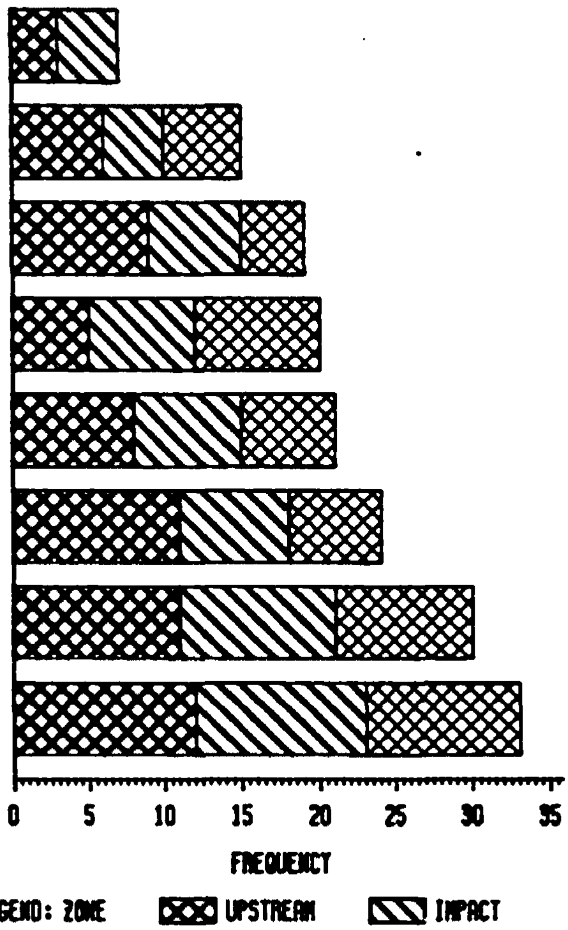


Figure 11. Stream Dilution Capacity and Level of Organic Wasteload.

Variable	N >0	Mean (%)	STD	Mean >0	STD >0	Min. >0	Max. >0
Detritus	24	4.9	5.9	8.8	5.2	2	25
Mud & Sludge	19	7.5	14.3	16.9	17.6	2	75
Clay	15	11.2	20.5	32.2	23.3	3	70
Silt	30	8.7	11.1	12.4	11.5	1	50
Sand	33	40.7	37.2	53.0	33.8	5	100
Gravel	20	8.7	14.1	18.7	15.6	5	60
Large Rocks	21	11.7	19.0	24.0	21.2	3	80
Bedrock	7	6.7	16.7	41.4	16.8	10	60

Table 12. Summary Statistics for Substrate Variables. Included are the number of observations >0 (N), means for all values and means for values >0, standard deviations for all values and for values >0 (STD), minimums and maximums for values >0.

SUBSTRATE TYPE BY ZONE



TYPE OF SUBSTRATE	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
BEDROCK	7	7	4.14	4.14
CLAY	15	22	8.88	13.02
MUD & SLUDGE	19	41	11.24	24.26
GRAVEL	20	61	11.83	36.09
LARGE ROCK	21	82	12.43	48.52
DETRITUS	24	106	14.20	62.72
SILT	30	136	17.75	80.47
SAND	33	169	19.53	100.00

Figure 12. Distribution of Substrate Types.

types organized in ascending order by frequency of occurrence. Sand was the dominant substrate type encountered both in frequency (33) and percentage of composition (40%). In contrast, detritus, which had the third highest frequency (24) of occurrence, had the lowest mean percentage of composition (4.9%). Bedrock, when present, tended to dominate the substrate categories with a mean value of 41% for observations >0.

Habitat Variables.

The presence or absence of twelve categories of potential fish habitat were evaluated at each of the sampling stations. Figure 13 presents this data in the form of a horizontal bar chart organized in increasing order of occurrence. The largest number of habitats present at any one station was 9, while the lowest was 3 and the mode was 5. Four categories of habitat (pools, brushpiles, undercut banks, and flat runs) accounted for half of the habitat richness as determined by frequency of occurrence. These were about equally distributed in all three sampling zones.

Riparian and Nonpoint Source Variables.

Table 13 gives the summary statistics for the nonpoint source dataset. These variables represent estimates of riparian, bankside and general watershed characteristics which in general may reflect the the potential for nonpoint

HABITAT ABUNDANCE BY ZONE

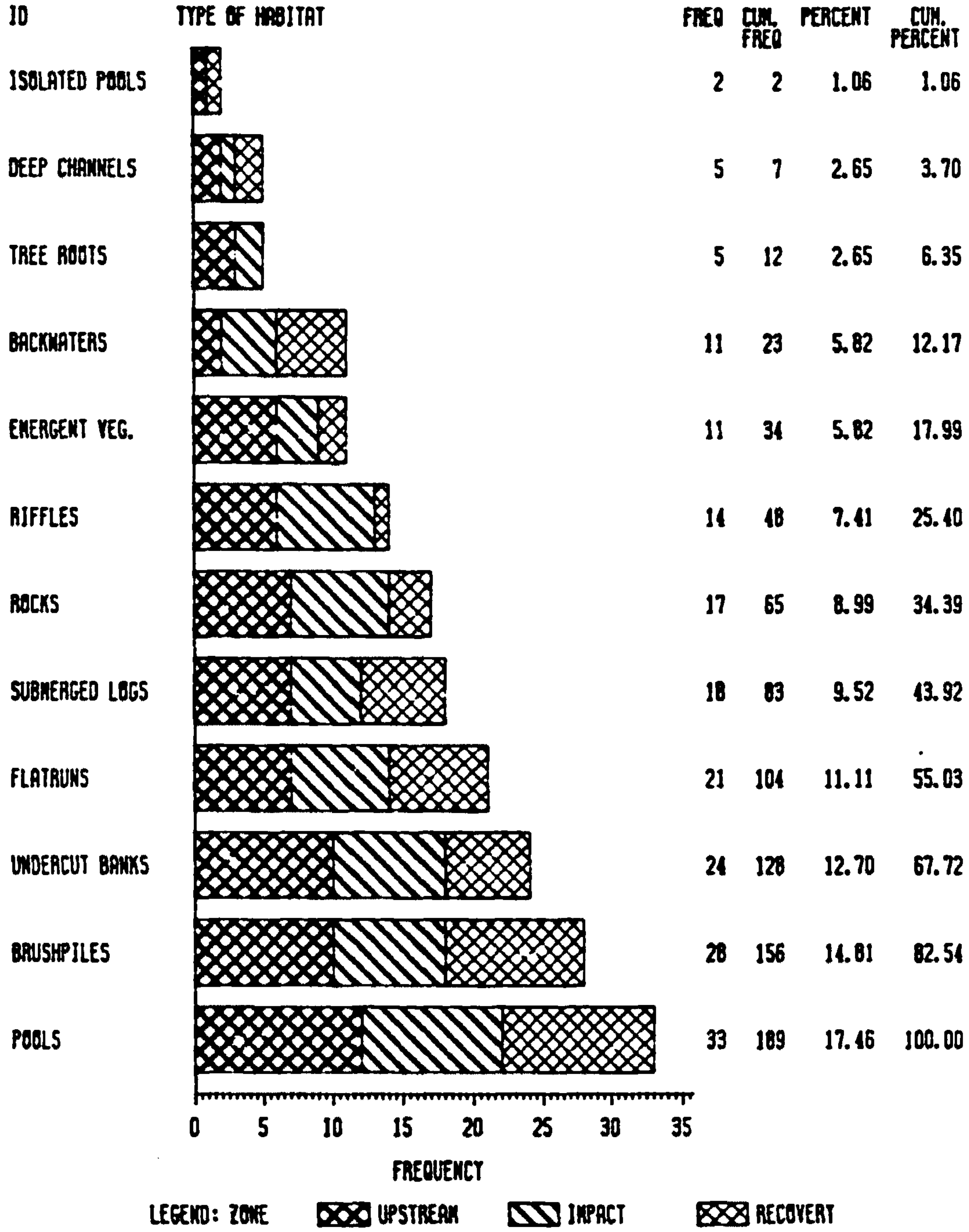


Figure 13. Distribution of Habitat Types.

Variable	N	Mean #1	Mean #2	Min. >0	Max. >0
Bankside Compostion					
Vegetation	31	15	22	2	100
Mud	35	45	58	5	100
Sand	35	35	46	5	100
Protective Category For Erosion					
Evident	38	26	31	5	80
Likely	44	29	29	5	80
Unlikely	41	45	48	10	95
Protective Category For Slope					
Flat	4	7	78	10	100
Moderate	33	31	41	5	100
Steep	39	44	50	15	90
Vertical	33	19	25	5	70
Protective Category Vegetation & Rock					
Rock	9	6	29	10	90
Trees	42	41	43	2	90
Grass	41	27	29	5	90
Shrubs	41	26	28	3	75
Land Use Category					
% Suburban	22	43	88	50	100
% Urban	8	10	56	10	100
% Agricultural	3	4	60	50	80
% Forest Like	19	14	32	10	100
% Pasture	30	40	60	10	100
% Cropland	12	13	50	20	100
Proportion of Cover					
Sparse(13.3%)	6				
Moderate(53.3)	24				
Dense(33.4)	15				

Table 13. Summary Statistics for Riparian and Nonpoint Source Variables. Included are the number of observations (N), Mean #1 (all values including 0), Mean #2 (only values >0), Minimum and Maximum for values greater than zero.

source impacts (e.g. erosion and sedimentation, urban and agricultural runoff). The estimates are based on the subjective evaluation of the sampling team.

The bankside protective categories and watershed land use characteristics were evaluated using the quidelines and classification schemes presented by Ball in EPA's Water Quality Management Handbook (7,44). In general, the ranges for values of variables were classified as poor, fair, good or excellent. Figures 14 thru 18 present block charts of the bankside protective categories for protective vegetation or rocks, erosion, slope, and bankside composed of sand and mud.

Figure 14 shows that most of the streams tended to possess sufficient bankside stability as evidenced by the high frequency of stations with excellent ratings. Figure 15 show that the protective categories for bankside slope tended to cluster in the moderate to steeply sloped ranges as evidenced by the frequency of good and fair ratings. Figure 16 shows bankside erosion tended to be classified as excellent, especially for upstream areas. However, impact and recovery zone stations had more stations classified as fair or poor then the upstream stations. This could be related to the increase in flow and the impacts of stormwater runoff, which would be larger at the downstream stations.

PROTECTIVE BANKSIDE VEGETATION

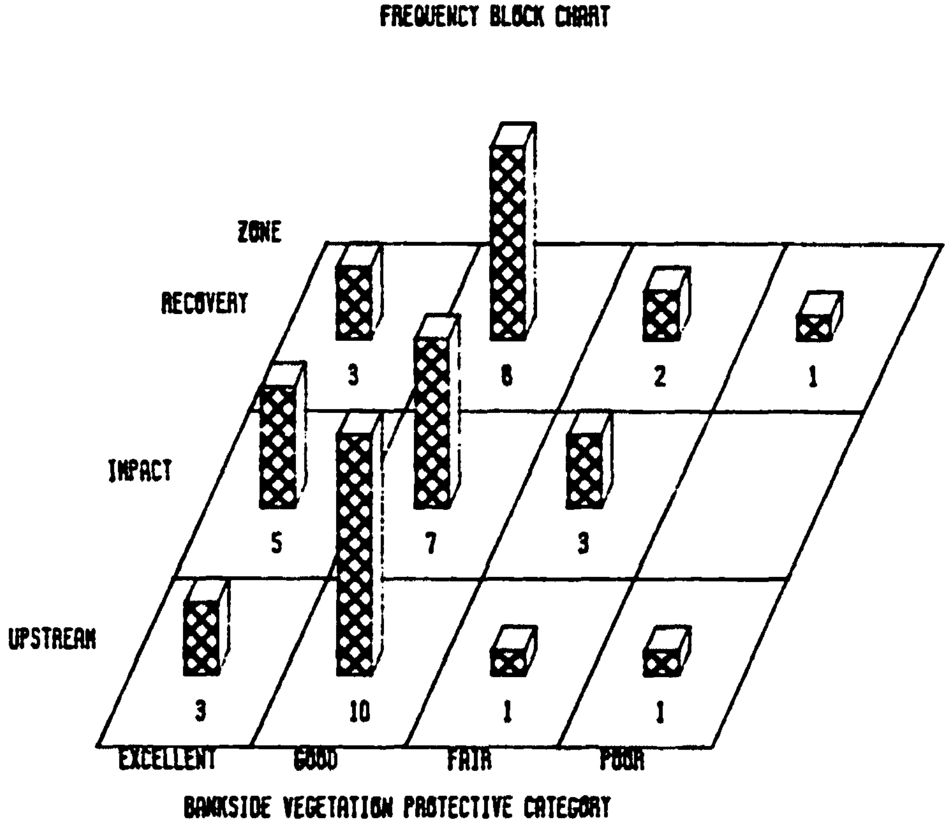


Figure 14. Frequency Distribution for Protective Bankside Vegetation.

BANKSIDE PROTECTIVE CATEGORY FOR SLOPE

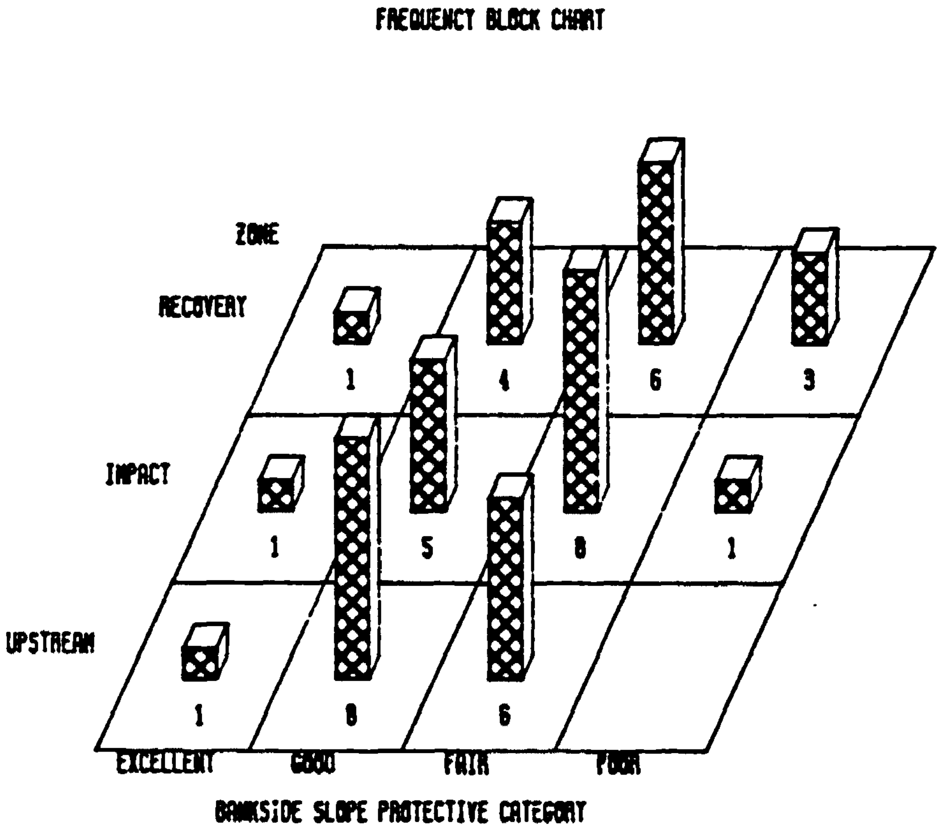


Figure 15. Frequency Distribution for the Bankside Protective Category for Slope.

BANKSIDE PROTECTIVE CATEGORY FOR EROSION

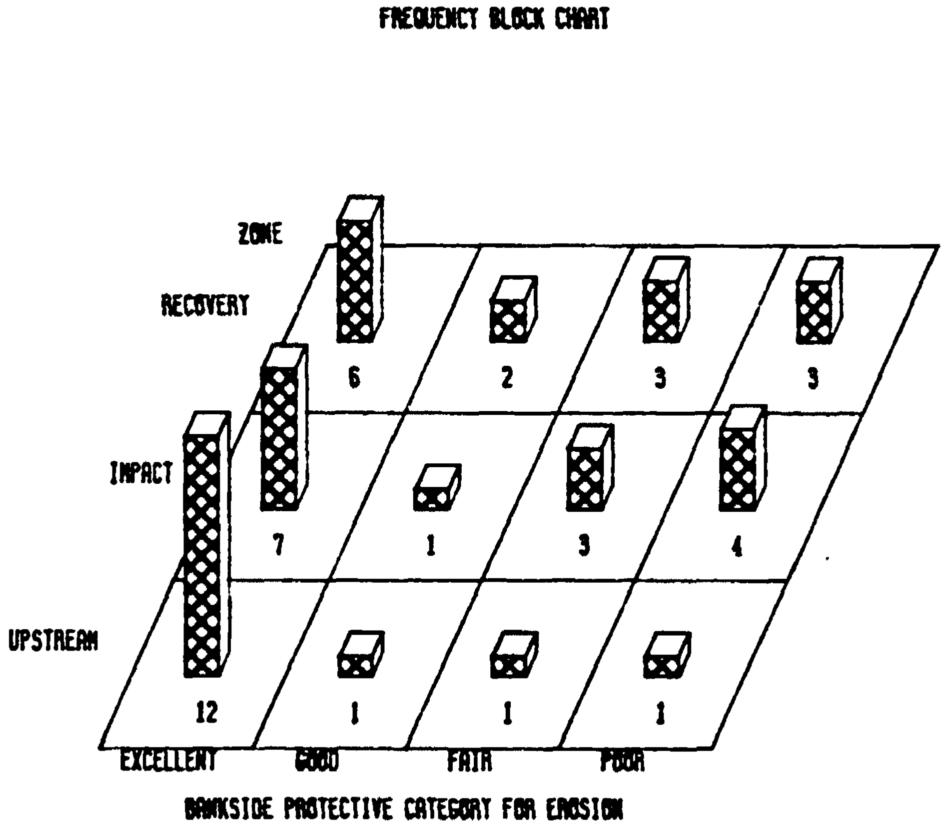


Figure 16. Frequency Distribution for the Bankside Protective Category for Erosion.

BANKSIDE PROTECTIVE CATEGORY FOR MUD

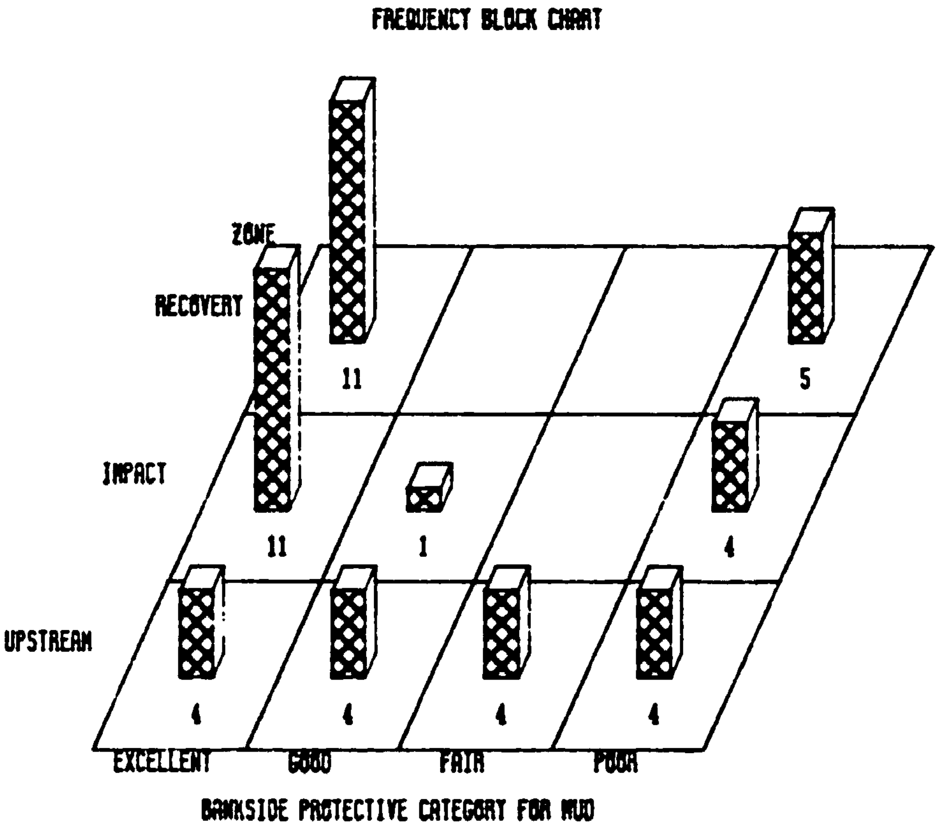


Figure 17. Frequency Distribution for the Bankside Protective Category for Mud.

BANKSIDE PROTECTIVE CATEGORY FOR SAND

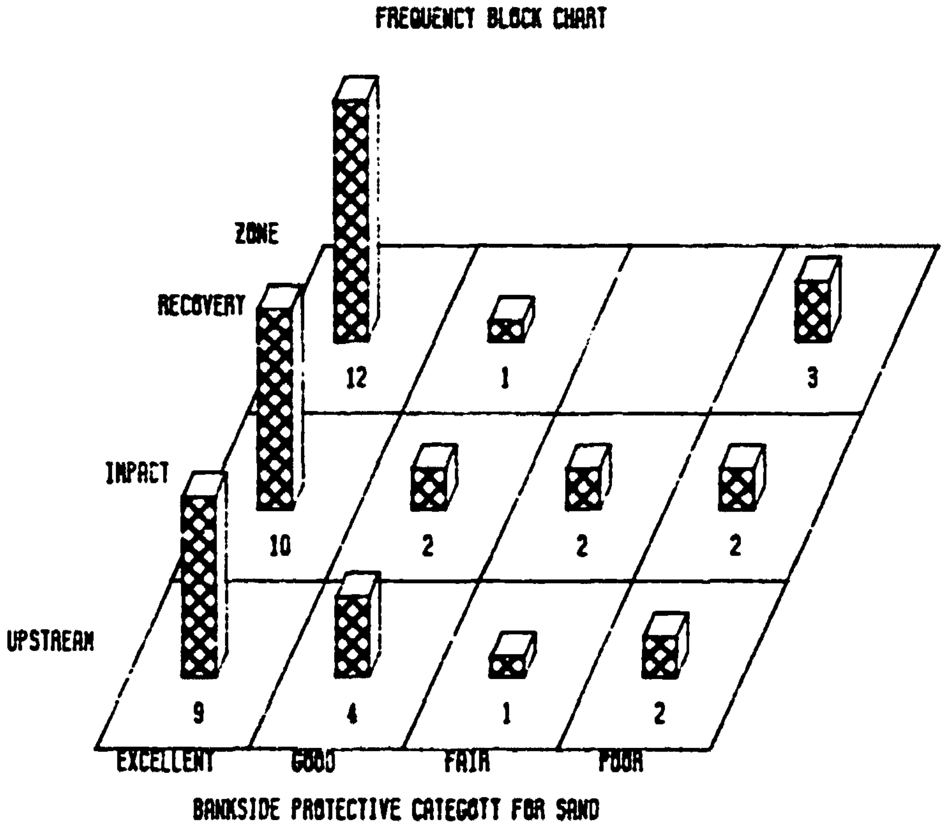


Figure 18. Frequency Distribution for the Bankside Protective Category for Sand.

Mud and sand are illustrated in Figures 17 and 18. These figures also show a large frequency of stations classified as excellent and good. Mud seemed to have a higher number of less protective bankside classifications than sand (19 versus 12).

Fish Variables.

The sampling procedure and related details on the collection of the fish during Oklahoma UAA program is outlined in the report provided in Appendix A. Essentially, the method consisted of a standardized level of effort; one manhour of sampling with seines at each location. As was true with most categories of assessment, not every site was suitable for sampling. Reasons for not sampling fish included, no water, septic or unhealthy sampling conditions, water which was too deep for effective sampling and lack of downstream access prior to recovery or confluence with another stream or river. In all 35 of the 48 stations were sampled for fish. Table 14 lists the species composition and frequency of occurrence of the 45 varieties of icthyofauna found at these stations.

One category of the fish community, fishable species, seemed to be of particular interest to the evaluation committee during the 1982 revisions of the Oklahoma Water Quality Standards. Figure 19 illustrates the frequency

FAMILY	SPECIES	COMMON NAME	FREQUENCY
Clupeidae	*Dorosoma cepedianum*	Gizzard Shad	8
Cyprinidae	*Campostoma anomalum*	Stoneroller	4
	Cyprinus carpio	Carp	6
	Hybognathus placitus	Plains Minnow	6
	Notemigonus crysoleucas	Golden Shiner	3
	Notropis atherinoides	Emerald Shiner	9
	Notropis buchanani	Ghost Shiner	3
	Notropis lutrensis	Red Shiner	32
	Notropis stramineus	Sand Shiner	7
	Notropis perpallidus	Colorless Shiner	3
	Notropis umbratilis	Redfin Shiner	1
	Notropis sp.	Unidentified	1
	Phenacobius mirabilis	Suckermouth Minnow	4
	Pimephales notatus	Bluntnose Minnow	3
	Pimephales promelas	Fathead Minnow	4
	Pimephales tenellus	Slim Minnow	1
	Pimephales vigilax	Bullhead Minnow	11
Catostomidae	*Carpiodes carpio*	River Carpsucker	9
Ictaluridae	*Ictalurus melas*	Black Bullhead	4
	Ictalurus natalis	Yellow Bullhead	5
	Ictalurus punctatus	Channel Catfish	13
	Noturus exilis	Slender Madtom	1
	Noturus nocturnus	Freckled Madtom	3
	Pylodictis olivaris	Flathead Catfish	3
Cyprino-	*Fundulus kansae*	Plains Killifish	1
dontidae	*Fundulus olivaceus*	Blackspotted Topmn.	2
Poeciliidae	*Gambusia affinis*	Mosquitofish	25
Atherinidae	*Labidesthes sicculus*	Brook Silverside	4
	Menidia audens	Mississippi "	2
Percichthyidae	*Morone chrysops*	White Bass	3
Centrarchidae	*Lepomis cyanellus*	Green Sunfish	23
	Lepomis gulosus	Warmouth	4
	Lepomis macrochirus	Bluegill Sunfish	15
	Lepomis humilis	Orangespotted "	12
	Lepomis megalotis	Longear Sunfish	26
	Lepomis microlophus	Redear Sunfish	1
	Micropterus salmoides	Largemouth Bass	6
	Pomoxis annularis	White Crappie	7
Percidae	*Etheostoma gracile*	Slough Darter	2
	Etheostoma radiosum	Orangebelly Darter	2
	Etheostoma spectabile	Orangethroated "	1
	Etheostoma whipplei	Redfin Darter	3
	Percina phoxocephala	Slenderhead Darter	3
	Percina sciera	Dusky Darter	1
Sciaenidae	*Aplodinotus grunniens*	Freshwater Drum	3

Table 14. List of Fish Species Composition and Frequency of Occurrence at 35 Sampling Stations.

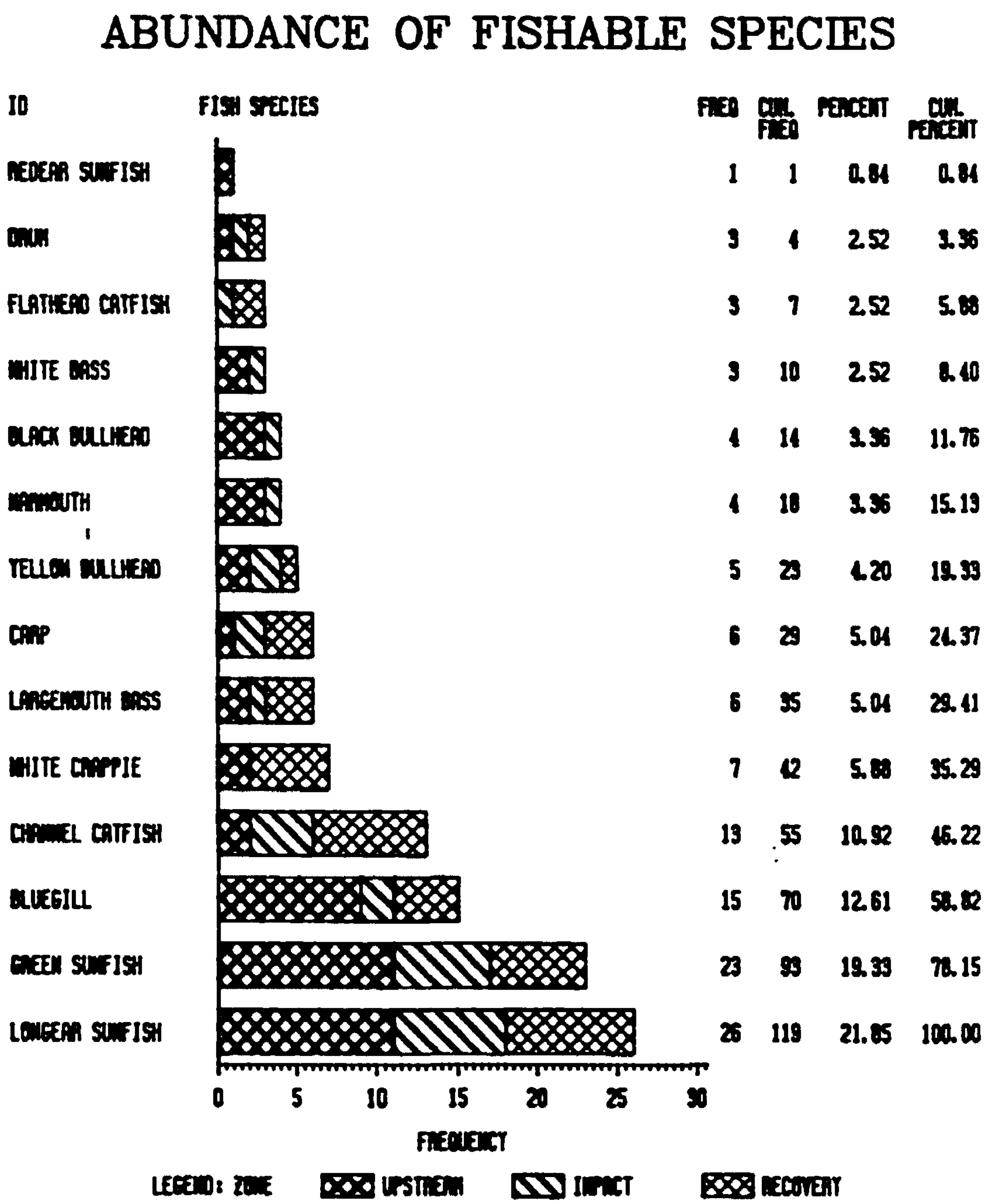


Figure 19. Frequency Distribution and Abundance of Fishable Species.

distribution of potentially fishable species present in the samples. Pan fish (i.e. Bluegill, Green and Longear Sunfish) dominated this catagory followed by Channel Catfish and Crappie. Together these varieties accounted for 70 percent of the fishable species. The size of these fish ranged widely, from four to six inch sunfish to a 40 pound Flathead Catfish. Further discussion on the significance the fish species composition is accomplished in subsequent sections of this chapter.

Invertebrate Variables.

The collection of invertebrate samples was accomplished through a qualitative standard level of effort consisting of one half manhour of dipnet sampling. Taxa were identified to the lowest taxonomic level attainable. Table 15 lists the classifications of 49 taxonomic units obtained as part of the Oklahoma UAA study. It should be noted that the identification of invertebrates resulted in a mixture of various levels of taxonomy. Most of the taxa were identified to the level of genus, while others were more consistently left at higher level of heirarchy such as Tribe (e.g. Chrinomini), and Family (e.g. Hirudinea). As was the case with the fish sampling, only 35 of the stations were sampled for similar reasons.

CLASSIFICATION	TAXON	FREQUENCY
Trichoptera	*Hydropsyche*	11
	Cheumatopsyche	9
	Chimarra	4
	Nyctiophylax	3
	Oecetis	4
Megaloptera	*Corydalus*	11
Ephemeroptera	*Isonychia*	3
	Baetis	16
	Calibaetis	3
	Cloeon	1
	Stenonema	22
	Tricorythodes	4
	Caenis	14
	Ephoron	5
Odonata	*Calopteryx*	9
(Zygoptera)	*Argia*	30
	Enallagma	2
(Anisoptera)	*Ophiogomphus*	2
	Anax	1
	Basiaeschna	3
	Epiaeschna	1
	Macromia	6
	Libellula	4
	Tramea	1
Coleoptera	*Dineutus*	1
	Gyrinus	1
	Berosus	8
	Tropisternus	1
	Helichus	7
	Dubiraphia	1
	Stenelmis	5

Table 15. List of Invertebrate Taxa and Frequency of Occurrence at 35 Sampling Stations.

CLASSIFICATION	TAXON	FREQUENCY
Diptera	Ceratopogonidae	1
	Culicidae	1
	Simuliidae	8
	Chironomini	32
	Tanytarsini	17
	Tanypodini	14
	Pentaneurini	1
	Macropelopiini	1
Isopoda	*Lirceus*	5
Amphipoda	*Hyalella*	11
Gastropoda	*Physa*	19
Pelecypoda	Sphaeriidae	13
Oligochaeta	*Limnodrilus*	7
Turbellaria	Planariidae	1
Hirudinea		2
Bryozoa		11
Decapoda	Palaemonetes	3

Table 15(cont.). List of Invertebrate Taxa and Frequency of Occurance at 35 Sampling Stations.

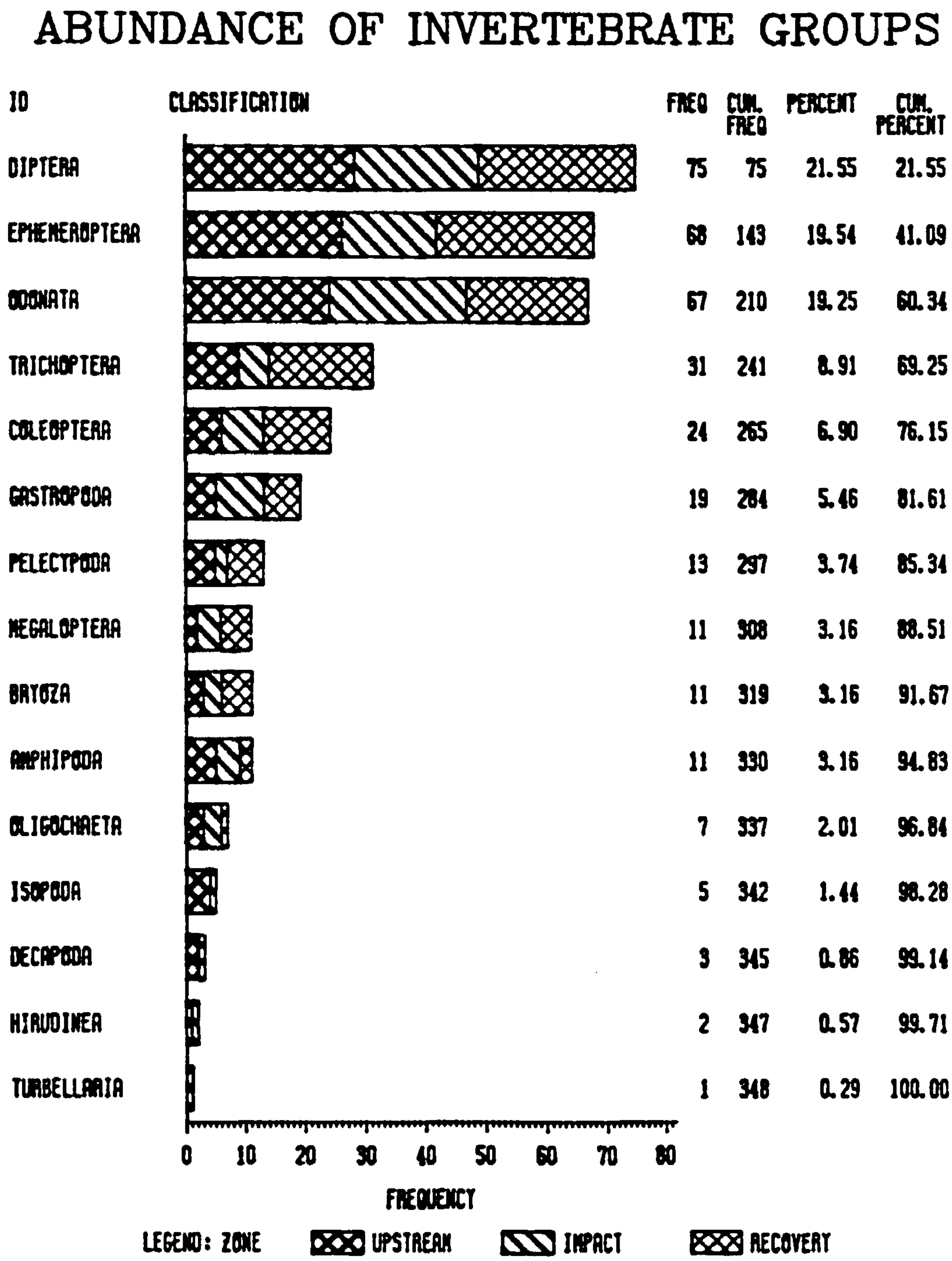


Figure 20. Frequency Distribution and Abundance of Invertebrate Classifications or Groups.

Figure 20 summarizes the frequency distribution of major invertebrate classifications. Diptera, Ephemeroptera, Odonata and Trichoptera accounted for 70 percent of the invertebrate fauna found in the study. Further discussion on the significance of the invertebrate species composition is made in the subsequent sections of this chapter.

Biological Indices.

Introduction.

This section presents the use of several pollution indices in the evaluation of fish and invertebrate species composition. Included when appropriate are further descriptive statistics, as well as, tables and illustrations. The choice of which indices to use was to a large extent influenced by the qualitative nature of the biological database. That is to say, traditional methods, which relied on calculation of species diversity, or species richness, require enumeration of the number of individuals in each taxonomic unit. The UAA database extends from a methodology which does not provide for the level of effort required to make such calculations. In this case, more emphasis is placed upon the species composition and discrete species richness at each location. Therefore, the choice of an appropriate index included the ability to use the existing data with only relative abundance designation serving as the scale of density for each species.

Chapter Two discussed the use of pollution indices in the assessment of aquatic hydrobiocenosis. The Trent Biotic Index, the Graham Index, Chandler's Score and the Karr Index, were chosen to scale the species composition of fish and invertebrate taxa obtained at those stations sampled as part of the Oklahoma UAA program.

The Karr Index.

The use of pollution indices for evaluation of fish species composition is not as well developed as their use in assessment of invertebrate populations. The Karr Index represents an attempt to scale the value of various categories of fish species composition and result in a quality index indicative of the fisheries inherent health and ecological value. The categories chosen by Karr were presented in Table 5 of Chapter Two. In the case of the Oklahoma UAA database, several adjustments in the Karr index were necessary in order to scale the quality of the fishery.

Karr utilized 12 categories of community attributes to scale the value of the fishery. Several of these categories were not scientifically evaluated in this study (i.e. hybrids and diseased fish). The selection of intolerant species, omnivores, and top carnivores was made in accordance with

EPA's lists of national fish species for each category (37). The selection of insectivorous cyprinids was made in accordance with food habit descriptions provided in Carlander (23,24) and Miller (74). The category of suckers was eliminated because only one member of this family (*Carpiodes carpio*) was obtained in the collections. The categories for sunfish excluded the Green Sunfish and only included the members of the genus *Lepomis*. Darters (Percidae) were expanded to include the genus *Campostoma* (Cyprinidae), which has a wider range than many of the darters encountered in this study and similar habitat preferences (37).

Those categories which are assessed based upon the density of the fish population were evaluated by recoding the relative abundance designations to estimates of their minimum density. This was accomplished by assigning the following values to the relative abundance scale: rare=1, occasional=5, common=10, and dominant=50. The categories were assigned a rating value consistant with the Karr scoring protocol, which assigns values of one, three or five to each category.

The values for each category were assigned according to the following protocol:

Category	Quality Points: Value Scale 1	3	5
Relative Abundance	<50	>=50 <=100	>100
Omnivorous Species	>25	>=10 <=25	<10
Top Carnivores	<=1	>1 <=5	>5
Green Sunfish	>5	>=1 <=5	<1
Intolerant Species	<=1	>1 <=5	>5
Insectivorous Cyprinids	<5	>=5 <=10	>10
Species Richness	<=6	>6 <=12	>12
Sunfish	<1	>=1 <=2	>2
Darters	<1	=1	>=2

Table 16 give the Karr Index scores for those stations sampled as part of this study. Figure 21 shows the plot of the Karr Index as adapted to use for the Oklahoma UAA program. In Karr's work a maximum score of 60 resulted from the evaluation of twelve attributes. In this study nine categories of attributes were evaluated which would yield a top score of 45. In proportion to the quality index developed by Karr, the following categories of quality classes were developed: excellent (>=42), excellent-good (<42 >=40), good (<40 >=37), good-fair (<=36 >=34), fair (<34 >=30), fair-poor (<30 >=27), poor (<27 >=21), poor-very (<21 >=18), very poor (<=17). Figure 22 presents a frequency block chart showing the distribution of station

STATION-ZONE	NO. INVERT.	TRENT INDEX	GRAHAM INDEX	CHANDLER SCORE	KARR INDEX	NO. FISH
BCC-1	10	5	1	337	31	11
BCC-2	10	5	1	304	-	-
BCC-3	13	7	1	590	-	-
CHC-1	8	6	3	370	21	7
CHC-2	5	4	2	176	19	3
CHC-3	6	6	3	280	23	6
COL-1	12	8	1	447	29	11
COL-3	8	6	3	376	31	15
DOG-1	13	8	1	409	23	4
DOG-3	11	7	2	509	31	12
ELK-1	12	7	2	386	17	4
ELK-2	10	6	1	468	17	5
ELK-3	10	6	1	451	17	6
LDF-1	14	7	2	482	27	12
LDF-2	11	8	1	531	25	9
LDF-3	13	8	1	563	29	9
MBC-1	5	2	4	88	27	8
MBC-2	9	7	2	447	35	14
MBC-3	11	7	3	448	31	11
NCR-1	4	4	3	119	35	14
NCR-2	11	7	2	354	23	10
NCR-3	-	-	-	-	19	7
NCW-1	6	6	3	202	25	12
NCW-2	12	7	2	470	25	10
NCW-3	11	7	2	499	27	14
PRC-1	-	-	-	-	23	7
PRC-2	6	5	4	117	27	8
RSC-1	13	8	1	872	21	8
RSC-2	5	3	4	172	23	10
SCR-3	10	6	3	246	23	13
SKC-1	11	7	1	370	21	8
SKC-2	14	6	1	435	17	3
SKC-3	11	7	1	392	17	2
STW-1	6	5	4	173	19	4
STW-2	2	2	5	25	21	5
WEC-3	17	9	1	955	19	4
WHC-1	7	3	4	238	15	4

Table 16. Summary of Scores for the Trent Biotic Index, Graham's Biotic Index, Chandler's Score and the Karr Index as Adapted for Use in the Oklahoma UAA Program. Included are the number of invertebrate and fish taxa found at each station. Sampling zones 1=upstream, 2=impact, 3=recovery. Station codes are presented in Table 8.

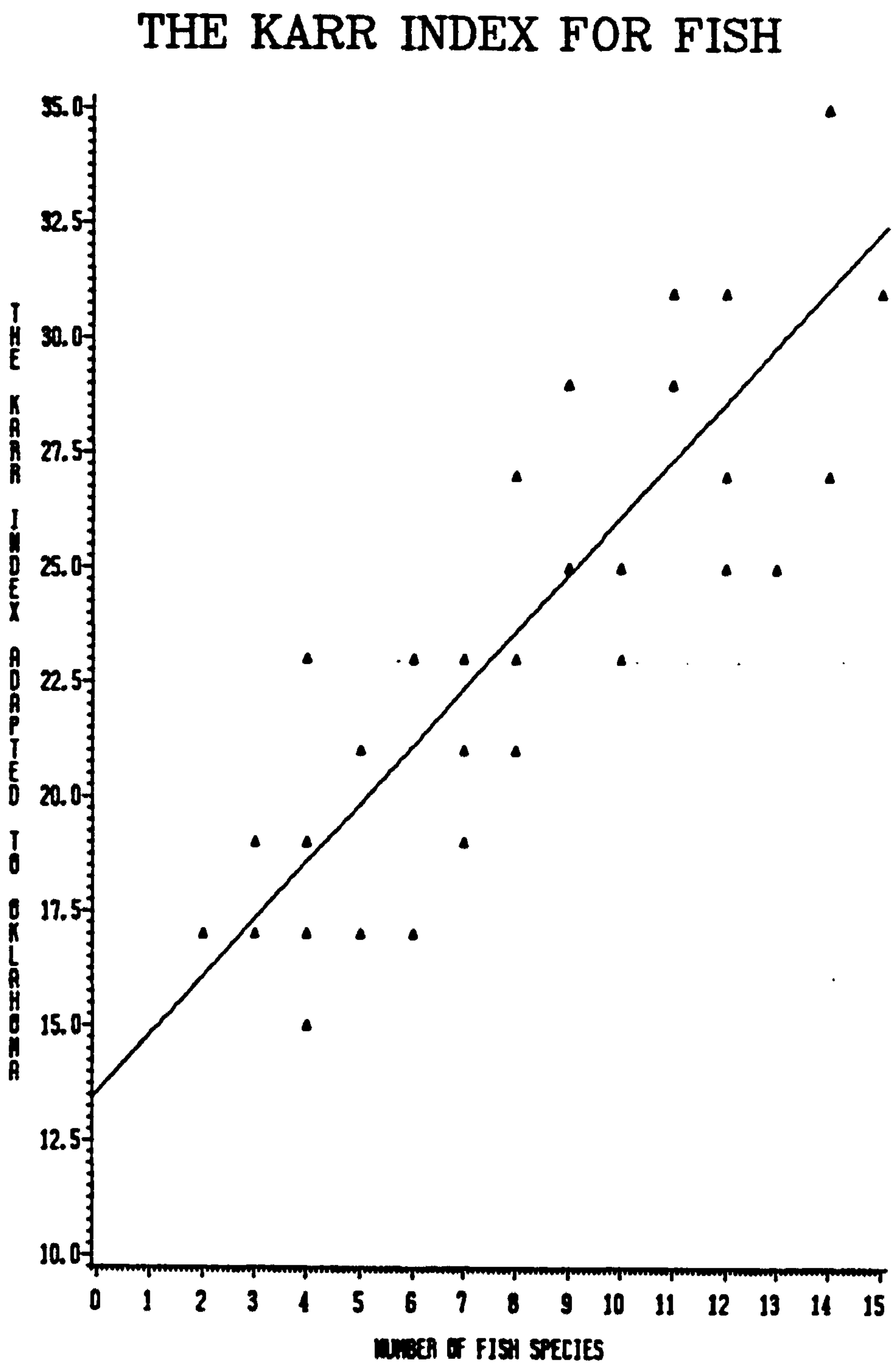


Figure 21. Plot of the Karr Index versus Number of Fish Species.

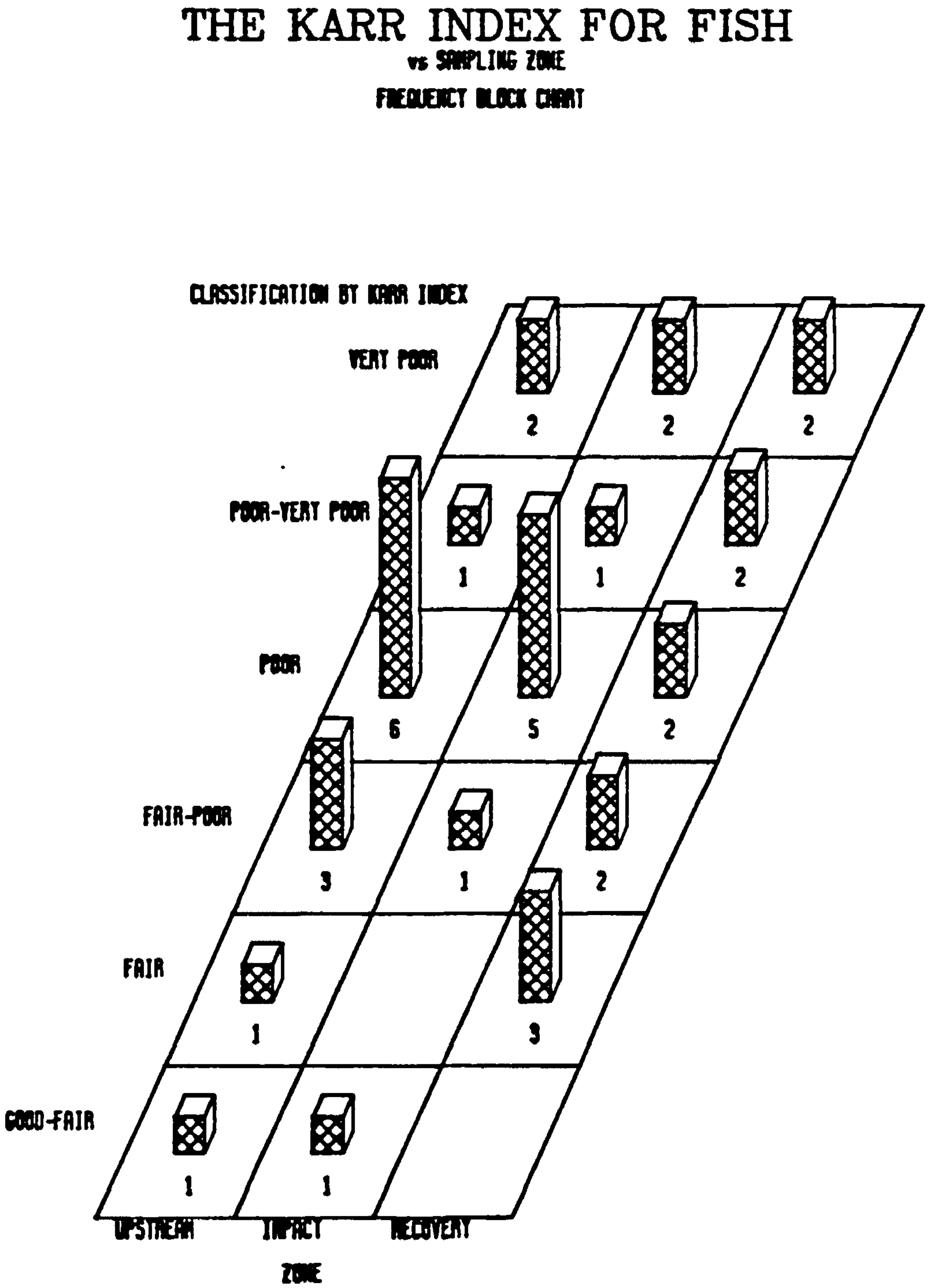


Figure 22. Frequency Distribution of Karr Index Classifications by Sampling Zone.

classification from good thru very poor by sampling zone. None of the stations warranted an excellent rating.

The Trent Biotic Index.

The application of the Trent Biotic Index was discussed in detail in Chapter Two. Table 2 presented the Index as it was first developed by Woodiwiss. In any given part of the world, the application of an index must take into account the differences in the composition of species and their significance. The classifications used in the Trent Biotic Index needed to be modified slightly to account for the differences in the taxa found in these Oklahoma streams.

The following modifications were performed on the orginal Woodiwiss scheme to adapt the Trent Biotic Index for use in evaluating the streams sampled during the Oklahoma UAA Program. Plecoptera were not present in any samples and as a result nine was the highest possible score. The mayfly, Stenonema, was treated like the genus Baetis on the basis of it's pollution tolerance (47,54). The Isopod, Asellus, was substituted with the genus Lirceus. The Amphipod, Gammarus, was replaced with the genus Hyalella. These latter two substitutions were made because of the differences in the fauna found in this Oklahoma study and the similar pollution tolerance and ecological significance of these Oklahoma varieties (47). None of the stations were without any of the varieties mentioned in the Woodiwiss scheme, and as a result the scores ranged from two to nine.

Table 16 list the scores for the Trent Biotic Index as adapted for use in this UAA study. Figure 23 plots the relationship of the Trent scores versus the number of invertebrate taxa found at the sampling stations. Six stations received scores below five. The corresponding species richness for these samples was five or fewer taxa present, in all but one of the samples.

Graham's Biotic Index.

The application of Graham's Biotic Index followed similar modifications as those previously discussed for the Trent Biotic Index. Table 3 in Chapter Two present the Graham Biotic Index. As was the case in the previously discussed index, the mayfly Stenonema, was treated like Baetis, and the same substitution was made for the genus Asellus was made. The Annelid, Tubifex, was substituted with the genus Limnodrilus on the basis of similar pollution tolerance (47). Table 16 list the Graham's Index scores for the sampling stations. Figure 24 illustrates the frequency distribution of the Graham's Index scores by sampling zone. Thirteen station were evaluated as being polluted, most of these stations had fewer than ten invertebrate taxa present.

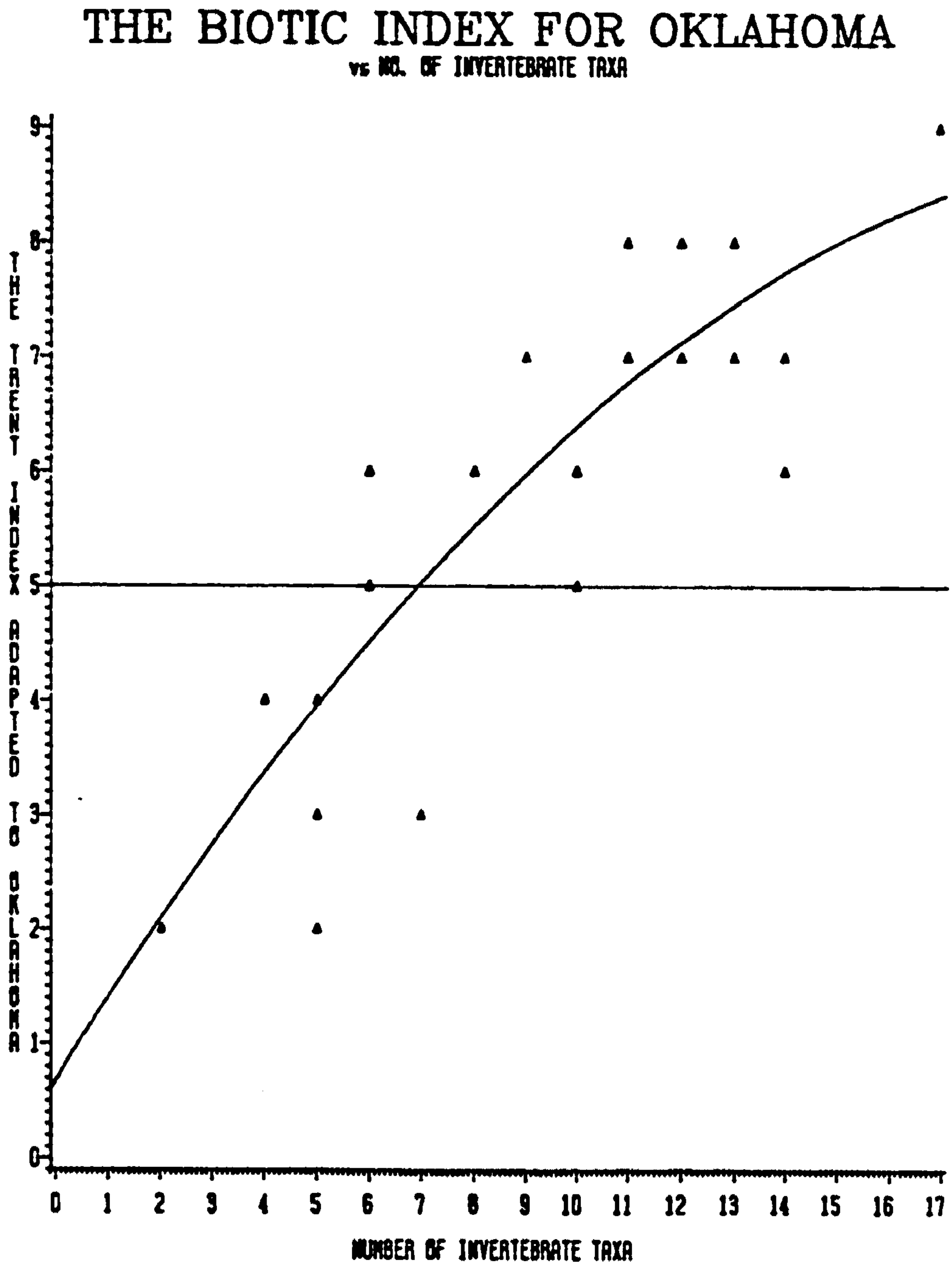


Figure 23. Plot of the Trent Biotic Index versus Number of Invertebrate Taxa.

THE GRAHAM INDEX BY SAMPLING ZONE

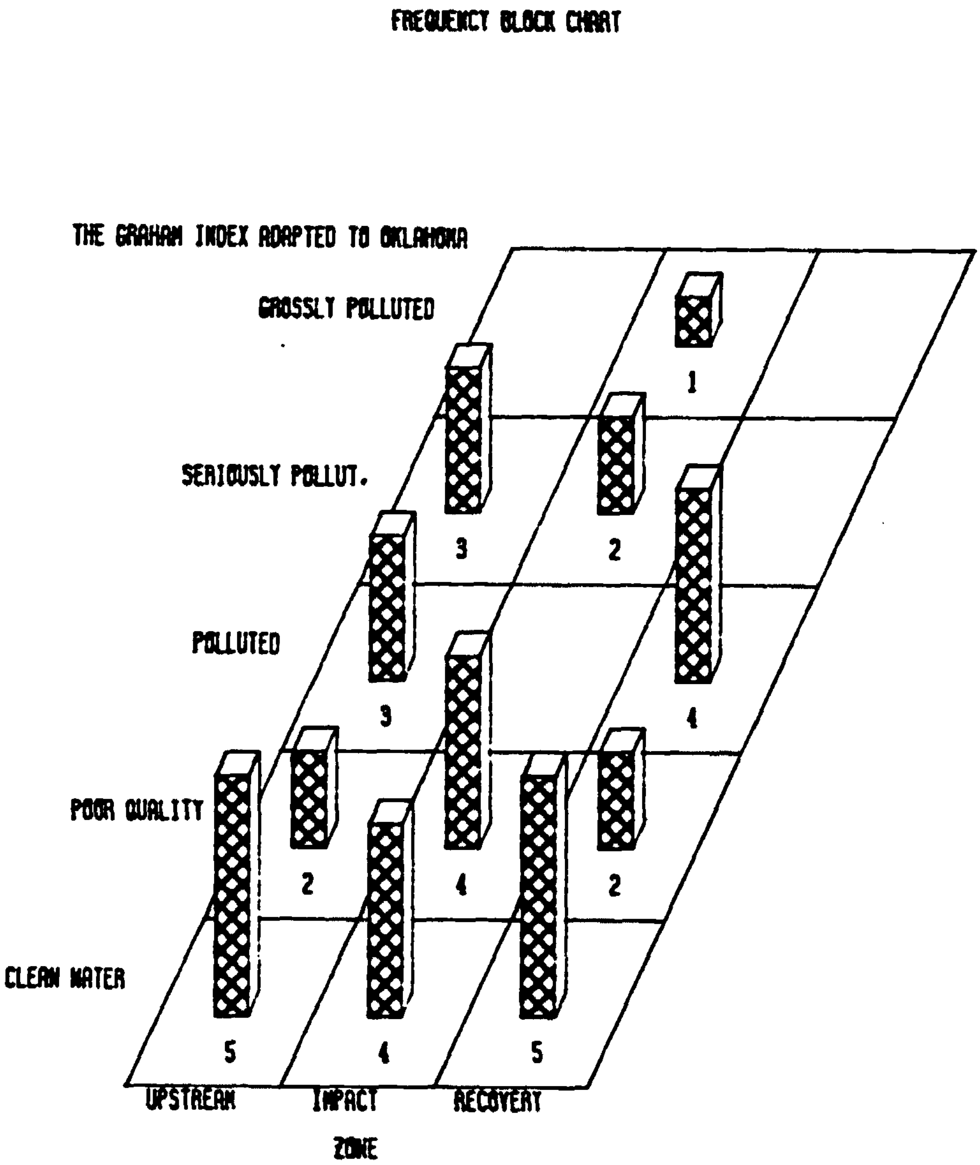


Figure 24. Frequency Distribution of the Categories of Graham's Biotic Index Scores by Sampling Zone.

The Chandler Score.

The process of adapting the approach use by Chandler to score the quality of sampling station on the basis of the numbers and types of invertebrate species present was considerably more involved than either the Trent or Graham Biotic Indices. The scoring scheme used in evaluating the Oklahoma UAA sampling stations is presented in Table 17. Table 16 shows the scores received by the sampling stations and Figure 25 illustrates the relationship between the Chandler scores and the number of invertebrate taxa present at each location. Scores below 300 are considered to be indicative of polluted areas (101) which possess fewer invertebrate taxa and include those members which accumulate the least point value in the scoring protocol. Ten stations scored below this threshold value which delineates cleaner or less polluted streams from areas or higher perturbation; as evidenced by a more depressed species compostion.

Cluster Analysis

Introduction.

The discussion of results presented in the following section is limited to the cluster analysis of fish, invertebrate, habitat and substrate variables. Essentially,

THE CHANDLER SCORE ADAPTED FOR OKLAHOMA UAA

GROUPS PRESENT IN SAMPLE	RELATIVE ABUNDANCE RARE	OCCASIONAL	COMMON	ABUNDANT
Ephemeroptera, excluding *Baetis* and *Stenonema*	79	84	90	94
Trichoptera, Megaloptera	75	80	86	91
Simuliidae	56	61	67	73
Coleoptera	51	55	61	66
Baetis and *Stenonema*	44	46	48	50
Hyalella	40	40	40	40
Physa and Sphaeriidae	30	28	25	22
Chironomidae, excluding Chironomini	28	25	21	18
Lirceus	25	22	18	14
Hirudinea	24	20	16	12
Tubellaria	22	18	13	12
Chironomini	21	17	12	7
All other species, excluding Bryozoa	19	15	9	5

Table 17. The Chandler Score Adapted for Use With the Oklahoma Use Attainability Database.

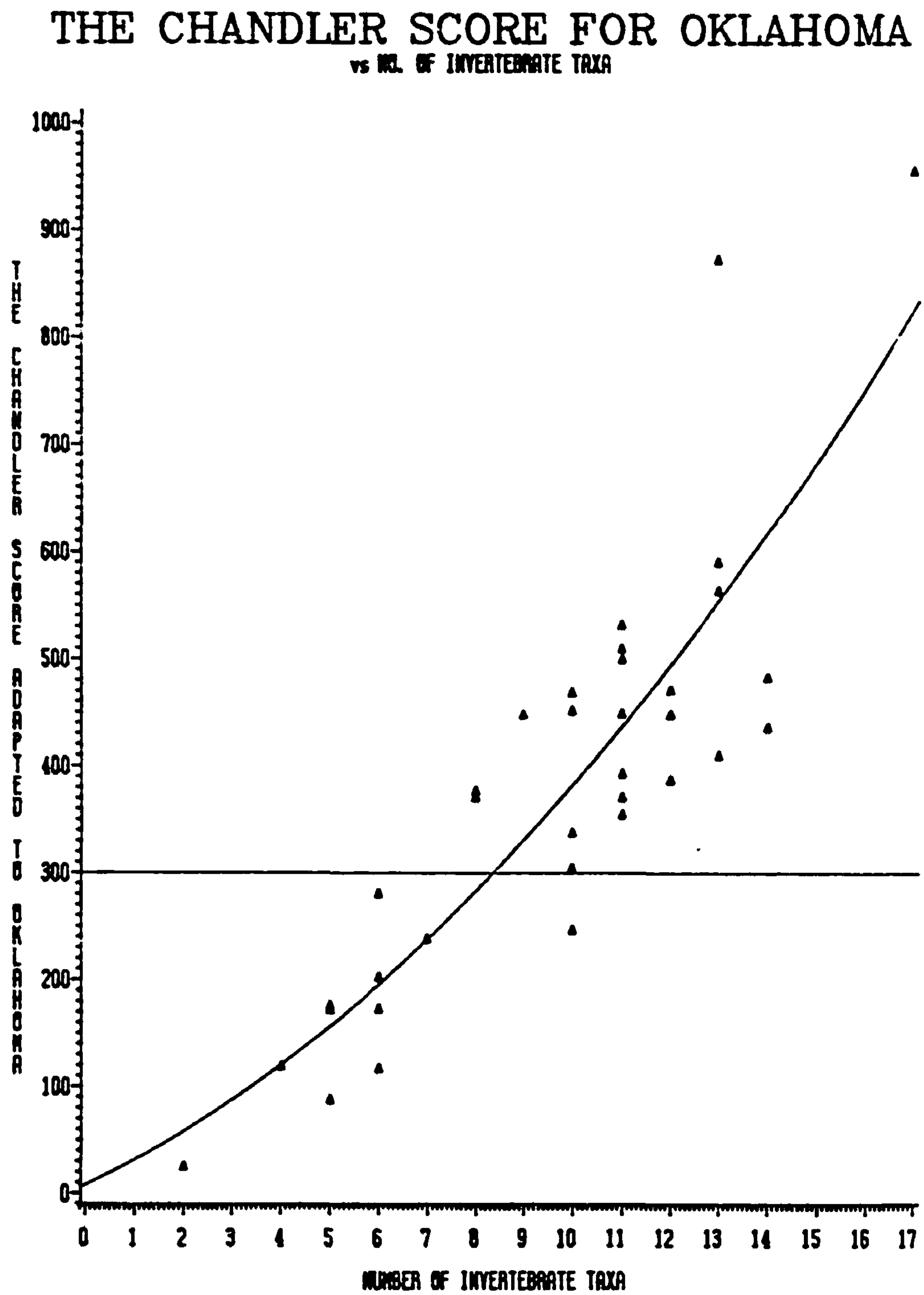


Figure 25. Plot of Chandler's Score versus the Number of Invertebrate Taxa.

two types of cluster analyses were performed on the datasets. The methods employed consisted of Wards's (96) minimum variance heirarchical clustering method and UPGMA, the unweighted pair-group method using arithmetic averaging (106). These two methods and some of their applications were discussed in Chapter Two. Ward's method was accessed through SAS, while UPGMA was accessed through the NT-SYS computer programs package. The main intent of the cluster analysis was to provide a method of classifying variables into groups of observations or clusters.

Ward's method uses a multivariate data matrix where the rows of the matrix are the sampling stations and the columns are the variables (e.g. fish species). The SAS procedure used was PROC CLUSTER and the output from the Ward's method was visualized by producing tree diagrams using PROC TREE. The resulting output produced a tree diagram with two main branches. Each branch was then subdivided by additional branching based on the associations of the variables and the number of clusters produced. The results obtained from Ward's analysis were utilized in a qualitative fashion based on the partitioning of variables into one or the other of the two branches produced.

In order to accomplish the Ward's clustering in a manner which would depict the distribution of the population of variables as common or less common to the dataset as a whole; data had to first be recoded to distinguish the variables as a function of the frequency of occurrence. This was accomplished by recoding each data entry as having the value of 1-1/n where 'n' is the total number of times a variable occurred in the dataset. When a given species or habitat variable was not present at a given location, that field of the data matrix received a value of negative one. This allowed the data to be clustered based on the frequency of occurrence in the dataset at large, rather than the simple binary presence or absence at a given location. The results of Ward's analysis are discussed in the following sections as "Branch A", containing the most commonly associated variables and "Branch B", containing a set of variables with a pattern of occurrence distinct from "Branch A", with a lower frequency of occurrence.

UPGMA cluster analysis was accessed through NT-SYS. Input data consisted of preparing a binary data matrix (0=absent, 1=present) for each variable and dataset using SAS. Output data sets were then read as input for the NT-SYS programs. The first step in the clustering process was the preparation of a matrix of similarity coefficients. The NT-SYS program 'SIMQUAL' was called upon to produce the data using the Jaccard Coefficient. Cluster analysis was accomplished using the 'TAXON' program and the UPGMA method option. The results were graphically illustrated as dendrograms using the NT-SYS 'PHENOGRAM' procedure. A cophenetic correlation coefficient was calculated for each dendrogram. This statistic is a measure of how well dendrogram resembles the values of the similarity coefficient data matrix from which it was created. Cophenetic values generally range from 0.6 to 0.95 (106). Only those dendrogram which had cophenetic values greater than 0.70 were chosen for illustration in the following sections. Both Q-mode, which clusters the variables (e.g. fish species) and R-mode, which clusters the records (e.g. sampling stations) was performed.

Fish Classification.

The species composition for the fish fauna was presented in Table 14. The results of Ward's analysis of this database yielded two distinct groups or branches. "Branch A" was a very small cluster of only four species of fish, *Notropis lutrensis*, *Gambusia affinis*, *Lepomis cyanellus* and *Lepomis megalotis*. The first three species listed above are noted for their pollution tolerance (37,61). The Longear Sunfish is considered less tolerant of pollution (37) and it's commonality in the distribution may be a result of other factors such as habitat preference. "Branch B" contained all the remaining species and had three subdivisions. The SAS tree diagram produced from Ward's analysis is provided along with the raw data for fish variables in Appendix B.

Ward's analysis was also performed on the database after sorting by the determination of the ranking committee as secondary warm water fisheries. The taxa included in "Branch A" included only three fish. These included Notropis lutrensis, Gambusia affinis, and Lepomis cyanellus. This group will be referred to as fish cluster group B (pollution tolerant varieties) in the subsequent section on factor analysis.

Figure 26 represents the dendrogram of Q-mode UPGMA cluster analysis of fish species composition. Several interesting grouping or clusters were revealed, many of which go beyond the scope of this presentation. The frequency distribution of one group, referred to as Group A, is presented in Figure 27. Within this group are several clusters which, for the most part, contain the largest percentage of pollution tolerant fish. These species are also the most abundantly occurring varieties. Numerous game fish are presented in this group as well. The remaining clusters contain considerably less tolerant species and

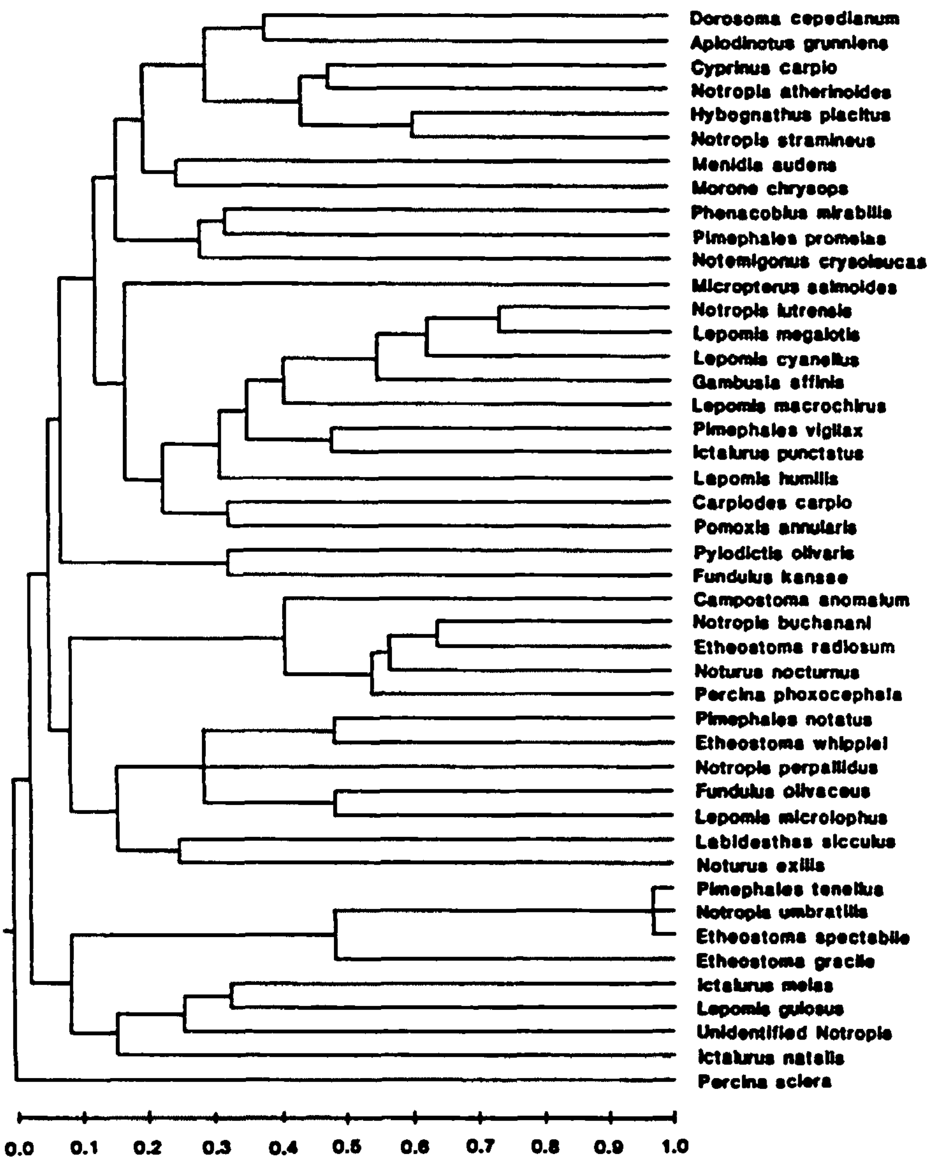
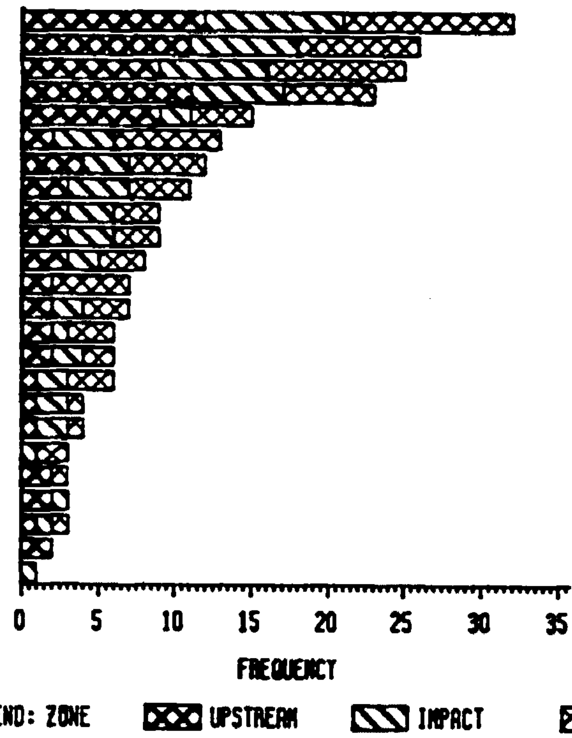


Figure 26. Dendrogram prepared by Q-mode UPGMA cluster analysis of Jaccard coefficients computed from binary data on fish distribution at 35 sampling stations. Cophenetic correlation coefficient is 0.840.

ABUNDANCE OF FISH SPECIES FOR GROUP A



ID	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
N. lutrensis	32	32	13.45	13.45
L. megalotis	26	58	10.92	24.37
G. affinis	25	83	10.50	34.87
L. cyanellus	23	106	9.66	44.54
L. macrochirus	15	121	6.30	50.84
I. punctatus	13	134	5.46	56.30
L. humilis	12	146	5.04	61.34
P. vigilax	11	157	4.62	65.97
M. atherinoides	9	166	3.78	69.75
Carpoides carpio	9	175	3.78	73.53
D. cepedianum	8	183	3.36	76.89
P. annularis	7	190	2.94	79.83
N. stramineus	7	197	2.94	82.77
M. salmoides	6	203	2.52	85.29
H. placitus	6	209	2.52	87.82
Cyprinus carpio	6	215	2.52	90.34
P. promelas	4	219	1.68	92.02
P. mirabilis	4	223	1.68	93.70
P. olivaris	3	226	1.26	94.96
N. crysoleucas	3	229	1.26	96.22
M. chrysops	3	232	1.26	97.48
A. grunniens	3	235	1.26	98.74
H. audens	2	237	0.84	99.58
F. kansae	1	238	0.42	100.00

Figure 27. Frequency Distribution of Fish Species For Group A.

varieties such as the darters and certain Cyprinidae which occupy more restricted geographical ranges in Oklahoma (74). This factor must be taken into account in any classification scheme which mixes species whose distribution or frequency of occurrence in a dataset may be more a function of range than any of the limiting factors present at a location (e.g. dissolved oxygen).

Figure 28 represents the R-mode cluster analysis of species showing the clustering of sampling stations based on the similarity matrix. Several groupings of stations stand out among the clusters. The group at the top of the dendrogram which clusters the North Canadian River below Oklahoma City (NCR-1, NCR-2) with the North Canadian River below Woodward, Oklahoma (NCW-2, NCW-3) is one example. The river below Oklahoma City received a seconday warm water fishery designation, while that portion below Woodward received a primary warm water fishery designation. Several streams, such as Pryor Creek, Chisholm Creek and Elk Creek, clustered all of their sampling stations together. Rush Creek and Little Deep Fork formed one cluster. In both the above instances, the streams had similar Karr Index values. The results of these R-mode dendrograms help to serve as powerful graphical techniques, which demonstrate how different streams or stations along the same stream cluster

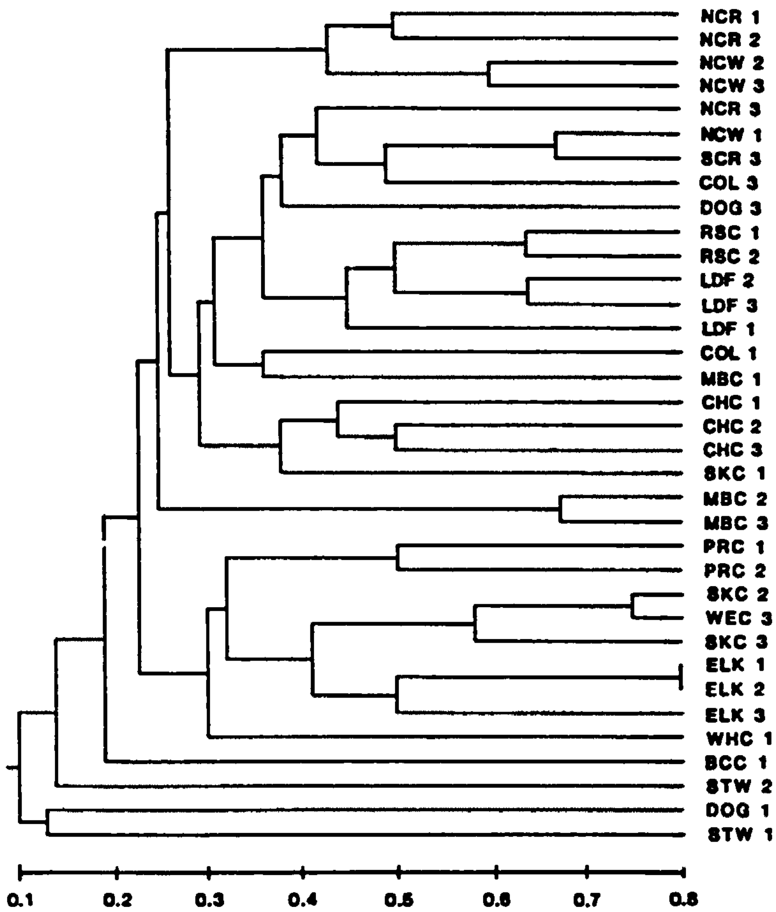


Figure 28. Dendrogram prepared by R-mode UPGMA cluster analysis of Jaccard coefficients computed from binary data on fish distribution for 35 sampling stations. Cophenetic correlation coefficient is 0.765.

based on the similarity of the fishery content.

Invertebrate Classification.

Ward's analysis of the invertebrate taxa found in Table 15 produced a cluster or branch containing 20 invertebrate taxons. The tree diagram for Ward's analysis of the invertebrates is found along with the raw data in Appendix B. The odonate, Argia and the dipterian tribe Chrinomini were the two most commonly associated benthic organisms. The second most common association contained the mayflies Stenonema and Baetis and the gastropod Physa. Ward's analysis was also performed on the dataset sorted by the determination of the ranking committee as primary or secondary warm water fisheries. The results after sorting yielded only 14 invertebrate taxa in "Branch A" for those streams ranked as primary and six for those ranked as secondary. The taxa included in "Branch A" for those stations ranked as secondary included the three dipterian tribes of the Chironomidae, Chironomini, Tanytarsini, Tanypodini, the odonate Argia and the genus Caenis (Trichoptera).

Q-mode UPGMA cluster analysis of the invertebrate taxa is present in Figure 29. The frequency distribution of one particular group of clusters referred to as Group A is

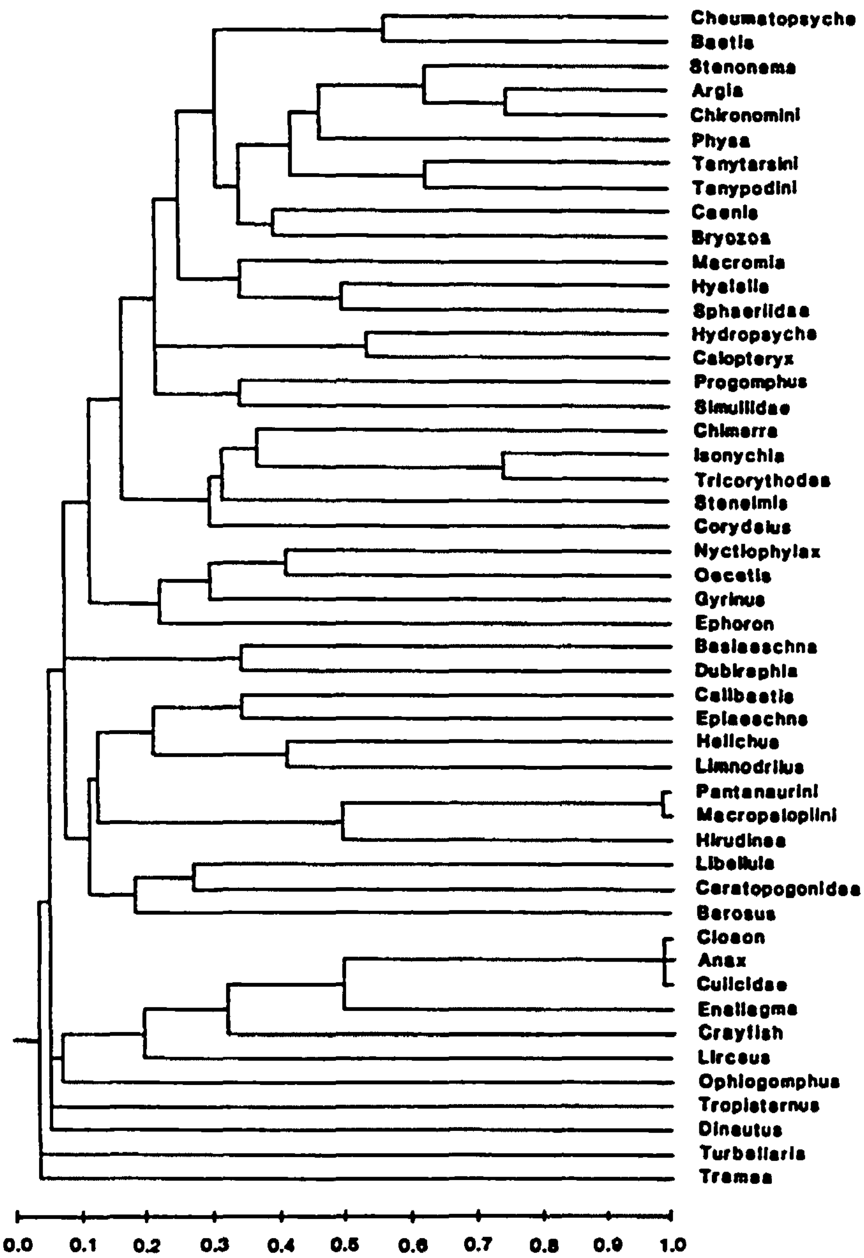


Figure 29. Dendrogram prepared from Q-mode UPGMA cluster analysis of Jaccard coefficients computed from binary data on distribution of aquatic invertebrates at 35 sampling stations. Cophenetic correlation coefficient is 0.846

illustrated in Figure 30. Some 50 percent of the frequency of occurrence of taxa within this group of 22 organisms consisted of only six taxa, Argia, Stenonema, Physa, Baetis, Chironomini and Tanytarsini. The remaining clusters, form other groups in the dendrogram, are to a large extent influenced by the relative rareness or sparse patterns of occurrence of individual taxa.

Figure 31 shows the dendrogram for R-mode UPGMA clustering of the sampling stations. Only two groups of sampling stations along the same stream clustered as one set. These were Big Cabin Creek and Stillwater Creek. There is considerably more heterogenicity in the clustering of stations for invertebrates as compared to the fish. The North Canadian River stations were more dispersed in this dendrogram clustering with other stations but still remained for the most part in the same large group. The pattern of clustering reveal some association with the Chandler Score values discussed in the previous section. Rush Creek (RSC-1) and Wewoka Creek (WEC-3), which clustered together, had the two higher scores, 955 and 872 respectively. The North Canadian River above Woodward (NCW-1), Chisholm Creek (CHC-2) and Muddy Boggy Creek (MBC-1) all clustered together and had similar Chandler Score values of 202, 176 and 88 respectively. The interpretation of the R-mode dendrogram

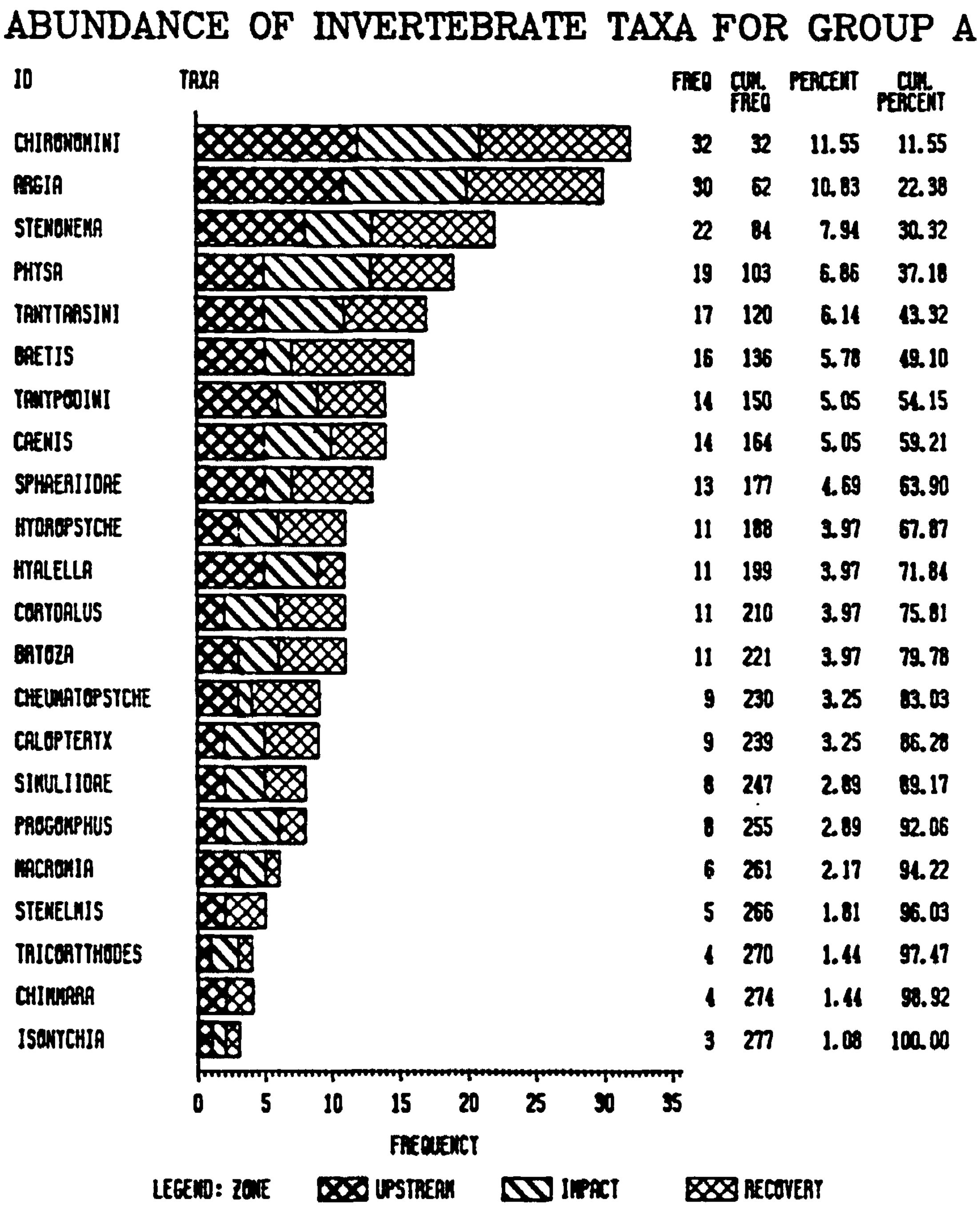


Figure 30. Frequency Distribution of Invertebrate Taxa for Group A.

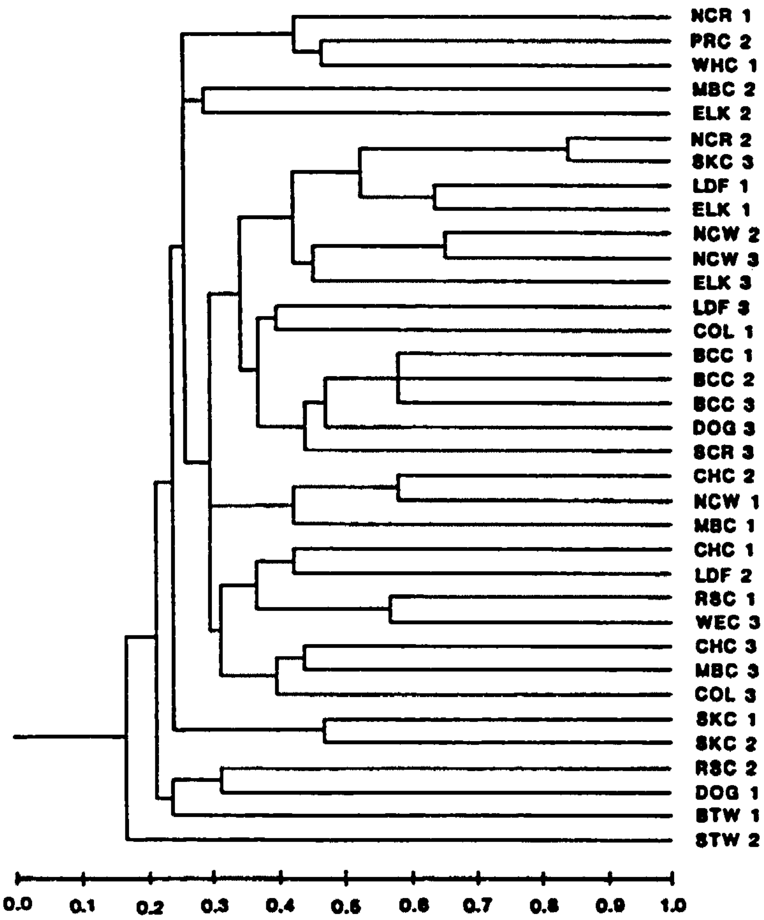


Figure 31. Dendrogram prepared by R-mode UPGMA cluster analysis of Jaccard coefficients computed from binary data on distribution of invertebrates at 35 sampling stations. Cophenetic correlation coefficient is 0.703.

for invertebrate sampling was significantly enhanced when done in conjunction with ratings, achieved by application of the pollution indices developed in the previous chapter.

Habitat and Substrate Classification.

Analysis of substrate and habitat variables by Ward's analysis produced a branch of common variables, "Branch A", containing the three most common habitat variables (pools, brushpiles and undercut banks) and the two most common substrate variables (sand and silt). The tree diagram of the clustering of substrate and habitat variables analyzed by Ward's method, is provided along with the raw data for habitat variables in Appendix B. The sorted data sets, based on the ranking committee's judgement as primary, yielded a cluster for "Branch A" containing submerged logs, sand, pools, silt, rock, undercut banks, brushpiles, gravel and large rock.

Q-mode UPGMA cluster analysis of substrate is presented in Figure 32. Softer substrates, characteristic of depositional areas, clustered together. These included silt, sand, detritus, mud and sludge. Harder substrates such as gravel and large rock clustered together as well. Bedrock, and to a lesser extent clay, stand out as independent types of substrate.

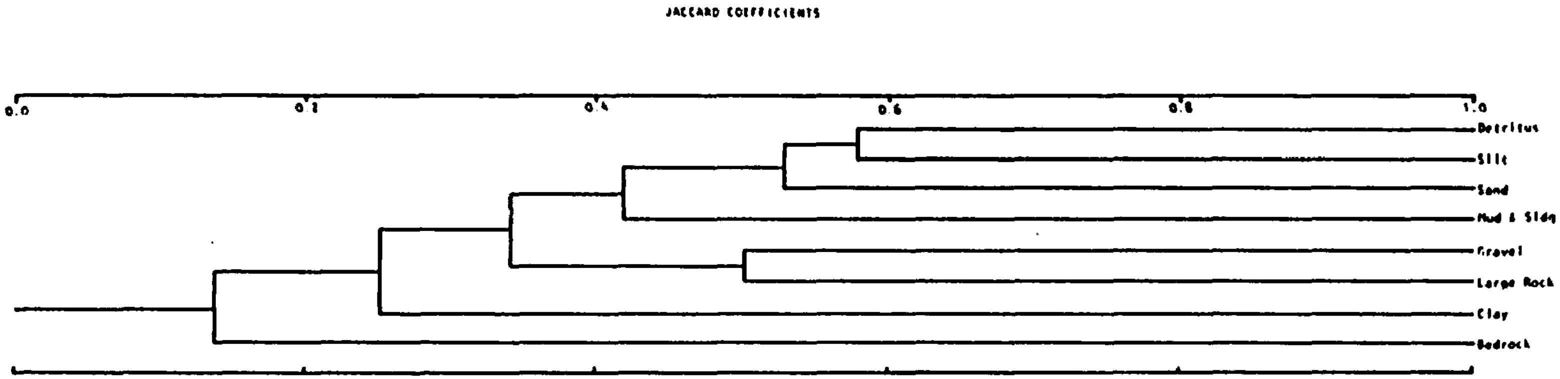


Figure 32. Dendrogram prepared by Q-mode UPGMA cluster analysis of Jaccard coefficients computed from binary data on distribution of substrate types at 35 sampling stations. Cophenetic correlation coefficient is 0.880.

R-mode UPGMA cluster analysis of the sampling stations for substrate variables yielded groupings of the stations based on substrate similarity. Figure 33 shows these groupings. The South Canadian River near Norman (SCR-3) stands out separate from the other clusters. This is due to the fact that the only substrate encountered at the sampling location was sand while other stations had at least one more type of substrate available. The clustering of the North Canadian River stations with a high similarity coefficient is noteworthy. The advantage of this dendrogram is that it allows for stations to be grouped on the basis of similar substrate. OWRB grouped the stations for the ranking committee evaluations on the basis of substrate types. This method provides a more scientific method of documenting such associations prior to evaluation by ranking or delphi teams.

Q-mode UPGMA analysis of the habitat types yielded a dendrogram with the highest cophenetic correlation. Figure 34 illustrates the habitat clustering in which pools, brushpiles and undercut banks cluster apart from habitats like deep channels and tree stumps or roots. The dominance of such categories as pools and brushpiles could account for the overwhelming abundance of the sunfish, especially the Longear Sunfish. Rocks and riffles clustered together, and as such, their exclusion as a set, from a stream may affect

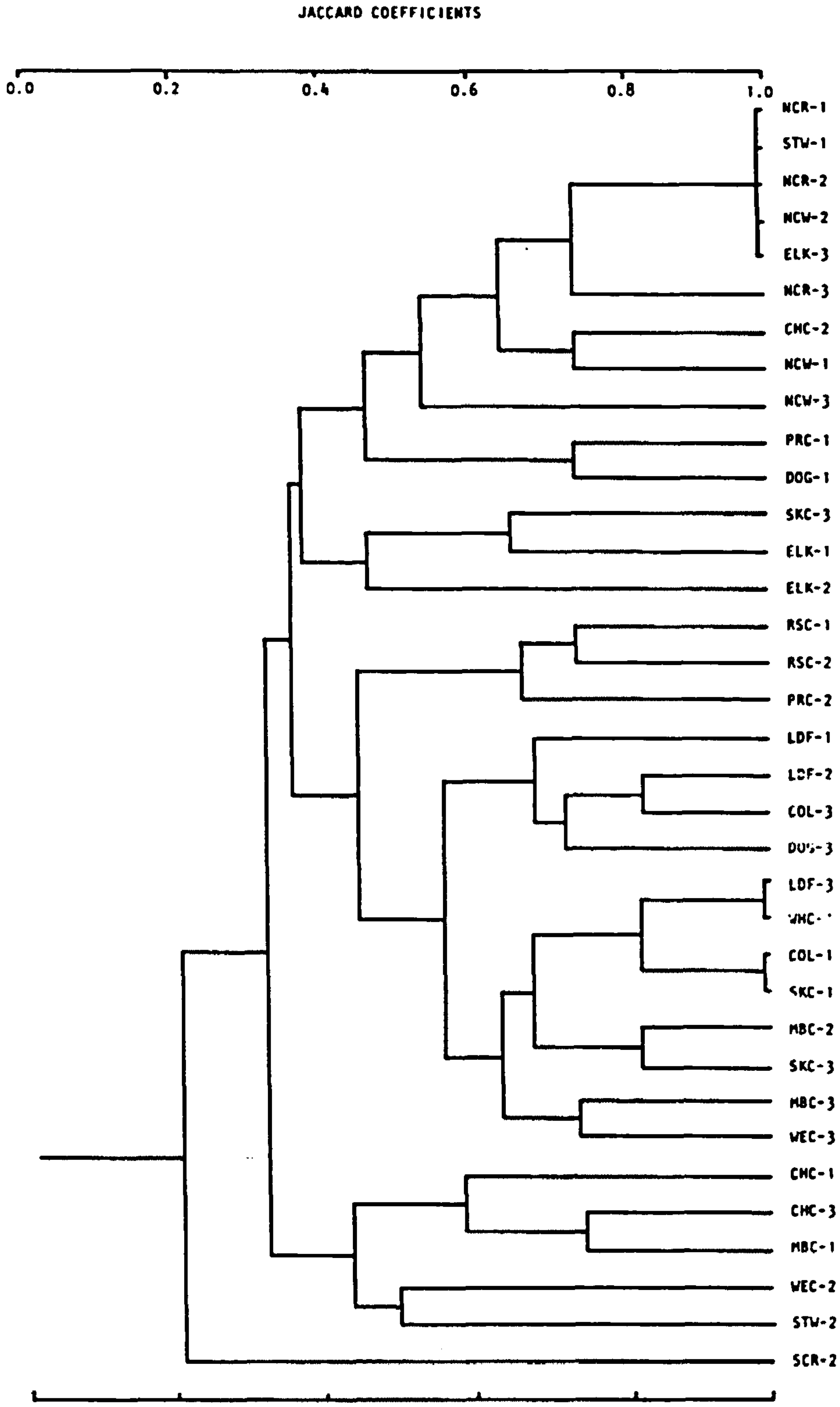


Figure 33. Dendrogram prepared by R-mode UPGMA cluster analysis of Jaccard coefficients computed from binary data on distribution of substrate types at 35 sampling stations. Cophenetic correlation coefficient is 0.733.

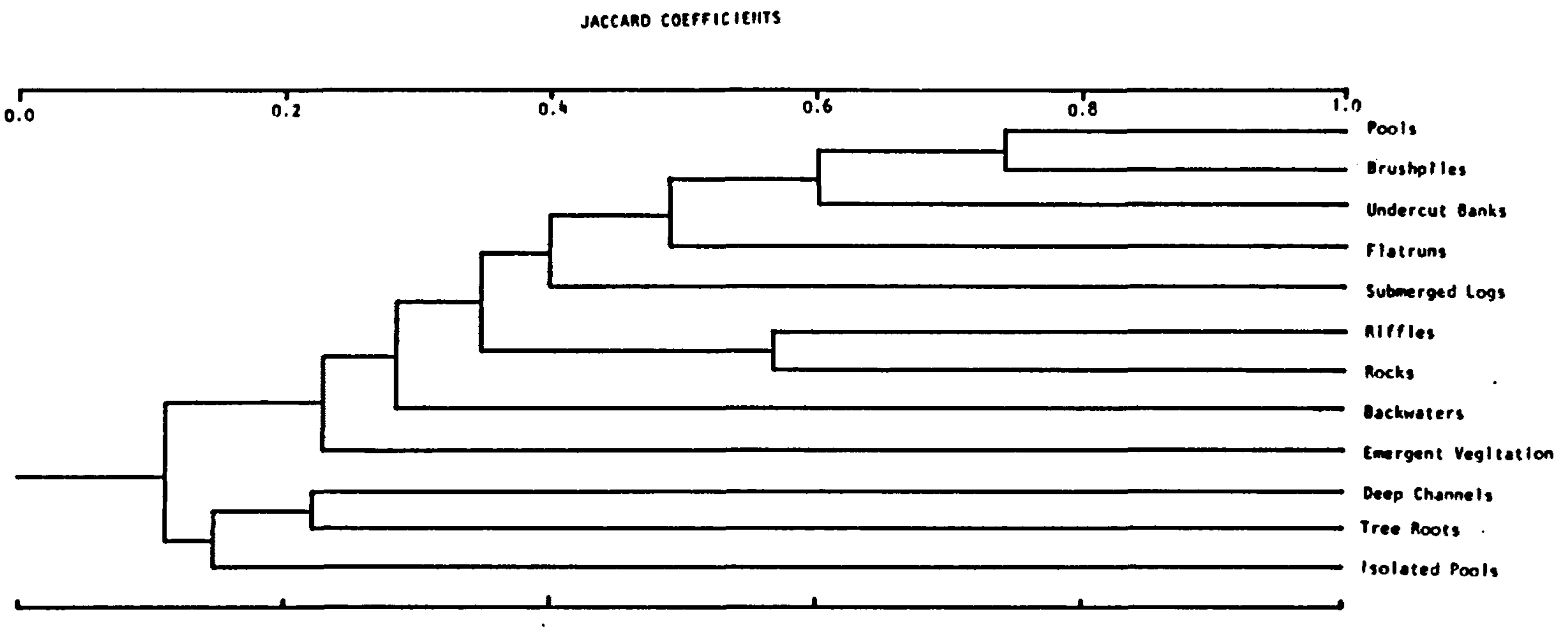


Figure 34. Dendrogram prepared by Q-mode UPGMA cluster analysis of Jaccard coefficients computed from binary data on distribution of habitat types at 35 sampling stations. Cophenetic correlation is 0.895.

the distribution of species which select such habitat over pools, brushpiles and undercut banks. R-mode cluster analysis yielded a cophenetic value less than 0.70 and, although the similarity coefficients are of use in compairing stations, the dendrogram was not selected for illustration for reasons discussed in the introduction to this section.

Combined Classification.

In an attempt to gain some picture of how the biological variables for fish and invertebrates group with habitat and substrate types, a Q-mode UPGMA cluster analysis was performed for all four categories of data combined. Figures 35a and 35b illustrate these groupings in a large multivariate dendrogram of community associations. Figure 35b is particularly significant because it contains the clusters of most of the common organisms, substrates and habitats types. At the top of the dendrogram in Figure 35b is a cluster of eight fish species. Four of these, *Dorosoma cepedianum*, *Aplodinotus grunniens*, *Morone chrysops* and *Menidia audens*, are more characteristic of lake environments (23,24). The next large grouping of clusters extending from *Notropis lutrensis* to Tanypodini is the most significant grouping in respect to this research. This group contains nine of the 12 habitat types, seven of the eight substrate

Continued See Figure 35b.

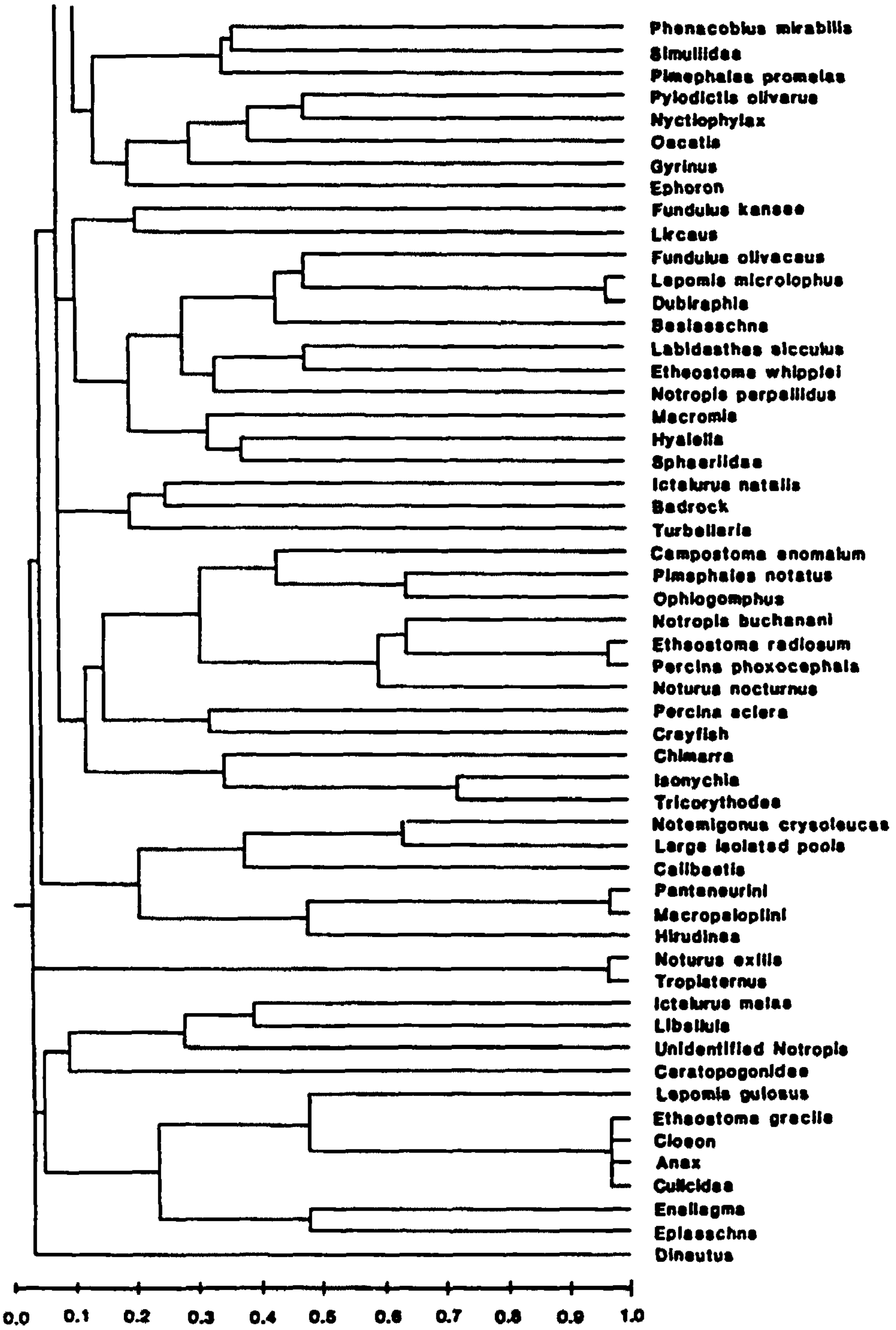


Figure 35a. Dendrogram prepared by Q-mode UPGMA cluster analysis of Jaccard coefficients computed from binary data on distribution of fish, invertebrate, habitat and substrate data at 32 sampling stations. Cophenetic correlation coefficient is 0.812.

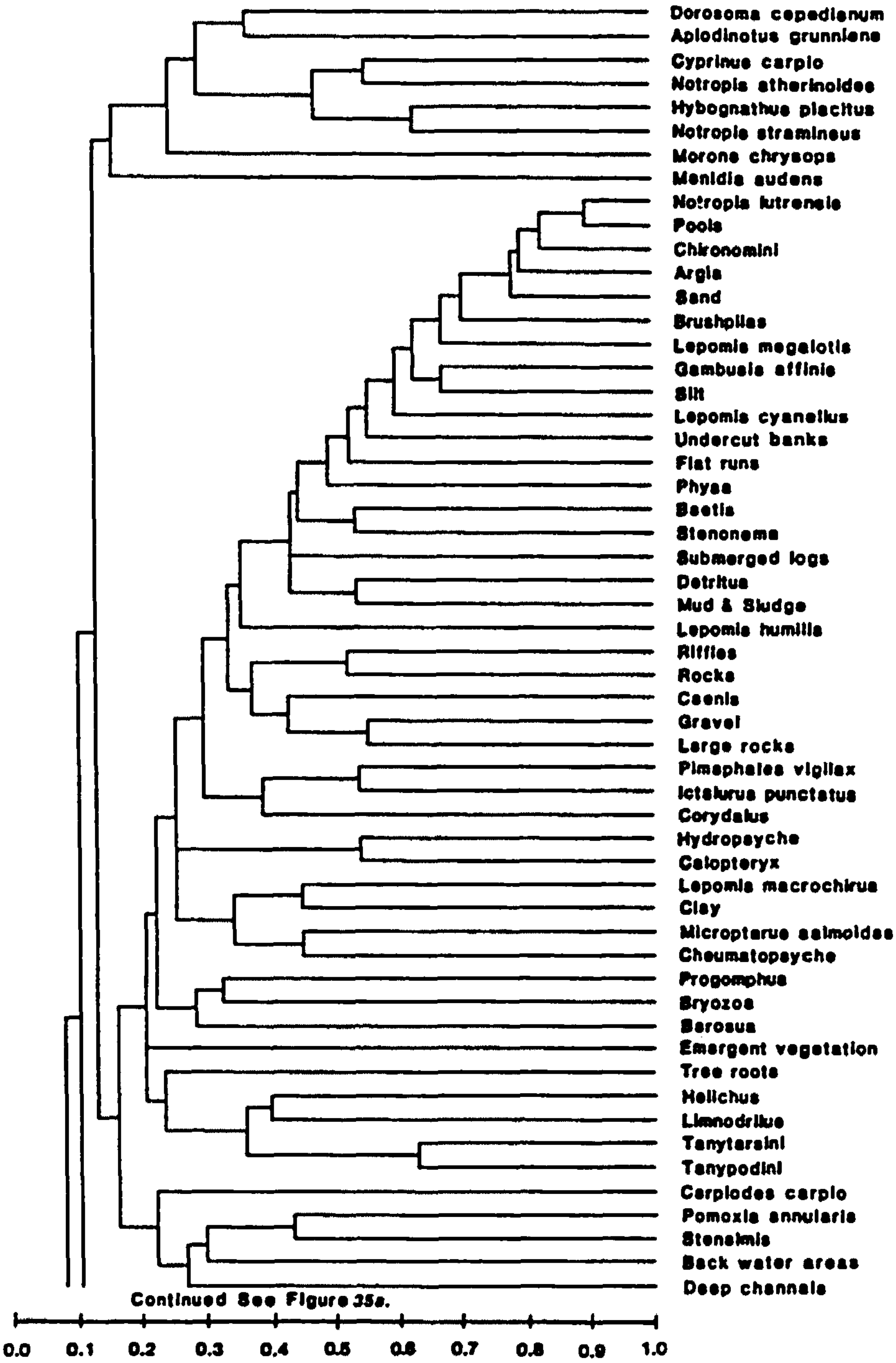


Figure 35b. Dendrogram prepared by Q-mode UPGMA cluster analysis of Jaccard coefficients computed from binary data on distribution of fish, invertebrates, habitat and substrate data at 32 sampling stations. Cophenetic correlation coefficient is 0.812.

categories, and essentially all of the most frequently occurring fish and insects. Five of the fish species are of fishable variety and two are game fish, the Channel Catfish and the Largemouth Bass.

Figure 35a contains groups of clusters whose associations are linked to their relatively lower frequency of distribution, scattered patterns of occurrence and other factors such as range. One group clusters three species of darters (Percidae) with *Compostoma anomalum* (Cyprinidae). This is noteworth since it helps support the inclusion of the Stoneroller with the darters in the adapted Karr Index. A detailed analysis of the ecological significance of each cluster is beyond the scope of this research. Rather, this dendrogram is provided as an attempt to classify the basic association of the common stream community. The large group of clusters referred to in the previous paragraph contains most of the common associations of variables including many pollution tolerant species of invertebrates and fish. This cluster can serve as an artifical reference community. This community of common fish, insects, habitats, and substrates is indicative of the degree of use attainment. The significance and other applications of cluster analysis in UAA is discussed in the last chapter of the dissertation.

Factor Analysis

Introduction

The following section attempts to summarize the application of factor analytical techniques in the evaluation of Oklahoma's UAA database. Chapter Two presented a detailed review of the numerous applications of principal component and factor analysis. The use of factor analysis for the purpose of this research is limited to the assessment of associations, or patterns among the variables. An example of such an association might include the clustering of similar variables in one factor (e.g. several different measurements of the biological community structure). Another example might include the clustering of sets of dependent and independent variables (e.g. fish species richness and the dissolved oxygen deficit). These associations, and the extent of the loadings on given components or factors, can be useful in evaluating the variation in data.

Multivariate methodologies, such as factor analysis, do not tolerate missing values for observations. Missing values cause a record to be deleted from consideration in the construction of the correlation matrix used to extract the factors. Thirty two records were chosen for consideration on the basis of having complete data for both fish and invertebrate species composition. The North Canadian River below Oklahoma City was deleted due the extreme values for flow. In all 28 observations were suitable for use in factor analysis.

Several iterations of analysis were conducted using SAS PROC FACTOR procedures. The factor method specified was the principal factor method. The correlation matrix was singular and as a result the estimates of prior communality for each variable were set at the maximum absolute correlation with any other variable (Priors=Max). The input dataset consisted of any combination of variables other than the binary data for fish, invertebrate, and habitat variables. The first three to five factors from each iteration were analyzed for associations among variables. Component loading values >0.50 and <-0.50 were flagged as having potential significance in the variation accounted for by their respective factor.

The rotation procedure, VARIMAX, was utilized in an attempt to simplify the variation among the variables. It works in such a way that each orthogonal factor extracted maximizes the variance of the squared loading of each variable. The goal of rotation is to simplify the structure of each factor and account for those variables which play the largest role in a given factor's variance. Examination of the loadings from rotated factors resulted in the selection of the variables which account for most of the variation in the UAA dataset.

Factor Analysis of UAA Data.

Records from twenty eight sampling stations containing fifty one variables were factor analyzed. Table 18 presents the loadings for those variables with significant correlation within each factor. Factor one (PF1) contained several categories of variables with significant loadings. These consisted of invertebrate community variables, dissolved oxygen, riparian and nonpoint source variables. The percent occurrence of the cluster of pollution tolerant fish (cluster group B) had some loading as well.

Rotation of factor one (PF1R) by the VARIMAX method simplified the associations by reordering the loadings for invertebrate community measurement and most of the riparian and nonpoint source variables into factors two and three respectively. Dissolved oxygen had the highest loading after rotation. The percentage of bankside erosion as evident or unlikely also improved. These two sets of collinear independent variables (some inversely proportional) clustered in factor one to account for the orthogonal group with the highest eigenvalue and proportion of variation.

Factor two (PF2) initally consisted of mixture of variables for fish community structure, Graham's Index and

VARIABLE	PF1	PF1R	PF2	PF2R	PF3	PF3R
	FACTORS					
Dissolved Oxygen	66	84				
Percent Saturation	75	81				
% Erosion Evident	-	73				
Fish Cluster B	55	50				
D.O. Deficit	-73	-80				
% Erosion Unlikely	-50	-77				
Invert. Species Richness	58	-		94	59	
Trent Biotic Index	-	-		91	67	
Chandler's Score	69	-		90	52	
Invertebrate Cluster A	-	-		87		
Invertebrate Cluster B	67	-		70	51	
Graham's Biotic Index	-50	-	50	-81		
% Bankside Sand	61					74
% Substrate Sand	55					68
Temperature						68
Fish Cluster A			66			60
% Bankside Slope Flat						58
% Bankside Shrubs						52
Width to Depth Ratio						50
Substrate Variety					50	-58
Karr Index			74			
Fish Species Richness			78			
% Substrate Large Rocks					51	
% Bankside Trees						
% Forest Area						
% Suburban Land Area						
Velocity						
% Substrate Mud & Sludge			-51			
% Bankside Mud						
% Urban Land Area						
Eigenvalue	7.56	5.57	5.07	5.44	4.38	5.02
Proportion	23.5	17.3	15.8	16.9	13.6	16.0
Cumulative Proportion	-	-	39.3	34.2	52.9	50.2

Table 18. Principal Factor Analysis Loadings for UAA Dataset. Included are the loadings for values <-0.50 or >0.50 for the first five principal factors (PF1-PF5) and the loadings after VARIMAX rotation (PF1R-PF5R). Loadings are multiplied by 100 and rounded to the nearest integer.

VARIABLE	PF4	PF4R	PF5	PF5R
	FACTORS			
Dissolved Oxygen	-56			
Percent Saturation				
% Erosion Evident				
Fish Cluster B				
D.O. Deficit				
% Erosion Unlikely	52			
Invert. Species Richness				
Trent Biotic Index				
Chandler's Score				
Invertebrate Cluster A				
Invertebrate Cluster B				
Graham's Biotic Index				
% Bankside Sand				
% Substrate Sand				
Temperature				
Fish Cluster A		55		
% Bankside Slope Flat				
% Bankside Shrubs				
Width to Depth Ratio				
Substrate Variety				
Karr Index		81		
Fish Species Richness		78		
% Substrate Large Rocks		53		
% Bankside Trees			-73	66
% Forest Area				56
% Suburban Land Area				51
Velocity				-56
% Substrate Mud & Sludge				
% Bankside Mud				
% Urban Land Area			55	
Eigenvalue	3.99	4.42	3.18	3.73
Proportion	12.4	13.8	9.9	11.6
Cumulative Proportion	65.3	64.0	75.1	75.6

Table 18 (cont.). Principal Factor Analysis Loadings for UAA Dataset. Included are the loadings for values <-0.50 or >0.50 for the first five principal factors (PF1-PF5) and the loadings after VARIMAX rotation (PF1R-PF5R). Loadings are multiplied by 100 and rounded to the nearest integer.

the percentage of substrate as mud or sludge. This factor was reassessed by rotation to exclusively include only the invertebrate community structure variables. This factor (PF2R) accounts for about the same amount of variation as factor one (PF1R) but, it consists of a cluster of essentially collinear biological variables.

Factor three (PF3) consisted of several invertebrate variables, percent of substrate as large rock, and the relative number of substrate types (i.e. substrate variety). Rotation of factor three (PF3R) yielded a group of variables consisting of mostly riparian measurements, temperature, the frequency of occurrence for members of fish cluster group A (see Figure 35b), substrate as sand, and width to depth ratio. The loadings for most of these variables was not very high. Therefore the associations should be considered weaker.

The proportion of variation measured by factors four and five are better represented in the rotated factors (PF4R and PF5R). Factor four consisted of fish variables and a weak association with substrate as large rock. Factor five consisted of a group of riparian and nonpoint source variables with a weak negative loading by stream velocity.

These five factors accounted for 75% of the variation of the eigenvalues. Interpretation of the remaining 7 factors having a minimum eigenvalue of 1.0 did not show any meaningful grouping of variables with high loadings. These five factors are dominated by the clustering of collinear dependent variables (i.e. biological data) or independent variables (e.g. D.O. or % erosion). There is essentially little or no grouping of dependent and independent variables in the same factor. The ability to ascertain cause and effect relationship of factors influencing the biotic index scores or fish species richness is not possible without high loadings in the same factor.

The results of this analysis did not extract evidence of any straightforward linear relationship between biological and environmental variables. Instead it points out that most of the measurement of variation was measured in terms of the biological parameters, 31% in PF2R and PF4R combined. Dissolved oxygen, substrate, riparian and nonpoint source variables made up most of the remaining variation distributed among the other three factors. Attempts to plot factors against one another to see if biological and environmental variables clustered together did not improve the essential orthogonal relationships between the biological and environmental measurements. The importance of improving the ability to correlate environmental measurements with biological data in future UAA studies is discussed in the following chapter.

CHAPTER IV

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction.

The main focus of this research has been to develop data management techniques which assess the present status of aquatic use attainment in Oklahoma. The database used included information from 16 streams distributed across the State. The information analyzed represented the only existing data collected for the specific purpose of evaluating the attainment status during low flow, high stress periods. The conclusions drawn are representative of conditions existing in these streams. Extrapolation of the information gained from this study to the State at large should only be done for those environments having similar impacts and attributes.

On November 8, 1983, the EPA issued the revised regulations on water quality standards in 40 CFR Part 131. This regulation issues the guidelines for the process by which States may propose to change existing beneficial uses. The rule specifically states that, "EPA is requiring that

States conduct and submit to EPA a use attainability analysis if the State

(a) is designating uses for the water body such that the water body will not have all the uses which are included in Section 101(a)(2) of the Act,

(b) maintaining uses for the water body which do not include all of the uses in Section 101(a)(2) of the Act,

(c) removing a use included in Section 101(a)(2) of the Act,

(d) modifying a use included in Section 101(a)(2) of the Act to require less stringent criteria".

This document goes on to require that in each triennial review process, States review the basis for not including uses for a specific waterbody. States need not repeat UAA but they must demonstrate that circumstances have not changed. That is to say, "protection and propagation of fish, shellfish, and wildlife and/or recreation in and on the water remain unattainable".

EPA issued the final version of the Water Quality Standards Handbook (36) in December of 1983. A supplemental publication entitled Technical Support Manual: Water Body Surveys and Assessments for Conducting Use Attainability Analysis (37), was released in November of 1983. These publications only became available to this author in late

February 1984. As a result they have not been fully utilized in this research. The following sections reference these publications when they help provide recommendations which might enhance future UAA programs in Oklahoma.

The secondary warm water fishery designation represents a modification of the fish and wildlife propagation criteria which were present in the 1979 Oklahoma Standards. The supportive documentation for these changes must include some identification of the characteristics which differentiate secondary from primary warm water fisheries. This research has attempted to characterize the relative degree of aquatic attainment through an analysis of Oklahoma's first set of UAA data.

The objective of this research was to develop assessment and data management techniques which summarize the environmental and biological attributes of a set of streams considered as candidates for redesignation. The results of the analysis provide the first set of reference attributes for such candidate streams. The decision for redesignation remains the administrative task of the State (subject to EPA approval). Recognition of the existing conditions is an essential part of the supportive documentation from which the proposal for redesignation are developed. The final phase of the redesignation process couples information on social and economic impacts with information revealed in UAA. Tables 19 summarizes the major conclusions which are discussed in more detail in the following sections. I hope that the evaluations provided in this research will give guidance to future UAA programs in Oklahoma.

Hydrologic Variables.

The hydrologic evaluation represented an attempt to characterize the role which factors such as flow and width to depth ratio play in the pollution ecology of these Oklahoma streams. The skewness of database to the left indicates that most of the data reflects conditions of flow less then 5.0 cfs. In fact, based upon the mode, the most frequently encountered conditions clustered in the 1.0 cfs range. This flow regime was not restricted to upstream areas. Several streams showed a loss of flow at downstream sampling stations. The low flow and low velocity conditions might account for the dominance of pool type habitats and depositional substrates. These conditions are reflected in the composition of fish and invertebrate species found as common members of these streams.

Water Quality Variables.

The parameters used to assess water quality focused on D.O. as a major determining factor affecting the degree of

MAJOR CONCLUSIONS

1. The dominance of low flow, low velocity and low gradient stream conditions influenced the habitat variety available to fish and benthic organisms.

2. D.O. levels ranged from between highly saturated to poorly oxygenated levels. This represented one of the most significant limiting environmental factors affecting the achievement of more desirable levels of use attainment in these Oklahoma streams.

3. The study streams were dominated by pool type habitats and depositional substrates, factors which were reflected in the species composition common to these streams.

4. Poorly protected bankside conditions may have affected the level of use attainment as a result of erosion and sedimentation which restricts the quality of benthic habitat by siltation.

5. Substrate categories were dominated by sand, silt and mud. The lack of more stable substrates, such as gravel and rock, restrict the variety of aquatic life to those adapted to less stable depositional habitats.

6. Fish cover was predominatly composed of pool type habitats. The resulting fish species composition was comprised of varieties which prosper best under such conditions.

7. The application of biotic indices provided a rapid qualitative means of differentiating the quality of the streams as reflected in the species composition. These methodologies can serve the State in documenting and redocumenting the level of use attainment assesed by UAA.

8. Cluster analysis of fish and aquatic invertebrate species provided a characterization of the assortment of assemblages of common and rare species which exemplify the degree of use attainment among these redesignation candidates. The coupling of biotic indices with cluster analysis produces results which can support proposals for redesignation.

9. Most of the methods use in this UAA program, while adequate in the description of the existing conditions, were not appropriate in their present form to correlate cause and affect relationships which differentiate primary from secondary warm water fisheries.

Table 19. Summary of Major Conclusions.

aquatic use attainment. The issue of what the appropriate criteria for D.O. should be was not the intent of this research. The levels of D.O. which can be attained are better addressed through a technical evaluation of treatment requirements in the overall wasteload allocation process. This study focused upon the role that D.O. levels play in the present degree of attainment of fish and wildlife beneficial uses.

D.O. levels fluctuate widely in Oklahoma streams. These ranges in D.O. create a spectrum of categories of D.O. deficit. One might expect, that in any given stream, regions of either highly saturated or poorly saturated waters could be occurring. The cause of supersaturated D.O. levels were not evaluated by this program. Future studies should attempt to account for the impacts of such areas. This condition represents an abnormality due to excessive oxygenation by algal photosynthesis. This source of oxygen is not a reliable asset. Algal respiration during the night time hours can significantly reduce the level of D.O. available to fish and other aquatic organisms. Future studies should plan to collect data on primary production rates and algal respiration via light and dark bottle testing.

Deoxygenation caused by the discharge of organic wastes represents a more overt source of perturbation. The impact zone stations were depicted in Figure 8 to have a mean D.O. concentration of 3.6 mg./l. when the D.O. deficit was in excess of 3.0 mg./l. This level of D.O. is just above the 3.0 mg./l. criteria established for secondary warm water fisheries.

The 1982 Standards removed the 1.0 mg./l. D.O. excursion due to natural diurnal fluctuations. The levels of D.O. deficit determined in this study serve to indicate that diurnal fluctuations may also represent a problem for use attainment. Furture studies should collect data on nocturnal D.O. levels as well as 24 hour D.O. profiles in upstream, impact, recovery and reference area sites. The necessity to reinstate this excursion in future revisions should be based on the evaluation of such data.

Temperature plays a role as a factor influencing D.O. saturation levels. None of the streams had temperatures in excess of the critical temperature of 90o F. set by the 1982 State standards. Other studies in Oklahoma (2) have demonstrated that daily maximum temperatures can exceed this criteria and as a result the affect of temperature on use attainment can not be ruled out.

Conductivity seems to be more a function of the drainage system within which a given stream is located. It may represent a problem in use attainment on a site specific basis. The pH remained within acceptable ranges established in the State standards.

Point Source Variables.

The value of relating conclusions obtained by analysis of the point source database was hampered by the fact that it represented a separate data collection effort. As mentioned previously, this information was considered to be qualitative. Future studies should attempt to incorporate effluent and receiving stream monitoring into the UAA sampling framework. Multivariate techniques such as factor analysis could then be utilized to identify sets of factors containing information on the relationship of effluent quality and instream biological variables. If such techniques are employed in future analysis, care should be taken to eliminate data points which represent outliers. The North Canadian River below Oklahoma City represented values for stream flow, effluent flow and wasteloading far beyond the values obtained from other sampling stations. This condition resulted in the exclusion of the NCR-OKC data from data analysis methods such as principal factor analysis.

Most of the streams sampled in this program had estimated wasteloads in the range of 500 lbs./day of carbonaceous B.O.D. Examination of compliance monitoring data shows that there was a considerable range in the concentrations of nitrogenous wastes. Future studies may want to collect data on the impacts of nitrogenous waste both from the stand point of their role in oxygen depletion and eutrophication.

The problem of insufficient dilution flow has been the focus of major concern in Oklahoma. This problem was addressed by OWRB in the State 208 Work Task 141 (83). More than half the streams in this study had less than a 2:1 relationship of stream dilution capacity. This condition places more of the burden of treatment on the physical plant processes of the individual treatment facility. The fact that this condition is usually seasonal does not change the requirement to meet D.O. criteria during low flow periods. Oklahoma has attempted to gain recognition of this factor in previous State standards (1968 and 1976). The degree to which this lack of dilution capacity influenced the level of aquatic attainment assessed in this study is not clear. Three of the stations (CHC-2, SKC-2 and STW-2), with Karr Index scores classified as poor, had dilution ratios <2.0. Evaluating the role which insufficient dilution capacity has on the attainment of aquatic uses in Oklahoma should be approached in more detail in future studies.

Riparian and Potential Nonpoint Source Variables.

Analysis of the information on riparian characteristics yielded descriptions of various levels of bankside protective categories. Most of the stations with numerous categories rated as fair or poor, had acceptable scores for both fish and invertebrate indices. Chisholm Creek (CHC-2)had both poor ratings for most of the bankside protective categories and poor ratings for the Chandler Score and the Karr Index.

These bankside protective categories are useful in describing the relative degree of bankside protection. The ability to scale the relative impact from poorly protective bankside characteristics was not addressed in this research. Attempts to correlate these variations in factor analysis identified several of the these variables as accounting for significant variation in the overall set of UAA measurements. Future studies should concentrate on producing a more quantitative scale of measurement for categories such as bankside erosion. The test of the appropriate measure could then be assessed by demonstrating relationships with biological variables via factor analysis or canonical correlation.

In general, most locations sampled were rural, suburban, and agricultural areas. Most of the urbanized areas clustered near the treatment plants. Bankside vegetation was mostly moderate to dense cover. Protective categories for bankside erosion and protective vegetation showed considerable variation.

Substrate Variables.

The most frequently occurring types of substrate encountered in this research included sand, silt and detritus. Sand dominates the proportion of substrate density. The high frequency of depositional substrates accounts for about half the density and one third the frequency of the substrate variety available in these streams. UPGMA cluster analysis showed grouping of stations on the basis of substrate similiarly. The commonality of substrates such as sand, silt, detritus and mud or sludge versus the categories of gravel, rock and clay may be responsible for the occurrence of specific species of fish and invertebrates.

The EPA technical manual on UAA (37) discusses many of the relationships of substrate composition and the occurrence of aquatic organisms. Invertebrates are affected by the composition of the streambed. Sand is considered to be the poorest habitat. Gravel, bedrock, and clay represent better substrates which support a larger biomass. One factor not accounted for in this program is siltation. The temporary or periodic covering of benthic habitat by silt and sand can reduce or eliminate colonies of benthic organisms. The dominance of the silt and sand substrates serves to indicate that siltation probably is a factor influencing the species richness of the benthic community. Future studies may want to develop measurements of the siltation impact for correlation with biological variables.

Substrate conditions can have similar adverse impacts on the fish community. In general, fish are less confined to the dependance on a specific type of substrate (37). Certain species (e.g. Stonerollers) utilize gravel areas of riffle habitats to develop nests and lay eggs. Streams dominated by sandy bottom pools complement the nest building habits of species like the Bluegill Sunfish and the Largemouth Bass. The dominance of the sunfish varieties in these streams may be in part accounted for by the abundance of pool habitats containing large amounts of soft sand and silt.

Habitat Variables.

EPA presents a discussion on the significance of habitat variation on the aquatic community in the previously referenced technical support manual for conducting UAA. Analysis of the habitat categories by cluster analysis showed a dominance of pool type habitats. Associated within the cluster containing pools are brushpiles and undercut banks. Pools provide a resting area for fish from the pressure of predation. The addition of undercut banks and brushpiles helps to diversify the components of the pool environment and perhaps the resulting variety of fish species as well.

The distribution of habitat frequencies shows that a lack of balance exists between pool type habitats and the faster flowing riffle areas. Pools outnumber riffle habitats by a factor of more than two to one. This is a discrete ratio. It indicates that there is a significantly high probability of encountering a stream with large reaches which are devoid of riffle habitats. This program did not assess the intraspecific diversity of habitat frequencies at each sampling location (i.e. # of pools vs. # of riffles). Future studies may want to expand this measurement to include accounting for the variation in the number of habitat types present within a given reach of stream.

Fish Community Structure.

Characterization of the fish community structure for the streams sampled as part of this study was accomplished through cluster analysis. The use of the Karr Index also assisted in the evaluation of the fish community by scaling the fishery content on the basis of nine attributes. EPA published a national list of intolerant fish species, omnivore fish species, and top carnivore fish species in the technical support manual for conducting UAA (37). Future attempts to scale the fishery in UAA using the Karr Index should expand upon the set of attributes used in this study. Inclusion of the proportion of omnivores and intolerant fish species should be based upon a similar list of State species for each category. This could be accomplished by the creation of a bioligical working group. Their task would be to create the list of species and categories of attributes use in future indices.

The cluster analysis of fish represented in Figure 26 was developed through UPGMA cluster analysis of Jaccard Coefficients. This group of 24 fish species contains the group of most commonly associated fish species as determined by the 1982 UAA sampling program. Three species are top carnivores, seven are members of the national list of omnivores, ten are potentially fishable varieties and one is a member of the national list of intolerant fish species.

The cluster presented in Figure 26 can serve as the reference group of fish species which characterized the degree of use attainment on the basis of cluster analysis. The remaining clusters identified in Figure 26 represent groups of species whose occurrence at a given location may be a function of range limitation. Inclusion of members such as the Percidae and some of the Cyprinidae as members of this group in a separate reference community for eastern Oklahoma should be considered. Evaluating the reference community for use attainment via cluster analysis should be performed on an ongoing basis during each triennial review. Expanding the UAA database to include more streams might well produce a cluster which exchanges or adds different species to the reference community. The major emphasis of this research was to illustrate the capabilities of techniques like cluster analysis in meeting the complex data management needs inherent to UAA. The production of this group seems to illustrate this utility quite well.

The coupling of R-mode UPGMA cluster analysis with indices such as the Karr Index can help support recommendations for redesignation by associating station with similar fishery contents and or Karr Index scores. The high loading obtained by the Karr Index in factor analysis indicates it is a good choice for measuring sample variation. This value is significantly enhanced by the assignment of the quality index classifications associated with this index.

The combined cluster analysis of fish, invertebrate, habitat and substrate variables presented in Figure 35b contains 80% of the species referenced in the previous paragraph. This cluster presents these fish species in association with the commonly occurring varieties of invertebrates, habitats and substrates. The dominance of pool type habitats and depositional substrates are placed within a cluster associating specific varieties of fish and invertebrate taxa.

Invertebrate Community Structure.

Assessment of the characteristics of the invertebrate community structure consisted of the application of cluster analysis and the use of biotic indices. Invertebrates were discussed in Chapter Two as having been recognized by many researchers as having better suitability for assessment of water quality than the use of fish. The question of whether to use invertebrate or fish indices to rank the quality of the biological attributes has to be addressed by the agency making the final recommendation on the choice for redesignation. A comparison of those streams ranked as poor by the Karr Index with those ranked as poor by the Chandler Score showed agreement for 9 out of the 21 stations ranked poor by both indices. In addition, two of the stations received opposite scores for fish and invertebrate indices.

Cluster analysis of the invertebrate taxa grouped the organisms on the basis of UPGMA clustering of Jaccard

Coefficients. Figure 29 presented the cluster of the most commmonly associated groups of invertebrate taxa. Most of these organisms are also present in the combined classification presented in Figure 35b. The display of the R-mode cluster analysis of the invertebrates yielded a lower cophenetic correlation coefficient than that calculated for the fish dendrogram. Nonetheless, coupling the Biotic Index and Chandler Score values with the associations illustrated by cluster analysis can provide additional supportive documentation for proposing redesignation.

The Secondary Warm Water Fishery.

The goal of UAA is to identify the prevailing conditions present in streams considered by States to be candidates for modification of benefical uses. The secondary warm water fishery designation introduced in the 1982 revisions of the Oklahoma Water Quality Standards represents a modification of the fish and wildlife benefical use criteria applied in previous standards. The ability of the State to support these redesignations with sound technical scientific data is referred to as supportive documentation. The methods employed in this research are meant to serve as helpful stepping stones which can assist the state in compiling supportive documentation during future UAA studies.

EPA defines the current level of aquatic use attainment as "the resident biota". "The prevailing chemical and physical attributes will determine what biota will be present, but little need be known of these attributes to describe current uses" (37). This attitude, reflected in the above quotation taken from EPA's UAA methods manual, directs the emphasis of UAA to serving only a descriptive role. This research fulfilled that goal. The ability to answer the question of what "secondary" warm water fisheries are and what factors differentiate them from "primary" warm water fisheries does not seem to fall within the present range of assessment techniques applied in UAA. This conclusion is reinforced in this research by the inability to associate environmental and biological variables in factor analysis. Future UAA which seek to differentiate secondary and primary warm water fisheries should enhance the quality of environmental measurement. Coupling UAA with wasteload allocation monitoring could help provide the necessary data to correlate cause and effect based on water quality and water quality modeling data.

Oklahoma's UAA study was conducted in a focused manner. It was designed to assess the current biological health of 16 rather polluted streams. The clusters of fish and invertebrates discussed in Chapter Three depict the associations of biota which commonly occurred in these streams. Determining the desirable species which a given D.O. criteria are to protect is the first step in the process which may warrant one stream's biota more protection than another. Methods such as cluster analysis, and Biotic Indices can serve the needs of the State in determining which streams to redesignate and which streams require maintainence of existing standards.

If secondary warm water fisheries exist in Oklahoma then the clusters of common fish and insects (Figures 26 and 29) discussed in Chapter Three provide some reference of the makeup of these communities. The decision to eventually redesignate one stream still remains an administrative responsibility which blends the scientific data from UAA with other factors such as economic impacts. The question of what biota are being afforded protection can now be answered and the justification or lack of justification for redesignation can therefore be based on this scientific documentation. As a result the question of what a "secondary" warm water fishery is remains unanswered by UAA. It is left up to the public forum of the standards setting process to decide such a designation. Now at least, this can be accomplished with a full disclosure of the existing attributes of those streams chosen as candidates for redesignation.

Recommendations For The Future.

The future of UAA for Oklahoma undoubtedly will require refinements which extend the detail of analysis to answer the questions posed during each Standards' revision. This research, while answering many of the questions regarding how to analyze and present the data collected through the application of UAA, raises thoughts in the mind of this researcher which are presented in the form of recommendations for use in future UAA studies and Oklahoma Standards' revisions. These are summarized in Table 20.

The major thrust of these recommendations are the elimination of the terms "primary" and "secondary" warm water fisheries and the formation of an academic advisory group referred to as a biological working party. Replacement of the present terminology by categories of warm water fisheries follows trends set by states such as Wisconsin which are outlined in EPA's Water Quality Standards Handbook (36). These categories allow the State to set D.O. criteria at various levels based on the assemblage of aquatic organisms inhabiting the stream and their relative tolerance or sensitivity to pollution. The biological working party, when first convened by the State, would develop the supportive documentation on the lists of biota which characterize each category or are used in a specific index to scale the quality of the fish, invertebrate or algal species composition.

The continued use of the terms "secondary" and "primary" as fish and wildlife beneficial uses in Oklahoma will require the State to better define these terms in respect to their individual biological attributes. This researcher does not believe that a "secondary" (second rate) community exists in Oklahoma. Rather, and as I believe this research points out, levels of biological integrity persist in the environment based on the degree of pollution tolerance which an assemblage of species inherently possesses. These attributes, reflected in the species composition, are better segregated by recognition of classes which are subdivisions of one ecological definition, that of the warm water fishery. If not then Oklahoma truly is the birthplace of a new and undoubtedly distinct environmental category.

MAJOR RECOMMENDATIONS

1. The terms "primary" and "secondary" warm water fisheries should be eliminated. Determination of D.O. criteria for streams which contain assemblages of more pollution tolerant aquatic organisms should be done as part of the overall site specific standards designation process.
2. Warm water fishery designations should be subdivided on the basis of the biological attributes of the assemblage of aquatic organisms inhabiting the stream proposed for redesignation.
3. UAA should serve as a rapid qualitative assessment technique designed to identify those streams (out of the list of redesignation candidates) which are presently not supporting the most desirable level of use attainment. These streams then enter the protocal for proposing site specific standards with the designation of appropriate quality criteria.
4. Categories or classes of warm water fisheries should be developed which stagger the D.O. criteria set through the site specific standards process.

Table 20. Major Recommendations for Conducting UAA Studies and Revisions in Fish and Wildlife Beneficial Uses.

MAJOR RECOMMENDATIONS

Proposed warm water fishery classes:

Class A- Warm water fishery capable of supporting a diverse assemblage of intolerant species of fish and macrobenthos and desirable sport fish. D.O. criteria at or above 5.0 mg./l.

Class B- Warm water fishery capable of supporting a limited number of intolerant fish and macrobenthos. Some desirable sport fish present. D.O. criteria set through site specific standards designation process and ranging between 5.0 and 3.0 mg./l.

Class C- Warm water fishery dominated by tolerant fish and macrobenthos. Desirable sport fish are rarely present. D.O. criteria set by site specific standards process at or below 3.0 mg./l.

In the latter two classes, the State will develop plans to improve the level of use attainment, where economically feasible, as part of its continuing planning process for water quality management.

5. Future UAA studies should develop a biological database on the species composition of reference streams.

6. The State should contract with the academic community in the State to organize a biological working party. This group, working with agency biologists, would have the responsibility of developing the list of representative biota which exemplify the level of use attainment typically found in the three warm water fishery classes. This group would also have the responsibility to formalize lists of taxa for use in scaling the quality of the streams by application of biological indices (e.g. Karr Index, and Chandler Score).

Table 20 (cont.). Major Recommendations for Conducting UAA Studies and Revisions in Fish and Wildlife Beneficial Uses.

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APPENDIX A

"ONE DAY SITE SPECIFIC SURVEY" (8).

ONE DAY SITE SPECIFIC SURVEY

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SECTION 1

INTRODUCTION

The purpose of doing one day site specific surveys is to assign beneficial uses to streams for a relatively low cost. It is not economically feasible to do surveys of all streams in a state using expensive intensive stream surveys.

All states have assigned beneficial uses in the past, sometimes based on insufficient data. In order to assign realistic and relevant beneficial uses to a state's streams, sufficient data must be obtained. Stream data are difficult, time consuming and expensive to acquire. Therefore, it is cost effective to use different levels of data acquisition depending on the difficulty in assigning beneficial uses.

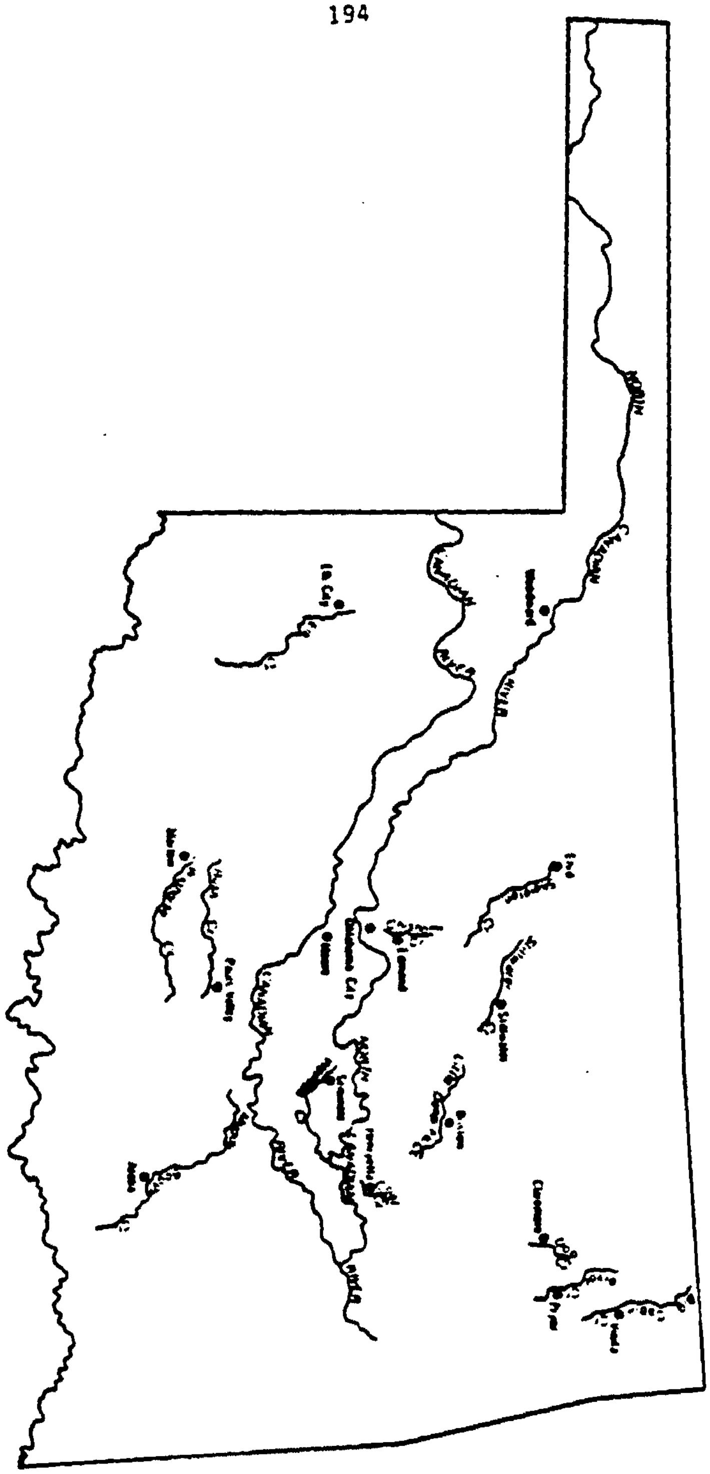
First, a literature survey must be performed on all streams. This survey should review all available data to determine the suitability of beneficial uses assigned in the standards. A basis for determining the suitability of beneficial uses is described in the Oklahoma Water Resouces Board (OWRB) Task 141. In a majority of cases, the recommendation from this previous process will be either no changes in the assigned beneficial uses or changes which tend to make the Water Quality Standards more stringent. In these cases the recommendations are submitted to the Standards revision process without further review. However, in some cases, changes in beneficial uses which tend to make the Standards less stringent will be recommended. When this occurs the one day site specific survey must be performed. It will be shown that in a majority of cases beneficial uses can be submitted to the standards revision process using this technique. However the one day survey is not adequate for some streams, and for these a complete survey as recommended in the EPA guidelines must be used to make adequate beneficial uses recommendations.

During the recently completed Oklahoma Water Quality Standards revision process, a literature survey was performed for more than half the state streams. Sixteen streams were identified for changes in the beneficial uses which could result in less stringent standards.

All these streams were impacted by pollution from municipalities (Figure 1). Site specific surveys were completed along these streams during September and October, 1982, to establish the existing physical, chemical and biological conditions in these streams. The results of these surveys were used to decide what uses were attainable with technology based control (TBC) for point source pollution and best management practices (BMP) for nonpoint source pollution (FR 210:49234-49240, October 29, 1982).

The site specific surveys addressed three kinds of beneficial uses: 1) primary or secondary warm water fisheries; 2) primary or secondary body contact recreation; and 3) public and private water supply (Appendix A). It was the objective of the surveys to collect adequate local information to assign realistic uses with minimal expenditures of time and resources. The methodology of the surveys reflected this objective.

Figure 1. Locations of the streams surveyed during the one day site specific surveys and the associated municipalities.



The surveys were one day qualitative assessments of the biological health, water quality, and physical habitats of the streams (Table 1). The pollution impacts of the municipalities were assessed by sampling a site in the control zone (upstream from the municipality), impact zone (below the municipal treatment works), and recovery zone (some distance downstream where the biota had recovered to the condition equivalent to that of the control zone). A basic assumption of the study is that each site reflected the conditions of the stream in that zone.

SECTION 2

SURVEY TEAM PERSONNEL

Surveys were completed by field teams consisting of either three or five individuals. The team consisting of five individuals included: 1) a team leader who coordinated field trips, maintained a work schedule, selected sampling sites, and also collected fish; 2) a biologist who collected fish and field identified the fish species; 3) a biologist who collected benthos and field identified benthos taxa, usually to the level of genera; 4) a hydrologist who made Hydrolab® and hydrological measurements; 5) and a biologist who assisted in benthos collections. The three man team consisted of: 1) a team leader who also collected fish; 2) a hydrologist who also collected fish; and 3) a biologist who collected benthos. Biological collections made by the three man team were identified in the laboratory.

Table 1. Components of the one day site specific surveys.

PUBLIC AND PRIVATE WATER SUPPLY	PRIMARY BODY CONTACT RECREATION
Presence of:	Ease of access
Upstream discharge	Adequate depth
Downstream reservoir	Acceptable substrate
Perennial flow	Signs of human use
High conductivity values	

PRIMARY/SECONDARY FISHERIES
Descriptions of:
Composition of stream substrate
Fish habitat
Benthos habitat
Potential fish species
Potential benthos taxa
Fish collections and identifications
Benthos collections and identification
Hydrolab measurements (temperature, pH, DO, conductivity)
Hydrological measurements (width, average depth, average velocity, flow)
Bank stability
Distribution and types of bank cover
Land use

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SECTION 3

FIELD METHODOLOGIES

Site Selection

Tentative sites were chosen from topographic maps before entering the field. Sites were chosen on the basis of probable access points. Usually, two or more of the tentative sites were visited in each zone. Sites were considered for their capacity to represent conditions in that zone and for their physical similarity to sites in other zones, e.g., substrate, flow, and availability of fish and benthic habitat.

In general, the selection of sites was constrained by the availability of access and the one day study period of the surveys. It was difficult to sample representative sites along a stream.

A stream section was not sampled if: 1) it was an intermittent stream and there was no flow in that section; 2) the water was septic and unhealthy to sample; 3) the stream was too wide or deep to be effectively sampled by the site survey methodology; and 4) the stream emptied into a larger one before a recovery zone developed.

Primary Body Contact Recreation/Public and Private Water Supply Suitability

Primary body contact recreation and public and private water supply suitability were determined by filling out check sheets at each site

(Appendix B, Example 1). The major determinants of primary body contact recreation were ease of access, suitable depth and substrate for swimming, and evident conditions affecting human health. The primary factors for public and private water supply were unhealthy discharges into the stream and perennial flow.

Primary/Secondary Warm Water Fisheries

Site specific surveys for fish and wildlife propagation were conducted to provide sufficient data to designate primary and secondary warm water fisheries. This is a difficult task, but an extremely important one. The dissolved oxygen standard for the receiving stream is determined by the type of warm water fishery designated. This in turn determines the type of publicly owned treatment works (POTW) required to protect the assigned beneficial use.

First, it must be determined if a depressed fishery exists in a specified stream reach. If this is the case, then the cause of the depressed condition must be assessed. If the cause is determined to be natural (e.g., habitat related) then the reach is automatically designated a secondary warm water fishery. If the fishery degradation is due to man's activities, it must be decided if it is feasible to reduce pollution to a level where the primary designation would apply. Since levels of treatment beyond secondary are not generally feasible in Oklahoma at this time, the simple modeling accomplished in 208 Task 141 is sufficient to determine the dilution flow required to protect a primary fishery with good secondary treatment. Therefore, when the dilution flow is less than the values obtained using the Task 141 methodology and local conditions do not mitigate the effects of secondary POTW effluent, then it is not feasible to obtain a primary fishery unless the local population insists on paying for advanced waste treatment. The factors which must be analyzed to determine a primary/secondary warm water fishery are listed below.

Bank Characteristics and Land Use

At each site stream banks were characterized by descriptions of vegetative cover and assessments of bank stability (Appendix B, Example 2). The evaluations were used to determine the likelihood of erosion. Land use in the immediate area was also recorded to suggest possible sources of pollution to the stream.

Water Characteristics

The temperature, pH, conductivity, and dissolved oxygen (DO) of the water were recorded at each site (Appendix B, Example 2). These measurements were taken as vertical profiles where depth permitted. Dissolved oxygen measurements were the best indicators of water quality. Very low levels of saturation or high levels of supersaturation were considered indicators of organic and nutrient loading.

Hydrological measurements were made by the methods described by Lind (1979). Adequate flow was the most important hydrological characteristic. Streams with intermittent flow presented a physical limitation to the biological health of the stream.

Evaluations of Potential Fish and Benthic Taxa

The potential fish and benthic invertebrates that might inhabit each site were listed (Appendix B, Examples 3 and 5). The habitat that would support each taxa was also listed. For example, the channel catfish (*Ictalurus punctatus*) might be listed as a potential species found beneath an undercut bank.

Potential species evaluations were made after the collections had been completed. It was then that the field crews knew what habitats were available to the organisms. Bias because of collections was minimized by choosing potential taxa based solely on the quality and availability of habitat.

Fish Collections

Fish were collected and preserved or analyzed in the field by methods similar to those described by EPA, 1973. Generally, two workers collected fish with 0.18 inch mesh x 6 feet deep x 10 or 20 feet long seines for 0.5 hour or one man-hour. This method gave good qualitative estimates of species richness and relative abundance in smaller streams. In streams more than 3-4 feet deep and 30-40 feet wide the fish were able to avoid the seine.

The results of the collections were recorded as: 1) an overall description of fish habitat; 2) the substrate composition; 3) species collected; 4) their relative abundance (rare, occasional, common, abundant); and 5) the specific habitats in which the fish were collected (Appendix B, Examples 3 and 4).

Benthos Collections

Benthos were also collected and preserved or analyzed in the field by methods similar to those described by EPA, 1973. Benthos were usually collected with dip nets by two workers for 0.5 hours or one man-hour. In some of the smaller streams 0.5 man-hours were expended to collect the qualitative samples. Organisms were collected from woody detritus and large rocks by picking them directly from the substrates.

Odonates, ephemeropterans, trichopterans, amphipods, coleopterans, gastropods, pelecypods and dipterans other than chironomids were identified as genera and, sometimes, species. Chironomids were identified to the subfamily level. The results of the benthos collections were recorded in the same manner as those for the fish collections (Appendix B, Examples 5 and 6).

SECTION 4

EVALUATIONS OF USE ATTAINABILITY

The attainability of public and private water supply and primary body contact recreation was decided by OWRB staff members. The field evaluations for these uses were compiled and considered in the context of local economic and social factors. These factors were primarily those issues brought out at public meetings related to the water quality standards process and through letters to the OWRB.

The designations of primary fishery and secondary fishery were controversial choices. These uses were very important to citizens of the affected communities, municipal governments and environmental groups. Choices of primary fishery or secondary fishery were also the most technically difficult choices because they required an understanding of the biological health of the streams.

Methods of Evaluations for Primary and Secondary Warm Water Fisheries

It was necessary to interpret the results of the site specific surveys within a framework which allowed decisions about use attainability. This criteria was met by evaluating similar sites as pair-wise comparisons. Thirty-four sites on the 16 streams were grouped on the basis of water velocity and the type of substrate; fast/rocky, moderate/sandy, moderate/clay, and sluggish/clay (Table 2). The groupings are narrative and only approximate the existing conditions at one point in time; their purpose was to divide the sites into manageable groups for the pair-wise technique.

Within each group, each site was compared with all others by consideration of four parameters: 1) water chemistry; 2) physical

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Table 2. Classifications of sampling sites by substrate and flow.

Moderate/Clay		Moderate/Sandy
Skeleton (D)	I	North Canadian, OKC (U)
Dog (D)		North Canadian, OKC (I)
Pryor (D)		North Canadian, OKC (D)
Elk (I)		North Canadian, WD (U)
Elk (D)		North Canadian, WD (I)
Big Cabin (D)		North Canadian, WD (D)
		Chisholm (I)
Sluggish/Clay		Chisholm (D)
		Rush (U)
Stillwater (U)		Rush (I)
Little Deep Fork (U)		
Muddy Boggy (U)	II	Wewoka (D)
Pryor (I)		Skeleton (U)
		South Canadian (D)
Fast/Rocky		Little Deep Fork (I)
		Little Deep Fork (D)
Skeleton (I)		Stillwater (I)
Dog (U)		
Pryor (U)		
Coal (U)		
Coal (D)		
Wildhorse (U)		
Chisholm (U)		
Muddy Boggy (I)		
Muddy Boggy (D)		
Big Cabin (U)		

U = Upstream WD = Woodward
D = Downstream OKC = Oklahoma City
I = Impact

habitat; 3) fish species richness, composition and relative abundance; and 4) benthic taxa richness, composition and relative abundance.

As a parameter was compared between two sites, a value of "1" was given to the better site, "0" to the worse site and, "½" to each site if they were considered comparable for that parameter (Appendix C, Example 1, Part I). For instance, in Example 1, the evaluator considered the downstream site (site A) on Skeleton Creek to be comparable to the downstream site on Dog Creek (site B) for water chemistry. Each site received "½" in that comparison.

The organization of the matrices used for pair-wise comparisons is also shown in Example 1 (Part II). For example, sites A and C are compared in rows A and C, column 2 (cells A_2 and C_2). Sites A and D are compared in cells A_3 and D_3. Sites A and E are compared in cells A_4 and E_4. Sites A and F are compared in cells A_5 and F_5. Each new set of comparisons begin to the right of the shaded cells. As final examples, sites D and E are compared in cells D_7 and E_7; sites D and F are compared in cells D_8 and F_8.

The pair-wise comparisons were completed by OWRB members of the field team and by an outside committee of experts in water quality from academia and government. The outside committee provided peer review for the methods of data collection and interpretation. Most importantly, the committee provided a set of comparative judgements about the existing and potential biological health of the sites so that fair assessments of use attainability could be developed.

Effective presentation of the results was the key to accurate judgements by the outside committee. Slides provided the best information about the physical habitat. Dissolved oxygen was presented as concentration (mg/L) and as percent saturation. Benthos collections were presented in terms of the richness and relative abundance of tolerant, facultative, and intolerant genera. Lists of potential benthos were not presented because the potential benthos were only indentified to the level of family during surveys completed by the three man team. The potential species and the richness and relative abundance of the collections were presented for fish.

Members of the field team completed the pair-wise comparisons by the same methodology as the outside committee. However, the field team discussed the sites based on personal recall. Pair-wise comparisons were still made as individuals. Diverging opinions are apparent in the final rankings.

Site Rankings and Statistical Analyses of Ranks

The results of the pair-wise comparisons were analyzed by a non-parametric two-way analysis of variance (ANOVA)(Wilcoxon and Wilcoxon, 1964). The sites in each group were ranked for each parameter based on the total numerical scores for each site (Appendix C, Example 1). The site with the lowest total was given a rank of "1". Ties in scores were given the average of two consecutive ranks. For example, if the ranks were "3" and "4" each site would be given the rank 3.5. The highest total was given the highest rank. The ranks of all evaluators for a parameter for a site were added as a subtotal for the parameter, e.g., Benthos (Appendix C, Example 2). The four parameter subtotals were added as the total numerical rank for the site.

Differences in site ranks were calculated for all possible combinations of sites (Appendix C, Example 3). Differences among ranks at the 95 percent confidence level were considered significant. When two ranks were significantly different, the higher rank was interpreted as indicating a PF; the lower rank indicated a SF. For instance, in Example 3 the difference between sites A and B was 29.5. This difference was greater than the significant difference of 26. The total rank for site A was 33 and the total rank for site b was 63.5, indicating that the stream reach around site A was a SF and stream reach around site B was a PF. Sites which were not significantly different could not be assigned a fishery status by this statistical analysis. These sites were assigned a use by further discussion among members of the field team or designated for further study.

The comparative results of the evaluations by the field team and the outside committee are shown in Table 3. The two groups gave the sites the same rank in 25 of 36 instances (69% agreement). Since the process was developmental, this is an acceptable amount of agreement. Eleven of 36 (31%) of the evaluations made by the field team were statisticly indeterminate. Seventeen of 36 (47%) of the outside committee evaluations resulted in indeterminate designations.

Table 3. Comparisons of use designations based on sites rankings by the field team and the outside committee.

STREAM	SITES					
	UP		IMPACT		DOWN	
	T	C	T	C	T	C
Big Cabin	P	P	NS	NS	P	P
Coal	P		NS	NS	P	P
Chisholm	P	I	S	I	P	I
Stillwater			S	S	NS	NS
Pryor	I	S	I	P	NS	NS
Little Deep Fork	P	P	P	P	P	P
Dog	S	S	NS	NS	P	P
Skeleton	I	I	S	S	S	S
Wildhorse	S	S	NS	NS	NS	NS
Muddy Boggy	P	P	P	P	P	P
Wewoka	NS	NS	NS	NS	S	I
Elk	I	I	I	I	S	S
S. Canadian	NS	NS	NS	NS	I	I
N. Canadian (OKC)	I	I	S	I	S	I
N. Canadian (Woodward)	I	I	I	I	I	I
Rush	P	I	I	I	NS	NS

P = Primary
S = Secondary
I = Indeterminate
NS = Not sampled
T = Team
C = Committee

The larger number of indeterminate designations by the outside committee is not surprising. A visit to the site was of primary value in evaluating a site. If the field data was not presented clearly, the judgements by the outside committees were necessarily indeterminate.

The final use designations published in the 1982 Oklahoma Water Quality Standards are presented in Table 4. The Standards have been adapted to approximate the study zones of the streams. No changes were made in the fishery status of Big Cabin Creek, Pryor Creek, Elk Creek, Stillwater Creek, and the North Canadian east of Woodward. These streams demand further study. Seines were ineffective for sampling the fish populations in Pryor and Big Cabin Creeks. The fish collections did not represent the population in these streams. Both groups of evaluators gave indeterminate rankings to all sites on the North Canadian and two of the three sites on Elk Creek. Obviously, the methodology did not provide sufficient information to assign fisheries uses to these sites. Stillwater Creek was heavily impacted by the municipal treatment plant. The final fishery designations for that stream are pending the results of an economic study to determine if the local community will financially support advanced treatment (AT).

The final uses listed in Table 4 are choices in which the biology of the streams is put in the context of the social and economic considerations of nearby communities. Once the survey had established the existing conditions in the streams, it was possible to determine if a PF was attainable by TBC and BMP. The results of the surveys suggested that depressed fisheries were caused by organic and nutrient loading from

Table 4. The 1982 Oklahoma Water Quality Standards Fishery for the one-day site-specific survey streams.

STREAM	SITES		
	UP	IMPACT	DOWN
Big Cabin*	P*	P*	P*
Coal	P	S	S
Chisholm	P	P	P
Stillwater*	P*	P*	P*
Pryor*	P*	P*	P*
Little Deep Fork	P	S	P
Dog	P	S	P
Skeleton	P	S	P
Wildhorse	P	P	
Muddy Boggy	P	P	P
Wewoka	S	S	S
Elk*	P*	P*	P*
Canadian, S. Fork	S	S	S
N. Canadian (OKC)	S	S	P
N. Canadian (Woodward)*	P	P*	P*
Rush	P	S	

* Zones will be studied more intensively to determine the existing condition of their fishery.

municipal treatment plants. This loading, probably by limiting the available DO, eliminated sport fish and intolerant benthos from the impact zones. Clearly, the uses of many streams were impaired by human inputs.

Models of wasteload allocations to these streams showed that AT was necessary to achieve a PF if local conditions did not mitigate the effects of the loading and at present support a PF (OWRB 208 Task 141). Since AT is not funded by the EPA Construction Grant Program, the cost of the treatment facilities would fall on the municipalities. In these cases a PF was not appropriate because the municipalities generally cannot afford this cost. In short, benefits would usually not be commensurate with costs.

SECTION 5

CONCLUSIONS AND RECOMMENDATIONS

The survey methodology and the ranking system was directly applicable to determining the attainability of uses. The one-day site survey is an effective tool in determining the local conditions in many streams. Physical descriptions of sites along with hydrological measurements allowed judgements about the biological potential of the habitat. This assessment was also reflected in the potential species lists. Chemical measurements provided information about existing water quality. The fish and benthos collections gave good qualitative estimates of the biological health of the streams. The integration of these components in the ranking system produced use designations for the stream segments based on their quality relative to similar areas. These uses could then be considered in the context of social and economic considerations.

The survey itself was cost effective. The cost to survey 16 streams was $11,263.00. Data were collected for the determination of three beneficial uses at a cost of $704.00 per stream. This methodology is an inexpensive tool with which to assess use attainability based on local conditions.

The entire use attainability process was developmental and modifications to the process are expected. Constructive criticisms have been made and it is hoped that they can be incorporated to improve the process.

The suggestion was made that the field data should be interpreted by comparison with an objective set of criteria defining primary and secondary fisheries in Oklahoma. Regulators would be better able to select attainable uses if the results of surveys could be evaluated by criteria that were understood by all concerned parties.

These objective criteria do not exist at present. The site-specific surveys have begun to provide a data base for that goal. The development of these criteria will demand a long term effort. Possibly, criteria can be developed on a regional basis or according to major stream characteristics, i.e. substrate and flow. It is doubtful that a statewide set of criteria can be developed that will account for the physical variability among streams in this state. It is recommended that the OWRB, along with other interested parties, develop sets of criteria with which to evaluate the biological health of Oklahoma streams.

Other criticisms have addressed the ranking methodology. One issue is how groups of sites are chosen. The total data base must be broken down into managable components for the pair-wise comparison. The defining characteristics of some groups of sites may better define some sites than others. The result is that some sites within a group are more comparable than others. It is recommended that a standard format be developed to classify streams for the pair-wise comparison.

A final issue is if the ANOVA is appropriate for determing fishery uses in groups of streams that vary in natural biological potential. In other words, is the relative comparison of streams grouped as clay/sluggish as valid as distinguishing among streams designated as fast/rocky? Yes, because both streams have a preferred fishery (primary) and thus a scale of degradation. A primary fishery may be less diverse in a stream that has less biological potential but it does exist and can be so designated.

In summary, the methodology of this survey provided comparative information about the existing and potential biological health of streams. The pair-wise comparison and non-parametric ranking methodology fitted the field information into a framework of use attainability. The overall process is a simple, inexpensive tool by which use attainability for many smaller streams can be determined on the basis of local conditions.

LITERATURE CITED

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APPENDIX A

DEFINITIONS OF BENEFICIAL USES

BENEFICIAL USE	DEFINITION
PRIMARY WARM WATER FISHERY	Water quality and habitat adequate to support sensitive warm water fish species in abundance. Environment suitable for a full range of warm water benthos. There shall be a minimum of seventy (70) perecnt saturation for dissolved oxygen at all times except at temperatures below 20°C where DO is no lower than 6.4 mg/L shall be maintained.
SECONDARY WARM WATER FISHERY	Water quality and habitat not adequate to support sensitive warm water fish species in abundance. Environment not suitable for the full range of warm water benthos. There shall be a forty-five (45) percent saturation level for dissolved oxygen at all times except at temperatures below 20°C where a DO is no lower than 4.1 mg/L shall be maintained.
PRIMARY BODY CONTACT RECREATION	Involves direct body contact with the water where a possibility of ingestion exists. In these cases the water shall not contain

chemical, physical or biological substances in concentrations that are irritating to skin or sense organs or are toxic or cause illness upon ingestion by human beings. Numerical limits to the concentrations of fecal coliform bacteria are stipulated for the summer months.

SECONDARY BODY CONTACT RECREATION

The water quality requirements for Secondary Body Contact Recreation are usually not as stringent as for Primary Body Contact Recreation. Secondary body contact recreational activities include boating, fishing, wading or other activities where ingestion of water is not anticipated. Waters shall be maintained to be free from human pathogens in numbers which may produce adverse health effects.

PUBLIC AND PRIVATE WATER SUPPLY

The quality of the waters of the shall be protected, maintained and improved, when feasible, so that they can be used as a source of public and private raw water supplies.

Drinking water standards dictate the quality of water that should be achieved in a municipal water distribution system without reference to desirable raw water quality. Although it is possible to renovate highly polluted surface waters to these standards, the process required would be both complex and expensive. Raw water quality criteria have been developed to aid in the selection of water sources so that the water supply chosen can, by commonly proven applied treatment processes, achieve the drinking water standards, all within reasonable economic limits. Numerical limits to the concentrations of fecal coliform bacteria are stipulated for the summer months. Numerical limits are also stipulated for toxic substances, pesticides, and radioactive materials. Waters shall be free of oil and grease and the taste and odors that emanate from petroleum products.

EXAMPLE 1

GROUP A - CHEMICAL WATER QUALITY COLUMNS

PART I

SITES	1	2	3	4	5	6	7	8	9	TOTAL SCORE	RANK
					COLUMNS						
Skeleton (down) A	½	0	1	1	1						
Dog (down) B	½	½	0	1	1	1					
Elk (up) C		1	1	½	1	1	1				
Elk (impact) D			0	0	0	½	1	1			
Elk (down) E				0	0	0	0		0		
Big Cabin (down) F					0	0	0	0	1		

PART II

Skeleton (down) A	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9
Dog (down) B	B_1		B_3	B_4	B_5	B_6	B_7	B_8	B_9
Elk (up) C	C_1	C_2	C_3		C_5	C_6	C_7	C_8	C_9
Elk (impact) D	D_1	D_2	D_3	D_4	D_5		D_7	D_8	D_9
Elk (down) E	E_1	E_2	E_3	E_4	E_5	E_6	E_7		E_9
Big Cabin (down) F	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9

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EXAMPLE 2

OBSERVER	SITES A	B	C	D	E	F
			ΔBENTHICS			
1	2.5	6	1	4	2.5	5
2	2	5.5	2	4	2	5.5
3	2.5	5.5	2.5	2.5	2.5	5.5
TOTAL	7	17	5.5	10.5	7	16
			ΔFISH			
1	4	6	2.5	1	2.5	5
2	3	5.5	3	3	1	5.5
3	1	5.5	3.5	3.5	2	5.5
TOTAL	8	17	9	7.5	5.5	16
			ΔHABITAT			
1	1.5	5.5	3	5.5	1.5	4
2	2	5	3	6	1	4
3	2	4.5	4.5	4.5	1	4.5
TOTAL	5.5	15	10.5	16	3.5	12.5
			ΔCHEMISTRY			
1	4	5	6	1	2.5	2.5
2	4	5	6	2.5	1	2.5
3	4.5	4.5	6	3	1	2
TOTAL	12.5	14.5	18	6.5	4.5	7
ΔTOTAL $\Delta_B+\Delta_F+\Delta_H+\Delta_C$	33	63.5	43	40.5	20.5	51.5

EXAMPLE 3

GROUP A

	A	B	C	D	E	F
A	X	29.5	10	7.5	12.5	18.5
B		X	20.5	23	43	12
C			X	2.5	22.5	8.3
D				X	20	11
E					X	31
F						X

$\alpha = 0.05$

Significant difference = 26

Stream Name: Dog Creek
Station Number: Downstream
Date: 9-20-82
Time: 1830 hrs.

Primary body contact recreation:

Access for stream use: Example 1

(1) Easy, several points of acess along stream
(2) Moderate, a few points of access along stream
(3) Hard, a very few access points along stream
(4) Access at road bridges only
(5) Access even at road bridges hard

Comments:
Almost impossible to gain access, had to get landowner permission and unlock gates to get to stream.

Are pools in the stream section deep enough for primary body contact recreation? Yes No
landowner stated that pools were deeper upstream

Describe general asthetic conditions:
Beautiful area, lots of Okla history connect w/ the area

Does bottom substrate preclude PBCR use? Yes No

Signs of human use:

Access Roads ☒
Footpaths ☐
Human trash ☐
Campfire sites ☐
Evidence of fishing ☐
RV tracks ☐
Boat docks ☐
Other ☐
Describe other:

Comments on human use:
used only by landowner and a selected few.

Evaluation of public water supply suitability:

(1) Is ther a reservoir downstream? Yes ~~No~~ Lake Claremore
(2) Are there plans to build one? Yes No
(3) Is the stream Perennial? Yes No
(4) Does the Presence of a discharge upstream preclude this use? Yes No
(5) What conductivity values were observed? 277

Comments:
The sampling team visited a site just downstream of the municipal discharger. This area appeared to be heavily impacted. There was bridge construction taking place so no sampling was done. This bridge activity almost totally impounded the creek. Only a small trickle was going downstream via.

Stream Name: Dog Creek | Station Number: Downstream | Date: 9-20-82
Time: 1930 hrs

Hydrolab Data:

Parameter	Surface	one foot	two feet	bottom
Temp.	20.3			
pH	6.5		Example 2	
DO	5.2			
Cond.	300			

Bank Characteristics:

1. Bank Cover: (Check and estimate %)

Categories

Devoid of vegetation X 5 % (if checked also check below)
Mud X 95 % Sand X 5 %

Rock ____ ____ %
Grasses X 10 %
Shrubs X 40 %
Trees X 40 %
Other ____ ____ % Describe other:

Vegetation Coverage: Sparce Moderate to Dense

2. Bank Stability:

(a) Erosion

erosion evident X 30 %
erosion likely X 40 %
erosion unlikely X 30 %

(b) Bank gradient

flat ____ ____ %
moderate slope ____ ____ %
steep slope X 70 %
verticle X 30 %

Hydrological Characteristics:

Width	Ave. Depth	Flow	Velocity (surface)
13'	4"	2.3 CFS	.67 ft/sec

Land Use:

Forest	X	20 %	Residential		____ %
Pasture/hayfield	X	80 %	Commercial		____ %
Row crop		____ %	Industrial		____ %
Urban		____ %	Other		____ %
Suburban	X	____ %	Describe other:		

Comments:

FISH

Stream Name: Coal Creek

Station Number: PTK Coal Co. Downstream

Date: 9-28-82

Time: 1330 hrs.

Sample Area Descriptions: (List all types of habitat sampled and describe fully)

Sample area is composed of long (50'-60') riffled areas, and large pools. Flow to this site comes out of a conduit, this allows stream to pass under the road. The site is extensively littered with rocks of all sizes. There are at least 3 major riffle sectio w/ good velocity (>1 ft/sec). These are broken up by shallow, moderate and deep pools. The flow ends up in a very lg. pool (100yds long 30yds and ~~over 8' deep~~ w in some section.

Bottom Compostion: (Check box(s) and estimate %)

Example 3

Type	Checked	%
Organic detintious		%
Mud/sludge		%
Clay	X	20 %
Silt	X	5 %
Sand	X	5 %
Gravel	X	20 %
Large rock	X	50 %
Bedrock		%

Describe size:

Habitat:

Habitat available for organism(s)	Potential species
1. Riffles	1. Darters
2. Pools (Large and small)	2. Stonerollers
3. Backwater	3. Notropis
4. Emergent vegetation	4. Pimephales sp.
5. Undercut banks	5. Lepomis sp.
6. Submerged Logs	6. Bass
7. Submerged Rocks	7. Crappie
8.	8. Silversides
9.	9. Channel Catfish
10.	10. Flathead Catfish
11.	11.
12.	12.
13.	13.
14.	14.
15.	15.
16.	16.
17.	17.

Example 4

Stream Name: Pryor Creek

Station Number: Impact Zone

Fish Benthics

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Organism Sample Results

Sampling Party . - Simpson
2 - Marshall

Taxa	Where/how caught or observed	Age	Health	Size	#'s	Rel. Abund.	Additional Co
Dorosoma cepedianum	overhanging bank/ sein haul		good	3-5"	40	occ.	occ. because they were see in only one sei
Chaenobryttus gulosus			good	5"		occ.	
Chaenobryttus gulosus			good	1"		common	more numerou than larger on
Lepomis cyanellus	found in most all habitats seined		good	1"	>100	common	These two sp were the dominant on found
Lepomis megalotis	found in most all habitats seined		good	1"		common	
Ictalurus natalis			good	6"	1	rare	
Ictalurus ~~natalis~~ melas	found in a ledge area by sein haul		good	10"	1	rare	
Notropus (sp. ?)			good			Rare	
Gambusia affinis	found mainly in backwater by sein haul		good			common	

Stream Name: Coal Creek Station Number: 224 Upstream Park in Henryetta Date: 9-28-82 Time: 1030

Sample Area Descriptions: (List all types of habitat sampled and describe fully)

Very little flow. Standing water in pools. Rubble bottom, probable riffles under conditions of greater flow. Banks well canopied. Naturally colored water (greyish). Sampled in a city park.

Bottom Composition: (Check box(s) and estimate %)

Organic detritious		%
Mud/sludge		%
Clay	X	15 %
Silt	X	5 %
Sand	X	30 %
Gravel	X	30 %
Large rock	X	20 %
Bedrock		%

Example 5

Describe size: large rock 5"–15" diameter
little organic detritus

Habitat:

Habitat available for organism(s)	Potential species
1. large rocks	1. Ephemeroptera
2. stones in shallows	2. Trichoptera
3. gravel substrate	3. Odonata
4. some woody detritus	4. Diptera (especially Chironomids)
5.	5.
6.	6.
7.	7.
8.	8.
9.	9.
10.	10.
11.	11.
12.	12.
13.	13.
14.	14.
15.	15.
16.	16.
17.	17.

Example 6

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Stream Name: Coal Creek Station Number: Upstream Henryetta Fish / Benthics

Taxa	Where/how caught or observed	Age	Health	Size	#'s	Rel. Abund.	Addl
Heptagenia	under rocks in pools and shallows.	all instars				abundant	
Caenis	gravel					common	
Calopteryx	root mats					rare	
Ephoron	only in grey clay in pools	early instar				rare	
Argia	in vegetation					abundant	
Basiaeschna	in large vegetation					rare	
Macromia	leaf and gravel litter					frequent	
Amphipods	backwaters with vegetative detritus					common	
Lirceus	" "					rare	
Chironomids = Tanypodinae		early instars				rare	probably preyed
Sphaeridae						frequent	
Dubiraphia						rare	

NO trichopterans, probably prey

APPENDIX B

RAW DATA

```
1        S A S   L O G    OS SAS 82.3          MVS/XA JOB SA11CMOY STEP SAS      PROC STEP1          17136 SATURDAY, FEBRUARY 18, 1984

NOTE: THE JOB SA11CMOY HAS BEEN RUN UNDER RELEASE 82.3 OF SAS AT THE UNIVERSITY OF OKLAHOMA (01227001).

NOTE: CPUID   VERSION = 03  SERIAL = 020553  MODEL = 3081 .
      CPUID   VERSION = 03  SERIAL = 220553  MODEL = 3081 .

NOTE: SAS OPTIONS SPECIFIED ARE:
       SORT=4

1          OPTIONS LINESIZE=132 PAGESIZE=60 NOCENTER;
2          GOPTIONS DEVICE=ZET14531
3          DATA;
4          * THIS DATABASE CONTAINS THE RESULTS OF THE HYDROLOGIC MEASUREMENTS TAKEN
5          AS PART OF THE UAA STUDY CONDUCTED BY OWRB DURING 1982.  THE VARIABLES
6          INCLUDED ARE:  FLOW(CFS), VELOCITY(FT/SEC), STREAM WIDTH(FT.)=WIDTH,
7          STREAM DEPTH(FT.)=DEPTH, WIDTH TO DEPTH RATIO=WDRATIO.;

NOTE: DATA SET WORK.DATA1 HAS 1 OBSERVATIONS AND 0 VARIABLES. 4766 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.05 SECONDS AND 92K.

8          DATA HYDRO;
9          INPUT
10         STATION  $  001-003
11         ZONE        004
12         SUB         005
13         DELPHI   $  006
14         GROUP    $  007-008
15         FLOW        009-013
16         VELOCITY    014-017
17         WIDTH       018-022
18         DEPTH       023-027
19         WDRATIO     028-032
20         ;
21         WDRATIO=WIDTH/DEPTH;
22         CARDS;

NOTE: MISSING VALUES WERE GENERATED AS A RESULT OF PERFORMING
      AN OPERATION ON MISSING VALUES.
      EACH PLACE IS GIVEN BY: (NUMBER OF TIMES) AT (LINE):(COLUMN).

      6 AT 21:10

NOTE: DATA SET WORK.HYDRO HAS 48 OBSERVATIONS AND 11 VARIABLES. 257 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.07 SECONDS AND 92K.

71         DATA NEW; SET HYDRO;
72         IF DEPTH=. THEN DELETE;

NOTE: DATA SET WORK.NEW HAS 42 OBSERVATIONS AND 11 VARIABLES. 257 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.06 SECONDS AND 92K.

73         PROC SORT; BY STATION ZONE;

NOTE: 4 CYLINDERS DYNAMICALLY ALLOCATED ON SYSDA FOR EACH OF 3 SORT WORK DATA SETS.
NOTE: DATA SET WORK.NEW HAS 42 OBSERVATIONS AND 11 VARIABLES. 257 OBS/TRK.
NOTE: THE PROCEDURE SORT USED 0.27 SECONDS AND 340K.

74         PROC PRINT;
75         TITLE RAW DATABASE FOR HYDROLOGIC VARIABLES;
```

RAW DATABASE FOR HYDROLOGIC VARIABLES

17:36 SATURDAY, FEBRUARY 18, 1984 1

OBS	STATION	ZONE	FLOW	VELOCITY	DEPTH	WIDTH	WDRATIO
1	BCC	1	7.50	0.1	3.00	45.0	15.0000
2	BCC	2	12.80	0.4	2.00	16.0	8.0000
3	BCC	3	25.00	0.9	1.20	25.0	20.8333
4	CHC	1	0.20	0.1	0.40	7.0	17.5000
5	CHC	2	6.30	0.5	1.00	16.0	16.0000
6	CHC	3	5.00	0.8	0.60	11.0	18.3333
7	COL	1	0.40	0.1	2.50	25.0	10.0000
8	COL	2	0.60	0.1	2.00	30.0	15.0000
9	COL	3	2.20	0.7	0.50	6.5	13.0000
10	BOB	1	0.10	0.1	2.20	36.0	16.3636
11	BOB	3	2.30	0.6	0.33	13.0	39.3939
12	ELK	1	2.10	0.2	1.50	12.0	8.0000
13	ELK	2	12.60	0.9	1.00	13.0	13.0000
14	ELK	3	5.00	0.7	0.50	15.0	30.0000
15	LBF	1	2.30	0.1	1.50	12.0	8.0000
16	LBF	2	1.70	0.1	0.80	20.0	25.0000
17	LBF	3	0.50	0.1	2.50	21.0	8.4000
18	MBC	1	1.40	0.1	4.00	35.0	8.7500
19	MBC	2	3.70	0.4	2.50	40.0	16.0000
20	MBC	3	9.00	0.1	6.00	15.0	2.5000
21	MCR	1	110.00	1.0	2.00	55.0	27.5000
22	MCR	2	150.00	1.6	2.00	45.0	22.5000
23	MCR	3	130.00	1.8	1.30	70.0	53.8462
24	MCW	1	3.50	0.7	0.40	26.0	65.0000
25	MCW	2	15.00	1.2	0.50	30.0	60.0000
26	MCW	3	9.50	1.0	0.50	19.0	38.0000
27	PRC	1	0.70	0.1	0.50	30.0	60.0000
28	PRC	2	1.90	0.1	3.00	45.0	15.0000
29	PRC	3	14.00	0.1	3.00	60.0	20.0000
30	RSC	1	5.40	0.7	0.30	25.0	83.3333
31	RSC	2	9.60	0.4	0.80	30.0	37.5000
32	RSC	3	9.60	0.4	0.80	30.0	37.5000
33	SCR	3	7.20	0.4	0.80	31.0	38.7500
34	SKC	1	1.50	0.9	3.00	50.0	16.6667
35	SKC	2	11.00	0.9	0.80	16.0	20.0000
36	SKC	3	25.00	0.9	1.20	25.0	20.8333
37	STW	1	0.25	0.1	1.50	21.0	14.0000
38	STW	2	0.00	0.7	2.00	6.0	3.0000
39	WEC	2	3.90	0.4	0.90	15.0	16.6667
40	WEC	3	0.60	0.3	0.20	10.0	50.0000
41	WHC	1	0.30	0.1	0.30	15.0	50.0000
42	WHC	2	0.40	0.1	1.50	23.0	15.3333

```
1        S A S   L O G    OS SAS 82.3          MVS/XA JOB SAFECHO2 STEP SAS      PROC STEP          15:05 SATURDAY, FEBRUARY 18, 1984

NOTE: THE JOB SAFECHO2 HAS BEEN RUN UNDER RELEASE 82.3 OF SAS AT THE UNIVERSITY OF OKLAHOMA (01227001).

NOTE: CPUID   VERSION = 03  SERIAL = 020553  MODEL = 3081 .
      CPUID   VERSION = 03  SERIAL = 220553  MODEL = 3081 .

NOTE: SAS OPTIONS SPECIFIED ARE:
        SORT=4

1           OPTIONS LINESIZE=132 PAGESIZE=60 NOCENTER;
2           *OPTIONS DEVICE=TEK4531;
3           DATA;
4           * THIS DATABASE CONTAINS THE RESULTS OF THE INVERTEBRATE SAMPLING FROM
5           THE 1982 UAA STUDY CONDUCTED BY THE OWRB.  THE INVERTEBRATE TAXA ARE
6           CODED AS FOLLOWS: CHEUMATO-CHEUMATOPSYCHE HYDROPSY-HYDROPSYCHE
7           CHIMARRA=CHIMARRA NYCTIOPH=NYCTIOPHYLAX OECETIS=OECETIS CORYDALS=
8           CORYDALUS ISONYCHA=ISONYCHIA BAETIS=BAETIS CALLIBAE CALLIBAETIS
9           CLOEON=CLOEON STENONEM-STENONEMA CAENIS CAENIS
10          EPHORON=EPHORON CALOPTER CALOPTERYX ARGIA-ARGIA
11          ENALLAGM=ENALLAGMA OPHIOGMP-OPHIOGOMPHUS PROGOMPH-PROGOMPHUS
12          ANAX=ANAX BASIAESH=BASIAESCHNA EPIAESCH=EPIAESCHNA MACROMIA=
13          MACROMIA LIBELLUL=LIBELLULA TRAMEA=TRAMEA DINEUTUS=DINEUTUS
14          GYRINUS=GYRINUS BEROSUS=BEROSUS TROPHIST-TROPISTERNUS HELICHUS=
15          HELICHUS DUBIRAPH-DUBIRAPHIA STENELMI-STENELMIS SIMULIID-SIMULIIDAE
16          CULICIDA=CULICIDAE CERATOPO=CERATOPOGONIDAE CHIRONOM-CHIRONOMINI
17          TANYTARS-TANYTARSINI TANYPODI TANYPODINI PENTANEU-PENTANEURINI
18          MACROPEL=MACROPELOPIINI PALAEMON-DECAPODA LIRCEUS-LIRCEUS HYALIELA HYALELLA
19          PHYSA-PHYSA SPHAERID-SPHAERIIDAE LIMNODRI-LIMNODRILUS DUGESIA-
20          TURBELLARIA BRYOZOA=BRYOZOA HIRUDINE-HIRUDINEA TRICHOPT TRICONTINUES
21          THE OCCURANCES OF THESE INVERTEBRATE TAXA ARE CODED BY RELATIVE ABUNDANCE
22          CODES.  1=RARE(<5 INDIVIDUALS) 2 OCCASSIONAL(5-10 INDIVIDUALS) 3 COMMON
23          (>10 TO 25 INDIVIDUALS) 4 ABUNDANT(>25 INDIVIDUALS).  ZERO INDICATES
24          THAT IT DID NOT OCCUR.;

NOTE: DATA SET WORK.DATA1 HAS 1 OBSERVATIONS AND 0 VARIABLES. 4766 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.06 SECONDS AND 92K.

25          DATA INSECTS;
26          INPUT
27          STATION  $  001-003
28          ZONE        004
29          BUD         005
30          DELPHI   $  006
31          GROUP    $  007-008
32          CHEUMATO    009
33          HYDROPSY    010
34          CHIMARRA    011
35          NYCTIOPH    012
36          OECETIS     013
37          CORYDALS    014
38          ISONYCHA    015
39          BAETIS      016
40          CALLIBAE    017
41          CLOEON      018
42          STENONEM    019
43          CAENIS      020
44          EPHORON     021
45          CALOPTER    022
46          ARGIA       023
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1      S A S   L O G    OS SAS 82.3         MVS/XA JOB SATICMOA STEP SAS      PROC STEP        14:13 SATURDAY, FEBRUARY 18, 1984

NOTE: THE JOB SATICMOA HAS BEEN RUN UNDER RELEASE 82.3 OF SAS AT THE UNIVERSITY OF OKLAHOMA (01227001).

NOTE: CPUID   VERSION = 03  SERIAL = 020553  MODEL = 3081 .
      CPUID   VERSION = 03  SERIAL = 220553  MODEL = 3081 .

NOTE: SAS OPTIONS SPECIFIED ARE:
       SORT=4

1          OPTIONS LINESIZE=132 PAGESIZE=60 NOCENTER;
2          OPTIONS DEVICE=ZETA153;
3          DATA;
4          * THIS DATABASE CONTAINS THE RESULTS OF THE WATER QUALITY MEASUREMENTS
5          TAKEN DURING THE UAA STUDY CONDUCTED IN 1982 BY OWRB.  INCLUDED IN THE
6          RECORDS ARE THE FOLLOWING PARAMETERS:  TEMPERATURE(DEGREES C.)=TEMP, PH,
7          DISSOLVED OXYGEN(MG./L) DISOXY, CONDUCTIVITY(MICROMOHS), SATURATION D.O.=PERCSAT
8          (CALCULATED FROM THE FIELD TEMPERATURE AND THE TABLE PROVIDED IN THE
9          14TH EDITION OF STANDARD METHOD FOR THE EXAMINATION OF WATER AND
10         WASTEWATER USING A SECONDDEGREE POLYNOMIAL REGRESSION CURVE TO ESTIMATE THE
11         PERCENT SATURATION AS SATDO 14.2133-0.3250TEMP+(0.0031*(TEMP**2)),
12         DISSOLVED OXYGEN DEFICIT=PERCSAT-SATDO DISOXY;

NOTE: DATA SET WORK.DATA1 HAS 1 OBSERVATIONS AND 0 VARIABLES. 4716 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.05 SECONDS AND 92K.

13         DATA WATER;
14         INPUT
15         STATION  $  001-003
16         ZONE        004
17         DUP         005
18         DELPHI   $  006
19         GROUP    $  007-008
20         TEMP        009-013
21         PH          014-017
22         DISOXY      018-021
23         PERSAT      022-024
24         DEFSAT      025-029
25         DEFPRI      030-034
26         DEFSEC      035-039
27         COND        040-044
28         ;
29         SATDO=14.2133-0.3250TEMP+(0.0031*(TEMP**2));
30         PERCSAT=DISOXY/SATDO*100;
31         PDEFSAT=SATDO-DISOXY;
32         PDEFPRI DISOXY-5.0;
33         PDEFSEC=DISOXY-3.0;
34         CARDS;

NOTE: MISSING VALUES WERE GENERATED AS A RESULT OF PERFORMING
      AN OPERATION ON MISSING VALUES.
      EACH PLACE IS GIVEN BY: (NUMBER OF TIMES) AT (LINE):(COLUMN).

      5 AT 29:17   5 AT 30:19   5 AT 31:19   5 AT 32:19   5 AT 33:19

NOTE: DATA SET WORK.WATER HAS 40 OBSERVATIONS AND 18 VARIABLES. 114 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.10 SECONDS AND 92K.

83         DATA NEW1 SET WATER;
84         IF TEMP=.THEN DELETE;
```

RAW DATABASE FOR WATER QUALITY MEASUREMENTS

OBS	STATION	ZONE	TEMP	PH	DISOXY	COND	SATDO	PERCSAT	DEFSAT
1	BCC	1	9.9	6.6	6.0	650	11.3290	52.961	5.3290
2	BCC	2	13.2	6.5	2.4	940	10.3157	22.833	8.1157
3	BCC	3	10.5	6.5	10.6	306	11.1756	94.849	0.5756
4	CHC	1	17.0	6.5	6.8	770	9.6709	70.314	2.8709
5	CHC	2	20.3	6.0	8.7	1385	9.0169	96.485	0.3169
6	CHC	3	19.3	6.9	8.2	1352	9.2073	89.060	1.0073
7	COL	1	18.6	6.0	7.3	439	9.3446	78.120	2.0446
8	COL	2	19.6	6.2	2.1	883	9.1494	22.952	7.0494
9	COL	3	22.2	6.7	10.4	794	8.6740	119.899	-1.7260
10	DOG	1	20.7	6.5	5.1	277	8.9127	57.220	3.8127
11	DOG	2	26.0	.	3.4	.	8.0617	42.175	4.6617
12	DOG	3	20.3	6.5	5.2	300	9.0169	57.669	3.8169
13	ELK	1	12.4	7.3	8.6	1324	10.7061	80.328	2.1061
14	ELK	2	16.3	7.5	14.9	1141	9.8191	151.744	-5.0809
15	ELK	3	13.9	7.5	12.9	1400	10.3527	124.605	-2.5473
16	LDF	1	17.0	6.5	7.6	639	9.6709	78.586	2.0709
17	LDF	2	20.1	7.2	7.7	1500	9.0544	85.041	1.3544
18	LDF	3	22.1	7.5	8.7	1519	8.6914	100.099	-0.0086
19	MDC	1	18.1	6.0	6.8	1286	9.4447	71.998	2.6447
20	MDC	2	20.3	7.0	12.6	834	9.0169	139.738	-3.5831
21	MDC	3	19.9	6.6	8.3	834	9.0922	91.287	0.7922
22	MCR	1	24.7	6.6	5.2	1725	8.2601	62.953	3.0601
23	MCR	2	27.2	7.1	7.2	1690	7.8088	91.249	0.6088
24	MCR	3	26.3	8.1	18.0	1486	8.0175	224.508	-9.9825
25	MCW	1	24.0	.	10.0	.	8.3717	129.006	-2.4703
26	MCW	2	24.0	.	3.4	.	8.3717	40.613	4.9717
27	MCW	3	24.0	.	8.6	2510	8.3717	102.727	-0.2283
28	PRC	1	18.7	6.7	7.2	386	9.3247	77.214	2.1247
29	PRC	2	19.7	6.7	6.0	599	9.1303	65.715	3.1303
30	PRC	3	21.3	6.9	5.5	579	8.8333	62.264	3.3333
31	RSC	1	20.2	7.3	9.2	2330	7.7521	118.677	-1.4479
32	RSC	2	20.7	7.4	13.1	1701	7.6863	170.432	-5.4137
33	RSC	3	20.7	7.4	13.1	1701	7.6863	170.432	-5.4137
34	SCH	1	32.5	7.7	8.0	368	7.2420	110.466	-0.7580
35	SRC	1	23.0	6.7	5.2	1000	8.5369	60.912	3.3369
36	SRC	2	28.6	7.4	7.6	2010	7.6994	98.709	0.0994
37	SRC	3	24.4	7.5	5.5	3040	8.3075	66.205	2.8075
38	STW	1	26.9	6.0	2.9	584	7.9311	36.565	5.0311
39	STW	2	27.7	6.4	4.4	891	7.8196	56.269	3.4196
40	WEC	2	27.3	7.0	3.9	1197	7.8740	49.529	3.9740
41	WEC	3	31.4	8.1	13.0	1564	7.3606	176.617	-5.6394
42	WHC	1	21.9	6.6	11.1	1760	8.7265	127.199	-2.3735
43	WHC	2	22.3	6.6	6.2	1436	8.6566	71.622	2.4566

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1        S A S   L O G    OS SAS 82.3          MVS/XA JOB SA11CH03 STEP SAS       PROC STEP1           10:48 TUESDAY, FEBRUARY 28, 1984

NOTE: THE JOB SA11CH03 HAS BEEN RUN UNDER RELEASE 82.3 OF SAS AT THE UNIVERSITY OF OKLAHOMA (01227001).

NOTE: CPUID   VERSION = 03  SERIAL = 020553  MODEL = 3081 .
      CPUID   VERSION = 03  SERIAL = 220553  MODEL = 3081 .

NOTE: SAS OPTIONS SPECIFIED ARE:
       SORT=4

          OPTIONS LINESIZE=132 PAGESIZE=60 NOCENTER;
          GOPTIONS DEVICE=ZETA;
          DATA;
          * THIS DATABASE CONTAINS INFORMATION ON NUMEROUS WASTEWATER PARAMETERS
          FOR FACILITIES DISCHARGING TO THOSE STREAMS SAMPLED AS PART OF UAA STUDY
          CONDUCTED DURING 1982 BY OWRB.  THIS INFORMATION WAS OBTAINED FROM
          THE OKLAHOMA STATE DEPARTMENT OF HEALTH.  IT INCLUDES A COMBINATION OF
          BOTH NPDES MONTHLY OPERATIONAL REPORTS AND COMPLIANCE MONITORING DATA
          FOR THE PERIODS BETWEEN AUGUST 1982 AND OCTOBER 1982.  THIS TIME FRAME
          ROUGHLY CORRESPONDS TO THE DATES WHICH THE SAMPLING TOOK PLACE.  THIS DATA
          IS IN SOME CASES COMPOSED OF EXTRAPOLATED ESTIMATES.  THE DATA SHOULD
          BE CONSIDERED AS QUALITATIVE AND NOT IN ANY WAY AS ACCURATE OR RELIABLE
          AS IT COULD HAVE BEEN IF IT WAS COLLECTED AT THE SAME TIME AS THE UAA
          STUDY WAS CONDUCTED.  THE PARAMETERS INCLUDED IN THE DATABASE ARE:
          STREAM FLOW=QS, EFFLUENT FLOW=QE, RATIO OF STREAM FLOW TO EFFLUENT FLOW
          =QSE, AVERAGE STREAM TEMPERATURE FOR THE MONTH OF AUGUST 1982=TEMPAUG,
          EFFLUENT D.O. LEVEL DOLEVEL, PRESENT SATURATION D.O.=PSATDO, D.O. DEFICIT=
          DODEF, FIVE DAY B.O.D.=BODFIVE(MG./L.),ULTIMATE CARBONACEOUS BOD UCBOD
          (MG./L.)(ESTIMATED AS BODFIVE/0.47), LOADING IN LBS/DAY OF UCBOD(ESTIMATED
          AS FLOW IN MILLION GALLONS/DAY X UCBOD=LAUCBOD), AMMONIA NITROGEN AS N
          (MG./L)=NHN, ULTIMATE OXYGEN DEMAND=UOD(ESTIMATED AS 4.57NHN+UCBOD),
          LOADING OF COMBINED CARBONACEOUS AND NITROGENOUS B.O.D.(ESTIMATED AS
          LBS/DAY BY MULTIPLING UOD8 EFFLUENT FLOW IN MGD)=LTCNBOD, TOTAL KJEDHAL
          NITROGEN(MG./L.) TKN, NITRATE NITROGEN AS N(MG./L.)=NITRATE, TOTAL
          PHOSHATE AS P(MG./L.) TPHOS, TOTAL SUSPENDED SOLIDS(MG./L.) TSS
          LOADING OF TSS BY (ESTIMATED IN LBS/DAY BY MULTIPLYING TSS THE EFFLUENT
          FLOW) LSTSS, ALKALINITY=ALK(MG./L.), CHLORIDES=CHLORIDE(MG./L.),
          CHEMICAL OXYGEN DEMAND(MG./L.)=COD, TOTAL ORGANIC CARBON(MG./L.)=TOC;

NOTE: DATA SET WORK.DATA1 HAS 1 OBSERVATIONS AND 0 VARIABLES. 4764 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.07 SECONDS AND 92K.

          DATA PSOURCE;
          INPUT                 2          S A S   L O G    OS SAS 82.3
          STATION  $  001
          ZONE        004          UOD         037-040
          BOD         005          LTCNBOD     061-065
          PELPHI   $  006          TKN         066-069
          GROUP    $  007          NITRATE     070-073
          QS          009          TPHOS       074-078
          QE          014          /
          QSE         019          TSS         001-004
          TEMPAUG     024          LSTSS       005-009
          DOLEVEL     026          ALK         010-012
          PSATDO      030          CHLORIDE    013-017
          DODEF       033          COD         018-022
          BODFIVE     038          TOC         023-027
          UCBOD       043          ;
          LAUCBOD     048          QSE=QS/QE;
          NHN         053          CARDS;
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OBS	STATION	ZONE	QS	QE	FQSE	IEHFAUU	DOLLV.LL	PSAIDU	DUDLF	PODFIVE	UCROD	LAUCBON	NHN	UOD	LTCHBOD	TKN	NITRAIF	TPHOS	TSS	LSTSS	AIK	CHLORIDE	CUD	IUC
1	BCC	1	7.50	2.17	3.4562	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2	BCC	2	12.80	2.17	5.8986	21	1.50	16	7.70	43.00	43.00	778	0.170	43.0	118	17.7	11.1	4.32	30.0	543	237	242	105.0	14.8
3	BCC	3	25.00	2.17	11.5207	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4	CHC	1	0.20	4.64	0.0431	28	3.00	58	3.50	13.20	.	.	.	.	.	.	.	.	.	.	.	.	.	.
5	CHC	2	6.50	4.64	1.4009	.	.	.	.	1.33	1.95	76	0.130	2.6	101	1.6	.	4.90	3.3	128	157	192	.	.
6	CHC	3	5.00	4.61	1.0776	27	6.30	72	2.40	10.30	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7	COL	1	0.60	0.77	0.7792	26	3.50	25	4.90	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
8	COL	2	0.60	0.77	0.7792	26	2.20	27	6.00	14.50	21.30	137	0.056	24.3	136	2.7	6.9	2.70	9.9	64	.	40	31.0	9.2
9	COL	3	2.20	0.77	2.8571	26	3.20	25	5.20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
10	DOG	1	0.10	1.92	0.0521	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
11	DOG	2	2.00	1.92	1.0417	26	3.40	39	5.40	23.50	34.60	553	.	.	.	.	.	.	27.7	444	.	.	.	.
12	DOG	3	2.30	1.92	1.1979	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
13	ELK	1	2.10	2.30	0.9130	.	8.40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
14	ELK	2	12.60	2.30	5.4783	28	11.90	.	.	16.30	24.00	460	1.500	31.0	598	3.5	6.7	4.54	65.0	1247	226	.	61.0	8.3
15	ELK	3	5.80	2.30	2.5217	.	9.60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
16	LOF	1	2.30	0.55	4.1818	22	6.20	71	2.60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
17	LOF	2	1.70	0.55	3.0909	22	2.80	32	6.00	50.70	74.60	342	0.964	80.0	367	6.1	0.5	3.70	44.4	204	.	.	123.0	25.2
18	LOF	3	0.50	0.55	0.9091	22	5.80	46	3.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
19	MBC	1	1.40	0.84	1.6667	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
20	MBC	2	3.70	0.84	4.4048	.	.	.	.	12.20	18.00	126	6.010	15.0	318	10.0	0.8	4.25	9.0	63	181	.	58.0	10.3
21	MBC	3	9.00	0.84	10.7143	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
22	NCR	1	130.00	40.00	3.7500	28	11.70	134	-2.76	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
23	NCR	2	110.00	40.00	2.7500	26	3.70	44	4.70	27.00	39.70	13246	.	.	.	.	.	.	23.7	7895	141	296	.	.
24	NCR	3	130.00	10.00	3.2500	27	7.30	80	1.77	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
25	NCW	1	5.50	3.87	1.4212	24	10.80	128	-2.40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
26	NCW	2	15.00	3.87	3.8760	24	3.40	26	5.10	18.10	26.60	859	11.900	90.0	2905	15.6	2.9	2.90	26.1	842	253	.	67.1	12.4
27	NCW	3	9.50	3.87	2.4548	24	8.40	102	-0.20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
28	FRC	1	0.20	1.13	0.1770	28	6.40	71	2.30	5.20	.	.	.	.	.	.	.	.	.	.	.	.	.	.
29	FRC	2	1.40	1.13	1.2389	28	6.10	79	1.70	25.10	37.00	348	7.300	71.0	664	10.8	1.4	5.18	33.0	311	188	48	90.0	.
30	FRC	3	14.00	1.13	12.3894	28	3.20	38	2.60	11.20	.	.	.	.	.	.	.	.	.	.	.	38	.	.
31	RSC	1	5.60	3.87	1.4470	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
32	RSC	2	9.30	3.87	2.4005	.	.	.	.	6.00	8.82	235	10.700	57.0	1844	13.6	0.5	7.10	32.0	1023	.	.	22.7	9.5
33	RSC	3	9.60	3.87	2.4806	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
34	SCR	1	0.00	5.64	0.0000	32	11.90	201	-7.60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
35	SCR	2	5.64	5.64	1.0000	28	1.10	13	7.00	43.50	64.00	3009	17.300	143.0	6731	22.5	0.5	9.53	77.5	3645	300	83	92.0	48.5
36	SCR	3	7.20	5.64	1.2766	32	1.17	16	6.10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
37	SKC	1	1.50	8.82	0.1701	26	7.10	81	1.60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
38	SKC	2	11.00	8.82	1.2472	25	6.40	73	2.10	27.70	40.70	2996	13.200	101.0	7429	14.9	5.9	.	29.0	2133	231	184	50.0	7.4
39	SKC	3	25.00	8.82	2.8345	26	7.20	83	1.50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
40	STW	1	0.30	7.18	0.0418	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
41	STW	2	8.00	7.18	1.1142	20	6.80	74	2.40	26.50	39.00	2333	10.100	85.0	5101	13.2	7.1	6.88	29.0	1317	.	.	81.0	12.6
42	STW	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
43	WEC	1	0.00	0.80	0.0000	29	7.30	80	1.80	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
44	WEC	2	0.60	0.80	0.7500	26	4.00	19	3.00	32.70	48.00	321	14.100	113.0	751	17.9	.	8.28	14.0	93	190	69	105.0	12.6
45	WEC	3	3.90	0.80	4.8750	29	5.40	64	2.10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
46	WHC	1	0.30	0.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
47	WHC	2	0.40	0.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
48	WHC	3	.	0.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

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1       S A S   L O G    OS SAS 82.3        MVS/XA JOB SALIPNES STEP SAS      PROC STEP1             11:36 WEDNESDAY, MARCH 7, 1984

NOTE: THE JOB SALIPNES HAS BEEN RUN UNDER RELEASE 82.3 OF SAS AT THE UNIVERSITY OF OKLAHOMA (01022001).

NOTE: CPUID   VERSION = 02  SERIAL = 020593  MODEL = 3081 .
      CPUID   VERSION = 02  SERIAL = 120593  MODEL = 3081 .

NOTE: SAS OPTIONS SPECIFIED ARE:
       SORT=4

1          OPTIONS LINESIZE=132 PAGESIZE=60 NOCENTER;
2          OPTIONS DEVICE=ZETA7 ;
           DATA1;
3          * THIS DATABASE CONTAINS THE RESULTS OF THE RIPARIAN, BANKSIDE, AND
5          GENERAL LAND USE (AS REFERRED TO AS NON-POINT SOURCE VARIABLES),
6          FOR THE USA STUDY CONDUCTED BY THE OWRB DURING 1982.  THE VALUES IN THE
7          DATASET REFLECT QUALITATIVE ESTIMATES AS PERCENT COMPOSITION FOR THE
8          FOLLOWING VARIABLES: VEG=BANKSIDE VEGETATION, BSMUD BANKSIDE COMPOSED OF
9          MUD, BSSAND BANKSIDE COMPOSED OF SAND, BSROCK BANKSIDE COMPOSED OF ROCK,
10         BSGRASS BANKSIDE COMPOSED OF GRASSES, BSTREES=BANKSIDE COMPOSED OF TREES,
11         EVIDENT=EROSION EVIDENT, ELIKELY EROSION LIKELY, EUNLIKELY=EROSION UNLIKELY,
12         SFLAT=BANKSIDE SLOPE FLAT, SMOD BANKSIDE SLOPE MODERATE, SSTEEP BANKSIDE
13         SLOPE STEEP, SVERT BANKSIDE SLOPE VERTICAL, PURBAN=PERCENT URBANIZED,
14         PAGRIC=PERCENT AGRICULTURAL, COVER CATAGORY OF COVER AS DENSE MODERATE OR
15         SPARSE(D M S RESPECTIVELY), PFOREST PERCENT FOREST LIKE, PPASTUR PERCENT
16         PASTURE, PCROP=PERCENT CROPLAND, PSUBURB PERCENT SUBURBANIZED.;

NOTE: DATA SET WORK.DATA1 HAS 1 OBSERVATIONS AND 0 VARIABLES. 4766 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.06 SECONDS AND 92K.

17         DATA NPS;
18         INPUT
19         STATION  $  001-003
20         ZONE        004
21         RUN         005
22         DELPHI   $  006
23         GROUP    $  007-008
24         VEG         009-011
25         BSMUD       012-014
26         BSSAND      015-017
27         BSROCK      018-020
28         BSGRASS     021-023
29         BSSHRUBS    024-026
30         BSTREES     027-029
31         BSOTHER     030-032
32         EVIDENT     033-035
33         ELIKELY     036-038
34         EUNLIKLY    039-041
35         SFLAT       042-044
36         SMOD        045-047
37         SSTEEP      048-050
38         SVERT       051-053
39         PURBAN      054-056
40         PAGRIC      057-059
41         COVER    $  060-062
42         PFOREST     063-065
43         PPASTUR     066-068
44         PCROP       069-071
45         PSUBURB     072-074
46         ;
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1?          RUN;

NOTE: DATA SET WORK.NES HAS 49 OBSERVATIONS AND 2? VARIABLES. ?? OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.12 SECONDS AND ??K.

            DATA NEW; SET NES;
            IF VEG=. THEN DELETE;
            * THE FOLLOWING ROUTINE RECODES THE DATA FOR THE BANKSIDE PROTECTION FOR
            VEGETATION V, 1=EXCELLENT 2=GOOD 3=FAIR 4=POOR.;
            IF VEG > .90 THEN V=1 ; ELSE
            IF VEG >=.70 .90 THEN V=2 ; ELSE
            IF VEG >=.50 .70 THEN V=3 ; ELSE
            IF VEG <.50 THEN V=4 ; ELSE V=2;
            * THE FOLLOWING ROUTINE RECODES THE DATA FOR THE BANKSIDE PROTECTION FOR
            SLOPE S, 1=EXCELLENT 2=GOOD 3=FAIR 4=POOR.;
            IF SFLAT=. THEN S=.; ELSE
            IF SVERT=50 AND SSTEEP=50 THEN S=3; ELSE
            IF SSTEEP=50 AND SMOD=50 THEN S=2; ELSE
            IF SFLAT >SMOD THEN S=1; ELSE
            IF SMOD >SSTEEP THEN S=2; ELSE IF
            SSTEEP > SVERT THEN S=3; ELSE IF
             SVERT > SSTEEP THEN S=4; ELSE S=2;
            * THE FOLLOWING ROUTINE RECODES THE DATA FOR THE BANKSIDE PROTECTION FOR
            EROSION=E, 1=EXCELLENT 2=GOOD 3=FAIR 4=POOR.;
            IF ELIKELY=. THEN E=.; ELSE
            IF EUNLIKLY>ELIKELY THEN E=1 ; ELSE
            IF EUNLIKLY<ELIKELY AND ELIKELY>EVIDENT THEN E=2 ; ELSE
            IF ELIKELY=EVIDENT THEN E=3 ; ELSE
            IF EUNLIKLY=ELIKELY THEN E=3 ; ELSE
            IF EVIDENT>ELIKELY THEN E=4 ; ELSE E=2;
            * THE FOLLOWING ROUTINE RECODES THE DATA FOR THE BANKSIDE PROTECTION FOR
            PROTECTIVE VEGETATION OR ROCK=R, 1=EXCELLENT 2=GOOD 3=FAIR 4=POOR.;
            PSS=PSTREES+PSSHRUBS;
            PSO=PSGRASS+PSROCK;
            IF PSROCK=. THEN R=.; ELSE
            IF PSTREES > 50 THEN R=1; ELSE
            IF PSROCK >=50 THEN R=4; ELSE
            IF PSGRASS >=50 THEN R=3; ELSE
            IF PSO >50 THEN R=3; ELSE R=2;
            * THE FOLLOWING ROUTINE RECODES THE DATA FOR THE BANKSIDE PROTECTION FOR
            MUD=M, 1=EXCELLENT 2=GOOD 3=FAIR 4=POOR.;
            IF PSMUD >=.90 THEN M=4 ; ELSE
            IF PSMUD >=.70 .90 THEN M=3 ; ELSE
            IF PSMUD >=.50 .70 THEN M=2 ; ELSE
            IF PSMUD <.50 THEN M=1 ; ELSE M=2;
            * THE FOLLOWING ROUTINE RECODES THE DATA FOR THE BANKSIDE PROTECTION FOR
            SAND=PS, 1=EXCELLENT 2=GOOD 3=FAIR 4=POOR.;
            IF PSSAND >=.90 THEN PS=4 ; ELSE
            IF PSSAND >=.70 .90 THEN PS=3 ; ELSE
            IF PSSAND >=.50 .70 THEN PS=2 ; ELSE
            IF PSSAND <.50 THEN PS=1 ; ELSE PS=2;
            NPSSCORE=V+S+E+R+PS+M;
            *NPSSCORE=SUM OF BANKSIDE PROTECTIVE RATINGS THE HIGHER THE SCORE THE
            MORE THE RATINGS WERE INDICATIVE OF POOR BANKSIDE PROTECTION;
            RETAIN;

NOTE: MISSING VALUES WERE GENERATED AS A RESULT OF PERFORMING
      AN OPERATION ON MISSING VALUES.
```

OBS	STATION	ZONE	VLG	ISCMUD	PSSAND	PFROCK	PSDFAS	PSSHRUBS	ISIPELS	FVIPFNT	FLIPIIY	FUHLIL	SLAT	[illegible]	SSTEF	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	S	E	V	H	H	RS	NF
1	PCC	1	0	90	10	0	20	10	20	10	10	50	0	5	15	5	0	0	M	10	40	0	0	2	1	4	4	1	1	13
2	PCC	2	0	95	5	0	5	10	65	5	20	25	0	5	50	20	0	0	P	10	50	0	0	3	1	1	1	1	1	11
3	PCC	3	5	0	0	0	10	20	40	10	10	80	0	0	70	30	0	0	M	10	50	0	0	3	1	4	1	2	1	12
4	CHC	1	0	75	20	50	0	0	70	5	10	65	0	45	45	10	0	0	M	0	85	25	100	2	1	1	2	4	1	15
5	CHC	2	0	95	5	0	20	0	80	50	10	10	0	10	40	50	0	0	M	10	10	80	100	4	4	4	4	1	1	18
6	CHC	3	15	90	10	0	20	20	60	20	40	40	0	40	50	10	0	0	P	20	20	0	100	3	3	4	4	1	1	16
7	COL	1	20	60	40	0	20	20	60	20	20	40	0	75	15	10	0	0	M	0	0	0	100	2	1	4	2	1	1	11
8	COL	2	2	0	0	0	10	40	50	0	20	80	0	65	30	5	75	0	P	0	20	0	50	2	1	4	1	2	1	11
9	COL	3	40	70	10	70	5	1	2	75	25	0	0	10	40	50	100	0	S	0	0	0	0	4	4	4	4	4	1	21
10	DOO	1	40	95	5	20	20	20	40	10	20	70	0	25	60	15	50	50	P	0	20	0	50	3	1	4	4	2	1	15
11	DOO	3	5	95	5	0	10	45	15	30	10	30	0	0	70	30	0	0	P	20	80	0	0	3	2	4	4	2	1	16
12	ELK	1	20	95	5	0	40	20	40	30	40	30	0	55	45	15	0	0	M	0	0	100	0	2	2	4	4	2	1	15
13	ELK	2	90	10	0	10	60	10	20	30	30	20	0	20	80	0	0	0	M	0	50	50	0	3	4	1	1	3	1	13
14	ELK	3	100	0	0	0	10	20	70	50	30	20	0	20	50	30	6	0	P	0	0	0	0	3	4	1	1	1	1	11
15	LDF	1	20	90	10	0	30	20	50	10	20	70	0	10	80	10	0	0	M	80	20	0	100	3	1	4	4	2	1	15
16	LDF	2	30	30	20	0	50	20	30	50	40	10	0	10	50	40	0	0	M	50	50	0	100	2	1	1	1	3	1	16
17	LDF	3	20	10	90	0	30	20	30	50	40	10	0	20	30	50	0	0	M	20	80	0	0	4	4	4	1	3	4	20
18	MBC	1	0	85	15	0	40	10	50	70	30	0	0	50	40	10	0	0	P	20	80	0	100	2	4	4	3	2	1	16
19	MBC	2	0	0	0	0	50	40	10	50	30	20	0	5	90	5	0	0	M	10	90	0	100	3	4	4	1	3	1	16
20	MBC	3	5	0	0	20	10	10	40	20	20	40	0	80	20	5	0	0	P	100	0	0	100	2	1	4	1	1	1	10
21	NCR	1	0	50	50	0	40	40	20	10	40	50	0	70	30	0	50	50	P	0	0	0	50	2	1	4	2	2	2	13
22	NCR	2	0	50	50	0	20	60	20	10	40	50	10	65	30	5	50	50	M	0	0	0	50	2	1	4	2	2	2	13
23	NCR	3	0	0	0	0	40	10	30	5	35	40	0	30	60	10	10	0	M	0	0	0	90	3	1	4	1	2	1	12
24	NCW	1	0	0	100	.	.	.	.	.	.	.	.	.	.	.	0	0	P	0	100	0	0	.	.	1	1	.	4	.
25	NCW	2	0	0	100	0	10	10	80	5	25	70	0	80	20	0	0	0	P	0	100	0	0	2	1	1	1	1	4	13
26	NCW	3	10	0	100	0	10	40	50	20	30	50	0	50	50	0	0	0	P	10	90	0	0	2	1	1	1	2	4	14
27	FRC	1	10	75	25	0	5	15	80	0	40	60	0	30	60	10	0	0	M	10	90	0	100	3	1	4	3	1	1	13
28	FRC	2	25	100	0	0	10	0	90	0	10	90	0	0	50	50	0	0	M	20	80	0	100	3	1	4	4	1	1	14
29	FRC	3	5	95	5	0	0	50	50	10	80	10	0	0	30	70	0	0	S	40	60	0	100	4	2	4	4	2	1	17
30	RSC	1	20	20	80	0	20	40	40	10	30	60	0	100	0	0	70	0	M	0	30	30	0	2	1	4	1	2	3	13
31	RSC	2	20	10	40	0	40	20	10	40	30	30	0	10	40	70	0	0	M	30	40	30	0	2	3	4	1	2	2	14
32	RSC	3	20	40	40	0	40	20	40	40	30	30	0	40	30	30	0	0	M	30	40	30	0	2	3	4	1	2	2	14
33	SCR	1	10	5	95	0	40	50	10	80	10	10	100	0	0	0	0	0	S	0	0	0	0	1	3	4	1	2	4	15
34	SCR	2	10	5	95	0	40	50	10	80	10	10	100	0	0	0	0	0	S	0	0	0	0	1	3	4	1	2	4	15
35	SCR	3	10	5	95	0	40	50	10	80	10	10	100	0	0	0	0	0	S	0	0	0	0	1	3	4	1	2	4	15
36	SKC	1	5	50	50	0	90	10	0	0	5	95	0	0	90	10	50	0	P	0	100	0	50	3	1	4	2	3	2	15
37	SKC	2	30	30	70	30	10	45	15	40	20	40	0	30	40	30	0	0	M	0	50	50	100	3	1	4	1	2	3	14
38	SKC	3	50	95	5	0	40	20	40	5	30	65	0	5	90	5	0	0	S	0	0	0	0	3	1	3	4	2	1	14
39	STW	1	5	50	50	0	0	75	25	0	20	80	0	10	80	10	0	0	M	0	0	0	0	3	1	4	2	2	2	14
40	STW	2	0	0	0	10	30	30	30	0	10	90	0	0	70	30	0	0	M	0	0	0	0	3	1	4	1	2	1	12
41	WEC	1	10	30	50	0	25	75	0	10	25	65	0	100	0	0	0	0	M	0	50	50	0	2	1	4	1	2	2	12
42	WEC	2	25	20	80	20	10	50	20	50	50	0	0	50	25	25	0	0	M	0	75	75	100	2	3	4	1	2	3	15
43	WEC	3	3	15	85	0	50	10	40	20	30	30	0	50	10	10	0	0	M	0	50	50	100	2	1	4	1	3	3	14
44	WHC	1	0	20	30	10	40	20	30	10	30	60	0	0	80	20	0	0	M	0	0	0	100	3	1	1	3	2	1	14
45	WHC	2	0	100	0	0	20	10	70	20	30	30	0	10	60	30	0	0	P	10	30	40	0	3	2	4	4	1	1	15

```
1         S A S    L O G    OS SAS 82.3          MVS/XA JOB SATICHOI STEP SAS       PROC SITE1           15:27 SATURDAY, FEBRUARY 18, 1984

NOTE: THE JOB SATICHOI HAS BEEN RUN UNDER RELEASE 82.3 OF SAS AT THE UNIVERSITY OF OKLAHOMA (01227001).

NOTE: CPUID   VERSION = 03  SERIAL = 020553  MODEL = 3081 .
      CPUID   VERSION = 03  SERIAL = 220553  MODEL = 3081 .

NOTE: SAS OPTIONS SPECIFIED ARE:
       SORT=4

1           OPTIONS LINESIZE=132 PAGESIZE=60 NOCENTER;
2           GOPTIONS DEVICE=ZETA453;
3           DATA;
4           * THIS DATABASE CONTAINS THE RESULTS OF THE HABITAT EVALUATION FOR
5           THE WAA STUDY COMPILED DURING 1872 BY THE UWRD.  INFORMATION IS CODED
6           DESIGNATING THE PRESENCE(1) OR ABSENCE(0) OF A PARTICULAR CATAGORY OF
7           HABITAT IN THE STREAM SEGMENT SAMPLED AT STATIONS.  THE CATAGORIES OF
8           HABITAT INCLUDE:  POOLS=POOL, RIFFLES, SHALLOW FLAT RUNS=FLATRUNS,
9           DEEP CHANNEL AREAS=DCHANNEL, UNDERCUT BANKS UCUTBANKS, SUBMERGED LOGS=
10          SUBLOGS, SUBMERGED TREE ROOTS OR STUMPS TREES, BRUSHPILES=BRUSHPIL,
11          LARGE ISOLATED POOLS OR OXBOWS OXBOWS, BACKWATER AREAS BKWATER,
12          SUBMERGED ROCKS=ROCKS, EMERGENT VEGETATION EMGVEG.;

NOTE: DATA SET WORK.DATA1 HAS 1 OBSERVATIONS AND 0 VARIABLES. 9736 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.05 SECONDS AND 92K.

13          DATA HABITAT;
14          INPUT
15          STATION  $  001-003
16          ZONE        004
17          DUP         005
18          DELPHI   $  006
19          GROUP    $  007-008
20          POOL        009
21          RIFFLES     010
22          FLATRUNS    011
23          DCHANNEL    012
24          UCUTBANK    013
25          SUBLOGS     014
26          TREES       015
27          BRUSHPIL    016
28          OXBOWS      017
29          BKWATER     018
30          ROCKS       019
31          EMGVEG      020
32          ;
33          CARDS;

NOTE: DATA SET WORK.HABITAT HAS 40 OBSERVATIONS AND 17 VARIABLES. 156 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.08 SECONDS AND 92K.

82          DATA NEW; SET HABITAT;
83          IF POOL=. THEN DELETE;
84          IF STATION='WEC' AND ZONE=1 THEN DELETE;

NOTE: DATA SET WORK.NEW HAS 35 OBSERVATIONS AND 17 VARIABLES. 156 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.07 SECONDS AND 92K.

85          PROC SORT; BY STATION ZONE;
```

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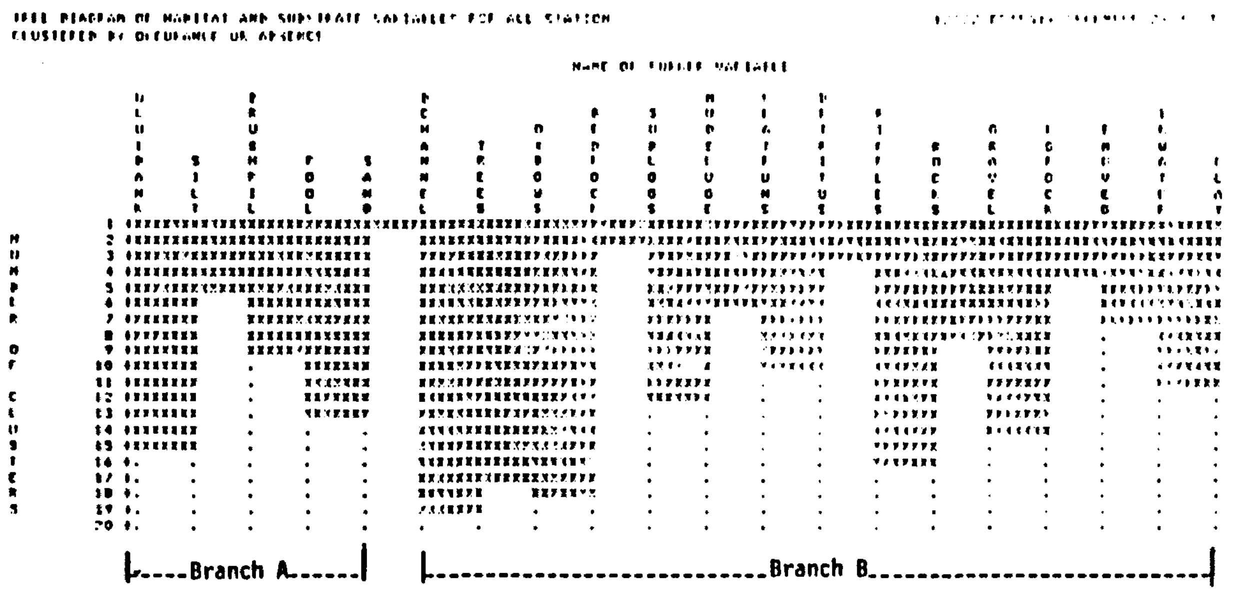
RAW DATABASE FOR HABITAT VARIABLES   15:27 SATURDAY, FEBRUARY 10, 1984   1

OBS	STATION	ZONE	POOL	RIFFLES	FLATRUNS	BCHANNEL	UCUTBANK	SUBLOGS	TREES	BRUSHPIL	OTHOMS	BRWATER	ROCKS	EMGVEG
1	CHC	1	1	1	0	0	1	0	0	1	0	0	1	0
2	CHC	2	1	0	1	0	1	1	0	1	0	0	0	0
3	CHC	3	1	0	1	0	0	1	0	1	0	1	0	0
4	COL	1	1	0	0	0	1	1	0	0	0	0	1	1
5	COL	3	1	1	0	0	1	1	0	0	1	1	1	1
6	DUB	1	1	1	0	0	1	1	0	1	0	0	1	0
7	DOB	3	1	0	1	1	1	0	0	1	0	0	0	0
8	ELK	1	1	1	1	0	1	0	0	1	0	0	0	0
9	ELK	2	1	1	1	0	1	0	0	1	0	1	1	0
10	ELK	3	1	0	1	0	1	0	0	1	0	0	0	0
11	LPF	1	1	1	1	1	0	1	1	0	1	0	0	0
12	LPF	2	1	1	0	0	0	1	0	1	0	0	1	0
13	LPF	3	1	0	1	0	0	1	0	1	0	0	0	0
14	MDC	1	1	0	0	0	1	1	1	1	0	0	0	1
15	MDC	2	1	1	1	0	1	0	0	1	0	0	1	1
16	MDC	3	1	0	0	0	1	1	0	1	0	0	1	0
17	MCR	1	1	1	1	1	1	1	1	1	0	1	0	0
18	MCR	2	1	0	1	0	1	1	1	0	0	0	0	0
19	MCR	3	1	0	0	0	1	0	0	1	0	1	0	0
20	MCW	1	1	0	1	0	0	0	0	1	0	0	1	0
21	MCW	2	1	0	1	0	0	0	0	1	0	1	0	0
22	MCW	3	1	0	1	0	0	0	0	1	0	0	0	0
23	PRC	1	1	1	1	0	1	0	0	1	0	1	1	0
24	PRC	2	1	1	0	0	1	1	0	0	0	1	1	0
25	RSC	1	1	1	0	1	0	0	0	1	0	1	1	0
26	RSC	2	1	0	1	1	1	0	0	1	0	1	0	0
27	SCR	3	1	0	1	0	0	0	0	1	0	1	0	0
28	SRC	1	1	0	1	0	1	1	0	1	0	0	0	1
29	SRC	2	0	1	0	0	1	0	1	1	0	0	1	1
30	SRC	3	1	0	0	1	1	1	0	1	0	0	0	1
31	STW	1	0	0	0	0	1	1	0	1	0	0	1	1
32	STW	2	1	1	0	0	1	1	0	1	0	0	1	1
33	WEC	2	1	1	1	0	0	0	0	0	0	0	1	0
34	WEC	3	1	0	1	0	0	1	0	1	0	1	1	0
35	WHC	1	1	0	0	0	1	0	0	0	0	0	1	1


Branch A
Branch B

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NOTE: THE JOB SSTICHOT HAS BEEN RUN UNDER RELEASE 82.3 OF SAS AT THE UNIVERSITY OF OKLAHOMA (01227001).

NOTE: CPUID   VERSION = 03  SERIAL = 020553  MODEL = 3081 .
      CPUID   VERSION = 03  SERIAL = 220553  MODEL = 3081 .

NOTE: SAS OPTIONS SPECIFIED ARE:
        SORT=4

1          OPTIONS LINESIZE=132 PAGESIZE=60 NOCENTER;
2          GOPTIONS DEVICE=ZETA4531;
3          DATA;
4          * THIS DATA BASE CONTAINS THE RESULTS OF THE SUBSTRATE EVALUATION
5          PERFORMED AS PART OF THE UAA STUDY CONDUCTED DURING 1982 BY OWRB.
6          THE DATA REPRESENTS THE RELATIVE AREA FOR WHICH A GIVEN SUBSTRATE
7          TYPE WAS FOUND TO BE PRESENT.  THE VALUES ARE PERCENTAGES, AS DETERMINED
8          BY THE SAMPLING TEAM.  A VALUE OF 0 REPRESENTS THE FACT THAT THE
9          TEAM DID NOT FEEL THAT THE SUBSTRATE TYPE WAS PRESENT, EITHER AT ALL,
10         OR IN SUFFICIENT AMOUNTS TO WARRENT ESTIMATION.  CATAGORIES INCLUDE:
11         DETRITUS, MUD AND/OR SLUDGE MUDSLUGE, CLAY, SILT, SAND, GRAVEL,
12         LARGE ROCKY AREAS-LGROCK, SOLID BEDROCK-BEDROCK.;

NOTE: DATA SET WORK.DATA1 HAS 1 OBSERVATIONS AND 0 VARIABLES. 4765 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.06 SECONDS AND 92K.

13         DATA SUBSTRAT;
14         INPUT
15         STATION  $  001-003
16         ZONE        004
17         BUD         005
18         DELPHI   $  006
19         GROUP    $  007-008
20         DETRITUS    009-011
21         MUDSLUGE    012-014
22         CLAY        015-017
23         SILT        018-020
24         SAND        021-023
25         GRAVEL      024-026
26         LGROCK      027-029
27         BEDROCK     030-032
28         ;
29         CARDS;

NOTE: DATA SET WORK.SUBSTRAT HAS 48 OBSERVATIONS AND 13 VARIABLES. 211 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.09 SECONDS AND 92K.

78         DATA NEW; SET SUBSTRAT;
79         IF STATION='WHC' AND ZONE 2 THEN DELETE;
80         IF SAND=. THEN DELETE;

NOTE: DATA SET WORK.NEW HAS 43 OBSERVATIONS AND 13 VARIABLES. 211 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.07 SECONDS AND 92K.

81         PROC SORT; BY STATION ZONE;

NOTE: 4 CYLINDERS DYNAMICALLY ALLOCATED ON SYSDA FOR EACH OF 3 SORT WORK DATA SETS.
NOTE: DATA SET WORK.NEW HAS 43 OBSERVATIONS AND 13 VARIABLES. 211 OBS/TRK.
NOTE: THE PROCEDURE SORT USED 0.32 SECONDS AND 310K.
```

OBS	STATION	ZONE	DETRITUS	MUDSLUDGE	CLAY	SILT	SAND	GRAVEL	COBBLE	BEDROCK
1	BCC	1	16	3	3	5	0	5	10	60
2	BCC	2	15	3	0	2	0	0	40	40
3	BCC	3	15	0	0	15	0	35	35	0
4	CHC	1	2	3	10	0	10	0	25	50
5	CHC	2	5	0	0	2	90	0	3	0
6	CHC	3	5	10	35	0	50	0	0	0
7	COL	1	5	5	0	10	10	60	10	0
8	COL	3	0	0	20	5	5	20	50	0
9	DOG	1	25	15	0	20	0	0	40	0
10	DOG	2	0	0	35	20	0	10	5	0
11	DOG	3	0	0	45	20	0	10	5	0
12	ELK	1	5	10	25	30	0	0	0	30
13	ELK	2	0	10	0	40	0	0	0	50
14	ELK	3	10	30	0	20	40	0	0	0
15	LDF	1	0	0	50	20	20	0	10	0
16	LDF	2	5	0	5	5	60	15	10	0
17	LDF	3	5	0	0	5	75	5	10	0
18	MBC	1	0	30	40	0	30	0	0	0
19	MBC	2	5	0	0	5	10	40	30	10
20	MBC	3	0	0	0	10	10	20	60	0
21	NCR	1	10	5	0	10	75	0	0	0
22	NCR	2	10	5	0	10	75	0	0	0
23	NCR	3	0	30	0	10	60	0	0	0
24	NCW	1	5	0	0	5	90	0	0	0
25	NCW	2	2	2	0	1	95	0	0	0
26	NCW	3	0	0	0	2	98	0	0	0
27	FRC	1	5	0	0	15	0	0	80	0
28	FRC	2	0	0	70	10	10	10	0	0
29	RSC	1	0	0	50	0	40	10	0	0
30	RSC	2	10	0	20	0	60	10	0	0
31	RSC	3	10	0	20	0	60	10	0	0
32	SCR	1	0	0	0	0	100	0	0	0
33	SCR	2	0	0	0	0	100	0	0	0
34	SCR	3	0	0	0	0	100	0	0	0
35	SPC	1	10	30	0	10	30	5	15	0
36	SPC	2	0	0	0	2	20	18	10	50
37	SPC	3	10	75	5	5	0	5	0	0
38	STW	1	10	25	0	50	15	0	0	0
39	STW	2	0	20	0	0	30	50	0	0
40	WEC	1	0	0	0	0	100	0	0	0
41	WEC	2	0	10	0	0	80	0	10	0
42	WEC	3	0	0	0	0	80	15	5	0
43	WHC	1	10	0	0	10	20	20	40	0

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1        S A S   L O G    OS SAS 82.3          MVS/XA JOB SAIICHOI STEP S/S      PROC STEP1          13:56 SATURDAY, FEBRUARY 18, 1984

NOTE: THE JOB SAIICHOI HAS BEEN RUN UNDER RELEASE 82.3 OF SAS AT THE UNIVERSITY OF OKLAHOMA (01227001).

NOTE: CPUID   VERSION = 03  SERIAL = 020553  MODEL = 3081 .
      CPUID   VERSION = 03  SERIAL = 220553  MODEL = 3081 .

NOTE: SAS OPTIONS SPECIFIED ARE:
       SORT=4

          OPTIONS LINESIZE=132 PAGESIZE=60 NOCENTER;
          GOPTIONS DEVICE=ZETA;
          DATA;
          * THIS DATA BASE CONTAINS THE RESULTS OF THE FISH SAMPLING FROM THE 1982
          OAA STUDY CONDUCTED BY THE OWRB.  THE FISH SPECIES ARE CODED V001-V070,
          AND THEIR OCCURANCES IS REPRESENTED BY RELATIVE ABUNDANCE CODES. FOR
          V001 THRU V070 1=RARE(<5 INDIVIDUALS) 2=OCCASIONAL(5-10 INDIVIDUALS)
          3=COMMON(>10 UP TO 50 INDIVIDUALS),ALSO REFERED TO AS ABUNDANT IN TEXT,
          4 DOMINANT(>50 INDIVIDUALS AND PRESENT IN NEARLY EVERY SEINE HAUL).
          THESE RELATIVE ABUNDANCE DESIGNATIONS SHOULD NOT BE CONSIDERED AS
          STRICT CATAGORICAL RECORDING OF ABSOLUTE DENSITIES FROM FIELD SAMPLING.
          RATHER THEY REPRESENT THE RANGES OF DENSITY FROM WHICH SUBJECTIVE JUDGE-
          MENT WAS MADE IN THE FIELD AND AFTER THROUGH IDENTIFICATION IN THE LAB.
          SPECIES CODES: THESE WILL BE REFERRED TO BY NUMBER(I.E. VOO LEFT LEFT
          OFF) 1=DOROSOMA CEPEDIANUM 2=CAMPOSTOMA ANOMALUM 3=CYPRINUS CARPIO
          4=HYBOGNATHUS PLACITUS 5=NOTEMIGONUS CRYSOLEUCAS 6 NOTROPIS ATHERINOIDES
          8=N.BUCHANANI 10=N.LUTRENSIS 11=N.STRAMINEUS
          12=N.PERPALLIDUS 13=N.SPECIES(UNIDENTIFIED) 14 N.UMBRATILIS
          20=PHENACOBIUS MIRABILIS 21=PIMEPHALES NOTATUS 22 P.PROMELAS
          23=P.TENELLUS 24=P.VIGILAX 25=CARPIODES CARPIO 30=ICTALURUS MELAS
          31=I.NATALIS 32=I.PUNCTATUS 33=N.NOCTURNUS 34=PYLODICTIS OLIVARIS
          35=NOTURUS EXILIS 40=FUNDULUS KANSAE 42=F.OLIVACEUS
          43=GAMBUSIA AFFINIS 44=LABIDESTHES SICCULUS 45=MENIDIA AUDENS
          46=MORONE CHRYSOPS 47=LEPOMIS GULOSUS 48 L.CYANELLUS
          49=L.HUMILIS 50=L.MACROCHIRUS 51=L.MEGALOTIS 52 L.MICROLOPHUS
          53=MICROPTERUS SALMOIDES 54=POMOXIS ANNULARIS 60 ETHEOSTOMA GRACILE
          61=E.RADIOSUM 62=E.WHIPPLEI 63 E.SPECTABILE 64=PERCINA PHOXOCEPHALA
          65=P.SCIERA 70 APLODINOTUS GRUNNIENS.  ;

NOTE: DATA SET WORK.DATA1 HAS 1 OBSERVATIONS AND 0 VARIABLES. 5766 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.06 SECONDS AND 92K.

          DATA RAWFISH;
          INPUT
          STATION  $  001-003
          ZONE        004
          SUB         005
          DELPHI   $  006
          GROUP    $  007-008
          V001        009
          V002        010
          V003        011
          V004        012
          V005        013
          V006        014
          V007        015
          V008        016
          V009        017
          V010        018
          V011        019
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2       S A S   L O G    OS SAS 82.3         MVS/XA JOB SAILEMOT STEP SAS      PROC STEP1        11:56 SATURDAY, FEBRUARY 18, 1984
47          V020         020
48          V021         021
49          V022         022
50          V023         023
51          V024         024
52          V025         025
53          V030         026
54          V031         027
55          V032         028
56          V033         029
57          V034         030
58          V040         031
59          V041         032
60          V042         033
61          V043         034
62          V044         035
63          V045         036
64          V046         037
65          V047         038
66          V048         039
67          V049         040
68          V050         041
69          V051         042
70          V052         043
71          V053         044
72          V054         045
73          V060         046
74          V061         047
75          V062         048
76          V070         049
77          V012         050
78          V013         051
79          V014         052
80          V063         053
81          V064         054
82          V065         055
83          V035         056
84          RICHNESS     057-058
85          MINNOWS      059
86          CATFISH      060
87          SUNFISH      061
88          RARE         062
89          OCASONAL     063
90          COMMON       064
91          DOMINANT     065
92          FISHABLE     066
93          ;
94          CARDS;

NOTE: DATA SET WORK.RAWFISH HAS 40 OBSERVATIONS AND 62 VARIABLES. 37 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.18 SECONDS AND 102K.

143         DATA NEW; SET RAWFISH(DROP=V007 V009 V0111);
144         IF V001=. THEN DELETE;
145         IF STATION='ASC' AND ZONE=3 THEN DELETE;
146         IF RICHNESS=0 THEN DELETE;

NOTE: DATA SET WORK.NEW HAS 35 OBSERVATIONS AND 59 VARIABLES. 41 OBS/TRK.
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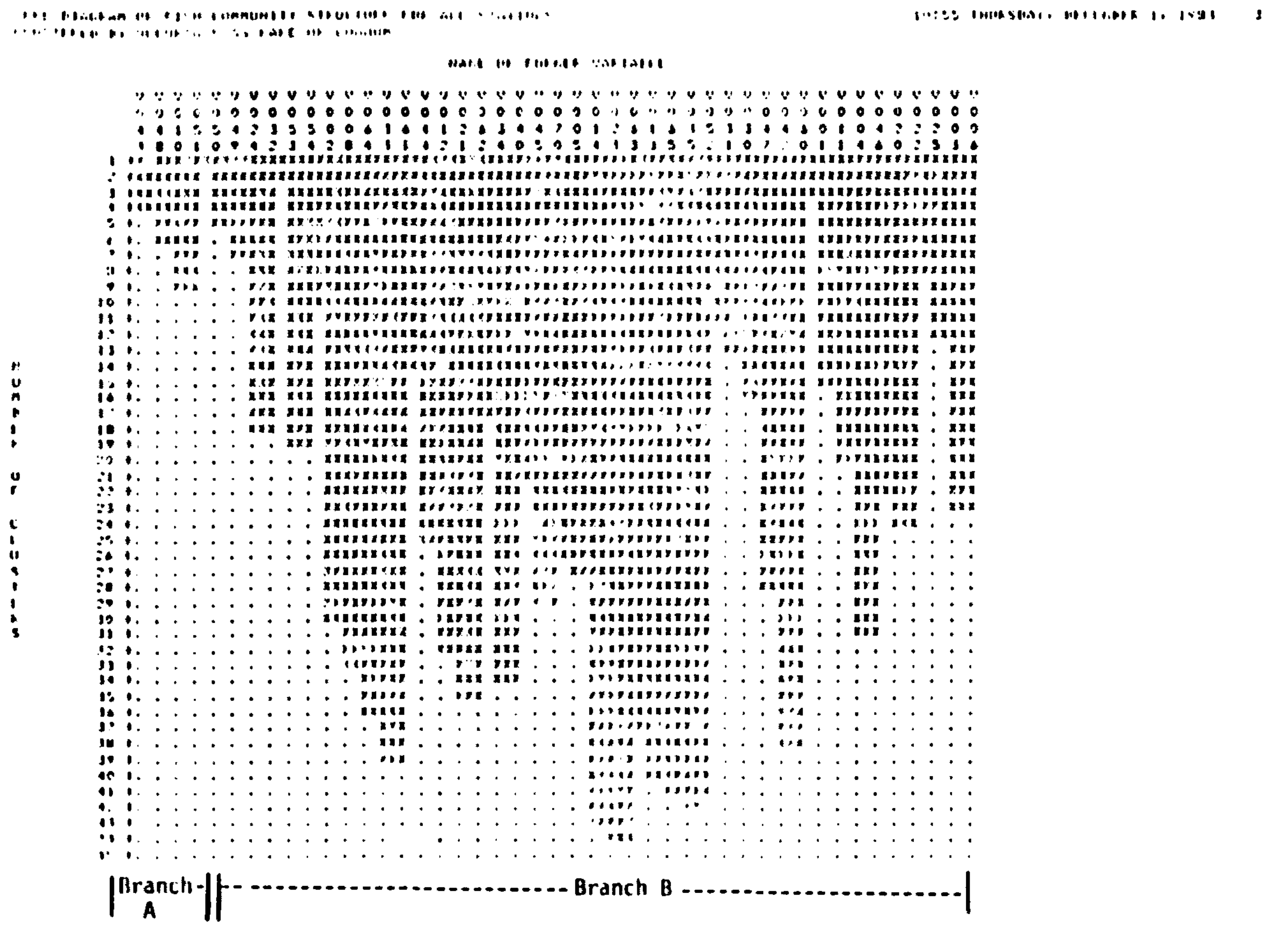
243

OBS	STATION	ZONE	V001	V002	V003	V004	V005	V006	V008	V010	V011	V020	V021	V022	V023	V024	V025	V030	V031	V032	V033	V034	V040	V042	V043	V044	V045	V046	V047	V048	V049	V050	V051	V052	V053	V054	V060	V061	V062	V070	V012	V013	V014	V063	V064	V065	V035
1	BCC	1	0	0	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	3	0	0	2	2	0	2	2	0	0	0	1	0	0	0	0	0	2	2	1	0	0
2	CHC	1	0	0	0	0	0	0	0	3	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	CHC	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	CHC	3	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0
5	COL	1	0	0	0	0	0	0	0	3	0	0	2	0	0	0	0	0	0	0	0	0	0	3	2	2	0	0	0	1	0	2	3	2	0	0	0	0	2	0	3	0	0	0	0	0	0
6	COL	3	2	2	0	0	2	0	0	2	0	0	2	0	0	0	1	0	0	1	0	0	0	2	0	0	0	0	0	1	0	3	3	0	3	2	0	0	1	0	2	0	0	0	0	0	0
7	DOO	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
8	DOO	3	2	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	3	0	0	0	0	3	2	0	0	0	2	0	0	1	0	0	2	0	0	1	1	0	0	0	0	0	0	2
9	ELA	1	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	ELA	2	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0	2	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	ELA	3	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	1	0	0	0	0	2	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	LDF	1	0	0	0	0	1	0	0	3	0	0	0	0	0	3	0	0	2	0	1	0	0	0	2	0	0	0	0	2	3	3	3	0	1	3	0	0	0	0	0	0	0	0	0	0	0
13	LDF	2	0	0	0	0	0	0	0	3	0	2	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	1	2	1	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0
14	LDF	3	0	0	0	0	0	0	0	3	0	0	0	0	0	2	0	0	0	2	0	1	0	0	2	0	0	0	0	0	2	3	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0
15	MBC	1	0	0	0	0	0	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
16	MBC	2	0	2	0	0	0	2	2	3	0	0	0	0	0	2	0	0	0	1	2	0	0	2	2	0	0	0	0	1	3	0	3	0	0	0	0	1	0	0	0	0	0	0	1	0	0
17	MBC	3	0	2	0	0	0	2	2	3	0	0	2	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0
18	MCA	1	3	0	3	3	0	2	0	4	2	0	0	0	0	2	0	0	0	0	0	0	0	0	3	0	0	1	2	0	1	3	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
19	MCR	2	3	0	3	3	0	2	0	4	2	0	0	1	0	0	2	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
20	MCA	3	0	0	2	0	0	0	0	3	0	0	0	0	0	0	2	0	0	2	0	0	0	0	3	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
21	MCW	1	2	2	0	1	0	1	0	3	0	0	0	0	0	0	3	0	0	2	0	0	0	0	2	0	0	2	0	1	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	MCW	2	0	0	0	2	0	0	0	3	2	2	0	2	0	2	0	0	0	2	0	0	0	0	1	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	MCW	3	0	0	2	2	0	1	0	3	2	2	0	1	0	1	0	0	0	3	0	2	0	0	3	0	0	0	0	2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	PRC	1	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	3	3	0	0	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0
25	PRC	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	3	4	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
26	RSC	1	0	0	0	0	0	0	0	3	0	0	0	0	0	2	2	0	0	2	0	0	0	0	0	0	0	0	0	2	0	3	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0
27	RSC	2	0	0	0	0	0	0	0	3	0	0	0	0	0	2	2	0	0	3	0	1	3	0	3	0	0	0	0	2	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	SCR	3	3	0	2	3	0	2	0	3	2	0	0	0	0	0	3	0	0	3	0	0	0	0	3	0	0	0	0	2	0	2	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0
29	SKC	1	3	0	0	0	2	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	SKC	2	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	BRC	3	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	STW	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	STW	2	0	0	1	0	0	2	0	2	0	0	0	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	0	0	1	0	0	0	0	0	0
34	WCC	3	0	0	0	0	0	0	0	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	WHC	1	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0


Branch A
Branch B

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2       S A S   L O G    OS SAS 82.3         MVS/XP JOB SASICHO2 STEP SAS      PROC STEP          15:05 SATURDAY, FEBRUARY 18, 1984

47          ENALLAGM     024
48          BLANK        025
49          OPHIOGMP     026
50          PROGOMPH     027
51          ANAX         028
52          BASIAECH     029
53          EPIAESCH     030
54          MACROMIA     031
55          LIBELLUL     032
56          TRAMEA       033
57          DINEUTUS     034
58          GYRINUS      035
59          BEROSUS      036
60          TROPHIST     037
61          HELICHUS     038
62          DUBIRAPH     039
63          STENELMI     040
64          SIMULIID     041
65          CULICIDA     042
66          CERATOPO     043
67          CHIRONOM     044
68          TANYTARS     045
69          TANYPODI     046
70          PENTANEU     047
71          MACROPEL     048
72          PALAEMON     049
73          LIRCEUS      050
74          HYALLELA     051
75          PHYSA        052
76          SPHAERID     053
77          LIMNODRI     054
78          TURBELLA     055
79          BRYOZA       056
80          HIRUDINE     057
81          TRICHOPT     058
82          REM       $  059-079
83          ;
84          CARDS;

NOTE: DATA SET WORK.INSECTS HAS 48 OBSERVATIONS AND 56 VARIABLES. 42 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.17 SECONDS AND 100K.

133         DATA NEW; SET INSECTS(DROP=BLANK);
134         IF ANAX=. THEN DELETE;

NOTE: DATA SET WORK.NEW HAS 35 OBSERVATIONS AND 55 VARIABLES. 43 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.10 SECONDS AND 100K.

135         PROC SORT; BY STATION ZONE;

NOTE: 4 CYLINDERS DYNAMICALLY ALLOCATED ON SYSDA FOR EACH OF 3 SORT WORK DATA SETS.
NOTE: DATA SET WORK.NEW HAS 35 OBSERVATIONS AND 55 VARIABLES. 43 OBS/TRK.
NOTE: THE PROCEDURE SORT USED 0.31 SECONDS AND 318K.

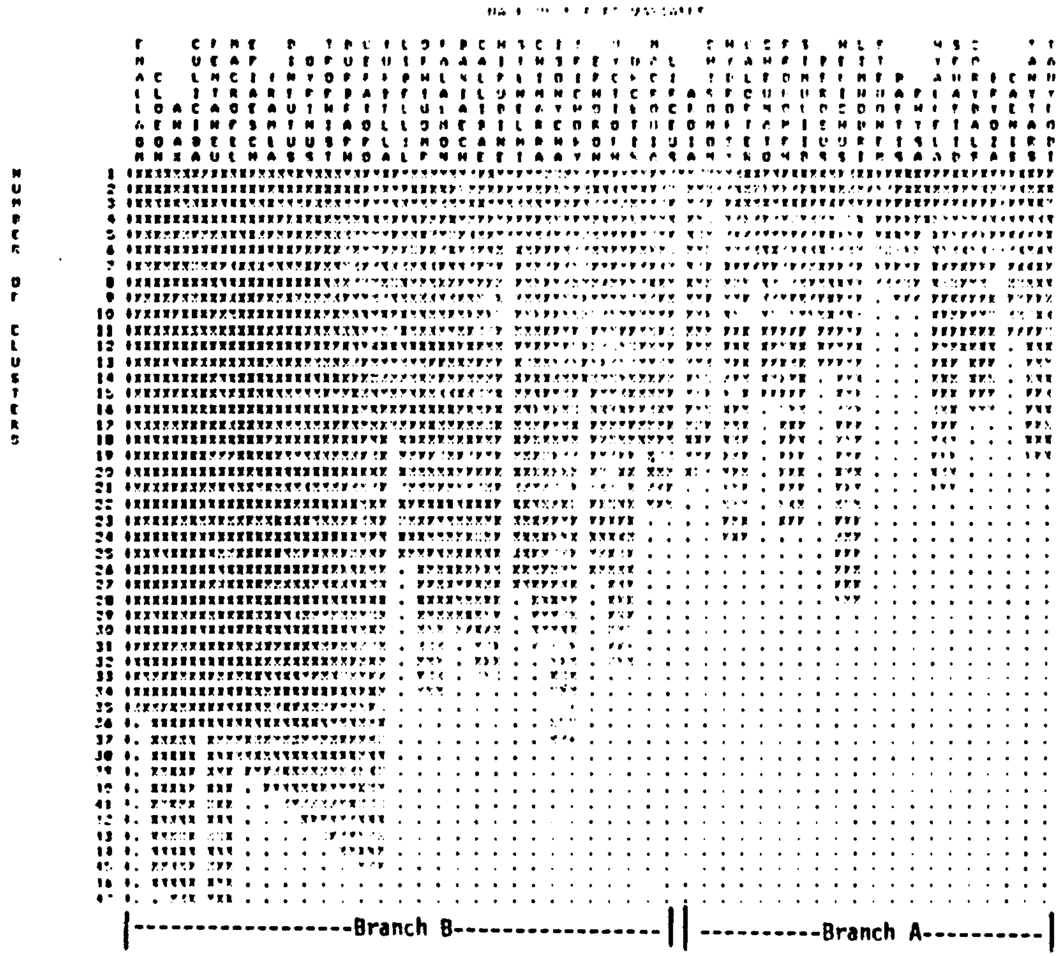
136         PROC PRINT;
137         TITLE RAW DATABASE FOR INVERTEBRATE SPECIES COMPOSITION;
138         VAR STATION ZONE ENCHANTO-- TRICHOPT;
```

RAW DATABASE FOR INVERTEBRATE SPECIES COMPOSITION

15:05 SATURDAY, FEBRUARY 18, 1984 1

OBS	STATION	ZONE	CHEUMATO	HYDROPSY	CHIMARRA	NYCTIOPH	OECETIS	CORYDALU	ISONYCHA	BAETIS	CALLIBAE	CLOEON	STENONEM	CAENIS	EPHORON	CALOPTER	ARGIA	ENALLAGM	OPHIOGOM	PROGOMPH	ANAX	BASIAECH	EPIAESCH	MACROMIA	LIBELLUL	TRAMEA	DINEUTUS
1	BCC	1	0	0	0	0	0	0	0	0	0	0	3	1	0	0	1	0	0	0	0	4	0	0	0	0	0
2	BCC	2	0	0	0	0	0	0	0	0	0	0	3	2	0	0	4	0	0	0	0	0	0	1	0	1	0
3	BCC	3	4	0	0	0	0	3	0	1	0	0	3	2	0	0	2	0	0	0	0	0	0	0	0	0	0
4	CHC	1	4	0	1	0	0	0	0	1	0	0	4	0	0	0	3	0	0	3	0	0	0	0	0	0	0
5	CHC	2	0	0	0	0	0	0	0	0	0	0	3	1	0	1	3	0	0	0	0	0	0	0	0	0	0
6	CHC	3	4	0	0	0	0	0	0	3	0	0	4	0	0	0	3	0	0	0	0	0	0	0	0	0	0
7	CDL	1	0	0	0	0	0	0	0	0	0	0	0	3	2	1	1	0	0	0	0	1	0	2	0	0	0
8	CDL	3	3	1	0	0	0	0	0	3	0	0	0	0	0	0	4	0	1	0	0	0	0	0	0	0	0
9	DOD	1	0	0	0	0	0	1	0	0	0	3	0	1	0	0	3	1	0	0	1	0	0	0	0	0	0
10	DOD	3	0	0	0	0	2	4	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	ELK	1	3	0	0	0	0	0	0	1	0	0	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0
12	ELK	2	0	4	0	0	0	2	0	0	0	0	0	1	0	0	4	0	0	4	0	0	0	0	0	0	0
13	ELK	3	0	4	0	0	0	2	0	2	0	0	3	0	1	2	2	0	0	0	0	0	0	0	0	0	0
14	LDF	1	1	0	0	0	0	0	0	1	1	0	4	0	0	0	4	0	0	0	0	2	0	3	0	0	0
15	LDF	2	3	0	0	0	0	1	0	1	0	0	2	1	0	0	3	0	0	2	0	0	0	0	0	0	1
16	LDF	3	0	0	0	1	3	0	0	0	0	0	2	1	2	0	4	0	0	4	0	0	0	1	0	0	0
17	MDC	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0	0	0	0	0	0	3	0	0	0
18	MDC	2	0	0	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
19	MDC	3	4	0	1	0	0	4	0	3	0	0	3	0	0	0	3	0	1	0	0	0	0	0	0	0	0
20	MCR	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
21	MCR	2	0	3	0	0	0	0	0	1	0	0	3	0	0	1	4	0	0	0	0	0	0	0	0	0	0
22	MCU	1	0	3	0	0	0	0	0	0	0	0	3	0	0	1	3	0	0	1	0	0	0	0	0	0	0
23	MCU	2	0	4	0	1	0	0	0	0	0	0	1	0	0	1	1	0	0	3	0	0	0	0	0	0	0
24	MCU	3	0	4	0	1	1	0	0	3	0	0	4	0	0	1	1	0	0	0	0	0	0	0	0	0	0
25	PRC	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	2	0	0
26	RSC	1	0	4	3	0	1	4	4	3	0	0	4	3	1	0	4	0	0	0	0	0	0	0	0	0	0
27	RSC	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
28	SCR	3	0	0	0	0	0	0	0	1	0	0	3	0	0	0	3	0	0	0	0	0	0	0	3	0	0
29	SRC	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
30	SRC	2	0	0	0	0	0	0	0	0	1	0	0	1	0	0	3	2	0	1	0	0	1	0	4	0	0
31	SRC	3	0	3	0	0	0	0	0	1	0	0	0	4	0	1	4	0	0	0	0	0	0	0	0	0	0
32	STU	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	STU	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	MEC	3	4	3	4	0	0	3	4	4	0	0	3	3	0	1	1	0	0	2	0	0	0	0	0	0	0
35	WHC	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0	3	0	0

OBS	GYRINUS	BEROSUS	TROPISTE	HELICHUS	DUBIRAPH	STENELMI	SIMULIID	CULICIDA	CERATOPO	CHIRONOM	TANYTARS	TANYPODI	PENTANEU	MACROPEL	PALAEMON	LIRCEUS	HYALELLA	PHYSA	SPHAERIU	LIMNODRI	TURBELLA	BRYOZA	HIRUDINE	TRICHOPT
1	0	0	0	0	0	1	0	0	0	3	2	1	0	0	0	0	2	0	1	0	0	2	0	0
2	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0	3	2	2	0	0	2	0	0
3	0	0	0	0	0	0	3	0	0	3	1	2	0	0	0	0	4	3	3	0	0	1	0	0
4	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3	0	0
5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	3	0	2	0	0	0	0	0
8	0	3	0	0	0	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	3	0	4	4	3	0	0	4	3	4	0	0	0	0	0	0	0
10	0	3	1	0	0	1	0	0	0	2	2	3	0	0	0	0	4	0	4	0	0	4	0	0
11	0	0	0	1	0	0	0	0	0	3	3	1	0	0	0	0	0	1	1	4	1	0	0	0
12	0	0	0	3	0	0	1	0	0	0	3	0	0	0	0	0	4	1	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	1	0	0	0	0	0
14	0	0	0	1	0	0	0	0	0	4	1	3	0	0	0	0	3	1	2	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4	0	2	0	2
16	1	1	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	3	1	0	0	3	0	0
17	0	0	0	0	0	0	0	0	0	1	0	0	0	0	4	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	3	2	2	0	0	2	0	4
19	0	0	0	0	0	0	0	0	0	3	1	0	0	0	4	0	0	0	4	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	4	0	0	0	0	0
21	0	0	0	3	0	0	0	0	0	4	3	1	0	0	0	0	0	1	0	1	0	0	0	0
22	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	3	0	0	0	0	3	0	0	4	1	1	0	0	0	0	0	4	0	0	0	0	0	0
24	0	0	0	0	0	0	3	0	0	4	0	4	0	0	0	0	0	1	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3	3	0	0	0	0	3	0
26	0	0	0	0	0	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3
27	0	4	0	0	0	0	0	0	0	3	0	0	0	0	0	4	0	0	0	0	0	0	0	0
28	0	1	0	0	0	0	0	0	4	[illegible]	4	0	0	0	0	0	0	3	1	0	0	4	0	0
29	0	1	0	0	0	0	0	0	0	3	1	3	3	3	0	0	0	3	0	3	0	4	1	0
30	0	4	0	3	0	0	0	0	0	4	1	4	0	0	0	0	0	3	0	4	0	0	0	0
31	0	0	0	3	0	0	0	0	0	4	3	1	0	0	0	0	0	4	0	4	0	0	0	0
32	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	1	0	1	2	0	0	0	0
33	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	4	1	0	0	4	2	4	0	0	0	0	0	0	0	0	0	3	0	4
35	0	0	0	0	0	0	3	0	0	1	0	1	0	0	0	0	0	3	0	0	0	0	0	0


Branch B
Branch A